Industry 5.0 for Healthcare 5.0: Opportunities, Challenges and Future Research Possibilities

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Abstract—Industry 5.0 is the subsequent stage in the development of manufacturing and production systems that combines cutting-edge technology with human intelligence and skills. The healthcare sector has been developing over time, going through significant changes at every stage. The emerging idea of Industry 5.0 in the healthcare sector, also known as Healthcare 5.0—and its potential applications in the healthcare sector are examined in this paper. Healthcare 5.0 makes use of cutting-edge technologies to revolutionise healthcare delivery, improve patient outcomes, and improve the healthcare experience as a whole. Industry 5.0 places a strong emphasis on the integration of humans, machines, and technology in the manufacturing industry. The paper discusses Healthcare 5.0's potentials and opportunities, including personalised medicine, sophisticated diagnostics, telemedicine, and more patient-centric care, all of which are made possible by the application of cutting-edge technologies like Artificial Intelligence (AI), blockchain, big data analytics, and robotics. The paper also discusses the difficulties and problems that must be solved for Healthcare 5.0 to be implemented successfully, including data security and privacy, ethical and legal issues, the need for appropriate skills and training for healthcare professionals, and cost-effectiveness.

Index Terms—Industry 5.0, Healthcare, Artificial Intelligence, Blockchain, Cognitive Systems, Big Data Analytics, HumanCentric, Sustainability

I. Introduction

Building on the first four industrial revolutions [1], Industry 5.0 is the most recent manufacturing and industrial sector evolution. This idea emphasises the significance of human skills and abilities in manufacturing and production processes. In the late 18th century, mechanisation and steam power gave rise to Industry 1.0, while the assembly line and mass production was brought about by Industry 2.0 in the early 20th century. In the 1970s, industry 3.0 introduced the use of computers and automation; in industry 4.0 [2, 23 and 24], the Industrial Internet of Things (IIoT), and Artificial Intelligence (AI) emerged along with the widespread adoption of data and connectivity in the manufacturing sector. Since the first Industrial Revolution, advancements in manufacturing have made manufacturing processes more complex, automatic, and sustainable so that machines can be operated, effectively, and persistently.

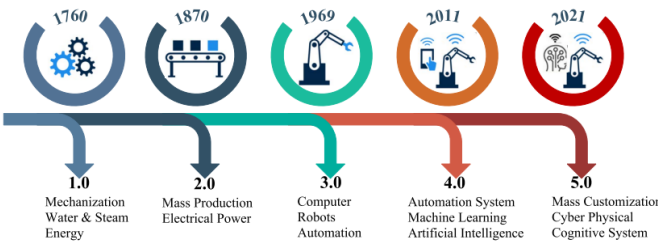

Figure 1: Evolution of Industry 5.0

These advancements range from water and steamdriven devices to electrical and digital electronic production. Industry 5.0 assists businesses in transitioning from mass manufacturing to mass personalization because people today demand mass personalization. Figure 1 shows the evolution process of industry 5.0 in detail.

- Mass Customization: Mass customization [16] is becoming a reality due to Industry 5.0, and the industry needs to quickly advance manufacturing techniques, production system digitization, and intelligence. Mass customization was activated by Industry 4.0 before, but it was insufficient. The ability to produce goods and services with a high degree of customization while retaining the effectiveness and affordability of mass production methods are known as mass customization. Mass customization is a key component of Industry 5.0 because it enables businesses to produce goods that are tailored to specific customers while still reaping the advantages of mass production methods. The ability to produce highly customizable products using cutting-edge technologies like 3D printing, AI, and robotics is one of the main advantages of Industry 5.0. For instance, 3D printing enables producers to produce unique products and parts on demand without the expense of expensive tooling or stock. Automating the customization process with robotics and AI enables manufacturers to produce customised products quickly and effectively at scale. Utilising data and analytics to comprehend customer needs and preferences and tailoring products accordingly is another advantage of Industry 5.0. Manufacturers can gather data on customer behaviour, product usage, and other factors with the help of sensors and Internet of Things (IoT) devices, which enables them to optimise product design and customization options to meet the particular needs of each customer. Mass customization is a crucial component of Industry 5.0 because it enables producers to develop highly customised products that cater to the particular needs of each customer while preserving the effectiveness and affordability of mass production methods. Manufacturers can create highly customizable products that are effective and economical while also offering a distinctive and satisfying customer experience by utilising cutting-edge technologies and data analytics.
- Cyber-physical systems (CPS): The seamless fusion of physical systems and digital technologies are made possible by CPS, which are a key element of Industry 5.0. When physical elements like sensors, actuators, and machines are combined with digital elements like software and data analytics, the result is a system that is intelligent, integrated, and has many different functions. This type of system is known as a cyber-physical system. Increasing efficiency,

productivity, and customization are all made possible by CPS in Industry 5.0 [17]. They enable devices to interact with other digital systems as well as with other machines, resulting in a manufacturing environment that is highly connected and quick to react. This makes it possible for manufacturers to gather data on production processes in real-time, enhance performance, and recognise and resolve problems as soon as they arise. A smart factory, which is a largely automated and networked manufacturing facility that makes use of cuttingedge technologies like the IoT, AI, and big data analytics to optimise production processes, is one example of a CPS in Industry 5.0. Real-time data on manufacturing processes are gathered by smart factories using sensors and other digital technologies. This enables manufacturers to quickly identify and resolve problems, optimise production, and enhance product quality. A linked supply chain, which makes use of sensors and other smart technologies to increase transparency and oversight over the supply chain, is another example of a CPS in Industry 5.0. As a result, manufacturers can optimise inventory control, enhance logistics, and enhance the transportation of goods. The seamless integration of physical systems and digital technologies in Industry 5.0 is made possible by CPS. They give manufacturers the ability to design highly interactive and dynamic production environments, streamline workflows, and enhance product quality and customization.

- Cognitive Systems: Another crucial element of Industry 5.0 is cognitive systems, which allow machinery and equipment to carry out tasks that previously required human intelligence and decision-making. AI and machine learning technologies (including deep learning technologies) [22, 27] are the foundation of cognitive systems, which are intended to learn from data and adapt to changing circumstances. Cognitive systems [18] can be applied in a variety of ways in Industry 5.0 to enhance production methods and results. By examining data on equipment performance and pinpointing areas for improvement, they can be used, for instance, to optimise production processes. By analysing data on product flaws and spotting patterns that might be a sign of a bigger issue, they can also be used to locate and address quality issues. Predictive maintenance is a further use of cognitive systems in Industry 5.0. Cognitive systems can forecast when equipment is likely to fail by analysing data on its performance and usage, giving manufacturers the opportunity to perform maintenance and repairs in advance of a breakdown. By doing this, you can cut downtime and the price of replacing broken equipment. By examining data on inventory levels, demand projections, and production schedules, cognitive systems can also be used to improve supply chain management. This can aid manufacturers in better inventory control, waste reduction, and delivery times. Cognitive systems are essential to Industry 5.0 because they allow machinery and other pieces of equipment to learn, adapt, and make data-driven decisions. Manufacturers can increase productivity, cut costs, boost customization, and improve product quality by utilising these technologies.
- Green Manufacturing: Green manufacturing, which uses sustainable practices and technologies to lessen its negative effects on the environment and increase resource efficiency, is a key component of Industry 5.0. Utilising renewable energy sources to power manufacturing processes, cutting back on energy use, and minimising waste are all examples of green manufacturing. A variety of cutting-edge techniques and technologies are available in industry 5.0 that can be used to promote green manufacturing. By measuring and modifying production processes in real-time, for instance, advanced sensors and IoT devices can be used to optimise energy use and reduce waste. By lowering the need for manual labour and enhancing process control, robotics and automation can also be used to increase energy efficiency. A further opportunity provided by Industry 5.0 is the use of renewable energy sources in manufacturing. For instance, using solar and wind energy to produce electricity for industrial processes can lessen the need for fossil fuels and cut greenhouse gas emissions. Circular economy practises, which aim to reduce waste by creating products that can be reused or recycled at the end of their useful lives, are another opportunity provided by industry 5.0. This can include implementing closed-loop supply chains that reduce waste and maximise material reuse, as well as using cutting-edge materials and manufacturing processes that support the circular economy. Green manufacturing facilitates resource sustainability and energy efficiency in production processes, making it a significant component of Industry 5.0. Manufacturers can lessen their impact on the environment, increase productivity, and develop more sustainable products and processes by utilising cuttingedge technologies and practices.
- Cultural Collaboration: As it involves bringing together people from various cultural backgrounds to work together in a collaborative and inclusive environment, cultural collaboration is a crucial component of Industry 5.0. This is crucial in the context of Industry 5.0 because it is a highly interconnected and globalised environment with global supply chains and manufacturing processes. By bringing together people from various perceptions and experiences, cultural collaboration can aid in enhancing innovation, creativity, and problem-solving. This can result in fresh ideas and methods that might not have emerged in a setting that was more homogeneous.

  Additionally, cultural collaboration can support the development of stronger connections and collaborations among the various players in the manufacturing ecosystem, such as producers, suppliers, buyers, and regulators. It is critical to establish an inclusive environment that values diversity and encourages open communication and collaboration in order to facilitate cross-cultural collaboration in Industry 5.0. This may entail offering instruction and assistance to people with different cultural backgrounds as well as encouraging cultural sensitivity and awareness among all employees. Utilising tools like virtual reality, video conferencing, and collaboration software can also support collaboration and communication across cultural and geographic boundaries. Industry 5.0 places a strong emphasis on cross-cultural collaboration because it fosters creativity, innovation, and problem-solving while also fostering stronger connections and alliances. Manufacturers can foster a more productive, creative, and sustainable manufacturing environment by encouraging cross-cultural collaboration and inclusivity.

With the development of technology and the growing demand for better health outcomes, healthcare has changed over time. The most recent stage of this evolution, known as healthcare 5.0 (refer figure 2 and 3), is characterised by the incorporation of various technologies and methodologies to achieve individualised, patient-centred care.

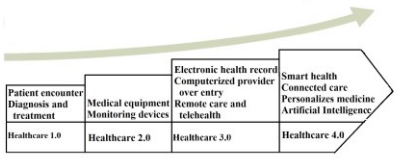

Fig. 2. Evolution of Healthcare 5.0

Following are the various stages of healthcare evolution [21]:

- Healthcare 1.0: This is the conventional healthcare system in which patients receive in-person attention from physicians, nurses, and other healthcare professionals.
- Healthcare 2.0: In this phase, patient data was stored and managed using electronic health records (EHRs) and other digital technologies.
- Healthcare 3.0: This phase put a strong emphasis on patient education and public health campaigns, as well as disease prevention and health promotion.
- Healthcare 4.0: To enhance patient care and health outcomes, various technologies, including AI, the IoT, and big data analytics, were integrated. The foundation of Healthcare 4.0 is expanded upon in this stage, which also emphasises the integration of non-medical factors like social and environmental determinants of health. Healthcare 5.0 aims to achieve a comprehensive understanding of patient health and wellbeing and to offer individualised care catered to each person's needs and preferences.
- Healthcare 5.0: The need for better patient outcomes, increased effectiveness, and the incorporation of new technologies to enhance the delivery of care has driven the evolution of healthcare. The most recent phase in this evolution, known as healthcare 5.0, is characterised by a focus on patient-centred, personalised care that considers a wide range of factors affecting health and well-being.

Industry 5.0 aims to bring together the advantages of Industry 4.0 with the skills and advantages of human workers. It recognises that even though automation and technology can increase productivity and quality, some jobs and decision-making processes are better left to human employees. The goal of Industry 5.0 is to improve communication and cooperation between people and machines. Industry 5.0 aims to use automation to improve human workers' abilities and enable them to work alongside machines, as opposed to replacing human workers with robots. As a result, there may be more opportunities for employees to contribute their skills and expertise and for manufacturing processes to be more adaptable and responsive. Overall, Industry 5.0 is a future scenario in which human workers and technology collaborate to develop more effective and efficient manufacturing processes while also giving humans more fulfilling and rewarding jobs.

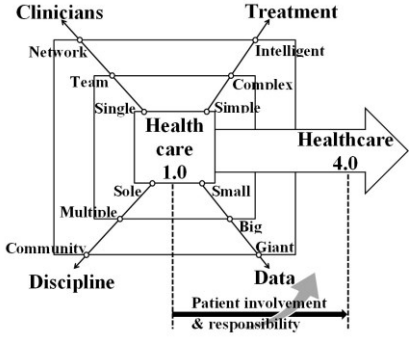

Fig. 3. Characteristics of the Healthcare Revolution

With numerous potential advantages like better patient outcomes, personalised medicine, automation of tedious tasks, remote care and telemedicine, and preventive care, Industry 5.0 is predicted to revolutionise the healthcare sector. The adoption of Industry 5.0 in the healthcare sector has the potential to significantly improve the standard of care, lower expenses, and boost productivity. Personalised medicine, which involves adjusting medical care to a patient's unique needs, genetic makeup, and lifestyle, is one of Industry 5.0's most important benefits for the healthcare sector. Healthcare professionals can develop individualised treatment plans that are suited to a patient's particular characteristics with the aid of cutting-edge technologies like AI, data analytics, and the IoT. Healthcare industry 5.0 can also automate routine tasks by entering patient data and performing administrative duties, freeing up medical professionals to concentrate on more difficult tasks. This may result in greater effectiveness, financial savings, and better patient outcomes. Telemedicine and remote care are two important examples of Industry 5.0 applications in the healthcare sector. This makes it possible for medical professionals to perform medical procedures, virtual consultations, and even remote patient monitoring. Patients in remote areas, who might not have easy access to medical facilities, may find remote care to be especially beneficial. Another area where Industry 5.0 has the potential to make a big difference in preventive healthcare. Medical professionals can identify patients who are at high risk for specific diseases or conditions and offer early intervention and preventive care by utilising data analytics and AI. Despite the many advantages, there are some difficulties in implementing Industry 5.0 in healthcare, including the need for a substantial infrastructure, issues with data privacy, and ethical issues. Nevertheless, the healthcare sector is likely to experience significant advancements in the near future due to the continued development of Industry 5.0.

Organization of the work: Section II discusses the recent literature work on new technological advances in the healthcare sector. Section III defines Industry 5.0 and Healthcare 5.0, as well as their broader implications. Section IV delves into the potential and opportunities of utilising Industry 5.0 for Healthcare 5.0. Section V then delves into the challenges and roadblocks associated with implementing Industry 5.0 for Healthcare 5.0. Following that, a brief discussion concludes the work in section VI.

II. LITERATURE REVIEW

Industry 5.0 is a relatively new idea, and there is not one set of defining pillars that everyone agrees upon. There are, however, a few major themes that are frequently connected to Industry 5.0. These themes consist of:

1) Human-centricity: Industry 5.0 places a lot of emphases on the importance of human workers in the production process [19]. Industry 5.0 integrates workers with cutting-edge technologies in order to empower them and increase their productivity rather than trying to replace human workers with machines and automation.
2) Interconnectivity: Industry 5.0 envisions a manufacturing ecosystem that is highly connected to the internet and comprises machines, sensors, and other devices. This enables the manufacturing process to be more flexible and agile while also making better use of available resources.
3) Intelligent automation: Industry 5.0 aims to incorporate cutting-edge technologies like robotics, machine learning,

and AI into the manufacturing process. Utilising these technologies can increase quality, decrease waste, and optimise production.

4) Sustainability: Industry 5.0 places a strong emphasis on the need for environmental responsibility and sustainability in the manufacturing process. This entails lowering waste and carbon emissions, utilising renewable energy sources, and engaging in other eco-friendly behaviours.
5) Innovation: A culture of innovation and ongoing improvement is what defines Industry 5.0. Companies that adopt Industry 5.0 are encouraged to experiment with cutting-edge equipment and procedures as well as to adopt a culture of continuous improvement.

The term "Healthcare 5.0" refers to the incorporation of Industry 5.0 technologies into the provision of healthcare. Healthcare 5.0 aims to boost sustainability in healthcare delivery, lower costs, and improve patient outcomes. Numerous studies have been conducted on the emerging technologies that are driving the technological revolution in the healthcare system, which primarily include IoT, AI, and Big Data. These studies also highlight various ethical and privacy concerns that are inherent in the digital space.

In [28], author provides a high-level overview of all the fundamental ideas, such as AI, IoT, and 5G communication, that enable high-speed data transmission networking techniques in healthcare units and raise the bar for healthcare philosophy to a new level. It emphasises the importance of improving 5G, or fifth-generation communication, as the fundamental network infrastructure, embedded AI, and IoT machines in the growth and progress of new technologies in healthcare units, and advancement in people's lives leads to a healthier life. [29] proposes a framework for image classification and segmentation in computerised tomography based on an Explainable AI (EXAI) ensemble. A case study on electrocardiogram (ECG) monitoring is provided, along with metric validation using federated learning (FL) and EXAI. The study uses real-life model deployments in a variety of clinical use cases to demonstrate the efficacy of EXAI in health settings. [30] introduces the framework for a super-smart, sustainable healthcare system in Society 5.0. This system will integrate cutting-edge technologies like AI, Big Data, Cloud Computing, and IoT to deliver equitable, reliable, and optimised healthcare to every member of society. It also discusses the roles and responsibilities of various stakeholders, key technologies and their value in the advancement of such systems, various approaches to managing and analysing healthcare data, and the ethical considerations that must be made with regard to patient safety, data security, and people's well-being. [31] discusses the significance of cutting-edge digital innovations and how AI-based algorithms present a once-in-a-lifetime opportunity to have an impact on the urban context by utilising massive amounts of data in an integrated manner. It proves that, from the standpoint of public health, nations that enjoy a harmonious coexistence of financial resources, technological infrastructure, and public health professionals should foster a synergy for the development of research on digital technologies to address the factors that influence health in the urban context, which opens the door for sustainable living conditions. [32] discusses the rapidly developing digital technologies that present health systems with previously unheard-of opportunities to enhance healthcare service delivery and virtual care. The authors draw attention to the dearth of emotive smart devices and personalised, pervasive health applications, as well as the lack of emotive recognition, which ultimately calls for the incorporation of intelligent sensor health systems through emerging technologies. The successful implementation of healthcare 5.0 has been described as potentially being hampered by a number of organisational challenges, technological and infrastructural barriers, a lack of regulatory and legal structures and e-health policies, individual perceptions, a lack of funding, and religious and cultural barriers. [33] examines the emotive sensory web known as Web 5.0, which offers numerous opportunities to revolutionise the provision of healthcare services. The authors come to the conclusion that the implementation of sensory emotive Web in virtual healthcare depends heavily on emerging technologies. Because of the threats to the integration of these technologies posed by security, privacy, standardisation of protocols, and interoperability issues, they emphasise the need for formulating policies and technological capabilities that support Web 5.0 in virtual healthcare. [34] implemented a hybrid federated learning and blockchain approach in healthcare 5.0 to enhance the clinical data learning process, with a focus on data security and confidentiality concerns. In order to significantly improve secure communication and efficient healthcare monitoring, the authors suggest a model that enables effective collaborative architecture using numerous Internet of Medical Things (IoMT) devices and manages training.

As can be seen, the majority of studies in this field are solely concerned with the technologies that support Healthcare 5.0, as well as the associated security and privacy concerns. They overlook other challenges, such as the initial high cost of emerging systems, patient acceptance and adoption of new technologies while ensuring a smooth transition, integration and interoperability, and many more.

III. DEFINING INDUSTRY 5.0 AND HEALTHCARE 5.0

The fact that the term is still relatively new and evolving is one of the main problems with defining Industry 5.0. Although it is generally acknowledged that Industry 5.0 is the next stage of industrial development following Industry 4.0, there is less agreement on the specific traits and traits that characterise it. So, Industry 5.0 may be interpreted and defined slightly differently by various researchers and organisations. Additionally, because Industry 5.0 emphasises the value of human workers, its definition contains a subjective component that is open to interpretation. For instance, while some may see Industry 5.0 as a radical departure that places a greater emphasis on human skills and creativity, others may see it as a continuation of the trend towards greater automation and digitization.

The widely used definitions of industry 5.0 all place equal emphasis on the necessity of human-centricity [10], the incorporation of cutting-edge technologies, and the development of adaptable and value-driven production ecosystems. Industry 5.0, in contrast to earlier industrial revolutions, places human workers at the centre of the production process and emphasises their distinctive cognitive and creative capabilities in conjunction with cutting-edge technologies like robotics and AI. A more flexible and adaptable production process that can respond to shifting market conditions and customer demands is made possible by Industry 5.0's design of machines to work closely with human workers. By allowing humans to concentrate on tasks that call for their special talents and skills while leaving more routine or hazardous tasks to machines, this manufacturing strategy also aims to improve the

work environment for human employees. A growing understanding of the significance of striking a balance between technological advancement and the needs and aspirations of human workers and developing a more sustainable and inclusive vision of the future of work is reflected in Industry 5.0's emphasis on human centricity. Another key component of the definition of Industry 5.0 is sustainability [11]. This is due to the fact that Industry 5.0 seeks to develop a more eco-friendly and sustainable manufacturing ecosystem that boosts productivity and efficiency while lowering waste and carbon emissions. In order to optimise resource use and reduce waste, Industry 5.0 is created to integrate sustainable practices and technologies, such as renewable energy, circular economy principles, and the use of advanced analytics and machine learning. The focus on sustainability reflects a growing understanding of the need to strike a balance between economic development and environmental protection, as well as to develop a more ethical and responsible manufacturing process. Industry 5.0 seeks to build a more resilient and adaptable manufacturing ecosystem that can respond to shifting market demands and environmental conditions. By taking into account the needs and aspirations of both present and future generations, this manufacturing approach also aims to create a more moral and socially conscious vision of the future of work. In general, Industry 5.0's emphasis on sustainability reflects a growing understanding of the need to strike a balance between economic growth, environmental protection, and social responsibility, as well as to develop a more sustainable and just vision of the future of work. It is difficult to compare research and development efforts across various organisations and nations due to the absence of a clear and widely accepted definition of Industry 5.0, which can impede progress in this area. But over time, it's likely that ongoing discussions and disagreements about Industry 5.0 will result in a more precise and nuanced understanding of the idea.

Although "Healthcare 5.0" is still in its infancy, it is generally accepted to be the next development in healthcare delivery systems. Healthcare 4.0 (digital healthcare), Healthcare 3.0 (patient-centric healthcare), and Healthcare 2.0 are all built upon in this stage (evidence-based healthcare). Healthcare 5.0 is anticipated to put an emphasis on providing personalised, preventive, and participatory care and to make use of technologies like blockchain, the IoT, and AI to enhance patient experiences and health outcomes [20]. With a focus on the value of patients taking an active role in managing their health, it seeks to go beyond simply treating illness and disease and towards promoting overall health and wellness.

IV. IMPLEMENTING INDUSTRY 5.0 FOR HEALTHCARE: POTENTIAL AND OPPORTUNITIES

Healthcare 5.0, a new paradigm that prioritises individualised, patient-centred, and preventive care, has the potential to completely transform how healthcare is delivered. The following are a few of Industry 5.0's major opportunities for Healthcare 5.0:

- Personalised Medicine: Industry 5.0 can support the development of personalised medicine by utilising AI, advanced analytics, and other digital technologies to examine vast amounts of patient data and produce insights into unique patient needs and preferences. The idea of personalised medicine entails adapting treatment plans and therapies to the specific needs of each patient by using patient-specific data, such as genetics, lifestyle, and medical history. Healthcare professionals may have access to a wealth of patient-specific data due to Industry 5.0 technologies like the IoT, big data [12], and AI, which generate enormous amounts of data and enable more precise diagnosis and treatment. By utilising advanced analytics, AI, and other digital technologies to analyse vast amounts of patient data and produce insights into specific patient needs and preferences, industry 5.0 can facilitate the development of personalised medicine. This may make it possible for medical professionals to offer more precise and efficient treatments, lowering the possibility of negative side effects and enhancing patient outcomes. For instance, personalised medicine in cancer treatment entails genetic analysis of a patient to determine the precise mutations causing cancer and the creation of a targeted therapy that specifically targets those mutations. Personalised medicine has the potential to enhance patient outcomes and deliver more individualised, precise care, making it a promising Industry 5.0 application in the healthcare sector.
- Improved Patient Outcomes: Industry 5.0 can enable continuous monitoring and tracking of patient health by integrating digital technologies and IoT devices [13], which can lead to the early detection of health issues and improved patient outcomes. In several ways, industry 5.0 technologies have the potential to significantly improve patient outcomes. Large volumes of patient data, including medical records, lab results, and imaging studies, can be analysed by Industry 5.0 technologies like AI and machine learning to aid clinicians in making more precise diagnoses. This may result in earlier disease detection and more efficient treatment. This can increase the efficacy of the treatment and lower the chance of adverse reactions. IoT and other connected devices can offer real-time patient health status monitoring, enabling medical professionals to quickly spot and react to changes in their patients' conditions. This may aid in avoiding problems. Industry 5.0 can help healthcare providers communicate and work together, enabling them to share patient data and more efficiently coordinate care. This can enhance patient outcomes, reduce errors, and improve care coordination. Healthcare industry 5.0 technologies have the potential to enhance the precision, effectiveness, and efficiency of treatment, improving patient outcomes.
- Enhanced Efficiency: By automating repetitive tasks, streamlining workflows, and lowering administrative burden, Industry 5.0 can improve efficiency in the delivery of healthcare. This will free up healthcare professionals to concentrate on more complex and valueadded tasks. Healthcare facilities frequently use electronic health record (EHR) systems to manage patient data, but data entry can be laborious and prone to mistakes. Natural language processing (NLP) and speech recognition are examples of Industry 5.0 technologies that can automate data entry, easing the burden on healthcare providers. Automation of the prescription filling and administration process can help to lower the possibility of errors and give pharmacists and nurses more time to work on other projects. For instance, robotics can be used to administer medications to patients while automated dispensing machines can prepare and dispense medication. It can be difficult and time-consuming for hospitals and other healthcare facilities to manage large inventories of medical supplies. By tracking supplies and automatically placing new orders when necessary, Industry 5.0 can assist in automating the inventory management process. By automating appointment scheduling and reminders, industry 5.0

can ease the workload on administrative staff and boost patient engagement. Appointment reminders can be sent via text message or email using chatbots and other virtual assistants. Many repetitive tasks in the healthcare industry can be automated with the aid of Industry 5.0 technologies, easing the burden on healthcare professionals and enhancing the effectiveness and efficiency of care.

- Remote Care: Telemedicine and remote care are made possible by Industry 5.0, allowing patients to receive treatment from the comfort of their own homes and relieving pressure on medical facilities. Remote consultations and follow-ups can be made possible for patients and medical professionals through the use of video conferencing and other communication technologies. Healthcare providers can track and manage patients' conditions without requiring in-person visits by using wearable sensors [14] and other IoT devices to remotely monitor patients' vital signs. Robots with cameras and other sensors can be used to treat patients remotely, enabling medical professionals to diagnose and treat patients while working at a distance. There is less need for in-person visits when mobile apps are used to monitor patient conditions and offer advice on managing chronic conditions. By utilising Industry5.0 technologies, remote care and telemedicine can increase access to care and lighten the load on healthcare providers, particularly in rural and remote areas.
- Preventive Care: Industry 5.0 in healthcare places a strong emphasis on preventive care, which can lessen the burden of chronic diseases and enhance general health outcomes. Industry 5.0 technologies make it possible to offer patients individualised, focused preventive care. By enabling earlier detection and intervention in chronic diseases, as well as by encouraging healthy lifestyles and disease prevention, Industry 5.0 can assist healthcare providers in transitioning from a reactive to a preventive care model. Healthcare providers can intervene early and stop the progression of the disease by analysing patient data using advanced analytics and machine learning algorithms to identify those who are most at risk of developing chronic diseases. Healthcare providers can use wearable sensors and other IoT devices to track patients' health status in real-time, enabling them to spot early disease signs and take action before the condition worsens. Based on each patient's unique health requirements and genetic profile, industry 5.0 technologies can be used to create individualised nutrition plans for them. This can enhance overall health outcomes and delay the onset of chronic diseases. Personalised health coaching can be offered to patients using industry 5.0 technologies, assisting them in adopting healthy lifestyle changes and behaviours that can delay the onset of chronic diseases. Healthcare providers will be able to deliver targeted, personalised preventive care that can enhance health outcomes and lessen the burden of chronic diseases due to Industry 5.0, which can help shift the focus of healthcare from reactive to proactive.

A. Focus on Sustainability

To achieve sustainability in Healthcare 5.0, a holistic approach that considers the social, economic, and environmental aspects of healthcare provision is required.

- Resource Efficiency: At the micro-operational level, Industry 5.0 emerging technologies have a positive effect on several sustainable environmental metrics, such as resource efficiency or emission reduction. These sustainability impacts are somewhat inadvertently achieved alongside the productivity maximisation goal. Stakeholders are essential components of Industry 5.0 because societal needs drive this trend. Industry 5.0 prioritises the three sustainability pillars equally, attempting to attack a harmonious equilibrium between economic development and the preservation of socio-environmental values. The Industry 5.0 agenda consistently recognises that stakeholder participation in the management and governance of digital industrial transformation is critical to achieving sustainability goals. Healthcare facilities can use Industry 5.0 technologies like IoT and artificial intelligence to optimise resource use and eliminate waste. For example, facility managers can use smart sensors and connected devices to track energy use, water use, and waste generation in hospitals and clinics. This allows them to spot inefficiencies and put policies in place to cut back on resource consumption. Healthcare facilities can monitor their energy, water, and waste usage using Industry 5.0 technologies like smart sensors and connected devices. This makes it possible for healthcare professionals to spot inadequacies and put plans in place to cut back on resource usage. To save energy, smart lighting systems, for instance, can be used to effectively control lighting levels based on occupancy and natural light. Automation is emphasised in Industry 5.0 as a means of increasing efficiency and reducing waste. This also applies to the delivery of healthcare, where routine tasks like patient registration, appointment scheduling, and billing are automated using robotic process automation (RPA) and AI. This not only boosts productivity but also lowers the chance of mistakes and waste. AI and machine learning are two examples of Industry 5.0 technologies that can be used to assess malfunctions in advance, allowing for condition monitoring and minimising downtime. This lessens the need for emergency repairs, which are frequently more expensive and resource intensive. Sustainable production practices and materials are emphasized in Industry 5.0. Using efficient and environmental components in medical equipment and supplies and the adoption of sustainable practises in healthcare facilities, can be extended to healthcare delivery as well. Large-scale data can be collected and analysed thanks to Industry 5.0 technologies, which can then be used to spot patterns and trends in resource consumption. Healthcare facilities can use this to find inefficient areas and put plans in place to better use resources. Industry 5.0 technologies can help achieve resource efficiency in Healthcare 5.0 by improving the efficiency and effectiveness of resource consumption, digitising repetitive tasks, assessing and mitigating equipment breakdown, implementing sustainable materials and practises, and analysing data to identify inefficient areas.
- Patient-centric Care: Healthcare 5.0 places a strong emphasis on the need for a patient-centric approach to healthcare, which entails modifying interventions and treatments to meet the specific needs of each patient. By avoiding the use of pointless tests and treatments, can aid in reducing the overall resource consumption in healthcare. Patients in rural areas can receive medical care using industry 5.0 technologies like video conferencing and remote monitoring. Lowering the need for travel, not only expands access to healthcare but also lowers the carbon footprint of providing it. Patient

information can be stored and accessed using EHRs in a centralised and secure manner. This increases care coordination and lowers the possibility of unnecessary tests and treatments by allowing healthcare professionals access to patient data from any location. As a result, waste is decreased and resource efficiency is increased. Smartwatches and fitness trackers are two examples of wearable technology that can be used to monitor and provide real-time feedback on patient health. Patients can manage their health more actively as a result, and healthcare professionals receive useful information that can be used to customise treatment plans. Precision medicine and other Industry 5.0 technologies can be used to tailor treatment plans to the needs of specific patients. This minimises the use of pointless tests and treatments while lowering the risk of adverse drug reactions. Social media and mobile apps, two examples of Industry 5.0 technologies, can be used to engage patients and give them the tools they need to manage their own health. This reduces the need for resource-intensive procedures while also improving patient outcomes. In addition to enhancing health outcomes, these technologies also advance sustainability by decreasing waste, enhancing resource efficiency, and lowering the carbon emissions of healthcare provision.

- Human-machine Collaboration: Industry 5.0 places a strong emphasis on the necessity of cooperation between humans and machines, which also applies to the provision of healthcare. Healthcare professionals can collaborate more efficiently and cut down on travel and other resource-intensive activities by utilising technologies like telemedicine and remote monitoring. Radiologists can be supported by industry 5.0 technologies like computeraided diagnosis (CAD) when interpreting medical images. Due to the increased accuracy and decreased need for repeat imaging, waste is reduced, and resource efficiency is increased. Robotic surgery is one example of an industry 5.0 technology that can help surgeons carry out intricate procedures more precisely and accurately. As a result, fewer resource-intensive interventions are required, which enhances patient outcomes and lowers the risk of complications. AI and machine learning are examples of Industry 5.0 technologies that can be used to analyse patient data and forecast the likelihood of unfavourable outcomes. Because of this, medical professionals can prevent negative outcomes by acting proactively, sparing resources and improving patient outcomes. The health of patients can be closely monitored using Industry 5.0 technologies like wearables and remote monitoring, which can give healthcare professionals feedback in realtime. With less need for resource-intensive measures, this enables healthcare professionals to step in early, preventing difficulties and enhancing patient experiences. AI and machine learning are examples of Industry 5.0 technologies that can be used to speed up the drug discovery process. As a result, it takes less time and money to develop new drugs, which increases their affordability and accessibility while lowering their carbon footprint. With the aid of Industry 5.0 technologies, human-machine collaboration in Healthcare 5.0 can be made possible, promoting sustainability by increasing accuracy and precision, lowering the risk of unfavourable outcomes, enhancing patient outcomes, and reducing the need for interventional procedures that require a lot of resources. Healthcare 5.0 can improve patient outcomes by utilising the advantages of both people and machines while also fostering sustainability in healthcare delivery. • Supply Chain: Healthcare supply chains can be made more efficient with the help of Industry 5.0 technologies, which will lessen the industry's carbon footprint. For instance, the application of blockchain technology can enhance the traceability and transparency of the supply chain, lowering the likelihood of wastage and inefficiencies. Medical supplies and equipment can be tracked in real-time using Industry 5.0 technologies such as IoT. This allows healthcare providers to manage their inventory more effectively, reducing waste and optimising supply chain management. AI and machine learning, for example, can be used to analyse supply chain data and forecast future demand for medical supplies and equipment. This allows healthcare providers to manage their inventory more effectively, reducing waste and optimising supply chain management. Industry 5.0 technologies, such as 3D printing, can be used to produce medical supplies and equipment on-demand, reducing the need for large inventories and waste. This also allows healthcare providers to respond quickly to changing patient needs, which improves patient outcomes. Medical supplies and equipment can be tracked for origin and authenticity using Industry 5.0 technologies like blockchain. This lowers the possibility of fake materials entering the supply chain, enhancing patient security, and cutting waste. The healthcare supply chain's carbon footprint can be decreased by using Industry 5.0 technologies to streamline logistics and transportation. This includes utilising hybrid or electric vehicles, planning delivery routes efficiently, and utilising renewable energy sources. Healthcare providers can raise the sustainability of healthcare delivery while also enhancing patient outcomes by optimising the healthcare supply chain.

Hence, Healthcare 5.0, a more patient-centred, personalised, and preventive approach to healthcare, has the potential to change healthcare delivery, enhance patient outcomes, and be a part of Industry 5.0. Healthcare 5.0 offers enormous potential and chances to completely transform the healthcare sector. The delivery of healthcare can be improved, patient outcomes can be improved, and the healthcare experience can be transformed through the integration of cutting-edge technologies like AI, blockchain [15], big data analytics, and robotics. Healthcare 5.0's personalised medicine makes it possible to customise medical treatments to a patient's particular genetic makeup and medical history, resulting in more effective treatments and better patient outcomes. With the aid of wearable sensors and AI algorithms, healthcare 5.0 also offers more sophisticated diagnostic tools that enable earlier disease detection and better disease management. Additionally, the telemedicine enabled by Healthcare 5.0 can give patients access to medical care from a distance, improving accessibility and cost. Healthcare 5.0 can also promote patient-centred care in which patients actively participate in their own healthcare. To improve their health and communicate with healthcare professionals, patients can use health-tracking apps, patient portals, and patient communities. Last but not least, the application of big data analytics in Healthcare 5.0 can assist medical professionals in finding patterns and trends in patient health, resulting in better healthcare outcomes.

V. IMPLEMENTING INDUSTRY 5.0 FOR HEALTHCARE: CHALLENGES AND OBSTACLES

Although Industry 5.0 has significant potential for healthcare, it also faces various challenges and obstacles. Some of the key issues are:

- Data Privacy and Security: Data security and privacy issues are raised by Industry 5.0's heavy reliance on the collection and processing of enormous amounts of data. Due to the use of cutting-edge technologies like AI, the internet of things (IoT), and cloud computing, which produce and process vast amounts of sensitive data, data privacy and security are crucial concerns in the implementation of Industry 5.0 for healthcare. While these technologies have the potential to significantly improve healthcare outcomes and delivery, they also pose new privacy and data security risks to patients. Strong emphasis must be placed on creating and implementing effective data privacy and security policies and protocols in order to address these concerns. This entails making certain that patient data is properly encrypted and safeguarded, limiting access to sensitive data, and putting in place the proper authentication and access controls. In addition, there needs to be explicit guidelines and rules in place to guarantee that patient data is gathered, saved, and used in accordance with ethical and legal standards. Healthcare organisations can make use of the skills of data privacy and security experts to help address these worries, and they can also collaborate closely with regulatory bodies to make sure they are abiding by all applicable laws and regulations. Additionally, to help ensure the secure transfer and storage of patient data, healthcare organisations can make use of cutting-edge technologies like blockchain.
- Integration and Interoperability: Healthcare systems comprise a number of stakeholders and components, making it difficult to integrate and incorporate them seamlessly and effectively. One of the biggest obstacles to implementing Industry 5.0 in healthcare is the integration and interoperability of various systems and devices. Electronic health records (EHRs), clinical decision support systems, and medical devices are just a few of the systems that healthcare organisations employ. These systems are occasionally incompatible with one another. The fragmentation of the healthcare system that results from a lack of interoperability could have an adverse effect on patient care. Industry 5.0 for healthcare needs an interoperable infrastructure that enables various systems to communicate with one another without interruption in order to address this challenge. Open standards, which guarantee that various systems can communicate and exchange data with one another in a standardised way, are one way to accomplish this. Utilising a Service-Oriented Architecture (SOA) is another strategy that enables standardised communication between various services and applications. The adaptable nature of SOA allows it to be tailored to the unique requirements of various healthcare organisations. Interoperability is not only a technical challenge, though. It also calls for a cultural change that emphasises communication and information exchange among various healthcare providers. Common standards and policies that promote data sharing and cooperation can be developed to accomplish this. Overall, interoperability is crucial to Industry 5.0's success in healthcare because it enables healthcare providers to share data and collaborate more successfully to improve patient outcomes.
- Ethical and Legal Considerations: The ownership of data, the responsibility of algorithms, and the possibility of biases and discrimination in the decision-making process are just a few of the ethical and legal questions raised by Industry 5.0. There are moral and legal issues that need to be resolved with the implementation of Industry 5.0 in the healthcare industry. As the use of technologies like AI and IoT may result in the collection and sharing of vast amounts of individual health information, protecting patient privacy and confidentiality is a crucial ethical consideration. There is also the moral issue of how the patient-provider relationship and the standard of care may be affected by using AI and other technologies. Legal issues must also be considered, particularly those relating to laws governing data privacy, security, and informed consent. For instance, if AI is used to make medical decisions, questions of liability and responsibility may arise, especially if the algorithm yields inaccurate results. The ownership and sharing of the data produced by these technologies may also present problems. The use of Industry 5.0 in healthcare must be governed by clear rules and regulations, and standards for data privacy, security, and interoperability must be created in order to address these ethical and legal issues. In order to make sure that the ethical and legal implications of Industry 5.0 for healthcare are carefully considered and addressed, it is also crucial to engage in ongoing stakeholder dialogue.
- Skilled Workforce: Industry 5.0 demands a workforce with skills, including data scientists, AI specialists, and healthcare professionals who are adept at using cuttingedge technologies. The need for a skilled workforce is one of the main obstacles to Industry 5.0 implementation in the healthcare sector. For the management of the intricate systems and technologies that will be used in Industry 5.0, the healthcare sector needs a workforce that is highly knowledgeable and skilled. A specialised workforce will also be necessary to design, create, and implement new systems and technologies. An important factor to take into account is the education and training of the current workforce as well as the development of new job roles that are pertinent to Industry 5.0. Additionally, the healthcare sector requires interdisciplinary cooperation and communication between various teams, departments, and organisations. To ensure that the workforce has the skill sets required to successfully integrate and use the technologies being developed for Industry

  5.0 in healthcare, the staff must be educated in working cooperatively with other experts such as data scientists, engineers, and software developers. Additionally, given the rapid evolution of Industry 5.0 technologies and the healthcare sector, there is a need for ongoing learning and the development of new skills. The ethical, legal, and social concerns related to the use of Industry 5.0 technologies in healthcare should be considered in the workforce's education and training. In conclusion, addressing the workforce issues associated with Industry 5.0 in healthcare will be essential to ensuring the successful adoption of new technologies and systems, which will result in better patient care.
- Cost and Infrastructure: Implementing Industry 5.0 in healthcare will cost a lot of money because it will require new

infrastructure and cutting-edge technologies. It will cost a lot of money upfront to implement Industry 5.0 in the healthcare industry, in terms of infrastructure, hardware, software, and staff training. Healthcare industry 5.0 systems might need routine maintenance, upgrades, and replacements, which could raise the overall cost. It can be expensive and support-intensive to integrate Industry 5.0 technologies with current healthcare systems and data infrastructure. Healthcare Industry 5.0 implementation will require specialised knowledge and skills, and it's possible that there won't be enough skilled workers or resources to manage and maintain these systems. Implementing Industry 5.0 in healthcare can also cause issues with rural and disadvantaged populations' access to technology. Many patients who cannot afford the additional expenses may also find it difficult to access healthcare services because of Healthcare 5.0's high cost.

- Acceptance and Adoption by Patients: The success of Industry 5.0 in healthcare depends on patients' acceptance and adoption, as some patients may be reluctant to use cutting-edge technologies. Patients who don't trust the data privacy and security measures in place may be reluctant to use new technologies like wearables or telemedicine. Additionally, in this new healthcare paradigm, patients with less technology access or health literacy may be left behind. Healthcare organisations and providers must address these issues and make sure that patients have access to the information and resources they need to fully engage in Industry 5.0 healthcare. Patients can better understand the advantages of new technologies and how they can use them to improve their health outcomes with the aid of education and awareness campaigns. By formulating open policies and procedures for data collection, healthcare providers can help address concerns about data privacy and security.

Industry 5.0 has the potential to transform healthcare, but in order for it to be implemented in a way that benefits patients and the healthcare system as a whole, it is critical to address these issues. While Healthcare 5.0 offers many possibilities and potential, it also has a number of problems and difficulties that must be resolved in order to make this new idea successful. Healthcare 5.0's implementation necessitates addressing a number of problems and difficulties, including data privacy and security, ethical and legal considerations, the right skills and training for healthcare professionals, and cost-effectiveness. Even though these obstacles may seem overwhelming, they must be overcome in order to fully realise the benefits of Healthcare 5.0 and enhance patient outcomes, enhance healthcare delivery, and transform the patient experience. To overcome these obstacles and enable a more effective, efficient, and patient-centred healthcare system, Healthcare 5.0 requires a collaborative effort between healthcare professionals, industry stakeholders, and policymakers.

VI. Conclusion

An emerging idea called "Industry 5.0" emphasises the fusion of technology, machines, and people in the manufacturing sector. This idea is also applicable to the healthcare sector, where it is referred to as healthcare 5.0. Healthcare 5.0 makes use of cutting-edge technologies to revolutionise patient outcomes, healthcare delivery, and the patient experience as a whole. The healthcare sector could gain a lot from incorporating Industry 5.0 ideas into healthcare 5.0. Healthcare 5.0 can benefit from applying Industry 5.0 principles to advance telemedicine, personalised medicine, and advanced diagnostics. Healthcare professionals may be able to deliver more effective, efficient, and patient-centred care with the help of cutting-edge technologies like wearable sensors, AI, blockchain, and big data analytics. Additionally, the accuracy and precision of medical care can be increased by incorporating robotics and AI into processes and treatments. The implementation of Industry 5.0 principles can raise healthcare's overall standard of care and enhance the patient experience.

However, there are obstacles to applying Industry 5.0 principles to Healthcare 5.0, including issues with data security and privacy, ethical and legal issues, and the requirement for the right skills and training for healthcare professionals. Healthcare professionals, business stakeholders, and policymakers must work together for healthcare 5.0 to be implemented successfully. In conclusion, Industry 5.0 can be used in the healthcare sector through healthcare 5.0 to enhance patient outcomes, improve healthcare delivery, and change the entire healthcare experience. A more effective, efficient, and patient-centred healthcare system may result from the incorporation of Industry 5.0 principles into Healthcare 5.0.

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