MEDICALCHAIN

Blockchain Technology for Secure Storage and
Transfer of Electronic Health Records

Contents

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システム

システム

システム

システム

システム

Introduction

In today's world, users from different sectors rely on the instantaneous and seamless flow of data. Many industries have adopted, and are constantly adopting, new technologies that guarantee their users' requirement of instant information. However, this has not been the case of the healthcare industry. Healthcare information systems have not adapted to this speed. Legacy systems are burdensome, slow, and often times vulnerable. Healthcare information cannot be easily or securely shared with these systems. Every step along the way stakeholders have to spend time filling out forms, verifying identities and information, whilst meticulously ensuring privacy and security standards are met. Moreover, the communication and exchange of data between stakeholders is impractical and often uses different formats and standards for their data. The result is a fragmented landscape where each stakeholder keeps their own record of the same data that is slightly different from every other stakeholder. No singular version of the truth exists.

Another problem is that current electronic health record (EHR) systems use centralized databases in which medical data remains largely non-portable. Centralization increases the security risk footprint, and requires centralized trust in a single authority. Moreover, centralized databases cannot ensure security and data integrity, regardless of de-identification and controlled access requirements.

The foundation of a new healthcare IT system lies in the creation of a platform that allows interoperability, safe storage of all the data collected by all healthcare agents and secure and efficient exchange of that information between stakeholders whilst respecting the privacy of all those whose information is involved. All this can be achieved by using blockchain technology.

Blockchain technology allows for decentralized peer to peer interactions that can be recorded and verified without a central authority. At it's core, blockchains are a network of peers that manage a shared database that is distributed among all of it's participants called a distributed ledger. They use complex cryptographic algorithms to keep records of everything that happens on them and ensure the ledger is not tampered with. This makes blockchains phenomenal for processes integral to healthcare, such as auditing information and verifying identities among multiple entities.

The Story So Far

Work on Medicalchain started in early 2016 when the founder Dr Albeyatti identified an issue with writing clinical notes on patients being discharged out of the hospital and having their care transferred back to their family doctor (general practitioner). These notes, known as 'Discharge Summaries' contain a substantial volume of mandatory information that is often written in freeform text by the doctors. The notes are subject to errors where doctors forget to include vital medical information or the correct dosage and/or course of a drug prescription. These errors put the hospital at liability and ultimately the patient's' wellbeing at risk. Dr Albeyatti co-founded www.dischargesummary.co.uk with Bara Mustafa. The tool first operated in Leeds Hospital, UK and is designed to solve the document generation problem of patient notes when they leave the hospital. It ensures doctors complete all the relevant information with a high degree of accuracy and in a timely manner. The result has been a positive welcome and adoption by junior doctors as well as consultants and other healthcare practitioners.

Discharge Summary only solves part of the problem. The main issue is still that documents are transferred (often on paper) to other organisations (general practitioners, private hospitals, etc) where the exchange of data results in no single version of the truth. Dr Albeyatti increased the team by bringing Mo Tayeb, Jay Povey, Robert Miller and a combination of medical doctors and experts from the blockchain community. Together, the team has developed the next phase which is Medicalchain – complementing Discharge Summary and completing the picture by joining up all of the players in the medical eco-system.

Discharge Summary is currently used in hospitals within the UK and the team is planning to onboard at least five more hospitals by the end of 2017. Discharge Summary has received a lot of positive feedback from doctors and is continuously being improved.

Legacy Healthcare Systems in a Changing World

The current healthcare ecosystem is not suited for the 21st century. Different stakeholders do not have the ability to talk to each other easily and if they do, it's likely that they are using different formats and standards for their data. Medicalchain is changing that.

For patients and professionals, this system is incredibly slow, inflexible and woefully opaque. A great example of this would be the claims process. In very simplified terms here's what happens: when a patient needs services from a provider such as: a general practice, a pharmacy, or nursing home, that provider uses their health plan to determine how much of the cost they will pay. In order to determine this cost, the health plan must validate services received from the provider against the agreement the patient and health plan have, and then share their findings with the provider. This only occurs if the provider is 'in-network' with a health plan. For a provider to be considered in-network a complex agreement needs to be negotiated which adds significant cost to the provider's administration costs. One part of these costs are Billing and Insurance Related (BIR) costs which includes activities like maintaining benefits databases and keeping records of services delivered. BIR costs are projected to reach $315 billion dollars by 2018 and take up to 3.8 hours for the average physician to navigate.1

On average, this whole process takes between one to two weeks if done electronically and takes three to five weeks by paper.2 Moreover, this process is rife with places for miscommunication and misunderstanding to occur. For care to actually take place multiple people need to check multiple archaic agreements against multiple records. The result is an inefficient and opaque process that leaves stakeholders and ultimately patients feeling confused and skeptical.

As cybercrime around the world is on the rise, healthcare systems also become targets and are no exception as shown by recent ransomware hacking. The technology that powers these systems is under attack on an unprecedented

scale. In fact, the healthcare industry has more data breaches than any other sector[3] and 95% of medical institutions polled said they had been victims of a cyber attack.[4] Medical records are being stolen and sold on darknet markets where they are 10 times more expensive than credit card data. In spring of 2017, over a dozen NHS Hospitals and GP surgeries in the United Kingdom and over 300,000 machines in 150 countries were the target of the WannaCry attack. This led to days of uncertainty for millions of patients, cancelled appointments and caused the NHS to come to a grinding halt. WannaCry was ransomware with shadowy origins which highlighted the vulnerability of our healthcare systems to potential threats and a sober warning about the inadequacies of the current infrastructure.[5] This is just one of countless accounts of cybercrime.

Sometimes the threat to your privacy isn't outside the healthcare system, but from within it. Over a million patients' health records attending London hospitals run by the NHS Royal Free Trust are being analyzed and mined by Google with little transparency and no option for withdrawal. In another case the medical records of 26 million patients were exposed because the systems being used by thousands of GPs were not secure.[7]

Whether the threat is from the inside or the outside, it is clear that in increasingly digitized and widespread healthcare systems there are more opportunities than ever for your records to be accessed without your permission. The patient has little autonomy to defend themselves against this and legacy healthcare systems are not properly prepared to protect patients' data.

From centralization, to slow speeds and vulnerable networks, healthcare systems have not evolved along with other industries. We need new tools for the 21st century. That's why we're launching Medicalchain. We want to power the healthcare of the future.
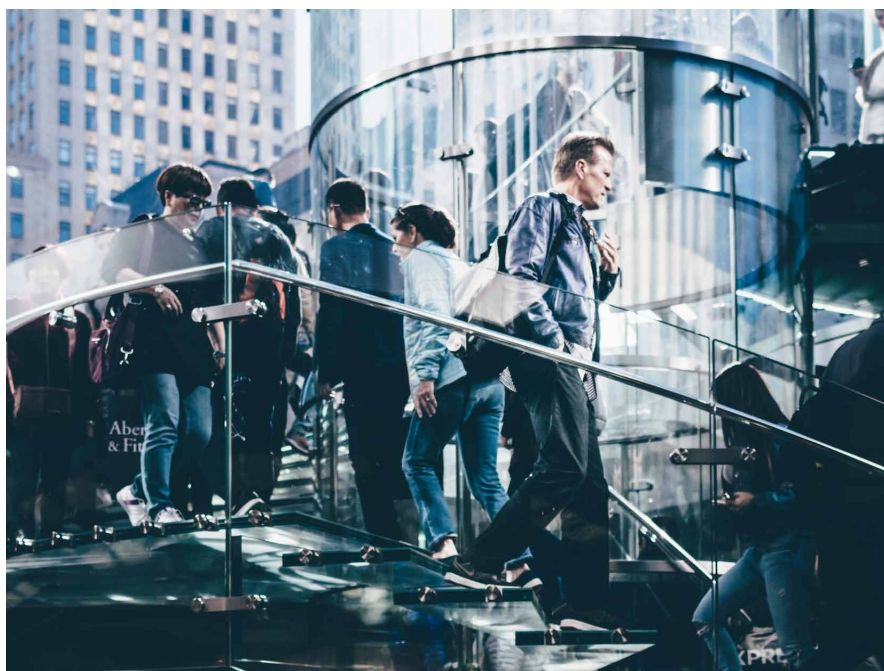
Medicalchain Solution

Our proposal involves the implementation of a blockchain healthcare record as an overarching access control manager of electronic health records (EHR).

When medical data is generated, for example from a doctor's notes or patient's wearable device, a digital signature is created for verification. This data is then encrypted and sent to the encrypted cloud storage where a pointer to the health record is registered in the blockchain along with the user's unique ID.

Similarly, when a patient's data is requested, the ID on the blockchain is used to retrieve the data from the encrypted cloud storage. The data is decrypted and displayed on the relevant device or application. The patient will be notified every time data is added to their blockchain, or when there is a request to access the data. Moreover, the users will be able to grant or revoke access on multiple levels of their data using their web or mobile applications. There are several different options for private keys. The private keys can be stored on behalf of the patient or it can be put on offline storage at the patient's convenience.

Medicalchain has been meticulously designed to do this in a legally compliant way. Patient consent is recorded on the blockchain as are records of any health information that is accessed or shared. Not only can we ensure this but we can also verify that all consent, data protection and privacy laws are being complied and adhered to.

Advantages:
- Data can only be accessed by the patient's private key, even if the database is hacked, the data will be unreadable.
- A patient will have full control over accessing their healthcare data. The patient will control who sees their data and what they see.
- Instantaneous transfer of medical data. Every member in the distributed network of the health care blockchain would have the same data of the patient's record.

Disadvantages:
- Patients will have to learn how to use their private key properly. They may wrongly assume these can be easily changed.
- Stakeholders will need to learn how to use blockchain technology.
- Legacy systems will either have to be tweaked or remade.

Medicalchain Solution in Steps

Development Timeline
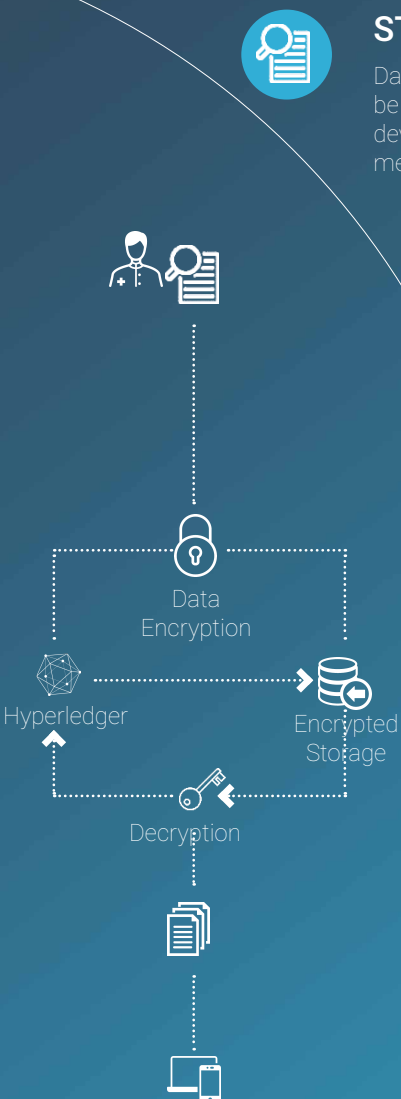
STEP 1

Data is generated. This could be by a patient's wearable device, a doctor's notes, a scan, medicine dispensation, etc.

STEP 2

The Data is encrypted and given an ID that is stored on the patient's blockchain. This data is sent to cloud storage.

STEP 3

Data is requested. The ID on the blockchain is used to retrieve the encrypted data.

STEP 4

The data is decrypted and displayed on the relevant device or application.

Data Encryption

Hyperledger

Encrypted Storage

Decryption

Feb 2016 -
Conceptualization of ideas. Development started.

Dec 2016 –
Cardiology department identified as good starting point to cultivate idea

April 2017 –
Discharge Summary website in production stages with data collection process

May 2017 –
Wide adoption of website throughout Cardiology department of Leeds Teaching Hospital Trust

June 2017 –
First release of Medicalchain source code for prototype.

December 2017 –
Discharge Summary moves to Hyperledger.

January 2018 –
Release of mobile app, patients can port medical record to blockchain.

January 2018 –
Doctor enrolment programme for Medicalchain platform

February 2018 –
Nationwide rollout of Discharge Summary

March 2018 –
First rollout of Doctor to Patient communication platform

June 2018 –
First direct connectivity to hospital EHR in Europe and US (Beta)

August 2018 –
Smart contract for insurers and researchers

October 2018 –
Rollout of platform to pharmacies and doctor practices

Competitive Landscape

This section aims to discuss the ways that Medicalchain is different from competing health record solutions powered by blockchain and traditional health record solutions. There is a plethora of electronic health record companies with varying solutions. At of the time of writing, Patientory remains the only other serious company which offers health records powered by blockchain technology.

The average person's mobile phone represents their point of contact to the rest of the world at most times. They are on or beside all of us practically 24 hours a day. With this in mind, Medicalchain believes that having a mobile app is integral to the success of any modern patient focused medical records solution. Since day one, this has been an integral part of our vision for Medicalchain and remains a high priority in our strategic development. Traditional health record solutions have varying levels of mobile adoption, ranging from Epic's powerful app to the NHS' disastrous and defunct £12bn National Programme for IT. For the most part, there is usually some form of mobile adoption or initiative under way. Moreover, in the case that there is no mobile app available, 3rd party software can be used instead.

It is important for a technology to be functional and broadly usable. All electronic health record solutions are functional but they often have steep adoption costs. For example, implementing a system like Epic can take years and cost over a billion dollars[2]. Patientory's solution is a 'plug and play' model acting like 'a bridge that connects siloed, centralized EMR systems.' The cost and time of implementing their solution is unclear but likely significant. Medicalchain has chosen to do things in a different, patient focused way. Health records will be viewable in a browser. Anyone, anywhere can use Medicalchain's technology as long as they have a computer and an internet connection. Moreover, this is very powerful when coupled with conditional permissioned access to health records. Patients can easily share their medical records with any doctor or stakeholder and know that their records will only be accessible for however long they deem are needed.

As we outlined towards the beginning of this paper, almost all legacy systems are plagued with privacy and security issues. Adopting blockchain solutions would help solve some of these problems but more action is needed. Patients need more control over how their medical records are handled. They should be

[2] http://www.healthcareitnews.com/news/mayo-clinic-kicks-massive-epic-ehr-go-live

able to choose who has access to their records and how long they have access for. This way, patient information is not shared without their permission, such as when the NHS provided DeepMind with hundreds of thousands of patient's records without the permission of those patients[3]. The only way to achieve this is for conditional permissioned access to be a core feature. Medicalchain is the only company that has implemented this.

A successful blockchain solution also needs to be sustainable. Medicalchain uses a private blockchain built using Hyperledger Fabric for backend functions, such as keeping a ledger of encrypted data's IDs and storing records of consent. This is done for a few reasons. First and foremost, it allows for permissioning which is core to Medicalchain's vision. Second, there are no gas costs associated with private blockchains because they use predefined verified nodes. That way every time a medical record is accessed or updated, it doesn't cost money. Third, it allows the platform to verify transactions at greater speeds.
Moreover, Medicalchain isn't trying to host actual medical records on the blockchain, but instead using it as a system to manage permission and keep immutable records of what goes on with those records.

We believe that without these components any blockchain solution would not be sustainable and will inevitably run into problems when upscaling.

In order to build a truly interoperable healthcare system, blockchain technology needs to be at the heart of systems instead of layered over legacy systems. Blockchain technology in this way acts analogous to a better form of encryption, stakeholders still have to develop their technologies to fit into legacy systems. Moreover, the opportunity for developing an interoperable health system is forgone because existing inoperable infrastructure is used.

In short, the benefits that blockchains bring are dramatically reduced and restricted without detailed planning and factoring in current infrastructure issues. The efficiency, reliability, and trustworthiness of blockchain technology will only be fully harnessed when technologies are created ground up around blockchains. Right now Medicalchain is the only company that offers this.

Medicalchain was designed first and foremost with patients in mind to give them control of their records. Its features and tools are designed such that patients can retain autonomy while not sacrificing functionality. Moreover, blockchain technology is going to change how healthcare works and there's no reason why that should be limited to a single country.

Medicalchain aims to bring the blockchain revolution to anyone anywhere that wants more control and security in their medical records.

[3] https://www.newscientist.com/article/2139395-google-deepminds-nhs-data-deal-failed-to-comply-with-law/

Medicalchain Applications

Multi-level Permissioned Access to EHRs

Medicalchain provides the user full access and control of their data and how this data is shared. The user will have the functionality of providing different access levels to different users; they would assign a set of access permissions and designate who can query and write data to their blockchain. The user will be able to fully control who accesses their data and which information they access. Moreover, the Medicalchain platform will provide the users a full log about who has access to their medical data, the time of access and the particular types of data that can be accessed.

Regulatory Compliance

Full, verifiable, and immutable records of the transactions on the blockchain make audits much easier to conduct and the decentralized nature of the blockchain lowers the risk of security breaches. Privacy laws regarding who gets access to EHR and the use of those EHR are easily complied with as individuals are associated with IDs and records of their actions are stored on the blockchain.

Insurance Claims

Private insurers can be granted access to verifiable and immutable records to check that the patient's treatment is consistent with their expectations. Insurance companies should be able to instantly see whether a doctor is accredited and covered within an insurance network if they are on the Medicalchain platform. As a result, insurance companies could provide better and lower cost policies if they knew more about the patient they are insuring by having access to their health records.

## Licensing EHRs to Pharmaceutical Companies for Research

Users have full access and control over their EHR on the Medicalchain platform. This could enable them to license their EHRs to pharmaceutical companies for research. When used in conjunction with Medicalchain's conditional permissioned access system the users will be able to easily set boundaries on what information companies have access to and how long they will be able to access it for.

Enabling Rapid Response by Emergency Services with our Medicalchain Bracelet

In future, Medicalchain plans to introduce a wearable bracelet which logs users health data. The bracelet will allow EHRs, or portions of critical information to be readily accessible by emergency services (in the case of an emergency situation) using NFC technology.

Generation and Storage of EHRs by Healthcare Professionals

Medicalchain will have the ability to quickly generate and store some EHRs such as discharge summaries. Healthcare professionals will record their actions on Medicalchain, including what they are doing and how long they are doing it for. In the case that drugs are being prescribed or used in a procedure, a doctor can quickly check what drugs the patient is currently prescribed and identify any potential allergies or conflicts.
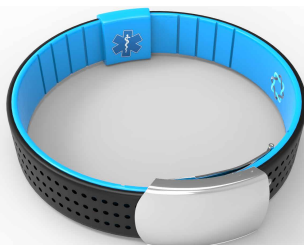
Medicalchain as a Platform

Medicalchain will allow third party developers to develop and showcase their applications within the eco-system. There have been many scientific advances recently with regards to health applications, including diet and nutritional advice[4]. Such applications will connect to the Medicalchain platform directly. Other examples of apps could be assessment of medications, interactivity with wearable data, fat measurement, etc. Patients will grant access to their health record to app(s) where they can be used in exchange for MedTokens.

[4] http://www.i-programmer.info/news/83-mobliephone/10522-bitesnap.html

Adoption

> " Medicalchain's adoption will be driven by patients. "

Medicalchain will provide unparalleled autonomy, privacy, and security to patients and the founders believe that this core value combined with the right education will bring meteoric user growth.

A key component of this will be our ability to bring users onto our platform. Medicalchain will offer a service where it will request medical records on patients' behalf and populate the medical record for them. Some of these will be physical records and will understandably take time to process, but some of them will be digital, which Medicalchain will be able to instantly download through API integration. Patients will complete a form with their name and any providers they wish to have their records requested from. Different healthcare systems have different health record systems and Medicalchain aims to accommodate all legacy systems. Physical documents will be scanned and mined for information which will then be encrypted and uploaded to data lakes. Electronic records will be standardized, encrypted, and uploaded.

An important part of the Medicalchain solution is how mobile it is. The software will be usable in any browser on any computer. As a result, any doctor with a browser and an internet connection will be able to access the documents that were shared with them. Moreover, Medicalchain is looking to partner with a range of stakeholders to develop cutting edge solutions and tools that work well for their specific needs.

Privacy and Governance

Medicalchain believes in the Caldicott Principles and has taken this approach when architecturing the platform. The Caldicott Principles is a framework developed by the NHS (UK National Health Service) of how patient data should be handled.

Principle 1 - Justify the purpose(s) for using confidential information.

Principle 2 - Don't use personal confidential data unless it is absolutely necessary.

Principle 3 - Use the minimum necessary personal confidential data.

Principle 4 - Access to personal confidential data should be on a strict need-to-know basis.

Principle 5 - Everyone with access to personal confidential data should be aware of their responsibilities.

Principle 6 - Comply with the law.

Principle 7 - The duty to share information can be as important as the duty to protect patient confidentiality.

Medicalchain realises that having one organisation controlling all the nodes of a distributed ledger can somewhat become a conflict of interest - or even interpreted as a private cloud. Medicalchain intends to solve this by adopting a truly decentralized approach with the distributed ledger nodes.

After reaching a critical mass of usage in each country or jurisdiction, Medicalchain will appoint independent non-profit organizations to be the guardians of the distributed nodes. This precedent has been set within the (DNS) domain name system root server organisations and still works today. The organizations will have regular board meetings between them to make strategic decisions about the integrity of the data. The organizations will also become the approvers of any local appointed representatives that help patients administer their electronic health record on the blockchain.

[5] https://www.igt.hscic.gov.uk/Caldicott2Principles.aspx

Token Mechanism

Medicalchain is issuing tokens (MedTokens) to create a new blockchain based healthcare eco-system. Using MedTokens is the best and easiest way to create a global marketplace for this. Moreover, using tokens means that considerable amounts of money are not spent on payment settlement mechanisms and their ensuing fees in individual countries. Patients will use tokens to pay for the hosting and storage of their record on our private blockchain powered by Hyperledger Fabric. Tokens will be used to pay for Medicalchain to request and populate a user's record for them.

Registered doctors and other healthcare professionals will be rewarded tokens to remotely review medical information and provide advice or a second opinion on a case. Pharmaceutical and other research companies will reward patients in tokens by having time limited access to their health record for research and experimental purposes.

Medicalchain's app ecosystem will play a role in the spending and redeeming of MedTokens.

Trusted users in the community will have the option to verify the identity, contact details and credentials of doctors that are added to our system in exchange for tokens.

Patients could pay a premium to have real time information from wearable devices streamed to their Medicalchain blockchain.

Potential Forces Driving Change in MedTokens' Price

Medicalchain does not purport to know how the price of MedTokens will change in the future. Supply, demand, industry trends, and sometimes ethereal forces drive the changes in markets. But, Medicalchain has identified a few broad forces that may cause MedTokens to appreciate or depreciate relative to fiat currencies.

Positive Factors

Every year more and more data is generated and stored. As the Internet of Things begins to materialize technologies such as wearables, sleep monitoring devices, refrigerators that track eating habits, etc will become increasingly common. In the current healthcare process, exponentially more data will be generated and stored as processes become more digitized and their quality improves. In short, there will be more and more demand for healthcare data storage solutions.

As more people adopt Medicalchain the demand for storage of data on the platform, and by extension MedTokens, will be driven up. Heightened demand could lead to an appreciation of the value of MedTokens.

Negative Factors

Future regulatory landscapes are unknown.Cryptocurrencies are new and obtuse technologies to governments. Hostile and constricting regulations are a possibility and even the uncertainty surrounding future regulations could cool demand for MedTokens and cryptocurrencies in general.

MedTokens are powered by Ethereum. In the unlikely scenario that Ethereum fails, services could be disrupted until Medicalchain changes technologies.

Medicalchain has hired trusted advisors from the medical field, legal profession and banking sector in order to help mitigate the possible negative factors and enable the success of the platform.

Contribution Period

The launch of Medicalchain, and the corresponding creation of MedTokens, is powered by smart contracts.

Medicalchain will be offering tokens in a crowdsale to allow participants to get their MedTokens early for later usage as well as to contribute to and support the further development of Medicalchain.

Participants will have the ability to contribute and receive MedTokens in exchange for their ETH by sending ether to a designated address.

Participants will be able to contribute BTC through a designated escrow. More instructions will be made available closer to the date of the crowdsale.
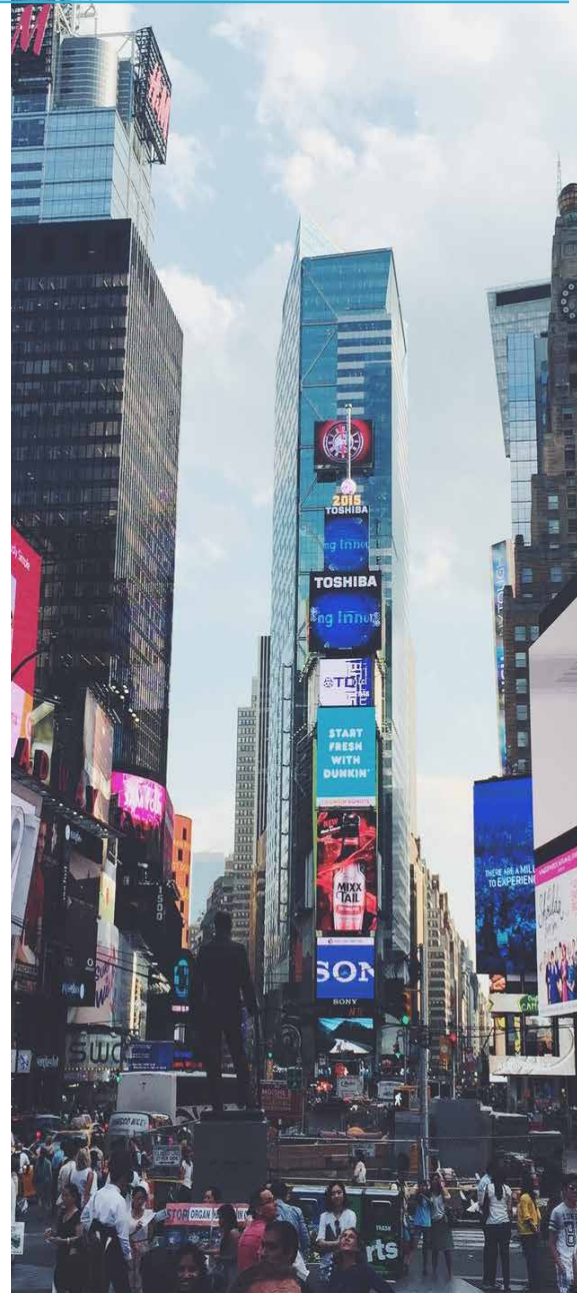
ICO Timeline

15th August 2017
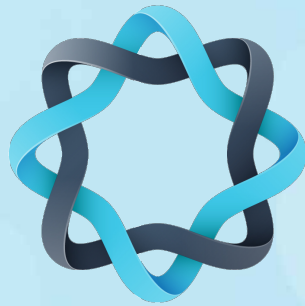Medicalchain
announces crowd sale

15th September 2017
Pre-sale begins

1st February 2018
ICO crowd sale begins

MEDICALCHAIN

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