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International Journal of Production Research

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tprs20

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To cite this article: Ozlem Bak, Ashley Braganza & Weifeng Chen (2025) Exploring blockchain implementation challenges in the context of healthcare supply chain (HCSC), International Journal of Production Research, 63:2, 687-702, DOI: 10.1080/00207543.2023.2286491

To link to this article: https://doi.org/10.1080/00207543.2023.2286491

Published online: 20 Dec 2023.

INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH
2025, VOL. 63, NO. 2, 687–702
https://doi.org/10.1080/00207543.2023.2286491

Exploring blockchain implementation challenges in the context of healthcare supply chain (HCSC)

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ABSTRACT
Blockchain technology enables supply chains to share and distribute data in secured and decentralised environments through validators who trust and validate transactions. The use of blockchain was crucial in the context of the healthcare supply chain (HCSC) during COVID-19, where transactions were secure, and links throughout the supply chain were physically disrupted. Current research has focused on the blockchain application in industry, reviewing its architecture and the mechanisms involved. However, limited empirical studies consider HCSCs and the associated implementation challenges. In this sense, our case study of Indian hospitals has engaged with various stakeholders of the HCSC including clinicians, nurses, doctors, hospital managers, and digital healthcare equipment companies to explore the context to answer the following research questions: (i) What is the impact of the blockchain technology in the HCSC context? and (ii) What are the challenges faced in utilising blockchain technologies in the HCSC? Our findings indicate that the challenges blockchain implementation faced were based on variations in patients' treatment needs, data storage and privacy, interoperability, digital transformation, technology resistance, training and skills development, resource restraints and capabilities, and supply chain-wide collaboration. The study emphasises challenges for Blockchain in HCSC setting that both practitioners and academics need to be cognisant of.

ARTICLE HISTORY
Received 11 March 2023
Accepted 11 November 2023

KEYWORDS
Blockchain; applications in healthcare systems; supply chain management; healthcare supply chain (HCSC); hospital; blockchain challenges; case study

1. Introduction

Supply chains involve members from initial raw material suppliers to the end customers, while establishing coordination, and collaboration as well as rewiring trust between its partners to compete and withstand disruptions. In order to run a smooth healthcare supply chain (HCSC), the operation adaption of new technologies has become paramount. As each of the supply chain members can serve a multitude of supply chains with varied goals, it becomes difficult to align the supply chain (Bak 2016). In this sense, blockchain technology has been viewed as a potential solution by the healthcare providers, as it provides three key benefits: (i) the potential to improve productivity and quality, (ii) increased transparency among parties, and (iii) potential venues for product and process innovation (World Economic Forum 2019). Blockchain technology enables supply chains to share and distribute data in a secured and decentralised environment through validators who trust and validate transactions Recently, the COVID-19 pandemic has generated an environment where HCSCs needed to evaluate and address the inefficiencies of the supply chain and find ways to address, improve, and respond to current and potential future disruptions in a rapid manner (Senna et al. 2021). With blockchain technology, the resilience of the HCSC can be established, as supply chain-wide data can be accessed to understand the inefficiencies throughout the end-to-end supply chain and to develop, monitor, and innovate strategies to mitigate or tackle the inefficiencies (Sim, Zhang, and Chang 2022). Especially within the context of HCSC, this has become imperative, as the disruptions in demand and supply may lead to unintended consequences, such as danger to human life, and would require rapid adjustments by the hospital managers (Riley et al. 2016).

Despite the recorded advantages of the worldwide use of blockchain in diverse industrial settings (Li, Lee, and Gharehgozli 2023; Van Nguyen et al. 2023), Min (2019, 36) stated that 'many firms are still either sceptical about blockchain's face value or unfamiliar with its inner workings and application potential.' Research has mainly focused on the successful application of Blockchain in the context of financial transactions as well as cryptocurrency (Attaran 2020; Huang et al. 2021;

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Min 2019). Attaran (2020, 1) notes that current research on blockchain in use 'by the healthcare industry does not adequately address these requirements due to limitations related to privacy, security, and full ecosystem interoperability' and with the limited implementation calls for assessing the challenges faced in HCSC. Ghadge et al. (2023, 6646) similarly noted that 'there are concerns that Blockchain interoperability in the healthcare/pharmaceutical system may be challenging'. Current research on the use of blockchain in HCSCs has addressed the decision-making process (Fusco et al. 2020; Huang et al. 2021); focusing on the use of electronic medical records with clinical data on a large scale (Fusco et al. 2020; Khan et al. 2021) and the creation of partnerships with pharmacies (Pouye 2021) whilst elucidating the implications of blockchain technologies on performance (Park and Li 2021) and barriers for blockchain adaption (Saberi et al. 2019). Tandon et al. (2020) reviewed for their structured literature review 42 studies that highlighted the need for blockchain implementation in healthcare setting, not only focusing on the platform and its performance but rather holistic implementation of blockchain and its use in healthcare. Similarly, Hermes et al. (2020) focused on the platform as well as the associated digital transformation in the healthcare context. Hence as discussed previously, the assessment of blockchain technology challenges in a healthcare supply chain (HCSC) context extant literature is limited (Hermes et al. 2020; Karakas, Acar, and Kucukaltan 2021; Riley et al. 2016; Sim, Zhang, and Chang 2022; Tandon et al. 2020) and lacks the implementation in a healthcare setting (Hermes et al. 2020; Tandon et al. 2020). Our study aims to contribute to the extant literature are threefold: (1) to contribute to the existing body of literature by comprehensively addressing blockchain challenges. Unlike previous works such as Sim, Zhang, and Chang (2022) and Riley et al. (2016), we aim to provide an exhaustive list of challenges, which we will elaborate on in greater detail; (2) to develop a robust conceptual framework for assessing the challenges associated with the implementation of blockchain technology. This endeavour aligns with the recommendations made by Saberi et al. (2019) and Hermes et al. (2020); (3) to bridge a gap in the current literature by conducting an in-depth case study focused on healthcare supply chain challenges. This particular aspect has been relatively underrepresented in the literature, as noted by Attaran (2020) and Hermes et al. (2020). With this aim, the next section will introduce the concept of blockchain technology and its context, followed by the developments in HCSC in terms of blockchain technology usage. We then present the methodology used and a case study from the supply chain of private Indian healthcare providers. We conclude by presenting our findings and indicating directions for future research.

2. Blockchain application in healthcare supply chain context

Hasselgren et al. (2020) stated that the HCSC operations is based upon the triage of health related problem-solving, clinical decision-making, and the realisation and assessment of knowledge-based care provided by a multidisciplinary team for diverse patient needs. The potential to keep and use patients' lifetime data and electronic record sharing is of interest to healthcare providers (Halamka, Lippman, and Ekblaw 2017). Hence, using blockchain, according to Gordon and Catalini (2018, 224), has the potential to improve and reduce the operational time for healthcare providers through 'five mechanisms: (1) digital access rules, (2) data aggregation, (3) data liquidity, (4) patient identity, and (5) data immutability.' However, the implementation challenges have not been discussed within healthcare nor its supply chain context (Riley et al. 2016; Sim, Zhang, and Chang 2022), which has been noted in the literature independently. We argue that the implementation of blockchain in the supply chain context faces the following challenges.

2.1. Challenge 1: variations in patients' diagnostic needs

Hasselgreen et al. (2020) noted that at its core, healthcare is based upon the patient's treatment, which can present variations across patients and over time. The challenge is that a patient's records are kept depending on the time and, thus, can show a variance across time based on the progress in the patient's health. Moreover, depending on changes in the patient's health status, the records provide input only across a time period. The size and volume of data and its interpretation across time can also be a challenge for blockchain implementation (Justinia 2019), which provides variation across time and across healthcare providers. Hence, we propose the following:

> Proposition 1a: Challenges stemming from patients' individual treatment needs affect blockchain implementation.

> Proposition 1b: Challenges stemming from patients' continuous health changes across time affect blockchain implementation.

2.2. Challenge 2: data storage and privacy

The operations in healthcare revolve around the storage of the data of individual patients, and privacy and trust between supply chain members is important (Hasselgren et al. 2020; Martins et al. 2019). According to Gordon and Catalini, 'The first way blockchain technology could improve patient-driven interoperability is through management of digital access rules' (Gordon and Catalini 2018, 227). Blockchain principles can provide increased efficiency in terms of data retrieval, usage, and collaborative work; however, the concern regarding the issues of privacy and data ownership becomes more complex in a supply chain context (Kleinaki et al. 2018). A smart contract established with blockchain partners in the supply chain (Hasan et al., 2023; Prause and Boevsky 2019) provides the opportunity for self-execution, meaning that it creates the conditions for trust and transparency through the supply chain via the process of consolidation, validation, and confirmation (Chang et al. 2019; Cole et al. 2019). As Govindan et al. (2023, 3513) noted '[s]ince blockchain has an open and transparent nature, it can create a climate of trust among the healthcare applications'. This, in turn, improves the data sharing, allays concerns regarding privacy, and allows more streamlined services, such as the automation of payments and an improved cashflow cycle (Prause and Boevsky 2019). However, within healthcare, the discussion about privacy and data sharing has been rather problematic. The use of data, data sharing, and data interoperability has given rise to significant concerns not only among the patients but also among members of the HCSC (Justinia 2019). Hence, we propose the following:

> Proposition 2: Challenges to data storage and privacy have a negative impact on blockchain implementation.

2.3. Challenge 3: system interoperability

The interoperability of systems permits data sharing, which helps improve the accuracy of diagnostics across diverse medical settings from doctors to lab technicians, pharmacies etc. (Zhang et al. 2018). The interoperability of the systems allows the accuracy of patients' diagnostics as well as their treatment (Hussien et al. 2019). Considering that blockchain is a distributed technology which is capable to address challenges of data standardisation and system interoperability, and safe electronic health-records accessibility to provide a patient-driven healthcare information systems and technology (Jabbar et al. 2020). Therefore, the use of blockchain technology can ease the sharing of information between, for instance, cancer specialists with different expertise to liaise, discuss, and explore treatment options as well as set up plans for treatments (Xie et al. 2021). According to Zhang et al. (2018), there are several interoperability-related challenges, one being the use of incompatible software and/or systems, access restrictions in electronic health records (EHR), or the use of multiple platforms ranging from mobile devices to clinic based internal firewall protected environments.

> Proposition 3: Challenges stemming from system interoperability may affect blockchain implementation.

2.4. Challenge 4: digital transformation (DT)

Digital transformation refers to 'a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies' (Hermes et al. 2020, 1034). According to Sebastian et al. (2017, 198), 'Most big old companies' digital transformations are at an early stage – in most industries, the vast majority of established companies' revenues still come from traditional products and services.' In the HCSC digital transformation indicated positive impact upon the operations performance as well as efficient workflow processes (Kraus et al. 2021).

Despite the positive outcomes, one of the challenges of system implementation stems from the associated cost and uncertainties involved in costing; as Sunmola et al. (2021, 514) stated, 'Critical barriers … for digital transformations of supply chains [can] include financial factors', which are associated also with the level of process reengineering that is needed within the supply chain (Bak 2016).

> Proposition 4a: Financial constraints can affect blockchain digital transformation.

> Proposition 4b: Challenges stemming from process engineering may affect blockchain implementation.

2.5. Challenge 5: technology resistance

Technology resistance has been seen as one of the major supply chain challenges due to issues with the implementation of new technology (Bak 2016). Teixeira et al.'s (2023) findings reported that within the HCSCs, staff reluctance is one of the challenges in blockchain implementation. Similarly, the HCSC literature has indicated that inadequate healthcare staff support for the blockchain technology can lead to technology resistance, which can be one of the main implementation challenges (Chong, Blut, and Zheng 2022; Kim et al. 2023; Oliveira-Dias, Maqueira, and Moyano-Fuentes 2022). The technology resistance in the blockchain context also stemmed from the notion that the HCSCs will be relying on third-party providers, where there will be a lack of trust between the supply chain members and the third-party providers (Bak and Papalexi 2022; Kassab et al. 2019).

Especially the technology resistance also may stem from the reported high cost of the systems and the unwillingness of the healthcare provider to cover such a cost (Kassab et al. 2019).

> Proposition 5: Challenges stemming from technology resistance can affect blockchain implementation.

2.6. Challenge 6: training and skills development

Skills and training are important to any organisation; however, in terms of blockchain, the digital skills seem to be a common dominator requiring the further training of healthcare professionals as well as administrators etc. Although these challenges remain currently, there are more educational settings providing

> Blockchain training programs have been increasing recently and are now being offered by some of the nation's leading universities, including MIT, Princeton, and Stanford. Many blockchain vendors such as Consensys, Blockapps, the Ethereum Foundation, and Hyperledger also provide training programs and certificates. (Kassab et al. 2021, 53).

Nunes et al. (2021) similarly highlighted that healthcare professionals are committed to patient care as their priority; however, IT skills are not seen as a primary area of concern. Continuous learning is also imperative in particular to develop the skill sets and to remain up to date regarding the systems and technologies utilised (Patan et al. 2023). Similarly, Kaur et al. (2018), Farooque et al. (2020), research indicates the need of existing staff members to be trained and updated with the relevant skills necessary for the relevant HCSCs' technology. Steele et al.'s (2020, 78) findings indicated that in low- to middle-income countries, 'Technology needs to be tailored to the skills and consumption needs'. For example, Munene, Egwar, and Nabukenya (2020, 40) reported that 'the African region lacks a standard DH [Digital Health] curriculum to guide the training of the health workforce in the region; this poses a risk for fragmented and uncoordinated DH skills workforce development'. This gives rise to the following proposition:

> Proposition 6: Challenges with skills and training can affect blockchain implementation in HCSCs.

2.7. Challenge 7: resource restraints and capabilities

One of the challenges faced by blockchain implementation is resource restraints and capabilities (Jiang et al. 2018; Kamalahmadi and Parast 2016). Similarly, Shukla et al. (2020, 169) noted that supply chain members may refrain from IT investments due to 'perceived high costs and unclear return on investments', especially where healthcare providers may have limited resources (Dagher et al. 2018; Hasselgren et al. 2020). The resource limitations can be based on staff, equipment, and finance, which hinders the development of the necessary capabilities (Bak and Papalexi 2022). Similarly, according to Xanthopoulou (2022, 558) 'the lack of equipment, had a great impact on the adoption and the successful integration of blockchain in the Greek public administration.' Steele et al.'s (2020) findings indicated especially that in low- to middle-income countries, the technology and its implementation required to be tailored based on the consumption needs, availability of equipment, as well as finances. Hence, we propose the following:

> Proposition7a: Challenges with equipment availability can affect blockchain implementation.

> Proposition7b: Challenges with staff constraints and capabilities can affect blockchain implementation.

> Proposition7c: Challenges with finance can affect block chain implementation.

2.8. Challenge 8: supply chain wide collaboration

Omar et al. (2021, 37397) noted that 'HCSC suffers from highly fragmented structures, obsolete processes and systems, and disconnectedness in information sharing among stakeholders'. As the complexity involved is fragmented, it is difficult to generate for blockchain the required degree of collaboration at every level (Bak and Papalexi 2022). For example, there are several structures in terms of purchasing, where 90% of US hospitals are members of (Omar et al. 2021), creating another layer of complexity. The system's supply chain-wide collaboration is also dependent upon government regulations as well as the supply chain contextual setting, such as private and public organisation settings (Dagher et al. 2018; Hasselgren et al. 2020; Omar et al. 2021).

> Proposition 8: Challenges of supply chain wide collaboration affect blockchain implementation.

Drawing upon the propositions developed above, we created a conceptual model to represent the effects of challenges on the implementation of blockchain in HCSCs. This is shown in Figure 1.

3. Case study

This research utilises a case study. According to Yin (2009, 18), 'A case study is an empirical inquiry that investigates a contemporary phenomenon within its real–life context, especially when the boundaries between phenomenon and context are not clearly evident'. The

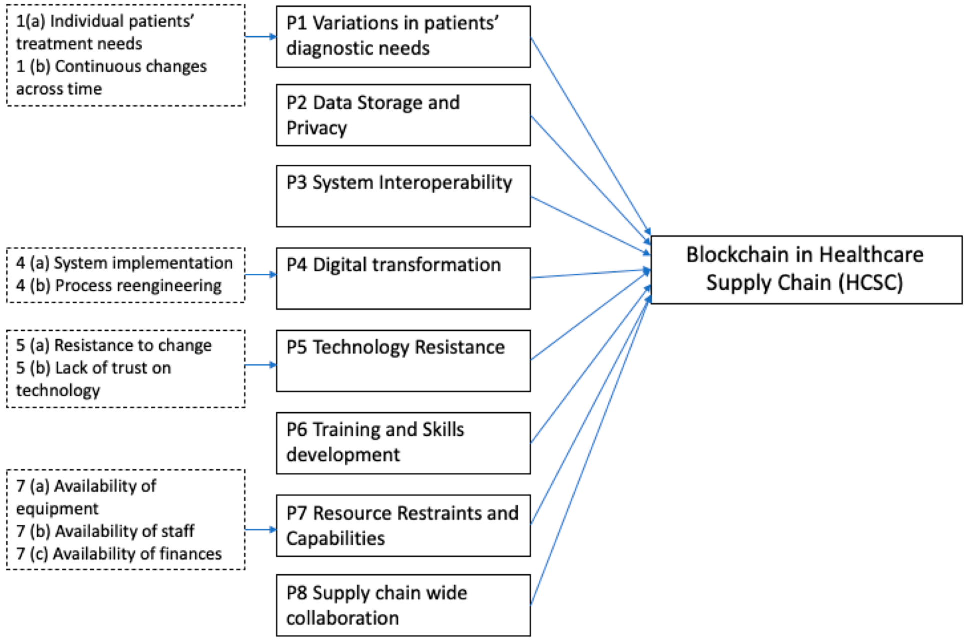

Figure 1. A figure of HCSC framework exploring the Blockchain implementation.

case study design in this study allowed us the much sought-after in-depth understanding of the challenges supply chain blockchain faces in HCSCs (Senna et al. 2021). The case study enabled the empirical grounding for providing an explanation whereby the quality of the research design and the construct validity have been established with multiple sources of evidence (Eisenhardt 1989; Voss et al. 2002). Within this case study, in-depth interviews with medical consultants, intensive care doctors, and nurses with diverse responsibilities and decision support roles were undertaken, allowing us to evaluate the blockchain challenges from diverse angles (see Table 1). Prior to collecting data, full ethical approval was sought and received from the university's Research Ethics Committee. At the start of each interview, it was confirmed that the interview would be kept anonymous, and during the interview process, the utmost effort was made to create a high degree of trust with the interviewee. A case study was developed based on the emergency centre in Indian private hospitals' supply chain. To explore the context of blockchain technologies during COVID-19, we propose two research questions: (i) What is the impact of blockchain technology in the HCSC context? and (ii) What are the challenges faced in utilising blockchain technologies in HCSCs? To explore the research questions, focus group discussions and semi-structured interviews were utilised in addition to access to hospital data and government reports.

The main steps of conducting the fieldwork in our study can be summarised as follows:

Table 1. Interviewee roles.

Current Role	Experience (approximate number of years)
Senior Role- Senior Nursing Staff	10 plus years
Medical Doctor	5 plus years
Critical Care Consultant	15 plus years
Critical Care Doctor	20 plus years
Associate Prof. Neuro Anaesthesiology & Critical Care	20 plus years
Professor Neuro Anaesthesiology & Critical Care	30 plus years
Professor Neuro Anaesthesiology & Critical Care	20 plus years
Intensivist, Intensive Care (Critical Care)	5 plus years

- Initial meetings: Meetings were set up with our India project partners, including clinicians, medical doctors, hospital managers, and digital ICU equipment providers, for the delivery of digitally driven ICU services in India to gain access to hospital data and government reports.
- Data collection: Researchers spent two and half years collecting data via face-to-face focus groups and interviews on site in India before the start of the pandemic in 2019 and via MS Teams during the pandemic. Data collection strategies included observation in meetings, interviews, and taking notes during focus group discussions with healthcare systems and medical equipment providers and deriving data from documents and from various online sources (e.g. official websites of healthcare (ICU) providers, digital ICU equipment

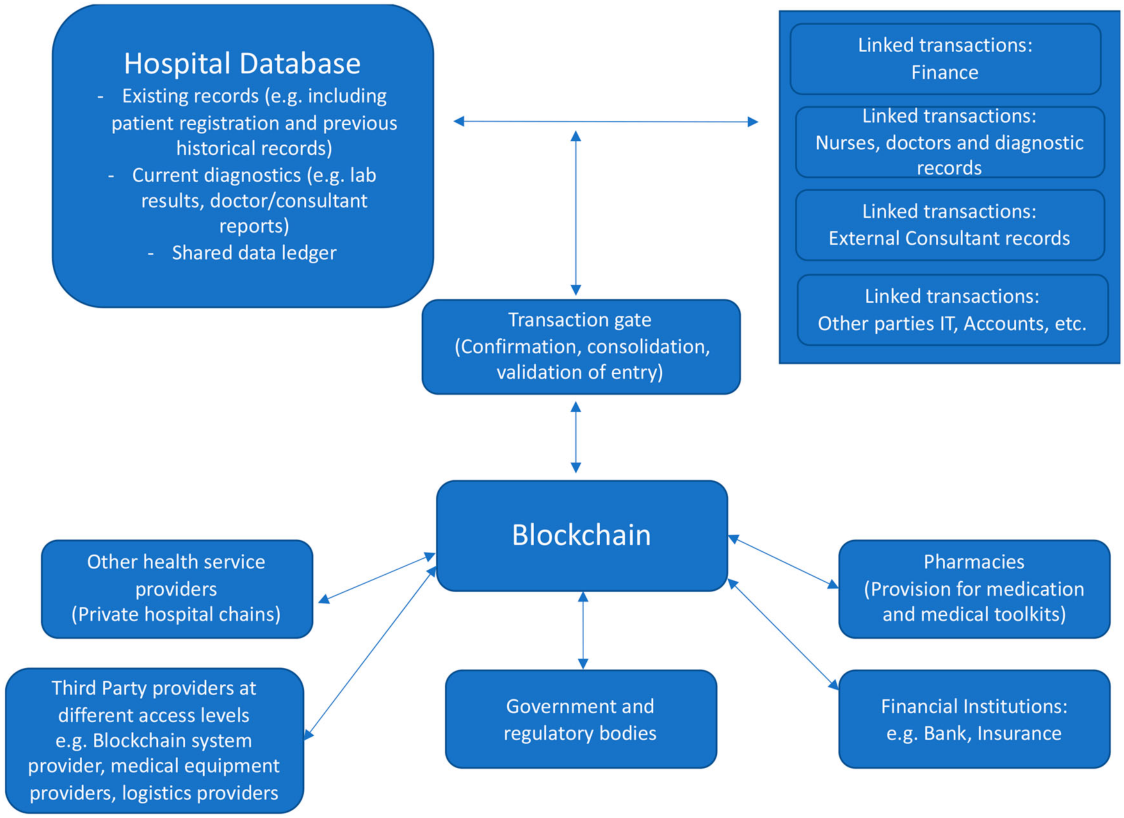

Figure 2. A figure of Blockchain within the Indian case study HCSC provider setting framework exploring the Blockchain implementation.

providers, and India's Ministry of Health & Family Welfare).

- The selected cases and interviewees (clinicians, medical doctors, hospital managers, and digital ICU equipment providers) were recommended by our project collaborators. Most of the interviews with clinicians and medical doctors were carried out in 2021 via MS Teams.

In total, we conducted two focus groups with providers of healthcare systems and medical equipment (three managers and directors) and 14 in-depth interviews with ICU clinicians and doctors. In addition, two focus group discussions with digital healthcare equipment companies were carried out. Each interview lasted between 30 and 60 min. It was very challenging to contact and set up interview meetings with ICU doctors, as they are normally extremely busy and were especially busy during the pandemic period. As evident in Table 1 below, our interviewees encompass a diverse spectrum of expertise, ranging from nurses to internists, intensive care specialists, anaesthesiologists, and medical doctors. Their cumulative experience spans a wide range, from 5 to 30 years, providing a comprehensive understanding of the challenges associated with the implementation of blockchain in healthcare. At the initiation of each interview, we assured our interviewees of strict anonymity. Throughout the interview process, we placed paramount importance on establishing a high level of trust with each participant, with a commitment to safeguarding their anonymity and the confidentiality of the interview content.

The Blockchain technology used in the private hospital setting has several layers and helps with the decentralised distribution of information that can be used across the healthcare supply chain (see Figure 2). Here the HCSC includes patients (e.g. inpatients, outpatients, and their EHRs), medical team members (e.g. consultants, doctors, nurses, diverse departmental administrators, and insurers), diverse hospitals and laboratories, governmental and regulatory bodies, and blockchain intermediary firms and third-party providers (Fichman, Kohli, and Krishnan 2011; Shukla et al. 2020).

The blockchain technology used in the private hospital setting has several layers, and this helps with the decentralised distribution of information that can be used across the HCSC including the link to payments via bank transfer, the link to pharmacies for prescriptions, the use of patients' existing EHRs, validation of the diagnostic and critical care including records of nurses, consultants (internal and external), as well as other HCSC parties.

4. Findings and analysis

The blockchain implementation in the Indian healthcare provider was initially attributed to several benefits, such as.

(1) ease of access to data – whereby one interviewee noted, 'That'll be very helpful in case even if we are shifting the patient from one place to one place, which we are going to CT scan or, like for an MRI or scan and on the way somebody wants to see the patient details .... access about the patient details anywhere';
(2) the verification process, which provides another layer of security, as each entry will have a time stamp – 'There is no way of tampering [with] these documents because it comes with a date and time, so it's a record. Once recorded, it is a permanent record, lifelong, so that has made life very much easier for us';
(3) reduction of processes – one interviewee noted, 'We had to look into, say, lab investigations or imaging the packs and all that – those who are located in the nursing station. So, every time it was like a back-and-forth from the patient's bedside to the nursing station. But now I've been able to do away with that because we have a computer on wheels.' Another interviewee noted that the systems in place can ease the data collection: '... and the data automatically flows into the ... our [patients' records], hospital information systems well – then the nurses need not duplicate the work. Now they, for example, they write on the chart. In addition to that, they must go and enter the notes. All the values you know ... .'.

These three main benefits described by the interviewees allow the HCSC operationalisation based upon the triage of health-related problem-solving, clinical decision-making, and realisation and assessment (Hasselgreen et al. 2020). The blockchain technology used in the private hospital setting has several layers, and this helps with the decentralised distribution of information that can be used across the HCSC including the link to payments via bank transfer, the link to pharmacies for prescriptions, the use of patients existing EHRs, validation of diagnostic and critical care including records of nurses, consultants (internal and external) as well as other HCSC parties (see Figure 2). Within the case setting based on our analysis, the following challenges were observed.

4.1. Challenge 1: variations in patients' diagnostic needs

> Proposition 1a: Challenges stemming from patients' individual treatment needs affect blockchain implementation.

The patient's treatment can present variations due to patients requiring individual treatment involving several supply chain members, which may be different when compared to other patients (Hasselgreen et al. 2020). In the case study, the variations of individual patients' needs resulted in an additional layer of complexity, as the patients' needs, particularly in ICU, may range from patients that require 'isolation like infectious patients and protective isolation – patients will be posted in other ICU, like, separate cubicles .... [a]nd other patients who are OK to be like in the main ICU'. The complexity involved in the variations of patients needs can generate a new layer of complexity, Bak and Papalexi (2022) mentioned that fragmentation and complexity involved may create difficulty in generating the required level of collaboration for blockchain at every level.

> Proposition 1b: Challenges stemming from patients' continuous changes across time affect blockchain implementation.

This indicates that variations at a given time can exist between patients' needs, and thus it also brings a level of unpredictability (Hasselgreen et al. 2020). Also, although very helpful in diverse ways, the trends in the use of blockchain technology need to be observed over a time period due to the changing condition of patients' needs. Similarly, an interviewee noted that some diagnostic tools, such as charts, were difficult to use solely in the digital environment:

> We tried getting it onto the electronic medical records because this is the most important part of any ICU because when I go to check on a patient, I need to know how the trend has been over the last couple of hours or the last few days ... this capture of the flow chart has not been possible for various reasons.

This is also aligned with Hasselgreen et al. (2020) whose research noted that depending on patients' changes in their health status is important however there are limitations to having the overview as highlighted by the interviewees. One of the reasons for this challenge can reflect also as stated by Justina et al. is the issue related to the size and volume of data and its interpretation across time can also be a challenge for blockchain implementation.

4.2. Challenge 2: data storage and privacy

> Proposition 2: Challenges with data storage and privacy have a negative impact on blockchain implementation.

According to Gordon and Catalini (2018, 227), 'The first way blockchain technology could improve patient-driven interoperability is through management of digital access rules'. As mentioned earlier, smart contracts established with blockchain partners in the supply chain (Hasan et al., 2023; Prause and Boevsky 2019) improve data sharing and allay concerns regarding privacy. In addition, they allow more streamlined services, such as the automation of payments, and improve the cash flow cycle (Prause and Boevsky 2019). In this case study, the system generated large data sets and detailed records, which are crucially important yet also confidential. However, in the healthcare supply chain in the case study, the interviewees reported that the data was shared across hospitals (including in the private chain) in terms of reference to patient diagnostic and treatment history, financial data etc. This does also provide the opportunity for trust and transparency through the process of consolidation, validation, and confirmation of data as noted by Chang et al. (2019) and Cole et al. (2019). Similarly, the interviewee noted the importance of trust in the system security noting that taking it further to other tools may be beneficial stating that 'If I were able to have some sort of a secure system that could relay data or the interface itself directly onto my mobile, that would be great'. However, within the healthcare case study, the discussion of privacy and data interoperability has been portrayed as a challenge across HCSC. This finding is also aligned with Peng, Chen, and Wang (2023, 4511) study in which they iterated' [i]t is worth examining how stakeholders' perceived levels of information security affect their willingness to share information via a blockchain application'.

4.3. Challenge 3: system interoperability

> Proposition 3: Challenges stemming from system interoperability may affect blockchain implementation.

Data integration and interoperability were available for the provider with individual and departmental access restrictions; this meant availability was limited, with access to levels in some cases requiring internal permission. Another interviewee noted the limitation and use of other technologies that were not embedded in the blockchain: 'Even if I'm at home, I should be able to monitor the ventilator interface or the hemodynamic interface of all of these patients'. Although it is beneficial to have systems that encourage transparency as highlighted by the interviewee '[t]here is no way of tampering [with] these documents… .[o]nce recorded, it is a permanent record, lifelong, so that has made life very much easier for us' however as seen in the case study this can be a challenge as noted by the interviewee

> [w]e… .take calls, so, even when I'm away from the hospital, like, we… I have defined days when I'm on call, so it's usually the registrar who calls me and gives me the, you know, information over the phone. Or sometimes he puts on his WhatsApp video and shows me a couple of things, which is, again, not the ideal thing to be doing.

Data integration and interoperability was available for the provider, but the individual and departmental access restriction meant availability was limited to access levels in some cases it required internal permission. This finding underlines Zhang et al.'s (2018) finding that interoperability challenges can be contextual based on the industry and supply chain setting due to incompatible software and/or systems, access restrictions in EHRs, or the use of multiple platforms ranging from mobile devices to clinic-based internal firewall-protected environments.

4.4. Challenge 4: digital transformation (DT)

> Proposition 4a: System implementation constraints can affect blockchain digital transformation.

The hospital selected for the case study was a private organisation. In this context, one interviewee noted that there is a difference between the HCSCs in India, stating that there is

> the private healthcare sectors, and there is a government sector as well. So, the private healthcare sectors in Bangalore, that is, corporate hospitals, work completely differently compared to the government setups. The care is the same, but the ancillary things are very different.

Another interviewee added, 'We have a huge quality difference between one small nursing home to the hospital to the corporate hospitals in India.' Hence, one of the blockchain challenges of system implementation stemming from the associated cost and uncertainties was evident to a lesser degree when compared to public hospitals. This is contradictory to the findings of Sunmola et al. (2021), which may be relevant to the contextual setting, in this case, the public/private division of the particular HCSC.

> Proposition 4b: Challenges stemming from process engineering may affect blockchain implementation.

Regarding the move from physical to digital recordings, one interviewee described it as follows:

> [Formerly], there was no electronic recording, and all the reports used to be hard copy like X- rays and CT scans - all those things used to be the hard copies, which we keep

> near the patient's bedside. Like whenever they come for the rounds, they can take it out and see.

This also provides freedom of location to a certain degree; as one interviewee noted, 'Right now, we have Saturday from Saturday telemedicine, wherein we can get the report of CT scans, MRIs at any time, even with the doctor being outside of the hospital, so they will get their records within those times', which was previously not possible. Similarly, Bak (2016) noted that one of the critical barriers to the digital transformation of supply chains stems from the level of process reengineering that is needed within the supply chain. In the case study, the recorded data was, in some cases, electronically transmitted directly into the system whereas, at other stages, this needed to be done individually. Notes taken manually needed to be transferred onto the system meaning in some cases as noted by the interviewees there was 'duplication and time difference in terms of entry when done manually'. An interviewee noted that continuous transfer of patients' graphs associated with one type of treatment is difficult to record and upload onto the system and difficult to interpret but noted improvements are being worked on.

4.5. Challenge 5: technology resistance

> Proposition 5: Challenges stemming from technology resistance can affect blockchain implementation.

The technology resistance challenge has been identified as one of the issues for blockchain implementation in HCSCs (Bak and Papalexi 2022; Chong, Blut, and Zheng 2022; Kim et al. 2023; Oliveira-Dias, Maqueira, and Moyano-Fuentes 2022). In this case study, although the interviewees acknowledged the benefits of the system, they noted that human interaction is paramount within the HCSC, 'We can stay without technology. But we can't stay without working hands'. This is also partially because the paper is still used alongside the system. As an interviewee noted,

> That is, we are not paperless yet. Of course, in my hospital, the outpatient system is paperless, but the inpatient is sort of a hybrid. There are certain things which we tried making paperless, but we always had a tough time. So, there is paper, and there is digital as well.

Referring to the duplication of data (electronic and physical records), another interviewee referred to staff resistance to technology:

> I don't know if everyone is comfortable with that either. There are some people who are having … for that matter, even I feel I am more comfortable with paper quite often. I know things must change; it's more the attitude, behaviour.

An interviewee indicated a technical problem stemming from chargers:

> So … we started giving a charge port at the bedside and maybe the computer on wheels next to the patients, so they try to enter all the notes and order entries there, but still, they are reluctant to sit there and do the work. Still, they come to, you know, the main nursing station to do that.

The technology resistance can present in different forms as stated by Bak (2016) and Teixeira et al.'s (2023) and can be seen as one of the major supply chain challenges when implementing new technology.

4.6. Challenge 6: training and skills development

In this case study in the context of the Indian setting, IT skills have been seen as the most developed. The interviewee noted,

> Some of the time, people [the public] will not be aware of, like, handling computers, but almost all educated staff [such as] … nursing, doctors and the like, those communities might be quite skilful, but … sometimes, there are people who come from the rural areas like the countryside, where even the teaching in nursing education is not computerized in a few of the colleges; it's like they won't be getting proper access to the computers, or they will not be advanced. Technology depends on … which place … which colleges [we] study at or which area we belong to. Because some will be skilful in handling the computers or advanced technology and gadgets, and somewhere … some … maybe [need to] study.

Another interviewee added, 'Once we join the hospitals like … or any other advanced technology hospitals with advanced technology … we may improve our skills. But it takes time. It might be challenging'. However, the healthcare system and medical equipment providers from the focus groups conducted for this study mentioned that significant training is required for doctors and nurses to use their medical equipment and systems embedded with blockchain technology. The interviewees acknowledged the advanced IT skills of certain staff members and the presence of an IT support team when introducing new technologies. Nevertheless, they emphasised the necessity of ongoing learning due to the frequent system updates. This resonates with the findings of Patan et al. (2023), whose recent study underscored the critical importance of continuous learning to develop and maintain the skill sets required to stay current with evolving systems and technologies.

> Proposition 6: Challenges with skills and training affect blockchain implementation in HCSCs.

4.7. Challenge 7: resource restraints and capabilities

Proposition 7a: Challenges with equipment availability affect blockchain implementation.

Our findings suggest the actual systems seem to work well, as reported by the interviewees. However, issues regarding the availability of some equipment were observed, such as the limited availability of laptops. For example, one interviewee noted that other than desktops, there were only four laptops available for the ward rounds, which made the resource allocation when doing the rounds difficult. Also, another issue was system- and software-related challenges, which required updates as well as maintenance. One interviewee commented, 'They [maintenance and software team] will help us out… in case of any power disconnections or we need any power cords or extra connections'. Another interviewee noted that sometimes downtimes to connectivity can happen: 'And there is always a central downtime. You know, for various reasons, there is a server downtime and things like that. So, when that happens, like, you're blocked.' This also highlights that equipment availability needs to be revisited based on consumption needs in HCSCs, which supports the findings of Steele et al. (2020).

Proposition 7b: Challenges with staff constraints and capabilities affect blockchain implementation.

One of the challenges that faced by blockchain implementation is the restraints of resources and capabilities (Jiang et al. 2018; Kamalahmadi and Parast 2016). This is also highlighted within this case study setting. There seem to be several tasks assigned to the nurses that require the nurses to be able to move swiftly through several supply chain operations relevant to the patients' needs. Despite the use of the systems, the nurses' station is seen as the central monitoring desk. One interviewee had observed why this was the case and provided a description of a critical incident:

> We had [a specific brand] monitors, for which we had pagers… the alarm goes off when something goes wrong with patients in case saturation comes down,… . It's like there will be an escalation system, like, if we don't respond, it will alert the next level manager, like, maybe nursing staff, then the charge nurse, and then the doctor; like, the three-alarm system needs to be there.

However, checks and monitoring are maintained by the nurses as well. The record entry system is also dependent on nursing staff where one interviewee stated that 'a single nurse going through the system and to the patient's side and to the charting, it will be quite hectic for a nurse to do because they – she'll be having so much other work.' Another interviewee also highlighted the problem stating that

> the system entry is set so that the nurse must leave the patient's side and go through the system and then she has to enter the data, like, whatever we will need to do. So that, maybe, in case the system is quite far away from the patient, it will be quite a hard task for us to leave the bedside and go.

Based on the case study, staff constraints may be observed at different levels due to the multitude of tasks involved in the HCSC operations.

Proposition 7c: Challenges with finance restraints and capabilities affect blockchain implementation.

Steele et al.'s (2020, 78) findings indicated that in low- to middle-income countries, 'Technology needs to be tailored to the skills and consumption needs'. However, as the case study setting was a private hospital, the finance capabilities of its supply chain for investing technologies were present. Nonetheless, based on the case study, there seems to be a variance between hospitals, as stated by one interviewee: 'Right now, I'm working in the hospital where we have electronic records and most advanced technologies… right now, like. But there are lots of differences… where some (hospitals) are technologically more advanced than others.' The interviewees highlighted a distinct contrast between private and public hospitals, emphasising that the adoption and operation of the system were primarily confined to private healthcare institutions. This discrepancy resonates with findings from a study conducted in Greek public administration, where Xanthopoulou (2022, 558) underscored a related concern, stating, 'The deficiency of equipment significantly impeded the adoption and effective integration of blockchain in the Greek public administration.'

4.8. Challenge 8: supply chain-wide collaboration

Proposition 8: Challenges of supply chain-wide collaboration affect blockchain implementation.

Omar et al. (2021, 37397) noted that 'HCSC suffers from highly fragmented structures, obsolete processes and systems, and disconnectedness in information sharing among stakeholders'. For example, in this case study, although the technology provided integration across the healthcare providers' supply chain and eased the critical share of information, sometimes there were still coordination problems within the supply chain. One interviewee noted,

> Sometimes the pharmacy might delay medicines. It won't happen routinely, but sometimes they will be short-staffed or something. But we have to give medicines

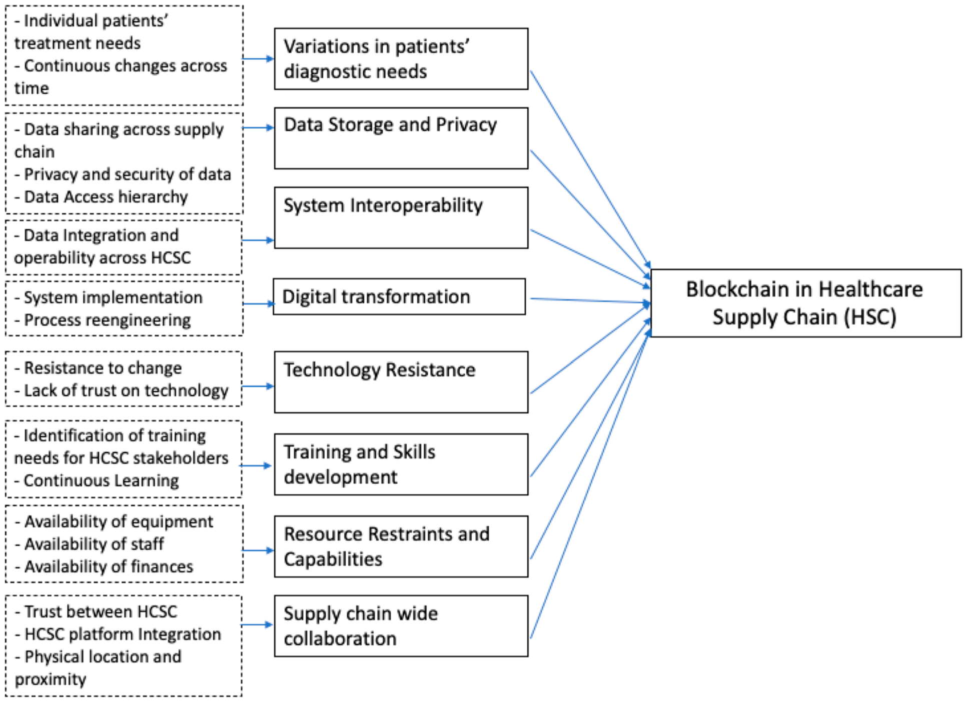

Figure 3. A figure of HCSC framework exploring the Blockchain implementation.

> within a specific time limit, so it will be stressed that we have to see, we have to send staff to the pharmacy to get medicines, so such things are quite challenging

Another interviewee highlighted the role of the centralisation of decision making when dealing with material enquiries:

> There is a central team which considers all of these things, and they are the ones who probably will be directly responsible. So, we are the end-users; we just must state what we want and what our requirements would be. So that gets discussed at a higher level and then we get to see whether it is being implemented or not.

As the complexity involved is fragmented, it is difficult to generate the required level of collaboration for blockchain at every level (Bak and Papalexi 2022; Koh, Dolgui, and Sarkis 2020). Billing particularly has been mentioned as being able to be coordinated when the patient is using the system and regarding the level of use. One interviewee noted how the process is streamlined:

> Let's say I'll just … I'll use the ultrasound machine, for example. OK, so this has this Bluetooth device tagged on to it, and then there's a central monitoring system which identifies the movement of this device. So, every time the moment of this device towards a particular bed is identified, it then realizes that the machine is lodged there for a couple of hours or whatever. It is sort of a billing - happens automatically now.

This is especially important where, as one interviewee noted, 'More than 60% of my patients pay from their pocket. … So that comes as a big impediment to us being able to do, you know, everything that we would like to do.'

The conceptual framework (Figure 1) and the findings and analysis of the propositions presented in the former sections have indicated some additional challenges. Based on these propositions, we devised an updated conceptual framework (see Figure 3 below) for blockchain technology implementation in HCSCs. Our framework introduces new areas of challenges investigated through our analysis to inform HCSC stakeholders. Nevertheless, the updated conceptual framework drawn from theory and the data provides an insight into the complex challenges for blockchain technology implementation in HCSCs (Table 2).

5. Conclusion

In this paper, we studied and discussed the implementation challenges of blockchain technology in the context of HCSCs in India. A conceptual framework based on eight areas with relevant stakeholders in the HCSC is developed based on our findings. The eight areas of blockchain technology challenges are depicted as variations in patients' treatment needs, data storage and privacy, interoperability, digital transformation, technology resistance, training and skills development, resource restraints and capabilities, and supply chain-wide collaboration. This study contributed by evaluating the blockchain challenges addressed in the extant literature

Table 2. Summary of findings from the case study.

Blockchain in HSC	Implementation issues highlighted in the literature	Case study findings
Variations in patients' needs	• Time and patients' treatment variance	- Interviews addressed the needs to continuous recording and assessment of the patients need as with the changes of health condition the treatment and patient needs might differ. - Although the integrated record presents the picture, the interpretation depends on the individual external/internal consultants. - One interviewee also noted that in a private hospital care setting, the individual patient may require the insight of two other consultants – internal/external – which can vary between patients as well.
Data storage, and privacy	• Data sharing across supply chain • Privacy and security of data • Data access hierarchy	- Data sharing has been not widely operational as in the banking sector. However, in the healthcare supply chain in the case study, the interviewees reported that the data was shared across hospitals (including in the private chain) in terms of reference to patient diagnostic and treatment history, financial data etc. - Access is provided to other parties, such as the blockchain system providers, pharmacies, external consultants, and other parties, who had access to the system with assigned access levels.
Interoperability	• Data integration and Interoperability	- Data integration and interoperability was available for the provider, but the individual and departmental access restriction meant availability was limited to access levels in some cases and required internal permission.
Digital transformation	• System implementation • Process reengineering	- The data was, in some cases, electronically transmitted directly into the system whereas, at other stages, this needed to be done individually. - Notes taken manually needed to be transferred onto the system and meaning in some cases as noted by the interviewees there was duplication and time difference in terms of entry when done manually. - Another interviewee noted that continuous transfer of patients' graphs associated with one type of treatment is difficult to record and upload onto the system and difficult to interpret but noted improvements are being worked on.
Technology resistance	• Resistance to change • Lack of trust on technology	- Some staff members would duplicate the data while taking additional handwritten notes to be entered at a later stage. - Some diagnostic tools are difficult to read in the documents due to the continuous nature of the data (i.e. progression over a time frame) requiring manual records to be kept. - Interviewees noted trust issues in terms of system capabilities and continuous record keeping.
Training/ skills development	• Identifying training needs • Continuous learning venues	- Interviewees noted the high level of IT skills of the employees and the availability of the IT support team in terms of the process. - With the system updates, however, they highlighted the continuous learning needs.
Resource restraints and capabilities	• Availability of equipment • Availability of staff • Availability of finances	- The lack of enough data-recording centres created in the location, as stated by the interviewees, creates strain on and limitations for the staff. - The interviewees noted the difference between private and public hospitals and that the availability of the system and running it was limited to private hospitals in general. - Staff are trained on specific fields and, as stated by an interviewee, a lack of staff, e.g. nurses, meant delays in the operations and in the recording and dissemination of data.
Supply chain-wide collaboration	• Trust between supply chain members • Integration of supply chain members' systems • Platform/data integration • The role of physical proximity	- The system allows the payments to be taken and verified on the system, - The pharmacies get direct instructions via electronic records where patients can be provided with the needed equipment/drug or continuous prescription. - The platform data integration between the chain of hospitals also allows the integration of information sharing as well as resource sharing. - Through the system, some patients could be sent home with mobile monitoring devices and data could be obtained 24/7 and assessed. - Through the data integration, the consultants can be reached outside the hospital premises when needed. - The location, however, was directly linked with the patient needs, i.e. under critical care, the patient needs to be monitored in hospital 24/7.

providing an exhaustive list of challenges which are not fully elaborated upon as addressed by Sim, Zhang, and Chang (2022) as well as Riley et al. (2016); in developing a conceptual framework that highlights the assessment of the challenges of blockchain technology implementation as also suggested by Saberi et al. (2019) as well as Hermes et al. (2020) and lastly by providing an in-depth case study to explore the healthcare supply chain challenges that are currently lacking in the literature (Attaran 2020; Hermes et al. 2020). Aligned with the three main contributions the theoretical and managerial contributions of the study have been included in detail below.

5.1. Theoretical contribution

The academic literature on blockchain in HCSC has focused on the decision-making process (Fusco et al. 2020; Huang et al. 2021), the use of electronic medical records with clinical data on a large scale (Fusco et al. 2020; Khan et al. 2021), and the creation of partnerships with pharmacies (Pouye 2021) whilst focusing on the implications of blockchain technologies on performance (Park and Li 2021) and barriers for blockchain adaption (Saberi et al. 2019) However, this case study examines the context for and assessment of blockchain technology, and identifies the challenges in an HCSC, addresses the contextual setting and the implications thereof, as this was limited in the existing literature (Hermes et al. 2020; Riley et al. 2016; Sim, Zhang, and Chang 2022; Tandon et al. 2020). Furthermore, we identified and presented issues that may affect the implementation of blockchain technology in the HCSC context. Our key findings and recommendations include the following:

- Blockchain challenges were evident in eight distinctive arenas of the HCSC; however, the challenges were specific and varied across the HCSC. For example, staffing had a particular impact in terms of nurses as the resource. The data access and sharing between hospital and pharmacy had a system-based relevant impact. Hence, adopting a stakeholder-based assessment may be valuable for responding to each challenge.
- The development of blockchain technology needs to be aligned with the current existing operation process and needs to address the grey areas, such as the use of non-integrated or recorded tools, including WhatsApp or telephone conversations. This will help HCSC members develop solutions to improve the process of reengineering.
- Blockchain technology is affected by the governance structure of hospitals, in this context, public and private HCSCs. It would be interesting to investigate whether other areas of challenges are present in the context of the supply chain of public hospitals.

Our study has provided a rich discussion and insights with empirical evidence. Future studies can be developed to see whether the framework represents the challenges in public HCSCs in India as well as in other country settings.

5.2. Managerial contribution

Our research addresses the Blockchain implementation challenges in the healthcare supply chain (HCSC) in India and provides insights into the policy implications of blockchain adoption in the healthcare sector. In this research context three practical issues have been highlighted for the policy makers which were; (1) Data distribution, security and transparency draw attention to privacy needs and establishment of regulation across the HCSC (Van Dijck et al. 2018), (2) In the case of any supply chain disruption (i.e. pandemic) in the HCSCs the benefits and disadvantages of health-relevant data needs to be considered not at the local, national level but also at the international level to enhance healthcare supply chain resilience, (3) lastly there is a concern of data's validity and reliability and whether an audit trail needs to be embedded at stages needs to be discussed, perhaps not at the HCSC level but specific areas of the supply chain for accurate data collection.

Our findings suggest that blockchain implementation challenges faced were based on variations in patients' treatment needs; data storage and privacy; interoperability; digital transformation; technology resistance; training and skills development; resource restraints and capabilities; and supply chain-wide collaboration. The Blockchain in HCSC has addressed the decision-making process (Fusco et al. 2020; Huang et al. 2021); focusing on the use of electronic medical records with clinical data on a large scale (Fusco et al. 2020; Khan et al. 2021) and creation of partnerships with pharmacies (Pouye 2021) whilst these issues are important, the impact of the identified challenges identified in our study need to be assessed on elucidating implications for supply chain resilience across different in the healthcare sector. Hence future studies need to address how the HCSC utilises mechanisms and tools to become more resilient, as resilience has been shown to be a major disrupter in the operation of healthcare as seen in the case of COVID-19.

Acknowledgements

We would like to acknowledge the support of British Council and Indian SPARC (Scheme for Promotion of Academic and Research Collaboration) Impact of Artificial Intelligence on Productivity, Employability and Business Models in Health Care Services.

Data availability statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data is not available.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by British Council and Indian SPARC (Scheme for Promotion of Academic and Research Collaboration).

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