



# Blockchain in surgery: are we ready for the digital revolution?

Francesco Maria Carrano<sup>1,2</sup> · Pierpaolo Sileri<sup>3,4</sup> · Susie Batt<sup>5</sup> · Nicola Di Lorenzo<sup>1,2</sup>

Received: 24 July 2021 / Accepted: 29 December 2021 / Published online: 9 January 2022  
© Italian Society of Surgery (SIC) 2022

**Keywords** Blockchain · Surgery · Transplant · Health economics · Electronic health record · COVID-19 · Artificial intelligence · Distributed ledger · Non-fungible token · NFT · Smart contract · Surgical logbook · Transplant · Internet of things

## Introduction

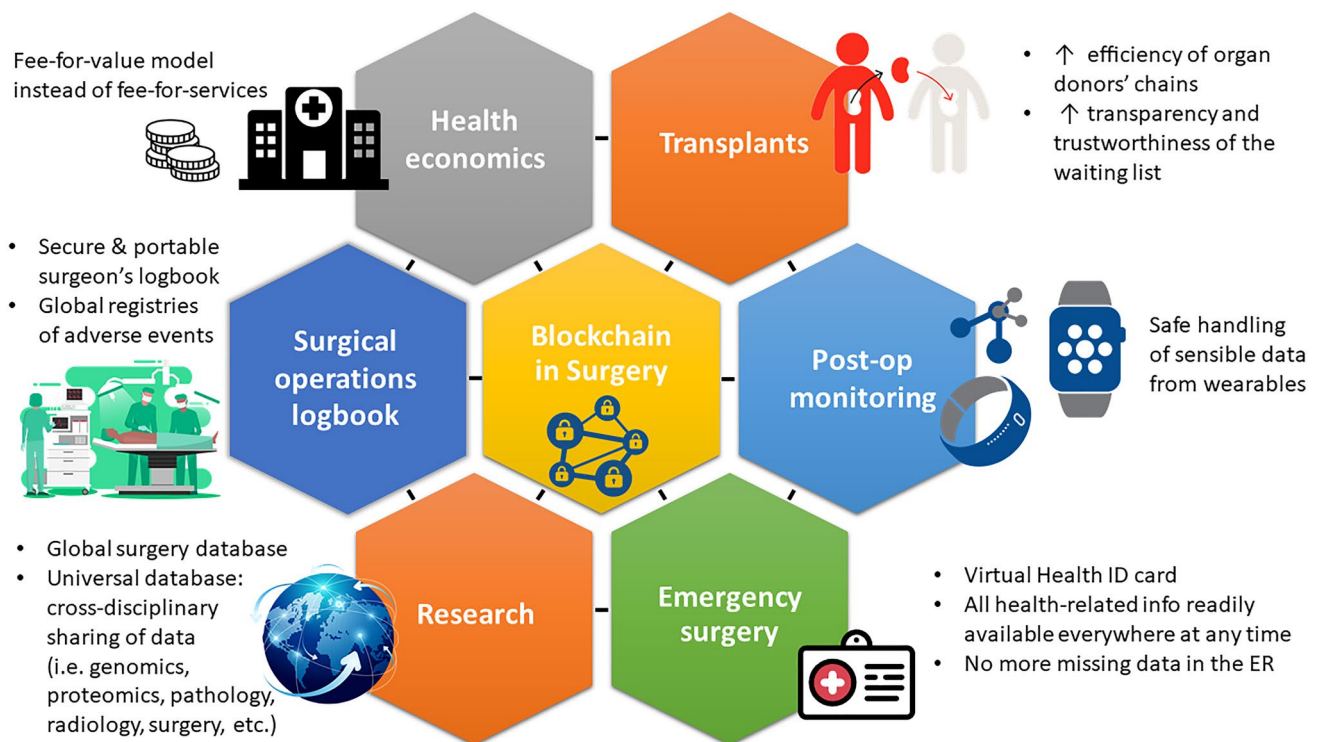
Throughout time, surgery evolved from an old fashioned and rough discipline to one of the most exciting fields in medicine, tightly linked to historical technological advancements. To cite only a few, minimal access surgery including laparoscopic and robotic surgery, real-time intraoperative angiography with fluorescent dyes and coherent laser imaging systems, 4K ultra-high-definition optics, 3D printing, virtual and augmented reality. Our daily practice has also changed with the introduction of electronic medical records, with the consequent possibility of running big data analytics and artificial intelligence algorithms. The latter will soon represent a major turning point in human history and, nonetheless, in surgery, although it may seem distant from our daily activities. Not taking part completely to the digital revolution will soon render our practice obsolete. In this process, it will be fundamental to manage the huge amount of digital data (patients' data, surgical video footage, etc.) with maximum attention to security and digital privacy, considered a human right by the United Nations [1]. In 1982, a new protocol for secure storage of information based on a chain of data blocks was created by David Chaum, considered the

“father” of modern-day cryptography [2], and expanded in 2008 by a person or a group of people under the name of Satoshi Nakamoto, that created blockchain. All kinds of information, including audio and video, can be secured in a blockchain, which is a specific type of database that stores data in programmable blocks, chained together in a chronological order. Once the information is on the blockchain, it becomes accessible to all the network participants and cannot be altered or counterfeited, thus protecting from fraud and cyberattacks, as every action leaves a trace. Blockchain technology is freely accessible and available to anyone, and one of its most famous real-world applications is the cryptocurrency Bitcoin. We would like to share some of the less known applications of blockchain to the medical field and point out how this technology can contribute to the evolution of our surgical world (Fig. 1).

The small Republic of Estonia, for example, has been one of the first countries to implement blockchain in the health-care system, securing the medical data of its entire population in a private blockchain. This has given the incredible possibility to the government to track epidemics in real time, to physicians to have all the patient's information available at any time, including imaging studies and laboratory analysis [3, 4]. Similarly, because of the COVID-19 pandemic, many Nations have been confronted with the need to track and manage a large amount of sensitive data, consequently raising important privacy issues. Various strategies have been investigated to protect privacy, and the adoption of the blockchain technology was one of them. For example, Xu et al. demonstrated a viable blockchain platform that can desensitize a user's identity and location information, ensuring identity protection of patients with COVID-19 and their public privacy in a decentralized environment. At the same time, the implementation of rapid, widespread testing and vaccination strategies have witnessed the parallel

✉ Francesco Maria Carrano  
carranofm@gmail.com

<sup>1</sup> PhD Program in Applied Medical-Surgical Sciences, University of Rome “Tor Vergata”, 00133 Rome, RM, Italy  
<sup>2</sup> Department of Surgical Sciences, University of Rome “Tor Vergata”, Viale Oxford 81, 00133 Rome, Italy  
<sup>3</sup> Department of Surgery, IRCCS San Raffaele Scientific Institute, Milan, Italy  
<sup>4</sup> Faculty of Medicine, Vita-Salute San Raffaele University, Milan, Italy  
<sup>5</sup> Crypto Ecosystem Lead, Opera Software, Oslo, Norway



**Fig. 1** Possible applications of blockchain technology in surgery

introduction of health and immunity certificates. Blockchain technology can provide a secure and decentralized environment for cross-border verification of COVID-negative or immunity status [5]. For example, the Government of South Korea has implemented, at a national scale, the world's first blockchain-based COVID-19 Vaccination Verification System (COOV) [6]. Unlike the European Union Digital COVID Certificate, which is based on verifiable credentials following the standard Public Key Infrastructure [7], COOV does not need to handle the complex management of cryptographic keys, thus avoiding the risk of having some of these keys being compromised or stolen. The adoption of the blockchain technology allows to prevent forgeries, and to encrypt sensitive personal information like social security numbers or other identifying factors. As an adjunct privacy protection feature, it also includes decentralized identity, which is a method that does not allow governments to access or store the data, as the exchange of information occurs directly between the visitor and the host through blockchain. With COOV, the passport holders have full control of their data [6]. Other examples of the current use of blockchain technology for the implementation of digital health credentials are the New York State's Excelsior Pass that allows individuals to access their COVID-19 vaccination record or negative test results through an integrated, secure platform that accesses the already existent State and City immunization registries [8], and the San Marino Digital

Covid Certificate that links info regarding the COVID-19 status to a Non-Fungible Token (NFT), i.e., a unique and non-repeatable certificate of digital authenticity that guarantees immutability and accessibility by being registered on a public blockchain [9]. Moving to our daily clinical practice, imagine how useful it would be to have that level of information on every patient that comes in the emergency room after a severe trauma or comes already intubated in the operating room. The application of the blockchain technology for the creation of a patient-centric electronic health record that is accessible across different hospital electronic platforms, which respects privacy, is trustworthy and reliable, has been already tested at the Stony Brook University in the United States, and a pilot study is already planned between health-care providers in the United States and Switzerland [10].

A possible, immediate application of the same principle in the surgical field would be the creation of a national registry of surgeons and surgical operations. This could be updated by any surgeon caring for the patient after the first operation, with the inclusion of imaging studies and video-recordings of the surgical procedures. Temporary access to data can be given by the patient with the use of private keys. Registry data could be used across specialties and institutions without limitations.

Another opportunity comes from the secure handling of biometric data coming from wearable technology, obtained before, during, and after a surgical operation. Early examples

of novel approaches to post-operative management are already being explored for elderly oncologic patients [11] and after esophagectomies [12]. All these devices generate an incredible amount of sensible data that require proper protection and, at the same time, easy distribution among sources. Blockchain technology would be the perfect solution for the purpose, however, its potential applications go beyond the management of registries and data analysis. Another real-world application is its use for the management of the supply chain. Faulty instruments or machinery could be located and recalled in seconds, and any equipment shortage will be prevented in advance. Technical servicing could be coded into a smart contract and automatically updated via the internet much like car manufacturers performs upgrades to their vehicles while idle.

## Organ transplantation

The great potential for supply chain optimization could turn useful also in the field of organ transplantation, especially in case of organ donations from living donors, like in a paired kidney exchange. Also known as a “kidney swap”, it occurs when a living kidney donor is incompatible with their recipient but does match another person on the waitlist. Two living donor transplants would occur. Donor chains work similarly to paired kidney donations, taking advantage of healthy and willing—but incompatible—donors. The chain is initiated by a non-directed donor, who is someone that offers to donate a kidney without a designated recipient, but with the explicit wish to donate to someone in need of a transplant. A blockchain-based architecture for human organ transplantation would incredibly simplify the whole process of organ donation, location, and distribution. The creation of an international waitlist database could also dramatically improve the chances to perform a paired kidney exchange or activate a kidney donor chain in the context of kidney living donation. The decentralized nature of the technology would ensure transparency and trustworthiness, as no single party would be in control of the waiting list priority, and every event would be visible to any person with access to the system. Every interested party would also be able to directly verify each step of the process, ensuring a reliable and secure exchange mechanism for recipient and donor health records. The efficiency of the transplantation network would greatly benefit from blockchain, with the reduction of the intermediaries present in the current systems [13], protection against fraud and “black market” sales of organs.

## Health economics

In terms of Economics, health is a durable good [14] that is tightly related to the wealth of societies. As they become wealthier, they tend to consume more health services, thus

leading to a growing burden on public or individual finance, according to the different healthcare systems. Such costs could be sustainable only with an increase in productivity, through cost savings, improved operational efficiency, and better use of technology and automation [15]. A central aspect of the new healthcare economics is how the information (i.e., patient records, professional licenses, research data, supply chains, etc.) is governed (e.g., through firms, governments, markets, and blockchains) and how the most effective governance changes through time as new technologies of trust are developed. In this regard, as a technology of trust, blockchain could steer the current economic organizational model of healthcare away from third parties (i.e., hospitals, companies, governments) to a new decentralized one, where data property rights are held by individual patients. The blockchain platform would then serve as a new economic infrastructure to govern those data rights, allowing new solutions to healthcare problems [15]. In surgery, for example, quantifying the worth of surgical care is a difficult and frustrating experience, we all know how bothersome it is the diagnosis-related group system. The use of blockchain-based smart contracts would permit the link of clinical outcomes to costs, possibly allowing the involved stakeholders to shift from offering their services with a fee-for-services model to a fee-for-value model.

## Conclusion

Although very promising, blockchain technology is just in its early stages of adoption in healthcare. The lack of confidence with the ever-evolving digital world, the often-limited involvement of the Information Technology department into the everyday clinical work, the fragmentation and lack of intercommunication of the existing electronic medical databases, are just some of the reasons why the use of blockchain technology in the medical field is untapped. As surgeons, we should enforce our role as innovators during this time of incredible opportunities, and actively contribute to the innovation process, including the adoption and development of blockchain. Being competitive in the future will not only be a matter of being the best in the operating theater, but also a matter of being among the leaders of technological advancement. We should not stay at the side watching history being done but thrive to know more and get involved in the action.

**Author contributions** FMC conceived the presented idea, NdL and PS developed the concept, SB provided technical insights and supervised the technical parts of the manuscript. All the authors have contributed to the final version of the manuscript.

**Funding** None.

**Data availability** Not applicable.

**Code availability** Not applicable.

## Declarations

**Conflict of interest** Nothing to disclose.

**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** No informed consent is required.

## References

- (2019) Human rights in the digital age - can they make a difference? Keynote speech by Michelle Bachelet, UN High Commissioner for Human Rights, Japan Society, New York. <https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=25158&LangID=E>. Accessed 17 Oct 2019
- Sherman AT, Javani F, Zhang H, Golaszewski E (2019) On the origins and variations of blockchain technologies. *IEEE Secur Priv* 17:72–77
- Bau T (2017) Why estonia is a good place for E-health (and why you should attend e-health tallinn). Healthcare Information and Management Systems Society, 12 th June. <https://www.himss.eu/himss-blog/why-estonia-good-placeehealth-and-why-you-should-attend-ehealth-tallinn>
- Guardtime AS (2021) World's Leading Blockchain Company. Official website: <https://guardtime.com/>. Accessed 12 Dec 2021
- Ng WY, Tan T-E, Movva PVH, Fang AHS, Yeo K-K, Ho D, Foo FSS, Xiao Z, Sun K, Wong TY, Sia AT-H, Ting DSW (2021) Blockchain applications in health care for COVID-19 and beyond: a systematic review. *Lancet Digit Health* 3:e819–e829
- Korean Disease Control and Prevention Agency official website. <https://ncv.kdca.go.kr/menu.es?mid=a12507000000>. Accessed 1 Dec 2021
- Schubert I (2021) The New Technology Powering Europe's COVID Certificates. <https://www.securid.com/en-us/blog/2021-09/the-new-technology-powering-european-covid-certificates>
- New York State Excelsior Pass Blueprint. <https://covid19vaccine.health.ny.gov/excelsior-pass-and-excelsior-pass-plus>. Accessed 1 Dec 2021
- Decreto - Legge 16 giugno 2021 n.109 - Ratifica Decreto – Legge 8 giugno 2021 n.105 - Norme di sicurezza per la emissione e gestione del San Marino Digital Covid Certificate (SMDCC). Available at: <https://www.consigliograndeegenerale.sm/on-line/home/lavori-consiliari/dettagli-delle-convocazioni/documento17125610.html>
- Dubovitskaya A, Baig F, Xu Z, Shukla R, Zambani PS, Swaminathan A, Jahangir MM, Chowdhry K, Lachhani R, Idnani N, Schumacher M, Aberer K, Stoller SD, Ryu S, Wang F (2020) ACTION-EHR: patient-centric blockchain-based electronic health record data management for cancer care. *J Med Internet Res* 22:e13598
- Jonker LT, Plas M, de Bock GH, Buskens E, van Leeuwen BL, Lahr MMH (2021) Remote home monitoring of older surgical cancer patients: perspective on study implementation and feasibility. *Ann Surg Oncol* 28:67–78
- Breteler MJM, Numan L, Ruurda JP, van Hillegersberg R, van der Horst S, Dohmen DAJ, van Rossum MC, Kalkman CJ (2020) Wireless remote home monitoring of vital signs in patients discharged early after esophagectomy: observational feasibility study. *JMIR Perioper Med* 3:e21705
- Chalissery BJ, Asha V (2020) Blockchain based system for human organ transplantation management. In: Smys S, Iiyasu AM, Bestak R, Shi F (eds) *New trends in computational vision and bio-inspired computing: Selected works presented at the ICCVIC 2018, Coimbatore, India*, Springer International Publishing, Cham, pp 829–838
- Phelps CE (2017) *Health economics*, 6th edn. Routledge, London. <https://doi.org/10.4324/9781315460499>
- Allen, Darcy and Berg, Chris and Pochesneva, Anastasia and Potts, Jason, *Blockchain and the New Economics of Healthcare* (May 30, 2019). <https://doi.org/10.2139/ssrn.3396218>. <https://ssrn.com/abstract=3396218>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.