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Blockchain in Healthcare

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This paper provides a brief overview of whether blockchain could be a promising technology for creating a healthcare ecosystem. The healthcare sector is traditionally a conservative and slowly adapting industry. Especially the current German healthcare market is revealed to be a very heterogeneous field of data stakeholders and management systems. By using blockchain-encrypted digital identity management, humans are placed in the center of medical data management. The central issues are the availability of medical data and trust of patients and stakeholders in data security and quality, which can be addressed by using blockchain technology.

Is blockchain a useful technology to create a healthcare ecosystem?

Now momentum shifts from an enormous hype in many industries around blockchain technology to how use can be made of it (Crosby, et al., 2016) in order to identify and build business applications (Pawczuk, et al., 2018). Gartner judgement goes one step further and describes in his hype cycle for blockchain that blockchain in healthcare is an upcoming trend around the world (Figure 1). Meanwhile, in the finance industry, for example, cryptocurrencies are an established part of the business, now facing further challenges with potential setbacks on their journey through the business cycle after the hype (Rimol, 2019). In the healthcare sector, one can observe multiple phases of introduction around the world. On the one hand, Estonia has already established a complete blockchain-based healthcare ecosystem within a decade (Müller, 2019), but on the other hand, only the first steps in applying the technology are made in countries like Germany (Zahorsky, 2018).

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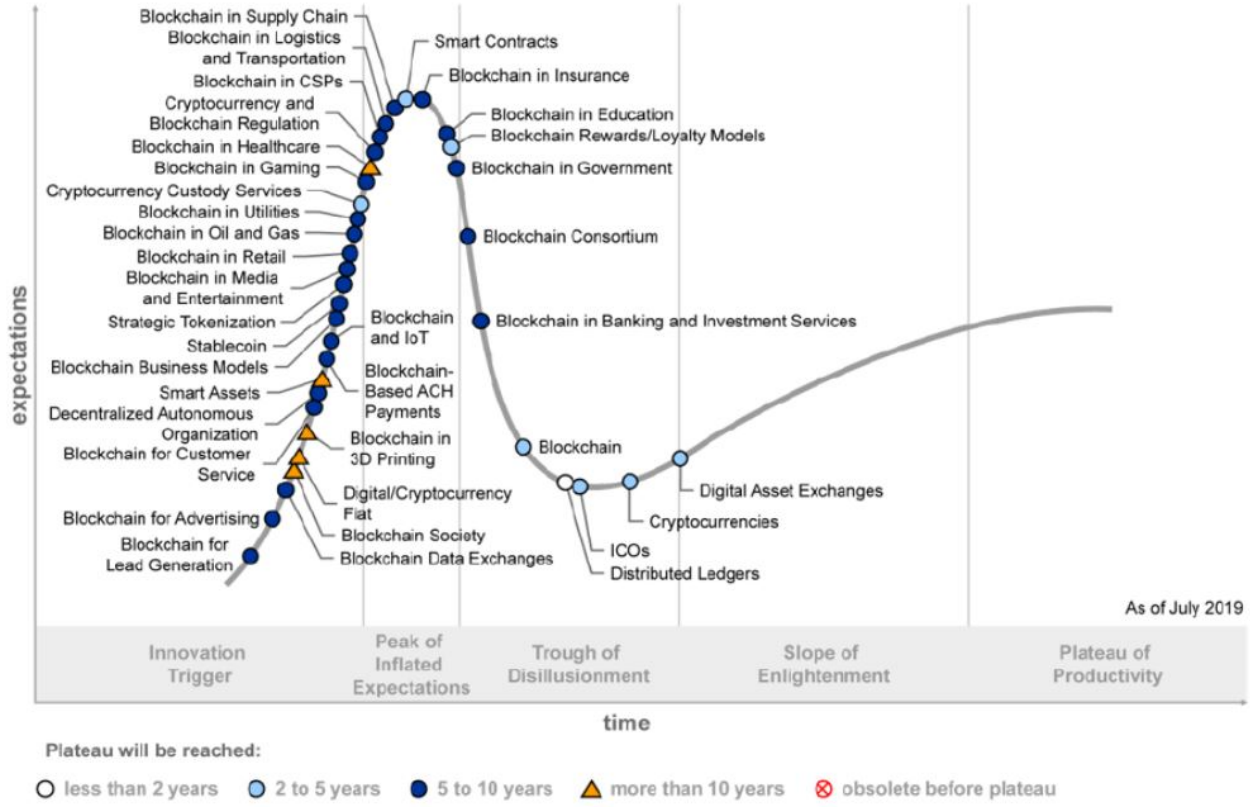
Figure 1

Gartner Hype Cycle for blockchain business 2019



Healthcare ecosystem

For governments and citizens, the rapid growth of health expenditures has become a significant concern for decades. In 2011, a World Health Organization (WHO) long-term analysis covering more than 143 countries pointed out different cost drivers in healthcare services depending on levels of economic development. The most important aspect is an increase in gross domestic product (GDP), which led to government health expenditure increase depending on different levels of economic development in the respective countries. Therefore, countries with high health expenditures need to find ways to increase the value received from their money (Kea, et al., 2011).

In 2017, countries like the USA, Germany, Switzerland, amongst others, spent more than 10% of their GDP on healthcare. Table 1 provides an extract from Word Bank statistics on healthcare expenditures and their ranking based on

% of GDP and expenditure per capita. *Purchasing power parity (PPP)* is a way of measuring economic variables in different countries without distorting comparison by exchange rate variations (PopulationPyramid.net, 2019):

Table 1

Health expenditure 2017, total (% of GDP) and per capita

Country	Health expenditures, total (% of GDP)	Health expenditures per capita, PPP
1 USA	17.14%	9,402.54 $
4 Sweden	11.93%	5,218.86 $
5 Switzerland	11.66%	6,468.50 $
8 Germany	11.30%	5,182.11 $
36 UK	9.12%	3,376.87 $
91 Estonia	6.38%	1,668.31 $

This leads to the urgent question: how can the resources be used efficiently and effectively to increase the value out of the invested money? Therefore, we analyze the German healthcare system and the blockchain-based healthcare system of Estonia to identify potential cost savings and possible solutions based on blockchain technology.

Digital identity is key

In the 1970s, pioneers of public-key cryptography explored concepts of decentralized digital identity to help people protect their privacy in the new digital age of computers. In 2016, Christopher Allen published a concept of self-sovereign identity development (Allen, 2016).

Nowadays, data is the new commodity, and in time of General Data Protection Regulation (GDPR) and data hack, the question of ownership and identity management has never been more relevant than today. Blockchain technology is able to push the development further to self-sovereign identity. In

the internet era, web sites force the users to juggle dozens of identities on dozens of different sites, while having control over none of the identities.

Digital identity is a key factor for using blockchain technology in healthcare data management

In Germany, digital identity management tools based on blockchain are e.g. *Jolocom* (Jolocom.GmbH, 2019), *Blockchain Helix* (Naegele, 2019) and *idento.one* (Bauer & Corneliussen, 2019). The user decides who gets access to which personal data and for how long. Companies could provide incentives for the usage of personal data. GDPR regulations are included and respected in the service for users, companies, and public authorities.

In the healthcare ecosystem, the medical information is stored and distributed in various silos. Digital identity is an excellent opportunity to bring patients in an owner position of all health information to choose whom to allow access and how data is used or purchased.

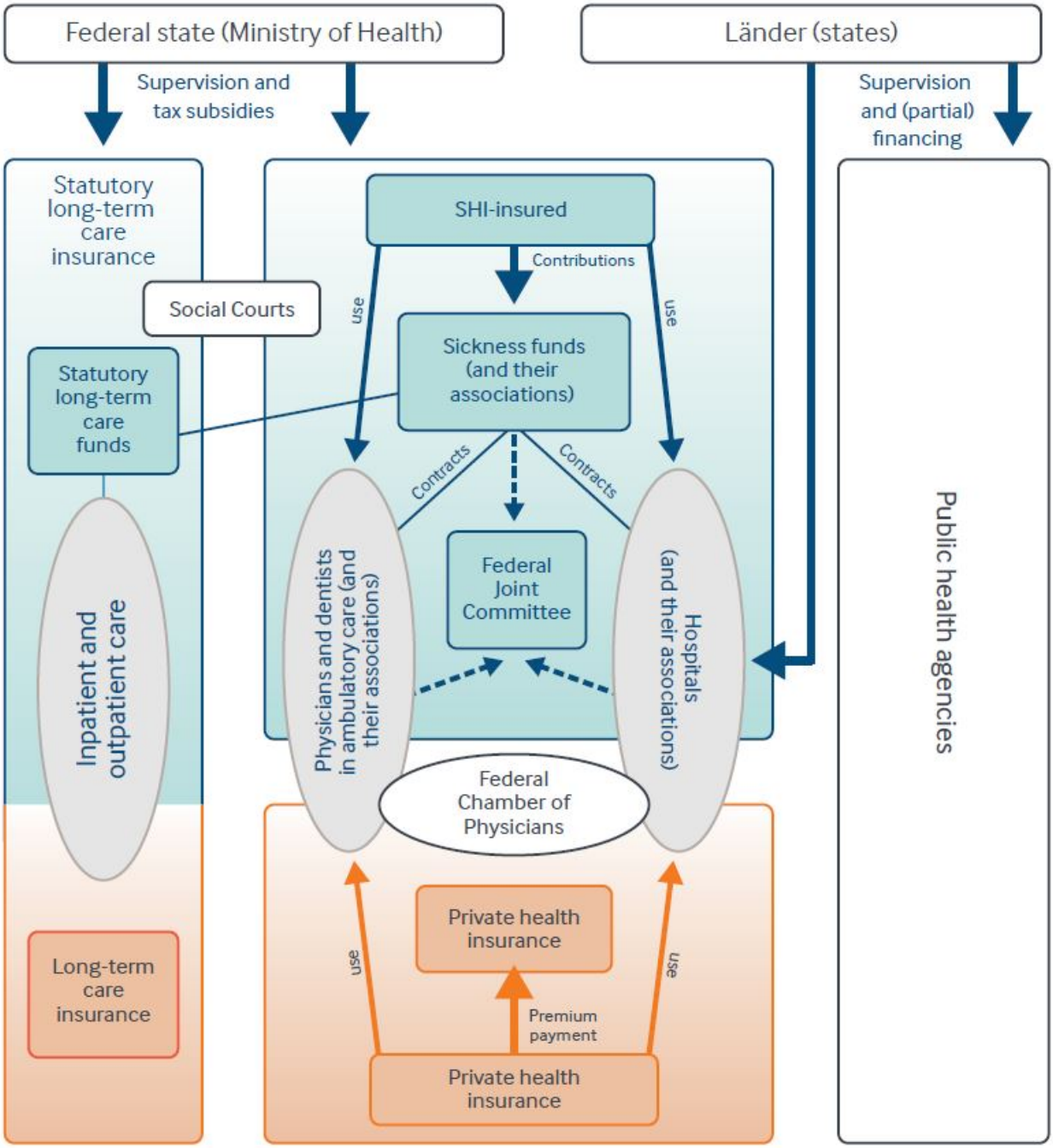
Germany: a traditional healthcare ecosystem

Currently, 80.4 million people live in Germany, and more than 17 million are older than 65 years (number 4 in world ranking). A further increase of older people is expected (PopulationPyramid.net, 2019). For all citizens and permanent residents in Germany, health insurance is mandatory and has two main pillars. On the one hand, a statutory health insurance (SHI) system, with 118 competing SHI insurers ("sickness funds" in a national exchange), is mandatory. The insurers are competing, not-for-profit, nongovernmental health insurance funds. On the other hand, above 11% of citizens opts out from statutory insurance for private coverage to substitutive private health insurance (PHI, 42 companies). This depends on their high income. SHI and PHI contribution rate is round about 15 percent of gross wages, shared equally by the employer and employees, as well as in long-term care and social support (LTCI). To a large degree, regulation is delegated to self-governing associations within sickness funds and provider associations, which are

together represented by the most important body, the Federal Joint Committee. The interplay of the different stakeholders is shown in Figure 2 (Mossialos, et al., 2017):

Figure 2

Interplay of different stakeholders in the German healthcare system



In 2015, the Federal Cabinet passed a law for secure digital communication and health care applications (*E-Health Act*), which provides concrete deadlines for implementing infrastructure and electronic applications. It introduces incentives and sanctions if schedules are not adhered to (Zahorsky, 2019).

In December 2018, "*gematik*", a federal commission of stakeholders in German healthcare, published their technical specifications about interoperability standards for healthcare data exchange. The German regulator put them in charge of strategic development in the digitalization of the German healthcare industry after being founded in 2005. For more than one decade, gematik was responsible for these technical specifications. Nevertheless, ineffective patient data management could be experienced in Germany every day if a patient tries to receive medical reports for the last five years. As described, many different stakeholders in healthcare handle and store medical data: General practitioners (GP), medical specialists, hospitals, physiotherapists, insurance companies etc. The data are stored in standalone systems and deliver only a specific point of view about the patient or policy holder. These data silos are not connected to share data with the patient or other stakeholders (Krawiec, et al., 2016).

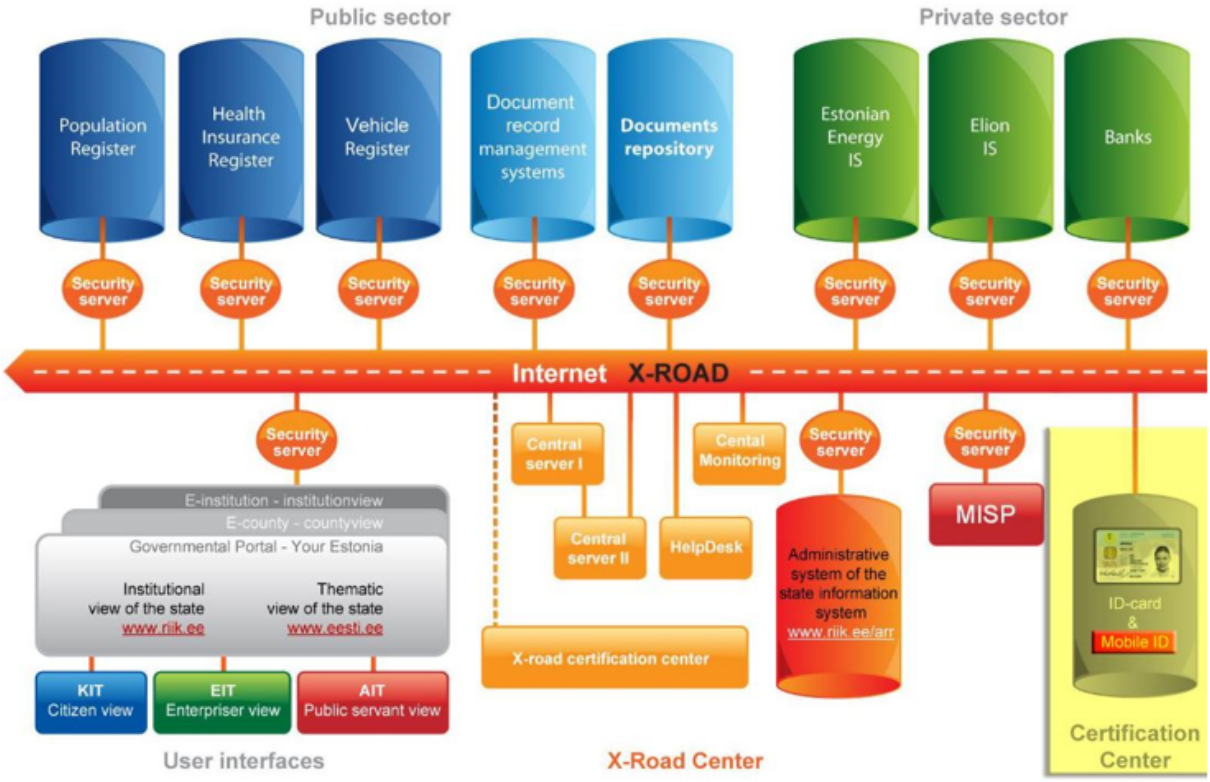
Blockchain technology is able to deliver a sufficient solution for all these problems. A key role in the development of trust and interconnected use of data is a digital identity for users or patients. All changes have to respect the data protection rules (GDPR) to establish a trusted environment and wellbeing for citizens by using their healthcare information (Maxwell & Salmon, 2017). For the patient, immutable and safe data storage will deliver a real medical history. Further, data analytics and cognitive computing/machine learning, in addition to blockchain secured data, could be used to deliver a broader view of personal risk factors and possible solutions for personalized medicine. Furthermore, blockchain technology could enable access to a rich set of standardized, non-patient identifiable information to support medical researchers developing new treatments by using e.g. demographic data or genetic markers. Blockchain technology delivers the technical solution via smart contracts to reward the patient for its data donation (Krawiec, et al., 2016)

Estonia: a healthcare ecosystem on blockchain technology

Estonia has established a complete electronic government system based on blockchain technology and, therefore, has made a virtue of necessity. The platform is called *e-estonia* and provides most of the governmental services digitally. Only for marriage, divorce, or house purchase one has to arrive in person in a local city office (Thomas, 2017). At the forefront is the digital identity (e-identity). The national ID-card provides digital access to e-services, contains the digital, legally binding signature, and functions as a legal travel ID for Estonian citizens and identification for bank accounts and e-voting. Similar to a national health insurance card, it is used for identification to get access to personal medical records and e-prescriptions (E-Estonia, 2019a). Figure 3 provides a brief overview of e-estonia and the included digital governmental services (tere-tech, 2012):

Figure 3

Estonian information system



X-road is the backbone of public governmental and private services and secures the connection of different information systems. To ensure interoperability and security, all incoming data is authenticated and logged, all outgoing data is digitally signed and encrypted on keyless signature infrastructure (KSI) blockchain, which is able to scales to 1012 items of data every second. Already 99% of state services are online and reachable 24/7. The calculation demonstrates the cost-saving opportunities in a blockchain-based ecosystem: Assuming 5% of requests on X-Road are submitted by human users, and every request saves 15 minutes, *1,407 working years* were saved in 2018. Since 2018, X-Road is also implemented in Finland and enables federations to secure cross-border data exchange (E-Estonia, 2019c).

The structure of the Estonian healthcare system is very different from the German system‘s. A strict separation of stakeholder functions is implemented. Different parties are the Ministry of Social Affairs and its agencies, the Estonian Health Insurance Fund (EHIF), and independent provider units operating under private law (so-called autonomized units). The Ministry of Social Affairs and its agencies are responsible for the development of national healthcare policies and legislation, supervision of compliance with legal acts, collection, and analysis of data on activity volumes and economic indicators of providers, as well as registration of health care professionals and licensing of facilities. In addition, it is responsible for financing emergency care for the uninsured, as well as ambulance services and public health programs. Both the Ministry of Social Affairs and local governments finance social care (Doupi, et al., 2010).

The central issue is trust of all citizens in data security and quality.

In 2017, the health expenditures in Estonia equaled 6.4% of GDP and 1,668 $ per capita (PopulationPyramid.net, 2019). Compared to Germany, with a ratio of 11%, it seems that Estonia manages its system efficiently. The E-health record retrieves data from various healthcare providers using X-road and presents it in a standard format via the e-patient portal. Included databases are

imaging database, registries (cancer, deaths, births, drugs; depersonalized for inquiries/research) and electronic referral databases. A registry of insured people claims from partners and e-prescription database is included in EHIF databases. Currently, 99% of patients have a countrywide digital record. By logging in with the electronic ID card, the patient can review doctor visits and current prescriptions or have access to those of their underaged children. In addition, they can check, which doctors have had access to their files, check all billings and have the right to opt out from collecting data to central databases. Doctors get access to test results, including image files such as X-rays even from remote hospitals. Additionally, a mobile ID allows entering the portal and signing documents by mobile phone (E-Estonia, 2019b). The invoice system is completely electronic for medical treatments and prescriptions. The database enables planning, reporting, monitoring and controlling for the healthcare budgets in EHIF (Ross, 2015).

In summary, the greatest advantages of these implemented structures are an efficient and effective use of resources, interoperability of stakeholders and data transparency on different level for patients, doctors, pharmacists, and EHIF, by paying the price of centralized negotiation and regulation power of EHIF and the Estonian government in contrast to the German self-regulated system. The central issue is trust of all citizens in data security and quality.

Cost-saving opportunities

Health is an important social goal worldwide. Supporting this goal, Germany spends more than 11% of its GDP (374 billion euros in 2017) on healthcare, and the future increase of costs is one of the biggest challenges for the society (PopulationPyramid.net, 2019). One of the most important tasks is the implementation of an efficient and effective structure to identify potential savings (Engelhardt, 2017).

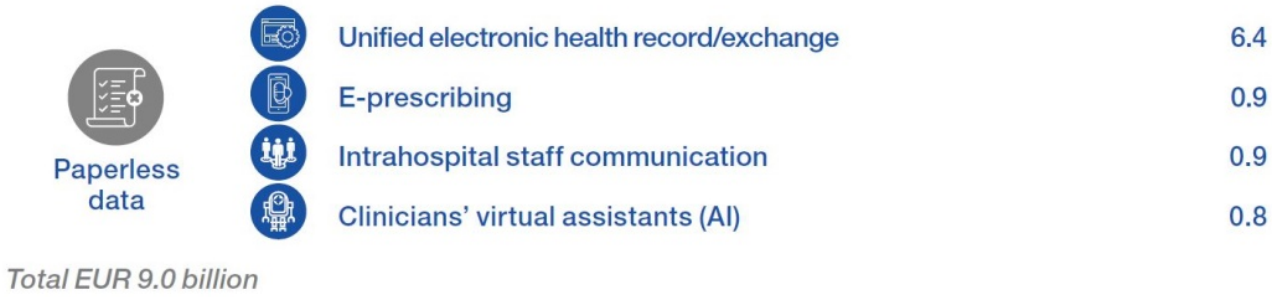
In 2018, McKinsey released a study in cooperation with the German Managed Care Association (BMC) to discover potential cost-saving opportunities by digitizing the complete healthcare system. In conclusion, they found six solution categories to realize savings up to *EUR 34.0 billion*. (Hehner, et al., 2018). The study did not favor a specific technology choice, but distributed ledger technology with the possibility of using smart contracts will deliver

sustainable solutions for the suggested cost-saving opportunities (Schumacher, 2017).

The study identified the necessity to decrease demand by avoiding duplicate examinations, minimizing double hospital admissions and subsequent treatments, and for improvement of treatment quality. The overall saving potential of EUR 34 billion will be mostly divided into inpatient hospital care, outpatient GP care, and specialist care. The most valuable category was the paperless data category with saving opportunities of EUR 9.0 billion in total (see Figure 4) (Hehner, et al., 2018):

Figure 4

Cost savings: paperless data



Teleconsultation and other online interactions could provide further cost savings of EUR 8.9 billion by supporting structural problems because of staffing shortages in rural areas and time savings for GP and patients by requesting advice from specialists. It could improve the quality of nurses' care by using electronic medical records (EMR) and thereby facilitate efficiency in the monitoring of patients. Using online booking tools for appointments with GP or other specialist consultants will support convenience for patients with time and cost-saving opportunity of 0.5 EUR billion (Hehner, et al., 2018).

Establishing management tools in patient treatment plans could lead to further savings of EUR 5.6 billion by reaching a higher degree of effectiveness and efficiency. As argued above, patient self-treatment and patient self-care are useful tools to promote personal responsibility for health and could deliver around EUR 4.3 billion of the potential cost savings. Another interesting

use case in this scenario is pushing the usage of fitness wearables to collect health data.

In conclusion, distributed ledger technology and smart contracts are able to deliver ground-breaking solutions for problems in the healthcare industry. Combined with a digital identity, blockchain technology can boost efficiency and effectiveness in healthcare for providers, payers, and patients and provides data security as a basic need for trust.

Figure 5 shows the cost-saving opportunities by automation of service chains to push forward effectiveness and efficiency (Hehner, et al., 2018):

Figure 5

Cost savings: Automation

Note: Radio-frequency identification (RFID) tracking of all assets (e.g., diagnostic tools, beds, expensive drugs)
Vital parameter tracking (eICU): Remote monitoring of intensive care unit patients

Importance of data ownership and trust

Research studies analyze whether there is now a clear need for further digitalization from a user or managerial point of view: In 2014, Biesdorf and Niedermann (McKinsey & Company) interviewed thousands of patients from different age groups, countries, genders, and income groups to get more insights into patients' needs. The main findings were that more than 75% of all patients expect to use digital services in the future independent of their age. The demand for mobile healthcare applications is strongest among younger

people. Interestingly, innovative services, better apps, and more social media were far less important to most patients. The most appreciated tasks are assistance with routine tasks and navigating through the often-complex healthcare system, finding and scheduling physician appointments as a service, selecting the right specialist and support for repetitive administrative tasks such as prescription refills. To address this aspect, no massive IT investment is needed (Biesdorf & Niedermann, 2014).

Deloitte's survey in 2018 focused on the managerial point of view. The authors are convinced that blockchain will cause disruption and can provide significant value through disintermediation, transparency, and auditability, industry collaboration by sharing information and new business models. Deloitte estimates that the outcomes from these consistent pursuits over the next 12 months will provide tangible evidence of blockchains value (Pawczuk, et al., 2018). The presented survey gained insights into the overall attitudes and relevance in blockchain as a technology for the healthcare market and related fields. Therefore, 108 participants were asked for their appraisals by answering 19 questions.

93% of the participants see blockchain as a useful technology for healthcare data.

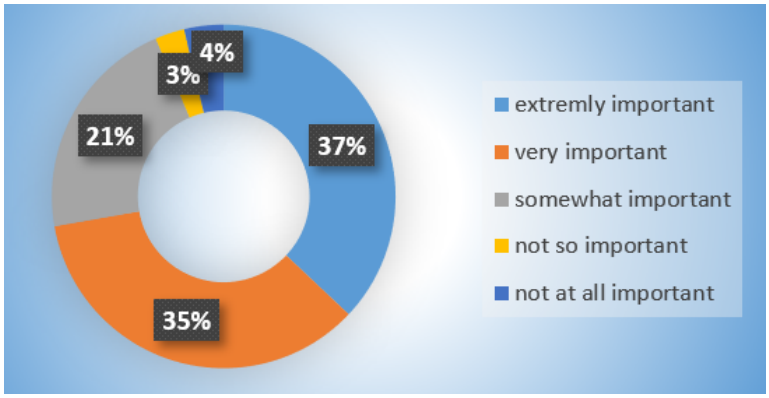
Most of the participants came from the fields of finance (25%), healthcare (19%), and tech sector (14%). Formal education was mostly a Master's degree (69%), a Ph.D. (13%) and a Bachelor‘s degree (14%). Most of the participants were working on a (senior) management level (55%) or as the business unit head (13%) in strategy & innovation (20%), sales (14%) or IT (13%). Most of the participants were 30-44 years old (73%), most of them were male (69%). In the self-assessment of their knowledge about blockchain technology, they indicated a professional (44%) or higher level (15%). The likelihood of transforming their industry by blockchain technology was quantified to 59%.

Most of the surveyed individuals' companies (61%) are working on different blockchain solutions, mainly in the fields of supply chain, digital records,

Internet of Things (IoT), payment, digital identity, digital currency. Most of them have been educated (26%) or experimenting (27%) with respect to blockchain technology. For their personal use, the participants (67%) pointed out the fields of finance & cryptocurrencies (30%), digital identity (16%) (followed by browser, supply chain, fitness app, legal contract, and insurance). In Figure 6, the results for the relevance of having control over healthcare data is shown.

Figure 6

Relevance of having control over healthcare data



Most of the surveyed individuals (58%) expect that blockchain technology solutions are more secure than conventional information technologies and will bring useful changes (66%) in the whole healthcare environment (and related fields) for the near future (Table 2).

Table 2

Expected changes in healthcare using blockchain

EMR; information accessibility for all doctors, medical specialists, therapists, researchers, and insurers to make sure that medical care is efficient. Institutional interoperability will increase.
Empowerment for patients, more involvement of patients for active and long-life ability, keep control of medical prescriptions and treatments, doctors' certificate for workers.
Identity management, digital ID card, patient-centric view of all existing data, personalized use cases for patients, customer acceptance
Transparency in data storing, data security, IT-based knowledge-transfer, better compliance with GDPR

More efficiency and cost reduction, payment solutions on smart contracts between hospitals, insurance companies and clients, automatic processes, less bureaucracy
Value-based healthcare model with higher cost-effectiveness, quality of treatment improvements
Tracking of pharmaceuticals, drug authenticity, even guarantee authenticity of medical equipment, supply chain improvements

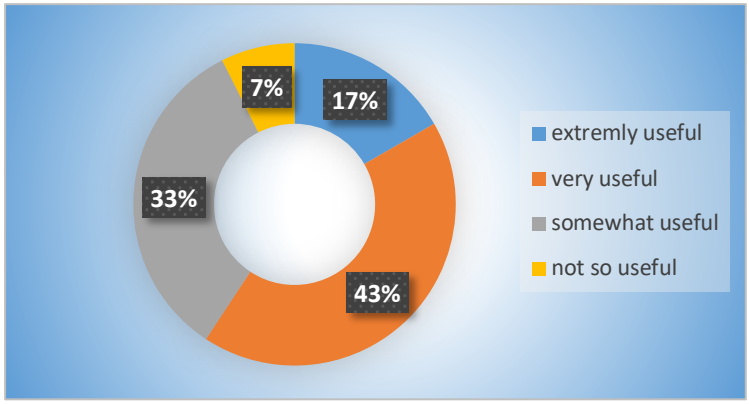
Only a few participants expected no changes, because healthcare systems in Europe are highly regulated so that innovation is slow. For Germany, they are also pessimistic because of the overall health system, lobbyism blocking changes from medical associations against data migration, etc.

Control over their data as a patient is relevant for 93% of the participants

Technical and legal requirements were seen as relevant obstacles for introducing blockchain technology in healthcare, which is necessary to establish patients' trust. But overall, cost-cutting opportunities in healthcare via blockchain technology are expected by participants (64%) as well. Most of the participants (93%) thought that blockchain is a useful technology to create a healthcare data ecosystem (Figure 7).

Figure 7

Blockchain as a useful technology for creating a healthcare data ecosystem



In comparison to Deloitte‘s study, the findings of the present survey display awareness and relevance of blockchain technology on different management levels and industries. For the healthcare industry, both studies pointed out clear developments necessary to keep competitive advantage as well as operational effectiveness. In this present survey, the relevance of operational efficiency and cost cuttings are clearly suggested. Patient control over their data is especially relevant for 93%. The expectation is to bring the patient in the center of the healthcare system. In total, the participants valued blockchain technology as a real game changer and a useful technology to create a healthcare ecosystem. Therefore, the result of the present study confirms the findings by McKinsey and Deloitte.

Benefits and challenges of blockchain technology

Coming back to the initial research question: “Is blockchain a useful technology to create a healthcare ecosystem?” most of the survey participants appraise that blockchain is a useful technology for this purpose. In Deloitte‘s study, 55% of organizations in healthcare believe that blockchain will disrupt in the next 12 months. Therefore, clear development needs to keep competitive advantage as well as operational effectiveness are pointed out (Pawczuk, et al., 2018).

The integration of blockchain technology within the healthcare sector can create tremendous changes in how individuals receive medical care. Blockchain and smart contracts provide a sophisticated ledger system. With its key components, cryptography, peer-to-peer network, consensus mechanism, and validity rules, it delivers transparency, anonymity, security, immutability, efficiency, and confidence for the patient and other stakeholders. Thus, used in recording financial transactions, storing medical records, or even tracking the flow of goods and payments through a supply chain, blockchain technology could serve as a sort of Trust-as-a-Service to ecosystem participants (Hileman & Rauchs, 2017).

Another important topic is the digital rights aspect of patients. 93% of the survey participants valued control over their data highly relevant. Digital identity requires interoperability of user’s identity across multiple locations, user’s consent, and true user control to create user autonomy (Allen, 2016).

Human digital rights must be at the heart of the changes. Digital identity is a great opportunity to bring patients in an owner position of all health information. They would be able to choose whom to allow access and how data is used or purchased. Additionally, digital identity could be used to develop personalized medicine without putting privacy at risk (Preukschat, 2018).

Therefore, the potential of blockchain technology should be recognized by the government and society. The legal requirements, such as compliance with data protection laws, like GDPR, could be directly encoded into smart contracts and thus be automatically enforced by the network (Crosby, et al., 2016). As a result, citizens, private and public institutions are able to interact in a decentralized and trusted manner. In times of data hacks, the question of ownership and identity management has never been more crucial than today and blockchain technology is able to support the development (Wagner, et al., 2018). In this present survey, most of the participants (58%) expected that blockchain technology solutions are more secure than conventional information technologies, supporting trust between different stakeholders like insurance companies, service providers (hospitals, GPs, pharmacists) and patients.

The lack of interoperability and interconnected data use is an enormous problem in the healthcare industry (Krawiec, et al., 2017). Therefore, blockchain technology can act as a real game changer to get out of data locks. (Schumacher, 2017). For a society with an aging population, an effective and efficient use of recourses is crucial to stop the further increase in healthcare costs (PopulationPyramid.net, 2019).

In this present survey, the relevance of cost cuttings and operational efficiency are clearly stated. 64% of the participants expect relevant cost-cutting opportunities in healthcare via blockchain technology. By using distributed ledger technology, the implementation of smart contracts will provide a great opportunity to reduce transaction costs in healthcare and in related industries. Automatic execution in a transparent manner, as well as the implementation of legal rules for transactions and a cut out of intermediaries, deliver cost-saving opportunities. Security derives from the use of different encryption protocols for the targeted level of pseudonymity. For individuals, time savings are achieved by using digital identity and cutting out time-consuming identification processes (Hileman & Rauchs, 2017). For all stakeholders, staff

savings are conceivable (CBinsights, 2019). In the real-world example of Estonia, they estimate a saving of 1,407 working years only in 2018 (E-Estonia, 2019c).

Another relevant cost driver is insurance, where dishonest providers and patients submit claims/information to receive payable benefits without performed services. Medicare fraud in the U.S. alone costs about $60 billion a year (Arnold, 2018). Receipt fraud from patients by getting medication several times and selling to others is a further issue. This practice accounts for several hundred million euros of losses in Germany and leads to higher insurance payments (Budinger, 2016) This issue could be solved by blockchain technology; smart contracts and its automatic execution deliver transparency (Galer, 2018). Pharmaceutical fraud and plagiarism could be solved by tracking the movement of drugs from manufacture to end points in the supply chain. This tracking could be recorded on a blockchain as a trustful and auditable solution in order to reduce drug counterfeiting (Arnold, 2018).

A few participants of the survey expect no changes in the health care sector because healthcare systems in Europe are highly regulated, leading to slow innovation. Especially for Germany, they are pessimistic because of the structure of the overall healthcare system. Lobbyism is blocking changes in the self-government of German healthcare. The takeover of the majority stake (51%) in gematik by the German Ministry of Health in January 2019 could be seen as the initial step to break down the self-government in German healthcare. It will foster further digital developments by further standardizations of EMR and changes of legal preconditions for digital identity (Ehneß, 2019).

Personalized medicine could be empowered by blockchain technology for transforming treatment and drug development of rare or/and chronical diseases. Sharing private genomic, metabolic, and other health data can support the next wave of scientific and medical advancements. Patient data as a service creates a new data economy with the opportunity to observe wide-reaching systemic patterns in medical treatment (Schumacher, 2019).

Conclusion

Nowadays, data is the new commodity, and in time of GDPR and data hacks data security, interoperability of all stakeholders and interconnected data use is a central topic in the healthcare industry (Krawiec, et al., 2017). The question of medical data ownership and digital identity is a key factor for a digital transformation strategy in healthcare. DLT and smart contracts are useful tools to create and develop the healthcare ecosystem. They offer decentralized, immutable, and trustable solutions by cutting out intermediaries and deliver cost-cutting opportunities and operational efficiency. Digitizing the healthcare system will affect every step of the value chain, especially pharmaceutical and medical technology firms, open up enormous potential for automation and deliver transparency and auditability (Schumacher, 2017). The central issue is trust of patients and stakeholders in data security and quality. The Estonian example clearly demonstrates how blockchain technology could be used as decentralized, trustworthy technology to support the need for healthcare and governmental services (Doupi, et al., 2010). Legal and further technical issues, like power consumption, have to be solved in the nearer future. But in conclusion, blockchain technology is not in question anymore, it is an outstanding opportunity.

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