"Unleashing the Power of Intelligent Cyber Physical Systems in Healthcare: A Paradigm Shift for the Workforce"

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Abstract:

The realm of healthcare is experiencing a remarkable transformation, propelled by the rise of Intelligent Cyber Physical Systems (ICPS). These ground-breaking systems possess the remarkable ability to automate numerous tasks previously undertaken by healthcare professionals. However, this progress raises concerns regarding the displacement and replacement of jobs. Delving into this pivotal issue, this chapter explores the potential impact of ICPS on the healthcare workforce, shedding light on both the challenges and opportunities that lie ahead. Additionally, it investigates the factors that will shape the future landscape of work within the healthcare industry, encompassing the vital skills and competencies required for success in this evolving paradigm.

By unveiling a nuanced perspective, this chapter asserts that ICPS will undoubtedly have a profound influence on the healthcare workforce, yielding a complex blend of outcomes. While certain job roles may be displaced, the advent of ICPS simultaneously generates fresh employment prospects. Consequently, proactive measures are necessary to prepare healthcare organizations for this paradigm shift. Recommendations include strategic investment in workforce development initiatives and fostering a culture of perpetual learning.

Keywords: Intelligent Cyber Physical Systems, Healthcare Workforce, Job Displacement, Job Replacement, Future of Work

1. Introduction

When computational, communication and physical systems combine to generate intelligence; the resulting systems are termed as intelligent cyber physical systems (ICPS). Wireless sensor networks play an important role in extending the services of

ICPS towards healthcare. Healthcare domain has seen a rise in medical devices and medical internet of things. ICPS in amalgamation with wireless sensor networks helps in providing high quality healthcare [1]. The general layered architecture of ICPS in healthcare comprises of physical layer, cyber layer and intelligence layer (Fig.1). It also consists of a feedback loop. The general architecture of healthcare ICPS is displayed in Fig. 2.

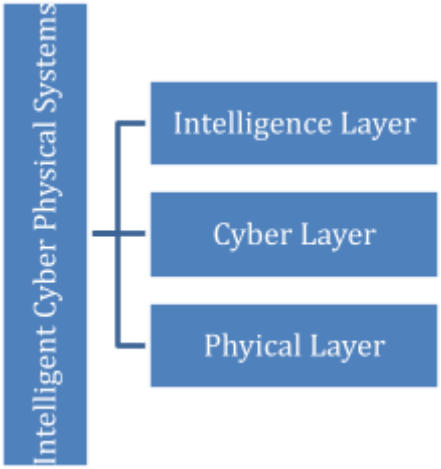

Fig. 1. Layered architecture of ICPS

There are various components of ICPS in Healthcare which are categorized under the physical, cyber and intelligence layers.

(i) Physical layer:

- This acts as low level layer which comprises of sensing nodes or devices which collect real time physiological data like ECG, EEG, environmental information such as air quality, temperature, weather, user interactions like button presses, voice recordings and other parameters like heart rate variability, pulse rate etc.
- Physical layer also contains actuators such as drug delivery pumps, smart home appliances, blood pressure monitors, robotic surgical tools etc.
- The backbone of the physical layer is the communication network that allows all devices to connect with each other through the realization of a wireless sensor network and interne of things. The communication network could have any topology depending upon the scenario where it is being used.
- There are a variety of other devices like wearables, fitness trackers, insulin pumps, pacemakers, implantable medical devices which are termed as Internet of Medical Things. These computing devices are

embedded with low-power and real-time electronics which handle data processing, control mechanisms and various communication protocols.

(ii) Cyber layer:

- The middle level layer is called cyber layer, which consists of data acquisition and pre-processing techniques and technologies.
- The raw sensor data acquired at physical layer might be prone to noise and might contain non uniform data. This is pre-processed using various kinds of techniques like noise removal, feature extraction, data augmentation etc.
- Edge computing is one important technology that is used at cyber layer to perform local level analysis and take decisions on critical data in real time.
- Machine learning and artificial intelligence helps to analyse data for detection, prediction and monitoring of health outcomes. It also helps to generate recommendations and train models. The amount of data generated at physical layer devices can lead to the applications of big data analytics [2].
- Cloud computing may also be used to store and analyse large datasets over cloud and process complex computations. Cloud based platforms provide data analysis capabilities by providing storage space and power thereby ensuring scalability, coverage, quality, efficiency and accessibility [3].
- As the word “cyber” is given to this layer, it ensures security and privacy of the data, ensures data integrity, confidentiality and availability. Sensitive data of patients must be protected and this is managed through encryption, access control, intrusion detection and secure communications.

(iii) Intelligence layer:

- This layer consists of various components like decision support system, adaptive control system, human machine interface etc.
- Decision support systems perform a variety of data analysis using artificial and machine learning models and provide suitable recommendations to healthcare professionals.
- Adaptive control systems ensure the adaptability of the system considering real time environment and changing conditions.
- Human machine interface provides an interconnection between users of the system and computer through interactive graphical user

interfaces. The graphical user interfaces may further be equipped with augmented reality and virtual reality for better user experiences.

- In addition, there can be remote monitoring tools and telemedicine to equip the medical professionals with keeping a check on the health status of patients from a remote location [2].

(iv) Feedback loop:

- In addition to above components, there is a continuous feedback loop that connects all the layers together. It ensures that information exchange occurs in a proactive way considering user inputs and feedbacks.
- The interoperability between various devices and systems can be managed by incorporating feedback loops and collaborative efforts.

(v) Networking Infrastructure:

- High speed networking infrastructure is essential part of intelligence CPS in healthcare in order to provide reliable and real-time communication and data transmission between various components of the layered structure of ICPS.
- The ethical considerations and regulations must be taken into account while designing the network structure and deciding on the software solutions to be used in various components.

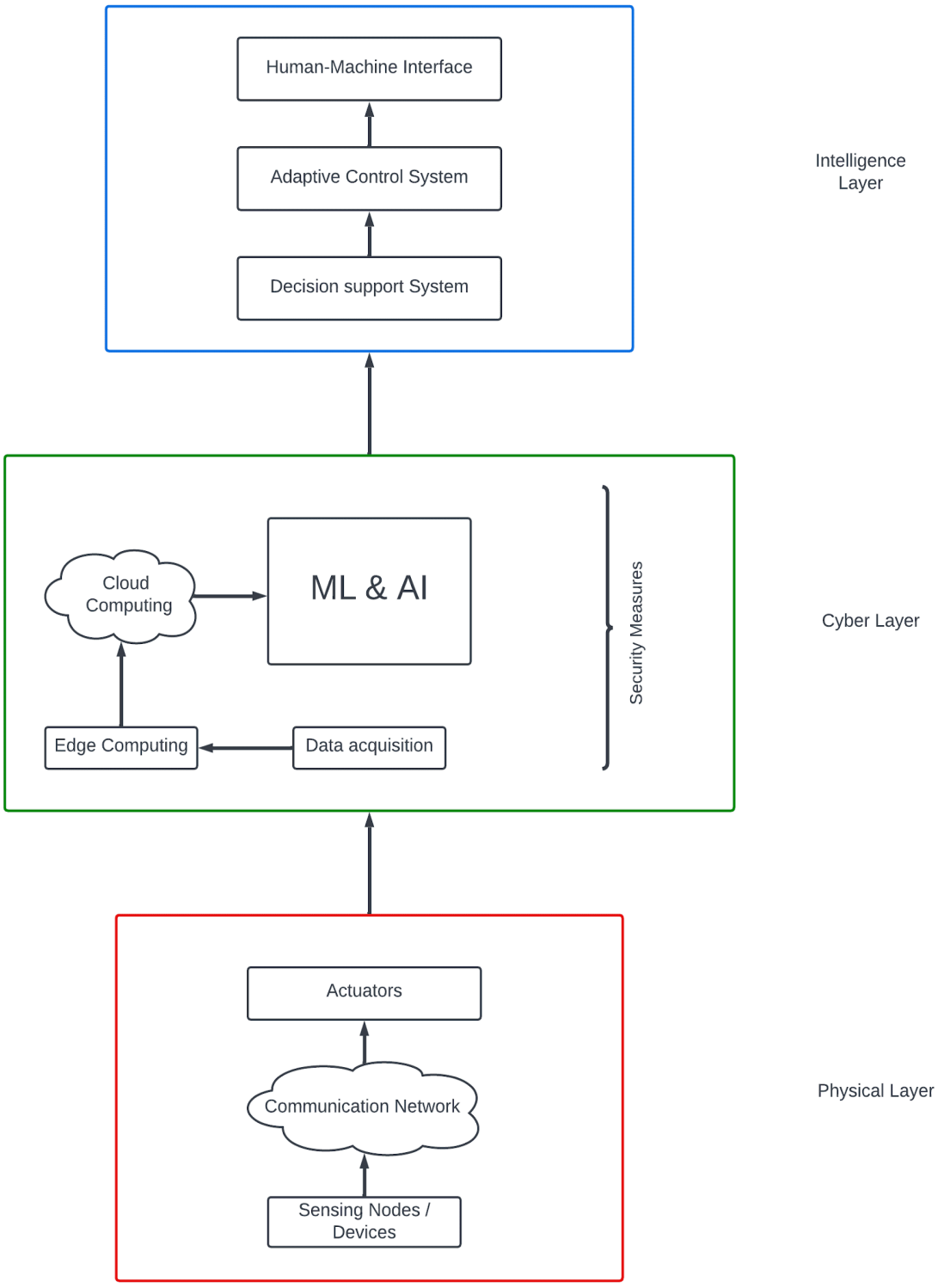

Fig. 2. General architecture of Healthcare ICPS system [5]

2. What Makes ICPS Intelligent in Healthcare?

ICPS in healthcare is a combination of various technologies that aspire to achieve intelligence and impact the diagnosis, treatment, detection and overall patient care. Following are some key points that make ICPS intelligent in Healthcare.

2.1. Data-Driven Intelligence:

- Real-time data acquisition: Sensors are used to collect physiological, psychological, environmental, and user interaction. This helps to provide a comprehensive picture of patient healthcare.
- Advanced data processing: Techniques like edge computing, cloud computing and big data analytics combine to draw meaningful insights from raw data and identifies trends and patterns [4].
- Artificial Intelligence and Machine learning: Machine learning models learn from vast datasets and enable accurate predictions of disease progression, personalized treatment interventions and risk analysis.

2.2. Adaptive and Responsive Systems:

- Edge computing: It helps in local analysis and decision making at the end system level and allows for faster response time and improvement in performance in critical circumstances.
- Closed loop control: ICPS is able to adapt to real time situations and adjust the systems as per real time data. Such as adjusting the dose of medication as per patient need, activating the robotic tools for surgery on conditional basis, generating alerts during complicated situations.
- Adaptive Algorithms: machine learning models are trained in such a manner that they can adapt to new data and improve their accuracy over time. The effectiveness of these models is depicted from the fact that they can continuously learn from the data.

2.3. Enhanced Human Decision-Making:

- Decision support systems: Healthcare ICPS provides recommendations based on evidence to medical professionals and aids diagnosis, treatment selection, and resource allocation.
- Clinical insights: The machine learning capabilities of ICPS makes it possible to analyze large datasets in order to identify hidden patterns and correlations

amongst the data points. This can lead to new clinical discoveries and improved patient treatment.

- Personalized patient care: ICPS through machine learning can generate personalized treatment plans based on individual patient preferences, characteristics and medical history. It can lead to reduction of cost and higher utilizations in large healthcare systems [6].

The intelligence abilities on the other hand lead to several challenges such as data privacy and security, ethical considerations, bias in algorithms, responsible usage, regulatory compliances and interoperability issues for seamless communication and data exchanges between various systems.

3. The Potential Impact of ICPS on Healthcare Job Replacement and Displacement

The introduction of ICPS in healthcare raises several concerns about potential job displacement, however it is multifaceted. While some jobs might be replaced or transformed, the integration of ICPS could also lead to the creation of a number of opportunities. Here's a breakdown of the potential effects:

3.1. Jobs at Risk of Replacement: These can be mainly broken down into 3 categories as follows:

- Routine tasks: These jobs face the highest risk of replacement and can already be seen in today's market. Automation brought by ICPS can computerize routine and repetitive tasks like data entry, scheduling appointments, and basic patient monitoring.
- Low skilled manual tasks: Robots and other automated systems might take over tasks like medication dispensing, basic lab tests, or patient transport, affecting some technician and support staff roles.
- Diagnostic tasks: Neural networks and machine learning models which are becoming increasingly accurate could be used to analyze medical images and data to provide a preliminary diagnosis, potentially impacting some radiologists and other diagnostic specialists.

3.2. Jobs Less Likely to be Replaced:

- Complex clinical decision-making: Like any intelligent system ICPS cannot be 100% accurate, Doctors and healthcare personnel would still be required to take critical decisions and judgements and provide

personalized care taking into account the recommendations provided by the system.

- Mental and emotional care: An integral part of healthcare is providing the necessary emotional and mental support to the patient. ICPS lack the human touch and emotional intelligence needed for patient interaction support. Jobs like that of nurses, therapists and other care providers will remain crucial.
- Creative and problem-solving skills: ICPS excel at repetitive tasks and data analysis, but they lack the ability to think creatively and solve unforeseen problems. These skills will remain essential for various healthcare roles.

3.3. New Job Opportunities:

- Data analysts and AI specialists: Integration of ICPS systems would lead to a large inflow of complex healthcare data which would need to be analyzed and processed leading to creation of new roles in data science and machine learning.
- ICPS developers and engineers: Designing, maintaining, and integrating ICPS into healthcare systems will require specialized skills in engineering and technology.
- Human-computer interaction specialists: Designing intuitive interfaces and ensuring ethical and responsible use of ICPS will require experts in human-computer interaction.
- Healthcare educators and trainers: Preparing healthcare professionals to work effectively with ICPS will require educators and trainers specializing in technology integration.
- Cyber Security specialists: ICPS need to ensure a level of safety and privacy so that the identity of the patients as well as their personal data is not compromised. This would require a healthy investment into cybersecurity roles.

As per above observations, ICPS are unlikely to cause widespread job displacement in healthcare. Instead, they will likely transform existing roles and create new opportunities requiring different skill sets.

The key lays in adapting and up-skilling the workforce to meet the changing demands of the healthcare landscape. In addition, the speed and extent of the displacements of jobs will heavily depend upon factors like the speed of technological advancements, healthcare system adaptations, workforce trainings

and educational programmes. Continuous investment in training and education will pave the way for a smooth transition. By understanding the impact of healthcare ICPS, one can ensure that it contributes to a more effective and efficient healthcare system while minimizing the job displacement and maximising the job opportunities.

4. Impact of ICPS on Healthcare workforce

ICPS in healthcare are meant to revolutionize the delivery of quality healthcare and might impact healthcare workforce in a variety of ways as listed below:

- Job displacement: There can be a possible effect on routine jobs such as data entry, monitoring, nursing and scheduling. And this affects the people in administration and technical roles.
- Job transformation: There would be rising need for healthcare professionals to transform and adapt according to the challenges posed by ICPS. This change will be required to facilitate complex decision making, human interaction and adopt critical thinking.
- Rise of new job opportunities: Due to generation of huge amount of sensor data, there would be a need of data analysts, human computer interaction experts and artificial intelligence specialists who can design, process, analyse, manage the data in accordance with the complexities of ICPS.
- Impact on roles and responsibilities: Healthcare ICPS automates routine workflows and allows healthcare professionals to focus on complex activities like patient care coordination, data processing and interpretation, decision making etc. This shift in responsibilities required re-evaluation of the job profiles and skill sets in the healthcare domain.
- Training and Education Requirements: Healthcare professionals need to have new skills and competencies in order to effectively engage with ICPS. The skill set required is of data analysis, artificial intelligence, cyber security and advanced medical technologies.

- Workforce shortage and redistribution: With the streamlining of healthcare workflows by ICPS, some redistribution of workforce needs to be done. Certain tasks which were previously performed by workforce can be automated and this leads to creating demand of skilled workers in some other areas.

- Ethical and legal considerations: The integration of artificial intelligence and machine learning in healthcare domain raises concerned related to data privacy, informed consent, bias in algorithms and other errors. Healthcare workforce needs to pass through these complex challenges to ensure patient safety and meeting all compliances.
- Collaboration with technologists: Technology specialists such as data scientists and engineers develop, implement and optimize the healthcare ICPS solutions. This requires interdisciplinary collaboration for successful integration and operation of these systems.

However, above-said changes come with significant number of challenges also as listed below:

- Reskilling and upskilling of workforce needs to be done in accordance with healthcare ICPS. The workforce needs to be equipped with the required skills to work effectively with ICPS and this needs significant investment in their training and education.
- Ethical considerations are also crucial to ensure patient privacy, security of data and fair access of healthcare by all stakeholders in this exceedingly data driven environment.
- The mental health status of healthcare workers is also a point of concern due to job displacements and automation, leading to stress, anxiety and resistance. The emotional well-being and empathy needs to be restored even with technological advancements, thereby maintaining the core human element.
- Resistance towards change: Some healthcare professionals who have been working with traditional methods find it difficult to adapt to the changing paradigm and are reluctant to embrace ICPS.
- Investment costs: Significant initial investment is required to implement ICPS. The investments in infrastructure, trainings, system integration etc are required and may pose financial challenges to the healthcare organizations.
- Data integration and interoperability: For seamless integration and interoperability of healthcare ICPS solutions, systems might use disparate software and inconsistent data formats. This causes several challenges during integration.
- Security issues: Cyber security vulnerabilities, data breaches, malware attacks, unauthorized access etc. may lead to compromise of sensitive patient information and requires robust security protocols.

In addition to challenges, there lies a world full of opportunities such as the following:

- ICPS can help to streamline the healthcare workflows leading to improved patient care and better healthcare delivery.

- AI-powered systems can provide personalized treatment plans and lead to better patient experience and satisfaction. For instance, diet and exercise recommendation via mobile application could help monitoring and tracking the health status of patients of various diseases which can be controlled via dietary interventions.
- Data Analysis and Artificial Intelligence can drive new discoveries and advancements in healthcare leading to improvements in diagnosis, detection, monitoring and treatments of the patients. Data driven insights can help healthcare professionals to take complex decisions with good level of accuracy.

In order to tackle above challenges, continuous education and training of healthcare professionals needs to be carried out to develop relevant skills and competencies. Regulatory frameworks and standards must be followed to ensure patient safety, data privacy and regulatory compliance. Collaboration and engagement with stakeholders is also essential for addressing the challenges and driving innovation in ICPS.

Data literacy, digital literacy, critical thinking and problem solving skills are required to be developed so as to enable them to make informed decisions. Interdisciplinary collaboration and effective communication between stakeholders can further lead to successful integration and operation of healthcare ICPS. Following are some suggested means to tackle the challenges associated with the paradigm shift caused by healthcare ICPS.

- Collaborative efforts between governments, healthcare institutions and educators can help in comprehensive developments of upskilling and reskilling programmes.
- Open communication amongst all these stakeholders will help to address concerns and anxiety related to displacement and replacement of jobs.
- The development and deployment of ICPS needs to be done in a way that follows ethical guidelines and ensure responsible usage and trust.
- Although, technology plays an important role, human skills can never be overshadowed. Communication, clear and critical thinking and collaboration plays a vital role.
- In addition, technological literacy through training programmes may help in understanding the basics of ICPS and its application in healthcare.
- Data analysis and interpretation skills can help to draw meaningful information from the raw data acquired via sensors.

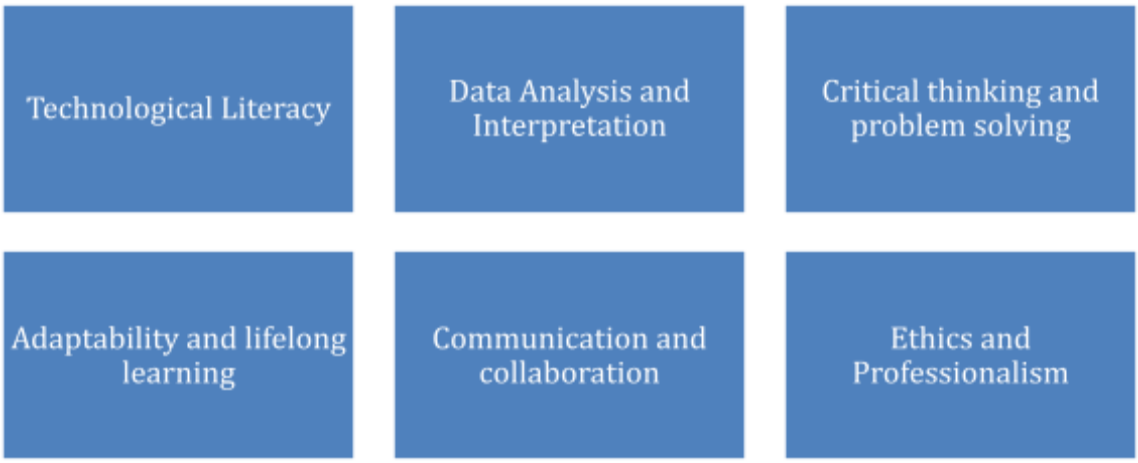

Fig. 3. Human skills and core competencies for better realization of healthcare ICPS

- Critical thinking and problem solving skills can help with better evaluation of information and designing solutions of complex problems in dynamic environment. Adapatabliltiy and lifelong learning skills may help the workers to learn continuously and adapt to the challenging and changing healthcare practices due to introduction of dynamic digital systems like ICPS. Effective communication skills help the professionals to interact with patients and make them understand the intricacies of digital systems and technology use. These skills and core competencies (Fig. 3.) may help healthcare workforce to remain the driving forces behind the ICPS and bridge the digital divide.

5. Paradigm Shift and New Opportunities

With the advent of intelligent cyber physical healthcare systems there has been a paradigm shift that leads to transformation of existing jobs and also generates fresh opportunities. Following are some key points related to this paradigm shift.

- Development and Implementation of Technology: The design, development, and implementation of healthcare ICPS solutions need a variety of skills which includes software and hardware development, big data analytics, cyber-security and systems integration. This also creates opportunities for healthcare professionals who have specializations in

these areas to work for various hospitals, research institutions, organizations etc.

- Data Science and Analytics: Healthcare ICPS at physical layer generate vast amounts of healthcare data through sensors and digital devices that need thorough analysis in order to extract actionable insights and information. This can lead to improvement of patient care, efficiency of operations and better clinical outcomes. There is an increasing demand of data scientists, statisticians, developers and analysts, who can collect, store, process, analyse, and interpret healthcare data. This leads to the development of personalized recommendations of medicine, predictive analytics and population health monitoring and management solutions.

- Artificial Intelligence and Machine Learning: These technologies play an important role in powering the intelligent decision support systems, predictive modelling and diagnosis in healthcare workflows. Professionals who have expertise in these technologies are required to develop and optimize these systems, in order to provide accurate diagnosis, recommendations and other interventions based on deep learning architectures.

- Telemedicine, Tele-health and Remote Monitoring: ICPS in healthcare will facilitate the rise of telemedicine and remote patient monitoring services. This can enable the healthcare professionals to deliver care remotely and monitor the health status of patients in real time. This also creates opportunities for the medical professionals to provide consultations in virtual mode and extend remote monitoring and tele-health support.

- Cyber-security and Privacy Concerns: With the rise of connected medical devices and digital platforms, the security and privacy of the sensitive patient information becomes vital. There is a high demand of cyber-security professionals who have specialization in healthcare information systems security, encryption technique, network security etc. Secure healthcare systems are the need of the hour to protect systems from cyber threats and terrorism.

- Clinical informatics and health information management: In order to integrate ICPS, expertise is required in the areas of clinical informatics, health information management and electronic health record systems. Healthcare organizations need professionals who have deep knowledge of

healthcare workflows and can understand the optimization strategies to implement and manage the ICPS solutions effectively.

- Improved patient outcomes: Healthcare ICPS enables more personalized recommendations, efficient and timely healthcare delivery leading to improvements in patient satisfaction and outcomes.

- Training and Education to strengthen healthcare workforce: Along with the adoption of ICPS solutions, there comes a growing need of professionals who can manage these solutions effectively. There is a need of training programmes, educational materials and curricula for the healthcare professionals so that they can enhance their proficiency for using the ICPS tools and technologies and increase their productivity.

- Policy development, ethics and regulatory compliance: The integration of ICPS systems in healthcare domain requires strict adherence to the ethical norms and regulatory standards governed by law. There is a need to follow the privacy laws and ethical guidelines religiously in order to avoid the misuse of sensitive information. Compliance officers and policy analysts are required to design and develop regulatory frameworks ensuring compliance with the legal requirements.

- Enhanced efficiency and productiveness: automation of routine activities and streamlining of workflows can help to achieve operational efficiency and productiveness in the healthcare organizations.

- Expanded Access to Healthcare: Through telemedicine and remote monitoring which is enabled by ICPS, healthcare access can be expanded. This paves the way for remote consultations, care at home based setup, outreach to underprivileged sections of the society.

- Blockchain based ICPS: Blockchain is the latest technology to offer an optimal solutions for healthcare ICPS applications. Blockchain is vulnerable to cyberattacks, there lies opportunities for cyber security professionals [7].

It is evident from the above points that ICPS in healthcare may lead to creation of a number of new employment opportunities and widen the scope of healthcare towards interdisciplinary job across various sectors like information technology,

data science and analytics, telemedicine, cybersecurity, clinical informatics and regulatory compliance. The skill and innovation required to embrace the digital transformation leads to the demand of experts in the diverse areas who can make a positive impact on the delivery of quality and effective healthcare to the patients.

6. Workforce development recommendations and initiatives

For the development of workforce, there are several recommendations and initiatives that can be taken into consideration in order to address the evolving requirement of healthcare workforce to adapt with the intelligent cyber physical systems.

- Comprehensive Training Programmes on ICPS integration: In order to educate the healthcare professionals on integration, operation, management and use of ICPS in healthcare settings, comprehensive training programmes should be developed. These programmes should cover topics such as data analytics, big data, artificial intelligence applications, cyber-security, human machine intelligence, computer vision etc. The training programmes must be developed in collaborations with healthcare professionals, engineers, data scientists, developers and managers, so as to cover all the possible aspects of the subjects. This will help in building strength of the workforce to tackle new challenges and leverage opportunities.
- Continuing Education and Professional development: Healthcare professionals should be offered with continuous education and professional development opportunities in order to remain updated about latest advancements, techniques and technologies related to ICPS. This may include workshops, seminars, webinar, online courses and other programmes targeted for various people in various healthcare roles and responsibilities.
- Simulation and hands on trainings: Simulation exercises may be useful to familiarize healthcare professionals with ICPS enabled solutions, virtual care platforms and decision support systems. This practical exposure will lead to increase in confidence and proficiency in using these technologies in real world scenarios.
- Industry-Academia Collaborations: Collaborations between industry and acadmics may be promoted in order to develop tailored curricula, training materials, certifications etc to enhance the knowledge exchange.
- Apprenticeship Programs: These programs help in allowing healthcare professionals to gain practical exposure working with ICPS under the mentorship of technology experts. These provide valuable hands on training

experience to individuals who are interested in pursuing their careers in the healthcare technological domain.

- Diversity and Inclusiveness: The inclusiveness in workforce development supports underprivileged people, women, minorities and people with disabilities. This enriches the talent pool and fosters innovations in healthcare technologies.
- Research funding and grants: Government funding and grants may encourage budding researchers to contribute in the development of efficient healthcare ICPS. This will generate evidence based best practices and innovative approaches for training to enhance the readiness of workforce to acceptance of ICPS.
- Clinical mentorship programmes: These programmes may provide guidance to navigate through the complexities of adopting ICPS in healthcare workflows.
- Evaluation and Quality Assurance: The effectiveness of all these workforce development initiatives related to ICPS need to be evaluated and quality improvement should be ensured. Regular feedbacks should be taken from the participants and learning outcomes may be assessed. The impact of ICPS in healthcare can be maximised if these programmes are benchmarked against industry standards and refined accordingly.

In addition to above points, several research studies have been conducted to study the barriers in realization of healthcare ICPS and digital health technologies. Table 1 describes the types of barriers in the effective realization of digital health technologies and their possible solutions with respect to healthcare IPS systems based on literature.

Table 1: Types of barriers and possible solutions [8]

S. No.	Type of Barrier	Description	Possible solutions
1	Infrastructure and technical	These barriers relate to issues with limited networks, lack of existing technology, lack of devices, connectivity speed, healthcare capacity of technology integration, interconnectedness, absence of standardized/harmonized systems at different facilities, limited access to electricity, and requirement of a	A) Ensuring availability (especially in rural areas) and affordability, guaranteeing high-speed fiber connectivity B) Involvement of healthcare

		functional database system or large disk space.	professionals in developing and implementing any health technology tool
2	Personal and psychological	They include complex thematic components including the healthcare professionals' resistance to change, difficulty understanding the technology, perception of less human interaction, technophobia, ages, education levels, professional experience, low literacy, poor writing skills, linguistic features, adherence behavior, and fear of using particular health technology. Unwillingness, low expectations and skepticism from healthcare providers are also factors	A) Using and adopting training programs suited to healthcare professionals' needs B) High-quality, real-time technical support and coaching to professionals C) User-friendly design, intuitive system navigation, and easy-to-use interfaces are critical to improving overall product performance
3	Time and workload-related	Concerns about increased workload and altered workflow, along with requiring additional purchase time and increased set-up, implementation, training, access, adaptation, and establishment stages	A) Useful written guidelines, instructions, and handouts B) Incentives from government agencies and multisectoral organizations were shown to significantly improve digital health technologies' effectiveness and chances of success in large-scale healthcare systems

4	Training and educational	Deficit or inadequate training impact the success and effectiveness of digital technologies. Without training, healthcare providers tend to feel low self-efficacy when utilizing any digital health technologies, resulting in negative attitudes toward these technologies.	A) Training could be provided through certain digital health technologies itself as well as mobile phones and computers
5	Legal and ethical related factors	Legal- and ethical-related barriers were shown to be a relevant factor for healthcare providers, as privacy and security concerns, national legislation, jurisdiction, and the existence of unclear legal liability regarding response protocols would directly affect healthcare professionals.	A) Development of safer storage systems B) Establishment of requirements on safety and security in cooperation with healthcare professionals and patients. C) The creation of an international legal framework and legislative norm, which would clarify security regulation policies that could help ensure patients' privacy and confidentiality, as well as define healthcare professionals' liabilities.

Apart from above barriers and proposed solutions, another research study was recently conducted to explore the barriers and facilitators for the use of digital health technology for management of chronic obstructive pulmonary disease and discussions were as follows:

- In this study, participants engaged in a discussion regarding the potential obstacle of data quality in the utilization of digital health technology (DHT).

- Their perception was that consumer devices often fail to meet the expected clinical standards, such as lacking validation and calibration. Consequently, there may be doubts regarding the accuracy of the generated data, which could give rise to patient safety concerns if inaccurate readings cause undue health anxieties.
- If patients are expected to collect objective data at home, it is imperative that the data is usable; otherwise, it would be wastage of resources and, more worryingly, could pose serious safety concerns.
- The participants expressed doubts about the diligence of their patients in generating complete datasets and deliberated on how this could impact the reliability of the data captured by DHT.
- They also discussed the necessity of a robust evidence base before adopting DHT in clinical practice.
- They believed that the absence of evidence not only affected their ability to prescribe these technologies safely but also influenced their willingness to promote or recommend DHT as a treatment option.
- Similarly, the lack of clinical guidelines outlining the use of DHT in COPD posed a significant barrier to adoption.
- Healthcare professionals mainly emphasized the need for guidelines to define the recommended actions patients should take based on the data observed from their DHT, as the absence of such guidelines could confuse patients regarding their treatment.
- The participants addressed the challenges their clinical setting would encounter if data from DHT were to become part of routine care.
- They expressed concerns that the necessary level of resources might not be available to oversee the management or utilization of the data generated by DHT, while others worried about ethical concerns arising from the inability to appropriately act upon the data due to limited resources [9].

One recent research was conducted about implementation of telehealth for remote surveillance of patient health. The involved nurses considered the experience with telehealth positive and raised issues about lack of resources, patient selection criteria, technical support, education and organizational support. They highlighted that these issues can become barriers in the successful implementation of telehealth services. They also suggested an increase in the team size, expanded patient selection criteria and widespread training in order to enhance and ensure the successful implementation of telehealth [10].

7. Conclusion

The integration of intelligent cyber physical systems in healthcare domain presents a transformative paradigm shift. This has profound implications for the healthcare professionals and workforce. As the healthcare ICPS continues to evolve and revolutionize the healthcare delivery, it is quite imperative to prioritize the workforce development initiatives that can equip the healthcare workforce with the requisite knowledge, skills and competencies required in order to leverage the benefits of these technologies in effective manner.

This chapter presents several challenges and opportunities associated with this paradigm shift and also provide key recommendations for the workforce development in context of healthcare ICPS. The recommendations include comprehensive training programmes by developing effective curricula inclusive of technologies like Artificial intelligence and machine learning, training on ICPS integration, development and implementation and interdisciplinary industry-academia collaborations, hands on simulation training, apprenticeship programmes, diversity and inclusiveness, research fundings, clinical mentorship programmes and quality assurance evaluations etc can further strengthen the healthcare workforce.

It is important to realise the barriers and facilitators while implementing digital technological solutions and take stakeholders inputs while designing such solutions so as to meet the ultimate objectives with better efficiency. By implementing these recommendations, healthcare organizations may empower their workforce and help them navigate through the complexities of ICPS integration, improve patient care outcomes and promote innovation. Investing in the workforce is essential to realize the full potential of healthcare ICPS and ensure the readiness of workforce to meet the evolving needs of patients and society at large. The paradigm shift is here to stay and evolve further, therefore the risk of job displacement and replacement is there, but there lies a world of opportunities which can lead to creation of new employment opportunities and strengthening the current workforce may help with the better and fruitful implementation and realization of ICPS healthcare.

References:

1. Haque SA, Aziz SM, Rahman M. Review of Cyber-Physical System in Healthcare. International Journal of Distributed Sensor Networks. 2014; 10(4). doi:10.1155/2014/217415.
2. Dey, N., Ashour, A. S., Shi, F., Fong, S. J., & Tavares, J. M. R. (2018). Medical cyber-physical systems: A survey. Journal of medical systems, 42, 1-13.
3. Sony, M., Antony, J., & McDermott, O. (2022). The impact of medical cyber–physical systems on healthcare service delivery. The TQM Journal, 34(7), 73-93.
4. Zhang, Y., Qiu, M., Tsai, C. W., Hassan, M. M., & Alamri, A. (2015). Health-CPS: Healthcare cyber-physical system assisted by cloud and big data. IEEE Systems Journal, 11(1), 88-95.
5. Sultanovs, E., Skorobogatjko, A., & Romanovs, A. (2016, October). Centralized healthcare cyber-physical system's architecture development. In 2016 57th International scientific Conference on power and electrical Engineering of Riga Technical University (RTUCON) (pp. 1-6). IEEE.
6. Fertel, B. S., Podolsky, S. R., Mark, J., Muir, M. R., Ladd, M. E., & Smalley, C. M. (2019). Impact of an individual plan of care for frequent and high utilizers in a large healthcare system. The American Journal of Emergency Medicine, 37(11), 2039-2042.
7. Mohammed, M. A., Lakhan, A., Zebari, D. A., Abd Ghani, M. K., Marhoon, H. A., Abdulkareem, K. H., ... & Martinek, R. (2024). Securing healthcare data in industrial cyber-physical systems using combining deep learning and blockchain technology. Engineering Applications of Artificial Intelligence, 129, 107612.
8. Borges do Nascimento, I. J., Abdulazeem, H., Vasanthan, L. T., Martinez, E. Z., Zucoloto, M. L., Østengaard, L., ... & Novillo-Ortiz, D. (2023). Barriers and facilitators to utilizing digital health technologies by healthcare professionals. NPJ digital medicine, 6(1), 161.
9. Slevin, P., Kessie, T., Cullen, J., Butler, M. W., Donnelly, S. C., & Caulfield, B. (2020). Exploring the barriers and facilitators for the use of digital health technologies for the management of COPD: a qualitative study of clinician perceptions. QJM: An International Journal of Medicine, 113(3), 163-172.
10. Odeh, B., Kayyali, R., Nabhani-Gebara, S., & Philip, N. (2014). Implementing a telehealth service: nurses' perceptions and experiences. British Journal of Nursing, 23(21), 1133-1137.