The Design Intervention Opportunities to Reduce Procedural-Caused Healthcare Waste Under the Industry 4.0 Context – A Scoping Review

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Abstract. The current medical device industry thrives on material redundancy and continues to advocate for a use-and-throw model of practice. Such redundancies are vital to ensure the safety of patients by preventing reinfection from reused devices, but the risks and costs of the waste generated are leaving hospitals and third-party resource handlers wary of future challenges.

The Industry 4.0 revolution has started to redefine the production and consumption models of many industries. The main advantages of adopting these methods have been increased efficiency of systems and a reduction of redundant resources. But how do these new technologies help reduce the waste generated in medical procedures? This paper scopes the opportunities that come with implementing industry 4.0 to reduce procedural caused medical waste. These challenges and opportunities have been analysed at four hierarchical levels of innovation; the system, service, procedural and product levels. The research indicates that although the adoption of industry 4.0 concepts in healthcare is contributing to a more efficient use of resources, more research is required focused specifically on its impact on the production of procedure-caused medical waste.

Keywords: Medical device design · Medical waste · Sustainability · Industry 4.0 · Advanced manufacturing

1 Introduction

The onset of the COVID 19 pandemic has brought with it an increased use of single-use disposable equipment in the healthcare industry. The production of single-use disposables has been consistently unable to meet the demand, and yet it is far too much for waste management systems to deal with (Bown 2020; Ranney et al. 2020). With the pandemic continuing to spread around the globe, a new approach is required to reduce the waste generated from the healthcare industry (Zambrano-Monserrate et al. 2020; Klemes et al. 2020).

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This study implements a scoping review approach to explore the opportunities for implementing Industry 4.0 (I4) technologies to reduce the diagnostic, treatment and rehabilitation procedural waste. The following sections cover the background of the research by exploring various definitions of medical waste, and I4. This study has a specific focus on waste produced by medical procedures, and four aspects of I4 which can have a strong impact on reducing procedural waste; lean production systems, internet of things (IoT), artificial intelligence and additive manufacturing. Due to … The application of these concepts in medical procedures has been reviewed from Scopus database.

There are various types of wastes produced in medical procedures, such as anatomical waste, product and packaging waste, pharmacological waste, material waste, and a waste of resources such as water, electricity, time, human resource and money. These types of waste can be attributed to various factors in a medical procedure. The product and packaging waste is often the result of how the product has been designed and used. Pharmacological waste is dependent on the use of medication as determined by the clinicians. The anatomical waste is dependent on the pathophysiology of the condition being treated and the design of the procedure. The waste of physical and human resources is also dependent on the design of the procedure and the systems within which these procedures are conducted, such as the hospital infrastructure, the financial model of operations for the hospital, and the efficiency of operations at the hospital. While design interventions may be possible at various levels of the overall healthcare system, this study focusses on interventions that are not policy driven and are achievable within the constraints of the hospital operations.

The study has been detailed in four sections covering four different levels of design intervention opportunities to reduce the procedural-caused medical waste. The first section explores the use of lean management approaches to make medical departments at healthcare facilities more efficient in delivering healthcare to patients. This covers the systems interventions that support the reduction in waste generated from medical procedures. The second section delves into the procedural-level interventions using the concept of internet of things. The third section explores the use of artificial intelligence and robotics in the delivery of healthcare services, and its impact in reducing waste from medical procedures. The fourth section explores the use of additive manufacturing in the development of products used in medical procedures. Through this review, a holistic analysis has been conducted on the scope for introducing industry 4.0 concepts in the healthcare setting to reduce medical waste from medical procedures.

1.1 Healthcare Waste and Its Causes

Healthcare waste is defined by the WHO as the waste produced by healthcare facilities (including laboratories and research centres) related to medical procedures. This also includes waste produced through healthcare related activities in households (Chartier et al. 2014). The terms healthcare waste and medical waste are often used interchangeably, and refer to the same types of waste.

The unregulated production and disposal of medical waste started with the big "plastics" explosion of the 1950s. The advent of plastics in industrial production empowered manufacturers to produce cost-effective devices which could be sterilized using Ethylene Oxide (ETO) or radiation methods. But hospitals found it cheaper to use and dispose of these devices than to sterilize and reuse them because the plastics would degrade in traditional autoclave machines, while ETO and radiation methods were expensive and inaccessible to most hospitals (Greene 1986). Today, the trend of single-use disposable products rides on the ambiguity of the safety of sterilization and reprocessing services, to ensure that infections are not re-introduced in the system. This occurs despite studies by the FDA showing there is no increased risk of infection due to the use of reprocessed devices (GAO 2008). The report reasserted that the adverse health events associated with the use of reprocessed devices were the same types and rates associated with non-reprocessed, new devices (GAO 2008). There is also an impetus for the industry to be cautiously wasteful to avoid legal implications of malpractice (Hailey et al. 2008). The result is the generation of a large amount of medical waste, often proportional to a country's GDP (Minoglou et al. 2017). Minoglou et al. (2017) observed the average amount of waste generated by a patient per hospital per day ranges from 0.44 kg in countries like Mauritius to 8.4 kg in the US.

A significant proportion of this waste is produced from medical procedures. Sa et al. (2016) conducted a surgical waste audit for hip arthroscopies and found that just 5 cases resulted in a total of 47.4 kg of waste. While 21.7 kg of that waste was biohazard, the rest was composed of sterile wraps, recyclables, non-hazardous waste and sharps (Sa et al. 2016). There is also a proportion of the waste which comes from expired or redundant inventory. In a review paper, Yazer (2018) talks about how there is a significant number of blood units collected by blood banks that get wasted due to expiration at the bank itself, or when in transit between the hospital and the blood bank. The waste produced, is not only an inefficient use of resources, but also has a financial impact on the stakeholders. In Canada, over 64,000 cases of total knee arthroplasty procedures take place annually (Yan et al. 2018). For each procedure, an average of 118g of bone cement is used, out of which 91.2g (77.2% by weight) gets wasted. This costs the Canadian Government $186 CAD per procedure, which when extrapolated for the annual number of procedures, results in a wasteful expense of almost $12 Million CAD per year (Yan et al. 2018).

In hospitals in the UK, under the NHS, decisions regarding the purchase of medical devices is on the discretion of the purchase department, on instruction of clinical staff and other users of the devices (Ison and Miller 2000). The decision to purchase a specific device is based on two criteria; the risks it poses to the patients and the users, and the price of the device. Two of the many effects not factored in this decision are; financial cost of treatment and disposal of the device, and the environmental impact of the device (Ison and Miller 2000).

When focusing on medical procedures, it has been evidenced that wasteful processes are inherently also increasing the energy and resource utilization, which can be quantified in terms of the carbon footprint generated and the toxic emissions released. Thiel et al. (2015) conducted hybrid life cycle analyses for 62 hysterectomies and found a notable environmental impact of the disposables, single-use devices, energy used for heating, ventilation, air-conditioning and the anaesthetic gases. Based on the identified culprits of emissions, they also proposed less environmentally harmful ways of providing the required care to the patient.

These environmental, financial and social problems of procedural medical waste are now being exacerbated by the COVID 19 pandemic, and call for transformative change in the way resources are used for medical procedures.

1.2 The Industry 4.0

The Industry 4.0 (I4) is believed to be the next leap in technology that will create a paradigm shift in the industrialization of our world (Lasi et al. 2014). Riding on the success of digitization in the third industrial revolution, I4 is preempted to re-define industrial production through a combination of smart objects and advanced digitization of production units. It was first announced by the German government as a key initiative towards a new industrial revolution (Ustundag and Cevikcan 2018). They imagined a future with products controlled by their own manufacturing process instead of people determining the manufacturing of products. Among the many social, economic and political advantages that this revolution brings, is the efficient use of resources. As society gears up for a shortage in supply of essential mineral ores and the impending ecological changes that are taking place, I4 can bring a stronger focus on sustainability in industrial production and consumption, while ensuring economic feasibility. This study focuses on how the fourth industrial revolution impacts the environmental sustainability of medical procedures (Lasi et al. 2014).

Sustainable industrial value creation is also believed to be one of the inherent advantages of I4 (Stock and Seliger 2016). At the macro scale, new business models focus more on selling functionality and accessibility to the consumers, rather than the tangible product itself. As companies retain ownership of their products, there will be a stronger incentive to ensure long-term use of the product before disposal. The business models will also focus more on long-term economic sustainability, consequently lengthening the value cycles of the materials used. I4 encourages closed loop product cycles, and cross-linked value creation networks, which improves the efficiency of resource usage (both material and energy). The inter-connected data streams allow horizontal integration of the product life-cycle, facilitating the interaction of various phases of product development and identification of efficient routes of value creation.

At the micro scale, there are multiple opportunities for the implementation of sustainability strategies at various stages of the product life-cycle as described below. The manufacturing units can retrofit sensors and actuators on existing machines to create Cyber-Physical Systems in which machinery can interact and communicate with each other to optimize processes. This reduces time, energy and material consumption in the manufacturing process. The role of humans will shift from machine operation to operation management. They will oversee production and identify opportunities to improve the operation flow, reduce lag time, and eliminate redundancies, all of which contributes to reducing time, human effort, energy and material usage. The role of organizations shifts to optimizing logistics for a smooth operation flow, and building the value creation network to improve end-to-end value cycles. In this entire system, the products created will be built for closed loop life cycles, encouraging, reuse and remanufacturing by implementing cradle-to-cradle principles. The usage data collected from the products will also help redesign products for better customer satisfaction, and reduce customer grievance time due to damage or bugs in the product function (Stock and Seliger 2016).

2 Method

This study uses the scoping review method as described by Arksey and O'Malley (2005). The main research question being addressed is 'How can the implementation of I4 technologies help reduce procedural caused medical waste?' Relevant published literature was sourced from SCOPUS database searches. The search criteria have been provided in Table 1. The time period used was from the proposition of I4 as a concept (Kagermann et al. 2011) until now.

Table 1. Search criteria for scoping review

Search criteria	
Databases	SCOPUS
Keywords	Industry 4.0; medical waste; medical procedure; lean system; internet of things; artificial intelligence; additive manufacturing
Type of Search	Journal articles; book chapters; conference proceedings
Languages	English
Time period	2010–2020

A total of 158 papers were identified from the search results, and 35 were found relevant to the study. The relevance was determined manually by studying the titles and abstracts of the identified papers. The identified published works were sorted based on their relevance to the role of new technologies in reducing medical waste from medical procedures. Due to the large scope of technologies found under the term of I4, studies pertaining to artificial intelligence, lean production systems, internet of things and additive manufacturing were prioritized. Papers relevant to industry 4.0 in healthcare but not focusing on the waste generated during medical procedures were not included in the review, as they are beyond the scope of this study. The results of the review have been structured to determine how interventions at various levels of a medical procedure can counter the waste generated in erstwhile procedural methods.

Table 2. Keywords searched for review

S. No.	Keywords	Total search results	Relevant results
1.	(TITLE-ABS-KEY (industry 4.0) AND TITLE-ABS-KEY (medical AND waste))	6	3
2.	(TITLE-ABS-KEY (lean AND system) AND TITLE-ABS-KEY (medical AND waste))	85	20
3.	(TITLE-ABS-KEY (internet AND of AND things) AND TITLE-ABS-KEY (medical AND waste))	18	2
4.	(TITLE-ABS-KEY (additive AND manufacturing) AND TITLE-ABS-KEY (medical AND waste))	30	6
5.	(TITLE-ABS-KEY (artificial AND intelligence) AND TITLE-ABS-KEY (medical AND waste))	19	4

3 Results - Existing Solutions and Future Prospects

This section investigates the current uses of I4 concepts in the healthcare industry, how they tackle the problem of waste generation, and future prospects of transitioning to cyber-physical systems. The section has been divided into 4 separate levels, using a top-down approach to look at system-level, procedural-level, service-level and product-level interventions to tackle waste generation using I4 (Fig. 1). As defined by Gaziulusoy and Ceschin (2016) in their Design for Sustainability (DfS) evolutionary framework, we use the first two innovation levels, namely product level and product-service system level to classify the opportunities identified in this study. We expand these two levels to distinguish procedures and systems from the products and services, as explained next. We define a product as a system of tangible and intangible elements designed to support a specific set of functions in a medical procedure. These could be surgical tools, packaging material, infrastructure connecting one product to another and softwares supporting the functionality of the products. We define a service as the interface between certain products and users that enables its use in medical procedures. Typically, services are provided by organizations or individuals in the form of access to the product functionality, repair and maintenance requirements for products and access to relevant information that is useful in a medical procedure. A medical procedure is defined as a set of tasks completed to achieve a specific diagnostic, treatment, or rehabilitation result on a patient (Becker et al. 1986). A procedure may involve the use of multiple products and services by clinicians to complete the required set of tasks for a patient. These procedures may be surgical, pharmacological, observational or a combination of the three. A system can be defined as a set of elements and the relationships between them. In this paper, we are more interested in the system that facilitates medical procedures. The system typically includes the organization responsible for the procedure, their facilities and infrastructure, and the products and services used to complete the procedure for a patient. The system-level explores uses of lean approaches to reduce waste from a systemic perspective in medical procedures. The procedural and service levels explore the interventions such as use of Internet of Things, digitization, automation and artificial intelligence in streamlining medical procedures. The product-level focuses on the role of additive manufacturing in creating products for medical procedures. Although each of the sections are interlinked, this top-down approach to the study helps identify multiple points of intervention to make the industry less wasteful.

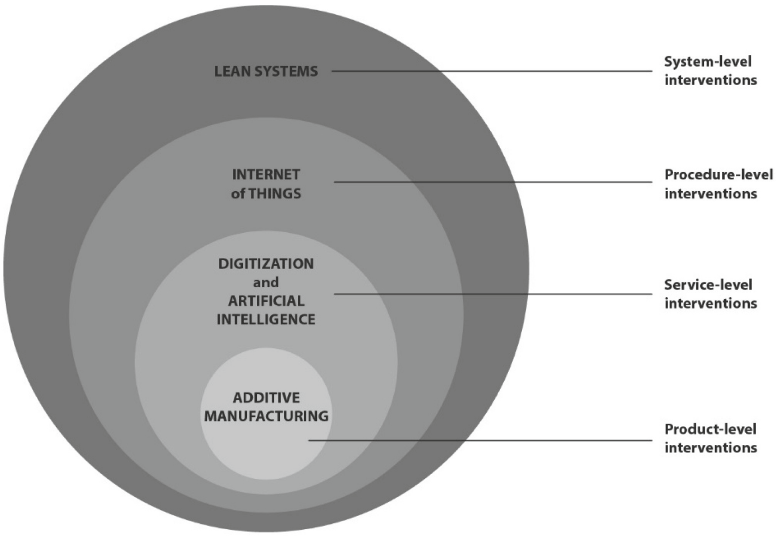

Fig. 1. The four levels of intervention to reduce procedural-caused medical waste

3.1 System Level Design Intervention Opportunities - Lean Approaches to Reducing Procedural Caused Waste

Lean production is an approach to manufacturing that adopts the philosophy of doing more with less. First witnessed in Toyota's Production System (Ohno 1988), the main purpose of this ideology is to streamline processes by eliminating various kinds of waste embedded in the system by continuously improving methods. The concept of lean thinking sits well with industry 4.0 through the creation of smart factories, connected systems and the goal of achieving efficient processes in industrial systems (Ustundag and Cevikcan 2018; Sanders et al. 2016).

A significant amount of research was found in implementing lean strategies for the reduction of procedural medical waste. The application of lean has been experimented in various medical procedures including hip fracture surgeries (Morales-Contreras et al. 2020), head and neck biopsies (Matt et al. 2014), continuous renal replacement therapy (Benfield et al. 2015) and total knee and hip replacement procedures (Gayed et al. 2013). The concept of lean is built on predictability and standardization, neither of which is yet achievable when treating individuals with unique conditions and physiologies (Edwards et al. 2012). But there is certainly a need for more efficient systems in healthcare, as Caloyeras et al. (2018) point out in their survey, which observed that nearly 15% of the time spent by physicians on work can be handled by non-physicians, and almost 10–15% of treatment provided was inappropriate. A study by Baccei et al. (2020) found that implementing a lean management approach to their musculoskeletal radiology department helped reduce expenses as well as time-frames for report submission, indicating significantly increased work efficiency in the department. Similarly observations were made in a study by Al Hroub et al. (2019), in an outpatient oncology pain clinic, by Fields et al. (2018) in a paediatric medical centre, by Sanders and Karr (2015) in an Emergency Department, and by Gjolaj et al. (2016) in an outpatient oncology infusion unit.

Overage constitutes items that are asked for by surgeons to be opened in the sterile field before a procedure, but do not get used. A study by Rigante et al. (2017) shows that overage constitutes almost 95% of the waste produced in neurointerventional procedures, evaluated at 676.49 EUR wasted per case. This is one part of medical waste that is produced purely because of probabilistic emergencies or unknowns which could be reduced with better protocols for immediate action, and better planning on procedures. A study by Lunardini et al. (2014) found that almost 40% of the instruments procured for orthopedic and neurosurgical spine cases could be removed through a lean process assessment, resulting in annual cost savings of $41,000. Similarly, Ahmadi et al. (2018) have compiled multiple gaps in knowledge in inventory management of surgical supplies, ranging from optimization methods to problems faced by practitioners. Some of their suggestions directly correlate with Industry 4.0 concepts, such as digitization, connected systems to reduce redundancy in supplies and analysing past usage statistics to efficiently prepare supplies for procedures.

The application of lean process management in medical procedures has been evidenced to reduce the dependence on instruments and material resources, along with reduced time frames for the delivery of health services and reduced costs associated with various procedures. While more research is required for the relevance on lean systems on the reduction of procedural waste, there is sufficient evidence to suggest that the application of lean management in healthcare has made significant progress in making health systems more efficient and less wasteful in time, money and efforts of health workers.

3.2 Procedure-Level Design Intervention Opportunities - Using IoT in Medical Procedures

The Internet of Things forms the basis of a connected system, where various parts of an economic chain can communicate with each other (Ustundag and Cevikcan 2018). In the industrial internet, connected systems have an important role in medical procedures.

The data generated and communicated by smart products depends upon the sensors used to collect this data, which forms the foundation of the ubiquitous computing society (Wang 2013). There has been a significant evolution in sensors over the last decade, which now enables robots to perceive information as well as, if not better than the human senses (Ustundag and Cevikcan 2018). Robots are now developed to automatically detect parts, handle them, navigate through obstacles, and complete complex movements to fulfil a task. This opens up a dialogue for robot-assisted medical procedures, especially when dealing with microscopic and nano-particles. The dexterity and precision with which robots can perform tasks, supersedes human abilities and can be constructively used for complex procedures. As summarised by Taylor et al. (2016), the role of medical robotics is not to replace clinicians, rather it is to aid them by transcending human limitations, and improving the safety, consistency, efficiency and overall quality of treatment provided.

While robots may make procedures safer and more efficient, they are not necessarily the most environmentally sustainable. A study by Woods et al. (2015) compared the carbon footprint of laparoscopy, robotically assisted laparoscopy, and laparotomy. Based on the solid waste generated and the energy consumed in each procedure, they concluded that the robotically assisted laparoscopy had a much higher carbon footprint than either of the other two (38% more than the laparoscopy and 77% more than the laparotomy).

The published sources reviewed in this study did not find specific information on the role of IoT in the reduction of procedural caused waste. The role of IoT, as reviewed in this study, is to make procedures more efficient and use technology to tackle procedures previously infeasible by human dexterity alone. This may have consequences on the waste generated, but more research is required to understand the implications of IoT on procedural caused waste.

3.3 Service-Level Design Intervention Opportunities - Digitization and AI in the Medical Industry

When it comes to patient treatment, most treatments prescribed are probabilistic and rely on the patients' response to evaluate the effectiveness of the treatment. Using data mining and artificial intelligence, it may now be possible to shift from probabilistic to definitive treatment, and allow doctors to focus more on the delivery of actual patient care (Bennett and Hauser 2013).

Imaging technologies have evolved well beyond the static imaging of X-Rays and CT scans. New imaging technology not only allows us to visualize human structures and disease states in real time, but also allows us to generatively predict the onset and spread of disease in the body. The ability to simulate disease states before the onset provides opportunities for localised rehabilitation, control and limit the disease from spreading (Dukart et al. 2013).

Data mining and predictive modelling of Electronic Health Records can help predict the optimal clinical treatment for a patient. This in turn reduces the reliance on corrective procedures, post-procedural care and treatment redundancies in cases of ineffective treatment (Bennett and Doub 2010).

The enormous amount of data generated at healthcare centres opens up multiple opportunities to use predictive analytics to reduce decompensations and hospital readmissions, estimate the risk of procedural complications (triage), and predict adverse effects such as multiple organ failures (Bates et al. 2014). These analyses can warrant timely action, and thus reduce resource consumption at hospitals.

Big data and real-time monitoring of patient data can help reduce the stress on hospitals by encouraging home care for non-critical patients. Remote monitoring of patients with wearable and implantable devices can help manage and prevent their re-hospitalization (Wang and Moriarty 2018; Arun Kumar 2014). This will benefit elderly patients by identifying both short-term critical conditions, and long-term patterns that help build personalized treatment (Grossglauser and Saner 2014).

A majority of the published research studied in the application of AI in healthcare focused on the reduction of treatment and use of healthcare facilities, and increasing the timely detection and cause of illnesses. Although the reduction of the use of healthcare facilities may suggest a reduction in resource use and waste generation, there was little information on the direct impact of AI on the reduction of procedural caused medical waste.

3.4 Product-Level Design Intervention Opportunities - Additive Manufacturing

One of the key advances in technology to reduce waste in the manufacturing process is the development of additive manufacturing. As opposed to the method of subtracting and morphing material to develop the required part, additive manufacturing uses a 3D digital model to precisely create the required part in layers of material. This not only saves material, but also enables the generation of complex structures previously not feasible using subtractive manufacturing. The reduced time required to generate a prototype, reduced labour, and the flexibility in customizing prototypes makes this technology a go-to strategy for efficient resource consumption (Gibson et al. 2015).

Additive manufacturing is now being extensively used in dentistry (Torabi et al. 2015), maxillofacial surgery (Suomalainen et al. 2015), head and neck surgery (Chan et al. 2015), correction of bone deformities (Yang et al. 2015), and plastic surgery (Choi and Kim 2015) to name a few sectors. Although the uses of additive manufacturing are plenty in the medical industry, the technology is yet to evolve to become faster, more accurate, more efficient and cheaper, for the use to be accessible to all (Martelli et al. 2016).

The use of additive manufacturing in the medical industry has been gaining speed over the last few years (Javaid and Haleem 2018). Rapid prototyping enables clinicians to not only visualize the human body, but also provide tactile insights into physiological processes and complex pathologies (Nocerino et al. 2016). This manufacturing method also helps reduce material requirements while providing the same structural strength as predicate devices (Yan et al. 2019). Despite the advances in the use of additive technologies in medical procedures, there are a number of challenges yet to be overcome. The research on manufacturing with new materials, and the high cost of AM often prevents this technology from competing with traditional manufacturing methods (Mishra et al. 2014; Garg and Mehta 2018). Even so, the publications reviewed in this study indicate that AM is one of the most promising ways forward in the reduction of procedural medical waste, and further research will only strengthen the merits of this argument.

4 Discussion and Conclusion

Healthcare systems today are far from sustainable in their practice, this includes the waste in material, waste in time, waste in expenditure and redundancies in treatment provided to the patient. With growing concerns on the environmental impacts of healthcare waste, and the concerns of exorbitant expenses by hospitals, there is a need for timely solutions to reduce the production of procedural waste in the medical industry.

As evidenced above, the application of Industry 4.0 concepts and technologies can be beneficial in reducing procedural caused medical waste, but it is important to note that the implementation of industry 4.0 can be highly complex and require huge investments of time and money. The transition to cyber-physical systems requires large infrastructural overhauls and a considerable change in mindset and behaviour of hospital staff and clinicians. A digitized system also requires ethical clearances from patients to participate and contribute their data, and health systems will need to provide adequate assurances that this data will not be misused or shared unless specifically authorized (Ustundag and Cevikcan 2018; Stock and Seliger 2016).

The concept of industry 4.0 and advanced manufacturing systems could potentially provide multiple avenues to tackle this problem at various levels. Lean production strategies are one way to streamline processes and treatment procedures and make the system more efficient. In this review, we identified four design intervention opportunities based on a variety of literature that supports the argument for a transition to industry 4.0 concepts and technologies as a means of reducing the waste generated from medical procedures. The potential applications of these design interventions can be summarized from the following three perspectives:

1. From an assistive method perspective, the seamlessly connected healthcare devices and creating cyber-physical systems in healthcare, procedures requiring skill beyond human abilities can be assisted advanced automations. Such as the assistive robots can then feed in procedure statistics and patient data through sensors back to the clinicians creating a feedback loop which allows the system, and the clinicians to learn more with every procedure.
2. From a data perspective, the digitization of systems and the use of data through artificial intelligence can shift the clinician's role from probabilistic treatment to definitive treatment. Real-time monitoring of the patient can prevent unnecessary hospitalization, provide timely treatment and reduce chances of decompensation.
3. From a manufacturing perspective, additive manufacturing has revolutionized the way in which we produce structures and parts essential for medical practice and for the wellbeing of patients. The ability to produce customized parts created for human structural reconstruction, and to use this capability in procedure simulation,

part reconstruction and even as a tool to educate future clinicians has a timely role in reducing procedure-caused medical waste and redundancies.

Yet, more research is required to quantify the benefits of cyberphysical systems in the reduction of procedural medical waste. The focus of the literature reviewed continues to be primarily about the cost incentive and the temporal efficiency of shifting to cyberphysical systems.

To summarize, this study explores the concepts of industry 4.0 that have generated significant interest in the healthcare community and can be very impactful, but Industry 4.0 is not limited to the concepts explored here. There is scope to expand on this topic and put forth many more ways in which procedural waste can be reduced in the medical industry. As we see pockets of industry 4.0 crop up in various aspects of this industry, it is important to democratize this knowledge and plan the transition in an effective manner. Multiple roadblocks are yet to be overcome in terms of data privacy, cost optimization and knowledge gaps. It could also be beneficial to develop a structured process for this transition to a smart digitized system so that adoption of new technology is simplified, and under-developed nations can leapfrog the mistakes made by developed nations to provide universal access to sustainable healthcare.

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