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HUMAN CAPITAL RESOURCE EMERGENCE FOR ROBOTIC SURGERY DEPLOYMENT IN HEALTHCARE

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Lastly, I would like to declare, “Aš ne robotas” (I am not a Robot)!

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KEY DEFINITIONS

Human Capital is defined as an individual's knowledge, skills, abilities, experiences, and other characteristics that one might leverage to achieve a desired outcome. (Ployhart & Moliterno, 2011).

Human Capital Resources are individual or unit-level capacities based on individual knowledge, skills, abilities (KSAOs), and other characteristics that are accessible for unit-relevant purposes. (Ployhart & Hale, 2014).

Human Capital Resource Emergence is a situation in which a group of individuals, with all their relevant human capital, merges into a unit-level human capital construct. (Ployhart & Moliterno, 2011).

Healthcare Professionals (HCP) study, advise on or provide preventive, curative, rehabilitative, and promotional health services based on an extensive body of theoretical and factual knowledge in the diagnosis and treatment of disease and other health problems. They may conduct research on human disorders and illnesses and ways of treating them, and supervise other professionals. The knowledge and skills required are usually obtained as the result of study at a higher educational institution in a health-related field for 3–6 years, leading to the award of a first degree or higher qualification. (WHO, 2020).

Robot-Assisted Surgery is defined as "[a] computer-controlled manipulator with artificial sensing that can be reprogrammed to move and position tools to carry out a range of surgical tasks" (Dasgupta et al., 2005, p. 20).

A surgeon is a doctor who removes or repairs a part of the body by operating on the patient (National Instutute of Cancer).

Capacity Building has been defined by UNDP (2002) as "the process by which individuals, groups, organisations, institutions, and societies increase their abilities to (1) Perform core functions, solve problems, define, and achieve objectives; and, (2) Understand and deal with their development needs in a broad context and a sustainable manner" (Ionel, 2017, p. 3).

Social Capital is "By analogy with notions of physical capital and human capital--tools and training that enhance individual productivity—'social capital' refers to features of social organisation such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit" (Putnam, 1995, p. 67).

Resource Co-Specialisation in the organisational perspective, the “[co] specialised assets are those for which there is a bilateral dependence” (Teece, 1986, p. 289). it is a strategy of bilateral specialisation in which two parties are bound into a relationship with sustained mutual commitment, which requires continuous specialisation (Kim et al., 2019).

Emerging Technology is "A radically novel and relatively fast-growing technology characterised by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s), which is observed in terms of the composition of actors, institutions and patterns of interactions among those, along with the associated knowledge production processes” (Rotolo et al., 2015, p. 13).

INTRODUCTION

"Technology is best when it brings people together." (Mullenweg, 2021)

The healthcare industry is among the world's largest and fastest growing (Ortega et al., 2020; Roy et al., 2022). The healthcare industry includes a workforce from five different generations, starting from baby boomers, with different working and learning styles, an aspect which further adds to the uniqueness of the industry (Teunissen et al., 2020). According to the World Health Organization (WHO), "a health system comprises all organizations, individuals, and activities whose primary job is advancement, re-establishment, and health maintenance." (WHO, 2017). Creating value for society is considered an essential to health systems (Roppelt et al., 2024). Healthcare delivery organizations have always been in great demand (Starfield, 2000); currently, this demand is greater than ever, a development that is ongoing on a global scale (Schurmann et al., 2025).

To fulfil this ongoing and increased demand for high efficiency care delivery, it is pivotal to embrace the pressing need for deploying technologies in healthcare. Maskuriy et al. (2019) elucidated that industry 4.0, which includes Robotics, Artificial Intelligence (AI), Internet of Things (IoT), cloud computing, Big Data, Immersive technologies (AR/VR) and Machine Learning (ML) is a brand-new philosophy that is creating an upsurge in social change by affecting all areas of life, ranging from safety, education, science, labour market and welfare systems. Comparable to other industries, healthcare is going through a phase of transformation by integrating new technology-based solutions, which are helping to reduce costs, enhance performance, and overcome the shortage of healthcare practitioners, but technologies are facing deployment blockage (Bienefeld et al., 2025; Lee & Yoon, 2021; Thacharodi et al., 2024).

Human capital resource emergence (HCRE) is a situation where a collection of people, together with all of their pertinent human capital, collectively becomes a unit-level construct of human capital (Ployhart & Moliterno, 2011). This is a relatively new topic in the management literature compared to human capital and the human capital resource domain (Jun et al., 2024). It is overall in the early stages of exploration and is understudied, especially in the context of healthcare. Under the micro-foundations agenda, human capital resource emergence is essential in comprehending how human capital integrates to create a valuable unit-level resource, wherein the sum of human capital produces results that surpass what can be explained by the sum of its individual components (Steve WJ Kozlowski, 2019).

During the last seven decades, Human capital theory has evolved in multiple perspectives. (Goldin & Katz, 2024). Beginning from the economist approach for economic gains to the organizational sustainability, human capital has been widely discussed in the literature (Becker, 1962; Nyberg et al., 2018). According to Ray, Essman, et al. (2023) Human capital theory is an individual-level paradigm and was not sufficient to explain the variances across various levels. As a consequence, the longstanding discipline saw the birth of a unit-level modern component, i.e., Human capital resources (Ployhart et al., 2014). Interestingly, there is insufficient evidence on the creation of Human capital resources and a lack of clear understanding of the mechanism of multilevel value creation at a unit level (Ray, Nyberg, et al., 2023).

Centred on the interplay of many individuals, emergence research into human capital resources has resulted in a new era of inquiry into social processes within the last twenty years (Harris et al., 2018). Current literature explains the emergence in a general and obscure manner during the transformation of individual human capital into unit-level human capital resources, and the process is unclear (Jun et al., 2024). As elucidated by Felin et al. (2015, p. 606) “in all, the notion of ‘emergence’ remains vague and thus opportunities remain for both micro and macro disciplines to carefully specify the underlying actors, social mechanisms, forms of aggregation, and interaction that lead to emergent outcomes”. Ployhart and Moliterno (2011) have argued that to comprehend *how, why, and when* HCR arises from human capital, a multilevel approach that incorporates emergence is necessary.

Healthcare systems are complex (Tulchinsky & Varavikova, 2014). The multidisciplinary approach in healthcare indicates that individual capabilities should merge, and adoption of technology should be considered as a collective act of all the actors involved in the delivery of care. To establish a full understanding of the process of human capital resource emergence, where an individual level human capital (Knowledge, Skills, Attributes and Other characteristics - KSAO) is transformed into a unit level resource, the literature is scarce and there is a pressing need to investigate this phenomenon, (Eckardt et al., 2021), especially in healthcare. Although healthcare is introducing technologies but the promise of these technologies, like increasing the efficiency, enhancing the patient experience, and reducing the healthcare practitioner`s burnout, should be further evaluated and analysed. Because healthcare professionals are equally interested in adopting technology if there are positive effects on clinical outcomes of the patients and reduction in their mundane tasks.

The COVID-19 pandemic not only had dreadful effects on people and society, but it has also increased the need for incorporating technological solutions in healthcare at a pace that has never been seen before (Clipper, 2020; Okolo et al., 2024). Based on this increasing demand for technology in healthcare, recently the Tech giants such as Apple, Microsoft, Google, IBM and Oracle are leaning towards penetrating the healthcare industry, placing large bets on a promising return on investment (ROI) in the coming years (Juttukonda, 2024; Rikap, 2022). However, implementation of technology in healthcare is facing deployment blockage due to a lack of comprehensive frameworks and a systematic approach (Reddy, 2024). Healthcare is unique and deeply interdependent, where highly qualified individuals with cultural diversity work together closely in interdisciplinary teams to deliver safe patient care (Uman et al., 2022). Complex Healthcare systems involve a very wide variety of participants with varying levels of knowledge, skills and authority (Grol & Wensing, 2013). The more complex and dynamic a system is, the higher the need for a systemic approach for the deployment of the technology into those systems (Lappalainen, 2019). Akin to other industries, healthcare has barriers for technological deployment, but due to an interdisciplinary approach and human life at stake, the complexity grows to a critical point.

During the last three decades, technological developments have been accepted not only as a source of value generation but also as a source of profitability in many industries (Blichfeldt & Faullant, 2021). For systematic and sophisticated deployment of a technology into a complex system like healthcare, Ployhart and Moliterno (2011) have emphasized that for adaptability, coordination is necessary for complex tasks and context-generic human capital resources. These tasks are based on general cognitive ability, personality, values, and interest, and these are active ingredients of the establishment of context-specific human capital resources. According to Beane and Orlikowski (2015), a new technology in a healthcare system (introduction of the robotic or telepresence) should be accepted as an implementation of a new practice through institutionalization, to incorporate it with the complex, dynamic, and distributed work in a hospital setting. However, guidelines that guarantee data security and patient privacy must go along with successful technological adoption and dissemination (Liu & Miguel-Cruz, 2022).

Recently, the benefits of emerging technologies have been widely and extensively discussed in medical and academic research (Galbusera et al., 2019), particularly post-pandemic COVID-19 (Junaid et al., 2022; Krishnamoorthy et al., 2021; Licardo et al., 2024; Olalekan Kehinde, 2025) highlighting the importance of the usage of these technologies to improve the healthcare system`s efficiency. But consumer receptivity (clinicians and patients) remains under-explored (AlQudah et al., 2021; Lee et al., 2025; Rudawska et al., 2024; Tekkesin, 2019). Rudawska et al. (2024) have argued that additional and improved usage of emerging technologies can identify inaccuracies and resolve matters in a speedy manner for the dynamic healthcare system and will be cost-effective.

Bamel et al. (2023) have expressed the pressing need to investigate the factors that facilitate the implementation of the emerging and transformative technologies. Successful establishment and integration of emerging technologies in any field is possible by overcoming the gap among the developers, implementers and the end-users (Proksch et al., 2019). Many researchers have documented that the technology development often presents the challenge of poor value alignment between the supply-side and demand-side (Greenhalgh et al., 2018; Lehoux et al., 2017; Markiewicz et al., 2014). It is important to note that the work attitude of healthcare professionals and technology developers is different, which acts as a hindrance in finding solutions for medical-related problems and the adaptation of new technologies (Anwar & Prasad, 2018). Physicians and nurses are the front-liners of healthcare and the success of the technology deployment depends on their level of adoption. By effectively utilizing these human resources in healthcare, initiatives for adopting cutting-edge technologies can be implemented more smoothly (Prajogo & Oke, 2016) and can lead to sustainable future developments (Cavicchi, 2017). To meet the challenges of new technology deployment will require experimentation, dialogue, and continuous monitoring of the change (Schartinger et al., 2015). Hence, it is crucial to directly involve healthcare professionals during the development and deployment of a healthcare technology as a stakeholder (Anwar & Prasad, 2018; Heijsters et al., 2022). Because acceptance and adaptability by the professional staff can be considered as the single most important determinant that will decide the fate of a new technology (Aryee et al., 2024; Gheorghiu & Ratchford, 2015; Wade et al., 2014).

In general, implementation of new technologies requires a holistic view and approach, keeping all processes, actors and factors into consideration. Particularly in healthcare, preparing the Human capital, the healthcare professionals, to embrace the impact of forthcoming emerging technologies through proper training, availability of social, technical and intellectual support is the need of the time. Inadequate technological adoption or limited adoption without a systematic approach or framework will not yield the anticipated advantages and outcomes in healthcare. Currently, multiple technologies are being developed and utilized in the healthcare industry; however, a model or framework for the deployment of these emerging technologies into sophisticated healthcare systems is notably absent.

This thesis has taken into consideration the importance and necessity of Human capital resources and capability building at a micro-level in a healthcare setting (surgery department) for co-specialization of the Surgeon and the surgical team with minimally invasive robotic surgery. We have studied the emergence of new skills and work design of the surgical team at the unit level with the deployment of surgical robots, resulting in successful technology integration and human capital resource emergence among surgeons and surgical teams to perform Robot-Assisted Surgeries (RAS) safely and successfully, prioritizing patient safety and clinical efficiency. We have developed a model that will systematically guide the future successful technology integration in healthcare. The selection of the surgery department for this research is based on the fact that during the last three decades the most widely accepted technology in healthcare is the surgical robot (De Ravin et al., 2023; Ginoya et al., 2021).

Healthcare human capital greatly needs capability building in relevance to co-specialize with emerging technologies. This change is inevitable and demands prompt attention. Strong scarcity of reliable literature and its systematic contextual analysis on the topic of healthcare human capital resource emergence and Human robot co-specialization indicates a fertile ground for future research. It is momentous to identify the need for an established theoretical framework or a process design to expedite the valuable implementation of the emerging technologies in the dynamic yet complex healthcare system. Healthcare industry was embracing the impact of new technologies pre-pandemically and in this COVID-19 post-pandemic era, the urge and pressure is growing (Schurmann et al., 2025). Healthcare professionals are also acknowledging the need of technological adoption (Yousif et al., 2024) and parallelly, Tech companies are pouring money and resources into the development of new technological solutions for healthcare (Juttukonda, 2024).

The transitional approach required for a new technology demand is to take the interests and perspectives of all stakeholders into account. For the successful and profitable deployment of emerging technologies (like robots) into the healthcare systems, the adoptability by all the players is extremely essential. Nevertheless, there is a pressing need to further study the behaviours, enablers and inhibitors that influence the acceptance of the advanced technologies. A deeper need exists for bridging the gap in the deployment process through the establishment of a systematic and organised approach, keeping the focus on users (healthcare professionals) and the receivers (patients). This will require an understanding of Human capital resource emergence and a deep focus on the co-specialization of Humans with machines to achieve effective and thorough outcomes in the cross-functional and intricate healthcare systems.

Healthcare Industry Prevailing Challenges Healthcare is already facing multiple challenges that are prevailing and growing (Yakubu et al., 2022). Globally, most healthcare institutions are facing similar issues or challenges (Roppelt et al., 2024; Tortorella et al., 2020). Use of technology in care delivery can be a substantial solution to overcome these challenges. The most pressing issues of the healthcare industry are discussed below, necessitating prompt action, and the adoption of technology can mitigate these challenges significantly.

(a) Rise of Chronic Diseases: Increasing population and upsurge in health issues and diseases further aggravate the consequences (Guntur et al., 2019). Diabetes, cancers, cardiovascular and respiratory diseases are chronic and require continuous management (Meetoo, 2008). The population affected by chronic diseases is on the rise, therefore increasing the pressure on the healthcare systems and demanding more trained healthcare professionals to manage the population (Claessens et al., 2024). In 2010, chronic diseases were attributed to 67% deaths globally, increasing to 74% in 2019 and further climbing during COVID-19 pandemic (Thomas et al., 2021). Increasing population, an increase in the average life expectancy and an upsurge in health issues and diseases, with an existing physician shortage, further aggravate the consequences (Guntur et al., 2019; Lanza et al., 2020).

(b) **Pandemic COVID-19:** On 30th January 2020, World Health Organization (WHO) announced COVID-19 as ‘emergency of international concern’ (WHO, 2020). Global Healthcare systems were under-prepared to be exposed to the unanticipated pandemonium of the COVID-19 pandemic (Deer et al., 2020). This not only created a state of emergency worldwide, but it also created chaos for governments, practitioners and patients. On March 11, 2020, the World Health Organization (WHO) announced COVID-19 as a ‘pandemic’ (WHO, 2020). An end to this public health emergency was declared on May 11, 2023 (WHO, 2023). Only in the span of three (3) years, the COVID-19 pandemic has severely affected healthcare, posing a significant concern for the world`s economy. The pandemic not only devastatingly hit the financial stability, but it also greatly impacted the healthcare professionals, both physically and psychologically. It aggravated the disease burden, intensified the healthcare professionals shortage and probed the threat of failure to the healthcare industry (Coccia & Benati, 2024; Kaye et al., 2021; Liu et al., 2022; Wang et al., 2020).

(c) **Shortage of Physicians and Surgeons:** It is a prevailing, rising and core problem, which is posing threats to the healthcare industry (Harp, 2022; Heponiemi et al., 2019; Michaeli et al., 2024; Scannell et al., 2021; Sheldon, 2011; Stephens, 2025; Williams & Ellison, 2008; Yakubu et al., 2022). Increasing population and an upsurge in health issues and diseases is further aggravating the consequences (Guntur et al., 2019). It is estimated that by the year 2050, 22% of the population will reach the age of sixty-five (65) or above (Di Nuovo et al., 2016). It is projected that by the year 2030, there will be a further shortage of physicians (Zhang et al., 2020). During the pandemic, this shortage has further grown and is becoming an exacerbated global issue (Abdel-Razig & Stoller, 2025; Krasna et al., 2021; Mbunge et al., 2022; Riaz et al., 2021). Collaborators (2022) conducted a detailed analysis on the migration of physicians from Low-income countries to higher-income countries in the last forty years. They have highlighted that this migration has expedited post-pandemically and has resulted in disparities and inequalities. Global Burden of Disease Study projected that the world is facing a shortage of 6.4 million Physicians (Collaborators, 2022).

The scarcity of Surgeons is prevalent in both urban and rural regions, with a greater intensity in rural areas (Khoury Stephanie, 2022; Stringer et al., 2020). Due to stress, extended hours and discomfort during the procedure, surgeons are choosing early retirement in many specialties, hence compounding the current shortage (Jella et al., 2023; Mahoney et al., 2020; Morton & Stewart, 2022; Soriano et al., 2022). World Health Organization (WHO) revealed a disproportion between current and required healthcare workforce for the future, estimating a global shortage of eighteen (18) million healthcare practitioners, which are required to achieve the sustainable development goals for healthcare by 2030, and has urged the need for digital education for healthcare professionals (WHO, 2020). Due to a lack of skilled healthcare workers globally, healthcare resources can be stretched by the adoption of new technologies (Zimlichman et al., 2021).

(d) Burnout of Healthcare Professionals: Freudenberger (1989) have explained that burnout is an emotional and behavioural impairment which is characterized by mental fatigue, depersonalization, and a lower sense of personal achievement. Professional burnout typically means continuous stress that hinders an individual’s ability to exhibit professional responsibilities under challenging circumstances (Chetlen et al., 2019). It is prevalent among healthcare professionals, and particularly physicians, are most affected globally (Sequeira & Aish, 2023; Shanafelt et al., 2015; Van Mol et al., 2015; Zambrano-Chumo & Guevara, 2024). Working conditions are stressful in healthcare where physicians are continuously involved in listening to health complaints, making critical decisions and crucial judgments on treatment plans of their patients with ongoing resource constraints. Feeling overwhelmed in a demanding job is emotionally draining for healthcare professionals (Batanda, 2024). Emotional exhaustion has contributed to the intellectual challenges among surgeons, leading to medical errors (Chahal & Matwala, 2025). Consequences of burnout encompasses clinical errors, patient dissatisfaction, financial and reputation loss to the health institute (Hodkinson et al., 2022; Lee et al., 2024).

Current state of research and remaining gaps. Human Capital (HC) is defined as an individual's knowledge, skills, abilities, experiences, and other characteristics that one might leverage to achieve a desired outcome (Ployhart & Moliterno, 2011). Human Capital Resources are individual, or unit-level capacities based on individual knowledge, skills, abilities and other characteristics (KSAOs) that are accessible for unit-relevant purposes (Ployhart & Hale, 2014). The importance of Human Capital Resources (HCR) is well acknowledged in the management research; however, the literature does not provide sufficient evidence on the process of emergence of human capital resources (Jun et al., 2024). Human Capital Resource Emergence (HCRE) is a situation where a group of individuals, with all their relevant human capital, jointly emerges into a unit-level human capital construct (Ployhart & Moliterno, 2011). Although during the last few years there is evidence of progressive research on human capital resource emergence, it requires further exploration (Eckardt et al., 2021; Ray, Essman, et al., 2023). Human capital resource emergence is overall in the early stages of exploration and under-studied, especially in the context of healthcare. Distinctively, it is scarce in the context of the technology deployment process in general and particularly in the healthcare domain. To gain understanding and to establish a full comprehension of the process, where an individual-level KSAO is transformed into a unit-level resource, the literature is limited, and there is a pressing need to investigate this phenomenon (Eckardt et al., 2021).

The global diffusion of common technologies was linked to the COVID-19 pandemic's early phase in 2020. Technological transformation enhances organizational agility and eventually elevates competitiveness (Chatterjee & Mariani, 2022). It is becoming more prevalent that the emerging technologies, like robotics, artificial intelligence (AI), and big data, are the most agile and forward-thinking resources for the improvisation of healthcare (Junaid et al., 2022). These technologies can enhance the quality and efficiency of healthcare and can have a significant impact on the cost as well (Zemmar et al., 2020). These approaches can lead to reliable preventive care, which can revolutionize healthcare organizations, resulting in a positive impact on public health outcomes (Thacharodi et al., 2024). Nevertheless, technology deployment in healthcare has been hindered, a problem that is intensifying due to the increased demand of usage of new technologies. This issue has remained understudied in healthcare and is deficient in practical, holistic and innate frameworks (Cresswell et al., 2020).

Today’s emerging technologies will be shaping the future of tomorrow’s world and there is a timely need for the adoption of those technologies (Adler et al., 2016; Licardo et al., 2024). Automations based on artificial intelligence, robotics, big data and the internet of things (IOT) are the bright realities of today. Because emerging technologies are believed to enhance productivity and the quality of life (Iizuka & Ikeda, 2019), the deployment of new technologies has a direct impact on both employees and organizations (Sima et al., 2020). These challenges are not limited to the development of the new technologies but are more prevalent in the arena of adoptability and adaptability of these new technologies for successful implementations into the existing systems. The complex dynamics of social and welfare sectors, such as healthcare, demand a systemic approach for the deployment of robots into those systems (Lappalainen, 2019). To embrace the challenges of new technology deployment, there is a need for continuous monitoring of the adoption process (Schartinger et al., 2015). Grisot et al. (2017) have suggested a deeper need for 'sociotechnical sensibility' for the smooth translation of emerging technologies into healthcare. Sociotechnical dynamics requires a comprehensive and contextual understanding of human interaction and experience with machines (Riedl, 2020). Thus, understanding and managing people's attitudes and behaviours in response to technological change are both necessary for successful implementation (Lennon et al., 2017).

According to Cong (2021), seven out of ten healthcare institutions have adopted or are considering the adoption of emerging technologies in the United States of America and the United Kingdom. In the same report, it was highlighted that seventy-eight percent (78%) of healthcare business leaders have revealed that with the deployment of technologies in healthcare, workflow improvements in operational and administrative activities have been observed. Cong (2021) further alleged that, to thoroughly embrace new technologies, the business models of healthcare systems will require adjustments. One of the most important issues facing health care provider organizations today is addressing the factors that promote value-based care; that list also includes enabling health care technologies (Garrison et al., 2018; Nguyen et al., 2023). Utilisation of these technologies is providing more time to clinicians to work more closely with their patients, thus facilitating the efficient delivery of care (Haleem et al., 2022; Okolo et al., 2024). Healthcare managers understand that becoming a preferred provider requires offering a streamlined and consistent patient experience, which is possible with the integration of technologies. Governments, scientists and physicians are investigating the importance of the deployment of robotics in healthcare (Karaferis et al., 2024).

It is necessary that recognizing and monitoring the progression of application of new technology in an industry, particularly in healthcare, should start with an in-depth analysis of the challenges and development of supporting policies, particularly in terms of liability (De Micco et al., 2024; Fosch-Villaronga et al., 2021). A crucial obstacle while implementing new technologies in healthcare systems is the adoption of the emerging technology by the front-liners (healthcare professionals), not the technology itself (Zemmar et al., 2020). Many researchers have documented that health technology development often presents the challenge of 'poor value alignment' between the supply-side and demand-side (Greenhalgh et al., 2018; Lehoux et al., 2017; Markiewicz et al., 2014). Lanza et al. (2020) noted that, due to the dynamism of clinical practice and the demand for full autonomy in healthcare for patient treatment, the technology developers can't identify and plan for all possible situations. It is interesting to note that healthcare professionals are underestimated as facilitators of technology; however, technology developers should consider them as the main stakeholders of an emergent technology (Timmis, 2021).

To face the current and future challenges, multiple potential implementations are being proposed to utilize robots in healthcare (Yang et al., 2020). This approach to the integration of robots into the health system will not only improve the lives of the vital healthcare professionals, but it will reduce the cost of healthcare in the long term, while simultaneously improving efficiency (Yang et al., 2020). According to the current literature analysis, there have been numerous studies focused on the integration of robots in the manufacturing industry, while robotics is still considered new to the healthcare industry. In recent times, surgeries assisted by robots are becoming the norm (Hettiarachchi et al., 2023). However, inclusion of robots into the service in healthcare systems is still at the stage of infancy and the process forward is still unclear.

However, this implementation of emerging technologies such as robotics has posed serious adoption challenges for healthcare professionals. It is important to avoid the abrupt implementation of a new technology into the healthcare system; the organization must establish a conducive culture to adopt and adapt to the change (Kim, 2022; Lee, 2018). There is a link between an individual's propensity to adopt new technologies and their perception of the organizational culture (Melitski et al., 2010); particularly, the switch from conventional minimally invasive procedures to robotic surgery is a significant step and requires a clear understanding of behaviour and the development of enabling supportive culture for the implementation of surgical systems(Cunningham et al., 2012). Previously, there was evidence of refusal, resistance and lack of interest in accepting robots for patient care, both by health care providers and by patients and their families (Krings & Weinberger, 2018; Pekkarinen et al., 2020). But during the pandemic, robotic systems came to be considered as a clinical advantage for the optimization of healthcare resources (Lawrie, Gillies, Davies, et al., 2022; Moawad et al., 2020). A rise in the acceptance of surgical robots has also been observed and, post-pandemic, the number of robotic surgeries increased (Zemmar et al., 2020). However, the process of adoption and implementation of robotics in surgery remains underexplored (Giedelman et al., 2021).

In the last decade, many studies have focused on the benefits of robot-assisted surgery, training of surgeons, technology enhancement, perspectives of healthcare professionals and patients, and comparisons of robotic surgery with traditional and laparoscopic procedures. Yet, little attention has been paid to human factors-based research, which simultaneously captures the surgeon`s training, the surgical team`s training, adjustment to new work design and specialization with the machine. Hence, there is an enormous need to study and evaluate the implementation process of this emerging technology and its impact on the current and future human capital of the healthcare. This collective approach investigation will aid in better understanding the perspectives to build a comprehensive framework and corresponding HRM policies and practices to embrace the consequences of deployment today and the challenges of forthcoming technologies.

Research Question. The research question for this study is “How does Human Capital Resource emerge and evolve for the surgical team with the deployment of robotics?”

Research aims and objectives. This research examines the social and behavioural aspects of human capital resource emergence for the deployment of robotic technology in the surgery department. This investigation delves into the broader issue of technology deployment in healthcare, with the goal of investigating the process of human capital resource emergence in a healthcare setting for co-specialization of the surgeon and surgical team with robotics in the surgery department.

The **objectives** of this study are:

1. To provide the theoretical grounding of Human Capital Resource Emergence (HCRE) by investigating the under-explored process.
2. To explore the process of Human Capital Resource Emergence (HCRE) in the co-specialization of a surgical team with robotics.
3. To develop Human Capital Resource Emergence (HCRE) framework for the adoption of technology in healthcare.
4. To recommend practices for healthcare policy makers, HR personnel, decision makers and technology developers to facilitate the technology integration into the health system.

To achieve these objectives, we have adopted a qualitative approach; using an interview guide, semi-structured interviews were conducted with surgeons who are currently performing robot-assisted surgeries (RAS) upon completion of training. The 35 interviewed surgeons belonged to multiple specialities and are in different regions (Australia, Europe, India, Malaysia, Middle East, UK and USA). Data analysis was performed through Gioia methodology by sifting interview data into 1^{st} and 2^{nd} order codes.

Scientific novelty and contributions. This thesis makes several contributions to the literature. Firstly, it explores the process of technology (Robotics) deployment in a healthcare setting and adds to the technology adoption research in the healthcare context. Secondly, the study extends Human Capital (HC) and Human Capital Resource (HCR) by exploring the Human Capital Resource Emergence (HCRE) process in the healthcare domain. Thirdly, this study contributes to the Human Capital Resource (HCR) literature by disclosing the process of emergence of human capital resources among surgical teams during the adoption of robotics, an emerging technology. Fourthly, it contributes to the healthcare management literature by revealing the process of implementation and integration of emerging technology into healthcare systems. This social sciences thesis is directed towards the robotics learning ‘process’ of the surgeons and surgical team rather than the learning ‘curve’ of the surgeon. Lastly, the findings and recommendations of this research are being addressed to the healthcare industry, the technology industry, and the management research to overcome the resistance and deployment blockage of the technology in the healthcare industry.

Practical Implication: The results of this study will aid in understanding the existing process of Human Capital Resource Emergence (HCRE) and will provide clarity on the facilitators and roadblocks of the technology deployment in healthcare. The investigation will assist in advocating a sophisticated model/framework for future technological implementations in health systems. It is addressed to healthcare human resource managers (HRM) and policy makers to develop policies, strategies and culture to achieve the successful implementation of technology and desired outcomes/value with optimization of resources. In addition, this research serves as a guide to technology developers in the practice of system thinking and allows them a better understanding of healthcare professionals' (end user) behaviours, challenges and work design, which can aid them to develop and upgrade technologies in accordance with healthcare practitioners' needs and compatibility of usage.

PUBLICATIONS AND PRESENTATIONS AT THE CONFERENCES

Publications in Peer Reviewed Journals:

1. Pereira, V., Neal, M., Temouri, Y., & Qureshi, W. (2020). Introduction. In V. Pereira, M. Neal, Y. Temouri, & W. Qureshi (Eds.), *Human Capital in the Middle East A UAE Perspective* (pp. 1-21). Cham: Palgrave Macmillan. https://doi.org/10.1007/978-3-030-42211-0_1
2. Qureshi, W. (2020). The role of human capital in the implementation of healthcare innovation in the UAE. In V. Pereira, M. Neal, Y. Temouri, & W. Qureshi (Eds.), *Human Capital in the Middle East A UAE Perspective* (pp. 275-310). Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-42211-0_11
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Presentation at International Conferences:

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2. Qureshi, W. (2023). Human capital resource emergence and capacity building with co-specialization for emerging technologies (robotics) in the context of healthcare 5th International Conference on Organization and Management, 22–24 February, United Arab Emirates (Abu Dhabi). ICOM 2023
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1. THEORETICAL GROUNDING

At its heart, this research seeks to ignite both academic and industry curiosity in the emergence process, which begins with the transformation of human capital into human capital resources through the introduction of new technology and concludes with the co-specialization of humans and robots in healthcare. The importance of social capital and value creation throughout this process is also being discussed. This thesis is primarily based on Human capital theory to study the process of transformation of Human Capital to Human Capital Resource Emergence for the adoption of emerging technology, robotics. We have conducted a literature analysis in terms of exploring peer-reviewed published articles and relevant authentic websites.

1.1 Analysis of Human Capital Theory

Human capital is a multi-level concept and is considered to be an intangible, socially complex resource (Black & Boal, 1994). It has been agreed upon and defended that the investigation and analysis of human capital is intrinsically historical and can be traced to the nineteenth century (Goldin & Katz, 2024). This theory has gained significant attention in recent decades, due to an upsurge in the knowledge economy, where the significance of human capital is increasingly recognised as a crucial catalyst for economic development (Kell et al., 2018). Human capital theory claims, at its foundation, that putting resources toward people's education, training, and other skill-building opportunities may boost national incomes and productivity (Kell et al., 2018). Building sophisticated and comprehensive human capital for achieving national development goals necessitates new strategies in education and training to manage the skillset deficiencies of the workforce (Pereira et al., 2020).

The term “human capital” refers to the economic worth of an organization's total workforce as a whole, including their abilities and the quality of their work. It is the stock of skills that the labour force possesses (Goldin, 2016). It has been discussed in the economics, HR, strategy, accounting, and psychology literature, with each field's research utilising slightly different language and making a variety of assumptions (Ployhart & Hale, 2014). During the last six decades, academics have extensively emphasized the significance of investment in human capital. The World Economic Forum (WEF, 2013) emphasizes that a nation’s human capital endowment, the skills and capacities that reside in its people, can be a more important determinant of its long-term economic success than virtually any other resource. Thus, Human Capital theory stimulates the concept of developing the skills and knowledge of the employees by investing in learning through education or training (Hatch & Dyer, 2004; Riley et al., 2017). These resources can be of three main types: competencies, attitude, and intellectual agility.

Human capital has been defined by multiple researchers in several ways in the fields of economics, management and organizational context yet, at the organizational level, their focus has remained on the value added by the knowledge and skill set of the humans to an organization, which results in the sustainability of profits and competitive advantage of the firms. The Glossary of Human Resources defines human capital as “the return an organization gains from the loyalty, creativity, effort, accomplishments, and productivity of its employees” (Tracey & Bronstein, 2003). Similarly, Thomas et al. (2013, p. 03) defined human capital as the “ people, their performance and their potential in the organization” (p. 3). In an organization, human capital plays a vital role in the development and creation of new ideas and unique knowledge (Mahoney & Kor, 2015); additionally, it also prompts internal relationships through an exchange of ideas and skills. As claimed by Scarbrough and Elias (2002, p. 10), “[a] theory of human capital places emphasis on how employee competencies create value for the organization” (p. 10). A greater utilization of the specialized knowledge and skills of employees results in the economic growth of the organization (Edwards & Starr, 1987; Rosen, 1983). The simplest definition of this theory indicates that human capital is an asset; if organizations invest in building the knowledge, skills and capabilities of their employees through training and providing opportunities to use that training, all while keeping their well-being in mind, their ROI will be sustainable profitability and competitive advantage. With human capital, individuals can transform their time today into more productive time for tomorrow (Goldin & Katz, 2024).

As discussed by Weisbrod (1966), human capital refers to the resources that humans have employed to enhance their personal productivity. (Kwon, 2009) stated that human capital serves as a building block that could offer additional value through its utilisation. Ployhart and Moliterno (2011, p. 132) argued that “the roots of human capital lie at the individual level and exist in the full range of employee’s knowledge, skills, abilities and other characteristics (KSAO)” (p. 132); for the purpose of this dissertation, we focused on the definition of human capital in which ‘KSAO’ means

Knowledge (K) - the procedural information required to accomplish a task and leads to skills development; Skill (S) - an individual's capacity and expertise to do a job; Ability (A) - a long term aptitude needed job completion successfully; and Other characteristics (O) - additional traits like personality and behaviours which impact job performance (Ployhart et al., 2014).

At the individual level, human capital encompasses personnel skills, work-related expertise and competencies, entrepreneurial drive, collaboration skills, motivation and alignment with organizational strategy (Cisi & Centrone, 2021). When examining the multiple definitions and explanations from the literature, it becomes evident that human capital means individual-level KSAO. Most academics have agreed that KSAO is embedded in individuals and, as such, provides economic value to a firm (Becker, 1962; Jiang et al., 2012; Nyberg & Wright, 2015). Fostering the knowledge and skills of a committed employee can yield a sustainable competitive advantage for an organization (Hamadamin & Atan, 2019).

In summary, the 'human' component of human capital refers to the 'creator', an individual who employs and applies the knowledge, skills, competency, and experience that develops through a continuous interaction with the surroundings wherein it exists. In a recent review, Islam and Amin (2021) proposed job-relevant, three-part competence framework (cognitive, functional, and behavioural), which can provide a more realistic view of the concept of human capital. According to them, human capital encompasses the knowledge and skills required to execute the job of the employee. The distinct skills and experiences that people bring make human capital invaluable, but it may also be difficult to come by, especially in highly specialized fields. Ultimately, to have a lasting advantage, human capital must be linked to isolating the processes that deer competitors (Coff & Kryscynski, 2011).

1.1.1 Economists' Perspective on Human Capital

It has been claimed that, in 1897, Irving Fisher originally introduced the term "Human Capital" in economics, but it became more prevalent in the literature during the late 1950s (Khaykin et al., 2020). The origins of Human Capital theory can be traced back to the mid-twentieth century during the Third Industrial Revolution, when it was used to develop macroeconomics theory (Goldin, 2016). In those times, labour, physical capital and management were considered to be the primary production factors and means of profitability (Mincer, 1962). Economists wanted to place emphasis on the skill sets of those who developed machines and were mastering certain abilities to effectively work with that equipment. In the context of economics, capital is referred to as the factors of production used to create goods or services that are not themselves significantly consumed in the production process (Boldizzoni, 2008), while the human element is the subject who is taking charge of all economic activities, such as production, consumption, and transactions. Economists have emphasised the point that value is only created when the use of human capital results in an increase in a firm's revenues and/or a decrease in its costs. They have pointed to the importance of the investments in this physical capital, which can result in sustainable profitability (Becker, 1962; Becker et al., 1990; Schultz, 1988; Schultz, 1961). These scholars have argued that a set of knowledge, skills and/or abilities can be found in every member of the organization and these knowledge and skills can be improved, aggregated and/or augmented by the provision of training and education.

Smith (2002) explained that the development of abilities through education or apprenticeship incurs a tangible expenditure, which becomes capital in an individual. Those abilities build the wealth of a nation and society. American economists, Gary Becker, Theodore W. Schultz and Jacob Mincer, coined the phrase human capital in the 1960s to characterize the skills, knowledge, experience, conduct and personality that may be employed productively in the labour market (Becker, 1975**; Teixeira, 2005). In those times, it was not known by many that capital existed in humans and the usage of the term was uncommon in economic literature (Goldin & Katz, 2024). Schultz (1961) elucidated that, "human capital consisted of the 'knowledge, skills and abilities' of the people employed in an organization" (p. 140). Twenty years later, focusing more on attributes and taking 'value' into consideration, human capital was redefined by Schultz (1988) as "all human abilities to be either innate or acquired. Attributes which are valuable and can be augmented by appropriate investment will be human capital' (Schultz, 1988, p. 21). Mincer (1962, 1989) is credited with the groundbreaking work of connecting the distribution of firm revenue to humans and the benefits of on-the-job (OTJ) training to establish and strengthen human capital. Later, in 1993 and 1997, he further explored the influence of spending on human capital in relation to employee turnover, as well as to technological development.

In 1964, Gary Becker, now considered the father of this theory, published revolutionary research which was built and expanded upon his work from 1960 to 1962, encompassing a theoretical framework and a comprehensive overview of the concept that would later be called human capital theory. Becker (1962, p. 11) established the idea of human capital theory by explaining “activities that influence future monetary and psychic income by increasing the resources in people” (p. 11). In later years, he presented the idea of ‘specific‘ and ‘general’ human capital based on the type of training provided by the organization to the employee and the set of skills acquired through those trainings (Becker, 1975*). Training that increases the capability and productivity of an employee in the firm where it is provided is referred to as ‘specific training’ and will formulate specific human capital. On the other hand, ‘general training’ increases trainees' marginal productivity for both the firm providing that training and other firms, thus increasing general human capital (Becker, 1964; Becker, 1975*). Becker (1975**) analysed the ROI of human capital and emphasized that investing in education and training is comparable to corporate spending in materials and other resources. Becker (1994) interpreted human capital as the economic worth of a labour force's aggregated competence and quality, which determines organisational financial output, expanding his research on human capital without further redefining the term.

1.1.2 Management and Organizational Perspective of Human Capital

In the management literature, human capital has been defined as an individual’s knowledge, skills, and abilities used to produce a given set of outcomes (Hitt et al., 2001). Armstrong (2006) emphasized that human capital is knowledge and skills, which individuals create, maintain, and use. The Organisation for Economic Co-operation and Development defines human capital as the knowledge, skills, competencies, and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being (Kwon, 2009). According to management researchers, the performance of a firm is influenced by the knowledge, skills, abilities, experience, and education of its human capital (Hitt et al., 2001; Wright et al., 1994). In their later research, Wright and McMahan (2011) highlighted that there are three primary elements to the idea of human capital: talent, qualified, and competence (Osiobe, 2020).

At the organizational level, human capital refers to the economic worth of an organization's total workforce, including their abilities and the quality of their work. It is the stock of skills that the labour force possesses (Goldin, 2016). Bontis et al. (1999) have suggested that human capital is the collection of intangible resources that are embedded in the members of the organization. That human capital has a direct impact on the knowledge pool of an organization, as the intangible skills and abilities of the employees in which the knowledge is embodied in the organizational processes, systems and routines (Mahoney & Kor, 2015). The performance of a firm is influenced by the knowledge, skills, abilities, experience, and education of its human capital (Hitt et al., 2001; Kianto et al., 2017; Veltri & Silvestri, 2011; Wright et al., 1994). In the organizational context, an assessment of all types of capital is necessary for understanding the ways in which individuals impact a firm`s success, because human capital is only valuable if it can be transformed into profitable commodities and services (Baron, 2011).

In a detailed meta-analysis aimed at studying the relationship between human capital and firm performance, Crook et al. (2011) were able to identify that most studies have indicated that investments in human capital certainly contribute to an improved firm-level performance. However, to achieve positive outcomes, adequate time and expenditure should be invested in training workers and enhancing their knowledge and skills. It is widely believed that learning is the essence of increasing human capital because of the accumulation of knowledge and skills (Kwon, 2009). Extensive research in this domain has concluded that the education and training necessary to build human capital is pivotal in creating and maintaining a competitive advantage for firms (Barney, 1991; Becker, 1994; Becker et al., 1990; Coff, 1997; Combs et al., 2006; Mincer, 1989). The core of human capital theory is that knowledge enhances cognitive capacities, making humans more productive and efficient in the activities they perform (Zane, 2022).

Research has shown that human capital development, combined with the commitment of employees, results in the establishment of sustainable competitive advantage for the firm (Terblanche & De Villiers, 2018). According to Wright et al. (1994), human capital will be impactful for an organization's performance if the owners of the human capital allow the organization to take advantage of it through their behaviours. Behaviour may act as a mediator between human capital and performance (Harris et al., 2018). Deming (2022) emphasized that human capital contributes to at least one-third of labour market income variability within nations, while human capital stock variation may account for a minimum of half of per capita income variability among countries. Effective management of human capital enhancers such as leadership practices, information accessibility, development capacities and employee engagement boosts organizational performance, efficiency and growth (Mutua et al., 2024). As a result, human capital is seen as essential to future development and success in any industry or nation.

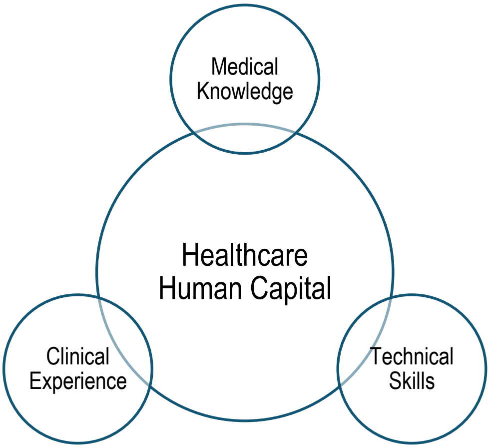
1.1.3 Healthcare Human Capital

Human capital in healthcare was defined by Benos and Zotou (2014) as the set of knowledge, skills, competencies and abilities embodied among people and acquired through education, new learning, training, medical care and experience. Santos-Rodrigues et al. (2010) explained that, in the healthcare industry, human capital is the manifestation of health knowledge. In general, all healthcare professionals (HCPs) comprise the human capital of the healthcare industry. Bartel et al. (2014) explored human capital in healthcare, focusing their research on nurses. Based on the department, specialty and level of experience, they investigated general and special human capital in nursing for productivity and teamwork among nurses that would result in improved patient outcomes. Yakusheva et al. (2024) claimed that nurses are essential human capital for the healthcare industry, developing a model reflecting the economics of nursing worth and guiding investments in nursing human capital, therefore enhancing the value creation for patients, health organizations and the nurses themselves. Medical doctors comprise the pivotal human capital of the health industry; their expertise, knowledge and clinical practice, i.e., higher human capital, lead to better patient outcomes and the financial stability of their health institutes (Doyle Jr et al., 2010; Wang et al., 2024).

Singh et al. (2023) investigated the advantages of using emerging technology in healthcare and urged policymakers to use technology in policymaking as well, which will guide them towards modern human capital management in their field. It is the clear reality of today that, on one hand, the development, growth and integration of technology are creating challenges for health care providers, whereas, on the other hand, such technology is creating opportunities for both employees and organizations to learn, evolve and effectively embrace the future (Vrontis et al., 2021). From the above discussion, it can be seen that human capital is essential for an organization to build and maintain a competitive edge, to innovate and to strategically grow to accommodate new practices and processes. Human capital, in general and in healthcare in particular, will require investment and support for learning new skills and to accommodate new standards/practices, which will be introduced with the deployment of new technology in the existing systems.

There is no clear definition of healthcare human capital in the literature; therefore, we felt that, considering the uniqueness of the healthcare industry, it would be of added value to define healthcare human capital rather than using a general definition. Drawing on a variety of arguments and interpretations found in the literature about human capital and health professionals, human capital in healthcare can hence be defined as the medical knowledge, clinical experience, technical skills and attributes of social skills, communication and building a reputation with patients and families of a clinician. Based on their expertise, a clinician should be capable of delivering safe, competent and efficient care, which will result in value for patients and financial growth of the healthcare organization. Furthermore, a newly graduated nurse or staff nurses can be considered the 'general human capital' of healthcare, whereas nurses holding years of experience and training in a particular field like the ICU, robotic surgery, infection control, etc., should be thought of as the 'special human capital' of a health institute (Bartel et al., 2014). Building on the same approach, we propose that a fresh medical graduate and/or a doctor under training can be considered as 'general human capital' while after acquiring special training and years of experience in a particular speciality, like endocrinology, gynaecology and surgery, etc., a specialist/ consultant is considered as a 'special human capital'.

Figure 1. Elements of Healthcare Human Capital



1.2 Conceptualization of Human Capital Resource

As discussed above, the acquisition and development of human capital have been extensively researched in multiple dimensions and industries (Wright, 2021; Wright & McMahan, 2011). Research in the human capital resource domain emanates from the Human Capital theory (Becker, 1964). Human capital theory is an individual-level framework that was not sufficient to demonstrate how variations or changes across different levels of human capital distinguished it from the individual level (Ray, Essman, et al., 2023). This resulted in the emergence of a new contemporary component known as human capital resource within the traditional field of human capital (Nyberg & Wright, 2015). The strategic implications of individual knowledge, skills, abilities, and other characteristics (KSAOs) are the epitome of human capital resources (Ployhart & Hale, 2014). Nyberg et al. (2018) have argued that there is a pressing need to study, explore and understand the effective utilization of human capital in terms of its contribution to a unit or department. Ployhart and Moliterno (2011) introduced the term "human capital resource" and discussed its integration.

Human capital resource research has concentrated on analysing its impact on unit accomplishments and the strategic orientation of an organization (Nyberg et al., 2018). Initially, Ployhart and Moliterno (2011, p. 128) defined a human capital resource as "a unit-level resource created from the emergence of an individual`s KSAOs" (p. 124). Later, Ployhart and Hale (2014) defined Human Capital resources in the organizational and unit-level context, focusing on performance outcomes and value generation, respectively. Human Capital Resources is defined as “individual or unit-level capacities based on [individual knowledge, skills, abilities, and other characteristics] (KSAOs) that are accessible for unit-relevant purposes” (Ployhart & Hale, 2014, p. 374). According to Harter et al. (2002), at the unit level, the term, human capital resources, means the influence of workforce engagement on firm outcomes such as customer satisfaction, productivity, employee turnover and accidents, all of which contribute to best practices. Hence, strategic human capital resources can be defined as “the individual- or unit-level (collective) capacities based on individual KSAOs that contribute towards competitive advantage (Ployhart & Hale, 2014, p. 381).

Academics and practitioners have both expressed interest in the question of human capital resources (Nyberg et al., 2012; Weller et al., 2019; Wright & McMahan, 2011). Practitioners are more interested in learning the impact of such resources on organizational outcomes (Nyberg & Wright, 2015), whereas academics who are more focused on micro-level research concentrate on the strategic outcomes of human capital resources (Ployhart, 2012). According to Ployhart and Moliterno (2011) Human capital resources can be strategically leveraged to substantiate a sustainable competitive advantage. This is best understood as the specific KSAOs possessed by an individual that are relevant economically, are accessible within an organization and strategically aligned to contribute positively to an organization`s economic activities (Gerhart & Feng, 2021; Ray, Essman, et al., 2023).

When employed together, human resources and their management in particular may be seen as contributing value to the organization, fulfilling the demands of unstable environments (Kazlauskaite & Buciuniene, 2008). Nyberg and Wright (2015) conducted a systematic review of empirical articles published in the strategy and strategic human resource management (HRM) on human capital resources literature, proposing three core dimensions, i.e., HCR type, context and antecedents. Based on their extensive exploration, they concluded that HCR at the unit level is supported by a multi-level micro foundational structure that includes both KSAOs at the individual level and organisational processes, such as the HRM practices that form the HCR at the collective level. Conclusively, Ployhart and Hale (2014) stated that the term “human capital resources” is applicable to both individual Human Capital Resources (HCRs) and human resources at the unit-level.

Nyberg and Wright (2015) have recommended that the human capital should be limited to individual KSAOs; however, when taking unit-level outcomes into consideration, the term should be adopted and practiced. Moliterno and Nyberg (2019, p. 05) argued that “[t]o summarize, when we think about the individual's KSAOs, then human capital is the correct term. However, when we talk about human capital from the unit's (e.g., firm, team, and department) perspective, then we are talking about Human Capital Resources”. Eckardt and Jiang (2019, p. 77) defined it “as the transformation and amplification of individual human capital into a unit-level human capital resource”.

Barney (1991, p. 99) argued that resources of a firm include “all assets, capabilities, organizational resources, firm attributes, information and knowledge controlled by a firm that enable the firm to conceive and implement strategies that improve efficiency and effectiveness. These resources are the competitive edge of a firm and, as such, are valuable, rare and imperfectly imitable. Human Capital Resources is one of the strongest assets of an organization, and attempting to imitate it can be difficult for competitors (Barney & Wright, 1998; Coff, 1997). Ployhart et al. (2014) further argued that Human Capital Resources not only exist at the unit level as individual KSAOs but if leveraged significantly, even an individual can become an element of firm-level performance, allowing them to pursue organizational objectives. The value of human capital resources can only be justified when it has a positive impact on the performance and competitive advantage of a firm and this behaviour should be firm-specific (Ployhart, 2021). Resources in human capital are available and pertinent to an organization`s function, highlighting the need for synchronizing individual competencies with organizational requirements to generate value (Islam & Amin, 2021).

Simply, if described on an individual-level then Human Capital is the appropriate term; however, from a unit or department perspective, i.e., task-specific, then Human Capital Resources is the terminology to be applicable (Moliterno & Nyberg, 2019). In general, to establish a full understanding of the process, where an individual-level KSAO is transformed into a unit-level resource, the literature is scarce and there is a pressing need to investigate these phenomena and their interrelationship as a process (Eckardt et al., 2021). To be effective at an organizational level and to establish a higher order of Human capital construct, the Human Capital Resource requires a process of emergence (Ployhart & Moliterno, 2011). Based on multi-level theories, academics have commended that Human Capital Resources implicates a complex emergence process (Barney et al., 2021; Ployhart & Hale, 2014). This gap in current literature provides an opportunity to explore the process of its creation or emergence (Jun et al., 2024).

1.3 Human Capital Resource Emergence Theory

Ployhart (2012) conducted extensive research on human capital, introducing new dimensions of knowledge about Human Capital Resource, specifically, Human Capital Resources Emergence. According to Ployhart and Moliterno (2011), human capital resource emergence occurs through emergence-enabling factors they identified as behavioural, affective, and in cognitive states. The concept of emergence was developed some hundred years ago, when Pepper (1926, p. 242) made the interesting claim that "[e]mergence is supposed to be a cosmic affair" (p. 242). Ablowitz (1939) posited that, like many things, emergence itself was based on the idea that a whole can be more than the sum of its parts, a significant concept when attempting to realize a multilevel construct. Meehl and Sellars (1956) debated that emergence is an aggregate change whereby certain existing characteristics combine to form a new level. Pienemann (1984, p. 191) defined emergence as "the first systematic use of a structure, so that the point in time can be located when a learner has, in principle, grasped the learning task". Protevi (2006) explained that the process of emergence takes place when the diachronic development of functional frameworks in intricate structures attains a synchronic emphasis on systematic behaviour while constraining the activities of individual components.

Galatzer-Levy (2008) took the human perspective into account and hypothesized that emergence can be seen as an unexpected appearance of something new. As explained by Fitz-Enz (2010), during the emerging transformation process, constraining and driving forces conflict and, consequently, a new structure emerges. Human capital resource emergence theory suggests that individual traits alone may not be sufficient for determining the effect of human capital on overall performance. But how this process of evolution happens still requires further investigation and, thus far, research has been limited, particularly for technology deployment. This is especially deficient from a healthcare perspective. Effective organizational human capital requires emergence, with an emphasis on the knowledge, skills, attributes and other characteristics (KSAO) contained in individuals coming together and thus constituting unit-level human capital resources to generate higher-order human capital. This process of conversion remains underexplored in literature.

Over the last two decades, human capital resource emergence research has propelled the advent of a new dominion of social process research, like behaviour, based on the interaction between and among actors (Harris et al., 2018). Klein and Kozlowski (2000, p. 55) described this as “a phenomenon (as) emergent when it originates in the cognition, affect, behaviours, or other characteristics of individuals, is amplified by their interactions, and manifests as a higher-level, collective phenomenon” (p. 55). Emergence has been referred to as a point at which the structure commences for the first systematic use, which obligates the involvement of the “receptive processes like apperception, comprehension, intake, and integration (Pallotti, 2007). DeHaan (2006) argued that emergence is universal, diverse and is a mechanism which cultivates novelty. Chalmers (2006) proposed the concept of strong and weak emergence, whereby one phenomenon arises from a high-level domain and another from a domain that is of a lower level. Holman (2010, p. 14) interpretation of emergence is one of order arising out of chaos, where new possibilities surface, new coherence arises, stating that “This pattern of change flows as follows: Disruption breaks apart the status quo; The system differentiates, surfacing innovations and distinctions among its parts; As different parts interact, a new, more complex coherence arises”.

Mnif and Müller-Schloer (2011) determined quantitatively that absolute emergence results from the increase of order by self-organization processes among the components of a system. Human capital resource emergence is a situation where a group of individuals, with all their relevant human capital, jointly emerges into a unit-level human capital construct (Ployhart & Moliterno, 2011). Similarly, Argyris (2014) argued that when nonlinear and complex systems emerge from a chaotic state into a structured state, this capacity is known as emergence. However, what is behind the chaos and why systems need order and how this structured state is achieved, remains an area which can be considered a fertile ground for further exploration. Anjum and Mumford (2017) further discussed emergence as a novel composition where the ‘whole’ has divergent qualities from its parts, but also consists of properties of its parts.

Ployhart and Moliterno (2011) developed a theoretical model of human capital resource emergence, maintaining that two components conduce the emergence of individual human capital into a unit-level resource, the unit's task environment (interdependence) and emergence enabling states (behaviours). They postulated a human capital emergence model, which provides a framework for assessing human capital at an individual level, later aggregating it to the unit and/or organizational level. The authors suggested that the impact of human capital on performance is complex and is not limited to aggregated individual characteristics. However, Kozlowski and Ilgen (2006) brought to light the concept of an 'emergence enabling process' which propels and directs this transformation of individual level KSAO to a unit level. According to S. W. Kozlowski (2019), the emergence of human capital resources is the process of translating from one domain to another, where a new systematic domain arises that combines the value.

Ployhart and Moliterno (2011) emphasized that advanced adaptability and coordination are necessary for complex tasks and that context-generic human capital resources, which are based on general cognitive ability, personality, values, and interest, are the active ingredients of the establishment of context-specific human capital resources. Based on multi-level theories, academics have commented that Human Capital Resources implies a complex emergence process (Barney & Felin, 2013; Ployhart & Hale, 2014). Current literature has recognized the value of human capital resources (HCR), but further investigation about their creation or emergence process is needed. According to Ployhart and Moliterno (2011), Human Capital Resources emergence occurs through emergence-enabling factors identified as behavioural, affective, and cognitive states. Thus, the study of human behaviour should naturally be included in Human Capital Resource research since individual behaviour is pivotal to unit-level resources (Felin et al., 2015; Ployhart & Hale, 2014).

The process of the creation of Human Capital Resource emergence cannot be understood from the definitions of Human Capital Resource emergence. According to Kozlowski and Chao (2012, p. 267), "the result of bottom-up processes whereby phenomenon and constructs that originate at a lower level of analysis, through social interaction and exchange, combine, coalesce, and manifest at a higher collective level of analysis" because the emergence process starts at the individual human capital level, with social interactions facilitating that emergence, significantly influencing unit results or outcomes (p. 267).

Morgeson and Hofmann (1999) believed that multilevel theorization required a deep understanding of social interactions. This idea has been conceptualized through research indicating that human capital resources' emergence is enabled through shared states, which are derived from environmental conditions (Ray et al., 2021). Those conditions or enablers are unit (internal) characteristics “that are typically dynamic in nature and vary as a function of [unit] context, inputs, processes, and outcomes” (Marks et al., 2001, p. 357). Human capital resource emergence is multilevel and has a collective construct; hence, understanding of the social interactions involved is pivotal. According to (Cannella & Sy, 2019), extrinsic variables can also influence maintenance and the emergence of human capital resources. Understanding human capital resource emergence requires a focus on tasks with high interdependence and cooperation among unit members. The main challenges in understanding human capital resource emergence process are related to enabling conditions, social context, measurement challenges, employees` behaviour and coordination (Harris et al., 2018; Ployhart & Moliterno, 2011; Wright & McMahan, 2011; Wright et al., 1994).

Ray et al. (2021) stated that social interactions were the epitome of all emergence processes. Their theory proposes how special characteristics of social interactions influence the development of human capital resources through the emerging process, adding much-needed precision to theoretical viewpoints on emergence to fill this gap in the literature. Following the nature of tasks and social environment, the individual knowledge and skills of unit members are revolutionized, resulting in synergistic factors that amplify the value created by the unit of an organization. Campbell et al. (2014) examined the social dimension of human capital and its influence on performance on the individual level, while Harris et al. (2018) studied it from a social perspective as well, but on an organizational level, emphasising the importance of social aspects, processes and behaviours. Thus, human capital emergence is of utmost importance for unit performance to achieve organizational goals and emphasizing social processes and individual behaviours (Ployhart & Moliterno, 2011). Further investigation is required to study the process of Human Capital Resource Emergence to fully understand and disclose the potential value embedded in the Human capital of employees (Biały & Piasek, 2024; Grand et al., 2016; S. W. Kozlowski, 2019). In particular, there is a lack of evidence in the literature to sufficiently explain how this emergence process occurs in healthcare ecosystems when new technology is put into practice.

1.3.1 Human Capital Resource Emergence in Healthcare

Healthcare is distinctive because highly skilled personnel work together in a socially dynamic environment to accomplish profoundly interconnected tasks with the goal of ensuring safe patient care (Schmidt et al., 2023). Healthcare professionals are the human capital of the healthcare structure; teams working together in a department serve as the human capital resources of each unit. Building on the requirements of highly qualified capabilities in all healthcare activities, especially the effective delivery of care, human capital in healthcare is of extremely significant value (Huang et al., 2020), yet the process of resource emergence remains understudied in general and especially for the implementation of emerging technologies. When a technology is deployed into the complex, intense, and multidisciplinary environment of healthcare, it results in chaos; its impact on an already hectic healthcare sector becomes amplified (Jose et al., 2023).

Although not specifically trained in leadership, physicians largely work with multidisciplinary teams and are treated as leaders or main decision-makers of the care (Kozlowski et al., 2016). With Industry 4.0 affecting all dimensions of life and the accompaniment of the chaos of the recent pandemic, it would be timely to investigate the emergence of human capital resources in healthcare systems, which work on continuous social interactions, to effectively and efficiently embrace, adopt and co-specialize with the emerging technologies. When a technology is implemented in the healthcare system, it affects not only the specific unit but also departments due to the multidisciplinary nature of the work (Vassolo et al., 2021). Thus, exploration of human capital emergence in healthcare settings to study the transformation process from the perspective of individual- to unit-level KSAO with the implementation of new technologies is essential.

1.4 Capacity Building

Wright and McMahan (2011, p. 102) proposed that the combined strength of the human capital and social capital facilitates “human capability,” or “… the ability of a group of individuals to cooperatively perform a function or set of functions.” Capacity building aims to constitute an infrastructure for the transformations of the future (Stafford-Smith et al., 2017). Capacity building is crucial to the progress of the organizations, emphasizing the enhancement of employees' skills and knowledge for human capital development (Jain et al., 2024). This research examines its crucial role in promoting creativity, adaptation, and the efficiency of human capital. Particularly, with the implementation of new technologies, it is crucial that existing human capital advances its capabilities to adapt to the new requirements and adjust to new work designs (Smith et al., 2011).

Capacity building and critical thinking are the approaches that lead to sustainable development (Wals, 2011). The United Nations Development Programme UNDP (2002) has defined capacity building as “the process by which individuals, groups, organizations, institutions, and societies increase their abilities to:

1. Perform core functions, solve problems, define, and achieve objectives.
2. Understand and deal with their development needs in a broad context and a sustainable manner” (Ionel, 2017, p. 3).

Similarly, the United Nations Development Program (UNDP, 2002) highlighted that capacity building is broader than organizational development since it includes an emphasis on the overall system, environment, or context within which individuals, organizations, and societies operate and interact (Fukuda-Parr et al., 2002). Capability building is an inclusive term for a wide range of activities aimed at enabling individuals, places, and objects to be more equipped to deal with problems and thrive. Development of skills, mobilization of resources, and cultivation of supporting social ties are all facets of capability building (Chaskin, 2001).

Eade (2007) made the claim that there is no ‘one-size-fits-all’ formula for capacity development; rather, it is more like a collection of components than a physical object. Its development involves numerous diverse and competing actors, the engagement of an outsider to assist locals in determining those elements’ importance, and the formation of committees to act upon and maintain these values for the common good, all while shaping the physical and moral cosmos. According to Baker and Dutton (2017, p. 328), “capacity refers to the abilities of people and groups to achieve their personal and professional goals. Capacity is ‘generative’ when it can reproduce and renew itself, expand abilities, and enable the combination and recombination of resources in new and novel ways” (p. 328). The building of the capacity aids in identifying the need for further development as well as the need for new competencies, which may enable the formulation and achievement of goals (Jensen & Krogstrup, 2017).

New technologies demand comprehension, alignment, and adaptation to new trends to stay current (Cosa, 2023). According to DeCorby-Watson et al. (2018), efforts focused on enhancing capacity can have a positive impact on knowledge, skill, self-efficacy (including confidence), policy or practice changes, behaviour change, application, and system-level capacity. Capacity building has a temporal orientation towards the achievement of an improved future state (Brix, 2019). This alignment and adaptation can be realized through capacity building, which, in turn, requires appropriate training and/or acquisition of new, skilled talent that will aid and assist in the adaptability (Beane, 2018). Hence, capacity building is a proactive approach (Jensen & Krogstrup, 2017) and is a prerequisite for the co-specialization of human capital with technology (Kim et al., 2019).

1.4.1 Capacity Building in Healthcare

Representing a broad spectrum of disciplines and industries, capacity building linked to a workforce encompasses human resources and their expertise, professional association, training and development (Sorensen et al., 2021). With the deployment of a new technology, the human resources of a hospital must be prepared to provide opportunities and time to healthcare professionals, which will facilitate the acquisition of new skill sets and capacity building. Ongoing learning to build capacity is essential for healthcare professionals to remain updated with the new information and to deliver better care to their patients (Aryee et al., 2024). While studying the challenges and opportunities for the deployment of an emerging technology in healthcare, Petersson et al. (2022) concluded that, in addition to sophisticated systems thinking, transforming learning processes at all organizational levels is required in a healthcare system. They also observed a lack of internal capacity for strategic change management for the implementation of a new technology. We argue that human capital (individual-level) and human capital resources (unit-level) will require social capital and capacity building to co-specialize with the technology/machine and to emerge into a combined talent, which will deliver unit-level outcomes and organizational strategies to become a sustainable source of competitive advantage. Yet, the synthesis of all these aspects requires further investigation and empirical evidence.

1.5 Social capital

In a recent study about human capital resource emergence, Ray et al. (2021) built on the social capital literature to propose a Human Capital Resource Emergence

(HCRE) theory, further enhancing the unprecedented features of social interactions that act as the main influencers/catalysts of the creation of human capital resources through the emergence process. Individuals exist in a social setting that could influence their perspectives, thinking styles and responses to knowledge. Interactions among social processes influence people's degree of coordination and cooperation, therefore creating a kind of social capital (Ployhart & Moliterno, 2011). Humans are social animals and exist in a social setting that could influence their perspective, way of thinking, and reaction to knowledge. Social capital is inherent to social structures that facilitate specific actions (Cisi & Centrone, 2021). Three forms of social capital are obligations/expectations, information channels, and social norms (Coleman, 1990).

Academics have defined the concept in various ways; nevertheless, they have all focused on the capacity of individuals to gain advantages by participating in social networks or frameworks to share knowledge. Trust, accessibility, facilitation of action, and mutual benefits are common elements in these definitions. It is believed that Pierre Bourdieu (1985) created the first modern systematic study of social capital, defining the concept as “the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition” (Bourdieu, 1985, p. 248). Later, Baker (1990) defined the concept as “a resource that actors derive from specific social structures and then use to pursue their interests; it is created by changes in the relationship among actors” (Baker, 1990, p. 619).

Schiff (1992) further elaborated on the concept by providing the definition of social capital as “the set of elements of the social structure that affects relations among people and are inputs or arguments of the production and/or utility function” (p.). However, Coleman (1988, p. 98) defined the term by its function as “a variety of entities with two elements in common: They all consist of some aspect of social structures, and they facilitate certain actions of actors—whether per-sons or corporate actors—within the structure.” He claimed that social capital, in contrast to physical or human capital, had the characteristics of a public benefit, often resulting in its underinvestment. Putnam (1995, p. 67) provided a more cumulative and explanatory definition as, “by analogy with notions of physical capital and human capital—tools and training that enhance individual productivity—'social capital’ refers to features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit.”

Social capital acts as a catalyst for leveraging and augmenting human capital, enabling individuals and groups to achieve more than they could through human capital alone. It creates learning-conducive environments, cooperation, and mutual support, all of which are crucial for the advancement and efficient development of human capital (Swanson et al., 2020). The link between human and social capital is characterized by interdependence and reciprocal reinforcement, whereby each form of capital enhances the value and impact of the other, combining individual KSAO and social structures (Coleman, 1990; Lee et al., 2015). In an organizational perspective, social capital plays an ambidextrous role in the emergence of human capital resources, primarily by facilitating access to opportunities, information, and support networks, which leads to enabling actions within a structure (Dinda, 2014). Christoforou (2012) emphasized that individuals are not isolated actors but are embedded in social relationships and organizations that shape their behavior and opportunities by shaping identities and providing alternative opinions and active and reflexive behaviors. It can be argued that social capital is an individual or community asset when, in fact, it can be considered as both an individual asset and a societal resource having collective elements. Some researchers have focused on individual social capital, while others have seen social capital as a group-level phenomenon that collectively contributes to economic growth (Christoforou, 2012; Glaeser & Sacerdote, 2002).

Baker and Dutton (2017, p. 349) identified “six types of enablers of positive social capital that operate through the mechanisms of motivation and opportunities: selecting on relational skills, participatory selection practices, relational socialization practices, rewarding for relational skills, using group incentives, relational meeting practices, and using collaborative technologies” (p. 349). They claimed that when people in an organization are encouraged and given the chance to build high-quality relationships based on generalized reciprocity, positive social capital is developed, which, in turn, contributes to organizational output. Fukuyama (2000) explained that a system of informal rules among the group members allows them to cooperate, to perceive others to be honest, and to develop trust, which helps any organization function to become more efficient and is considered social capital. This perspective aligns with the broader understanding of social capital, wherein two essential components, i.e., trust and reciprocity, foster solidarity and collective action. For this research, we will focus on and consider the definition of Fukuyama (2002), which is as follows: “Social capital is an instantiated informal norm that promotes cooperation between two or more individuals” (Fukuyama, 2002, p. 03).

It is worth noting that although the significance of social capital has been fully recognized, research on its construction and preservation remains insufficient. Further study is required to ascertain the determinants that influence the development of social capital at the organizational and individual levels (Zhang et al., 2019), as well as its impact on or role in human capital resource emergence. The concept of social capital has a significant influence on collaborative creativity during times of crisis, as well as the sustainability of organizations. There is a clear relationship between social capital and managing chaos during uncertainty (Al-Omoush et al., 2022). With close connections and coherent networks in an organization, recognizing issues and problems, as well as analyzing ideas, priorities, and alternatives, can become feasible. The pandemic brought chaos to all the industries, but healthcare was heavily affected. Kim and Lee (2021) observed that the digitalization of healthcare was expedited during the uncertainty of the pandemic, which positively contributed to the development of social capital among the healthcare professionals. But it is unclear if social capital did or did not contribute towards the adoption of technology. However, even though social capital, innovative activities, and organizational performance are all closely linked, there is a deficiency of empirical research that investigates these variables together (Ozgun et al., 2022). Healthcare being a deeply social industry, these concepts have been barely investigated in the healthcare system (Malik et al., 2024).

1.6 Resource Co-specialization

A concept rooted in the resource-based theory and dynamic capabilities theory focused on the development of a firm's competitive advantage gained through the utilization of interdependent assets (Barney et al., 2021; Teece, 2007). The term was introduced by Teece (1986) in terms of organizational assets as “[co]specialized assets are those for which there is a bilateral dependence” (Teece, 1986, p. 289). It is the idea of striking an equilibrium between cooperation and competitiveness to achieve breakthroughs (Teece et al., 1997). Resource co-specialization is a strategy of bilateral specialization whereby two parties are bound into a relationship with sustained mutual commitment, which requires continuous specialization (Kim et al., 2019). Reskilling and/or upskilling of existing human capital through training and education has always been considered essential to evolve and remain contemporary (Anteby et al., 2016). Since the requirement of the emerging technologies is incorporating new trends to remain relevant, it also requires the acquisition of fresh and competent talent that will support adaptation (Beane, 2018). Resource co-specialization agglutinates the resources to create a specialized combination, which is valuable, unique, and difficult to imitate (Teece, 2007).

Mahoney and Pandian (1992) argued that resource co-specialization demands the creation of 'idiosyncratic bilateral synergy' through ongoing mutual adjustments by both exchange parties. This partnership results in the development of resource bundles to create value (Cennamo et al., 2018). Hence, when two or more assets are combined to create value that is significantly greater than the value of each asset when used separately, this is known as co-specialization. For instance, a newly trained worker might gain insight from an experienced employee. Resource co-specialization has been extensively discussed for collaborations between firms to acquire competitive advantage jointly by outsourcing or other partnerships. In the management literature, it is generally accepted that, for firms to be able to capture the financial benefits of gaining access to new resources and capabilities, there must be some degree of co-specialization amongst those firms' respective sets of skills and resources (Barney et al., 2021). However, in terms of human capital and robots, the current literature is limited for resource co-specialization.

In knowledge-intensive industries like healthcare, co-specialization enhances development and acceptance of technology (Helfat & Peteraf, 2003). But how co-specialization happens when resources from these industries come together has not been widely explored. Charlier et al. (2016) suggested that, to promote co-specialization, organizations should encourage employees to invest in job-specific skills, which will in turn lead to job embeddedness, confidence, and retention. Human capital resource emergence requires co-specialization of the resources in a unit (Kim et al., 2019). Through this research, human capital resource co-specialization between health care providers and the surgical robots is being explored, and an in-depth understanding of the relationship is investigated to gain insights into the process of resource emergence by exploring the related challenges for the co-specialization and capacity building of health care providers with the robots for maximum value achievement.

Human-machine teamwork is happening today and is expected to be more prevalent in the near future; a clear opportunity lies in exploring the enhancement of this co-specialization (Stowers et al., 2021). The success of a team is dependent on its members' ability to work together and effectively integrate their various responsibilities; robots that enable work with people will be crucial for future human-machine collaborations (Funke et al., 2022). Consequently, human-robot co-specialization will become increasingly relevant. With the deployment of robots, co-specialization should happen between healthcare human capital and the machines to fully optimize the benefits of this new technology, and this will require research into ways to streamline the process.

1.7 Co-Specialization of Human Capital with Technology

Based on theories concerning the creation of new technology, technology enhances skills and raises return on investment (ROI); this indicates that technological progress accelerates when there is a greater number of individuals involved (Goldin & Katz, 2024). Human capital in a team-based structure not only enables knowledge sharing but also results in co-specialization of the members among themselves and with the technology (Liu, 2013). When human capital interacts with other organizational assets/resources, co-specialization happens, resulting in better value when these resources work in combination and collaboration (Mahoney & Kor, 2015). Barro (1991) developed a framework to demonstrate that investing in education and building human capital boosts productivity and technological advancement.

Agolla (2018) proposed that the current human capital must accommodate the fact that their existing tasks and skills will no longer prevail in the future, because of the integration of new technologies, the changes are abrupt, and uncertainty is on the rise. Industry 4.0 is meant to utilize emerging technologies thoroughly and comprehensively to meet global challenges (Wang et al., 2016). Sima et al. (2020) noted that, with the advent of Industry 4.0 and the presence of emerging technologies, organizations must be ready to transform their work dynamics. With ongoing technological advancements in the world, human capital is more relevant, and it requires more attention than before to adjust to new technologies. Paździor et al. (2023) have highlighted that the complexity of modern socio-economic systems with the integration of emerging technologies is not only enhancing the value of technological resources but is simultaneously intensifying the value of intangible resources, such as human capital (knowledge, skills, and attributes).

In the global economy, Industry 4.0 is one of the most important leaps (Schwab, 2024). The Industry 4.0 revolution is composed of Robots, Mobile, Cloud, Big Data analytics, machine-to-machine (M2M), man-to-machine interactions (M2MI) and 3D Printing (Agolla, 2018). Maskuriy et al. (2019) stated that Industry 4.0 is a brand-new philosophy, which is causing a social change by affecting all areas of life, ranging from safety, education, science, the labour market, and welfare systems. Schumacher et al. (2016) explained that Industry 4.0 is referred “to as recent technological advances where the internet and supporting technologies (e.g., embedded systems) serve as a backbone to integrate physical objects, human actors, intelligent machines, production lines, and processes across organizational boundaries to form a new kind of intelligent, networked, and agile value chain” (p. 162).

These technological advancements are prevalent in every walk of life today. The development of more advanced technologies is demanding more advanced human capital. Similar to the past, where tangible machines in the manufacturing industry required intangible human capital to run them, today we need more knowledgeable, technically skilled, and agile human talent to optimally use these technologies. According to the World Bank (2019, p. 51), “people with higher human capital adapt faster to technological change” (p. 51). It could be said that human capital is the primary driver of the acceleration of technological advancements. Simultaneously, the introduction of a new technology demands new knowledge, skills, and attributes for adjustment and acceptance. When humans use technology and interact with it, they adapt to it in different ways, with a variety of usage and application outcomes (Eze et al., 2019).

Today, the most substantial agenda and priority of an economy or an organization should be the development of technology co-specialized human capital. However, developing more advanced and dynamic human capital for the attainment of sustainable growth requires progressive approaches towards education and technical training to build the capability of the workers. This will assist in the identification of the gaps and will support the effective planning of relevant strategies that are time-bound, achievable, and practical when deploying emerging technologies and the development of co-specialized human capital.

As the time of Industry 5.0 is approaching, it is crucial to comprehend its implications for all sectors in every industry. That requires an in-depth understanding of the challenges faced during the implementation phase of new technologies. Development of human capital in preparation for this upcoming era is already in the phase of change and will require more robust approaches to prepare human capital for Industry 5.0 and beyond, when co-specialization between humans and machines is expected to increase (Khubulova et al., 2022; Maltseva, 2021; Ortina, 2020). Martišková (2019) coined the term ‘Superhuman Capital’, which means going above and beyond creativity, knowledge, and technical skills. To develop this highly skilled and advanced human capital, both governments and organizations should invest in specific training and education. Researchers are providing information on human/machine interaction; thus far, it appears limited to human and machine co-specialization.

1.8 Emerging Technology

Following their systematic review, Rotolo et al. (2015, p. 13) defined Emerging Technology (ET) as “a radically novel and relatively fast-growing technology characterized by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions, and patterns of interactions among those, along with the associated knowledge production processes” (p. 13). This definition had been derived from the five identified attributes of the ET, which the authors extracted from the multiple definitions available in the literature available at that time (Boon & Moors, 2008; Martin, 1995; Small et al., 2014). These included traits such as radical novelty, relatively fast growth, coherence, prominent impact, uncertainty, and ambiguity. Among these attributes of ET, uncertainty and ambiguity are the most difficult to assess and demand further research and exploration (Baiod & Hussain, 2024).

Emerging technologies have the potential to deliver quality healthcare services (Shaheen, 2021). To ensure the readiness of healthcare practitioners, it is important that healthcare institutes and management, medical education institutions and other stakeholders plan and undertake appropriate measures to prepare the healthcare human capital for successful adoption of these technologies (Jain, 2023). Herzlinger (2006) pointed to the six forces that can accelerate or inhibit efforts during the implementation phase of new technologies in healthcare systems, namely, industry players; funding; public policy; technology; customers; and accountability. Jacobs et al. (2015) quantitatively proved that the physician perceptions of implementation climate directly affect the effectiveness of the adaptability of a new technology or work routine. Although advancements in technology development are accelerating and continually becoming more sophisticated, the human capital of healthcare is not adopting those technologies at a similar pace.

Recently, the benefits of emerging technologies have been extensively discussed among medical and academic researchers (Galbusera et al., 2019), particularly following the COVID-19 pandemic (Junaid et al., 2022; Krishnamoorthy et al., 2021; Licardo et al., 2024; Olalekan Kehinde, 2025), highlighting the importance of the usage of these technologies to improve healthcare systems' efficiency. However, consumer receptivity (clinicians and patients) remains underexplored (AlQudah et al., 2021; Lee et al., 2025; Rudawska et al., 2024; Tekkesin, 2019). Rudawska et al. (2024) argued that additional and improved usage of emerging technologies can detect inaccuracies and resolve matters in a speedy manner, as well as being cost-effective.

The introduction and adoption of a new technology in an organization is a dynamic process (Eze et al., 2019). Emerging technologies are abruptly challenging the status quo and causing a demand for updated policies and procedures, not only for personnel management but also for the appropriate selection of human capital to sustain the use of these technologies in the future. Burmaoglu (2019) indicated that, within a set time frame, the cyclical process of technological development in highly scientific networks must demonstrate high functionality, continuous innovation, and synergy. Sustainable human resource management has been described as the ". . . adoption of HRM strategies and practices that enable the achievement of financial, social, and ecological goals, with an impact inside and outside of the organization and over a long-term time horizon while controlling for unintended side effects and negative feedback" (Ehnert et al., 2015, p. 90). The rapid development and availability of these technologies are associated with uncertainties, like both risks and benefits, and have effects on society (Nelson & Gorichanaz, 2019).

Liu and Porter (2020) noted that technology emergence is becoming more evident and trendier in management research. However, measuring indicators to study the impact of these emerging technologies requires identification. Any challenge to recognizing the progression of applying new technology in the industry necessarily starts with a thorough analysis of those challenges. Embracing the challenges of new technology deployment will require experimentation, dialogue, and continuous monitoring of the change (Schartinger et al., 2015). Many studies have documented that health technology development often presents the challenge of poor value alignment between the supply-side and demand-side (Greenhalgh et al., 2018; Jian et al., 2024; Lehoux et al., 2017; Markiewicz et al., 2014; Polisena et al., 2018). Lanza et al. (2020) urged that due to the dynamism of clinical practice and the demand for full autonomy in healthcare for patient treatment, it is not possible for the technology developers to identify and implement all the possible situations. Hence, it is crucial to understand the challenges of medical experts because acceptance and adaptability by the professional staff can be considered as the single most important determinant of the fate of a new technology (Gheorghiu & Ratchford, 2015; Metallo et al., 2022; Nezamdoust et al., 2022; Pols, 2012; J. Taylor et al., 2015; Wade et al., 2014).

1.8.1 Challenges of Emerging technology in healthcare

The global diffusion of common technologies was linked to the COVID-19 pandemic's early phase in 2020. Technological transformation enhances organizational agility and eventually elevates competitiveness (Chatterjee & Mariani, 2022). It is becoming more prevalent that the emerging technologies, e.g., robotics, artificial intelligence (AI), and big data, are the most agile and forward-thinking resources for improvisation of healthcare (Junaid et al., 2022). These technologies can enhance the quality and efficiency of healthcare and can have a significant impact on the cost as well (Zemmar et al., 2020). These approaches can lead to reliable preventive care, which can revolutionize healthcare organizations, resulting in a positive impact on public health outcomes (Thacharodi et al., 2024). While the healthcare industry is struggling with increasing costs and declining performance globally, the clinical entrepreneurs, policymakers, politicians, and computer and data scientists are insisting that the integration of emerging technologies is indispensable and will be a fundamental part of the solution (Morley et al., 2019).

Emerging technologies are revolutionizing and strengthening healthcare by enhancing the availability of clinical data, reducing the burden of mundane work, and advancing analytics systems (Rayan, 2019). Those technologies are considered to be a critical enabler of healthcare simplification and the establishment of intelligent care delivery systems (Lee & Yoon, 2021). Vaishya et al. (2020) stated that, during COVID-19, healthcare did require the support of emerging technologies to cope with the then-current challenges and to be prepared for the future ones. Similarly, AI data-driven medicine has the potential to enhance precision and agility in making better treatment decisions, which will be the future of individualized medical care (Hummel & Braun, 2020). With the goal of better patient outcomes and improved efficiency, robotics, machine learning (ML), blockchain, and the Internet of Things (IoT) are some of the technologies that have been integrated into healthcare (Olalekan Kehinde, 2025).

The usage of cutting-edge technologies presents the challenge of assigning accountability to human or instrument-related factors in cases of errors or failures (Usluogullari et al., 2017). Hence, only machines are shielded from blame for surgical accidents. Stefanini et al. (2020) have emphasized that the likelihood of adverse events and errors during a procedure is lower if the surgical team exhibits a higher level of team cohesion and coordinates implicitly. Earlier research has also shown that emphasis on teamwork and communication, combined with more efficient training and evaluation techniques, may help to reduce some of the risks related to robotic surgery (Gaba et al., 2001; Guerlain et al., 2007; Helmreich et al., 2017). Upon observing the increase in robotic surgery-related adverse events, Garg et al. (2013) proposed team training and the use of intraoperative crisis checklists after observing deaths and accidents during robotic surgery. Ferrarese et al. (2016) identified that device malfunction, whereby a surgical conversion to open surgery is required due to robotic arm failure, is becoming less common, and the capacity of the operator to fix the device in the middle of an operation has improved. Manuguerra et al. (2021) found that risk was well managed during a robotic surgical procedure when the entire team was properly trained.

Those working in healthcare have widely embraced new technologies (Charulatha, 2020). The integration of new technologies and machines in healthcare diagnostic, therapeutic, and rehabilitation approaches is creating a radical transformation of the field of medicine (Giansanti, 2022). The pressing need for establishing a global health policy with a systemic, holistic, and preventive paradigm with emerging technologies is becoming profound. The adoption of digital technologies can enhance the efficiency of key business operations in the healthcare industry, boosting productivity and benefiting many stakeholders, including patients, healthcare practitioners, and healthcare systems (Laurenza et al., 2018). Many researchers have documented that technology development often presents the challenge of poor value alignment between supply-side and demand-side (Greenhalgh et al., 2018; Lehoux et al., 2017; Markiewicz et al., 2014). It is important to note that the work attitudes of healthcare professionals and technology developers differ, which acts as a hindrance in finding solutions for medically related problems and adaptation of new technologies (Anwar & Prasad, 2018).

Practical implementation challenges are hindering the adoption of technology in health systems, and technologies are facing a deployment blockage. Because of cultural, operational, and technological factors, achieving seamless integration into the current healthcare systems is not an easy task. Concerns over the intracity and reliability of emerging technologies are leading to resistance among healthcare professionals (Junaid et al., 2022). Also, the challenge of balancing technology development with conformity to global care standards is another problem for healthcare organizations trying to comply with complicated regulatory frameworks. (Olalekan Kehinde, 2025). Development and purchasing of robots is costly, although once implemented, they hold the promise of cost reduction. In addition, upon deployment, there is a need for extensive training of healthcare professionals, placing them away from patient care, which is time-consuming and indirectly affects the cost burden of a healthcare organization. (Licardo et al., 2024). Meeting the challenges of new technology deployment will require experimentation, dialogue, and continuous monitoring of the change. (Schartinger et al., 2015). All these barriers are slowing the adoption of technology in healthcare.

Additionally, it is being considered that emerging technology like artificial intelligence (AI) may be useful for making diagnoses; treatment decision assistance, contact tracing, and efficiency can be achieved with the deployment of AI-driven technologies (Fujita, 2020; Reddy, 2024; Vaishya et al., 2020). However, deployment of new technologies into patient care in healthcare increases policy concerns and must be examined carefully in an early developmental stage to minimize potential risk of harm (Faulkner & Kent, 2001). It is certain that emerging technologies like robots, AI, and other applications have ethical and privacy issues (Olalekan Kehinde, 2025; Reddy et al., 2023), both for patients and health care providers.

According to Liu et al. (2017) a high-commitment human resource management (HCHRM) system has a direct and positive correlation with organizational human resources capability and technologies. Organizational polices, culture, and decisions can influence the strategies for the implementation of emerging technologies (Moullin et al., 2015). However, although there is extensive literature available discussing the development and advancement of emerging technologies, the implementation of these technologies on the individual and unit levels remains underexplored. (Liu et al., 2017; Vrontis et al., 2021). The expeditious and advantageous implementation of new technologies depends on both the adoption of the technology and the modification of current processes and/or services to allow optimum adoptability and adaptability. (Savory & Fortune, 2015). To fulfil the growing demand for healthcare advances while also offering efficiencies which allow those advances to operate within resource constraints, it will be crucial for the development of sustainable healthcare systems with integration of technological innovations, covering regulatory and cost-related aspects. (Clark et al., 2019; Junaid et al., 2022).

Table 1: Emerging Technologies in Healthcare

Based on: (Hiran et al., 2024; Junaid et al., 2022; Vishwakarma et al., 2025)

No.	**Emerging Technology**	**Usage in Healthcare**	**Adoption Level**
1.	**Surgical Robots**	Physical Robotic Arms- Assist surgeons to perform complicated surgery precisely and cause less harm to the patients.	Most adopted before pandemic & Fastest Growing
2.	**Service Robots**	Physical robots assist in hospitals with disinfection activities, delivering food & linen to patient rooms, monitoring admitted patients, transporting blood samples from wards to labs, and delivering medications to wards from the pharmacy.	Minimally adopted, still in the phase of research & development.

No.	Emerging Technology	Usage in Healthcare	Adoption Level
3.	**Nanotechnology**	Nanoparticles & devices optimize medication delivery inside the blood vessels to the affected organ, e.g., cancer therapies.	Minimally adopted, still in the phase of research & development.
4.	**Artificial Intelligence**	Clinical decision support tools assist in treatment plans, medical imaging, mining medical records, and precision medicine.	Increasing adoption post-pandemic & fast-growing.
5.	**Blockchain**	Reimbursement & insurance claims processing, reducing fraud & overspending.	Limited adoption by a specific sector of the industry.
6.	**IoT & Wearables**	Wearable devices & sensors for observing, monitoring, & tracking patient health for telemedicine.	Widely adopted post-pandemic.
7.	**Big Data**	Assists in diagnosis, therapy customization, disease outbreak forecast, preventive tactics, and population health trends.	Minimally adopted, still in the phase of research & development.
8.	**Virtual Reality (VR) and Augmented Reality (AR)**	Immersive technologies are being used for the training of doctors. AR is assisting in diagnostic imaging. VR is being utilised for physical therapies & surgery field.	Increasing adoption post-pandemic, still in the phase of research & development.

1.9 Robotics in Healthcare

Research into the use of robotics in healthcare dates to 1986 with the introduction of robots in treatment and care. Such research was more focused on the benefits of minimally invasive procedures and clinical outcomes for the patient, but technology organizations conducted much of that research in secrecy due to commercial concerns (Wickham, 1987). The latest research is supporting the idea that robots can strengthen future healthcare (Kyrarini et al., 2021; Licardo et al., 2024), which will result in the enhancement of healthcare systems. However, according to the current literature analysis, many studies have focused on the integration of robots into manufacturing industries, while robotics is still considered new to the healthcare industry.

Based on the current situation of the post-pandemic and increasing burden on healthcare, a paradigm shift is required in the current global health governance, that is, from a specific reactive paradigm to a systemic, coordinated, collegial, and preventive paradigm (Paul et al., 2020; Zelmer et al., 2022). As a preventive approach, the deployment of robots into health systems will have an amplified effect. This strategy will save the lives of skilled, valuable healthcare professionals and will also aid in lowering healthcare costs while increasing healthcare efficiency (Jain, 2023; van de Vijver et al., 2023). The deployment of robots into healthcare systems has enhanced the efficiency of care, provided targeted, tailored treatments, and reduced error rates, while the burnout of the healthcare practitioners is lessened through the reduction of mundane work (Fosch-Villaronga et al., 2021; Kyrarini et al., 2021; Lluch et al., 2022).

Formerly, the deployment of robots in healthcare has reduced error rates, resulted in expedited processes due to automation, and given relief to the healthcare providers from mundane tasks (Morrell et al., 2021). Advanced robotic systems can perform technically challenging procedures and are being used across different surgical specialties for a variety of surgical procedures (Wong & Crowe, 2023). With shorter lengths of post-operative hospital stays, reduced blood loss, and speedy recovery due to reduction in post-operative infections, minimally invasive robotic surgery has contributed towards cost reduction and has improved clinical efficiency (Ljungqvist et al., 2017; Yun et al., 2019; Zemmar et al., 2020). Nonetheless, working with robots brings new challenges into play and is fertile ground for future research.

Surgeries utilizing a robotic arm are becoming a norm (Alip et al., 2022; Hettiarachchi et al., 2023). However, the inclusion of robots into healthcare systems is still at the stage of infancy, and progress is unclear. The discussions about introducing humanoid robots for social and elderly care are also prevailing in healthcare (Andtfolk et al., 2021; Nwosu et al., 2019; Papadopoulos et al., 2020; Wu et al., 2016). Currently, the focus of healthcare research has shifted from molecular and tissue biology towards health-related technologies to improve patient care; this focus largely takes into account economic and commercial issues (Tarkkala et al., 2019). Nonetheless, working with robots brings new challenges into play and is fertile ground for future research, as the implementation of technology in health is deficient in practical, holistic, and innate frameworks (Cresswell et al., 2020).

There are multiple definitions of robots in the literature. According to Khan and Anwar (2020), based on requirements, performance, abilities, and the technology used, robots can be defined and classified in multiple domains. According to the Robot Institute of America (1979), "a robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks" (Albus, 1981). The word 'robot' is derived from the 'robota', which in the Czech language means worker or servant, or labourer (Guizzo & Ackerman, 2016; Hockstein et al., 2007; Ozkil et al., 2009). Scientifically, the robot is defined as a reprogrammable, computer controlled mechanical device equipped with sensors and actuators (Stoianovici, 2000).

Kaplan (2005) defined the robot as "an object that retains three (3) properties: a physical object; functioning in an autonomous and situated manner, where it manipulates information and physical things (Hegel et al., 2009). Riek (2017, p. 68) claimed that "[t]he robots are physically embodied systems capable of enacting physical change in the world" (p. 68). Ginoya et al. (2021) expanded on this, stating that "robots are generally defined as machines that can be programmed to perform a specified set of simple or complex tasks, with or without human assistance" (Ginoya et al., 2021, p. 01). In summary, a robot is a mechanical apparatus that performs automatic physical tasks under direct human oversight, a predetermined program, or a series of generic directives (Ahmed & Zestos, 2007). Today, the development of robots is accentuating and intensifying in all walks of life; they have entered both our workplaces and homes (Dhanwe et al., 2024). Earlier, the robots were largely developed for industrial purposes; later, the trend shifted towards healthcare (Licardo et al., 2024).

Particularly in the healthcare domain, the definition and categorization of robots are multifaceted (Maibaum et al., 2021; Oborn et al., 2011). In the 1960s, the preliminary prototypes of surgical robots were based on industrial robots (Kolpashchikov et al., 2022; Kujat, 2010). In 1983, the first surgical "Arthrobot" was developed and used in Canadian healthcare (Mohammad, 2013). Sixty arthroscopic surgeries were performed after its first usage in 1984 at the UBC Hospital in British Columbia (Takács et al., 2016). In 1991, the Imperial College in London developed the ProBot robotic system, which was used for transurethral excision of the prostate (Davies et al., 1991). In 2004, Davis Medical Centre at the University of California introduced a 1.68-meter-tall robot, ‘Rudy the Robo-Doc’, which performed rounds in the post-surgery department. With the aid of Rudy, patients and surgeons were able to communicate and interact while surgeons were not physically present in the hospital (Dobson, 2004). Robots have become a remarkable and eminent tool for efficient healthcare delivery (Esterwood & Robert, 2020). Healthcare robots or care robots can be defined as “virtual and mechanical robots” which aid in diverse routine tasks in healthcare systems (Kujat, 2010). In 2008, the European Commission described healthcare robots as “the domain of systems able to perform coordinated mechatronic actions (force or movement exertions) on the basis of processing of information acquired through sensor technology, to support the functioning of impaired individuals, medical interventions, care and rehabilitation of patients and also to support individuals in prevention programs” (Fosch-Villaronga & Drukarch, 2021).

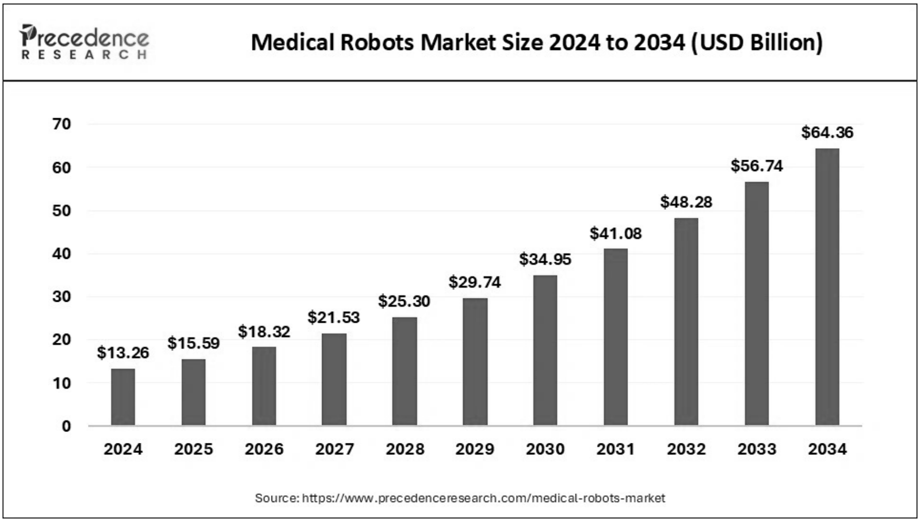
The European Parliament endorsed the theory that robots could possibly be considered as “electronic persons” in operating rooms as a means of addressing the legal responsibility aspects of that use (Nathalie, 2016). Beyond surgery, it is interesting to note that a robotic agent can be of great assistance by reducing patient care work, strenuous/repetitive manual tasks, and management of pandemics like the recent novel coronavirus (COVID-19) infection or any pandemics in the future (Lanza et al., 2020). In addition to the robotic surgeries, supplemental tasks can be performed by the robots, like digitized patient admission, triage, monitoring of vital signs, identification of high-risk nodes, sterilization, disinfection, blood sample collection, checking body temperature, and delivery of food and drugs to patients (Zemmar et al., 2020; Zeng et al., 2020). A very recent example from China will be interesting to mention here. With the increasing number of patients, Wuhan Hongshan Stadium was revolutionized into a robot-led smart field hospital to accommodate more patients (Zeng et al., 2020). Moreover, multiple types of robots (drones, delivery and service robots) were recently used to manage COVID-19 crisis (Yang et al., 2020). This thesis is focused on the robotic surgical arm; hence, AI, chatbots and AI-integrated surgical robots are not considered, with the only focus on mechanical robotic arms for surgery.

The concept of using robotics in surgery was introduced during the mid-20th century (Kolpashchikov et al., 2022; Morrell et al., 2021; Okamura et al., 2010). The first use of the robot-assisted surgical procedure was documented in the year 1985, where a robotic arm was used for a Computerized Tomography (CT)-guided brain tumour biopsy with accuracy (Kwoh et al., 1988) which resulted in the rapid and impactful progress of robotic technology in healthcare (Kyrarini et al., 2021). Almost four decades ago, Fennell et al. (1988) suggested that healthcare institutions could benefit from the adoption of a technological innovations due to the general competitive climate, to avoid malpractice suits, or to gain status. Christensen et al. (2000) expressed the pressing need to investigate the enablers for the emerging technological breakthroughs in healthcare systems. The demand for robotic surgery was gradually increasing in healthcare due to its effect on reducing in workload for complex tasks in the healthcare system (Perez & Schwaitzberg, 2019; Taylor, 2006) but post-pandemic, we have seen an upsurge (Silvera-Tawil, 2024).

In healthcare, among all specialties, the field of surgery has most actively and steadily accepted and adopted robots in the last forty years (Biswas et al., 2023; Ginoya et al., 2021; Peters et al., 2018). The promising role of robots for elderly care and nursing has already been established, in addition to assistive care (Abdi et al., 2018; Pierce & Fosch-Villaronga, 2020; Simou, 2014; Taylor, 2006). In a decade, from 2007 to 2017, the number of robotic surgeries performed changed from less than 100,000 procedures to 877,000 in 2017 (Nik-Ahd et al., 2019). The usage is increasing every year (Zhao et al., 2020) and in every specialty (Biswas et al., 2023; Chung et al., 2021; Sheetz et al., 2020). Globally, more than 9 million robotic-assisted procedures have been performed to date in multiple specialties like general surgery, neurosurgery, colorectal surgery, urology, gynaecology, maxillofacial surgery, ophthalmology, orthopaedics, otolaryngology, thoracic and cardiac surgery (Kakuturu & Toker, 2022; Krings & Weinberger, 2018; Wagner et al., 2021; Xue & Liu, 2022).

In 2015, the global medical robotics market in the healthcare industry was valued at US$ 7.3 billion in 2015 and was anticipated to rise to US$ 21 billion by 2023 (Guntur et al., 2019). Following the recent pandemic, the value inflated more than expected (Fattal et al., 2022). Beginning with surgery, nursing, laboratory testing, diagnosis, and rehabilitation, robots have been widely deployed in multiple medical services and the demand has been steadily rising (Guntur et al., 2019; Sheetz et al., 2020). In the year 2024, it reached USD 11.1 billion (MarketsandMarkets, 2024). Currently, the global medical robots market size is calculated at USD 15.59 billion in 2025 and is forecasted to reach around USD 64.36 billion by 2034. In addition, it is anticipated that, particularly for robotic surgery, the market size will reach $19 billion by 2027 (Taylor et al., 2022).

Figure 1: Medical Robots Market Size 2024-2034



Source: Precedence Research: https://www.precedenceresearch.com/medical-robots-market

During the last decades, technological advancements in healthcare have been accepted not only as a source of value generation but also of profitability (Biswas et al., 2023; Garber et al., 2014). In a very limited time, exceptional progress has been observed in the use of robots for surgery, which has resulted in mutual benefits, both for patients and surgeons (Kumar et al., 2016; Morrell et al., 2021). The International Federation of Robotics observed that demand for service robots, particularly in healthcare, has grown from 2.2% to 9.1% during 2017-2019 (Jurkat et al., 2022) It is estimated that the growth rate in 2022 was 17.16% (BusinessWire, 2023) and it is forecasted that the healthcare robotics industry will grow at a compound annual growth rate of 23.21% during the years 2025 – 2030 (MarketsandMarkets, 2024). Furthermore, it is observed that there has been wider adoption of robots in the field of surgery and rehabilitation; however, the probability of deploying the robots in other healthcare specialties is continuously growing (Kyrarini et al., 2021; Loh, 2018; Soriano et al., 2022).

Since the beginning of the year 2020 and the spread of the COVID-19 pandemic, the topic of changing norms through the adoption of emerging technologies in healthcare has been in discussions more frequently and compellingly, for the adoption of robots in particular (Holland et al., 2021). Due to the COVID-19 pandemic, uncertainty was high, and this resulted in extensive deployment of technologies, especially of robotics into the healthcare systems (Holland et al., 2021; Mbunge et al., 2022; Murphy et al., 2022). Khan and Anwar (2020) stated following extensive study that, in past decades, the healthcare industry has been nascent in the deployment of the robots compared to the manufacturing industry. But since year 2020, the approach has vastly transformed due to the pandemic (Wilk-Jakubowski et al., 2022), which resulted in shortage of clinical staff and high risk of exposure to the virus, thus stimulating the usage of emerging technologies, especially robots, in the healthcare industry (Chandra et al., 2022; Khan et al., 2020; Thomas et al., 2021).

Currently, robots are further being deployed in multiple clinical settings in addition to surgery, for example, in elderly care, childcare, pharmacy, and rehabilitation. Over the last two years, the robots were also used in laboratory settings for the collection and delivery of samples (Khamis et al., 2021). In addition, remote ultrasounds were performed with the assistance of the robots (Bucolo et al., 2023). In Italy, the robots have been used for hospital disinfection to reduce the work burden of the health care providers as well as to reduce the chances of exposure to the virus (Soriano et al., 2022). Overall, during the global emergency, the robots were efficaciously and productively used to manage the healthcare crisis (Bartosiak et al., 2022; Junaid et al., 2022; Yousif et al., 2024).

According to the findings of Wirtz (2020), the cost of developing robotics is usually high but once deployed, the cost of robot maintenance is minimal. Moreover, the cost of virtual robots, once deployed, is negligible. These findings have encouraged the integration of the robots into healthcare. Research has found that installing a robot is cost-effective in healthcare (Goldhahn et al., 2018; South et al., 2025). However, if the existing human capital lacks the ability to adopt these emerging technologies, then expected outcomes appear unrealistic. Vrontis et al. (2021) developed a model that may be used to analyse the effects of the robots, artificial intelligence, and other advanced technologies on human resources strategies and activities. The proposed model is based on a thorough systematic examination of the literature and was modified to concentrate on general workforce management with the deployment of emerging technologies and using these technologies for enhancing the effectiveness of human resource decisions.

The core of service provision and exchange in a healthcare setting is anchored in the social interaction which has evolved over a period of time based on the values, competencies, knowledge, and related expectations of all the involved actors (Edvardsson et al., 2010). In 2009, Ozkil et al. (2009) researched the implementation of the logistics of a robot system in which autonomous robots were deployed for the internal transportation systems (for medicines from pharmacy, documents, sterilization, laundry and kitchen) of a hospital in Denmark. Their analysis revealed the challenges caused by the complexity of the networks, multiple resources, cost and time constraints that existed. They found that the use of mobile robots for the hospital internal transportation activities was clearly necessary, but their deployment must be based on a thorough examination of the entire logistics system, and their designs must be made in accordance with requirements that may vary from one hospital to another. Similarly, Lehoux and Grimard (2018) studied the implementation of the robots in elder care and argued that robots lacked emotions and had a limited ability to provoke emotions in humans. Thus, they were unable to take part in meaningful communications.

Although healthcare professionals are being assisted by a variety of virtual and mechanical robots in the areas of surgery, rehabilitation, physiotherapy, long-term care, prosthetics, assisting people with disabilities and training (Holland et al., 2021; Speich & Rosen, 2004), the focus of this research in on mechanical robots used for surgical procedures. For the next generation of this innovative technology utilization, surgical decision making regarding the precise therapeutic goals requires further and better-quality evidence. Accurately measuring the quality of delivered healthcare services is crucial to the success of healthcare organizations in comprehending the level and mode of the services being rendered (Piligrimienė & Bučiūnienė, 2008). Although healthcare surgical robots are designed to improve performance, movement and control (Haleem et al., 2022), any convenience and accessibility achieved also pose risks and challenges (Betriana et al., 2022; Riek, 2017), especially when the technology is not adopted meticulously through a proper adoption cycle and without considering the element of resource emergence from a human capital perspective. Hence, emerging technologies, especially robotics, are providing opportunities to study the relationship and interaction between the robots and healthcare human capital, leading to a smooth pairing and resulting in human/robot co-specialization.

1.10 Robot-Assisted Surgery

Whether elective or emergency, surgery is considered to be a foundation of any healthcare system (Zemmar et al., 2020). Surgery is a planned, intrusive injury (Mendivil et al., 2009). It is performed “for the purpose of structurally altering the human body by the incision or destruction of tissues and is part of the practice of medicine. Surgery also is the diagnostic or therapeutic treatment of conditions or disease processes by any instruments causing localized alteration or transposition of live human tissue” (AMA, 2013). During or after a surgical procedure, complications can happen, which are an undesirable and unexpected result of an operation, directly affecting both the patient and the clinical outcomes. Even the scar at the site of incision is considered a post-surgical complication if not managed properly or if the scar is large (Clavien et al., 1992; Sandy-Hodgetts et al., 2021). The communication, coordination and synchronization of information and activities among the surgical team is imperative for the success of the procedure (Zhang & Zheng, 2022).

A robot-assisted surgery (RAS) or robotic surgery is defined as “[a] computer-controlled manipulator with artificial sensing that can be reprogrammed to move and position tools to carry out a range of surgical tasks" (Dasgupta et al., 2005, p. 20). Robot-assisted surgery means that an expert surgeon, positioned at a console, performs a minimally invasive procedure (MIS) by controlling the robotic arms with extreme precision (Howard et al., 2022). Minimally invasive surgery (MIS) is one in which small, yet multiple incisions are made to utilize the surgical instrument at the site of the procedure. Due to 3-D cameras, the visibility of organs and vessels is very clear and results in less or no damage to the surrounding organs (Andrade et al., 2014).

The robotic surgical system is constituted of a large, central robot which has multiple arms bearing surgical instruments and mounted with an endoscopic camera. The surgical instruments on the arms are operated by the surgeon who sits at a console and remotely controls the movements with a joystick (Trute et al., 2021). These robotic arms introduce instruments into the body of the patient through small incisions (Pelikan et al., 2018). Currently, robotic surgery is considered the gold standard for surgeries in many specialties (De Marchi et al., 2022). However, in addition to cost and longer preparation time, this technology also has limitations, including instrument-level manoeuvrability, field of vision and range of action. Additionally, at the clinical level, limitations are more related to the size and complexity of the tumour since surgeons lack tactile feedback (Cacciamani et al., 2019).

This surgical technique leads to achieve better performance and enables surgeons to perform complex procedures using complex instruments with accuracy, scalable motion due to greater degree of movement and better ergonomics (Van't Hullenaar et al., 2019; van der Schatte Olivier et al., 2009; Wong & Crowe, 2023). Guided by expert human surgical practices, a computer program generates a plan to accomplish a complex surgical task (Shademan et al., 2016). Robot-assisted surgery is a complex procedure and requires a significant level of coordination, communication, and synchronization among the surgical team members (Dias et al., 2021). The robotic surgery team typically includes the surgeon, anaesthesiologist, surgical technologist, and nurses (Harmanli et al., 2021; Olasky & Jones, 2022).

In the past, several accidents and injuries were noted for robotic surgery, despite the appropriate training of surgeons (Alemzadeh et al., 2016). Improvements were only observed and efficiency was achieved for robot-assisted surgery when the whole surgical team was trained for the new work design and job responsibilities. Physicians and nurses are the frontliners of healthcare who are currently working with or expected to work with the emerging technologies of Artificial Intelligence (AI) and robotics. Particularly in healthcare, the lack of technical training of healthcare providers is considered the most pronounced problem, despite having funding support and seasoned leadership (Asch et al., 2014). Coulentianos et al. (2020) explained that inadequate resources for the transition from prototype to clinical operations and insufficient physical space for convergence among interdisciplinary teams are the primary barriers to the actualization of technologies in healthcare. In addition, a crucial obstacle while implementing new technologies in healthcare systems is the adoption of the emerging technology by the frontliners, i.e., healthcare providers (Zemmar et al., 2020).

1.10.1 Traditional vs Robotic Surgery Differences

To fully capture the gravity of the issue, the changing work dynamics and implementation challenges of the deployment of robotic surgery, it is vital to understand the procedural difference between traditional surgery and one that is robot-assisted.

i) **Incision size:** Technically, the difference between traditional and robotic surgery is the variance in the incision size. In comparison to a traditional surgery incision, a smaller incision is made during the robot-assisted procedure, which results in faster recovery time and a smaller scar. The precision and accuracy of robotic surgery are greater due to the use of advanced imaging technology. Robotic surgery minimizes the size of incisions, which results in minimal scarring, less blood loss, shortened healing period because robotic arms have the ability to fit through small wounds (Peters et al., 2018). The bigger incisions used in conventional surgery usually mean greater scars and more time spent recovering. Additionally, this has been helpful in children`s surgeries (Kawal et al., 2020).

ii) **Precision and Accuracy:** The precision and accuracy of a robotic arm are well known. A surgeon's control in the robotic surgery is finer because the robotic arms provide a range of motion and better dexterity, compared to traditional surgical instruments and equipment (Buckingham & Buckingham, 1995; Najarian et al., 2011). With the use of the camera and small tools, the surgeon can visualise the surgery site magnified and with clarity. The less invasive approach, not the platform itself, is what makes the robotic approach advantageous compared to traditional surgery (Muaddi, Stukel, et al., 2022). Conversely, traditional surgery requires advanced hand-eye coordination and greater visual perception abilities of the surgeon.

iii) **Work design:** The robotic surgery team works differently from a traditional procedure team. The whole operating room changes (Annex 2) require more space for the robot to be planted; docking and undocking of equipment add to the workload of team members; to maintain communication, the members should remain focused simultaneously on the mic and speaker as well as the patient (Kanji et al., 2021). However, during a traditional procedure, the team is around the patient and verbal and nonverbal communication happens with ease. The surgical equipment required during the traditional procedure will be requested by the surgeon as per his surgical technique requirements and will be handed over to him by a scrub nurse who will be staying close to him. All the equipment used during traditional surgery is sent to the operating room in a set of trays and is counted before the start of the procedure and will be recounted after the completion of the procedure (Tiferes et al., 2016). Once used, contaminated equipment is counted, collected, rearranged and sent to another department for autoclaving, which disinfects the equipment using water and steam.

In robotic surgery, before the start of the procedure, the robotic arm is docked with the instruments required for the specific surgery based on the clinical scenario. The nursing staff and the surgery trainees assist the robotic surgeon in docking the equipment on the robotic arm; these pre-operation preparations are time-consuming, especially when the clinical scenario changes from patient to patient. Sometimes they have to change and dock new instruments as per the instructions of the surgeon who is sitting either in the same room or next room. Once the procedure is completed, the docked equipment on the robotic arm is immediately removed; in fact, the entire operating room is disinfected using ultraviolet radiation (Randell et al., 2016).

iv) **Recovery Time:** Patients who undergo robotic surgery typically experience a shorter recovery time than with traditional surgery. This is due to the smaller incisions, reduced blood loss, and less trauma to the surrounding tissues. Traditional surgery can result in a longer recovery, especially for more invasive procedures (Muaddi, Stukel, et al., 2022; Peters et al., 2018).

v) **Skills and Training requirements:** Robotic surgery requires specialized training for the surgeons, which may take longer, and the learning curve can result in added cost. Both types of procedures have risks involved, like organ damage, burns and probability of human error. Further, equipment failure due to robotic system malfunction can cause accidents during the robotic more often than traditional surgery (Fosch-Villaronga et al., 2022).

vi) **Cost:** Due to the cost of the robotic system and the need for specialised training, robotic surgery can be more expensive than traditional surgery, but early discharge from post-operatively and expedited recovery can save hospital stay billing cost. This cost varies depending on the type of procedure and patient's clinical condition. Given the prevailing economic pressures on healthcare professionals, robotic surgery may still constitute a burden rather than a relief. Nonetheless, as the robotics business expands and new cost-effective options emerge, there is genuine optimism for global access to minimally invasive surgery. However, eliminating robotic surgery will significantly hinder technological and therapeutic advancement in healthcare. Robotic surgery represents a significant advancement in surgical development, and, with other developing technologies, it promises to improve surgical quality and safety (Eckhoff et al., 2023).

1.10.2 Importance of Standardized Training for Robot-Assisted Surgery

Since robotics procedures require special techniques, the importance of specialized training cannot be neglected. It is worth noting that until 2019, a standardized training program for robotic surgeons was not globally available (Trute et al., 2021). In 2014, Smith et al. (2014) anticipated the need for a curriculum for the robotic surgeons, which should be standardized globally to certify the robotic skills of the surgeons. The authors presented a detailed report about the unified and standard procedure for approving a robotic surgeon's abilities and certification. On the matter of a robotic curriculum, they provided documentation of the procedures utilized to create educational materials; those materials have been adopted as World Health Organization (WHO) guidelines and received approval from fourteen surgical subspecialties. Also, it is important that the technical training for the device was confederated with surgical training (Ferrarese et al., 2016).

Farivar et al. (2015) highlighted the issue of a lack of guidelines or standardized training requirements for general surgery residents and studied their perception of the robot-assisted surgeries. Authors urged that general surgery residents should be trained in robotics as well during the training program and authorities should pay attention to the credentialing of practicing surgeons. With the growing need for a standardized curriculum. Moit et al. (2019) presented their study, conducted at Illinois University Hospital, and proposed a standard curriculum of robotic surgery to be incorporated in the general surgery training. It is interesting to note that the training of surgeons is usually focused on specific operations based on the specific specialty and general methods of credentialing do not take learning curves into consideration (Sheetz & Dimick, 2019). The Joint Commission (TJC) has emphasized that all healthcare organizations acquiring robotic surgery must ensure the competency of the surgeons through training and credentialing policies (Stefanidis et al., 2022).

Stefanidis et al. (2022) collected consensus from twenty-eight expert robotic surgeons on the credentialing standards to confirm a newly trained surgeon's competency. All experts agreed that privileges should be provided to a surgeon upon completion of training and after video examination of surgical performance, with objective proficiency requirements met. Authors have also proposed continuing result monitoring for technical skills like training, proctoring, and performance evaluation suggestions. Sinha (2023) emphasized standardizing trainee performance evaluation and argued that each robotics curriculum and platform has pros and cons. They have recommended following the European Robotic Urology Section (ERUS) curriculum, which is an evidence-based curriculum for novice-to-expert training. They have pointed out that a multi-modality approach to robotic-assisted surgical training addresses the rising need for skilled and safe surgeons. Robotic surgical training should emphasize on pre-console, basic knowledge, and advanced procedure-specific training with competency, deliberation, and distribution. Currently, a standard training program to learn robot-assisted surgery has been approved and is in use globally (South et al., 2025). Yet the approved training curriculum only focused on the surgeon’s training, with little emphasis on holistic team training for the changing dynamics of an operating theatre.

1.10.3 Patient`s and HealthCare Provider`s Perspective of Robot-Assisted Surgery

Researchers during the last decade have collected the potential users’ perspective, which alleges that the robots should amplify and boost the health care practitioners' tasks (Bedaf et al., 2018; Wang & Wanberg, 2017; Wu et al., 2016). Academics have also emphasized that it is critical that direct robot end users remain directly involved in the research, development, and deployment of robots throughout the entire lifecycle of the robotic project to continuously provide clinical insights and their expectations of the technology (Betriana et al., 2022; Riek, 2017). Engaging target users in the design process is entailing for better meeting the needs of the end users (Cunningham et al., 2012). The value creation in complex systems augmented by robotics empirically demands further exploration and investigation (Danaher & Gallan, 2016; Lappalainen, 2019). Čaić et al. (2018) urged the need to reconsider value for the healthcare environments where ‘human-to-non-human’ interactions will come into play due to emerging technologies like digitalization and automation.

Valles-Peris et al. (2021) studied the perspective of the patients about robotics in healthcare by collecting data through interviews during the first and second waves of COVID-19. With thorough examination, authors have discovered opposing views on healthcare robots in many aspects of the care provision. They have identified two interpretive repertoires from patients' perspectives on healthcare the robotics which are the responsibility repertoire, which is linked to interpersonal relationships and the idea of "good care” and the well-being repertoire, which is linked to individual and group responsibility to support the system's smooth operation and the assurance of health assistance in a stressful setting of healthcare. To understand how complex patients’ approaches to the automation of medical treatment are, both aspects are important. The authors have recommended that the processes for developing and implementing robotics and AI systems in healthcare are the only way to guarantee that these technologies aim to address both individual and societal well-being. Chan et al. (2022), conducted a cross-sectional study involving 427 patients and discovered that 43.6% of the respondents believe that robotic surgery is fully automated, and they have the fear of wrong surgery being performed in the absence of a surgeon.

Similarly, Muaddi, Zhao, et al. (2022) also studied public perception of robotic surgery and claimed that the public has recovery fears from robotic procedure. Robotic surgery may be more widely used because of institutional or surgeon perspectives than because of public desire. The authors urged that the surgeons who perform robotic surgery should make sure their patients feel at ease and are knowledgeable about the procedure. Aldousari et al. (2021) conducted a survey in a Middle Eastern hospital and discovered that the better is the knowledge and proficiency of the patients with computer technology, the better they understood and positively perceived robot-assisted surgery. In the detailed meta-analysis conducted by Tan et al. (2016) for the initial thirty years of robotic surgery, the authors have concluded that despite lengthier operating durations remaining a drawback, robotic surgery did improve some operative outcomes and reduced postoperative complications. They have emphasized that a multidisciplinary strategy during technology development must include deep partnership among surgeons, engineers and patients to achieve superior outcomes in future robotic surgery.

1.10.4 Driving and Restraining Forces for Robot-Assisted Surgery Implementation

Howe and Matsuoka (1999) discussed the technical and implementation challenges, and their study was published during the initial stages of surgical robots. They have suggested that to adopt robotics, surgeons must be familiar with the technology, and they called for collaboration among computer scientists, robotics researchers, and surgeons for the establishment of effective systems. A model or framework for adoption was not provided. The research is extensively focused on clinical aspects as well as mechanical and technical issues, briefly emphasizing the need of standardized training for surgeons. Similarly, Brodie and Vasdev (2018) have discussed the future of robotic surgery but their research is confined to the novelty, mechanics and functionality of the current and future instruments docked on the robotic arm.

Silveira Thomas Porto and Catal (2021) collected data from 114 operating rooms and explored the opinions of the nurses. They found that operating room nurses had positive views on robotic surgery, and they were motivated to perform well. Among the respondents, only 35.8% of the nurses attended training before joining the robotic team, while 55.2% had independently sought knowledge. Training, collaboration, and hands-on experience were identified as enabling aspects; insufficient training and technological issues were noted as hindrances. Bayram et al. (2023) emphasized that it is critical to determine effective and simple team composition policies with evaluation methods for improving the composition of surgical teams and to evaluate the impact of team members on the operation's performance. Bakshi and Puranik (2022) have studied the driving forces behind robotics technology adoption in healthcare and proposed that intention to adopt robots by the healthcare practitioners are based on four (4) factors, i.e., relative advantage, observability, trialability, and perceived usefulness of the technology founding on Technology Acceptance Model (TAM) and Diffusion of Innovation (DOI) theory.

1.10.5 Challenges of Robotic Surgery Implementation

Introduction of robotic surgery resulted in many injuries, deaths and adverse events in the initial years (Sheetz & Dimick, 2019). Based on past research, there is evidence that the quick adoption of sophisticated new technology and people's lack of experience and knowledge with it have complicated human-machine interactions which led to numerous avoidable accidents and incidents (Cunningham et al., 2012; Dyer, 2018; Gawande et al., 1999). Confusion and difficulties with human-machine interaction were identified as being caused by the rapid introduction of complex technologies and a lack of experience with the new technology (Cook & Woods, 1996; Cunningham et al., 2012). Alemzadeh et al. (2016) conducted a retrospective study of fourteen (14) years of FDA data and presented 144 deaths and 1391 patient injuries which were reported as device/instrument malfunction. Cooper et al. (2015) highlighted a grave issue that complications of the robotic surgery are being underreported intentionally, after surveying John Hopkins Hospital.

The usage of cutting-edge technologies presents the challenge of assigning accountability to human or instrument-related factors in case of errors or failures (Usluogullari et al., 2017). Earlier research has also shown that emphasis on teamwork and communication, combined with more efficient training and evaluation techniques, may help to reduce some of the risks related to robotic surgery (Gaba et al., 2001; Guerlain et al., 2007; Helmreich et al., 2017). Upon observing the increase in robotic surgery-related adverse events, Garg et al. (2013) proposed team training and use of intra-operative crisis checklist after observing deaths and accidents during robotic surgery. Ferrarese et al. (2016) identified that the device malfunction, where a surgical conversion to open surgery is required due to robotic arm failure, is becoming less and the capacity of the operator to fix the device in the middle of an operation has improved, presently. Stefanini et al. (2020) has emphasized that the likelihood of adverse events and errors during a procedure is lower if the surgical team exhibits a higher level of team cohesion and coordinates implicitly. Manuguerra et al. (2021) found that risk was well managed during a robotic surgical procedure when the whole team was well trained. Hence, the machine cannot be blamed for the surgical accidents.

1.10.6 Existing Literature and Research on Robot-Assisted Surgery

During the early phase of robotic surgery, Edmondson et al. (2001) rigorously focused on collective team learning with the deployment of a new technology in hospitals by emphasizing the notion of ‘Collective Learning in Collaborative Work.’ The data was collected from sixteen (16) hospitals through interviews with surgical teams. The authors have proposed a 4-step model of collective learning, which is developed on constructs of enrolment, preparation, trials, and reflection, leading to the adoption of the new practices as routine by the whole team, thus resulting in the organization-wide change. It is suggested that for the successful adoption of a new technology in healthcare, teams must be motivated, adequate training and practice sessions to be provided to develop psychological safety, opportunities of improvement and reflection must be unlocked to achieve a shared vision for acceptance of new technology, new work design.

Further building on collaborative work, Edmondson (2003) has focused on learning about the interdisciplinary teams in action, especially surgical teams for minimally invasive cardiac surgery. The findings of the interviews and case studies disclosed that learning of new process of minimally invasive cardiac surgery is challenging. Research disclosed that ‘speaking up’ is of great value during the learning process of the new practice for mutual understanding, experimentation and brainstorming of ideas. Similarly, speaking up helped in the real operating room setting as well. The ease of speaking up and the behaviour of the leader, Surgeon, facilitated team learning and adoption of the new technology successfully.

Camarillo et al. (2004) investigated the topic but more from the technology perspective, focused on the limitations of the existing surgical robots in terms of instruments and introduced the term “clinical engineers”, who can act as a bridge between the technology developers and the surgeons to fill the gap between mechanical and clinical aspects. Faust (2007) published a book regarding robotics in the field of surgery. The book is centred on clinical aspects and the utilization of robotics in surgery. The authors have focused on technical issues, enhancement of technology, and have determined the legal and regulatory barriers in detail. Hockstein et al. (2007), presented a comprehensive and historical account of surgical robots in their study. They have focused on the development of the machine from earlier prototypes and have proposed suggestions for future designs and functionalities to better serve the clinical aspects of the procedure.

Mendivil et al. (2009) discussed the emergence of robot-assisted surgery in the gynaecology specialty at UNC and Florida Hospital. They dove into the topics of historical development of robot-assisted surgery in medicine; training and observer-ship of residents and medical trainees; surgical skill set requirements; strategies of building robotic surgery; development of a robotic surgery team for minimally invasive procedures and establishing guidelines. They verified that it is usual to face resistance in the initial phase of robotic surgery from the operating room staff. But while discussing the strategies to build a surgical team for minimally invasive robotic procedure, their discussion is focused on surgeons and their role as leaders of the program, institutional commitment and patient selection.

Schreuder et al. (2012) performed a systematic review to examine the robotic assisted laparoscopic surgery by examining 114 published articles on the topic of training and learning methodologies for surgery team. They included papers related to the training, learning, education, and instruction of robotic-assisted laparoscopic surgery across multiple specialties. They sought to enhance the execution of organized robotic surgical training programs and reached a conclusion that robotic surgical training includes system training and procedural instructions. They proposed that System training should be competency-based rather than time-based. Procedural training must be structured in a sequential manner, with objective evaluation at each stage. The authors have emphasized on team training including surgeons, scrub nurse and others in the operating room particularly in the initial curve of learning. However, they did not propose a training module or framework to be used for these trainings.

Elprama et al. (2013) investigated the obstacles to integrating robot-assisted telesurgery into healthcare. They highlighted that previous research have focused on financial, legal and technical issue and they have focused on overlooked aspect, i.e., social and communicative dimensions. According to their findings, it is crucial to focus on team communication for robotic surgery because failure to effectively communicate may lead to medical accidents. They have suggested that a versatile and proficient surgical team is likely to adjust to diverse circumstances and adaptation process will become smooth with enhanced communication among the team members.

Beane and Orlikowski (2015), explored the effect of the robotic telepresence system in the context of provisional settlements and distributed coordinated teamwork at a post-surgical intensive care unit (SICU) during night shifts, where assistive robots were deployed for the monitoring of the critical patients. It is concluded that the robotic telepresence affected the coordination both positively and negatively which is conditional to the preparation work of the post-surgery ward team and is highly dependent on the coordination and interactions among the members. Tiferes et al. (2016) probed into the team activities encompassing communication, physical movements, and procedural interruptions at a wider level. They collected data during thirty-seven the robotic surgeries involving eighty-nine surgical staff and provided suggestions for the improvement of non-technical aspects of robot-assisted surgeries by identifying factor which hinder the performance of the surgical staff.

Randell et al. (2016), conducted their study in North America and Europe across nine hospitals and interviewed forty-four operating room staff to collect their perspective to investigate the influence of the robotic surgery on the decision making of the surgeons. Drawing on the interview data, authors have concluded that in addition to surgeon's level of concentration, a positive relationship and clear communication between surgeon and the surgical team is essential for successful outcome of the robotic surgery. Enayati et al. (2016) studied the limitations of the robotic surgery related to absence of haptic feedback/ tactile perception for surgeons because surgeons are trained to touch and feel the surgical site as well organs. They have urged the surgical robot manufacturers to develop and install haptic sensory channel for the improved outcome of the robot-assisted surgeries.

Pelikan et al. (2018) investigated the distributed and collocated teamwork in the hybrid form for the 'Teleoperated Surgical Robot'. The study is focused on teamwork and collaboration and explains how existing technology mediates teamwork, taking spatial, cognitive and affective distance into account. It proposes a physical-cognitive-affective framework for the better understanding of collaboration and exchange among surgical team members related to task, space and interpersonal aspects. They have concluded that with new job design of the robotic surgery, the leader (surgeon) is physically away from the surgery and team which creates spatial, cognitive and affective distance among the team members resulting into redesigning of collaborative practices of the surgical team.

Beane (2018), criticized the learning techniques and traditional pathways of adoption of technology in surgery and proposed that shadow leaning (allows a new person to observe medical professionals in action) is more effective and beneficial for new the robotic surgeons. By using the case study approach and endowing on resource-based theory. (Dal Mas et al., 2019)focused on the transformation of intellectual capital and considers it as the base component of Human capital for innovation. They have viewed integration of new technology in surgery as the transformation of the human capital into structural capital. Building on the concepts of societal capital, social capital, structural capital and human capital, they have proposed a model which leads to innovation capital for the integration of new technologies into the healthcare organizations. The proposed framework is about injection of human capital after training by HR and new knowledge dissemination is considered as new human capital which leads to market capitalization and value for patient.

Randell et al. (2019) building on stakeholder theory, forty-four surgery room staff were interviewed to understand their perspective on the process of acceptance of the robotic surgery and making it a routine practice in the respective hospital. Based on the interview data, they have established that consistent support of surgical colleagues is of utmost importance in addition to support from hospital management and team leaders. Randell et al. (2019), probed into the experiences and challenges of the surgical teams from the operation theatre where the robotics was newly introduced. The main challenge discussed is the isolation of the surgeon at console which compromises the communication with the surgical team. They have suggested that through use of standardized communication the gap can be managed, also locating console into a position where surgeon can directly view the patient to have better situational awareness, can be considered as a possible solution. The study proposes strategies for the introduction of the robotic surgery, to be imbedded in the routine by providing extra time in operation theatre to the staff who are learning the new skill of collaborating for assisted surgery. A framework or model is not proposed, and more attention has been paid to communication among the surgical team. Furthermore, it was suggested by the interviewees that in the initial phase of surgical the robot deployment, hand picking a dedicated team is beneficial which will result in instantaneous acquiring of experience and confidence for new technology.

Catchpole et al. (2019) examined the human factor with the implementation of the robotic technology in surgery, mainly in terms of communication and coordination among the surgical team members. The study also investigates the challenges of workload distribution, operating room size difference from traditional surgery, changes in instrument cleaning protocol, environmental and organizational considerations, support of engineers and quality assurance teams for the successful delivery of robot-assisted surgeries. They have concluded that due to physical distance in the robotic surgery, explicit communication can result into improved communication and coordination, but surgical teams must be trained for the usage of specific verbal and non-verbal cues during the procedure.

Cheatle et al. (2019) studied two different teaching hospitals from ethnographic perspective, where robot-assisted surgeries were recently deployed. They observed the surgical team in the operation theatre in real time during the operation and focused on co-operation among the members in the new working environment. They have investigated the phenomenon of inter-sensory dependencies (vision and touch) and how these senses are challenged in the new work design of the robotic surgery and recalibration of work among surgical team members. The study draws on sensory compensation and through anthropological approach they have developed suggestions for the technology designers for the employment of interconnected multiple senses for the collaborative task in the surgical operation theatre. Further studies from developing and emerging economies like Pakistan and India, shared their insights. Ghazanfar (2019) described the challenges of cost, training of staff and lack of feasibility and planning for the implementation of Robotic surgery.

Sergeeva et al. (2020) studied the robotic surgery introduction into complex healthcare systems from an organizational perspective. They have proposed a model for the integration of the new technologies, keeping in scope the progression and transformation of coordination and information flow for embodied actions of all the actors and their roles (Surgeons, nurses, surgical residents). The model is focused on 'How Coordination Changes in Surgery After the robot Introduction', highlighting possible disruptions at the level of work, coordination, and professional roles, which may provide opportunities to the lower-status occupational groups who will take advantage of fluctuating situation during the times of technology deployment. Oyebamiji (2020) presented the possibility of the robotic surgery implementation in Africa and suggested that critical investment in healthcare systems and human capital with effective leadership can lead to successful deployment of surgical robots.

Satava et al. (2020) conducted a randomized control trial to analyse and inspect the existing curriculum of the robotic surgery skills and concluded that with the use of simulation platforms of fundamentals of the robotic surgery (FRS), trainee surgeons showed positive learning for acquiring new skill. Soomro et al. (2020) published the systematic review of learning curves of the robotic surgeons and proposed that optimal quantitative methods should be adopted for the appraisal of learning curves and surgical training programs for the robotic surgeons. El Rassi and El Rassi (2020), have built their study on the similar grounds of haptic feedback/ tactile perception by further probing into the benefits and limitations of 'Cutaneous feedback' (spatial distribution of pressure) and ‘Force feedback’ (measure the force applied to the patient by the surgical instrument) modalities during the robotic surgery.

Chao (2019) studied healthcare technology adaptation and applied Technology Acceptance Model (TAM) and concluded that this theory is only for business and firms hence not suitable for healthcare. By using the Unified Theory of Acceptance and Use of Technology (UTAUT) model, Vichitkraivin and Naenna (2020) explored the acceptance of technologies in healthcare and aimed at determining the elements responsible for robotics adoption in healthcare. According to the research, enabling factors are social circle impact, effort expectation, performance expectation, and safety concerns which favours the use of robotics for healthcare providers. Similarly, Nguyen et al. (2020) also applied TAM and concluded that the passive integration with existing IT systems is important for health technologies to improve clinicians' productivity and workflow. And from patient`s perspective, user-friendliness and easy access to technological help are useful.

Kerray and Yule (2021) probed into consideration of ‘human factors’ with the rise of machines in healthcare. According to authors, only technical skills do not make a surgeon successful. In fact, it is the team, system and process around the surgeon, comprehensively complementing the surgeon for excellence during both traditional and the robotic surgery. The authors have emphasized the need of standard training programs for the implementation of the technology where the whole team is trained together, not only the robotic surgeon for the optimization of team performance and patient safety simultaneously. However, a framework or a training model is not presented by the authors yet training modules from early research are endorsed.

Gillespie et al. (2021) in their recent study presented the analysis of existing literature as systematic mixed studies review for the team performance with the introduction of the robotics in surgery. They have concluded that with the deployment of the robotics, new types of error have emerged and the addition of surgical the robot as a team member has introduced new challenges by intensifying the complexity of the work. For the successful usage of the new technology, there is a great need of multitasking. The surgical team members should possess clinical, technical and instrumental knowledge. Additionally, they have highlighted the obligation of standardized workflow processes for clinical efficiency maximization. Khan and Anwar (2020) and Kyrarini et al. (2021) presented a detailed survey of the robotics in healthcare but their studies have drawn on to the scope of the robot into clinical practice and they have studied the uses of different types of the robots in different health specialties.

Attanasio et al. (2021), studied the levels of autonomy in the surgical the robots with the evolving technology and prescribed five levels from zero to four where level zero means absolutely no autonomy and level four means that the robot can autonomously plan and execute a sequence of surgical tasks. Fosch-Villaronga et al. (2021), briefly studied the role and responsibilities of the surgical teams particularly in case of an accident or ambiguous situation and have emphasized on the need of a framework, which clearly explains the responsibilities and accountabilities based on the autonomy during the robotic procedure. According to their findings, the current surgical the robots are at the level three of autonomy which in future can complicate the accountability of an adverse event during the robotic surgery between human and machine, once the technology becomes more advanced and autonomous.

Maibaum et al. (2021) presented a detailed critique of prevalence of the robotics in healthcare and demonstrated the interplay of care organizations, innovation politics and the robotic engineers for the role of assisted robots in nursing for elderly care. With the threefold critique, they have rationalized and predicted that more dependence on assisted the robots will result into de-professionalization of nursing. Marcos-Pablos and Garcia-Penalvo (2022), have taken into account the use of the robots for health care providers education and training as a didactic tool. They have concluded that the robots can facilitate learning and can foster learning into practice and can act as agents of quality assurance. However, in the recent study by Alip et al. (2022) highlighted that haptic feedback function is not impacting significantly the robot-assisted learning of the surgeons, regardless of their experience level in the field of urology.

In their qualitative study, Lawrie, Gillies, Duncan, et al. (2022) conducted interviews and focus groups with NHS staff (the robotic surgeons, operation theatre staff and surgical trainees) in United Kingdom from different specialties, who are working as the robotic surgery team, to explore the prevailing issues of the robotic-assisted surgery and to develop future strategies for the extensive implementation of the technology into healthcare systems. The staff has expressed the following existing issues of 'governance, workforce training, organization delivery, potential workforce deskilling and a continuing need for public education'. They have concluded that by having a corrective and curative approach toward these highlighted issues, healthcare managers and surgeons can improve the adoptability of the robotic surgery in future. Specific corrective measures, strategies and managerial implementations for improved adoptions are not endorsed by the authors. They have proposed Theory-informed strategies to over the implantation barrier.

Cormi et al. (2022) conducted the study in France, exclusively focusing on surgeons (from different levels of experience) to understand their behaviour, perceptions and viewpoints towards robot-assisted surgeries by collecting qualitative data via semi-structured interviews. According to authors, since a robot-assisted surgery isolates the surgeon from the rest of the team, hence better and clear understanding of their activities, teams' activities, and mutual context of all activities during a surgical procedure requires exploration. Additionally, how risk between the robot and the surgeon is distributed and how surgeons integrate the performance of the robot into their own ongoing risk assessment demands deeper understanding. Olasky and Jones (2022) examined the practice of simulation in the operating room for educating surgical teams, ultimately aiming to minimize surgical errors and enhance the safety of surgical inpatients. They used simulation because it has been used in training across several medical fields. They have documented that Simulation-based training for surgical teams has shown improvement in cooperation and communication skills, which is usually the reason behind a patient harm. They have confirmed that replicated operating room not only ensured a secure setting for both the patient and the surgical team, but it also gives chance to the surgeon to practice essential technical skills and prepare for infrequent but recognized problems.

Fosch-Villaronga et al. (2022) have studied the challenges of autonomous robotic surgery. In particular, they have argued that the boundaries between human surgeons, other healthcare professionals, and robots will become more porous as robots gain more autonomy, making it harder to determine who is liable in the event of an error. They have emphasized that it is important to explore and agree on the precise function of humans and their performance in highly autonomous robotic procedures. They have demanded more focus on transforming healthcare professionals through education and training as well as an improvement in the complex interplay between manufacturers, healthcare providers, and patients. Hernigou et al. (2023) recently conducted investigation about the human–the robot relationship, emphasizing that future the robots should become more autonomous and must collaborate as active partner/agent instead of being extensions of humans, following the commands only. Autonomous surgery means that the robot performs the surgical procedure according to its own will, with minimum to no human intervention at all (Yip, 2017). The authors are expecting the robots to be an ‘intelligent entity’ between the surgeon and the patient sharing the responsibility of clinical outcomes with legal liability and hence this highlights the immediate requirement of regulation and ethics for the emerging technologies in healthcare.

Catchpole et al. (2024) have analysed the methodological and practical challenges of technology integration in surgery, evidence-based advancements, and the importance of systems engineering and clinical human factors specific to robotic-assisted surgery (RAS). They have highlighted that the new technology presence in the operating room may benefit patients and staff, yet also poses challenges to physical, procedural, team, and organizational integration. They have concluded that enhancement of safety and quality via the integration of human systems in care is essential. Because previous RAS research has focused on the capabilities of the surgeon's console, rather than the skills of team members, the usage of workstations, or organizational modifications. They have uncovered the concealed complexities which influence individuals, teams, procedures, and immediate outcomes. The authors have proposed human factors research in robotic surgery has proposed it as a remedy. We assess robotic surgical workload, communication, workflow, workspace, and coordination studies, elucidating their potential to improve the healthcare system.

As robotic telesurgery is becoming more popular to increase the accessibility of specialist surgical treatment, telecommunications infrastructure is crucial to its viability and safety. Dohler et al. (2024) have investigated the use of 5G and 6G technology for remote robotic surgery. This research discusses how 5G and 6G networks may improve robotic telesurgery by reducing latency and improving data reliability for real-time procedures that are performed remotely. The study has emphasized on Kinaesthetic signals, network dependability, QoS agreements, and 6G networks' potential to cut latency and incorporate AI-driven predictive analytics. The researchers expect that these advances will expand telesurgery's reach and improve accuracy and safety, ushering in a new era of remote surgery. However, they have not investigated the importance of efficient team capability building and social capital among surgical team to adjust to this advanced job design, which is equally crucial safety.

1.11 Conclusion of Literature Review

Based on the above in-depth and lengthy literature analysis of multiple theories and concepts, it is evident that, to fully understand the process of deployment of a technology and its acceptance by the individual surgeons, as well as the emergence of skills and knowledge at the unit level by the surgical team, further inquiry should be directed at the evolution and emergence of the micro-level human capital of the surgical unit. There is a gap in the literature on human capital resource emergence theory, in which the significance of human capital resources (HCR) is well recognised while the creation process remains inadequately understood. During this analysis of the literature, it was also observed that most of the past research revolved around topics of surgeons' training, clinical outcomes and benefits of minimally invasive robotic surgery.

Capacity building is a proactive strategy and a prerequisite for the co-specialization of human capital with technology. Only a handful of studies have investigated this concept in terms of the technology implementation in healthcare. Similarly, the role of social capital in the context of structural, relational, and cognitive aspect has been examined in general, but not as an enabler of human capital resource emergence in healthcare industry. Due to the deeply integrated work styles of members of the healthcare industry, this holistic approach is indispensable and has not been thoroughly investigated. Through the literature review, we have presented a detailed discussion on the differences between traditional and robotic surgery. This was intended to provide a clear understanding of the situation for the readers, particularly those who do not belong to the healthcare industry or may have little knowledge of the work dynamics of a surgical procedure in the operation theatre of a hospital.

Lastly, this literature review has also made apparent that very few researchers have focused on team collaboration and communication. Many studies have highlighted the benefits of the RAS and features of the robotic arm. Recent literature is more intended to examine technological advancements and further augmentation of the robotic arm with additional emerging technologies like AI and 5G. Very few recent studies have focused on the challenges of the humans involved in a robotic surgery and have highly recommended theory based and humanistic approach for the future explorations. Hence, it is noticeable that the full process of the robotic surgery adoption in the surgery department has not been studied in the light of the emergence of human capital resources.

2. RESEARCH METHODOLOGY

The objective of this social and behavioural research was to explore the challenges faced by clinicians who are currently engaged or are anticipated to be engaged with emerging technologies such as robotics. It aimed to investigate the emergence of the human capital resources and capability building of healthcare providers to facilitate the effective integration of robotic systems and its successful adoption by clinicians, thereby ensuring meaningful and successful deployment and implementation of these technologies in healthcare. This study was conducted through the perspective of frontliners and primary end users of this technology, i.e., surgeons, the human capital of a surgery department.

To accomplish our research aims, we selected a qualitative approach, which is exploratory in nature and facilitated the collection of “information from individuals about their own practices, beliefs, or opinions” to gather data regarding past or current behaviours or experiences and obtain underlying information or access the expert knowledge of an individual (Harrell & Bradley, 2009, p. 25). We preferred utilising a qualitative research method as we needed a deeper exploration of surgeons` opinions and this method enabled us to hear not easily measurable and “silenced voices” (Creswell & Poth, 2017, p. 45). Another argument to select qualitative research was to “capture the richness of people's experience in their own terms” (Labuschagne, 2003, p. 101).

Qualitative research has become a well-established and a popular mode of inquiry in healthcare and social science fields (Marshall & Rossman, 2014). Sandelowski (2004) stressed that, for the progression of healthcare research, qualitative research findings constitute a prerequisite. Eppich et al. (2019) emphasized that interview-based qualitative inquiry allows flexibility in the exploration of emergent topics in healthcare. Considering its attributes and advantages, this approach has been employed across several healthcare issues and subtopics, encompassing the experiences of healthcare personnel, the opinions of patients and guardians regarding different diseases, and evaluations of care quality (Maula et al., 2019; Pyo et al., 2021; Sion et al., 2020). It has been observed that seasoned healthcare researchers like Golden-Biddle and Locke (2006) and Reay et al. (2006) have extensively used this mode to investigate change management in healthcare systems.

2.1 Research Philosophy

Epistemology addresses “the nature of knowledge, its possibility, scope and general basis” (Hamlyn, 1967, p. 242) and has three major types, i.e., objectivism, constructionism, and subjectivism (Crotty, 1998). To examine human behaviour, theoretical and scientific insights are required for the interpretation of human motivations, behaviours, needs, practices according to their environment (Volker, 2018). Constructionism describes the emergence of meaning from human interaction under real-world circumstances, positing that truth is not pre-existing and that meaning requires a cognitive element, suggesting that subject and object coalesce as collaborators or partners in the creation of meaning by exploring “the minds and meaning-making, sense-making activities” (Lincoln & Guba, 2016, p. 40). Since we wanted to explore the process of robotic technology adoption by the surgeons and surgical teams, we have applied the constructivist epistemological approach for data analysis.

This research was specifically intended to explore and understand the ways in which healthcare practitioners (Human Capital Resource HCR) in a surgery department developed the capability to achieve co-specialization with new technology, when a surgical robotic arm is deployed in the healthcare systems. Further, we looked into the process whereby individual co-specialization with surgical robots leads to and facilitates unit-wide co-specialization, a process known as human capital resource emergence. The experiences of the surgeons interacting and working with the surgical robots in a hospital setting have been recorded via interviews for the purpose of primary data collection. To collect primary data, a semi-structured interview method was utilized.

2.2 Research Instrument

2.1.1 Interviews

In qualitative research, interviewing is a fundamental approach which can provide in-depth details of behaviours, attitudes, perspectives, and experiences of respondents in the healthcare systems (Nathan et al., 2019; Pope & Mays, 2020). One of the most prevailing and recognized methods in qualitative research is the interview (Ruslin et al., 2022). Interviews are one of the common and important techniques for the collection of the primary data in all types (positivist, interpretive, or critical) of qualitative research (Doody & Noonan, 2013; Myers, 2019; Myers & Newman, 2007). Qualitative interviews allow us to broaden and deepen our understanding of a specific collection of situations and/or experiences (Silverman 2021) and can provide insights into the subjective experience of a social world and how it might be understood through specific viewpoints (Davies & Hughes, 2014).

Since this research was focused on the individual (micro) level, that is, how healthcare professionals (human capital) acquired new knowledge and developed new skills to build the capacity to co-specialize with the robots deployed in healthcare systems. Although asking questions might appear to be simple, conducting interviews with clinicians, who are well trained in the communications skills needed to effectively interact with their patients, the interviewer must be able to encourage the interviewee and should be skilled with active listening while keeping the situation safe so clinicians can share their experiences openly (Hinton & Ryan, 2020). For this research, we conducted semi-structured interviews, defined as exploratory interviews (Lincoln & Guba, 1985; Magaldi & Berler, 2020) with some pre-formulated questions, while leaving room for new questions to arise during conversations (Myers, 2019). In qualitative research, interviews are meant to determine "what is important in the mind of informants: their meanings, perspectives, and definitions; how they view, categorize, and experience the world" (S. J. Taylor et al., 2015, p. 88) with the goal of addressing research questions. Hence, qualitative research interviews are considered to be "conversations with a purpose" (Burgess, 2003, p. 102).

We conducted the semi-structured interviews while maintaining an informal and conversational tone. Semi-structured interviews provide opportunities to explore in details an individual's perspective through explaining their objective while answering open ended questions, which presents an inductive approach, deriving codes from interview data, towards the exploration of subjective perception of the interviewee through dialogue (Husband, 2020; Low et al., 2019), leading to discovery of concepts and ideas which will go through transition from one interviewee to another (Magaldi & Berler, 2020). Serry and Liamputtong (2010) suggested that interviews must maintain a balance between the researcher's and participant's interests, with questions covering a variety of topics while permitting the interviewer to enquire about emerging subjects and stories that arise during conversation. Narrative and descriptive approach towards semi-structured interviews has become a favourable approach of many qualitative researchers generally and in healthcare particularly (DeJonckheere & Vaughn, 2019; Hunt et al., 2011; Renjith et al., 2021).

Interviews give insight into participants' thoughts, their articulation of feelings and behaviours (S. J. Taylor et al., 2015). The semi-structured approach assisted in maintaining a degree of specificity, shedding additional light on phrases that are unclear and addressing any step missing in the processes while maintaining discussion focus and dialogue. Research based on interviews has the potential to pave the way for new theories and frameworks that may account for human conduct (Anderson & Jack., 2015). Such research in healthcare has the potential to overcome alienation and transform social practice via a participatory and meaningful process of knowledge translation, the reason that a semi-structured interview approach was adopted for this research.

2.1.2 Interview Guide

According to Mears (2012) a well-planned interview guide is essential for effective interviewing. The interview guide is a set of written questions that the respondent answers, which are either restricted or free (Patten, 2016). Based on the scientific rules, the questions for this research were kept simple, open-ended, unidirectionally comprehensive and unique to probe into any actual challenges (Krosnick & Presser, 2010). The interview guide was used as a tool in this research to discover the process and factors influencing the adoption of the robots in healthcare by the surgeons and surgical team, to determine the behavioural change/upgrade required for pairing with the robots, to establish the competitive training necessary to bridging any gaps in the skill set of the healthcare human capital, and to develop a framework which can become a guide for the future deployments of the robotics or other emerging technologies in the healthcare system.

We adopted a narrative approach for the interviews. The initial interview questions were structured, organised, and guided by the interview guide; nevertheless, these questions were augmented by follow-up enquiries and probes to guarantee an effective interview. In general, the interview included open-ended questions about the experiences, tenures, and the robotic adoption journeys of surgeons. The interview guide used during data collection is available in Annex 1. It was composed of four (4) sections. We started with introductory questions asking the participants to provide information about their positions and responsibilities in their current role at the hospital. The second section was dedicated to a detailed inquiry about their learning journey and challenges embraced during the adoption of robot-assisted surgery. The third section was focused on exploring their experience with the robotics and changes in their clinical responsibilities. The fourth and final section was intended to allow us to understand their future projections and expectations from this emerging technology.

2.3 Data Collection

Due to the global emergency of the pandemic, the robotic surgeons were unreachable during the early phase of this research. In mid-2021, few interviews were conducted, only because most of the surgeons were busy as there were more robotic procedures being conducted. With the ease of pandemic-related restrictions, we were able to approach more surgeons and data collection was expedited during 2022. Interviews were conducted until April 2023, but an additional interview was conducted in March 2025. To achieve consistency, the interviews were conducted by the author herself, either in-person at the surgeons` clinic or virtually. For virtual interviews, Zoom software was used, which provides and experience similar to face-to-face, and should be considered as being on par with or even better than in-person interviews (Johnson et al., 2019). All interviews were recorded and later transcribed using the software, TRINT. The average time consumed by conducting an interview (both in person and online) was between forty-five to sixty (45-60) minutes. The criteria used for sampling was a qualified surgeon who was trained for open/traditional surgery in his/her early years of practice but who has been certified for robot-assisted surgical procedures for one (1) year or more.

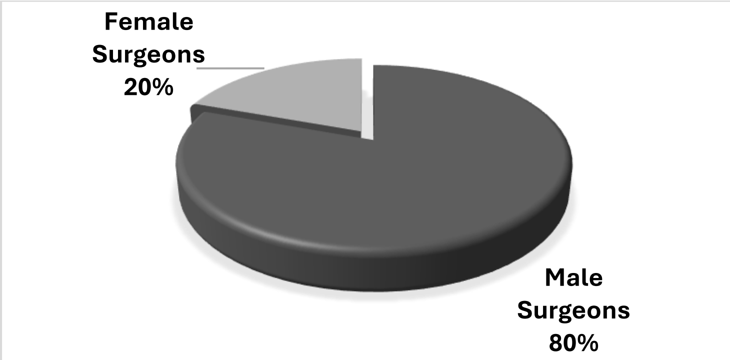
In total, thirty-six (36) interviews were conducted with robotic surgeons from 13 countries as follows; Lithuania, Pakistan, France, Italy, Spain, Germany, United Kingdom (UK), United Arab Emirates (UAE), Malaysia, Saudi Arabia, Australia, India, and the United States of America (USA). The interviewed surgeons belonged to a variety of specialties, including gastroenterology, cardiology, urology, gynaecology, head and neck, thoracic, liver transplant and vascular surgery, in addition to general surgery (Annex 3). After conducting thirty interviews, we observed the emergence of similar codes and themes. Upon conducting an additional five interviews when similar themes were exemplified in the data, data collection was ended. Tran et al. (2017) argued that data saturation is the guiding notion for sample size in research where open-ended questions are used. The suspension of data collection is based on the judgment and competence of the researcher.

On similar grounds, Guest et al. (2020) presented a simple method to assess and report thematic saturation in qualitative research. They utilised three primary elements in the calculation and assessment of data saturation, i.e., base size, run length, and new information threshold. Base size assessment means that new information is evaluated in contrast to previously acquired data. Run length refers to an accumulation of contiguous occurrences or observations. New information threshold corresponds to the proportion of new information that is equal to five percent (5%) or less. Using the above method, we terminated data collection because of the similarity in acquired data earlier and later, aggregation of contiguous occurrences and less than 5% ratio of new information. As Squire et al. (2024) noted, proximity to saturation may serve as an adequate criterion for aiming to conduct additional interviews because, beyond that point of saturation, one may gain less information.

2.4 Social and Demographic Characteristics of Interviewees

The tenure of the interviewees ranged from three to twenty-eight years overall in surgery and from a year and a half to eighteen years for working with the surgical robots. It was noted that all interviewed surgeons were primarily trained for traditional (open) surgery. Among the thirty-six interviewees, only 20% were females (7 interviewees) and 80% were males. This distribution corresponds to the global gender distributions in the surgeon profession, as surgery is considered a masculine field (Acai et al., 2020). According to the Royal College of Surgeons of England during early 1990s there were only 3% female surgeons and after three decades, in the year 2022, the number has increased to 14.7% only in United Kingdom (RCSE, 2022). In North America, a survey of surgeons carried out at the turn of the current century showed that only 20.3% of surgeons were female, hence, the field of surgery remains male dominated. Globally, the progress in gender equity for male and female surgeons is quite behind-hand in many healthcare systems, especially in terms of remuneration, opportunity and work-life balance (Köhler et al., 2021; Lim et al., 2021).

Figure 2. Interviewee Demographics



2.5 Data Analysis

The rigor and richness of the findings enhances the transparency of the qualitative analysis (Grodal et al., 2021). Qualitative analysis enhances comprehension of the reasons underlying a phenomenon in the social realm and elucidates individuals' behaviour (Al-Ababneh, 2020). This approach has been recognised as optimal when addressing research queries that begin with "how," particularly those examining behaviours or processes (Müller & Klein, 2019). Over time, as the interviews were being conducted and data were being collected, we performed inductive analysis of that data simultaneously and progressively, using the guidelines for naturalistic inquiry method (Lincoln & Guba, 1985; Maxwell, 2013). Müller and Klein (2019) emphasized that qualitative inquiries arise from the variety of viewpoints which are ontological, epistemological, and methodological. Using an epistemological approach, we completed coding of the emerging themes using Gioia methodology to organise the data, as coding is central to the Gioia method (Locke et al., 2020).

2.6 Coding

Codes are essentially the “language used by the informants” (Corley & Gioia, 2004, p. 183). A code in qualitative study design often consists of a word or brief phrase that figuratively represents a summative, significant, essence-capturing, and/or emotive characteristic of a segment of language-based or visual data (Saldaña, 2021). During analysis, we collected and selected the codes from the interview data, using the phrases of the interview participants. Coding is the process of giving a piece of data a shorthand label which describes its meaning, breaks it down to fragment the data and to discover the processes in the data (Wertz, 2011). Coding entails the work of scrutinizing, pondering, and organizing collected observations and relating them to theoretically relevant abstract features, possible relationships, and research questions (Locke et al., 2020). Coding simply means identifying segments of meaning in the data and labelling them with a code (Skjott Linneberg & Korsgaard, 2019).

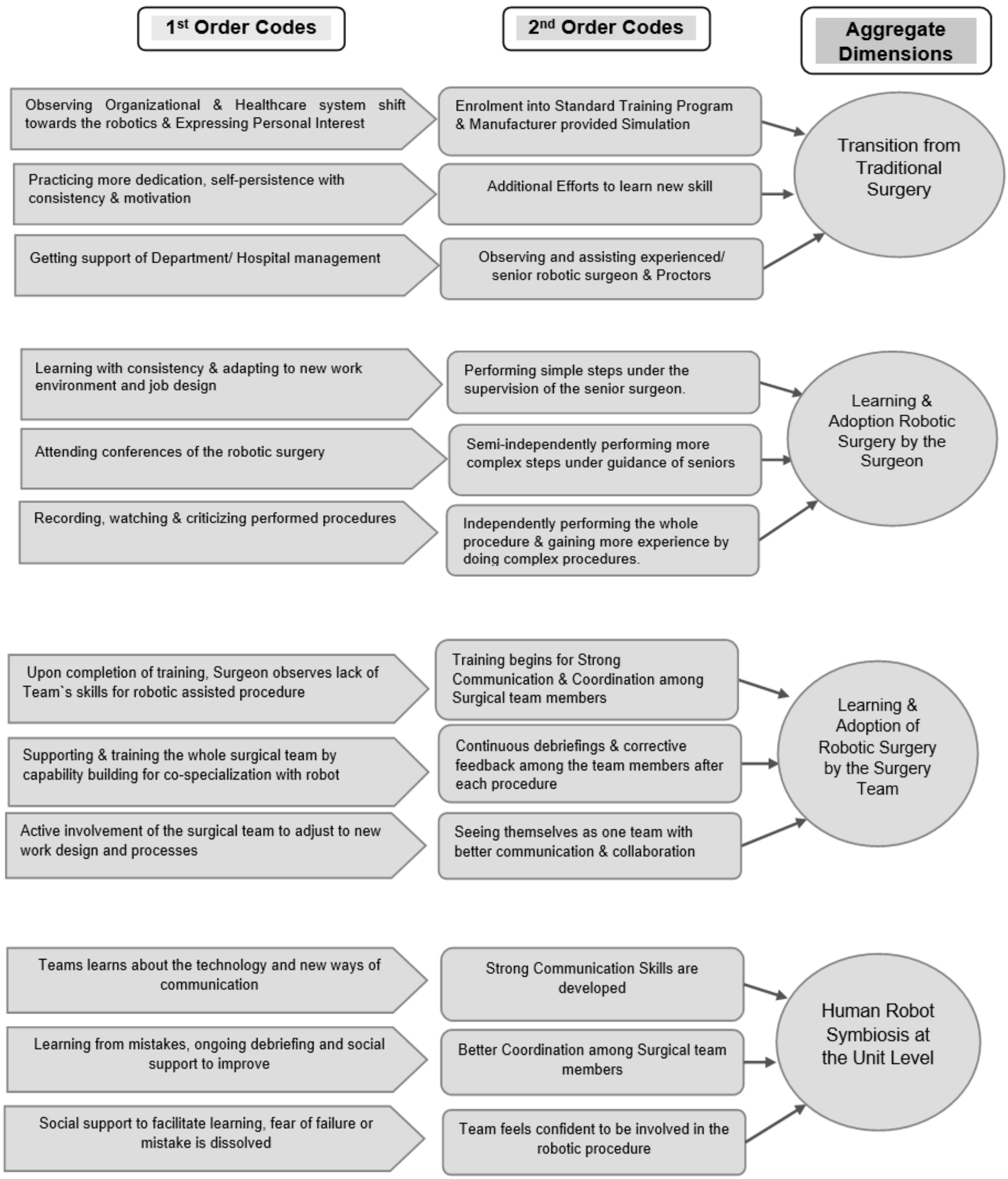
In this study, we used the progressive coding of collected data, which is of structural importance in qualitative research (Williams & Moser., 2019), which enabled us to perform data analysis and progressively lead us to the construction of meanings. We performed open coding for the collected data, a first degree or first level of coding which does not follow absolute sequencing (Themelis et al., 2022; Williams & Moser., 2019). During open coding, concepts arise from raw data and are then systemised into conceptual groups (Khandkar, 2009; Thomas, 2003). In the process of open coding during this study, when the concepts emerged from the raw data, we grouped those codes into conceptual categories. As argued by (Makri & Neely, 2021, p. 08), “data analysis should begin soon after the first data are available by studying the interview transcripts for emerging themes, and by constantly comparing and updating them.” The codes are not created beforehand and applied to the data; in fact, the researcher's engagement and interaction with the data produces the codes (Charmaz, 2016).

We conducted in vivo coding, which means using the participant's actual words and is ideal for developing a realistic final report that reflects the perspectives and viewpoints of the participants (Creswell & Poth, 2017). We did in vivo coding with the objective of constructing a comprehensive, multi-faceted preparatory framework for this study by using the phrases from the conversations of the interview participants i.e., robotic surgeons. The goal was to build a descriptive, multi-dimensional preliminary framework for later analysis. By reading and re-reading the interviews, insights were gained, a basic process surfaced, and we developed the first order codes staying closer to the intent and meanings of the participants. We paid close attention to the explanations of the surgeons about their journey of learning robotics and transitioning from traditional surgical procedure to the adoption of robot-assisted surgery. In addition, we took in account the details of the process of transforming the individual knowledge of surgeons to the surgical team and training of the unit for technology adoption.

2.7 Gioia Methodology

Qualitative methodology often serves as generative research. We used Gioia's approach as a qualitative methodological strategy for generating a systematic data analysis and building a data structure. This approach adheres to the stringent criteria of reliable research (Magnani & Gioia, 2023). We applied Gioia methodology primarily for inductive data analysis for further refining and thematic categorization of first-level codes for this research. As data collection progressed, the differences and similarities among categories arose, which facilitated managing the data categories (Gioia et al., 2012). Later, we did second-level coding based on the relationships of the open codes, which led to an aggregate dimension to evolve and arise. During the second round of coding, we refined and categorised the first-order codes to develop themes, practicing pattern coding to achieve second-level codes. Framing codes in this manner enabled us to observe their capacity for facilitating the recurrent execution of analytical processes, which supported maintaining our analyses as active and dynamic. The process of coding leads to the construction of meanings (Williams & Moser, 2019). Sifting through the second-level codes allowed aggregate dimensions to appear, and we were able to develop the Gioia chart seen below:

Figure 3. Gioia Chart



2.8 Ethical considerations

Ethical approval for this research was sought and granted from the ethics committee at the ISM University of Management and Economics in June 2020. Ethical approval was shared with all participants via email prior to their interviews. Consent to conduct and record the interviews for this research was acquired from all participants, who were thoroughly informed about the research objectives and the use and storage of their replies. Anonymisation in this research was important; hence, all participants were fully informed about confidentiality and anonymity.

3. RESEARCH FINDINGS

The findings of this research disclosed that for surgeons to adjust with new work design and to acquire new skill set of robots assisted surgery, such as refined hand movements while using a console and clear communication among the team while handling complex instruments, demanded additional knowledge and a deeper comprehension and development of these additional skills. During and upon completion of training, the surgeons realized the need to practice these skills and the need to train their teams in the smooth collaboration needed during robotic procedures.

Analysis of the interviews revealed that during this journey of adoption of robotics by the surgeons, self-motivation and the support of senior, experienced surgeons and hospital administration played fundamental roles. The surgeons mentioned that they pursued a robotic surgery career path in their own interest, as they realized how global healthcare is welcoming and embracing technology of the robotics. Some surgeons were excited to learn this new skill when they saw the healthcare industry's and organizational shift towards technologies. All of them were initially trained in traditional surgery, with most later learning to conduct laparoscopic surgery and then transitioning to robotic surgery. According to some, learning and practicing laparoscopic surgery were helpful to adapting robot-assisted procedures.

The interviewed surgeons took and active approach towards robotics. Intense personal efforts were dedicated by the surgeons themselves to adopt this technology by enrolling, attending and completing the trainings, continuously practicing the new skill, recording their own videos during the procedure and watching them later to analyse and criticizing their own work. They diligently and continuously practiced consistency, dedication and perseverance in order to adopt and adapt to the robotic surgery. They all underwent various forms of training and highlighted the necessity and value of a systematic approach towards adoption of a new technology.

Although the process of learning and adoption was challenging, they were able to overcome the difficulties because of personal characteristics and additional attributes. They invested time and effort into learning the new skill and enhancing their own human capital since they all had faith in technology and had witnessed improved patient outcomes. They felt that working with the robot increased their confidence and they felt less exhausted at the end of the day. In addition, they actively and willingly participated in the further training of their peers and staff, which prompted the creation of their own department of human resources.

The robotic surgeons were emphatic that training their teams was of the utmost importance and that they preferred to work with the same teams over and over. The surgeons assumed the responsibility of training their teams to align them with the changes in the work dynamics with surgical robots. They focused on knowledge, skills and communication to give the team members self-confidence, and to assist them in adjusting to new work styles made necessary by the changing operation room structure and design brought about by robotic surgeries.

After completing their own certification and credentialing processes, the surgeons focused on their teams' training. They conduced training internally and, in some instances, surgeons even invited their nurses to attend sessions with them and with the machine manufacturers abroad. It was also mentioned that selecting and training the team and continually working with that same team produced benefits, not only for the surgeon, but also to facilitate positive outcomes of the surgery and acceleration of the procedure, which helped in overcoming the time constrains. It was advantageous for them to collaborate and share expertise to solve problems, mutually develop troubleshooting techniques and ensure patient safety and procedure success.

In contrast, out of thirty-six (36) interviewed surgeons, one surgeon mentioned that he did not choose by himself to work with the robotics; in other words, he did not get the choice to be the robotic surgeon. Hospital management decided to purchase and install the surgical robot without any discussion with the surgeons or involving surgical teams. Instead, one day, they were told that now they should adjust to this new technology and, after completion of required trainings from the manufacturer, start performing surgical procedures using it.

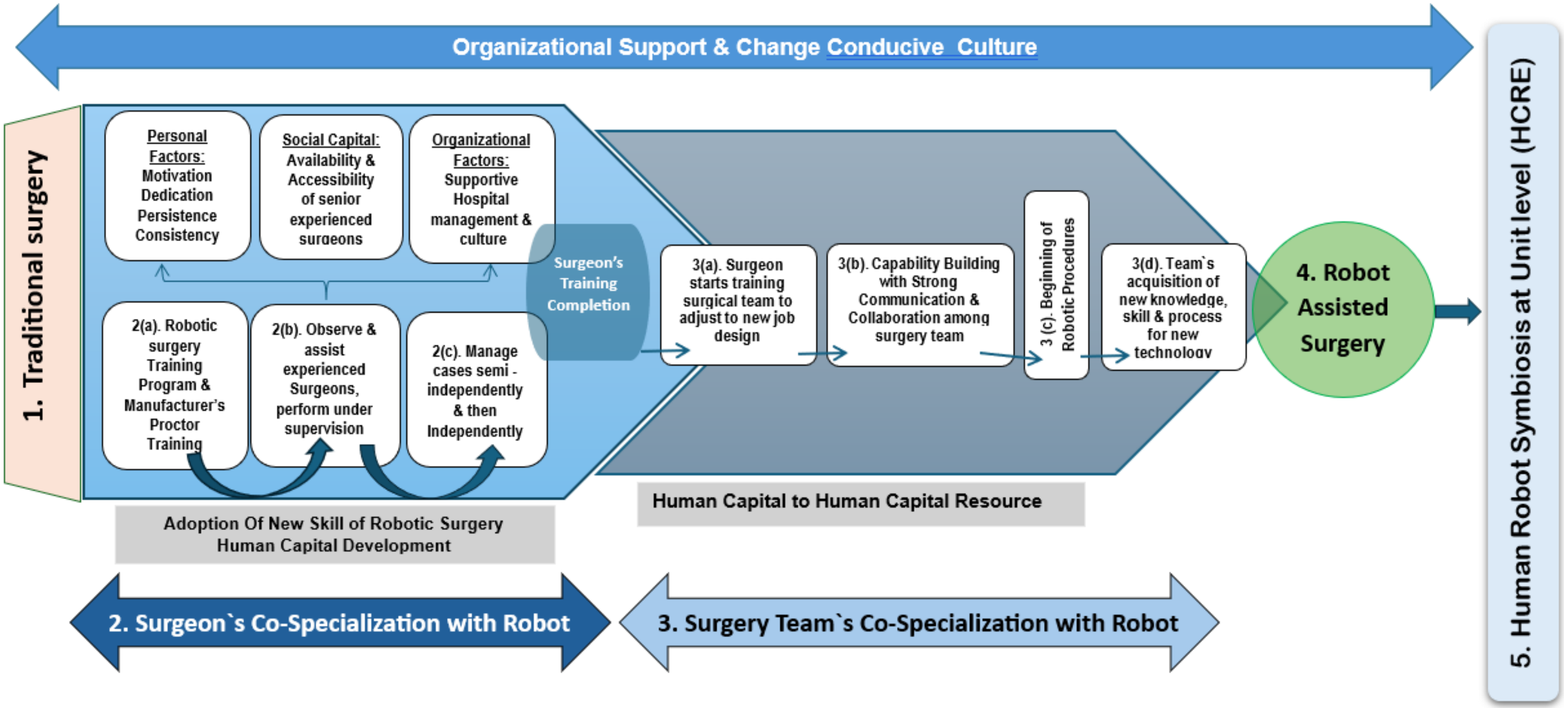
It was also noted that all of the surgeons highlighted the importance of traditional surgery training and of proficiency in human anatomy during the early learning phase of the new surgeons. This knowledge and skill will not only give them more experience and confidence but will also help them to immediately convert the robotic procedure into open surgery in case of an accident, machine failure or other related complications.

3.1 Emergent Model from Data

This study compared the requirements of human capital in the surgery department in terms of traditional surgery to the adoption of the robotic-assisted surgery. The emergence process was explored and studied. Overall, it was observed that the outcome of successful adoption is ‘human/robot symbiosis.’ Based on the analysis of the data collected from interviews with surgeons, a process of co-specialization emerged, i.e., the transition from traditional to robotic surgery and human capital resource emergence jointly leading to the co-specialization of surgeons and surgical teams, with the utilisation of robots leading to valuable accomplishments for surgeons, patients, health organization and healthcare systems. This model can be used as template or guide for implementing new technologies in the healthcare industry.

The emergent model is presented below:

Figure 4 Emergent Model - Human Capital Resource Emergence Model for Robot-Assisted Surgery



As per analysis of the semi-structured interviews, the above model emerged. On the left side, the column shows the traditional surgery job design, with a comparison to the right side in which the approach is transforming into the robot-assisted surgery, a new job design, resulting in a human/robot symbiosis that leads to resource co-specialization in the surgery department. In the next sections the emergent model is being explained in four phases, i.e.,

1. Old and new work designs (traditional vs robot-assisted surgery).
2. Co-specialization of surgeons with robots,
3. Co-specialization of surgical teams with robots,
4. Human Capital Resource Emergence – unit-wide adoption of robot-assisted surgery resulting in human/robot symbiosis.

3.1.1 Old and New Work Design

(a) Traditional Surgery

In a traditional surgical procedure, the entire surgery team surrounds the patient from the start until the end of the procedure. Generally, a standard arrangement within the operating room (OR) during a surgical procedure comprises two main surgeons, a surgical nurse, an assistant nurse, anaesthetist, an aesthesia nurse and some junior surgeons. The surgeon must remain continuously connected with the team verbally, using face-to-face communication with eye contact, and being physically present in the operating room. As mentioned by the respondents, "[d]uring surgeries, you are talking a lot about different subjects, your assistant and your colleagues, but during the robotic surgery you are sitting at console alone" (Interview 06).

All of the interviewed surgeons were initially trained in the traditional manner for open surgery; they emphasized that this experience of traditional surgery is very important, especially in cases of an accident or an ambiguous situation during the robotic procedure in which an urgent need arises to convert into an open surgery. Most of them had been involved with laparoscopic surgery before adopting robotics; this had helped them to more quickly adapt to the use of robotics, especially in terms of refined hand movements, better control and adjustment with the console. As one interviewee mentioned:

> *"I had gone there for a fellowship, laparoscopic the robotics fellowship. The fellowship was initially meant to be address laparoscopy. Then they told me to have the robotic and I would be able to get trained in that. So, it was almost*

by default when I arranged the fellowship. It wasn't so much about the robotic, but by then, by the time, as we said, that the robot cases increased." (Interview 02).

In traditional surgery, doctors frequently used a single phrase or hand signal to express what they required, but in robotic surgery, when most team members cannot see one another, everything needs to be said aloud through a microphone. Members of the robotic surgical team communicate differently, delivering and verifying verbal directions. This requires efficient active listening and good synchronisation among teams. As was noted by one surgeon, "when you are doing the robotic surgery, you have to learn how to be more in tune with the team. You have to listen" (Interview 22). In the initial phases of transition, this can be challenging because the console is mounted in the room next to the operating room. As mentioned by one surgeon, "if you are in a system where you have like two rooms at the same time as a surgeon and you jump between the rooms. So, this is like one of the main challenges" (Interview 31).

The surgical staff involved in traditional surgical procedures has both a distinctive mindset and a certain skills set. Since robotic surgery is a complicated technique, the surgical team members must work closely with the surgeon and remain in constant communication. As one surgeon mentioned, "You need to be super specialized because the mindset to use robot is different than the mindset of doing traditional surgery" (Interview 33). This change of mindset is challenging and requires continuous support and training, as mentioned in the following quote, "[a]nd you have to change your mindset and do something new. Know that it is always difficult and gives you a lot of pressure when you're developing it" (Interview 14).

Since physicians are trained to manually examine the patients, doctors, especially surgeons, develop the strong tactile skills necessary for gauging the texture of tissues during a traditional surgical procedure. When transitioning to robotic procedures, they must focus on developing the new skill of visual examination. This change in performing surgical tasks comes with a challenge, which is discussed in the following quotes: "With the robot, you have no feel, zero feel" (Interview 06) and "You can feel the texture, the thickness of tissue with your eyes" (Interview 04). As another surgeon explained:

But in the robotic surgery, there is no tactile feeling; you cannot feel what you are doing, what you can see. So, I call it as a visionary feeling. So, when you see something, you try to feel it with your vision. So that takes a bit of a time. (Interview 23).

Initially, the surgeons train the teams based on existing processes to enhance their understanding of how and where the processes are changing. During interview 29, the participant expressed that, "I think having a trained team is important and the lack of it will make it harder financially." This training of the team by the surgeons not only includes an understanding of the technology but also of specific procedures. Surgeons were motivated to upskill their teams. As they explained, "I am going to teach my people the robotic which is an easier learning curve, and I will teach them every and all the steps very professionally" (Interview 10) and "But I think as you develop the skills, then you start matching and then obviously convincing the people around you, developing the team around you that this is the way to go" (Interview 4).

(b) Robot-Assisted Surgery

Robot-assisted surgeries have altered the designs of tasks undertaken in the surgical theatre. During procedures, although the team is nearby, they are not in the operating room and must communicate via microphone. The surgeon sits at a console to control and govern the movement of the robotic arm in the operating room. Only one standby surgeon will go through the process of scrubbing and will enter the operating room only in case of emergency or an event such as equipment failure. One participant discussed the challenges involved, saying that "[i]f you are in a system where you have like two rooms at the same time as a surgeon and you jump between the rooms. So, this is like one of the main challenges."

During a robotic procedure, the operating room is organized differently. The surgeon is positioned in a corner, focused on the screen in front of him or her at the console and the robot occupies the central position in the room. The remaining medical personnel are dispersed, typically unable to view one another's faces and frequently uninvolved for extended periods:

The setup is different compared to open or laparoscopic because you're a little bit far away. So, make sure that you're sitting on the console. If you want to lift your head out, you can actually see the patient, the robot, the assistant *descriptors and anaesthetists, because actually sometimes the setup, even if you actually do that, you might not be able to see them. (Interview 35)*

Although surgeons sometimes miss face-to-face contact with the team, they have come to realize that, while everybody is focused on the screen of the camera the team is more involved, and the procedure goes smoothly. Since the whole team can simultaneously see the procedure with the help of a 3-D camera, they are more alert, involved and engaged. Also, as explained by another surgeon:

In laparoscopic or open surgery, everybody stands around the patient. And so, communication is straightforward face to face. When you're doing the robotic surgery, you are sitting in the console, you're not seeing the patient, you're not seeing your assistants, you're not seeing your nurses or the other stuff. You have a microphone in the console, and you have a speaker in the robot. So, the communication is via microphone and so on. So that is also something that you need to standardize. The communication must be straightforward, quite clear. (Interview 12)

The duration of the procedure is shorter with the robot, and there is less blood loss. Disinfection and sterilization techniques are different. It was mentioned during the interviews that surgical teams can conduct more surgeries due to the efficiency of a robotic arm. As was shared by one surgeon:

So that's I think this is a limitation because when you have a big tumour, and you can move it out and then we're constructing if more degrees of freedom now they can record. I think I told you about the haptic problem. (Interview 30)

Table 2. Key Differences between Traditional and Robotic Surgery Revealed by the Interview Data

Traditional Surgery	Robotic Surgery
1. Surgical team in one location around the patient	Surgical team in multiple locations- Around and near the operating room.
2. Traditional job design	New job design.
3. Traditional mind set	Changed mind set.
4. Traditional skills set	New skill set.
5. Face-to-face communication among surgery team members	Communication through microphone, which requires direct yet simple commands

Traditional Surgery	Robotic Surgery
6. Complex procedure with traditional surgical instruments	Complex procedure with a complex instrument (robotic arm)
7. Direct contact with patient and surgery site	Only visual contact with patient and surgery site, no tactile feedback, only feeling with eyes through camera
8. Post-surgery, there is risk of hospital-acquired infections and recovery takes longer	Post-surgery, recovery is fast and there are fewer possibilities of hospital-acquired infections
9. Surgeon health issues due to long hours of standing and handling equipment manually.	Longevity of surgeons

3.1.2 Transition of Surgeons from Robotic to Traditional Surgery

Many factors are involved in this transition process, as shown in the emergent model. From the organizational perspective, it is supportive management as well as a change- conducive culture which facilitate the transition of the surgeon. From a personal perspective, factors are persistence, dedication, consistency and self-confidence.

(a) **Organizational and Healthcare Shift:**

In the year 2000, robotic surgeries became increasingly common when the Food and Drug Administration (FDA) of United States of America (USA) approved the “da Vinci Surgical Systems” for use in robotic-assisted surgery. This resulted in an upsurge of robotic surgeries performed in the USA and later globally (Rivero-Moreno et al., 2023). Interview have data shown that most of the surgeons were in the early stages of training when they observed this trend shift in the healthcare market and practices. As one participant said:

> *When I met a professor from United Kingdom, he's one of the pioneers in the robotic surgery. So, he spoke about how the robotics is definitely going to change the landscape of medicine, and it was really good to have it for me. So, I packed and got hooked on the robotic surgery. So that's what got me started” (Interview 17). They decided to be the early adopters of the robotic surgery “I trained and lived in Sweden my whole life. And I finished my Residency in 2005 and 2010. I started with the robotic surgery, and the thing is that the states they started around year 2000 and in Europe they started from 2007, 2008. So, we were quite early adopters for the robotic surgery in Sweden. (Interview 12)*

The surgeons felt the change in the industry and decided to embrace this upcoming promising technological advancement in healthcare. As one surgeon mentioned, “So, the world has changed because of the robotics introduction” (Interview 19) and “so, the robotics is a game changer.” (Interview 08)

Surgeons made a personal choice to learn this necessary skill, enrolling in wet labs or simulation training or travelling to places where robotic surgery was being practiced and taught. Some opted to pursue a career in robotics by completing post-graduation work in that form of surgery. While some were inspired by the senior surgeons, others mentioned that the hospital management decided to adopt robotics, which resulted in igniting their interest as well. As the following quote illustrates:

> *I had gone there for a fellowship, laparoscopic robotics fellowship. The fellowship was initially meant to be address laparoscopy. Then they told me to have the robotic and I would be able to get trained in that. So, it was almost by default when I arranged the fellowship. It wasn't so much about the robotic, but by then, by the time, as we said, that the robot cases increased. (Interview 02)*

(b) Personal Traits:

Surgeons were highly self-motivated to transition from traditional operating rooms to robot-assisted surgeries. As shared in the following quotes, “We wanted to do things. We wanted to have an advantage over a conventional laparoscopic approach or an open” (Interview 08) and “[s]o, we used to lock ourselves in [the] lab, in New Jersey, outside the operating room, in the hallway and bring grapes, fruits, pieces of chicken and start working on that. And we timed ourselves because we wanted to suture faster than laparoscopy” (Interview 09).

All of the surgeons mentioned that they have continuously and thoroughly practiced consistency, dedication, persistence, and increased self-confidence that would allow them to adopt and adapt to robotic surgery, as illustrated in the quote, “It depends on the level of the training, and you need to have a lot of passion” (Interview 31). They all went through different types of training and emphasized the need for and importance of standardized training: “Really, I travelled across different states just so I can watch other surgeons and kind of learn from them” (Interview 19). The journey of learning and adoption was challenging but with these personal factors, they were able to overcome the challenges; as one surgeon said, “I would spend a lot of evenings extra, trying to make the professor happy. Persistence is very important” (Interview 05). The need for *d*edication and consistency were expressed as, “I sought out a lot of different mentors in different settings in order to get as much different experience as I can try to build my own skill set.” (Interview 11)

They all believed in the technology and saw their patients’ improved outcomes, which strengthened their trust in it, and they dedicated time and energy towards learning the new skill, thus increasing human capital. They were excited about adopting this new approach towards surgery. As one surgeon mentioned, “I was actually very excited to go work with the robot the first day I remember when we when I was only allowed to watch the robot, especially the first few cases. It was very fascinating” (Interview 02). Additionally, many were voluntarily involved in further training of their peers, which led to the emergence of their department’s their human capital. One participant expressed this dedication, saying that “I sought out a lot of different mentors in different settings in order to get as much different experience as I can try to build my own skill set.” (Interview 17)

(c) Supportive Hospital Management:

The interview data illustrated that hospital management's backing and support were crucial during this adoption phase and that management was willing to acknowledge and learn from mistakes. Surgeons and surgical teams were allotted time to learn the new skills and punitive measures were not taken by management in case of clinical error. Also, provision of financial and administrative support for training by the hospital management was of great value to the surgeons and their teams. Those in management positions provided the support and choice to the surgeons needed to gradually transit to competent robotic surgery:

> *[The] head of the institution was unequivocally the vanguard of this idea and the generator of this idea. He assumed the responsibility and a certain opposition that arose for the first system in Lithuania and the Baltic region. (Interview 27)*

Hospital management granted vacation days, in addition to financial assistance:

> *The hospital administration from, you know, the dean, the hospital administrator was very supportive. The chairman of the department was very supportive. They gave us the time off. They gave us the financial support. They allowed us to travel to get the training that we need. (Interview 26)*

The head of the surgery department also demonstrated dedication and persistence in purchasing deployment and acceptance of robotic technology in the surgery department. Surgical team coordination and communication were enhanced:

> *And I had a manager that was totally, totally supportive. So, and that meant that my robotics career just took off. And all of a sudden, I was doing most of all the surgeries in whole Sweden. I was training people around the world, and that was just because I had such a good support from my head of department, who was also a surgeon. (Interview 12)*

Direct managers who, in this case, were senior surgeons, also supported and assisted in this adoption journey. This was reiterated by one surgeon, who noted that "[w]hat helped me is that we had the manager and administrative manager that he was keen, and he had this vision about the robotic surgery" (Interview 16). This attitude and the assistance of the management resulted in greater motivation and dedication of the surgeons. As informed by an interviewee:

> *So there are quite a few people which help[ed] me during this journey. As I said, my initial bosses when I was [a] very junior trainee, they help me and they send me to Korea, they send me to Japan to have some hands-on practice there and for some case observations. (Interview 24)*

The surgeons felt safe, supported and more engaged in learning the new technology and acquiring the new skill. One participant shared that:

> *And the institution that I was working at was also very keen on developing robotics and was supportive of the program and they were willing to commit the necessary resources in order to get a program like this off the ground, including dedicating all our time. (Interview 26)*

Newly hired, experienced surgeons were happy to train and support the other surgeons, possibly due to supportive and understanding management. As one mentioned:

> *[…] definitely having good mentors. So, people who were able to help you both, theoretically speaking, as well as experience as far as getting hands on experience and teaching you how to do appropriate cases in sort of the best way possible. That's by far the most useful factor that helped me get better. (Interview 20).*

In addition:

> *What we decided is that we'll have a group of doctors who will be doing so. If I am going to do a procedure, I'll have two or three other guys who are as good as me with me. Watching me. Guiding me. Criticizing me. Helping me. So that we reduce the risk. (Interview 8).*

Other participants expanded on this by saying that “I was lucky to have good mentors. Okay, I always like it. They were very supportive. It's like this is the future. You have to invest.” (Interview 31) and “[s]o, in the robotic surgery, the only difference is we probably rely on more qualified colleagues as assistants.” (Interview 2)

The training and assistance provided by proctors from the manufacturers of robotic surgical arms was said to be substantial, with hospital management ensuring that manufacturers’ technical support was always available. These proctors not only provide support during the surgeons’ learning phase but also when that training is completed. Every robotic surgical room is equipped with a helpline phone and assistance from manufacturers is always available, at any time of the day: “It's all technical, you know, and we always have a technical team with us so they can tackle the problems.” (Interview 9).

Hospitals were not only investing in purchasing the robotic arm but were also recruiting experts from around the world to enhance the existing human capital of the surgery department and to expedite the implementation of the technology. As one surgeon mentioned:

> *Mr. A and S came into my office and said, we've got some news for you, but you have two jobs now. The laparoscope is a dying breed and more and more kidney surgery becoming the robotic rather than laparoscopic. (Interview 3)*

The transition to robotics happened in many cases due to hospital management deciding to implement such surgeries. Another surgeon expressed his feelings in this quote, “Our hospital was very supportive. We were the first few surgeons were sent for the robotic training, and they also gave us a very good kind of the robotics program” (Interview 15). Not only management but also nurses were supportive during this phase of learning and transitioning of the surgeons. A surgeon mentioned delightfully that “[w]hat helped me a lot helped was I think all the colleagues, the entire team and their team, I must say, goes to our nurses. Also, nurses were a great support. Good! Excellent!” (Interview 10)

3.1.3 Surgeon`s Co-Specialization with Robots

(a) Standard Training for Robotic Surgeons

All robotic surgeons completed the standard training program used in the adoption of robotics. Some surgeons completed it in a later phase of their career; however, some opted to undertake it during their residency and fellowship training. As mentioned by two surgeons:

> *I went to the more modern week of robotic training, which is via fellowship. So, I applied for a fellowship post in grad school and successfully gotten that post and I worked with robots. (Interview 19)*

> *First, I did it when there was no training. Then, in 2014, when they established a training program, I enrolled in the training program. (Interview 14)*

A standard training program in robotics provides an overview of the robotic surgical system, instructional guidance on robotic surgical systems, a curriculum for psychomotor skills development and training, communication skills training, and staff education. The surgical trainee uses simulations to refine the competencies necessary for robotic operations during training. The activities encompass the use of articulated and three-dimensional (3D) optical tools, enhancement of forceps manoeuvres, suturing, knot tying, dissection of structures, and application of various energy modalities. What this learning process involved was shared in this quote:

> *There are a set of about ten different exercises on the simulator that teach you how to manipulate and utilize the robot. And so, everybody had to complete those with a passing grade. So that was one additional requirement. And then, you know, at the time we had no robotic surgery available onsite to train us. So, we went to Strasbourg and did the Da Vinci sponsored training on the machine" (Interview 28). Also explained in this quote about simulation training," So from the entry point of view, one has to do online modules and then they have to complete 50 hours of simulation exercises before they can get on to the patient. (Interview 24)*

In addition to virtual reality simulators, there were physical simulators with which surgeons engaged in exercises to cultivate abilities such as suturing, cauterising, and closing anatomical planes in organic tissues. The apprentice observes and, ideally, engages in robotic surgeries as a supervised assistant, practicing appropriate patient positioning, port placement, docking, and manipulation of the robot's arms and instruments, while also acquiring skills to troubleshoot system issues. Observing an experienced surgeon in real-time enables the apprentice to gain familiarity with essential standard procedures in their speciality and acquire key insights and technical techniques. This was mentioned by a surgeon who said that:

> *You watch other experienced surgeon do cases. Then the last step is being able to do the robotic parts of the robotic procedure while experienced surgeons sitting next to you at another console and they can take over and help you or guide you verbally with how to proceed. (Interview 19)*

To achieve a more authentic experience, porcine organs may be utilised within domes and mannequins. Upon certification in the pre-clinical/basic level, the trainee surgeon can begin their clinical/advanced stage. This phase comprises a minimum of 10 robotic treatments overseen by a supervising surgeon possessing substantial expertise in robotics. Initially, the trainee should undertake simpler surgeries, progressing to more difficult procedures as their proficiency with robotic technology increases. The process of completing these steps of training was shared by a surgeon, who explained that “[s]o we get to do that simulation. And the simulation took me around six weeks to complete and then we followed the EU model, the system of robotic prostatectomy training, which is divided into 12 steps.” (Interview 18)

(b) Performing under the Supervision of Seniors

It was mentioned by the surgeons that, during the early phases of the robotic surgery adoption and completion of training, they had to work under the supervision of experienced surgeons, during which they had an opportunity to perform some of the steps of the surgery. As they explained:

> *In my training, we had two consultant robotic surgeons who really sort of like monitored me from day one until [we] just finished the fellowship and really looked at how I progressed and allowed me to progress accordingly to what they felt will be necessary or adequate progression. (Interview 18)*

Later, surgeons semi-independently performed more complex steps while still under the guidance and with the mentorship of senior surgeons:

With these dual consoles, the operating surgeon can give control to the trainee at any time and then also take back control of the instruments at any time. So that's a very helpful tool for a trainee because you're again in a proctored way under direct supervision, doing portions of the case and getting real time feedback on your performance. And it's also a way that makes it safe for the patient. (Interview 24)

They always had a backup experienced surgeon available in the hospital who was able to guide and provide corrective feedback in case of an ambiguous situation. This was reiterated by a surgeon who explained that "[s]o that was constant supervision in surgery that was first. So, teaching by example and then there was constant supervision, and I think that's what had the most" (Interview 12). In addition, they had access to experienced surgeons remotely, as well as to the proctors of the robotic arm manufacturing companies. This constant support allowed them to complete their training in a timely manner:

I think, you know, getting the support of your colleagues because obviously when I was training, I then couldn't do many of the other operations. So, my colleagues were having to take on some of my other non- robotic work, so to allow me to train. (Interview 8)

(c) Completion of Training and Independent Management of Cases

Upon completion of training, the surgeons were certified by the robot manufacturer proctors and the mentoring senior surgeons. Upon being certified, they were allowed to progress towards more independent procedures. One surgeon provided details, saying that "I did, I think about 60 cases under supervision before I start doing cases independently" (interview 17). Initially, they performed simple procedures independently and, with more experience with and control of the robotic arms, they were performing more complex and critical procedures without supervision. Discussing this transition period, another surgeon shared that "[s]o that takes a bit of time. So, I would say that for a newcomer who knows the operation, but trying to learn robotic surgery, at least 20 cases from my point of view" (Interview 25).

3.1.4 Surgery Teams' Co-Specialization with a Robot

The surgical team goes through the transition process as well. The surgical staff involved in traditional surgical procedures have a certain mindset for this particular job design and a certain skills set. Since robotic surgery is a complicated technique, the surgical team members must work closely together with the surgeon and communicate well. For co-specialization with the robot, initially, the surgeons will train the teams internally based on the existing processes to make the team fully understand how and where the processes are changing.

This training by the surgeons for the surgical team not only included an understanding of the technology but also demonstrations by the surgeon as to the way in which devices are used on the patient by providing a clear understanding of the procedure. As one surgeon said:

> *So, I don't mean to say that it's the surgeon who gets the accolades. It's the team that gets the accolades. So, if you have the right team and the right infrastructure in place, then the robotic surgical program you are doing is set to succeed. (Interview 13)*

(a) Training of the Surgical Team by Trained Surgeons

With the changing operation room structure, work design and processes with the robotic surgeries, the surgeons are responsible for training their team, which helps to provide them with self-confidence, helps them adjust to a new work style and align them with these changes in terms of knowledge and skills. As one surgeon highlighted:

> *Verbal communication is very important because again, you can’t see the body language, you can't see what people are doing. So, you can’t really even look at the monitors and what's happening to the patient, like vital signs. So, you start to rely a lot on verbal as well as just listening to the sound in the room and trying to understand what is happening. (Interview 14).*

Training the surgical team to adjust to this new work design, job roles and process requirements was equally important as training the robotic surgeon. The surgeons had a clear understanding of this and, upon the successful completion of their own training program and certification, they started training their teams. As one surgeon ruefully remarked, “[i]f he's got a bad assistant, he can't perform. So, I think it's very important to have the right team” (Interview 16). This mutual sharing of knowledge, development of strategies for troubleshooting and working collaboratively to ensure patient safety and a successful outcome of the procedure benefited them as well. It was mentioned by the interviewed surgeons that having a good team that shared a similar background and understanding of the process will make the day easy and procedures efficient. As mentioned previously, *o*ne surgeon said that “I think having a trained team is important and the lack of it will make it harder financially.” (Interview 28)

During this training, the surgeon accustoms the team to the new improvements in interaction and communication. To achieve a better outcome following adoption of the robotic arm, patient safety and success of the procedure, effective, clear, and strong communication skills are required. Communication among the team members must be strengthened because a great deal of nonverbal communication might also happen during robotic procedures. It has been observed during data analysis that key competencies for technology adoption in healthcare not only encompass knowledge of technology but also require strong communication skills. As mentioned during interviews, “You need to communicate with the team. You have to make a quick decision about things, and you have to be prepared” (Interview 11) and “it's not like in an open surgery that you can put your fingers and stop it. You need to communicate with the team” (Interview 27).

If, with no preparation, they must work with new teams or with staff who are not trained, they face challenges during robotic surgery. One surgeon suggested that “[…] my advice with the people is to select the case. Select and do it. Same team. Same team!” (Interview 33). They observed that training the surgical team and then consistently working with them not only makes the procedure feasible, but surgeons feel more confident.

(b) Capability Building among Surgery Teams

With the changing operation room structure, work design and processes that occurred with the onset of robotic surgeries, the surgeons took responsibility for training their team, which bolstered their self-confidence, helped them adjust to the new work style and align them with these changes in terms of knowledge and skills. It benefited them to have a mutual sharing of knowledge, to develop strategies for trouble shooting and working collaboratively towards the goal of patient safety and successful outcomes of the procedure. This quote explains that, with the adoption of robotics, the whole surgical team should adopt and adapt to the new job design and collaboratively achieve success: “But then do you have a dedicated team of they've been working with you for long. And when your team's getting better, you get better as well” (Interview 35).

In some situations, the surgical team developed a certain language and selected particular words for communication, those to which they would instantly respond, whereas, in some scenarios, teams established sign language. Also, surgeons further polished their active listening skills to allow them to focus on the surgical site while simultaneously remaining connected with the team. It was noted from the interviews of robotic surgeons that to use the technology successfully and impactfully the team must build capability collectively towards it. As exemplified in the following quote:

> *So the robot is a real revolution in surgery. And when you do it with your team, It's the Bond. the bond which brings team together. We have better communication, better understanding, better collaboration. And everyone sees the importance of what you are doing. This is a process because you do you do things together. And you know that It's a value added for your patient. (Interview 18)*

(c) Acquisition of New Skills and Knowledge by the Surgery Team

When asked during the interview 'what makes a good day and what makes a bad day?', the initial response of all the surgeons is that a good day is one during which the procedure goes smoothly, and successful outcomes are achieved due to team collaboration. This is only possible with a very smart, collaborative, well-trained, and familiar team. It is interesting to note that the surgeons, once they have trained their internal teams, prefer to continue working with the same team when performing robotic surgery. This preference has not been specifically observed earlier for traditional surgery, the reason being that robotic surgery is fast-paced and immediate responses are expected. The addition of a robot as a team member complicates surgical operations even more when the entire team in not in synchronization, with the humans and machine working simultaneously.

Hence, a skilled and committed workforce is essential for the successful deployment of the robotics in surgery and the team's comprehension of the process is of the utmost importance. As per the findings from the interview data, the robotic surgeons consider working with the team with whom they are familiar to always always efficient, convenient and productive. Some of them have even also mentioned that they consider a bad day to be the day when, due to circumstances, they have to work with unknown or unfamiliar team members for the robotic procedure.

(d) Human Capital Resource Emergence in Surgery Department for Robotics

With all the phases explained above completed, the surgical department experiences human capital resource emergence (HCRE) and all the surgical teams become fully acquainted with the technology, the robotic surgical arm. As highlighted in the following quote:

> *So, I don't mean to say that it's the surgeon who gets the accolades. It's the team that gets the accolades. So, if you have the right team and the right infrastructure in place, then the robotic surgical program you are doing is set to succeed. (Interview 13)*

Surgeons started their learning journey individually and became the human capital of the surgical department with newly acquired knowledge, skills and attributes required to perform robot-assisted procedures. In later phases, the surgical team was trained and upskilled to adopt and adjust to the robotics and with ongoing collaborative task completions and proactive communication, the whole surgical team emerged collectively with new set of attributes. Full adoption of the technology was not feasible in the healthcare system with only surgeons being trained. It is imperative that departmental teams are involved, trained and acquainted with a holistic approach towards the new technology. As mentioned by a surgeon, “[b]ut my advice with the people is select the case, select the team and do it. Same team, same team, work as a system” (Interview 35).

As per the findings of this research, human capital (the surgeon) was important for the robotics’ integration. The surgeons in the surgical unit have more effectively utilised their KSAO to enhance unit-level outcomes. However, human capital resources (the surgical team) was crucial to full implementation and adoption. Without human capital resource emergence, the comprehensive human and robot ‘symbiosis’ was inconceivable due to complexity and interdependence of tasks in healthcare settings. The modification of individual KSAO to the unit level was the vital step in the process of technology deployment and effective use in the healthcare system. The expected outcomes and value to the patients were only made possible when the whole surgical team was adequately trained to embrace the new job design and its requirements.

3.1.5 Additional Findings

(a) Master/Slave Relationship between Surgeon and Robot

All of the robotic surgeons believe that the robotic arm is a machine, has no autonomy, and is being controlled by the surgeon, which most of them consider to be a master-slave relationship. This was made quite clear when one surgeon mentioned that “[t]he robot is a slave. It doesn't do anything on its own. It doesn't have any. It's a master/slave relationship” (Interview 27); “[so], I am the master, and the robot is the slave (interview 10); and “I'm operating the machine. That machine is like a slave under my hand” (Interview 26). All interviewed surgeons mentioned that it is the surgeon and the team who are responsible for the clinical outcomes of the procedure e.g., “[y]ou do what you have to do, and you are responsible of what you are doing” (Interview 17). In case of an accident or adverse event, they all have the firm belief that the machine cannot be blamed; it is the surgeon who should take full responsibility and who is accountable for any resulting damage or adverse event. As several surgeons said, [t]he robot is not a person, so it has no responsibilities. Like the responsibility for the whole operation lies with the primary surgeon” (Interview 33); and “as I told you, the robot is not an autonomous system. Everything which is done by the robot is done by me. So once again, it is only me who is responsible” (Interview 31).

(b) Trust In the Robots

All surgeons find the surgical robots to be reliable. Some of them have named their robots; most are female names like Alexa, but it can be a male name as well, such as Leo, because they feel that the robot is a team member. However, they believe that the relationship between them and the robotic arm is one of a master and slave, in which the surgeon is master. They all mentioned that it is a machine which is meant to assist them by precisely following their commands and manoeuvres, because they believe that the robot is just an efficient assistant, and it’s the surgeon who has full autonomy and accountability for the procedure and the clinical outcomes. There was an exception to this naming of the robot that one female surgeon mentioned, i.e., that it is an assisting machine, and she would not prefer naming it because since she is not naming her mobile phone or her car, which are other types of machines, so why would she name a surgical robot? As she said, “[i]t's a tool that makes difficult things much easier and helps you to standardize. That means to democratize the surgery and make it more global in all the ways you know, all the time" (Interview 35).

(c) Patient Safety and Outcomes

In general, the surgeons mentioned that patients are usually excited to be operated on by the robotic arm controlled by the surgeon, especially the younger generation. However, the surgeons explain the whole setup of the robotic surgery operating room to the patients and their families. They also discuss the possible positive and negative outcomes, so the patient and their families fully understand the technology and its capabilities. Some surgeons are even using small miniature plastic modules of the robotic operating room, which clearly demonstrate the scenario to the patients.

Also, with increasing competition in the robotic market, the cost is becoming competitive and affordable. And with shorter post-operative stays, fewer complications and faster surgery due to robotic arm assistance, they believe that, along with patients and clinicians, healthcare systems are also gaining, both in efficiency and financially.

Since robotic surgery is minimally invasive and results in less blood loss during a procedure, reduced, post-surgical complications have been observed, as well as a lower number of readmissions (De Marchi et al., 2022). During robot-assisted surgery, due to small and precise incisions, blood loss is minimal, which results in faster recovery of the patients with less pain, thus shorter hospital stays and early discharge (Grimsley et al., 2022). This reduces the burden of the surgical team, improves quality of life for the patients, and minimizes the chances of hospital acquired infections.

(d) Ergonomical Benefits of Robotic Surgery

Overall, robot-assisted procedures have curtailed the burden on healthcare systems. In addition, due to long hours of standing and bending during complicated procedures, handling of complex instruments and strain on the body joints, the surgeons may retire early due to neck, back or muscular pain and other work-related injuries. However, during a robotic procedure, surgeons are more comfortable and, instead of standing, are in a seated position. Since the surgeon sits at a console and performs complex movements with the assistance of the robotic arm, which minimizes ergonomic and posture-related issues, the longevity of those surgeons is improved. This can also help in combating the shortage of surgeons, which is a matter of global concern.

(e) Future of Robotics is AI Integration

Lastly, all mentioned that they are eagerly waiting for robotics to be upgraded with artificial intelligence (AI) in the near future. They are excitedly looking forward to guidance provided by an AI-integrated robotic arm with smart sensors and imaging capabilities that will provide feedback to the surgeon during the procedure; all of which will support better outcomes of the surgery and higher benefits to the patients. Some surgeons believe that in the future, with the help of AI as an assistive tool, the robotic arm will be performing the surgery autonomously yet semi-independently under the supervision of an experienced surgeon.

Additional Quotes from interviews are also presented in Annex 4.

4. DISCUSSION

We wanted to investigate the process of Human Capital Resource Emergence (HCRE) in a healthcare setting (surgery department) for co-specialization of surgeons and surgical team with the deployment of an emerging technology, robotics. We intended to explore the ways in which human capital resource evolves and emerge for the surgical team with the deployment of robot-assisted surgery. In asking this question, our research assumed a unique perspective by investigating the end-to-end process of adoptability, adaptability and acceptance by the surgeons at a microlevel and the surgery team at a unit level, where the frontliners, i.e., the human capital of a surgery department, have fully and successfully accepted both the use of robots and a new work design.

This research has also explored which individual knowledge, skills, and attributes (KSAO) at the individual level of the robotic surgeon are required to be transformed into unit-level KSAO for the advantageous acceptance of the robot, successful procedures and better patient outcomes. In examining this process, we learned about the learning journey of robotic surgeons and surgery teams through interviews and how individual skills and knowledge are converted into unit-wide abilities. With the purpose of the exploration of the emergence process, we aimed to conduct an inquiry to analyse theoretical implications in the arena of human capital resource emergence literature by investigating this underexplored process in the healthcare industry. The aims of this research were to study co-specialization with robots in surgical teams and the human capital resource emergence process, to develop a human capital resource emergence healthcare technology adoption framework, and to provide guidance to healthcare policymakers, HR personnel, and technology developers for future technology deployment in healthcare systems.

The primary objective of this research was to establish the theoretical foundation of human capital resource emergence by examining inadequately explored processes. According to the findings of this empirical research, a model has emerged that demonstrates the process of human capital resource emergence with the implementation of the robot in the surgery department. We have presented the process in the form of the model (Figure 4) above in the findings section; it is evident from the emergent model that deployment of a new technology in healthcare departments is a multi-dimensional, synergetic, gradual, cohesive, and comprehensive process. It had been observed by Konttila et al. (2019) that key competencies for technology adoption in healthcare not only encompass knowledge of technology but also require social and communication skills. The emergent model (Figure 4) from the results of this study demonstrated that adoption of this technology on individual and team levels not only required basic training but training to a level at which both individual- and team-level co-specialization are achieved. Further, the availability of social capital, new forms of effective communication, and a strong collaborative approach to build capabilities to create value are also required; only then will relevant groups of individual human capital merge into a unit-level construct (Ployhart & Moliterno, 2011). Our research also confirms the claim of previous researchers that when emergence originates as a phenomenon in the thought processes, actions, or other traits of individuals, it is amplified by their interaction and results in a higher-level, collective phenomenon (Kozlowski & Klein, 2000). Ployhart and Moliterno (2011) claimed that two components, i.e., a unit's task environment (interdependence) and emergence-enabling states (behaviours), facilitate the emergence process. Our study has demonstrated that performing surgery in a surgical department is an interdependent task and the motivation of the surgeons to acquire a new skill and dedication to train their teams created the conducive situation for the emergence to happen.

With the deployment of new technology, chaos or disturbances can be created in the routine. Earlier researchers have claimed that emergence is an outcome of chaos and disruption in the routines in the existing systems (Argyris, 2014; Holman, 2010; Mnif & Müller-Schloer, 2011). To further clarify, we found that chaos in the surgery department was created due to deployment of a new technology, robotics, which changed work design and communication styles and demanded a new set of skills. This chaos-stimulated disruption led to the activation of an emergence process in the surgery department. Previous studies have not defined this chaos clearly; however, according to our findings, we are claiming that technology implementation created the chaos in the existing systems of the healthcare system. Surgeons were motivated to adopt robot-assisted surgery and received the training; however, as a whole, the surgical department lacked the knowledge and skills for this new technology. This disruption resulted in the activation of the emergence process. The Individual KSAO of the surgeons was transformed into the unit-wide human capital to achieve work synergy. This stimulated the collaborative learning of new skills and the acquisition of new knowledge among the team members to overcome the disruption, and the process of HCRE happened. This led to a new, structured domain which is better than before and capable of adding value to the organization.

As discussed earlier that it was claimed that there is a difference between specific/special human capital and general human capital. The concept of 'specific' and 'generic' human capital is predicated on the kind of training offered by the organization to the employee and the corresponding skill set obtained through such training (Becker, 1975*). Previous research has claimed that nurses in a particular department who are serving a particular specialty are the specialized human capital in nursing. Based on specialty and experience level, these nurses are considered as 'specific' human capital (Bartel et al., 2014). Building on these concepts, we have observed in our empirical study that the process of emergence occurred among the specialised healthcare practitioners of the surgery department. This finding further adds to the human capital resource emergence (HCRE) literature that 'specific' human capital is an enabler of the emergence process. The specialised skill set and knowledge of the specific human capital act as a motivator for equal understanding of the disruption in routine and lead to synergy among team members to upgrade their knowledge and skills, which aids in adjusting to the new situation and emerges as a 'new whole'. All interviewed surgeons mentioned that once they have trained their teams, they continue conducting surgeries with them and ensure that the team remains together.

Based on the preceding exploration and evaluation of the literature on human capital (HC) theory, human capital resources (HCR) and human capital resource emergence (HCRE), we have observed a sequential connection among these phenomena. We are suggesting that these concepts should be considered sequentially interconnected because the concepts of human capital resource and human capital resource emergence are built on the Human Capital theory. This thesis contributes to the literature by clarifying the relationship among these concepts. As shown in Figure 5 below, by keeping focus on organizational outcomes, the individual capabilities of an employee evolve and develop into human capital. In relevance to previous research, our findings confirm that human capital resource emergence is a bottom-up approach, as claimed by Kozlowski (2012), whereby individual-level human capital aggregates into unit-level. By bringing individual attributes together, this human capital contributes to the development of knowledge and skill set of the unit through social capital and capacity building. This results in the emergence of human capital resources while unit-level capabilities are established.

Figure 5. Relationship between Human Capital (HC), Human Capital Resource (HCR) and Human Capital Resource Emergence (HCRE) (Theoretical Contribution)

Physicians and nurses are the front-liners of healthcare, and the success of innovation deployment depends on their level of adoption. (Qureshi, 2020). By effectively utilizing these human resources in healthcare, initiatives for adopting cutting-edge technologies can be implemented more smoothly (Prajogo & Oke, 2016) and can lead to sustainable future developments (Cavicchi, 2017). It was observed in this research that the transitional approach required for a new technology demand is taking the interests and perspectives of all stakeholders into account. For the successful and profitable deployment of emerging technologies (like robots and AI) into the healthcare systems, simultaneous adoptability by all players is essential. It is crucial to mention here that previous studies have criticized the resistance of the health system, but the literature is quite reserved on the importance of HCRE for cohesive and collaborative technology adoption in healthcare. It is visible from our data analysis that the direct involvement of insiders during the technology development and implementation process is of utmost importance. To embrace the challenges of new technology deployment, there is a need for continuous monitoring of the adoption process (Schartinger et al., 2015).

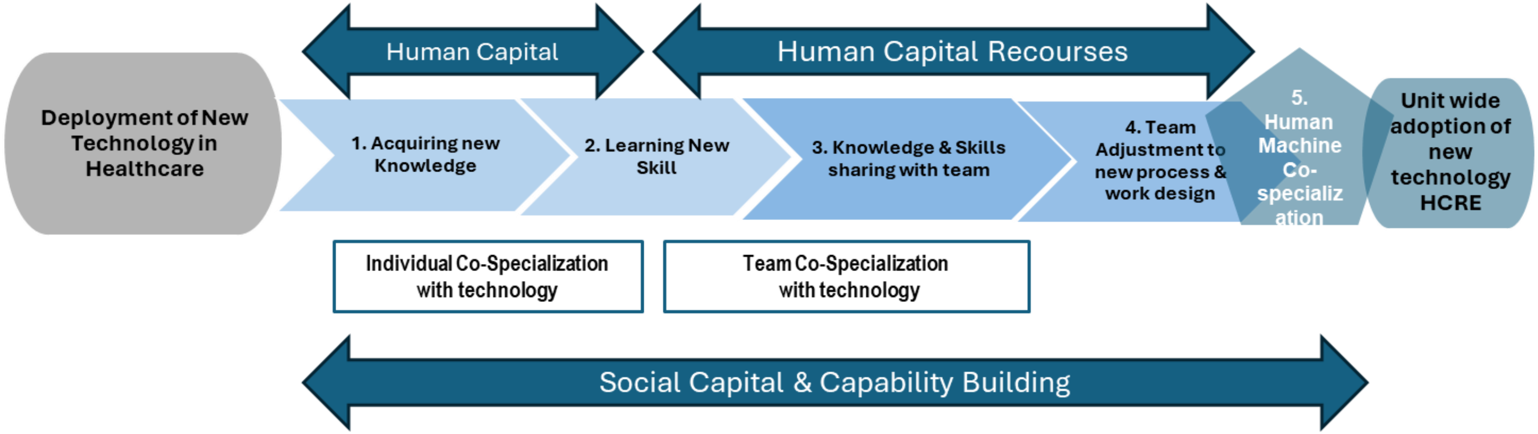
It has been mentioned in previous studies that, for the successful deployment of emerging technologies in any field, the gap between the developers and the users must be managed (Proksch et al., 2019). Grisot et al. (2017) noted a deeper need for ‘sociotechnical sensibility’ for the smooth translation of emerging technologies into healthcare. Most health technologies are developed with minimal involvement from the healthcare practitioners. When these technologies are deployed in the health systems, the healthcare practitioners have the tendency to perceive the process of implementation of these unknown technologies as enforcement or imposition rather than an implementation process, which results in deployment blockage or resistance. Earlier researchers have highlighted that acceptance and adaptability by the professional staff can be considered to be the most important determinants of the fate of a new technology (Aryee et al., 2024; Gheorghiu & Ratchford, 2015; Wade et al., 2014). This is a crucial piece of information for healthcare policy makers, HR personnel, and technology developers for future deployment of the technology in healthcare, because there is a rise in technology development and usage for the healthcare industry since the pandemic.

One of the aims of this research was to develop and propose a framework that will assist in future technological deployment in healthcare. The model emerging from the findings was detailed in the findings section. To summarize the findings in terms of phases of adoption and human capital resource emergence, the following process has been extracted from interview data for the technology adoption in healthcare. We are proposing that the adoption of the technology in healthcare must take an organised and systematic approach. In general, healthcare providers are accustomed to following processes and clinical guidelines; therefore, the abrupt deployment of technology should be avoided. During the implementation of technology, the importance of social capital and capacity building should be maintained in healthcare. It is advantageous to consider the benefits of the overlapping tasks and interconnected work design of the healthcare system, rather than treating them as a barrier. The complex dynamics of social and welfare sectors, like healthcare, demand a systemic approach for the deployment of robots into those systems (Lappalainen, 2019).

For the optimization of the deployment of the technology in healthcare and to prevent the blockage, the following model can serve as a guide. This is a generalized model that can assist in different technological integrations into healthcare systems, similar to AI, IOT, or AR/VR. This process will encompass five (5) phases, i.e., the initial two phases are to develop an individual's co-specialization with a new technology and a co-specialized human capital, followed by three subsequent phases encompassing the teams' co-specialization with the new technology, which leads to co-specialized human capital resources and, lastly, emergence at the unit level as an outcome. During all these phases, the availability of social capital and ongoing capability building will contribute as a catalyst for change. The phases are:

1. Acquiring knowledge on new technology on an individual level;
2. Individually learning and practicing new skills to work with technology;
3. Sharing technological knowledge and skills with the team;
4. Through social interactions, adjusting communications and processes to work with new technology at the team level; and
5. Unit-wide co-specialization with the new technology of human capital resources, resulting in human capital resources emergence at a unit level.

Figure 6. Phases of Technology Adoption in Healthcare



For the healthcare industry, technologies should be developed by the real-time challenges of clinicians and must be focused on adding value and efficiency to the routine. Technology developers must consult with healthcare providers (end-users) before, during and after the development of a new technology. Technology development companies must take into account the needs of healthcare providers during the planning, designing and development of a technology. This approach will provide them with an opportunity to understand the challenges and requirements of the healthcare providers and will also facilitate the future adoptability of that technology. It became evident from this research that all the robotic surgeons adopted the new technology because they recognized that robotics added value to them and their patients and provided a competitive advantage for their organization. Hence, it can be concluded that emerging technologies will be promptly and smoothly adopted in healthcare if value is being synchronously added to healthcare providers and to patients and their families while enhancing the overall efficiency of the healthcare system.

This research highlights that adoption of technology, particularly in healthcare, is a multi-level process where all end users should be adequately and collectively trained to use the technology efficiently. Since the robot becomes an additional assistant to the existing surgical team, it is not only the robotic surgeon who needs to co-specialize with robots as a primary end user; the entire team, including nurses, anaesthesiologists, and technicians, should co-specialize because the work design has changed, and the process is new. A technology will be considered successfully implemented when the incorporation is routine and there is continued usage of that technology in an organization (Szulanski, 2000). Our research emphasizes that from the deployment of a technology in healthcare to its full implementation, a multidimensional and multidisciplinary approach should be practiced. The transition from traditional to robotic surgery involves many factors, including individual and team learning, cohesion, communication skills and adaptability to a new work design. All these factors will influence the implementation outcomes. Our research showed that the implementation of robotics in surgery and human capital resource emergence are gradual processes and the stages involved in the process of technology adoption in the surgery department, beginning with the individual level (surgeons) and progressing and evolving into the human capital resources (nurses, technicians, anaesthesiologist) and finally emerging collectively at the unit level where all members of surgical team successfully co-specialize in the robotic surgery.

An imperative gap has been highlighted in previous studies of human capital resource emergence, that when it comes to multilevel value creation, the majority of studies ignore the emergence process and provide inadequate multilevel theory (Steve WJ Kozlowski, 2019) This study addresses the gap by providing a clear understanding of the manner in which social capital theory and resource co-specialization play a role in the conversion process of individual human capital to human capital resource and to human capital resource emergence. Our research has also explicated that social capital plays a crucial role in the emergence of human capital resources. Time together helps members understand the tasks and each other's strengths and limitations, allowing them to coordinate their behaviour to achieve improved task execution (Harris & Wright 2019). While surgeons were learning robotic surgery, the presence of experienced surgeons helped them to overcome fear and enhanced their confidence. Similarly, when a surgical team was being trained to adopt the technology, social interactions and support acted as catalysts. Experienced surgeons conducted formal and informal debriefing sessions among surgeons and teams, which facilitated their adjustment to a new work style. With mutual understanding, they developed a new communication style to effectively use the technology, thus creating value. Hence, the evolution of human resource emergence for the adoption of an emerging technology in healthcare requires the availability of social capital, which will promote co-specialization.

As explained earlier, the traditional surgery system is different from that of robotic surgery. During traditional surgery, the entire team of health care providers is present in the operating room, surrounding the patient. Close face-to-face communication happens, and surgeons work simultaneously and collaboratively with the surgical team. Nurses are also present to assist in the operation by providing the required equipment. Coordination is a vital employee activity arising from human capital emergence, improving organizational performance (Harris & Wright 2019). To transform this collaboration or to enhance it for robotic procedures, capacity building and social capital are of utmost importance. While the robotic arm enhances and minimizes errors, the surgeon`s expertise is essential to operating the technical attributes of the tool and assessing its suitability for the patient and the procedure (Jonsson et al., 2019). Furthermore, the surgical team's capacity to communicate, docking instruments on the robot, using microphones for effective communication, continuously paying attention to the screen, and perhaps recording and archiving sessions must operate in conjunction with the technical functionalities and the surgeon's actions to engage in the process actively. Sociotechnical dynamics require a comprehensive and contextual understanding of human interaction and experience with machines (Riedl, 2020). Thus, understanding and managing individuals' reactions in response to technological change is necessary for successful implementation (Lennon et al., 2017).

Through this research, we wanted to develop practice recommendations recommend practice for healthcare policy makers, HR personnel, and decision makers intending to facilitate the integration of robot technology. The introduction and implementation of emerging technologies into all industries indicate certain upcoming challenges, creating the need to find redesigned and modernized human resource management approaches. Healthcare management and human resources should actively participate in the valuable and profitable integration of new technologies in healthcare. Subsequently, healthcare human resources management should develop policies, procedures, strategies, and training to achieve the maximum desired outcome and to gain value from integration of technologies conveniently and instantaneously. We observed that all the surgeons interviewed mentioned organizational support and a change-conducive culture as important elements in the successful deployment of robotics. Some of them were given a certain level of autonomy, which helped them to easily make changes in the routine and to provide training to the surgical team. It is crucial that healthcare human resources management and policy makers should create a psychologically safe culture for healthcare professionals for technology adoption because errors are prone to happen during transformations. Punitive measures must be avoided, and all failures or errors should be treated as opportunities to learn and improve. In addition, rewarding and acknowledging technology champions among healthcare professionals will motivate participation. Furthermore, the availability of experienced staff, either from internal resources or hiring externally, had a positive impact on the adoption of robotics. Healthcare human resources management should make these resources available to enrich social capital.

Hence, deployment of the robots into the healthcare systems will balance the demand and supply, prevent the loss of skilled and knowledgeable HCPs, enhance their efficiency and relieve the burnout. Overall, the findings of this doctoral dissertation support that efficient implementation of a new technology in healthcare systems is a multi-dimensional and comprehensive process, which requires training and adoptability by all the stakeholders, particularly by the healthcare providers, dealing with human capital resource emergence process through social support and ongoing capability building for co-specialization with technology. Clear understanding of Human Capital Resource Emergence can potentially fill the gap between technology and clinical practice. This multi-theory concept is the missing piece of the puzzle to mitigate the deployment blockage of technology in the healthcare systems.

LIMITATIONS AND FUTURE RESEARCH SCOPE

Emerging technologies are dynamic, fast-evolving, and fast-paced. This characteristic is one of the major limitations of the research. The agility of these technologies demands agile research, expeditious adoption, and rapid implementation. Hence, setting a realistic timeline was crucial for the successful completion of this research project. A word of caution would be to understand that the collection of primary data for this research is a limitation because, while we conducted semi-structured interviews, additional surveys or focus groups were not performed. Arranging appointments with busy and overwhelmed surgeons for the interview was very challenging during the COVID-19 pandemic situation, a time when robotic procedures were on the rise. A deeper need exists for bridging the gap in the deployment process of healthcare emerging technologies through the establishment of a systematic and organised approach that maintains a focus on both users (healthcare professionals - HCP) and receivers (patients). This will require an ongoing understanding of human capital resource emergence and a deep focus on the co-specialization of humans with machines to achieve effective and thorough outcomes in the cross-functional and intricate healthcare systems.

Additionally, the research was limited to the deployment of surgical mechanical robots, and interviews were conducted with highly skilled and qualified surgeons. There is future scope for conducting empirical research with surgeons who are working with AI-integrated robots to investigate the changing landscape of the master-slave dynamics between human and machine to explore the challenges of autonomy and liability. This research has focused on co-specialization between robots and surgical teams; however, future research can dive into the possibility of hybrid Intelligence to explore how artificial intelligence can augment and assist human intelligence for better efficiency. Also, in the future, similar research can be conducted with the involvement of more healthcare providers, including more surgical staff such as scrub nurses, junior doctors, anaesthesiologists, operation room technicians and biomedical staff to collect an account of their learning process and adjustment to technology. In addition, there is a pressing need to further study the behaviours, enablers and inhibitors that influence the acceptance of the advanced technologies.

Also, the other emerging technologies like artificial intelligence (AI) and big data, which have been introduced in the healthcare systems extensively during the last three to four years, must also be considered. Deployment of emerging technologies in different health specialties or departments should be taken into account; for example, the prevalence of artificial intelligence in radiology departments is becoming a norm, and exploration for a human capital resource emergence for the acceptance of AI in the radiology department is another arena to be explored. For instance, big data is also being introduced into the area of healthcare, which is meant to manage hospital performance and patient health records and is utilized to create and manage enormous amounts of information. It will be interesting to explore the human capital resources emergence process with the implementation of these technologies to further strengthen the evidence that HCRE is the piece of the puzzle that, if utilized, will remove the blockage of technology deployment in healthcare. The scarcity of reliable literature and its systematic contextual analysis on the topic of healthcare and human capital resource emergence indicates a fertile ground for future research. In dynamic and complex healthcare systems, it is consequential to identify and establish a theoretical framework or a process design to expedite the implementation of the emerging technologies. This is yet another research space to explore and investigate the process of new technologies' implementation.

CONCLUSIONS

This thesis has investigated the process of emergence of human capital resources with the deployment of minimally invasive robotic surgery in the healthcare setting. Concerning research objectives and based on the findings, the following conclusions are drawn:

1. Upon investigating the process of Human capital resource emergence in a healthcare surgery department for co-specialization of surgical team with robotics, we conclude that the process of HCRE is a bottom-up phenomenon. Implementation of technology in the surgery department results in chaos and disruption to the routine, which activates enabling states for HCRE. Technology deployment in complex healthcare systems will keep facing dissolution, apprehension, and deployment blockage unless the focus shifts to the humans of healthcare, who must collectively adopt that technology using careful planning and execution. This implementation is a bottom-up strategy, whereby the full realization of the technology`s potential is contingent upon alignment with healthcare professionals' expectations, adaptability and adoptability, all of which require the HCRE process to happen. The deployment of technology in healthcare should be considered a system-wide, holistic change, simultaneously affecting many departments and healthcare providers. Hence, training one team member or main user of the technology is not helpful. It is the whole team and all impacted departments that should be trained for the successful and fruitful deployment of the technology. Implementation of the technology in healthcare demands a systematic, structured, and methodological approach and will certainly require human capital resources emergence due to a multidisciplinary approach and highly integrated networks for patient care. A thorough training program for the entire surgery team, including the surgeon, will ensure acceptance of and adjustment to the technology. Healthcare human capital greatly needs capability-building for co-specialization in relevance to the emerging technologies, and this should be achieved gradually and systematically with HCRE multilevel theory approach rather than abruptly. In the past, training surgeons only for robotic surgery didn’t produce desirable outcomes, and, as per the findings of this research, surgeons themselves understand the need for training the whole surgical team in the use of new technology. It was only after fully developing the capability of the surgical team that outcomes of the robotic

surgery started to improve, and the confidence of society was built into this new technology. Deployment of robots in the surgery department starts with the surgeon but completes and becomes successful with the full alignment of the whole surgical team. During this process of emergence, a multi-theory approach should be practiced, which includes roles of social capital, capability building, and resource co-specialization.

2. Analysis of the literature on human capital (HC) theory, human capital resource (HCR), human capital resources emergence (HCRE), and our investigation of this process in a healthcare setting has led us to the conclusion that these three phenomena are related and occur in a sequential fashion. Since human capital theory is the foundation upon which human capital resource and human capital resource emergence are created, we argue that these ideas should be seen as interrelated. The figure 6 above in the discussion section, we have presented this theoretical contribution. We conclude that successful pairing of technologies in healthcare is not possible without the emergence of human capital resources. This social phenomenon plays a vital role in the adoption, adaptation, and integration of emerging technologies into existing systems for the existing human capital and is required for updating their current knowledge, skills, and attributes for future tasks and responsibilities.

   Our findings of this qualitative research have clarified that HCRE occurs among the 'Specific' human capital. Surgery team is a specific human capital in a hospital, skilled to perform surgical procedures in different specialities for different diseases and conditions. We suggest that for HCR to emerge into a new form, specific or specialised human capital is required. Because emergence requires disruption in routines, and when this chaos happens for specific human capital, then a synergetic motivation is activated for the adjustment to the new demands, and the result is human capital resource emergence (HCRE). When specific human capital becomes a 'new whole' through the emergence process, then this must remain together to maintain this new level of expertise.

3. According to our empirical study, we developed a model that emerged which is presented in the Figure 4 in the findings section, demonstrating the multilevel theory approach essential to the HCRE process. With the aggregation and scrutiny of the interview data, the model highlights the interplay of multiple theories, i.e., social capital, resource co-specialization, capability building, along

with the HCRE theory, beginning at the individual level human capital, demonstrating emergence of human capital resources and concluding on successful symbiosis of surgery team and robot.

In addition to this model, we have developed a framework (Figure 6) for the deployment and successful implementation of technologies in healthcare. This framework provides a methodical and systematic approach by organising and outlining factors and their interrelationships, which sequentially demonstrate the process of conversion and emergence of individual human capital into unit-level resource. This framework can serve as a guide for healthcare industry decision makers and technology developers for efficient integration of emerging technologies in healthcare and to mitigate the deployment blockage.

4. Based on our research, we suggest to healthcare policy makers, HR personnels and Tech developers that technology used in healthcare should be developed and implemented to boost the efficiency of health care providers, improve clinical outcomes for the patients, and create creation for health organizations. We all need healthcare, and healthcare need technology integration to become efficient, resilient and sustainable. However, it is essential to identify potential advantages, risk and vulnerabilities in addition to required resources, like the infrastructure, processes and human capital. To ensure that healthcare providers successfully accept and integrate the new technology, compatibility with old systems should also be considered. It's critical to fully understand organizational goals, evaluate technological needs, and have a plan for training the staff. This change is inevitable and demands prompt attention and timely actions. Deployment of technology in healthcare smoothly and successfully demands that the HCRE process evolve. This evolution of HCRE requires continuous capacity-building for new technology with ongoing social interactions among the members of the unit where psychological safety is provided to adapt to the change, overcoming the chaos or disturbance to emerge as an improved ‘whole’. We have developed a model/framework, which can serve as a guide for the integration of technology in future for both technology developers, healthcare management and decision makers. Following these guidelines, healthcare organizations can minimize failure risk, ensure a smooth deployment process, and optimize the advantages of new technology for both patients and health care providers.

In summary, we conclude that deployment of the technologies into the healthcare systems will balance the demand and supply, prevent the loss of skilled and knowledgeable HCPs, enhance their efficiency, which will reduce the cost in the long term. Overall, the findings of this doctoral dissertation support the conclusion that efficient deployment of a new technology in healthcare systems is a multi-dimensional and comprehensive process, which requires training and adoptability by all the stakeholders, particularly by the healthcare providers (frontliners), dealing with human capital resource emergence process through social support and ongoing capability building for co-specialization with technology, filling the gap between technology and clinical practice. We have developed a model and a framework, which can serve as a guide for the integration of technology in the future for both technology developers and healthcare decision makers.

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ISM VADYBOS IR EKONOMIKOS UNIVERSITETAS

Wardah Qureshi

ŽMOGIŠKOJO KAPITALO IŠTEKLIŲ FORMAVIMASIS ROBOTIKA PAREMTŲ CHIRURGINIŲ SISTEMŲ DIEGIMUI SVEIKATOS PRIEŽIŪROS ORGANIZACIJOSE

Daktaro disertacijos santrauka

Socialiniai mokslai, vadyba, (S 003)

Vilnius, 2025

Disertacija rengta 2019–2025 m. ISM Vadybos ir ekonomikos universitete pagal ISM Vadybos ir ekonomikos universitetui suteiktą doktorantūros teisę (kartu su Aarhus universitetu [Danija], BI Norvegijos verslo mokykla [Norvegija] ir Tartu universitetu [Estija]).

Mokslinis vadovas: Prof. dr. Ilona Bučiūnienė (ISM Vadybos ir ekonomikos universitetas, socialiniai mokslai, vadyba, S 003)

Daktaro disertacija ginama ISM Vadybos ir ekonomikos universitete, Vadybos mokslo krypties taryboje:

Pirmininkas:
Prof. dr. Raimonda Alonderienė (ISM Vadybos ir ekonomikos universitetas, socialiniai mokslai, vadyba, S 003)

Nariai:
Doc. dr. Jannis Angelis (KTH Karališkasis technologijos institutas, Švedija, socialiniai mokslai, vadyba – S 003)
Prof. dr. Aurelija Blaževičienė (Lietuvos sveikatos mokslų universitetas, medicinos ir sveikatos mokslai, slauga – M 005)
Prof. dr. Virginija Poškutė (ISM Vadybos ir ekonomikos universitetas, socialiniai mokslai, ekonomika – S 004)
Prof. dr. Vida Škudienė (ISM Vadybos ir ekonomikos universitetas, socialiniai mokslai, vadyba – S 003)

Daktaro disertacija bus ginama viešame Vadybos mokslo krypties tarybos posėdyje 2025 m. rugsėjo 10 d., 11:00 val. 210 a., ISM Vadybos ir ekonomikos universitete, Gedimino pr. 7, Vilniuje, Lietuvoje.

Daktaro disertacijos santrauka išsiųsta 2025 m. rugpjūčio 10 d. Disertaciją galima peržiūrėti Lietuvos nacionalinėje Martyno Mažvydo ir ISM Vadybos ir ekonomikos universiteto bibliotekose.

ĮVADAS

„Technologijos yra veiksmingiausios, kai jos suartina žmones“ (Mullenweg, 2021)

Sveikatos priežiūros sektorius yra vienas didžiausių ir sparčiausiai augančių pasaulyje (Ortega ir kt., 2020; Roy ir kt., 2022). Sveikatos priežiūros sektoriuje dirba penkių skirtingų kartų darbuotojai, pradedant „kūdikių bumo“ kartos atstovais. Kiekviena karta pasižymi skirtingais darbo ir mokymosi stiliais, o tai dar labiau padidina šio sektoriaus išskirtinumą (Teunissen ir kt., 2020). Pasak Pasaulio sveikatos organizacijos (PSO), „sveikatos sistema apima visas organizacijas, asmenis ir veiklas, kurių pagrindinis tikslas yra sveikatos gerinimas, atstatymas ir palaikymas“ (PSO, 2017). Vertės kūrimas visuomenei yra esminis sveikatos sistemų elementas (Roppelt ir kt., 2024). Sveikatos priežiūros paslaugas teikiančių organizacijų paklausa visada buvo labai didelė (Starfield, 2000); šiuo metu ši paklausa yra didesnė nei bet kada anksčiau, ir šis procesas vyksta visame pasaulyje (Schurmann ir kt., 2025).

Siekiant patenkinti šį nuolatinį ir didėjantį poreikį teikti aukštos kokybės sveikatos priežiūros paslaugas, būtina atsižvelgti į skubų poreikį diegti technologijas sveikatos priežiūros srityje. Maskuriy ir kt. (2019) paaiškino, kad „Pramonė 4.0”, apimanti robotiką, dirbtinį intelektą (DI), daiktų internetą (IoT), debesų kompiuteriją, didelius duomenis, imersines technologijas (AR/VR) ir mašininį mokymąsi (MM), yra visiškai nauja filosofija, lemianti socialinius pokyčius visose gyvenimo srityse, tokiose kaip saugumas, švietimas, mokslas, darbo rinka ir gerovės sistemos. Kaip ir kitos pramonės šakos, sveikatos priežiūros sektoriuje vyksta permainos, nes jame yra integruojami nauji technologiniai sprendimai, kurie padeda mažinti išlaidas, gerinti veiklos rezultatus ir spręsti sveikatos priežiūros paslaugų teikėjų trūkumo problemą. Tačiau diegiant technologijas susiduriama su kliūtimis (Bienefeld ir kt., 2025; Lee ir Yoon, 2021; Thacharodi ir kt., 2024).

Žmogiškojo kapitalo išteklių formavimasis vadybos literatūroje yra palyginti nauja, nepakankamai ištirta tema (Jun ir kt., 2024 m.), ypač sveikatos priežiūros organizacijų kontekst. Pagal mikrofondų dienotvarkę, žmogiškojo kapitalo išteklių formavimasis yra būtinas norint suprasti, kaip žmogiškasis kapitalas integruojamas siekiant sukurti vertingus vieneto lygio išteklius, kur žmogiškasis kapitalas duoda rezultatų, kurie viršija tai, ką galima paaiškinti atskirų jo komponentų suma (Steve WJ

Kozlowski, 2019)

Per pastaruosius septyniasdešimt metų žmogiškojo kapitalo teorija vystėsi įvairiais aspektais (Goldin ir Katz, 2024). Žmogiškasis kapitalas buvo plačiai aptariamas literatūroje – pradedant ekonomistų požiūriu į ekonominę naudą ir baigiant organizaciniu tvarumu (Becker, 1962; Nyberg ir kt., 2018). Pasak Ray, Essman ir kt. (2023), žmogiškojo kapitalo teorija yra individualaus lygio paradigma. Ji buvo nepakankama siekiant paaiškinti skirtumus tarp įvairių lygių. Dėl to šioje seniai egzistuojančioje disciplinoje atsirado modernus komponentas – žmogiškojo kapitalo ištekliai (Ployhart ir kt., 2014). Įdomu tai, kad nėra pakankamai įrodymų apie žmogiškojo kapitalo išteklių kūrimą ir trūksta aiškaus supratimo apie daugiapakopio vertės kūrimo mechanizmą vieneto lygiu (Ray, Nyberg ir kt., 2023).

Žmogiškojo kapitalo išteklių formavimosi tyrimai, sutelkti į daugelio individų sąveiką, per pastaruosius dvidešimt metų atvedė į naują socialinių procesų tyrimo erą (Harris ir kt., 2018). Dabartinėje literatūroje šis reiškinys apibūdinamas bendrai ir neaiškiai, kaip individualaus žmogiškojo kapitalo transformavimasis į vieneto lygio žmogiškojo kapitalo išteklius, o pats procesas yra neaiškus (Jun ir kt., 2024). Kaip paaiškino Felin ir kt. (2015, 606 p.), „apskritai „formavimosi“ sąvoka lieka neaiški. Todėl tiek mikro-disciplinose, tiek ir makro-disciplinose yra galimybė atidžiai apibrėžti pagrindinius veikėjus, socialinius mechanizmus, sujungimo formas ir sąveiką, kurie lemia atsirandančius rezultatus“. Ployhart ir Moliterno (2011) teigia, kad norint suprasti, *kaip, kodėl ir kada* ŽKI formuojasi iš žmogiškojo kapitalo, būtinas daugiapakopis požiūris, apimantis formavimosi procesą.

Sveikatos priežiūros sistemos yra sudėtingos (Tulchinsky ir Varavikova, 2014). Daugiadisciplinis požiūris į sveikatos priežiūrą rodo, kad turėtų būti sujungti individualūs gebėjimai, o technologijų diegimas turėtų būti laikomas visų su priežiūros teikimu susijusių dalyvių kolektyviniu veiksmu. Literatūros šaltiniai yra nepakankami, kad būtų galima visapusiškai suprasti žmogiškojo kapitalo išteklių formavimosi procesą, kai individualaus lygio žmogiškasis kapitalas (žinios, įgūdžiai, savybės ir kitos savybės – ŽĮSKS) transformuojamas į vieneto lygio išteklius, todėl būtina tirti šį reiškinį (Eckardt ir kt., 2021), ypač sveikatos priežiūros srityje. Nors sveikatos priežiūros srityje diegiamos naujos technologijos, tačiau toliau turėtų būti vertinamos ir analizuojamos jų teikiamos galimybės, pavyzdžiui, darbo našumo didinimas, pacientų patirties gerinimas ir sveikatos priežiūros paslaugų teikėjų perdegimo mažinimas, kadangi sveikatos priežiūros specialistai yra taip pat suinteresuoti technologijų diegimu, jei tik jos turi teigiamą poveikį pacientų klinikiniams rezultatams ir palengvina specialistų kasdienes užduotis.

COVID-19 pandemija ne tik turėjo baisių padarinių žmonėms ir visuomenei, bet ir padidino poreikį integruoti technologinius sprendimus į sveikatos priežiūrą greičiau nei bet kada (Clipper, 2020; Okolo it kt., 2024). Atsižvelgdamos į šį didėjantį technologijų poreikį sveikatos priežiūros srityje, pastaruoju metu į sveikatos priežiūros sektorių linksta tokios technologijų milžinės kaip „Apple“, „Microsoft“, „Google“, „IBM“ ir „Oracle“, siekdamos didelės investicijų grąžos (ROI) ateityje (Juttukonda, 2024; Rikap, 2022). Tačiau technologijų diegimas sveikatos priežiūros srityje susiduria su kliūtimis dėl to, kad trūksta visuotinių sistemų ir sistemingo požiūrio į sveikatos priežiūrą (Reddy, 2024). Sveikatos priežiūra yra unikali ir glaudžiai tarpusavyje susijusių elementų sritis, kurioje aukštos kvalifikacijos, kultūriškai įvairiapusiški asmenys glaudžiai bendradarbiauja tarpdisciplininėse komandose, siekdami užtikrinti saugią pacientų priežiūrą (Uman ir kt., 2022). Sudėtingos sveikatos priežiūros sistemos apima labai įvairius dalyvius, kurie turi nevienodas žinias, įgūdžius ir įgaliojimus (Grol ir Wensing, 2013). Kuo sistema yra sudėtingesnė ir dinamiškesnė, tuo didesnis poreikis taikyti sisteminį požiūrį diegiant technologijas į tas sistemas (Lappalainen, 2019). Kaip ir kitose pramonės šakose ir sektoriuose, sveikatos priežiūros srityje taip pat kyla kliūčių technologijų diegimui. Tačiau dėl tarpdisciplininio požiūrio ir žmogaus gyvybės svarbos, sveikatos priežiūros sektoriuje vyraujanti painiava pasiekia kritinę ribą.

Per pastaruosius tris dešimtmečius technologijų plėtra buvo pripažinta ne tik kaip vertės kūrimo šaltinis daugelyje pramonės šakų, bet ir kaip pelningumo šaltinis (Blichfeldt ir Faullant, 2021). Kalbant apie sistemingą ir sudėtingą technologijų diegimą tokioje painioje sistemoje kaip sveikatos priežiūra, Ployhart ir Moliterno (2011) pabrėžė, kad siekiant prisitaikyti, yra būtina koordinuoti sudėtingas užduotis ir bendro konteksto žmogiškojo kapitalo išteklius. Šios užduotys grindžiamos bendraisiais pažinimo gebėjimais, asmenybe, vertybėmis ir interesais. Tai yra aktyvios konkretaus konteksto žmogiškojo kapitalo išteklių kūrimo sudedamosios dalys. Pasak Beane ir Orlikowski (2015), nauja technologija sveikatos priežiūros sistemoje (robotų diegimas ar galimybė atlikti chirurgines procedūras nuotoliniu būdu)
turėtų būti priimta kaip naujos praktikos įgyvendinimo per institucionalizavimą galimybė, kad būtų galima ją integruoti į sudėtingą ir dinamišką darbą ligoninėje, kur

viso užduotys yra aiškiai paskirstytos. Tačiau gairės, užtikrinančios duomenų saugumą ir pacientų privatumą, turi būti suderintos su sėkmingu technologijų diegimu ir sklaida (Liu ir Miguel-Cruz, 2022).

Pastaruoju metu medicinos ir akademiniuose tyrimuose plačiai ir išsamiai diskutuojama apie naujų technologijų privalumus (Galbusera ir kt., 2019), ypač po COVID-19 pandemijos (Junaid ir kt., 2022; Krishnamoorthy ir kt., 2021; Licardo ir kt., 2024; Olalekan Kehinde, 2025), pabrėžiant šių technologijų naudojimo svarbą gerinant sveikatos priežiūros sistemos efektyvumą. Tačiau vartotojų (gydytojų ir pacientų) imlumas vis dar yra nepakankamai ištirtas (AlQudah ir kt., 2021; Lee ir kt., 2025; Rudawska ir kt., 2024; Tekkesin, 2019). Rudawska ir kt. (2024) teigia, kad papildomai ir geriau naudojant naujas technologijas, galima greitai pastebėti netikslumus ir išspręsti problemas dinamiškoje sveikatos priežiūros sistemoje. Ir tai bus ekonomiškai efektyvu.

Bamel ir kt. (2023) teigia, kad poreikis ištirti veiksnius, kurie palengvina naujų ir transformacinių technologijų diegimą yra neatidėliotinas. Sėkmingas naujų technologijų diegimas ir integravimas bet kurioje srityje yra įmanomas, jei įveikiamas atotrūkis tarp kūrėjų ir vartotojų (Proksch ir kt., 2019). Daugelis tyrėjų patvirtino, kad technologijų plėtra dažnai kelia iššūkį dėl prasto vertės suderinamumo tarp pasiūlos ir paklausos (Greenhalgh ir kt., 2018; Lehoux ir kt., 2017; Markiewicz ir kt., 2014). Svarbu pažymėti, kad sveikatos priežiūros specialistų ir technologijų kūrėjų požiūris į darbą skiriasi ir trukdo rasti sprendimus kylančioms medicinos problemoms spręsti ir diegiant naujas technologijas (Anwar ir Prasad, 2018). Gydytojai ir slaugytojai yra sveikatos priežiūros priešakinėse linijose. Technologijų diegimo sėkmė priklauso nuo jų įsisavinimo lygio. Efektyviai panaudojant šiuos žmogiškuosius išteklius sveikatos priežiūros srityje, galima sklandžiau įgyvendinti pažangiausių technologijų diegimo iniciatyvas (Prajogo ir Oke, 2016) ir užtikrinti tvarią plėtrą ateityje (Cavicchi, 2017). Norint įveikti naujų technologijų diegimo iššūkius, reikės eksperimentuoti, vesti dialogą ir nuolat stebėti pokyčius (Schartinger ir kt., 2015). Todėl labai svarbu, kad kuriant ir diegiant sveikatos priežiūros technologijas kaip suinteresuotosios šalys tiesiogiai dalyvautų sveikatos priežiūros specialistai (Anwar ir Prasad, 2018; Heijsters ir kt., 2022). Kadangi naujos technologijos likimas gali priklausyti nuo vienų svarbiausių veiksnių - nuo to, kaip darbuotojai specialistai priima technologijas ir kaip jie prisitaiko prie jų (Aryee ir kt., 2024; Gheorghiu ir Ratchford, 2015; Wade ir kt., 2014).

Apskritai, diegiant naujas technologijas yra reikalingas holistinis požiūris, atsižvelgiant į visus procesus, veikėjus ir veiksnius. Sveikatos priežiūros sektorius yra ta sritis, kurioje yra ypatingai svarbu šiuo metu paruošti žmogiškąjį kapitalą, t. y. sveikatos priežiūros specialistus, kad jie galėtų prisitaikyti prie būsimų naujų technologijų ir jų poveikio. Tai įmanoma per tinkamus mokymus, taip pat teikiant socialinę, techninę ir intelektinę paramą. Nepakankamas technologijų diegimas arba ribotas diegimas be sistemingo požiūrio ar sistemos nesuteiks laukiamos naudos ir rezultatų sveikatos priežiūros srityje. Šiuo metu sveikatos priežiūros sektoriuje yra kuriama ir naudojama daugybė technologijų, tačiau akivaizdžiai trūksta modelio ir sistemos, kaip šias naujas technologijas integruoti į sudėtingas sveikatos priežiūros sistemas.

Šioje disertacijoje atsižvelgta į tai, kad svarbu ir būtina sveikatos priežiūros įstaigoje (chirurgijos skyriuje) mikro-lygmeniu stiprinti žmogiškojo kapitalo išteklius ir gebėjimus, kad chirurgai ir chirurginės komandos gebėtų atlikti minimaliai invazines robotika paremtas operacijas. Buvo tiriamas naujų įgūdžių formavimasis ir chirurgijos komandos darbo organizavimas skyrių lygmeniu po chirurginių robotų įdiegimo. Tai lemia sėkmingą technologijų integraciją ir žmogiškųjų išteklių tarp chirurgų ir chirurgijos komandų formavimąsi, kad būtų galima saugiai ir sėkmingai atlikti operacijas, kurių metu yra naudojami robotai, teikiant pirmenybę pacientų saugumui ir klinikiniam produktyvumui. Buvo sukurtas modelis, kuris sistemingai padės sėkmingai integruoti technologijas į sveikatos priežiūros sistemą ateityje. Šiam tyrimui buvo pasirinktas chirurgijos skyrius, nes per pastaruosius tris dešimtmečius chirurginis robotas tapo plačiausiai pripažinta technologija sveikatos priežiūros srityje (De Ravin ir kt., 2023; Ginoya ir kt., 2021).

Sveikatos priežiūros sektoriuje reikia ugdymo žmogiškojo kapitalo gebėjimus, kad šio sektoriaus darbuotojai galėtų bendrai specializuotis naujų technologijų srityje.. Šis pokytis neišvengiamas ir būtina jam skubiai skirti dėmesį. Kadangi trūksta patikimos literatūros apie sveikatos priežiūros žmogiškųjų išteklių kapitalo formavimąsi ir žmogaus bei roboto bendrą specializaciją, o taip pat trūksta tokios literatūros sisteminės kontekstinės analizės, ateityje šioje srityje galima tikėtis naujų tyrimų. Svarbu nustatyti, ar reikia sukurti teorinį pagrindą arba proceso modelį, siekiant paspartinti vertingą naujų technologijų diegimą dinamiškoje, tačiau sudėtingoje sveikatos priežiūros sistemoje. Sveikatos priežiūros sektoriuje dar iki pandemijos pradžios buvo aktyviai diegiamos naujos technologijos, o dabar, po

COVID-19 pandemijos, ši būtinybė dar labiau išaugo (Schurmann ir kt., 2025). Sveikatos priežiūros specialistai taip pat pripažįsta technologijų diegimo būtinybę (Yousif ir kt., 2024). Technologijų įmonės lygiagrečiai investuoja pinigus ir išteklius į naujų technologinių sprendimų sveikatos priežiūros srityje kūrimą (Juttukonda, 2024).

Naujų technologijų poreikio užtikrinimui yra reikalingas pereinamasis modelis, atsižvelgiant į visų suinteresuotųjų šalių interesus ir perspektyvas. Siekiant sėkmingai ir pelningai diegti naujas technologijas (pavyzdžiui, robotus) sveikatos priežiūros sistemose, labai svarbu, kad jas galėtų pritaikyti visi dalyviai. Nepaisant to, yra būtina toliau tirti elgesį, veiksnius ir trukdžius, kurie įtakoja pažangių technologijų priėmimą. Yra gilesnis poreikis užpildyti diegimo proceso spragas, sukuriant sistemingą ir organizuotą metodą, orientuotą į vartotojus (sveikatos priežiūros specialistus) ir paslaugos gavėjus (pacientus). Siekiant veiksmingų ir išsamių rezultatų interfunkcinėse ir sudėtingose sveikatos priežiūros sistemose, būtina suprasti žmogiškųjų išteklių formavimąsi ir didelį dėmesį skirti žmonių ir mašinų tarpusavio specializacijai.

Vyraujantys iššūkiai sveikatos priežiūros sektoriuje. Sveikatos priežiūros sektoriuje jau susiduriama su daugybe vyraujančių ir gilėjančių iššūkių (Yakubu ir kt., 2022). Pasauliniu mastu dauguma sveikatos priežiūros įstaigų susiduria su panašiomis problemomis ar iššūkiais (Roppelt ir kt., 2024; Tortorella ir kt., 2020). Technologijų naudojimas teikiant priežiūros paslaugas gali būti esminis sprendimas šiems iššūkiams įveikti. Toliau aptariami aktualiausi sveikatos priežiūros sektoriaus klausimai, kuriuos reikia spręsti nedelsiant, o technologijų diegimas gali žymiai palengvinti gilėjančias problemas.

(a) Lėtinių ligų plitimas. Augant gyventojų skaičiui ir dažnėjant sveikatos problemoms bei ligų atvejams, pasekmės darosi dar sudėtingesnės (Guntur ir kt., 2019). Cukrinis diabetas, vėžys, širdies ir kraujagyslių bei kvėpavimo takų ligos yra lėtinės ir reikalauja nuolatinės kontrolės (Meetoo, 2008). Lėtinėmis ligomis sergančių žmonių skaičius nuolat auga, todėl auga ir spaudimas sveikatos priežiūros sistemoms bei poreikis turėti daugiau kvalifikuotų sveikatos priežiūros specialistų, kurie galėtų prižiūrėti gyventojus (Claessens ir kt., 2024). 2010 metais lėtinės ligos lėmė 67 proc. mirčių visame pasaulyje, o 2019 m. jų mastas išaugo iki 74 proc., ir toliau augo per COVID-19 pandemiją (Thomas ir kt., 2021). Situacija darosi dar sudėtingesnė dėl augančio gyventojų skaičiaus, ilgėjančios vidutinės gyvenimo trukmės, sveikatos problemų bei ligų dažnėjimo esant gydytojų trūkumui (Guntur ir kt., 2019; Lanza ir kt., 2020).

(b) **COVID-19 pandemija.** 2020 m. sausio 30 d. Pasaulio sveikatos organizacija (PSO) paskelbė COVID-19 „tarptautinės svarbos ekstremalia situacija“ (PSO, 2020). Pasaulinės sveikatos priežiūros sistemos buvo nepakankamai pasirengusios susidūrimui su netikėta COVID-19 pandemijos sukelta sumaištimi (Deer ir kt., 2020). Tai ne tik sukėlė nepaprastąją padėtį visame pasaulyje, bet ir chaosą vyriausybių, gydytojų ir pacientų tarpe. 2020 m. kovo 11 d. Pasaulio sveikatos organizacija (PSO) paskelbė COVID-19 pandemiją (PSO, 2020). Ši visuomenės sveikatos nepaprastoji padėtis buvo atšaukta 2023 m. gegužės 11 d. (PSO, 2023). Vos per trejus metus COVID-19 pandemija smarkiai paveikė sveikatos priežiūros sektorių, sukeldama daug rūpesčių pasaulio ekonomikai. Pandemija ne tik smarkiai pakenkė finansiniam stabilumui. Ji taip stipriai fiziškai ir psichologiškai paveikė sveikatos priežiūros specialistus. Dėl pandemijos padidėjo ligų keliama našta, išaugo sveikatos priežiūros specialistų trūkumas ir išryškėjo grėsmė sveikatos priežiūros sektoriui (Coccia ir Benati, 2024; Kaye ir kt., 2021; Liu ir kt., 2022; Wang ir kt., 2020).

(c) **Gydytojų ir chirurgų trūkumas**. Tai yra vyraujanti, auganti ir esminė problema, kelianti grėsmę sveikatos priežiūros sektoriui (Harp, 2022; Heponiemi ir kt., 2019; Michaeli ir kt., 2024; Scannell ir kt., 2021; Sheldon, 2011; Stephens, 2025; Williams ir Ellison, 2008; Yakubu ir kt., 2022). Pasekmes dar labiau apsunkina augantis gyventojų skaičius ir sveikatos problemų bei ligų padaugėjimas (Guntur ir kt., 2019). Manoma, kad iki 2050 m. 22 proc. pasaulio gyventojų bus sulaukę šešiasdešimt penkerių metų amžiaus ar bus vyresni (Di Nuovo ir kt., 2016). Prognozuojama, kad iki 2030 m. gydytojų trūkumas dar labiau išaugs (Zhang ir kt., 2020). Pandemijos metu šis trūkumas dar labiau išaugo ir tampa vis rimtesne pasauline problema (Abdel-Razig ir Stoller, 2025 m.; Krasna ir kt., 2021; Mbunge ir kt., 2022; Riaz ir kt., 2021). 2022 m. „Colaborators” atliko išsamią analizę apie gydytojų migraciją per pastaruosius keturiasdešimt metų iš mažas pajamas turinčių šalių į didesnes pajamas turinčias šalis. Jie pabrėžė, kad ši migracija paspartėjo po pandemijos ir sukėlė skirtumus bei nelygybę. „Pasaulinės ligų naštos” tyrime prognozuojama, kad pasaulyje trūksta

6,4 mln. gydytojų („Colaborators”, 2022). Chirurgų trūkumas jaučiamas tiek miestuose, tiek ir kaimo vietovėse. Tačiau kaimo vietovėse jis yra didesnis (Khoury Stephanie, 2022; Stringer ir kt., 2020). Dėl patiriamo streso, ilgų darbo valandų ir procedūrų metu patiriamų nepatogumų daugelio specialybių chirurgai anksti išeina į pensiją. Todėl esamas trūkumas dar labiau didėja (Jella ir kt., 2023; Mahoney ir kt., 2020; Morton ir Stewart, 2022; Soriano ir kt., 2022). Pasaulio sveikatos organizacija atskleidė disproporciją tarp dabartinio ir ateityje reikalingo sveikatos priežiūros darbuotojų skaičiaus, numatydama, kad iki 2030 m. visame pasaulyje trūks aštuoniolikos milijonų sveikatos priežiūros paslaugų teikėjų, kurie yra reikalingi siekiant tvaraus sveikatos priežiūros vystymosi tikslų, ir paragino skirti daugiau dėmesio sveikatos priežiūros specialistų skaitmeniniam švietimui (PSO, 2020). Dėl kvalifikuotų sveikatos priežiūros darbuotojų trūkumo visame pasaulyje sveikatos priežiūros ištekliai gali būti padidinti diegiant naujas technologijas (Zimlichman ir kt., 2021).

(d) Sveikatos priežiūros specialistų perdegimas. Freudenberger (1989) nustatė, kad perdegimas yra emocinis ir elgesio sutrikimas, kuriam būdingas protinis nuovargis, depersonalizacija ir menkesnis pasitenkinimas asmeniniais pasiekimais. Profesinis perdegimas paprastai reiškia nuolatinį stresą, kuris trukdo asmeniui atlikti profesines pareigas sudėtingomis aplinkybėmis. (Chetlen ir kt., 2019). Perdegimas plačiai paplitęs sveikatos priežiūros specialistų tarpe, tai gydytojams būdingiausias sveikatos sutrikimas visame pasaulyje (Sequeira ir Aish, 2023; Shanafelt ir kt., 2015; Van Mol ir kt., 2015.; Zambrano-Chumo ir Guevara, 2024). Sveikatos priežiūros srityje darbo sąlygos yra įtemptos. Čia gydytojai yra nuolat priversti klausytis nusiskundimų dėl sveikatos, priimti kritiškai svarbius sprendimus ir iš esmės spręsti dėl savo pacientų gydymo planų, esant nuolatiniam resursų trūkumui. Prislėgtumo jausmas dirbant sudėtingą darbą emociškai sekina sveikatos priežiūros specialistus (Batanda, 2024). Emocinis perdegimas prisideda prie protinių sunkumų, su kuriais susiduria chirurgai. Dėl to jie daro profesines klaidas (Chahal ir Matwala, 2025). Pedegimo pasekmės tai klinikinės klaidos, pacientų nepasitenkinimas, sveikatos priežiūros įstaigos patiriami finansiniai nuostoliai ir reputacijos praradimas (Hodkinson ir kt., 2022; Lee ir kt., 2024).

Dabartinė situacija tyrimų srityje ir išliekančios spragos. Žmogiškasis kapitalas (ŽK) apibrėžiamas kaip asmens žinios, įgūdžiai, gebėjimai, patirtis ir kitos savybės, kurias galima panaudoti norimam rezultatui pasiekti (Ployhart ir Moliterno, 2011). Žmogiškojo kapitalo ištekliai yra individualūs arba vieneto lygio gebėjimai, pagrįsti individualiomis žiniomis, įgūdžiais, gebėjimais ir kitomis savybėmis (ŽĮGKS), kurie yra prieinami vienetui svarbiems tikslams pasiekti (Ployhart ir Hale, 2014). Žmogiškojo kapitalo išteklių (ŽKI) svarba yra visuotinai pripažinta vadybos tyrimais, tačiau literatūroje nėra pakankamai įrodymų apie žmogiškojo kapitalo išteklių formavimosi procesą (Jun ir kt., 2024). Žmogiškojo kapitalo išteklių formavimasis (ŽKIF) tai situacija, kai žmonių grupė kartu su visais savo atitinkamais žmogiškaisiais ištekliais kolektyviškai tampa žmogiškųjų išteklių vieneto lygio struktūra (Ployhart ir Moliterno, 2011). Nors per pastaruosius kelerius metus buvo surinkta įrodymų, kad žmogiškojo kapitalo išteklių formavimosi tyrimai yra vis dažnesni, tyrimų vis dar trūksta (Eckardt ir kt., 2021; Ray, Essman ir kt., 2023). Žmogiškojo kapitalo išteklių formavimasis bendrai yra ankstyvoje tyrinėjimo stadijoje. Jis yra nepakankamai ištirtas, ypač sveikatos priežiūros srityje. Reikia akcentuoti, kad technologijų diegimo proceso kontekste jis apskritai yra nepakankamas, ypač sveikatos priežiūros srityje. Literatūros, leidžiančios suprasti ir visapusiškai suvokti procesą, kai individualaus lygio ŽĮGKS transformuojasi į vieneto lygio išteklius, yra nedaug. Būtina neatidėliotinai ištirti šį reiškinį (Eckardt ir kt., 2021).

Visuotinis įprastų technologijų plitimas buvo susijęs su ankstyvąja COVID-19 pandemijos faze 2020 metais. Technologinė transformacija didina organizacijos lankstumą ir galiausiai sustiprina jos konkurencingumą (Chatterjee ir Mariani, 2022). Vis dažniau pastebima, kad naujos technologijos, tokios kaip robotika, dirbtinis intelektas (DI), didieji duomenys, yra lanksčiausi ir pažangiausi ištekliai sveikatos priežiūros srities tobulinimui (Junaid ir kt., 2022). Šios technologijos gali pagerinti sveikatos priežiūros kokybę ir efektyvumą, taip pat stipriai įtakoti išlaidas (Zemmar ir kt. 2020). Šie metodai gali padėti patikimai užtikrinti prevencinę priežiūrą, kuri iš esmės pakeistų sveikatos priežiūros organizacijas ir teigiamai įtakoti visuomenės sveikatos rezultatus (Thacharodi ir kt., 2024). Nepaisant to, technologijų diegimas sveikatos priežiūros srityje buvo stabdomas. Ši problema stiprėja, nes padidėjo naujų technologijų naudojimo paklausa, o šis su sveikatos priežiūra susijęs klausimas liko nepakankamai išanalizuotas. Tam trūksta praktinių, holistinių ir prieinamų sistemų (Cresswell ir kt., 2020).

Šiandienos naujai besiformuojančios technologijos formuos būsimo pasaulio ateitį. Būtina jas laiku pritaikyti (Adler ir kt., 2016 m.; Licardo ir kt., 2024). Dirbtiniu intelektu, robotika, didžiaisiais duomenimis ir daiktų internetu (DI) paremta automatizacija yra šių dienų realybė. Kadangi manoma, kad naujos technologijos didina darbo efektyvumą ir gyvenimo kokybę (Iizuka ir Ikeda, 2019), naujų technologijų diegimas turi tiesioginį poveikį tiek darbuotojams, tiek ir organizacijoms (Sima ir kt., 2020). Šie iššūkiai neapsiriboja naujų technologijų kūrimu ir tobulinimu. Jie dažnesni, kai yra kalbama apie šių technologijų pritaikomumą ir sėkmingą diegimą esamose sistemose. Sudėtinga socialinių ir gerovės sektorių, pavyzdžiui, sveikatos priežiūros, dinamika reikalauja sisteminio požiūrio į robotų diegimą į šias sistemas (Lappalainen, 2019). Norint įveikti su naujų technologijų diegimu susijusius iššūkius, reikia nuolat stebėti diegimo procesą (Schartinger ir kt., 2015). Grisot ir kt. (2017) teigia, kad siekiant sklandžiai pritaikyti naujas technologijas sveikatos priežiūros srityje, yra reikalingas gilesnis „sociotechninis jautrumas“. Sociotechninė dinamika reikalauja išsamaus ir kontekstualaus žmogaus sąveikos su mašinomis ir darbo su jomis patirties supratimo (Riedl, 2020). Taigi, norint sėkmingai įgyvendinti procesus, būtina suprasti ir valdyti žmonių požiūrį ir elgesį reaguojant į technologinius pokyčius (Lennon ir kt., 2017).

Pasak Cong (2021), septynios iš dešimties Jungtinių Amerikos Valstijų ir Jungtinės Karalystės sveikatos priežiūros paslaugas teikiančių įstaigų yra įdiegusios arba svarsto galimybę įdiegti naujas technologijas. Toje pačioje ataskaitoje pabrėžiama, kad septyniasdešimt aštuoni procentai sveikatos priežiūros verslo lyderių, įdiegusių technologijas sveikatos priežiūros srityje, pranešė apie operacinės ir administracinės veiklos darbo eigos pagerėjimą. Cong (2021) taip pat teigė, kad norint visapusiškai įdiegti naujas technologijas, reikia pakoreguoti sveikatos priežiūros sistemų verslo modelius. Veiksnių, skatinančių verte pagrįstą sveikatos priežiūrą, sprendimas yra viena iš svarbiausių problemų, su kuriomis šiandien susiduria sveikatos priežiūros paslaugų teikėjai. Sveikatos priežiūros technologijų diegimas taip pat yra įtrauktas į šį sąrašą (Garrison ir kt., 2018; Nguyen ir kt., 2023). Šių technologijų naudojimas suteikia gydytojams daugiau laiko glaudžiau dirbti su pacientais, taip sudaromos palankesnės sąlygos veiksmingai teikti priežiūros paslaugas (Haleem ir kt., 2022; Okolo ir kt., 2024). Sveikatos priežiūros įstaigų vadovai supranta, kad norint tapti pageidaujamu paslaugų teikėju, reikia pasiūlyti paslaugas, kurios užtikrintų sklandesnę ir nuoseklesnę pacientų patirtį. Tai įmanoma integruojant technologijas. Vyriausybės, mokslininkai ir gydytojai tiria robotikos diegimo sveikatos priežiūros srityje svarbą (Karaferis ir kt., 2024).

Svarbu atpažinti ir stebėti naujų technologijų taikymo pramonės šakoje, ypač sveikatos priežiūros sektoriuje, pažangą, pradedant nuo išsamios iššūkių analizės ir pagalbinės politikos kūrimo, ypač turint omenyje atsakomybę (De Micco ir kt., 2024; Fosch-Villaronga ir kt., 2021). Ne pati technologija lemia svarbią kliūtį diegiant naujas technologijas sveikatos priežiūros sistemose, o tai, kaip ją įsisavina priešakinėse linijose dirbantys darbuotojai (sveikatos priežiūros specialistai) (Zemmar ir kt., 2020). Daugelis tyrėjų yra užfiksavę dokumentuose, kad sveikatos technologijų plėtra dažnai kelia iššūkius dėl „prasto vertės suderinimo“ tarp pasiūlos ir paklausos (Greenhalgh ir kt., 2018; Lehoux ir kt., 2017; Markiewicz ir kt., 2014). Lanza ir kt. (2020) pažymėjo, kad technologijų kūrėjai negali numatyti ir suplanuoti visų galimų situacijų dėl to, kad klinikinė praktika yra dinamiška ir yra būtina užtikrinti visišką autonomiją pacientų gydymo srityje. Įdomu tai, kad sveikatos priežiūros specialistai yra nepakankamai vertinami kaip technologijų diegimo tarpininkai. Tačiau, kalbant apie naujas technologijas, technologijų kūrėjai turėtų juos laikyti pagrindiniais suinteresuotais subjektais (Timmis, 2021).

Siekiant spręsti dabartinius ir būsimus uždavinius, siūlomi įvairūs galimi robotų panaudojimo sveikatos priežiūros srityje įgyvendinimo variantai (Yang ir kt., 2020). Toks robotų integravimo į sveikatos sistemą požiūris ne tik pagerins gyvybiškai svarbių sveikatos priežiūros specialistų gyvenimą, bet ir ilgainiui sumažins sveikatos priežiūros išlaidas bei padidins jų efektyvumą (Yang ir kt., 2020). Remiantis dabartine literatūros analize, buvo atlikta daug tyrimų, skirtų robotų integravimui į gamybos pramonę. Tačiau robotika vis dar laikoma naujove sveikatos priežiūros pramonėje. Pastaruoju metu robotų pagalba atliekamos operacijos tampa norma (Hettiarachchi ir kt., 2023). Tačiau dar tik pradedama robotus įtraukti į sveikatos priežiūros sistemas ir paslaugas. Tolesnis procesas išlieka neaiškus, tačiau tokių naujų technologijų, kaip robotika, diegimas kelia rimtų sunkumų sveikatos priežiūros specialistams. Svarbu vengti staigaus naujos technologijos diegimo sveikatos priežiūros sistemoje. Organizacija turi sukurti palankias sąlygas kad būtų galima priimti pokyčius ir prie jų prisitaikyti (Kim, 2022; Lee, 2018). Ypač svarbus žingsnis yra perėjimas nuo įprastų minimaliai invazinių procedūrų prie robotinės chirurgijos. Tam yra būtina suprasti elgseną bei plėtoti chirurginių sistemų diegimui palankią kultūrą (Cunningham ir kt., 2012). Anksčiau būta įrodymų, kad tiek sveikatos priežiūros paslaugų teikėjai, tiek pacientai ir jų šeimos atsisakė robotų naudojimo pacientų priežiūrai, priešinosi robotų naudojimui ir nerodė susidomėjimo jais (Krings ir Weinberger, 2018; Pekkarinen ir kt., 2020). Tačiau pandemijos metu robotinės sistemos pradėtos laikyti klinikine prasme pranašiomis, nes jos padeda optimizuoti sveikatos priežiūros išteklius (Lawrie, Gillies, Davies, ir kt., 2022; Moawad ir kt., 2020). Taip pat pastebėta, kad vis daugiau žmonių palankiai priima chirurginius robotus, o po pandemijos išaugo robotinių operacijų skaičius (Zemmar ir kt., 2020). Tačiau robotikos sistemų diegimo ir taikymo chirurgijoje procesas vis dar yra nepakankamai ištirtas (Giedelman ir kt., 2021).

Per pastarąjį dešimtmetį daugelis tyrimų buvo skirti robotų pagalba atliekamos chirurgijos privalumams, chirurgų mokymui, technologijų tobulinimui, sveikatos priežiūros specialistų ir pacientų požiūriui bei robotų pagalba atliekamos chirurgijos lyginimui su tradiciniais ir laparoskopiniais metodais. Tačiau mažai dėmesio skirta žmogiškųjų veiksnių tyrimams, kurie vienu metu apima chirurgo mokymus, chirurgijos komandos mokymus, prisitaikymą prie naujo darbo modelio ir specializuotą darbą su mechanizmais. Todėl būtina tirti ir vertinti šios naujos technologijos diegimo procesą bei jos poveikį dabartiniam ir būsimam sveikatos priežiūros žmogiškajam kapitalui. Šis kolektyvinis tyrimo metodas padės geriau suprasti perspektyvas, kaip sukurti visapusišką sistemą ir atitinkamą žmogiškųjų išteklių valdymo politiką bei praktiką, kad būtų galima prisitaikyti prie technologijų diegimo šiandien pasekmių ir įveikti būsimų technologijų keliamus iššūkius.

Mokslinė problema. Pagrindinė šio darbo mokslinė problema yra „Kaip atsiranda ir vystosi žmogiškojo kapitalo ištekliai chirurgų komandoje po robotikos sprendimų įdiegimo?"

Tyrimo tikslas ir uždaviniai. Šiame tyrime nagrinėjami socialiniai ir elgsenos aspektai, susiję su žmogiškojo kapitalo išteklių, reikalingų robotų technologijų diegimui chirurgijos skyriuje, formavimusi. Disertacijoje gilinamasi į platesnę technologijų diegimo sveikatos priežiūros srityje problemą, siekiant ištirti žmogiškojo kapitalo išteklių formavimosi procesą sveikatos priežiūros srityje, kad chirurgas ir chirurgijos komanda galėtų bendrai specializuotis chirurgijos skyriuje atliekant robotika paremtas operacijas.

Šio tyrimo **uždaviniai**:

1. Pateikti teorinį žmogiškojo kapitalo išteklių formavimosi (ŽKIF) pagrindimą tyrinėjant nepakankamai ištirtą procesą.
2. Tirti žmogiškojo kapitalo išteklių formavimosi (ŽKIF) procesą, kai chirurgų

komanda bendrai specializuojasi naudojant robotikos sprendimus.

3. Kurti žmogiškojo kapitalo išteklių formavimosi (ŽKIF) sistemą technologijų diegimui sveikatos priežiūros srityje.
4. Rekomenduoti praktinius sprendimus sveikatos priežiūros politikos formuotojams, žmogiškųjų išteklių personalui, sprendimų priėmėjams ir technologijų kūrėjams, siekiant palengvinti technologijų integraciją į sveikatos sistemą.

Siekiant šių tikslų, buvo pasirinktas kokybinis metodas. Naudojant interviu ėmimo vadovą, buvo atlikti pusiau struktūruoti interviu su chirurgais, kurie, baigę mokymus, šiuo metu atlieka robotų pagalba atliekamas operacijas. Apklausti 35 įvairių specialybių chirurgai, dirbantys skirtinguose regionuose (Australijoje, Europoje, Indijoje, Malaizijoje, Artimuosiuose Rytuose, Jungtinėje Karalystėje ir JAV). Duomenų analizė buvo atlikta taikant Gioia metodiką, suskirstant interviu duomenis į pirmos ir antros eilės sąvadus.

Disertacijos mokslinis naujumas ir nauda. Šia disertacija yra daromas svarbus indėlis į literatūros šaltinius. Pirma, joje nagrinėjamas technologijų (robotų) diegimo sveikatos priežiūros sistemoje procesas ir papildomi technologijų diegimo sveikatos priežiūros kontekste tyrimai. Antra, tyrimo metu išplečiamos žmogiškojo kapitalo (ŽK) ir žmogiškojo kapitalo išteklių (ŽKI) sąvokos. Tai įmanoma tyrinėjant žmogiškojo kapitalo išteklių formavimosi (ŽKIF) sveikatos priežiūros srityje procesą. Trečia, šiuo tyrimu daromas indėlis į literatūros šaltinius apie žmogiškojo kapitalo išteklius (ŽKI), atskleidžiant žmogiškųjų išteklių formavimosi procesą, kai chirurgijos komandose yra diegiama nauja technologija – robotika. Ketvirta, šiuo tyrimu yra daromas indėlis į literatūros šaltinius apie sveikatos priežiūros vadybą, atskleidžiant naujų technologijų diegimo ir integravimo į sveikatos priežiūros sistemas procesą. Ši socialinių mokslų disertacija yra veikiau orientuota į chirurgų ir chirurgijos komandos mokymosi apie robotiką procesą, o ne į mokymosi greitį. Galiausiai, šio tyrimo išvados ir rekomendacijos yra aktualios sveikatos priežiūros sektoriui, technologijų pramonės sektoriui ir vadybos tyrimams, siekiant įveikti pasipriešinimą technologijų diegimui sveikatos priežiūros sektoriuje ir su tuo susijusias kliūtis.

Praktinė reikšmė. Šio tyrimo rezultatai padės suprasti esamą žmogiškojo kapitalo išteklių formavimosi (ŽKIF) procesą ir suteiks aiškumo dėl palankių sąlygų ir kliūčių, susijusių su technologijų diegimu sveikatos priežiūros srityje. Tyrimas padės propaguoti sudėtingą modelį / sistemą, susijusį (-ią) su technologijų diegimu sveikatos sistemose ateityje. Jis (ji) skirtas (-a) sveikatos priežiūros sektoriuje dirbantiems žmogiškųjų išteklių vadovams ir politikos formuotojams kuriant politiką, strategijas ir formuojant kultūrą, siekiant sėkmingai įdiegti technologijas ir, optimizuojant išteklius, pasiekti norimus rezultatus/vertę. Be to, šis tyrimas yra technologijų kūrėjams skirtas praktinis sisteminio mąstymo vadovas, kuris leidžia jiems geriau suprasti sveikatos priežiūros specialistų (galutinių vartotojų) elgesį, iššūkius, su kuriais jie susiduria, ir darbo organizavimo modelį. Visa tai gali padėti jiems kurti ir tobulinti technologijas pagal sveikatos priežiūros paslaugų teikėjų poreikius ir naudojimo suderinamumą.

TEORINIS PAGRINDIMAS

Šis tyrimas yra grindžiamas žmogiškojo kapitalo teorija, kuri tiria žmogiškojo kapitalo transformavimąsi į žmogiškojo kapitalo išteklius, naudojant naujas technologijas, pvz., robotiką. Žmogiškasis kapitalas, kuris yra socialiai sudėtingas išteklius, yra gyvybiškai svarbus ekonomikos plėtrai (Goldin ir Katz, 2024). Investicijos į švietimą ir mokymą didina šalies produktyvumą (Kell ir kt., 2018). Organizaciniame lygmenyje žmogiškasis kapitalas skatina inovacijas ir konkurencinį pranašumą (Mahoney ir Kor, 2015). Pasaulio ekonomikos forumas žmogiškąjį kapitalą išskiria kaip ilgalaikės sėkmės veiksnį (PEF, 2013). Žmogiškasis kapitalas apima kompetencijas, požiūrį ir intelektualinį lankstumą, kuris skatina vidinius santykius ir žinių mainus (Scarbrough ir Elias, 2002). Apibrėžimais yra pabrėžiama žmogiškojo kapitalo pridėtinė vertė organizacijos tvarumui (Tracey ir Bronstein, 2003; Thomas ir kt., 2013).

1.1 Žmogiškojo kapitalo teorijos analizė

Becker (1964) sukurta žmogiškojo kapitalo teorija pabrėžia individo žinių, įgūdžių ir gebėjimų ekonominę vertę. Joje teigiama, kad investicijos į švietimą ir mokymą didina produktyvumą ir nacionalines pajamas (Schultz, 1961; Becker, 1975). Teorija buvo tobulinama siekiant spręsti darbo jėgos trūkumo problemas ir suderinti žmogiškąjį kapitalą su nacionaliniais vystymosi tikslais (Kell ir kt., 2018). Organizaciniu lygmeniu žmogiškasis kapitalas apibrėžiamas kaip įgūdžių ir kompetencijų, prisidedančių prie tvaraus konkurencinio pranašumo, visuma (Goldin, 2016; Mahoney ir Kor, 2015). Pasaulio ekonomikos forumas (2013) žmogiškąjį kapitalą akcentuoja, kaip veiksnį, kuris užtikrina ilgalaikę ekonominę sėkmę.

Žmogiškojo kapitalo teorija pabrėžia kompetencijų, požiūrio ir intelektualinio lankstumo ugdymo svarbą siekiant skatinti inovacijas ir vidinius santykius (Scarbrough ir Elias, 2002). Ji tebėra kertinis akmuo siekiant suprasti žmogiškojo kapitalo vaidmenį kalbant apie organizacijų ir šalies augimą.

Terminas „žmogiškasis kapitalas“ reiškia visos organizacijos darbo jėgos ekonominę vertę, įskaitant jos gebėjimus ir darbo kokybę. Tai yra darbo jėgos turimų įgūdžių visuma (Goldin, 2016). Žmogiškasis kapitalas buvo aptartas ekonomikos, žmogiškųjų išteklių, strategijos, apskaitos ir psichologijos literatūroje. Kiekvienos srities tyrimuose buvo naudojama šiek tiek skirtinga kalba ir daromos įvairios prielaidos (Ployhart ir Hale, 2014). Per pastaruosius šešis dešimtmečius mokslininkai labai pabrėžė investicijų į žmogiškąjį kapitalą svarbą. Pasaulio ekonomikos forumas (PEF, 2013) pabrėžia, kad, lyginant su bet kuriais kitais ištekliais, šalies žmogiškasis kapitalas, t. y. jos gyventojų įgūdžiai ir gebėjimai, gali būti svarbesnis ilgalaikės ekonominės sėkmės veiksnys. Taigi, žmogiškojo kapitalo teorija skatina darbuotojų įgūdžių ir žinių ugdymo koncepciją, investuojant į mokymąsi per švietimą ar mokymą (Hatch ir Dyer, 2004; Riley ir kt., 2017). Šie ištekliai gali būti trijų pagrindinių tipų: kompetencijos, požiūris ir intelektualinis lankstumas. Žmogiškųjų išteklių terminų žodyne žmogiškasis kapitalas yra apibrėžiamas kaip „grąža, kurią organizacija gauna iš savo darbuotojų lojalumo, kūrybiškumo, pastangų, pasiekimų ir produktyvumo“ (Tracey ir Bronstein, 2003). Panašiai Thomas ir kt. (2013, 3 p.) žmogiškąjį kapitalą apibrėžė kaip „žmones, jų veiklos rezultatus ir potencialą organizacijoje“. Pasak Scarbrough ir Elias (2002, 10 p.), „žmogiškojo kapitalo teorija akcentuoja tai, kaip darbuotojų kompetencijos kuria vertę organizacijai“. Apibendrinant, žmogiškojo kapitalo „žmogiškasis“ komponentas reiškia „kūrėją“ – asmenį, kuris naudoja ir taiko žinias, įgūdžius, kompetenciją ir patirtį, įgytą nuolat sąveikaujant su aplinka, kurioje jis egzistuoja.

1.2 Žmogiškojo kapitalo ištekliai

Žmogiškojo kapitalo išteklių tyrimai prasidėjo nuo žmogiškojo kapitalo teorijos (Becker, 1964) ir vystėsi siekiant spręsti vieneto lygio dinamikos klausimus, neapsiribojančius individualiais gebėjimais. Ployhart ir Moliterno (2011) įvedė terminą „žmogiškųjų išteklių kapitalas“ ir apibrėžė jį kaip vieneto lygio gebėjimus, kilusius iš individualių ŽĮGKS (žinių, įgūdžių, gebėjimų ir kitų savybių). Ši sąvoka pabrėžia strateginį panaudojimą konkurenciniam pranašumui pasiekti (Nyberg ir Wright, 2015). Žmogiškojo kapitalo ištekliai (ŽKI) yra vieneto lygio gebėjimai, pagrįsti individualiais ŽĮGKS, kurie prisideda prie organizacijos rezultatų (Ployhart ir Hale, 2014). Jie daro įtaką klientų pasitenkinimui, produktyvumui ir darbuotojų kaitai (Harter ir kt., 2002). ŽKI tyrimai daugiausia dėmesio skiria strateginiams rezultatams ir tvariam konkurenciniam pranašumui (Nyberg ir Wright, 2015). Atskirų ŽĮGKS transformavimas į vieneto lygio išteklius reikalauja veiksmų suderinimo su organizacijos tikslais (Kazlauskaitė ir Bučiūnienė, 2008). ŽKI yra labai svarbūs sprendžiant nestabilios aplinkos problemas ir siekiant konkrečios įmonės veiklos rezultatų (Ployhart, 2021). Nepaisant pripažintos ŽKI vertės, reikia toliau tirti jų formavimosi procesą.

1.3 Žmogiškojo kapitalo išteklių formavimasis

Žmogiškojo kapitalo išteklių formavimasis apima individualių ŽĮGKS transformavimąsi į vieneto lygio išteklius per socialines sąveikas (Ployhart ir Moliterno, 2011). Šį procesą įtakoja elgesio, afektinė ir kognityvinės būsenos (Ray ir kt., 2021). Formavimasis leidžia sujungti individualias savybes į kolektyvinius reiškinius, taip padidinant organizacijos vertę (Klein ir Kozlowski, 2000). Galimi iššūkiai tai reikiamos sąlygos, socialinis kontekstas ir vertinimo klausimai (Harris ir kt., 2018). Formavimosi procesas yra labai svarbus siekiant suprasti žmogiškojo kapitalo poveikį organizacijos veiklos rezultatams, ypač sveikatos priežiūros srityje diegiant naujas technologijas.

Sveikatos priežiūros specialistai yra sveikatos priežiūros sistemų žmogiškasis kapitalas, dirbantis daugiadisciplininėse komandose, kad būtų užtikrinta saugi pacientų priežiūra (Schmidt ir kt., 2023). Gydytojai, dažnai neturintys vadovavimo įgūdžių, priima sprendimus daugiadisciplinėse komandose (Kozlowski ir kt., 2016). „Pramonė 4.0" ir pandemija lėmė didesnį žmogiškojo kapitalo poreikį, siekiant veiksmingai įdiegti naujas technologijas (Jose ir kt., 2023). Diegiant technologijas sveikatos priežiūros įstaigose yra būtina tyrinėti šį transformavimosi procesą.

1.4 Gebėjimų stiprinimas

Gebėjimų stiprinimas padeda tobulinti įgūdžius ir gilinti žinias, kurie reikalingi siekiant prisitaikyti prie naujų technologijų ir darbo modelių (Smith ir kt., 2011). Pagal JT vystymo programos (JTVP) apibrėžimą (2002), gebėjimų stiprinimas apima gebėjimų, reikalingų tvariam vystymosi poreikių tenkinimui, ugdymą (Ionel, 2017). Jis skatina kūrybiškumą, prisitaikymą ir efektyvumą, žmogiškąjį kapitalą suderinant su technologiniais pasiekimais (Chaskin, 2001). Generatyviniai pajėgumai padeda siekti organizacijos tikslų, padidinant gebėjimus ir išteklius (Baker ir Dutton, 2017). Sveikatos priežiūros srityje gebėjimų stiprinimas susijęs su strateginių pokyčių valdymu ir socialinio kapitalo integravimu siekiant diegti technologijas (Petersson ir kt., 2022). Tai aktyvaus veikimo būdas, kuris yra būtinas žmogiškojo kapitalo ir technologijų tarpusavio specializacijai.

1.5 Socialinis kapitalas

Socialinis kapitalas – tai socialinės organizacijos ypatumai, tokie kaip tinklai, normos ir socialinis pasitikėjimas, kurie palengvina koordinavimą ir bendradarbiavimą, užtikrinant abipusę naudą (Putnam, 1995). Jis veikia kaip katalizatorius, padedantis panaudoti žmogiškąjį kapitalą, leidžiantis asmenims ir grupėms pasiekti daugiau dirbant kartu nei atskirai (Swanson ir kt., 2020). Socialinis kapitalas sukuria mokymuisi, bendradarbiavimui ir tarpusavio pagalbai palankią aplinką, kuri yra labai svarbi žmogiškojo kapitalo ugdymui (Coleman, 1990; Lee ir kt., 2015). Jis atlieka dvejopą vaidmenį žmogiškųjų išteklių formavimosi procese, sukurdamas sąlygas pasinaudoti galimybėmis, informacija ir parama (Dinda, 2014). Fukuyama (2002) socialinį kapitalą apibrėžė kaip neformalią normą, kuri skatina bendradarbiavimą tarp asmenų. Nepaisant pripažintos socialinio kapitalo svarbos, tyrimai apie jo formavimąsi ir išsaugojimą tebėra nepakankami, ypač diegiant technologijas sveikatos priežiūros paslaugų teikimo vietose (Zhang ir kt., 2019; Al-Omoush ir kt., 2022). Socialinis kapitalas palengvina koordinavimą ir bendradarbiavimą per tinklus, normas ir pasitikėjimą (Putnam, 1995). Jis veikia kaip katalizatorius, padedantis panaudoti žmogiškąjį kapitalą, sukuriantis mokymuisi ir tarpusavio paramai palankias aplinkas (Coleman, 1990; Swanson ir kt., 2020). Socialinis kapitalas sukuria sąlygas pasinaudoti galimybėmis ir informacija, taip darant įtaką žmogiškųjų išteklių formavimuisi (Dinda, 2014).

1.6 Išteklių tarpusavio specializacija

Išteklių tarpusavio specializacija apima tarpusavyje susijusių išteklių suderinimą, siekiant konkurencinio pranašumo (Teece, 1986). Ja yra akcentuojamas bendradarbiavimas ir konkurencingumas, siekiant skatinti inovacijas (Teece ir kt., 1997). Tarpusavio specializacijai yra būtinas žmogiškojo kapitalo perkvalifikavimas ir kvalifikacijos kėlimas, kad būtų galima prisitaikyti prie naujų technologijų (Beane, 2018). Ji sukuria unikalius, vertingus išteklių derinius, kuriuos sunku imituoti, ir palaikyti organizacijos augimą bei tvarumą (Kim ir kt., 2019; Teece, 2007).

1.7 Robotų pagalba atliekamos operacijos

Robotų pagalba atliekamos operacijos yra minimaliai invazinės. Šios procedūros yra robotikos taikymo sveikatos priežiūros srityje pavyzdys, užtikrinančios geresnius rezultatus ir trumpesnį reabilitacijos laiką. Siekiant sėkmingai atlikti šias operacijas, chirurgams reikalingi specializuoti mokymai, akcentuojantys žmogiškųjų išteklių kapitalo formavimąsi, siekiant kad chirurgai galėtų prisitaikyti prie robotų sistemų (Ray ir kt., 2021). Kalbant apie robotų pagalba atliekamas operacijas yra pabrėžiamas žmogiškojo kapitalo suderinimas su technologiniais pasiekimais. Tai svarbu siekiant užtikrinti optimalią pacientų priežiūrą.

Robotų pagalba atliekamos operacijos arba robotinės operacijos – tai operacijos, atliekamos „kompiuterio valdomo manipuliatoriaus su dirbtiniu jutikliu, kuris gali būti perprogramuotas judėti ir nustatyti įrankių padėtį, kad būtų galima atlikti įvairias chirurgines užduotis“ (Dasgupta ir kt., 2005, 20 p.). Robotų pagalba atliekamos operacijos reiškia, kad ekspertas chirurgas, sėdintis prie konsolės, atlieka minimaliai invazinę operaciją (MIO), labai tiksliai valdydamas robotines rankas (Howard ir kt., 2022). Minimaliai invazinė operacija (MIO) tai operacija, kurios metu yra padaromi keli, tačiau maži pjūviai, kurie būtini tam, kad operacijos atlikimo vietoje būtų galima naudoti chirurginį instrumentą. Operacijos metu naudojamos 3D kameros, todėl organai ir kraujagyslės matomi labai aiškiai. Dėl šios priežasties aplinkinių organų pažeidimo tikimybė yra mažesnė arba jos visai nėra (Andrade ir kt., 2014).

1.8 Literatūros apžvalgos išvados

Remiantis aukščiau pateikta išsamia literatūros analize (kurioje nagrinėjamos įvairios teorijos ir sąvokos), akivaizdu, kad tolimesnis tyrimas turėtų būti orientuotas į chirurgijos skyriaus mikro-lygio žmogiškojo kapitalo raidą ir formavimąsi. Tai leis pilnai suprasti technologijos diegimo procesą ir kaip jį priima chirurgai, bei kaip vieneto lygiu formuojasi chirurgijos komandos įgūdžiai ir žinios. Literatūroje apie žmogiškojo kapitalo išteklių atsiradimo teoriją žioji spraga: žmogiškojo kapitalo išteklių (ŽKI) svarba yra gerai pripažįstama, tačiau jų kūrimo procesas lieka nepakankamai išnagrinėtas. Atliekant šią literatūros analizę taip pat buvo pastebėta, kad dauguma ankstesnių tyrimų buvo susiję su tokiomis temomis, kaip chirurgų mokymai, klinikiniai rezultatai ir minimaliai invazinių robotinių operacijų privalumai.

Gebėjimų stiprinimas yra aktyvi strategija ir būtina sąlyga žmogiškojo kapitalo ir technologijų tarpusavio specializacijai. Ši koncepcija, kalbant apie technologijų diegimą sveikatos priežiūros srityje, buvo nagrinėta vos keliuose tyrimuose. Socialinio kapitalo vaidmuo struktūriniu, santykių ir kognityviniu aspektais taip pat buvo nagrinėjamas bendrai, bet ne kaip žmogiškojo kapitalo išteklių formavimosi sveikatos priežiūros sektoriuje veiksnys. Dėl stipriai integruoto sveikatos priežiūros sektoriaus darbuotojų darbo stiliaus, toks holistinis metodas yra būtinas, tačiau jis nėra išsamiai ištirtas. Literatūros apžvalgoje pateikta išsami diskusija apie tradicinės ir robotinės chirurgijos skirtumus. Tai buvo padaryta siekiant skaitytojams paaiškinti situaciją, ypač tiems, kurie nedirba sveikatos priežiūros sektoriuje arba turi mažai žinių apie operacinio darbo ligoninės operacinėje dinamiką.

Galiausiai, ši literatūros apžvalga taip pat parodė, kad tik labai maža dalis tyrėjų dėmesį skyrė bendradarbiavimui ir komunikacijai komandoje. Daugelis tyrimų pabrėžė robotų pagalba atliekamų operacijų privalumus ir robotinės rankos ypatumus. Naujausia literatūra yra labiau skirti technologinių pasiekimų tyrimams ir robotinės rankos tobulinimui naudojant pažangias technologijas, pvz., DI ir 5G. Labai nedaug naujausių tyrimų buvo skirta robotų chirurgijoje dalyvaujančių žmonių iššūkiams analizuoti. Taip pat nebuvo rekomenduotas teorinis ir humanistinis požiūris ateities tyrimams. Taigi, pastebima, kad visapusiškas robotinės chirurgijos įdiegimo chirurgijos skyriuje procesas nebuvo tiriamas žmogiškojo kapitalo išteklių formavimosi kontekste.

TYRIMO METODIKA

Disertacijoje tiriamas robotų sistemų integravimo sveikatos priežiūros sektoriuje procesas, akcentuojant žmogiškųjų išteklių formavimąsi chirurgijos komandose. Atliekant tyrimą naudota kokybinė metodika iššūkiams, su kuriais susiduria chirurgai, pereinantys nuo tradicinių chirurginių metodų prie robotų pagalba atliekamų operacijų, nagrinėti. Duomenys buvo renkami naudojant pusiau struktūrizuotus interviu su 36 įvairių specializacijų chirurgais, pvz., gastroenterologais, kardiologais ir urologais (7 moterimis ir 29 vyrais) iš 13 šalių. 2021 ir 2025 metais atlikti interviu buvo skirti išsiaiškinti chirurgų patirtį, jų nueitą kelią mokantis ir požiūrį į robotikos diegimą. Sisteminei duomenų analizei buvo taikoma Gioia metodika, kuri palengvina pirmos eilės sąvadų identifikavimą ir duomenų skirstymą į kategorijas pagal temas (Gioia ir kt., 2012; Magnani ir Gioia, 2023). Naudojant šį metodą buvo sukurta aprašomoji sistema, atspindinti chirurgų įžvalgas ir individualios bei komandinės tarpusavio specializacijos su robotų technologijomis dinamiką.

Tyrimas pabrėžia epistemologinio konstruktyvizmo svarbą siekiant suprasti žmogaus elgesio ir technologijų diegimo sąveiką (Crotty, 1998; Lincoln ir Guba, 2016). Jame pabrėžiamas kokybinių tyrimų vaidmuo fiksuojant perspektyvas, kurioms būdingi tam tikri niuansai, ir skatinant žinių perdavimą. Tyrimo išvados rodo, kad siekiant užpildyti įgūdžių spragas ir skatinti veiksmingą robotikos sistemų diegimą sveikatos priežiūros srityje reikia rengti tikslingas mokymo programas. Šis tyrimas prisideda prie sistemų, kurios padės ateityje integruoti technologijas sveikatos priežiūros paslaugų teikimo vietose, kūrimo.

TYRIMO IŠVADOS

Šis tyrimas parodė, kad chirurgai, norėdami operuoti robotų pagalba, turi įgyti papildomų žinių ir įgūdžių, pavyzdžiui, ištobulinti rankų judesius ir išmokti duoti aiškius nurodymus. Savimotyvacija ir patyrusių chirurgų bei ligoninės administracijos pagalba buvo labai svarbios į praktiką įvedant robotų pagalba atliekamų operacijų sistemas. Dauguma chirurgų pirmiau išmoko atlikti tradicines operacijas, tada perėjo prie robotinės chirurgijos. Jie aktyviai domėjosi robotika, skirdami laiko ir pastangų savo komandų mokymui ir savo žmogiškojo kapitalo stiprinimui. Su robotikos sistemomis dirbantys chirurgai prioritetą teikė savo komandų mokymui, kad jos prisitaikytų prie darbo su chirurginiais robotais dinamikos pokyčių. Jie sutelkė dėmesį į žinias, įgūdžius ir bendravimą, kad komandos nariai įgytų pasitikėjimo savimi ir galėtų prisitaikyti prie naujo darbo stiliaus.

Pasibaigus sertifikavimo ir kvalifikacijos patvirtinimo procesams, chirurgai surengė vidinius mokymus ir pakvietė slaugytojus dalyvauti užsienyje vykusiuose mokymuose kartu su jais bei įrenginių gamintojais. Chirurgai taip pat pabrėžė tradicinio chirurginio mokymo ir žmogaus anatomijos žinių svarbą naujų chirurgų mokymosi pradžioje. Šios žinios ir įgūdžiai padės jiems nelaimingų atsitikimų, įrenginių gedimų ar susijusių komplikacijų atveju, prireikus vietoje robotinės operacijos atlikti atvirą operaciją. Tyrime pabrėžiama sistemingo požiūrio į naujų technologijų diegimą sveikatos priežiūros srityje svarba. Jame analizuotas robotų pagalba atliekamų operacijų įvedimas chirurgijos skyriuje, atskleidžiant tarpusavio specializacijos procesą. Šis perėjimas nuo tradicinės chirurgijos prie robotinės chirurgijos ir žmogiškųjų išteklių formavimasis davė vertingų rezultatų ir naudą chirurgams, pacientams, sveikatos priežiūros organizacijoms ir sveikatos priežiūros sistemoms.

Formavimosi modelį sudaro keturi etapai:

1. Seni ir nauji darbo modeliai (tradicinės operacijos plg. su robotų pagalba atliekamomis operacijomis.
2. Chirurgų ir robotų tarpusavio specializacija.
3. Chirurgijos komandų ir robotų tarpusavio specializacija.
4. Žmogiškojo kapitalo išteklių formavimasis – robotų pagalba atliekamų operacijų sistemų diegimas visame skyriuje, kuris lemia žmogaus ir roboto simbiozę.

Šis modelis pateikiamas žemiau:

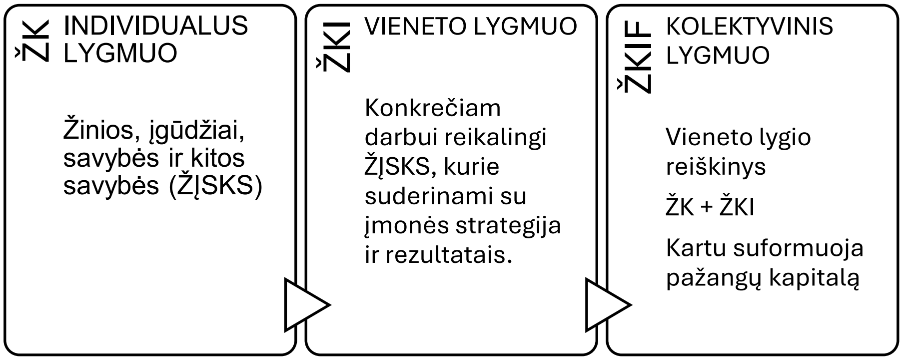
Organizacijos parama ir pokyčius skatinanti kultūra
1. Tradicinė chirurgija
Asmeniniai veiksniai:
Motyvacija
Pasišventimas
Atkaklumas
Nuoseklumas
Socialinis kapitalas:
Vyresniųjų patyrusių chirurgų buvimas ir prieinamumas
Organizaciniai veiksniai:
Palaikantis ligoninės valdymas ir kultūra
Robotinės chirurgijos mokymo programa ir gamintojo proktorinis mokymas
Pagalba patyrusiems chirurgams ir jų stebėjimas, darbas prižiūrint
Pusiau savarankiškas atvejų valdymas, o vėliau savarankiškas
Chirurgų mokymų baigimas
Chirurgas pradeda mokyti chirurgijos komandą, kaip prisitaikyti prie naujo darbo modelio
Gebėjimų ugdymas, užtikrinant glaudų bendravimą ir bendradarbiavimą tarp chirurgijos komandos narių
Pradedamos atlikti robotinės operacijos
Komanda įgyja naujas žinias, įgūdžius ir įsisavina naujos technologijos naudojimo procesą
Robotų pagalba atliekamos operacijos
Žmogaus ir roboto simbiozė vieneto lygmenyje (ŽKIF)
Naujų robotinės chirurgijos įgūdžių įsisavinimas
Žmogiškojo kapitalo ugdymas
Žmogiškojo kapitalo transformacija į žmogiškojo kapitalo išteklius
Chirurgo tarpusavio specializuota sąveika su robotu
Chirurgijos komandos tarpusavio specializuota sąveika su robotu

DISKUSIJA

Tyrimo metu nagrinėjamas žmogiškojo kapitalo išteklių formavimosi (ŽKIF) procesas sveikatos priežiūros paslaugų teikimo vietose, konkrečiai chirurgijos skyriuje, kur robotikos sistemos naudojamos chirurgų ir chirurgijos komandų tarpusavio specializacijai užtikrinti. Tyrimas sutelktas į visą procesą nuo pradžios iki pabaigos, apimantį chirurgų ir chirurgijos komandų gebėjimą pritaikyti, prisitaikyti ir priimti. Tyrimo metu taip pat nagrinėjamos žinios, įgūdžiai, savybės ir kitos savybės – ŽĮSKS, reikalingi tam, kad individualius įgūdžius asmuo galėtų paversti vieneto lygio ŽĮSKS, taip užtikrinant sėkmingas procedūras ir geresnius rezultatus pacientams. Tyrimo tikslas – analizuoti teorines implikacijas literatūroje apie žmogiškojo kapitalo išteklių formavimąsi ir pateikti gaires sveikatos priežiūros politikos formuotojams, žmogiškųjų išteklių personalui ir technologijų kūrėjams technologijų diegimui sveikatos priežiūros sistemose ateityje. Tyrimo rezultatai rodo, kad naujų technologijų diegimas sveikatos priežiūros skyriuose yra daugialypis, sinergetinis, laipsniškas, nuoseklus ir visapusiškas procesas. Tyrimas patvirtina ankstesnius tyrimus, kad žmogiškojo kapitalo ištekliai formuojasi individualių mąstymo procesų metu. Jį sustiprina jų sąveiką. Tai lemia aukštesnio lygio kolektyvinio reiškinio atsiradimą.

Tyrimas rodo, kad naujų technologijų, ypač robotikos, diegimas chirurgijos skyriuje sukėlė chaosą ir sutrikdė esamą sveikatos priežiūros sistemą. Chirurgai buvo motyvuoti pradėti atlikti robotų pagalba atliekamas operacijas, tačiau skyriuje trūko žinių ir įgūdžių, reikalingų šiai naujai technologijai. Šis sutrikimas paskatino formavimosi procesą, dėl kurio individualūs chirurgų ŽĮSKS transformavosi į viso skyriaus žmogiškąjį kapitalą. Šis procesas paskatino bendradarbiavimu grindžiamą naujų įgūdžių ir žinių įgijimą tarp komandos narių, o tai lėmė naujos, struktūrizuotos srities, galinčios kurti pridėtinę vertę organizacijai, atsiradimą. Tyrime taip pat pabrėžiamas skirtumas tarp specifinio ir bendrojo žmogiškojo kapitalo, kur „specifinis“ žmogiškasis kapitalas skatina formavimosi procesą. Tyrimas rodo, kad šios sąvokos turėtų būti laikomos nuosekliai susijusiomis, nes jos grindžiamos žmogiškojo kapitalo teorija. Tyrimas patvirtina, kad žmogiškųjų išteklių formavimasis yra metodas „iš apačios į viršų“, kai individualaus lygio žmogiškasis kapitalas perauga į vieneto lygio gebėjimus, ir taip prisidedama prie žinių ir įgūdžių ugdymo per socialinį kapitalą ir gebėjimų stiprinimą.

1 pav. Ryšys tarp žmogiškojo kapitalo (ŽK), žmogiškojo kapitalo išteklių (ŽKI) ir žmogiškojo kapitalo išteklių formavimosi (ŽKIF) (teorinis indėlis)



Technologijų diegimo sveikatos priežiūros srityje sėkmė priklauso nuo gydytojų ir slaugytojų pasirengimo jas taikyti. Perėjimas prie naujų technologijų reikalauja atsižvelgti į visų suinteresuotųjų šalių interesus ir perspektyvas. Siekiant sėkmingai ir pelningai diegti naujas technologijas, pavyzdžiui, robotus ir dirbtinį intelektą, sveikatos priežiūros sistemose, būtina, kad jas vienu metu pradėtų taikyti visi dalyviai. Labai svarbu, kad technologijų kūrimo ir diegimo procese tiesiogiai dalyvautų vidiniai specialistai. Siekiant sėkmingai diegti naujas technologijas bet kurioje srityje, būtina mažinti atotrūkį tarp kūrėjų ir vartotojų. Sociotechninis jautrumas yra labai svarbus siekiant sklandžiai perkelti naujas technologijas į sveikatos priežiūros sektorių. Naujos technologijos likimas priklauso nuo svarbiausių veiksnių – nuo to, kaip darbuotojai specialistai priima naujas technologijas ir kaip jie prisitaiko prie jų.

Šio tyrimo tikslas – sukurti ir pasiūlyti ateities technologijų diegimo sveikatos priežiūros srityje sistemą. Modelis susideda iš penkių etapų:

1) individualių žinių apie naujas technologijas įgijimas;

2) naujų įgūdžių, reikalingų darbui su technologijomis, įgijimas ir praktikavimas;;

3) technologinių žinių ir įgūdžių dalijimasis su komanda;

4) komunikacijos ir procesų pritaikymas darbui su naujomis technologijomis per socialinę sąveiką; ir

5) viso skyriaus ir naujos žmogiškojo kapitalo išteklių technologijos tarpusavio specializacija, kuri lemia žmogiškojo kapitalo išteklių formavimąsi skyriaus lygmeniu.

2 pav. Technologijų diegimo sveikatos priežiūros srityje etapai

Sveikatos priežiūros sektoriuje būtina kurti technologijas, kurios padidina kasdienės veiklos vertę ir efektyvumą, įtraukiant konsultacijas su sveikatos priežiūros paslaugų teikėjais. Šis metodas padeda kūrėjams suprasti sveikatos priežiūros paslaugų teikėjų iššūkius ir reikalavimus, palengvinant naujų technologijų diegimą. Robotinės chirurgijos sistemų įdiegimas yra daugiapakopis procesas, apimantis visus galutinius vartotojus, įskaitant chirurgus, slaugytojus, anesteziologus ir technikus, siekiant veiksmingai bendradarbiauti specializuotose srityse. Sėkmingas technologijų diegimas sveikatos priežiūros srityje reikalauja daugialypio ir daugiadisciplinio požiūrio. Perėjimas nuo tradicinės chirurgijos prie robotinės chirurgijos apima tokius veiksnius kaip individualus ir komandinis mokymasis, sanglauda, bendravimo įgūdžiai ir prisitaikymas prie naujos darbo struktūros. Robotikos diegimas chirurgijoje ir žmogiškųjų išteklių formavimasis yra laipsniški procesai, prasidedantys nuo chirurgų ir pereinantys prie slaugytojų, techninių darbuotojų ir anesteziologų.

Socialinio kapitalo teorija ir išteklių tarpusavio specializacija atlieka lemiamą vaidmenį kalbant apie žmogiškųjų išteklių formavimąsi. Kai dirba patyrę chirurgai ir yra socialinė sąveika, palengvėja prisitaikymas prie naujo darbo ir bendravimo stiliaus, kuriant vertę. Todėl, norint, kad formuotųsi žmogiškieji ištekliai, reikalingi naujų technologijų diegimui sveikatos priežiūros srityje, būtina turėti socialinį kapitalą, kuris skatina tarpusavio specializaciją. Tradicinė chirurgija skiriasi nuo robotinės chirurgijos tuo, kad operacinėje yra visa sveikatos priežiūros komanda. Todėl glaudus bendravimas ir bendradarbiavimas yra būtini.

Gebėjimų stiprinimas ir socialinis kapitalas yra labai svarbūs transformuojant bendradarbiavimą ir jį pritaikant robotinėms operacijoms. Chirurgijos komandos patirtis yra būtina norint naudoti įrankį ir įvertinti jo tinkamumą pacientui ir procedūrai. Sėkmingam įgyvendinimui būtina suprasti žmonių reakcijas į technologinius pokyčius ir jas valdyti. Sveikatos priežiūros politikos formuotojai, žmogiškųjų išteklių personalas ir sprendimų priėmėjai turėtų parengti politiką, procedūras, strategijas ir mokymus, kurie palengvintų robotų technologijų integravimą. Organizacijos parama ir pokyčiams palanki kultūra yra būtini sėkmingam robotų sistemų diegimui. Reikėtų vengti taikyti baudžiamąsias priemones, o nesėkmes vertinti kaip galimybę mokytis ir tobulėti. Technologijų diegimo lyderių apdovanojimas ir patyrusių darbuotojų skatinimas taip pat gali motyvuoti įsitraukti. Robotų sistemų diegimas sveikatos priežiūros sistemose padės subalansuoti paklausą ir pasiūlą, užkirsti kelią kvalifikuotų sveikatos priežiūros specialistų praradimui, padidinti efektyvumą ir sumažinti profesinį perdegimą. Siekiant veiksmingai diegti naujas technologijas sveikatos priežiūros sistemose, būtina mokyti visas suinteresuotąsias šalis, ypač sveikatos priežiūros paslaugų teikėjus.

IŠVADOS

1. Žmogiškojo kapitalo išteklių formavimosi (ŽKIF) procesas sveikatos priežiūros srityje yra reiškinys „iš apačios į viršų“, kuris reikalauja kruopštaus planavimo ir vykdymo. Technologijų diegimas sveikatos priežiūros srityje yra visą sistemą apimantis holistinis pokytis, turintis įtakos daugeliui skyrių ir sveikatos priežiūros paslaugų teikėjų. ŽKIF pasireiškia „specifinių“ žmogiškųjų išteklių tarpe, pvz., chirurgijos komandoje, kuri yra kvalifikuota atlikti įvairių specialybių chirurgines procedūras skirtingoms ligoms ir būklėms gydyti. Tam, kad atsirastų naujos formos žmogiškojo kapitalo ištekliai (ŽKI), yra reikalingi specifiniai arba specializuoti žmogiškojo kapitalo ištekliai. Kai specifinis žmogiškasis kapitalas tampa „nauja visuma“, jis turi likti kartu, kad būtų išlaikytas šis naujas kompetencijos lygis.
2. Siekiant tarpusavio specializacijos naujų technologijų srityje, sveikatos priežiūros žmogiškasis kapitalas būtinai turi stiprinti gebėjimus. Sėkmingas technologijų derinimas sveikatos priežiūros srityje neįmanomas be žmogiškojo kapitalo išteklių. Norint sėkmingai įdiegti technologiją, būtina apmokyti visą komandą ir visus susijusius skyrius. Norint, kad technologija būtų priimta ir pritaikyta, būtina parengti išsamią mokymo programą visai chirurgijos komandai, įskaitant patį chirurgą.
3. Tyrimo metu buvo sukurtas daugiapakopis teorinis požiūris į žmogiškojo kapitalo išteklių formavimosi (ŽKIF) procesą, pabrėžiant ryšį tarp socialinio kapitalo, išteklių tarpusavio specializacijos ir gebėjimų ugdymo. Modelis pradedamas nuo individualaus lygio žmogiškojo kapitalo, parodant žmogiškojo kapitalo išteklių formavimąsi. Jis užbaigiamas pademonstruojant sėkmingą chirurgijos komandos ir roboto simbiozę. Buvo sukurta sistema technologijoms diegti ir jų sėkmingam panaudojimui sveikatos priežiūros srityje. Joje apibrėžiami veiksniai ir jų tarpusavio ryšiai. Ši sistema gali padėti sveikatos priežiūros sektoriaus sprendimus priimantiems asmenims ir technologijų kūrėjams efektyviai integruoti naujas technologijas sveikatos priežiūros sektoriuje.
4. Tyrimas rodo, kad technologijos turėtų būti kuriamos ir diegiamos siekiant

padidinti sveikatos priežiūros paslaugų teikėjų darbo efektyvumą, pagerinti klinikinius rezultatus ir sukurti priemonę gydymo paslaugas teikiančioms organizacijoms. Diegiant naujas technologijas reikia nuolat stiprinti gebėjimus jas naudoti, užtikrinti nuolatinę socialinę sąveiką ir psichologinį saugumą. Visa tai svarbu norint prisitaikyti prie pokyčių. Modelis / sistema ateityje gali tarnauti, kaip technologijų integravimo gairės tiek technologijų kūrėjams, tiek sveikatos priežiūros srities vadovams, tiek sprendimų priėmėjams. Technologijų diegimas sveikatos priežiūros sistemose gali subalansuoti paklausą ir pasiūlą, užkirsti kelią kvalifikuotų ir savo darbą išmanančių sveikatos priežiūros paslaugų teikėjų praradimui, padidinti darbo efektyvumą ir sumažinti ilgalaikes išlaidas.

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ISM UNIVERSITY OF MANAGEMENT AND ECONOMICS

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HUMAN CAPITAL RESOURCE EMERGENCE FOR ROBOTIC SURGERY DEPLOYMENT IN HEALTHCARE

Summary of Doctoral Dissertation

Social Sciences, Management, S 003

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The public defense of the doctoral dissertation will be held on September 10th, 2025, at 11:00 A.M., room 210, at ISM University of Management and Economics. Address: Gediminas av. 7, Vilnius, Lithuania.

The summary of the dissertation was sent on August 10th, 2025. The dissertation is available at Martynas Mažvydas National Library and the library of ISM University of Management and Economics.

INTRODUCTION

"Technology is best when it brings people together." (Mullenweg, 2021)

The healthcare industry is among the world's largest and fastest growing (Ortega et al., 2020; Roy et al., 2022). The healthcare industry includes workforce from five different generations, starting from baby boomers, with different working and learning styles, an aspect which further adds to the uniqueness of the industry (Teunissen et al., 2020). According to the World Health Organization (WHO), "a health system comprises all organizations, individuals, and activities whose primary job is advancement, reestablishment, and health maintenance" (WHO, 2017, n.p.). Creating value for society is considered as an essential to health systems (Roppelt et al., 2024). Healthcare delivery organizations have always been in great demand (Starfield, 2000); currently, this demand is greater than ever, a development that is ongoing on a global scale (Schurmann et al., 2025).

To fulfil this ongoing and increased demand of high efficiency care delivery, it is pivotal to embrace the pressing need for deploying technologies in healthcare. Maskuriy et al. (2019) elucidated that industry 4.0, which includes Robotics, Artificial Intelligence (AI), Internet of Things (IoT), cloud computing, Big Data, Immersive technologies (AR/VR) and Machine Learning (ML), is a brand-new philosophy that is creating an upsurge in social change by affecting all areas of life, ranging from safety, education, science, labour market and welfare systems. Comparable to other industries, healthcare is going through a phase of transformation by integrating new technology-based solutions which are helping to reduce costs, enhance performance, and overcome the shortage of health care providers but technologies are facing deployment blockage (Bienefeld et al., 2025; Lee & Yoon, 2021; Thacharodi et al., 2024).

Human capital resource emergence (HCRE) is a situation where a collection of people, together with all of their pertinent human capital, collectively becomes a unit-level construct of human capital (Ployhart & Moliterno, 2011). This is a relatively new topic in the management literature compared to human capital and human capital resource domain (Jun et al., 2024). It is overall in the early stages of exploration and is understudied, especially in the context of healthcare. In accordance with the micro-foundations agenda, human capital resource emergence is essential in comprehending how human capital integrates to create a valuable unit-level resource, wherein the sum of human capital produces results that surpasses what can be explained by the sum of its individual components (Steve WJ Kozlowski, 2019).

During last seven decades, Human capital theory has evolved in multiple perspectives (Goldin & Katz, 2024). Beginning from the economist approach for economic gains to the organizational sustainability, human capital has been widely discussed in the literature (Becker, 1962; Nyberg et al., 2018). According to Ray, Essman, et al. (2023) human capital theory is an individual-level paradigm and was not sufficient to explain the variances across various levels. As a consequence, the longstanding discipline saw the birth of a unit-level modern component, i.e., Human capital resources (Ployhart et al., 2014). Interestingly, there is insufficient evidence on the creation of Human capital resources and a lack of clear understanding of the mechanism of multilevel value creation at a unit level (Ray, Nyberg, et al., 2023).

Centred on the interplay of many individuals, emergence research into human capital resources have resulted in a new era of inquiry into social processes within last twenty years (Harris et al., 2018). Current literature explains the emergence in a general and obscure manner during the transformation of individual human capital into unit-level human capital resources and the process is unclear (Jun et al., 2024). As elucidated by Felin et al. (2015), “in all, the notion of ‘emergence’ remains vague and thus opportunities remain for both micro and macro disciplines to carefully specify the underlying actors, social mechanisms, forms of aggregation, and interaction that lead to emergent outcomes” (p. 606). Ployhart and Moliterno (2011) have argued that in order to comprehend *how, why, and when* HCR arises from human capital, a multilevel approach that incorporates emergence is necessary.

Healthcare systems are complex (Tulchinsky & Varavikova, 2014). The multidisciplinary approach in healthcare indicates that individual capabilities should merge, and adoption of technology should be considered as a collective act of all the actors involved in the delivery of care. To establish a full understanding of the process of human capital resource emergence, where an individual level human capital (Knowledge, Skills, Attributes and Other characteristics - KSAO) is transformed into a unit-level resource, the literature is scarce and there is a pressing need to investigate this phenomenon, (Eckardt et al., 2021), especially in healthcare. Although healthcare is introducing technologies but the promise of these technologies like increasing the efficiency, enhancement of the patient experience and reduction of the healthcare providers burnout should be further evaluated and analysed. Because healthcare professionals are equally interested in adopting technology if there are positive effects on clinical outcomes of the patients and reduction in their mundane tasks.

The COVID-19 pandemic not only had dreadful effects on people and society, but it has also increased the need for incorporating technological solutions in healthcare at a pace that has never been seen before (Clipper, 2020; Okolo et al., 2024). Based on this increasing demand of technology in healthcare, recently the Tech giants such as Apple, Microsoft, Google, IBM and Oracle are leaning towards penetrating the healthcare industry, placing large bets on a promising return on investment (ROI) in coming years (Juttukonda, 2024; Rikap, 2022). However, implementation of technology in healthcare is facing deployment blockage due to lack of comprehensive frameworks and systematic approach (Reddy, 2024). Healthcare is unique and deeply interdependent where highly qualified individuals with cultural diversity work together closely into interdisciplinary teams to deliver safe patient care (Uman et al., 2022). Complex Healthcare systems involve a very wide variety of participants with variant levels of knowledge, skills and authority (Grol & Wensing, 2013). The more complex and dynamic a system is, the higher the need for a systemic approach for the deployment of the technology into those systems (Lappalainen, 2019). Akin to other industries, healthcare has barriers for technological deployment but due to interdisciplinary approach and human life at stake, the complexity grows to a critical point.

During the last three decades, technological developments have been accepted, not only as a source of value generation, but also as a source of profitability in many industries (Blichfeldt & Faullant, 2021). For systematic and sophisticated deployment of a technology into a complex system like healthcare, Ployhart and Moliterno (2011) has emphasized that for adaptability, coordination is necessary for complex tasks and context-generic human capital resources. These tasks are based on general cognitive ability, personality, values, and interest, and these are active ingredients of the establishment of context-specific human capital resources. According to Beane and Orlikowski (2015), a new technology in a healthcare system (introduction of the robotic or telepresence) should be accepted as an implementation of a new practice through institutionalization, to incorporate it with the complex, dynamic, and distributed work in a hospital setting. However, guidelines that guarantee data security and patient privacy must go along with successful technological adoption and dissemination (Liu & Miguel-Cruz, 2022).

Recently, benefits of emerging technologies are being widely and extensively discussed in medical and academic research (Galbusera et al., 2019), particularly post pandemic COVID-19 (Junaid et al., 2022; Krishnamoorthy et al., 2021; Licardo et al., 2024; Olalekan Kehinde, 2025), highlighting the importance of usage of these technologies to improve healthcare systems' efficiency. But consumer receptivity (clinicians and patients) remains underexplored (AlQudah et al., 2021; Lee et al., 2025; Rudawska et al., 2024; Tekkesin, 2019). Rudawska et al. (2024) have argued that by additional and improved usage of emerging technologies can perceive inaccuracies and resolve matters in a speedy manner for the dynamic healthcare system and will be cost effective.

Bamel et al. (2023) have expressed the pressing need to investigate the factors that facilitate implementation of the emerging and transformative technologies. Successful establishment and integration of emerging technologies in any field is possible by overcoming the gap among the developers and the users (Proksch et al., 2019). Many researchers have documented that the technology development often presents the challenge of poor value alignment between supply-side and demand side (Greenhalgh et al., 2018; Lehoux et al., 2017; Markiewicz et al., 2014). It is important to note that the work attitude of healthcare professionals and technology developers is different, which acts as a hindrance in finding solutions for medical related problems and adaptation of new technologies (Anwar & Prasad, 2018). Physicians and nurses are the front-liners of healthcare and success of the technology deployment depends on their level of adoption. By effectively utilizing these human resources in the healthcare, initiatives for adopting cutting-edge technologies can be implemented more smoothly (Prajogo & Oke, 2016) and can lead to sustainable future developments (Cavicchi, 2017). To meet the challenges of new technology deployment will require experimentation, dialogue, and continuous monitoring of the change (Schartinger et al., 2015). Hence, it is crucial to directly involve healthcare professionals during the development and deployment of a healthcare technology as a stakeholder (Anwar & Prasad, 2018; Heijsters et al., 2022). Because acceptance and adaptability by the professional staff can be considered as the single most important determinant which will decide the fate of a new technology (Aryee et al., 2024; Gheorghiu & Ratchford, 2015; Wade et al., 2014).

In general, implementation of new technologies requires a holistic view and approach, keeping all processes, actors and factors into consideration. Particularly in healthcare, preparing the Human capital, the healthcare professionals, to embrace the impact of forthcoming emerging technologies through proper training, availability of social, technical and intellectual support is the need of the time. Inadequate technological adoption or limited adoption without a systematic approach or framework will not yield the anticipated advantages and outcomes in healthcare. Currently, multiple technologies are being developed and utilized in healthcare industry, however, a model or framework for the deployment of these emerging technologies into sophisticated healthcare systems is notably absent.

This thesis has taken into consideration the importance and necessity of Human capital resources and capability building at a micro-level in a healthcare setting (surgery department) for co-specialization of Surgeon and the surgical team with minimally invasive robotic surgery. We have studied the emergence of new skills and work design of the surgical team at the unit level with the deployment of surgical robots, resulting into successful technology integration and human capital resource emergence among surgeons and surgical teams to perform Robot-Assisted Surgeries (RAS) safely and successfully, prioritizing patient safety and clinical efficiency. We have developed a model which will systematically guide the future successful technology integration in healthcare. The selection of the surgery department for this research is based on the fact that during the last three decades the most widely accepted technology in healthcare is the surgical robot (De Ravin et al., 2023; Ginoya et al., 2021).

Healthcare human capital greatly needs capability building in relevance to co-specialize with emerging technologies. This change is inevitable and demands prompt attention. Strong scarcity of reliable literature and its systematic contextual analysis on the topic of healthcare human capital resource emergence and Human robot co-specialization indicates a fertile ground for future research. It is momentous to identify the need for an established theoretical framework or a process design to expedite the valuable implementation of the emerging technologies in the dynamic yet complex healthcare system. Healthcare industry was embracing the impact of new technologies pre-pandemically and in this COVID-19 post-pandemic era, the urge and pressure is growing (Schurmann et al., 2025). Healthcare professionals are also acknowledging the need of technological adoption (Yousif et al., 2024) and parallelly Tech companies are pouring money and resources into development of new technological solutions for healthcare (Juttukonda, 2024).

The transitional approach required for a new technology demand taking the interests and perspectives of all stakeholders into account. For the successful and profitable deployment of the emerging technologies (like robots) into the healthcare systems, the adoptability by all the players is extremely essential. Nevertheless, there is a pressing need to further study the behaviours, enablers and inhibitors that influence the acceptance of the advanced technologies. A deeper need exits for bridging the gap in the deployment process through the establishment of systematic and organised approach keeping the focus on users (healthcare professionals) and the receivers (patients). This will require understanding of Human capital resource emergence and deep focus on co-specialization of Humans with machines to achieve effective and thorough outcomes in the cross-functional and intricate healthcare systems.

Healthcare Industry Prevailing Challenges Healthcare is already facing multiple challenges that are prevailing and growing (Yakubu et al., 2022). Globally, most of the healthcare institutes are facing similar issues or challenges (Roppelt et al., 2024; Tortorella et al., 2020). Use of technology in care delivery can be a substantial solution to overcome these challenges. The most pressing issues of healthcare industry are discussed below, necessitating prompt action, and adoption of technology can mitigate these challenges significantly.

(a) **Rise of Chronic Diseases:** Increasing population and upsurge in the health issues and diseases further aggravates the consequences (Guntur et al., 2019). Diabetes, cancers, cardiovascular and respiratory diseases are chronic in nature and require continuous management (Meetoo, 2008). The population affected by chronic diseases is on rise, therefore increasing the pressure on the healthcare systems and demanding more trained healthcare professionals to manage the population (Claessens et al., 2024). In 2010, chronic diseases attributed to 67% deaths globally, increasing to 74% in 2019 and further climbing during pandemic COVID-19 (Thomas et al., 2021). Increasing population, increase in the average life expectancy and upsurge in the health issues and diseases, with existing physician shortage, further aggravates the consequences (Guntur et al., 2019; Lanza et al., 2020).

(b) Pandemic COVID-19: On 30th January 2020, World Health Organization (WHO) announced COVID-19 as 'emergency of international concern' (WHO, 2020). Global Healthcare systems were under-prepared to be exposed to the unanticipated pandemonium of COVID-19 pandemic (Deer et al., 2020). This not only created a state of emergency worldwide, yet it also created chaos for governments, practitioners and patients. On March 11, 2020, the World Health Organization (WHO) announced COVID-19 as 'pandemic' (WHO, 2020). An end to this public health emergency was declared on May 11, 2023 (WHO, 2023). Only in the span of three (3) years, the COVID-19 pandemic has severely affected healthcare, posing a significant concern for world economy. The pandemic not only devastatingly hit the financial stability, but it also greatly impacted the healthcare professionals, both physically and psychologically. It aggravated the disease burden, intensified the healthcare professionals shortage and probed the threat of failure to the healthcare industry (Coccia & Benati, 2024; Kaye et al., 2021; Liu et al., 2022; Wang et al., 2020).

(c) Shortage of Physicians and Surgeons: It is a prevailing, rising and core problem, which is posing threats to healthcare industry (Harp, 2022; Heponiemi et al., 2019; Michaeli et al., 2024; Scannell et al., 2021; Sheldon, 2011; Stephens, 2025; Williams & Ellison, 2008; Yakubu et al., 2022). Increasing population and upsurge in the health issues and diseases is further aggravating the consequences (Guntur et al., 2019). It is estimated that by the year 2050, 22% of the population will reach the age of sixty-five (65) or above (Di Nuovo et al., 2016). It is projected that by the year 2030, there will be further shortage of physicians (Zhang et al., 2020). During pandemic, this shortage has further grown and is becoming an exacerbated global issue (Abdel-Razig & Stoller, 2025; Krasna et al., 2021; Mbunge et al., 2022; Riaz et al., 2021). Collaborators (2022) conducted detailed analysis on migration of physicians from Low-income countries to higher income in last forty years. They have highlighted this migration has expedited post pandemically and resulting into disparities and inequalities. Global Burden of

Disease Study projected that the world is facing the shortage of 6.4 million Physicians (Collaborators, 2022).

The scarcity of Surgeons is prevalent in both urban and rural regions, with a greater intensity in rural areas (Khoury Stephanie, 2022; Stringer et al., 2020). Due to stress, extended hours and discomfort during the procedure, surgeons are choosing for early retirement in many specialities, hence compounding the current shortage (Jella et al., 2023; Mahoney et al., 2020; Morton & Stewart, 2022; Soriano et al., 2022). World Health Organization (WHO) revealed disproportion between current and required healthcare work force for future, estimating a global shortage of eighteen (18) million Health care providers which are required to achieve the sustainable development goals for healthcare by 2030 and has urged the need for digital education for healthcare professionals (WHO, 2020). Due to a lack of skilled healthcare workers globally, healthcare resources can be stretched by the adoption of new technologies (Zimlichman et al., 2021).

(d) **Burnout of Healthcare Professionals:** Freudenberger (1989) have explained that burnout is an emotional and behavioural impairment which is characterized by mental fatigue, depersonalization, and lower sense of personal achievement. Professional burnout typically means continuous stress that hinders an individual's ability to exhibit professional responsibilities under challenging circumstances (Chetlen et al., 2019). It is prevalent among healthcare professionals and particularly physicians are most affected globally (Sequeira & Aish, 2023; Shanafelt et al., 2015; Van Mol et al., 2015; Zambrano-Chumo & Guevara, 2024). Working conditions are stressful in healthcare where physicians are continuously involved in listening to health complaints, taking critical decisions and making crucial judgments on treatment plans of their patients with ongoing resources constraint. Feeling overwhelmed in the demanding job is emotionally draining for healthcare professionals (Batanda, 2024). Emotional exhaustion has contributed to the intellectual challenges among surgeons, leading to medical errors (Chahal & Matwala, 2025). Consequences of burnout encompasses clinical errors, patient dissatisfaction, financial and reputation loss to the health institute (Hodkinson et al., 2022; Lee et al., 2024).

Current state of research and remaining gaps. Human Capital (HC) is defined as an individual's knowledge, skills, abilities, experiences, and other characteristics that one might leverage to achieve a desired outcome (Ployhart & Moliterno, 2011). Human Capital Resources are individual, or unit-level capacities based on individual knowledge, skills, abilities and other characteristics (KSAOs) that are accessible for unit-relevant purposes (Ployhart & Hale, 2014). Importance of Human Capital Resources (HCR) is well acknowledged in the management research; however, literature does not provide sufficing evidence on the process of emergence of human capital resources (Jun et al., 2024). Human Capital Resource Emergence (HCRE) is a situation where a group of individuals, with all their relevant human capital, jointly emerges into a unit-level human capital construct (Ployhart & Moliterno, 2011). Although, during last few years there is evidence of progressive research on human capital resource emergence, yet it requires further exploration (Eckardt et al., 2021; Ray, Essman, et al., 2023). Human capital resource emergence is overall in the early stages of exploration and under-studied, especially in the context of healthcare. Distinctively, it is scarce in the context of technology deployment process in general and particularly in the healthcare domain. To gain understanding and to establish a full comprehension of the process, where an individual-level KSAO is transformed into a unit level resource, the literature is limited and there is a pressing need to investigate this phenomenon (Eckardt et al., 2021).

The global diffusion of common technologies was linked to the COVID-19 pandemic's early phase in 2020. Technological transformation enhances organizational agility and eventually elevates competitiveness (Chatterjee & Mariani, 2022). It is becoming more prevalent that the emerging technologies, like robotics, artificial intelligence (AI), big data are the most agile and forward-thinking resources for improvisation of the healthcare (Junaid et al., 2022). These technologies can enhance the quality and efficiency of healthcare and can have a significant impact on the cost as well (Zemmar et al., 2020). These approaches can lead to reliable preventive care which can revolutionize healthcare organizations, resulting into the positive impact on the public health outcomes (Thacharodi et al., 2024). Nevertheless, technology deployment in healthcare has been hindered, a problem that is intensifying due to the increased demand of usage of new technologies. This issue has remained understudied in healthcare and is deficient in practical, holistic and innate frameworks (Cresswell et al., 2020).

Today's emerging technologies will be shaping the future of the tomorrow's world and there is a timely need for the adoption of those technologies (Adler et al., 2016; Licardo et al., 2024). Automations based on artificial intelligence, robotics, big data and the internet of things (IOT) are the bright realities of today. Because emerging technologies are believed to enhance productivity and the quality of life (Iizuka & Ikeda, 2019), the deployment of new technologies has a direct impact on both employees and organizations (Sima et al., 2020). These challenges are not limited to development and improvisation of the new technologies but are more prevalent in the arena of adoptability and adaptability of these new technologies for successful implementations into the existing systems. The complex dynamics of social and welfare sectors, such as healthcare, demand a systemic approach for the deployment of the robots into those systems (Lappalainen, 2019). To embrace the challenges of new technology deployment, there is a need for continuous monitoring of the adoption process (Schartinger et al., 2015). Grisot et al. (2017) have suggested a deeper need for 'sociotechnical sensibility' for the smooth translation of emerging technologies into healthcare. Sociotechnical dynamics requires a comprehensive and contextual understanding of human interaction and experience with machines (Riedl, 2020). Thus, understanding and managing people's attitudes and behaviours in response to technological change are both necessary for successful implementation (Lennon et al., 2017).

According to Cong (2021), seven out of ten healthcare institutions have adopted or are considering adoption of emerging technologies in the United States of America and the United Kingdom. In the same report, it was highlighted that seventy eight percent (78%) of healthcare business leaders have revealed that with the deployment of technologies in healthcare, workflow improvements in operational and administrative activities have been observed. Cong (2021) further alleged that, to thoroughly embrace new technologies, the business models of healthcare systems will require adjustments. One of the most important issues facing health care provider organizations today is addressing the factors that promote value-based care; that list also includes enabling health care technologies (Garrison et al., 2018; Nguyen et al., 2023). Utilisation of these technologies is providing more time to clinicians to work more closely with their patients, thus facilitating the efficient delivery of care (Haleem et al., 2022; Okolo et al., 2024). Healthcare managers understand that becoming a preferred provider requires offering a streamlined and consistent patient experience, which is possible with the integration of technologies. Governments, scientists and physicians are investigating the importance of the deployment of robotics in healthcare (Karaferis et al., 2024).

It is necessary that recognizing and monitoring the progression of application of new technology in an industry, particularly in healthcare, should start with an in-depth analysis of the challenges and development of supporting policies, particularly in terms of liability (De Micco et al., 2024; Fosch-Villaronga et al., 2021). A crucial obstacle while implementing new technologies in healthcare systems is the adoption of the emerging technology by the front-liners (healthcare professionals), not the technology itself (Zemmar et al., 2020). Many researchers have documented that health technology development often presents the challenge of 'poor value alignment' between the supply-side and demand-side (Greenhalgh et al., 2018; Lehoux et al., 2017; Markiewicz et al., 2014). Lanza et al. (2020) noted that, due to the dynamism of clinical practice and the demand for full autonomy in healthcare for patient treatment, the technology developers can't identify and plan for all possible situations. It is interesting to note that healthcare professionals are underestimated as facilitators of technology; however, technology developers should consider them as the main stakeholders of an emergent technology (Timmis, 2021).

To face the current and future challenges, multiple potential implementations are being proposed to utilize robots in healthcare (Yang et al., 2020). This approach to the integration of robots into the health system will not only improve the lives of the vital healthcare professionals, but it will reduce the cost of healthcare in the long term, while simultaneously improving efficiency (Yang et al., 2020). According to the current literature analysis, there have been numerous studies focused on the integration of robots in the manufacturing industry, while robotics is still considered new to the healthcare industry. In recent times, surgeries assisted by robots are becoming the norm (Hettiarachchi et al., 2023). However, inclusion of robots into the service in healthcare systems is still at the stage of infancy and process forward is still unclear.

However, this implementation of emerging technologies such as robotics has posed serious adoption challenges for healthcare professionals. It is important to avoid the abrupt implementation of a new technology into the healthcare system; the organization must establish a conducive culture to adopt and adapt to the change (Kim, 2022; Lee, 2018). There is a link between an individual's propensity to adopt new technologies and their perception of the organizational culture (Melitski et al., 2010); particularly, the switch from conventional minimally invasive procedures to robotic surgery is a significant step and requires a clear understanding of behaviour and the development of enabling supportive culture for the implementation of surgical systems(Cunningham et al., 2012). Previously, there was evidence of refusal, resistance and lack of interest in accepting the robots for patient care, both by health care providers and by patients and their families (Krings & Weinberger, 2018; Pekkarinen et al., 2020). But during the pandemic, robotic systems came to be considered as a clinical advantage for the optimization of healthcare resources (Lawrie, Gillies, Davies, et al., 2022; Moawad et al., 2020). A rise in the acceptance of surgical robots has also been observed and, post-pandemic, the number of robotic surgeries increased (Zemmar et al., 2020). However, the process of adoption and implementation of robotics in surgery remains underexplored (Giedelman et al., 2021).

In the last decade, many studies have focused on the benefits of robot-assisted surgery, training of surgeons, technology enhancement, perspectives of healthcare professionals and patients, and comparisons of robotic surgery with traditional and laparoscopic procedures. Yet, little attention has been paid to human factors-based research, which simultaneously captures the surgeon`s training, the surgical team`s training, adjustment to new work design and specialization with the machine. Hence, there is an enormous need to study and evaluate the implementation process of this emerging technology and its impact on the current and future human capital of the healthcare. This collective approach investigation will aid in better understanding the perspectives to build comprehensive framework and corresponding HRM policies and practices to embrace the consequences of deployment today and challenges of forthcoming technologies.

Research Question. The research question for this study is “How Human Capital Resource emerges and evolves for the surgical team with the deployment of robotics?”

Research aims and objectives. This research examines the social and behavioural aspects of human capital resource emergence for the deployment of robotic technology in the surgery department. This investigation delves into broader issue of technology deployment in healthcare, with the goal of investigating the process of human capital resource emergence in a healthcare setting for co-specialization of the surgeon and surgical team with the robotics in the surgery department.

The **objectives** of this study are:

1. To provide the theoretical grounding of Human Capital Resource Emergence (HCRE) by investigating the under-explored process.
2. To explore the process of Human Capital Resource Emergence (HCRE) in the co-specialization of a surgical team with robotics.
3. To develop a Human Capital Resource Emergence (HCRE) framework for adoption of technology in healthcare.
4. To recommend practices for healthcare policy makers, HR personnel, decision makers and technology developers to facilitate the technology integration into the health system.

To achieve these objectives, we have adopted a qualitative approach; using an interview guide, semi-structured interviews were conducted with surgeons who are currently performing robot-assisted surgeries (RAS) upon completion of training. The 35 interviewed surgeons belonged to multiple specialities and are in different regions (Australia, Europe, India, Malaysia, Middle East, UK and USA). Data analysis was performed through Gioia methodology by sifting interview data into 1st and 2nd order codes.

Scientific novelty and contributions. This thesis makes several contributions to the literature. Firstly, it explores the process of technology (Robotics) deployment in a healthcare setting and adds to the technology adoption research in the healthcare context. Secondly, the study extends Human Capital (HC) and Human Capital Resource (HCR) by exploring the Human Capital Resource Emergence (HCRE) process in healthcare domain. Thirdly, this study contributes to the Human Capital Resource (HCR) literature by disclosing the process of emergence of human capital resources among surgical teams during the adoption of robotics, an emerging technology. Fourthly, it contributes to the healthcare management literature by revealing the process of implementation and integration of emerging technology into healthcare systems. This social sciences thesis is directed towards the robotics learning ‘process’ of the surgeons and surgical team rather than the learning ‘curve’ of the surgeon. Lastly, the findings and recommendations of this research are being addressed to the healthcare industry, the technology industry, and the management research to overcome the resistance and deployment blockage of the technology in the healthcare industry.

Practical Implication: The results of this study will aid in understanding the existing process of Human Capital Resource Emergence (HCRE) and will provide clarity on the facilitators and roadblocks of the technology deployment in the healthcare. The investigation will assist in advocating a sophisticated model/framework for future technological implementations in health systems. It is addressed to healthcare human resource managers (HRM) and policy makers to develop policies, strategies, and culture to achieve the successful implementation of technology and desired outcomes/value with optimization of resources. In addition, this research serves as a guide to technology developers in the practice of system thinking and allows them a better understanding of healthcare professionals' (end user) behaviours, challenges, and work design, which can aid them to develop and upgrade technologies following healthcare providers needs and compatibility of usage.

1. THEORETICAL GROUNDING

This research is grounded in Human Capital theory, exploring the transformation of human capital into human capital resources through emerging technologies like robotics. Human capital, a socially complex resource, is vital for economic development (Goldin & Katz, 2024). Investments in education and training enhance national productivity (Kell et al., 2018). At the organizational level, human capital drives innovation and competitive advantage (Mahoney & Kor, 2015). The World Economic Forum highlighted human capital as a determinant of long-term success (WEF, 2013). Human capital encompasses competencies, attitudes, and intellectual agility, fostering internal relationships and knowledge exchange (Scarbrough & Elias, 2002). Definitions have emphasized the value added by human capital to organizational sustainability (Tracey & Bronstein, 2003; Thomas et al., 2013).

1.1 Analysis of Human Capital Theory

Human capital theory, introduced by Becker (1964), emphasizes the economic value of individuals' knowledge, skills, and abilities. It posits that investments in education and training enhance productivity and national income (Becker, 1975; Schultz, 1961). The theory has evolved to address workforce deficiencies and align human capital with national development goals (Kell et al., 2018). At the organizational level, human capital is defined as the stock of skills and competencies that contribute to sustainable competitive advantage (Goldin, 2016; Mahoney & Kor, 2015). The World Economic Forum (2013) highlighted human capital as a determinant of long-term economic success. Human capital theory underscores the importance of developing competencies, attitudes, and intellectual agility to foster innovation and internal relationships (Scarbrough & Elias, 2002). It remains a cornerstone for understanding the role of human capital in organizational and national growth.

The term “human capital” refers to the economic worth of an organization's workforce as a whole, including their abilities and the quality of their work. It is the stock of skills that the labour force possesses (Goldin, 2016). It has been discussed in the economics, HR, strategy, accounting, and psychology literature, with each field's research utilising slightly different language and making a variety of assumptions (Ployhart & Hale, 2014). Over the past six decades, academics have extensively emphasized the significance of investment in the human capital. The

World Economic Forum (WEF, 2013) emphasized that a nation’s human capital endowment, the skills and capacities that reside within its people, can be a more important determinant of its long-term economic success than virtually any other resource. Thus, Human Capital theory underlines the concept of developing the skills and knowledge of the employees by investing in learning through education or training (Hatch & Dyer, 2004; Riley et al., 2017). These resources can be of three main types: competencies, attitude, and intellectual agility. The Glossary of Human Resources defines human capital as the benefits of loyalty, creativity, effort, goals, and output an organization receives from the productivity of the employees (Tracey & Bronstein, 2003, p.). Similarly, Thomas et al. (2013) defined human capital as the “people, their performance and their potential in the organization” (p. 3). As claimed by Scarbrough and Elias (2002), “[a] theory of human capital places emphasis on how employee competencies create value for the organization” (p. 10). In summary, the ‘human’ component of human capital refers to the ‘creator’, an individual who employs and applies the knowledge, skills, competency, and experience that develops through a continuous interaction with the surroundings wherein it exists.

1.2 Human Capital Resources

Human capital resource research originates from Human Capital theory (Becker, 1964), evolving to address unit-level dynamics beyond individual capabilities. Ployhart and Moliterno (2011) introduced the term "human capital resource," defining it as unit-level capacities derived from individual KSAOs (knowledge, skills, abilities, and other characteristics). This concept emphasizes strategic utilization for competitive advantage (Nyberg & Wright, 2015). Human capital resources (HCR) are unit-level capacities derived from individual KSAOs that contribute to organizational outcomes (Ployhart & Hale, 2014). They influence customer satisfaction, productivity, and employee turnover (Harter et al., 2002). HCR research focuses on strategic outcomes and sustainable competitive advantage (Nyberg & Wright, 2015). The transformation of individual KSAOs into unit-level resources requires alignment with organizational goals (Kazlauskaite & Buciuniene, 2008). HCR is pivotal to addressing unstable environments and achieving firm-specific performance (Ployhart, 2021). However, despite its recognized value, further exploration of its emergence process is needed.

1.3 Human Capital Resource Emergence

Human capital resource emergence involves the transformation of individual KSAOs into unit-level resources through social interactions (Ployhart & Moliterno, 2011). This process is influenced by behavioural, affective, and cognitive states (Ray et al., 2021). Emergence enables the aggregation of individual traits into collective phenomena, amplifying organizational value (Klein & Kozlowski, 2000). Challenges include enabling conditions, social context, and measurement issues (Harris et al., 2018). The emergence process is critical to gaining an understanding of human capital's impact on organizational performance, particularly in healthcare settings during technology adoption.

Healthcare professionals represent the human capital of healthcare systems, working in multidisciplinary teams to ensure safe patient care (Schmidt et al., 2023). Challenges include enabling conditions, social context, and measurement issues (Harris et al., 2018). Physicians, often untrained in leadership, act as decision makers in multidisciplinary teams (Kozlowski et al., 2016). Industry 4.0 and the pandemic have amplified the need for human capital resources to emerge to embrace emerging technologies effectively (Jose et al., 2023). Exploration of this transformation process is essential for technology adoption in healthcare settings.

1.4 Capacity Building

Capacity building enhances skills and the knowledge to adapt to new technologies and work designs (Smith et al., 2011). Defined by the UNDP (2002), it involves developing abilities to address development needs sustainably (Ionel, 2017). It fosters creativity, adaptation, and efficiency, aligning human capital with technological advancements (Chaskin, 2001). Generative capacity supports organizational goals by expanding abilities and resources (Baker & Dutton, 2017). In healthcare, capacity building addresses strategic change management and social capital integration for technology adoption (Petersson et al., 2022). It is a proactive approach essential for the co-specialization of human capital with technology. It is a proactive approach, crucial for the co-specialization of human capital with technology (Kim et al., 2019).

1.5 Social Capital

Social capital refers to features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit (Putnam, 1995). Fukuyama (2002) defined social capital as an informal norm promoting cooperation between individuals. It acts as a catalyst for leveraging human capital, enabling individuals and groups to achieve more collectively than individually (Coleman, 1990; Swanson et al., 2020). Social capital creates environments conducive to learning, cooperation, and mutual support, crucial for advancing human capital (Coleman, 1990; Lee et al., 2015). It plays an ambidextrous role in human capital resource emergence, facilitating access to opportunities, information, and support networks, which enhances access to opportunities and information, influencing human capital resource emergence (Dinda, 2014). Social capital facilitates coordination and cooperation through networks, norms, and trust (Putnam, 1995). However, despite its recognized significance, research on its construction and preservation remains insufficient, particularly in healthcare settings during technology adoption (Al-Omoush et al., 2022; Zhang et al., 2019).

1.6 Resource Co-Specialization

Resource co-specialization involves aligning interdependent assets to achieve competitive advantage (Teece, 1986). It emphasizes cooperation and competitiveness to foster innovation (Teece et al., 1997). Co-specialization requires reskilling and upskilling human capital to adapt to emerging technologies (Beane, 2018). It creates unique, valuable combinations of resources that are difficult to imitate, supporting organizational growth and sustainability (Kim et al., 2019; Teece, 2007).

1.7 Robot-Assisted Surgery

Robot-assisted surgery (RAS) is minimally invasive and exemplifies the application of robotics in healthcare, offering improved outcomes and reduced recovery times. It demands specialized training for surgeons to adapt to robotic systems, emphasizing human capital resource emergence (Ray et al., 2021). The adoption of robot-assisted surgery highlights the importance of aligning human capital with technological advancements to achieve optimal patient care.

A robot-assisted surgery or robotic surgery is defined as “[a] computer-controlled manipulator with artificial sensing that can be reprogrammed to move and position tools to carry out a range of surgical tasks" (Dasgupta et al., 2005, p. 20). Robot-assisted surgery means that an expert surgeon, positioned at a console, performs a minimally invasive procedure (MIS) by controlling the robotic arms with extreme precision (Howard et al., 2022). Minimally invasive surgery (MIS) is one in which small, yet multiple incisions are made to utilize the surgical instrument at the site of the procedure. Due to 3-D cameras, the visibility of organs and vessels is very clear and results in less or no damage to the surrounding organs (Andrade et al., 2014).

1.8 Conclusion of Literature Review

Based on the above in-depth literature analysis of multiple theories and concepts, it is evident that, to fully understand the process of deployment of a technology and its acceptance by the individual surgeons, as well as the emergence of skills and knowledge at the unit level by the surgical team, further inquiry should be directed at the evolution and emergence of the micro-level human capital of the surgical unit. There is a gap in the literature on human capital resource emergence theory, in which the significance of human capital resources (HCR) is well recognised, while the creation process remains inadequately understood. During this analysis of the literature, it was also observed that most of the past research revolved around topics of surgeons’ training, clinical outcomes, and benefits of minimally invasive robotic surgery.

Capacity building is a proactive strategy and a prerequisite for the co-specialization of human capital with technology. Only a handful of studies have investigated this concept in terms of the technology implementation in healthcare. Similarly, the role of social capital in the context of structural, relational, and cognitive aspects has been examined in general, but not as an enabler of human capital resource emergence in the healthcare industry. Due to the deeply integrated work styles of members of the healthcare industry, this holistic approach is indispensable and yet has not been thoroughly investigated. Through the literature review, we have presented a detailed discussion on the differences between traditional and robotic surgery. This was intended to provide a clear understanding of the situation for the readers, particularly those who do not belong to the healthcare industry or may have little knowledge of the work dynamics of a surgical procedure in the operating theatre of a hospital.

Lastly, this literature review has also made it apparent that very few researchers have focused on team collaboration and communication. Many studies have highlighted the benefits of the RAS and features of the robotic arm, but recent literature has been focused on the examination of technological advancements and further augmentation of the robotic arm with additional emerging technologies such as AI and 5G. Very few recent studies have focused on the challenges of the humans involved in robotic surgery, nor have they recommended a theory-based and humanistic approach for future explorations. Hence, it is noticeable that the full process of robotic surgery adoption in the surgery department has not been studied in the light of the emergence of human capital resources.

2. RESEARCH METHODOLOGY

The thesis investigated the process of integration of robotic systems in healthcare, emphasizing the emergence of human capital resources within surgical teams. Using a qualitative methodology, the study explored the challenges faced by surgeons transitioning from traditional surgical practices to robot-assisted procedures. Data collection involved semi-structured interviews with 36 surgeons (7 female and 29 male) across 13 countries, representing diverse specialties such as gastroenterology, cardiology, and urology. The interviews, conducted between 2021 and 2025, aimed to capture the surgeons' experiences, learning journeys, and perspectives on robotic adoption (Lincoln & Guba, 1985; Myers, 2019). The Gioia methodology was employed for systematic data analysis, facilitating the identification of first-order codes and thematic categorization (Gioia et al., 2012; Magnani & Gioia, 2023). This approach enabled the construction of a descriptive framework reflecting the surgeons' insights and the dynamics of individual and team-level co-specialization with robotic technology.

This study underscored the importance of epistemological constructionism in understanding the interplay between human behavior and technological adoption (Crotty, 1998; Lincoln & Guba, 2016). It highlighted the role of qualitative research in capturing nuanced perspectives and fostering knowledge translation. The findings advocate for targeted training programs to bridge skill gaps and support the effective deployment of robotics in healthcare. This research contributes to the development of frameworks guiding future technological integrations in healthcare settings.

3. RESEARCH FINDINGS

This research found that surgeons need additional knowledge and skills to adapt to robot-assisted surgery, such as refined hand movements and clear communication. Self-motivation and support from experienced surgeons and hospital administration were crucial to the adoption of robotic surgery. Most surgeons were initially trained in traditional surgery, then transitioned to robotic surgery. They took an active approach towards robotics, dedicating time and effort to training their teams and enhancing their human capital. Robotic surgeons prioritized training their teams to align with changes in work dynamics with surgical robots, focusing on knowledge, skills, and communication to give team members self-confidence and assist them in adjusting to new work styles.

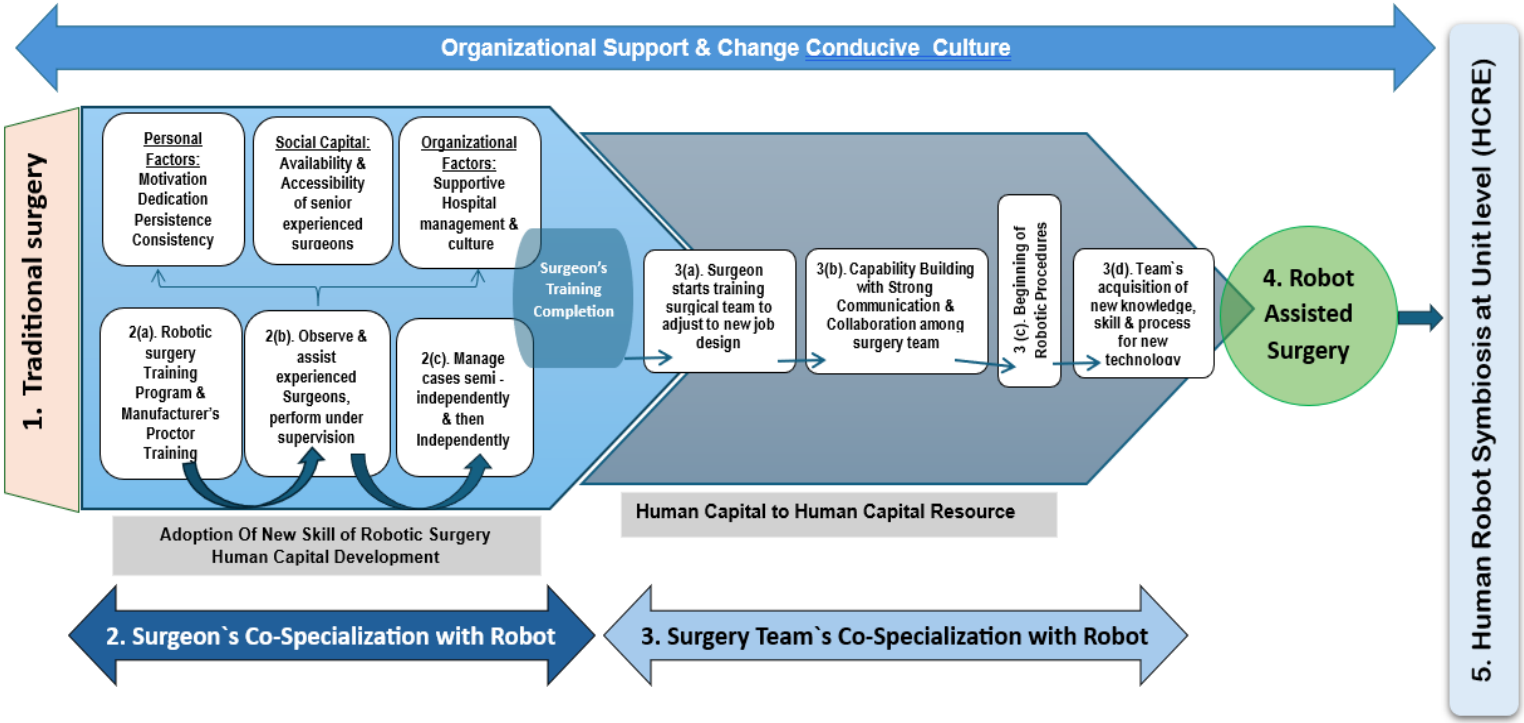
After completing their certification and credentialing processes, surgeons conducted internal training and invited nurses to attend sessions with them and machine manufacturers abroad. Surgeons also highlighted the importance of traditional surgery training and proficiency in human anatomy during the early learning phases of new surgeons. This knowledge and skill would help them convert robotic procedures into open surgery in the case of accidents, machine failures, or related complications. The study highlighted the importance of a systematic approach towards adopting new technology in healthcare, analysing the adoption of robotic-assisted surgery in the surgery department, thus revealing a process of co-specialization. This transition from traditional to robotic surgery and the emergence of human capital resources led to valuable accomplishments for surgeons, patients, health organizations, and healthcare systems.

The emergent model is being explained in four phases, i.e.,

1. Old and new work designs (traditional vs robot-assisted surgery).
2. Co-specialization of surgeons with robots,
3. Co-specialization of surgical teams with robots,
4. Human Capital Resource Emergence – unit-wide adoption of robot-assisted surgery resulting in human/robot symbiosis.

The emergent model is presented in Figure 1 below:

Figure 1. Phases of the Emergent Model



DISCUSSION

The study investigated the Human Capital Resource Emergence (HCRE) process in a healthcare setting, specifically in a surgery department, where robotics is being used for co-specialization of surgeons and surgical teams. The research focused on the end-to-end process of adoptability, adaptability, and acceptance by surgeons and surgery teams. The study also explored the individual knowledge, skills, and attributes (KSAO) required for the transformation of individual skills into unit-level KSAO to allow for successful procedures and better patient outcomes. The research aimed to analyze theoretical implications in the human capital resource emergence literature and provide guidance to healthcare policymakers, HR personnel, and technology developers for future technology deployment in healthcare systems. The results of the study demonstrated that the adoption of new technology in healthcare departments is a multi-dimensional, synergetic, gradual, cohesive, and comprehensive process. The study confirmed previous research, i.e., that emergence originates in individual thought processes and is amplified by the interaction of those individuals, resulting in a higher-level, collective phenomenon.

The study revealed that the deployment of new technology, specifically robotics, in the surgery department created chaos and disruption in the existing healthcare system. Surgeons were motivated to adopt robot-assisted surgery, but the department lacked the knowledge and skills to employ this new technology. This disruption led to the activation of the emergence process, which transformed the individual KSAO of surgeons into unit-wide human capital. This process stimulated collaborative learning of new skills and knowledge among team members, leading to the emergence of a new, structured domain capable of adding value to the organization. The study also highlighted the difference between specific and general human capital, with 'specific' human capital acting as an enabler of the emergence process, suggesting that these concepts should be considered sequentially interconnected, as they are built on Human Capital theory. The research confirmed that human capital resource emergence is a bottom-up approach, whereby individual-level human capital aggregates into unit-level capabilities, contributing to the development of knowledge and skill set through social capital and capacity building.

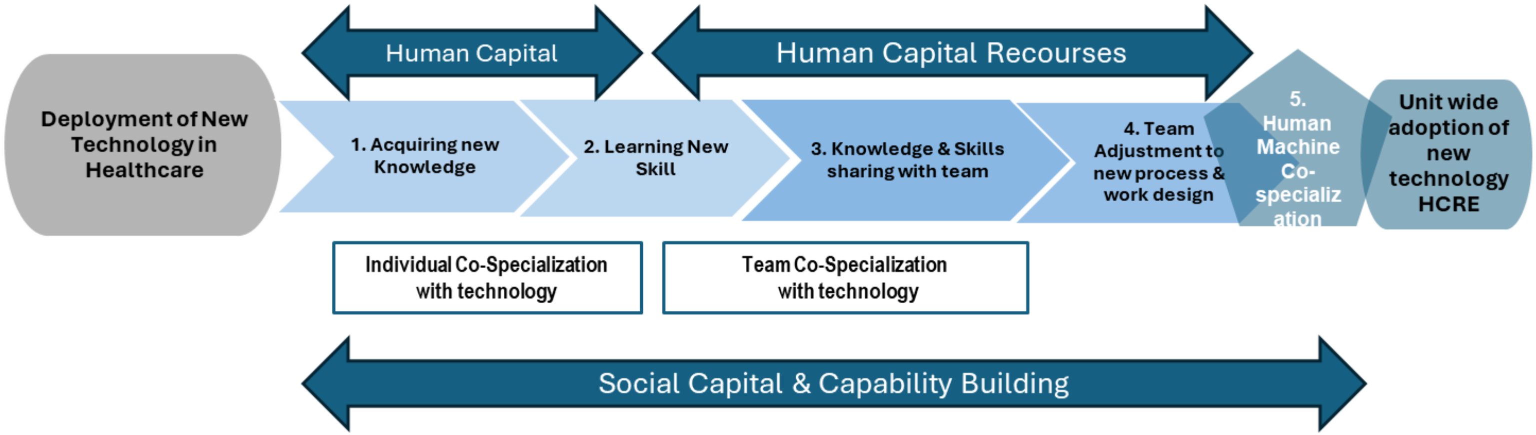
Figure 2. Relationship between Human Capital (HC), Human Capital Resource (HCR) and Human Capital Resource Emergence (HCRE) (Theoretical Contribution)

The success of technology deployment in healthcare depends on the level of adoption by physicians and nurses. The transitional approach required for new technology adoption requires considering the interests and perspectives of all stakeholders. Simultaneous adoptability by all players is essential for the successful and profitable deployment of emerging technologies such as robots and AI in healthcare systems. The direct involvement of insiders during the technology development and implementation process is of utmost importance. The gap between developers and users must be managed for the successful deployment of emerging technologies in any field. Sociotechnical sensibility is crucial for the smooth translation of emerging technologies into healthcare. Acceptance and adaptability by professional staff are the most important determinants of the fate of a new technology.

This research aimed to develop and propose a framework for future technological deployment in healthcare. The model consists of five phases:

1. Acquiring knowledge of new technology on an individual level;
2. Learning and practicing new skills to work with technology;
3. Sharing technological knowledge and skills with the team;
4. Adjusting communications and processes to work with new technology through social interactions; and
5. Unit-wide co-specialization with the new technology of human capital resources, resulting in human capital resource emergence at a unit level.

Figure 3. Phases of Technology Adoption in Healthcare



The healthcare industry must develop technologies that add value and efficiency to routines, involving consultation with healthcare providers. This approach helps developers understand the challenges and requirements of healthcare providers, facilitating the adoption of new technologies. Robotic surgery adoption is a multi-level process, involving all end users, including surgeons, nurses, anaesthesiologists, and technicians, to co-specialize effectively. A successful implementation of technology in healthcare requires a multidimensional and multidisciplinary approach. The transition from traditional to robotic surgery involves factors like individual and team learning, cohesion, communication skills, and adaptability to a new work design. The implementation of robotics in surgery and human capital resource emergence are gradual processes, starting with surgeons and progressing to nurses, technicians, and anaesthesiologists.

Social capital theory and resource co-specialization play a crucial role in the emergence of human capital resources. Experienced surgeons and social interactions facilitate adjustment to new work styles and communication styles, creating value. Therefore, the evolution of human resource emergence for the adoption of emerging technology in healthcare requires the availability of social capital, promoting co-specialization. Traditional surgery differs from robotic surgery, as the entire healthcare team is present in the operating room, requiring close face-to-face communication and collaboration.

Capacity building and social capital are crucial for transforming collaboration for robotic procedures. The surgical team's expertise is essential in operating tools and assessing their suitability for the patient and procedure. Understanding and managing individuals' reactions to technological change is necessary for successful implementation. Healthcare policy makers, HR personnel, and decision makers should develop policies, procedures, strategies, and training with an eye towards the facilitation of robot technology integration. Organizational support and a change-conducive culture are essential for successful robotic deployment. Punitive measures should be avoided, and failures should be treated as opportunities for learning and improvement. Rewarding technology champions and providing experienced staff can also motivate participation. Deployment of robots in healthcare systems will balance demand and supply, prevent the loss of skilled healthcare professionals, enhance efficiency, and relieve burnout. The efficient implementation of new technology in healthcare systems requires training and adaptability by all stakeholders, particularly healthcare providers.

CONCLUSION

1. The process of Human Capital Resource Emergence (HCRE) in healthcare is a bottom-up phenomenon, requiring careful planning and execution. The deployment of technology in that industry requires a system-wide, holistic change, affecting many departments and healthcare providers. HCRE occurs among the 'Specific' human capital, such as the surgery team, which is skilled to perform surgical procedures in different specialities for different diseases and conditions. For Human Capital Resource (HCR) to emerge into a new form, specific or specialized human capital is required. When specific human capital becomes a 'new whole' through the emergence process, it must remain together to maintain this new level of expertise.
2. Healthcare human capital greatly needs capability-building for co-specialization in terms of emerging technologies. Successful pairing of technologies in healthcare is not possible without the emergence of human capital resources. Training the entire team and all impacted departments is crucial for the successful deployment of the technology. A thorough training program for the entire surgery team, including the surgeon, is necessary for acceptance and adjustment to the technology.
3. The study developed a multilevel theory approach to the Human Capital Resource Enhanced (HCRE) process, highlighting the interplay of social capital, resource co-specialization, and capability building. The model starts at the individual-level human capital, demonstrating the emergence of human capital resources, and concludes with the successful symbiosis of the surgery team and robot. A framework was developed for the deployment and successful implementation of technologies in healthcare, outlining factors and their interrelationships. That framework can guide healthcare industry decision makers and technology developers in the efficient integration of emerging technologies in healthcare.
4. This research suggests that technology should be developed and implemented to boost healthcare provider efficiency, improve clinical outcomes, and create value for health organizations. The deployment of technology requires

continuous capacity-building for new technology, ongoing social interactions, and psychological safety to adapt to change. The model/framework can serve as a guide for the integration of technology in the future for both technology developers, healthcare management, and decision makers. The deployment of technologies into healthcare systems can balance demand and supply, prevent the loss of skilled and knowledgeable healthcare providers, enhance efficiency, and reduce long-term costs.

PUBLICATIONS AND PRESENTATIONS AT THE CONFERENCES

Publications In Peer Reviewed Journals:

1. Pereira, V., Neal, M., Temouri, Y., & Qureshi, W. (2020). Introduction. In V. Pereira, M. Neal, Y. Temouri, & W. Qureshi (Eds.), *Human Capital in the Middle East A UAE Perspective* (pp. 1-21). Cham: Palgrave Macmillan. https://doi.org/10.1007/978-3-030-42211-0_1
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3. Vaz, D., Qureshi, W., Temouri, Y., & Pereira, V. (2023). Unbundling the complexity of performance management of healthcare providers in the middle east. *IIM Ranchi Journal of Management Studies, 2*(2), 171–187. https://10.1108/IRJMS-03-2023-0026

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1. Qureshi, W. (2020). Human capital capacity building for emerging technologies (robotics) in the context of healthcare. In A. Pundzienė, R. Adams (Eds.), *1st KEEN Forum PhD Colloquium 2020 Conference Proceedings: Artificiality And Sustainability In Entrepreneurship* (pp. 87–90), Kaunas University of Technology. https://doi.org/10.5755/e01.2669-2090.2020
2. Qureshi, W. (2023). Human capital resource emergence and capacity building with co-specialization for emerging technologies (robotics) in the context of healthcare 5th International Conference on Organization and Management, 22–24 February, United Arab Emirates (Abu Dhabi). ICOM 2023
3. Qureshi, W. (2023). Diminishing FDI & underutilized human capital of Pakistan – a country under state of volatility. AIB-MENA 2023 Annual Conference, December 10–13, 2023, Morocco (Rabat). Academy of International Business MENA.
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CURRICULUM VITAE

Wardah is a graduate of medicine, a trained physician, and holds a General Practitioner (GP) license. She completed a Master of Business in 2019 as a Top graduate specializing in Innovation & Entrepreneurship. She is a dynamic and accomplished healthcare professional with 19 years of multifaceted experience spanning clinical practice, healthcare management, insurance, and strategic consulting. She blends clinical acumen with business insight to lead impactful health transformation initiatives.

She has specialised in quality improvement, patient safety, digital health, and accreditation, with a recent focus on value-based care (VBC). She is experienced in working across hospitals, home care, insurance, and healthcare business sectors. She has strong academic engagement and research interest in digital transformation and emerging technologies in healthcare. She is passionate about digital transformation strategies in the adoption of AI tools, telemedicine, and health data analytics. In her current role as healthcare consultant for Quality Improvement and Digital Transformation, she leads consulting engagements across healthcare institutions, focusing on quality enhancement, accreditation, and digital integration, in addition to design and implementation frameworks for clinical governance and performance, and advisory on patient experience improvements. She conducts workshops and training for healthcare professionals in leadership and technology adoption.

Wardah has achieved multiple certifications. She is a Health Quality & Patient Safety Specialist, Healthcare Training Specialist, Healthcare Insurance Specialist, Healthcare Accreditation Specialist, and Healthcare Transformation Specialist. Her recent achievements include certification in Value Based Care (VBC) and AI in Healthcare under the European Institute of Innovation & Technology (EIT).

Currently, she works as a healthcare consultant for Quality Improvement, Healthcare Training, and Digital Transformation. In addition, she is a lecturer at the Business School.

ANNEXES

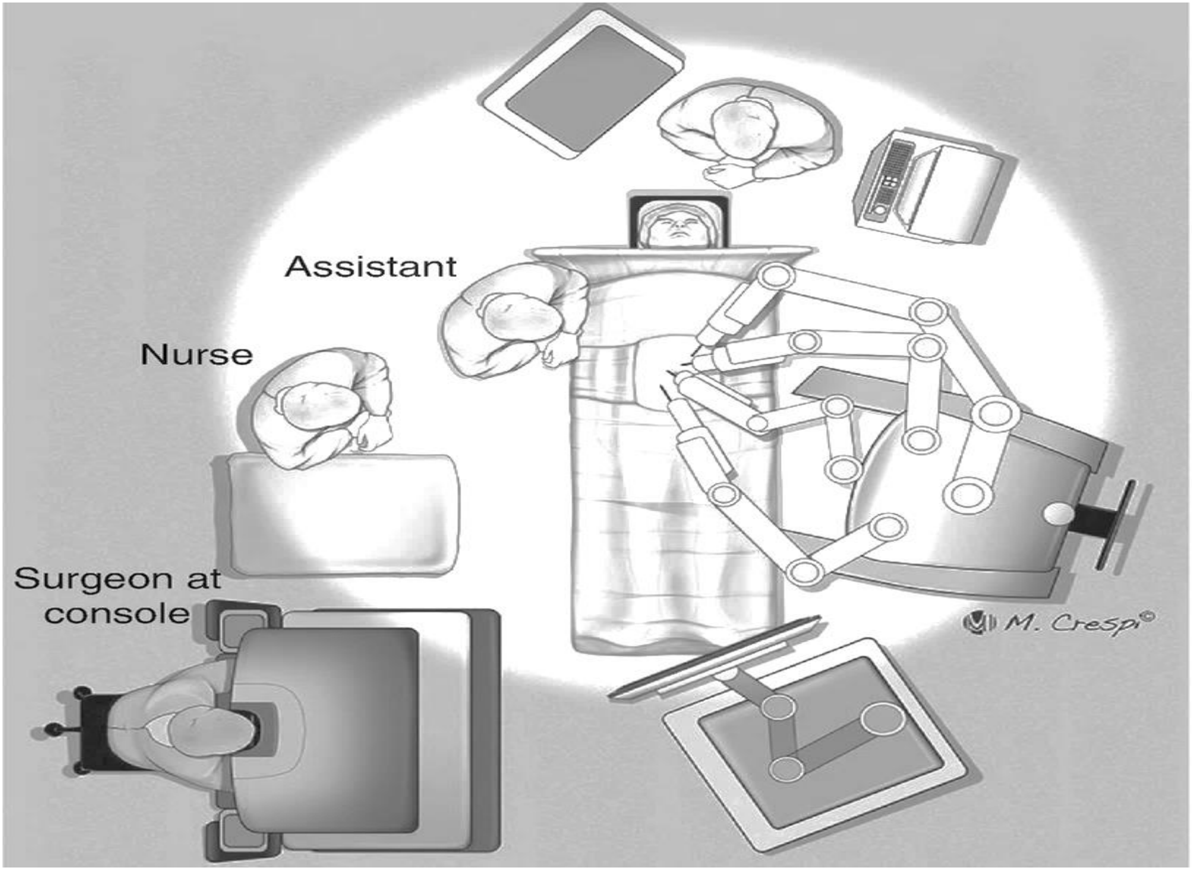
ANNEX 1: Interview scenarios

Section 1: Introduction
1. First, could you please tell me about your background and your position in the current health care organization?
Section 2: Learning Robotics
2. About how long have you worked with the robots? 3. [if not working with the robots: general opinion about the robots? Have you chosen not to work with the robots? Would you like to work with the robots?]
4. What makes a good day? 5. What makes a bad day?
6. How much time did it take until you had fully mastered working with the robot?
7. How have you learned to work with robots? Please remember and describe the process. [wait for an answer, do not hurry with a probe] 8. What helped? 9. What made it harder? 10. Is a manager (or someone else, like a senior surgeon) part of the story? 11. Explain what training you received and how effective you find it for working with the robots.
Section 3: Experience with robotics
12. How has working with robots affected your clinical practice and core values as a clinician?
13. How did it affect your responsibilities?
14. What is the difference between being a doctor working with robots and not?
15. How do you interact with other people? How do you interact with the robots? a. Has it changed over time? b. How do you think about the robots? c. Do you have a name(s) for the robots?
16. How do you think about yourself as you work with the robot?
17. Complete the sentence please, while working with the robot I am ____________

18. What attributes, knowledge, and skills do you believe that a doctor [or health care professional/nurse-depending on a respondent's position] should develop to work with the robots?
19. Share any difficulties you faced while working with the robots?
20. How much do you trust the robot? Or how reliable is the robot?
21. Have you had the undesirable outcomes of the robot treatment? Please give me examples.
22. In the case of ambiguous decision making, who takes the responsibility: the robot or you?
23. In case of an accident, how is responsibility shared between the robot and the doctor [health care professional]?
24. How do patients react when they learn they will be treated by the robot?
25. How is working with robots related to patient safety?
Section 4: Future of robotics
26. What do you think things will be like next?
27. Is there anything you think that I should have asked you about (but did not) that would help me understand your work with the robots?

ANNEX 2: Robot-assisted surgical theatre

(Malik, 2022)



ANNEX 3: Participants' employment / demographic information

No.	Job Title	Hospital	Location	Gender	Interview Date	Speciality
R1	Consultant Urologist	Bradford Teaching Hospitals NHS Foundation Trust	Bradford UK	M	10/04/2021	Urology
R2	Consultant Laparoscopic Colorectal & General Surgeon	Mediclinic Hospital, Dubai	Dubai UAE	M	15/04/2021	General Surgery
R3	Consultant Urological Surgeon	Bradford Teaching Hospitals NHS Foundation Trust	Bradford UK	M	20/04/2021	Urology
R4	Consultant Uro-Oncologist Surgeon	Bradford Teaching Hospitals NHS Foundation Trust	Bradford UK	M	29/04/2021	Urology
R5	Consultant Urologist	Mediclinic Hospital, Dubai	Dubai UAE	M	24/03/2022	Urology
R6	Consultant General Surgeon/ Surgical Gastroenterologist	Mediclinic Hospital, Dubai	Dubai UAE	M	16/04/2022	Gastroenterology
R7	Consultant Gastrointestinal & Liver Specialist	Mediclinic Hospital, Dubai	Dubai UAE	M	22/04/2022	Hepato-Pancreato-Biliary and Liver Transplant Surgeon
R8	Consultant general and colorectal surgeon	Poole Hospital-University Hospital Dorset	Poole UK	M	11/05/2022	Colorectal surgery

R9	Consultant Gastrointestinal & Liver Specialist	Apollo Hospital, India	Mumbai India	M	05/05/2022	Gastrointestinal & Gynae-oncology Surgeon
R10	Consultant Advanced Robotic Gynaecological Surgery	Mediclinic Hospital, Dubai	Dubai UAE	M	13/05/2022	Urogynecology
R11	Obstetrician & Gynaecologist	Ministry of Health and Prevention (MOHAP)	Sharjah UAE	F	16/05/2022	OBS/GYN
R12	Gynaecologist	Ministry of Health and Prevention (MOHAP)	Sharjah UAE	F	17/05/2022	OBS/GYN
R13	Consultant General Surgeon/ Surgical Gastroenterologist	Mediclinic Hospital, Dubai	Dubai UAE	M	22/05/2022	General Surgery
R14	Consultant Gastrointestinal & Liver Specialist	Apollo Hospital, India	Mumbai India	M	31/05/2022	General Surgery
R15	Consultant General Surgeon & Assistant Professor	American Hospital	Dubai UAE	M	04/10/2022	General Surgery
R16	Consultant Urologist	Capital Urology Centre, John James Medical Centre	Canberra Australia	M	17/12/2022	Urology
R17	Consultant Upper Gastrointestinal Surgery	The Regional Hospital Centre of Orléans	Orléans France	M	28/12/2022	Gastroenterology
R18	Consultant Urologist	Al-Sultan Abdullah Hospital	Selangor Malaysia	M	02/01/2023	Urology

R19	Bariatric & Gastroesophageal surgeon	Northern Nevada Medical Centre	Nevada USA	M	10/01/2023	Gastroenterology
R20	Director of Robotic General Surgery	Houston Methodist Hospital	Houston USA	M	12/01/2023	Gastroenterology
R21	Director, Robotic Living Donor Liver Transplantation	Houston Methodist Hospital	Houston USA	F	17/01/2023	Gastroenterology Liver Transplant
R22	Cardiac Surgeon	King Faisal Specialist Hospital & RC	Jeddah Saudi Arabia	M	18/01/2023	Cardiology
R23	Thoracic Surgeon	Houston Methodist Hospital	Houston USA	F	20/01/2023	Chest & Thorax
R24	Consultant Colorectal, Laparoscopic & Robotic Surgeon	University Hospitals Dorset NHS Foundation Trust	Poole UK	M	23/01/2023	Colorectal surgery
R25	Pancreas & Kidney Transplant Robotic Surgery	Houston Methodist Hospital	Houston USA	F	23/01/2023	Transplant Surgeon
R26	Pelvic floor surgeon	Norwest pregnancy & Women's health	Sydney Australia	M	25/01/2023	OBS/GYN
R27	Consultant Colorectal Surgeon and Robotic Surgical Oncologist	Cleveland Clinic	Abu Dhabi UAE	M	22/03/2023	Colorectal surgery
R28	Abdominal Surgeon, Proctologist, Endoscopist	Northway Medical Centre	Kalipeda Lithuania	M	23/03/2023	Abdominal Surgeon

R29	Consultant Robotic & Oncological Gynaecology Surgeon	Sheikh Shakhboot Medical Centre/ MAYO Clinic	Abu Dhabi UAE	M	27/03/2023	Surgical Gynaecology
R30	Director of General and Emergency Surgery	Azienda Ospedaliera di Rilievo Nazionale e di Alta Specialità San Giuseppe Moscati	Avellino Italy	M	01/04/2023	General Surgery
R31	Department Chair of General, Visceral, Vascular and Transplant Surgery	University Hospital Magdeburg	Magdeburg Germany	M	05/04/2023	Transplant Surgeon
R32	Urology & Robotic Surgery Consultant	Clemenceau Medical Centre	Dubai UAE	M	06/04/2023	Urology
R33	Paediatric Hepatobiliary and Pancreatic Transplant Surgery	Houston Methodist Hospital	Houston USA	F	09/04/2023	Paediatric Surgery
R34	Head of Colorectal Unit	Hospital Vall d'Hebron, Universidad Autonoma de Barcelona	Barcelona Spain	M	11/04/2023	Colorectal surgery
R35	Consultant Colorectal Surgeon and Honorary Associate Professor	Royal Derby Hospital	Derby UK	M	13/04/2023	Colorectal surgery
R36	Consultant Laparoscopic & General Surgeon	Jinnah Postgraduate Medical Centre Hospital	Karachi Pakistan	F	26/03/2025	General Surgery

ANNEX 4: Additional Quotes

Quotations	1st Order Code	2nd Order Code
"I had gone there for a fellowship, a laparoscopic robotics fellowship. The fellowship was initially meant to address laparoscopy. Then they told me to have the robotic and I would be able to get trained in that. So, it was almost by default when I arranged the fellowship." "When I met a professor from the United Kingdom, he's one of the pioneers in robotic surgery. So, he spoke about how robotics is definitely going to change the landscape of medicine, and it was really good to have it for me. So, I packed and got hooked on robotic surgery. So that's what got me started."	Observing Organizational & Healthcare system shift towards Robotics	Participation in Simulation/Training
"I was excited. In fact, I dreamed of it when I was a resident of my own institution, where now I serve as a director for robotic general surgery." "I know that they didn't intend to have me in the team, so I put myself in the team by going there and participating. And when they included me in the team, that was a very happy moment, of course."	Expressing Personal Interest in Laparoscopic & Robotic Surgery	Additional effort to learn new skill.

"I had spent a quite a bit of my own money to do those days, to be the first assistant to the robot surgeon." "I recorded all my surgeries in the beginning, and I went home and together with my wife, which is the work in the laboratory, I watched all my surgeries." "The robot was there in our institute, unfortunately, since 2006. Then I convinced them that I want to do robotic surgery."	More dedication, self-persistence with consistency & motivation	
"I was actually very excited to go work with a robot the first day I remember when we when I was only allowed to watch the robot, especially the first few cases. It was very fascinating." "You have to be ready to persevere to get the training because there's a lot of trainees and they all want to work with it all, but you just have to negotiate your way. So, I pretty much had to bribe my way to like at least be very nice to them."		Observing And Assisting Senior/Experienced Surgeons
"And I had a manager that was totally, totally supportive. So, and that meant that my robotics career just took off. And all of a sudden, I was doing most of all the surgeries in whole Sweden. I was training people around the world, and that was just because I had such a good support from my head of department, who was also a surgeon."	Getting support of Department/ Hospital management	

“Mr. Adler and Sunjammer came into my office and said, we've got some news for you, but you have two jobs now. The laparoscope is a dying breed and more and more kidney surgery becoming robotic rather than laparoscopic.” “You don't need to be an expert in technology. But you need to love technology. You need to embrace it”. “It's all technical, you know, and we always have a technical team with us so they can tackle the problems.” “You can feel the texture, the thickness with your eyes.” “With robot, you have no feel, zero feel”.	Learning & Adjusting with Robot (new Technology)	Performing simple steps under the supervision of the senior.
“There is no haptic feedback. Basically, you can’t feel anything. Yes. You can't do anything. The only the only feedback you have is visual.” “it's not like in an open surgery that you can put your fingers and stop it. You need to communicate with the team. You have to take a quick decision about things, and you have to be prepared.” “When you are doing robotic surgery, you have to learn how to be more in tune with the team. You have to listen. You have to include your perception of what's going on, what's going on around you, because you're usually a few feet away from the patients and from the patient in a corner of the room.”	Adapting to new working environment and job design	Receiving continuous mentoring and feedback from senior, while gradually performing more complex steps.

“A newer technology was the excitement helped me really put in a lot of effort, a lot of good people helped me.” It started with that desire and I never stopped wanting it.”		Gaining experience by performing real time procedures.
“I travelled across different states just so I can watch other surgeons and kind of learn from them. Same thing going to the different conferences. You learn what other surgeons are doing by watching the presentations or watching videos or talking to them.”	Attending conferences to learn more and develop social circle in the field	
“You have to be ready to persevere to get the training because there's a lot of trainees and they all want to work with it all, but you just have to negotiate your way. So, I pretty much had to bribe my way to like at least to be very nice to them.”		
“So that's helped me a lot, an in-depth of cognition or the muscle memory because I use to spend most evenings watching robotic surgery videos and then just go to the to the simulator and practice again and again.” “I think what helped me a lot was watching the videos online. You're learning by watching.”	Recording & Watching Videos of performed procedures	

"Obviously keep an eye on our outcomes and because we record everything we would have done. Then self-critiquing or basically, if you would, just watch parts of the videos just to make sure we were doing parts of the pieces efficiently as we would have done it open procedure." "I had other experienced surgeons that were helping me with different aspects of each procedure or each sort of sets of procedures." "So that was constant supervision in surgery that was first. So, teaching by example and then there was constant supervision, and I think that's what had the most."		Availability and accessibility of senior surgeons.
"What we decided is that we'll have a group of doctors who will be doing so. If I am going to do a procedure, I'll have two or three other guys who are as good as me with me. Watching me. Guiding me. Criticizing me. Helping you. So that we reduce the risk." "I think it was a mentor. We had a wonderful mentor who took us through every step. And I think that makes a big difference that there was someone who obviously we had from the industry to take us through the robotic, equipment itself and then the structured training program, starting from simulations to	Hiring of experienced surgeons by the hospital management.	Performing the whole procedure independently.

troubleshoot things and then to actually hands on, uh, and I think that's really helped to develop the skills. “We had two consultant robotic surgeons who really sort of like monitored me from day one until just finished the fellowship and really looked at how I progressed and allowed me to progress accordingly to what they felt will be necessary or adequate or progression. “ “Definitely having good mentors. So, people who were able to help you both, theoretically speaking, as well as experience as far as getting hands on experience and teaching you how to do appropriate cases in sort of the best way possible. That's by far the most useful factor that helped me get better.”		
“Easier is definitely having good mentors. So, people who were able to help you both, theoretically speaking, as well as experience as far as getting hands on experience and teaching you how to do appropriate cases in sort of the best way possible. That's by far the most useful factor that helped me get better.”	Surgeon Supporting & training the surgery team upon own Training completion.	
		Surgical Team training begins
“If there is a robot available, I'd need a team, I need a room, I need honesty and so on and so forth.”		

"I am going to teach my people the robotic which is easier learning curve, and I will teach them every and all the steps very professionally."		Continuous debriefing & corrective feedback
"I went to another centre with my scrub nurse and anaesthesiologist to observe the procedure and to provide them clear understanding of the change."		
"Typically for robotics, the team has to be further trained. They go to more exercises, more drills, they solidify their communication skills."	Supporting the whole surgical team by capacity building and co-specialization with Robot	
"But the thing is, you know, what we were doing with the robot was so new to everyone that, you know, it was just a time for everyone to to learn together how to do like robotic liver and pancreas surgery."		
"I work with this specific surgical team, which includes the scrub nurse, the operating room nurse, scrub nurse, tech physiologists, all these systems during the operation, you know, they can make your day either very easy and very efficient or they can make it very painful and difficult by not having a lot of experience working with you or doing specific kind of cases. I have trained them"	Better communication and collaboration among team.	. Strengthening skills of Communication & coordination

“I do have to make sure that my team is trained with the robot. So, I guess that's one added responsibility. So, you can't just do the same surgery with any regular team.”		
“Either the Operation War or actually talking to the team or going over like teaching strategies with the team, sometimes using like the robot videos for prior cases just to highlight what you mean.”	Seeing themselves as one team.	
“So, the robot is a real revolution in surgery. And when you do it with your team, It's the Bond. the bond which brings team together. We have better communication, better understanding, better collaboration. And everyone sees the importance of what you are doing. This is a process because you do you do things together.”		Team feels confident for robotic procedure
“I think, grew closer and work together closer because now they were dedicated robotic team, which means anytime we were doing robotics, I had my team with me, and we ended up working together more and the relationship became better.”		

Wardah Qureshi

Human Capital Resource Emergence for Robotic Surgery Deployment in Healthcare
[Žmogiškojo kapitalo išteklių formavimasis robotika paremtų chirurginių sistemų diegimui sveikatos priežiūros organizacijose]

Daktaro disertacija

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