

Blockchain Technologies: A Review of the Winning White Papers from the Office of the National Coordinator for Health IT Blockchain Challenge, and Potential Impact on Imaging Informatics and Healthcare.

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Overview

- Precision Medicine Initiative, the Office of the National Coordinator for Health IT (ONC) Shared Nationwide Interoperability Roadmap, and ONC Blockchain Challenge
- Blockchain Technologies
 - What is Blockchain?
- Proposed Roles of Blockchain Technologies in Healthcare
 - Information Security
 - Reimbursement and Claims
 - Interoperability and Data Mining
 - Research
 - Specific Implications on Medical Imaging and Imaging Informatics
- Challenges of Blockchain
- Conclusions

Driving Principles

Precision Medicine Initiative & ONC Interoperability Roadmap

- Precision Medicine Initiative¹
 - Announced by President Barrack Obama during 2015 SOTU
 - “To enable a new era of medicine through research, technology, and policies that empower patients, researchers, and providers to work together toward development of individualized care.”
 - Purposed \$5 million to ONC to support the development of interoperability standards and requirements that address privacy and enable secure exchange of data across systems.
- ONC Interoperability Roadmap²
 - Collective plan describing needed policy and technical standards to meet the vision of national health IT interoperability.
- July 2016, ONC announced its "Use of Blockchain in Health IT and Health-Related Research" Ideation Challenge to address the role of Blockchain in privacy, security, and scalability challenges of managing electronic health records and resources.³
 - 15 white papers selected from over 70 submissions spanning industry and academia, select papers discussed herein along with their potential impact on imaging informatics and health care.

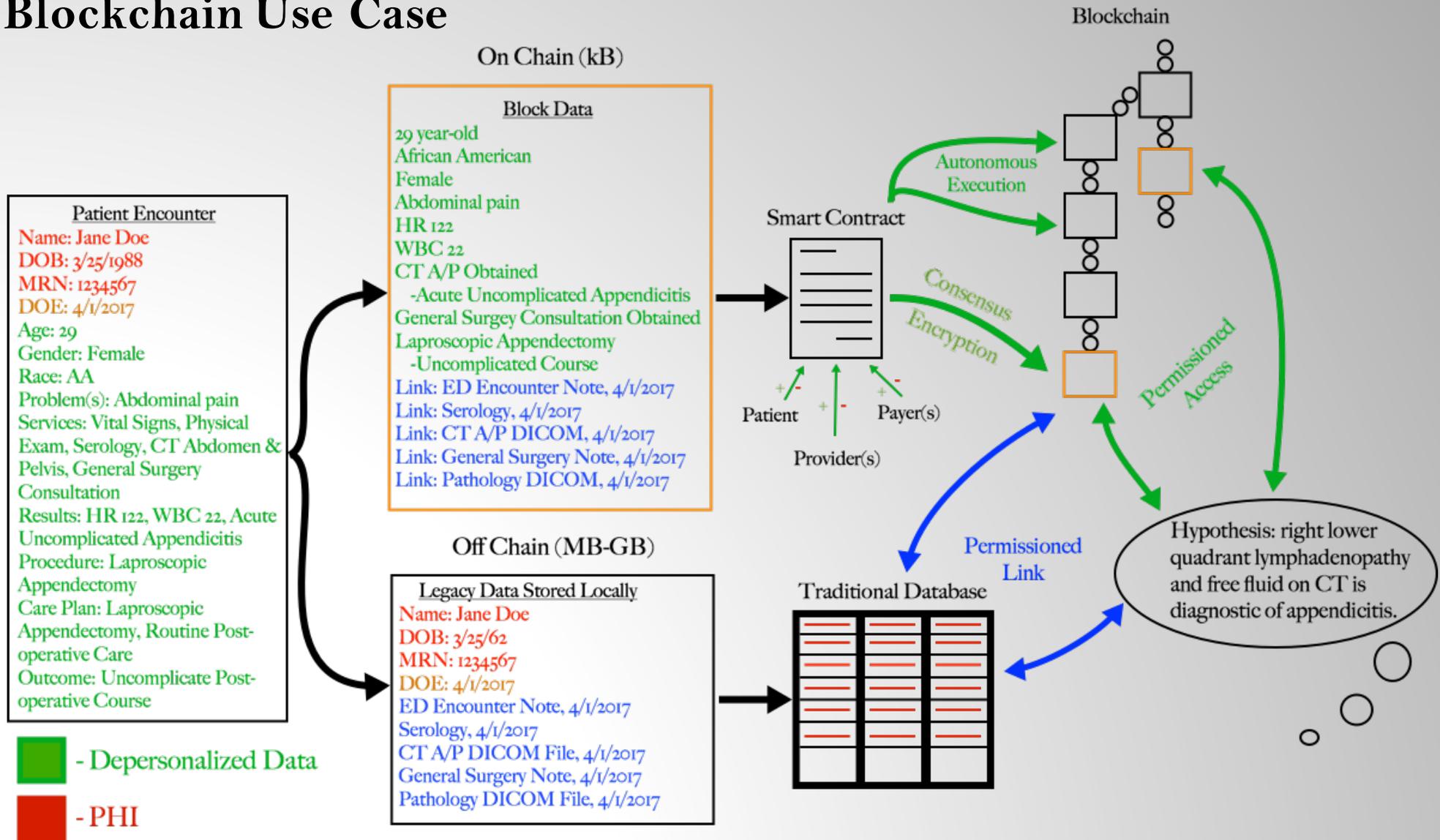
Blockchain Technologies

What is Blockchain?

- The technology underpinning the digital cryptocurrency Bitcoin.
- A collection of technologies centered on a distributed system for recording and storing transaction records in a shared and immutable fashion within a decentralized IT ecosystem.⁴
- Chains of transactions, or “blocks,” are stored information replicated and shared on a peer-to-peer network of computers, or “nodes.”⁵
 - Nodes interact anonymously and securely via cryptographic means, usually a combination of public and private key methods.
 - No centralized authority, rather transaction records are stored and distributed across the network of nodes with immutable and auditable trail.
- Interactions are known to all nodes, requiring verification and consensus prior to addition to the Blockchain.
- Incorporates Smart Contracts, transparent executable logic agreed upon by stakeholders prior to establishing an immutable block or block function.

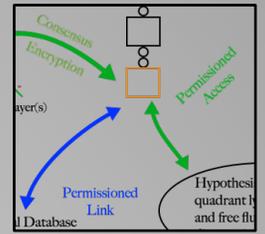
Blockchain Technologies

Blockchain Use Case



Proposed Roles of Blockchain

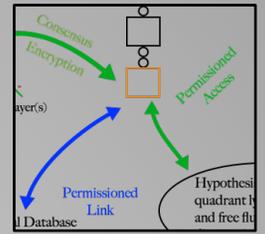
Information Security, Privacy and Integrity



- Blockchain is unlikely to replace legacy enterprise databases, however the technology may obviate challenges of current systems centered on a lack of transparency, extensively required and regulated access, unguaranteed integrity and vulnerability to wide scale data breach and hacking.
- Aside from the previously mentioned immutable nature of Blockchain, a combination of public and private key cryptography limits access to identifying information via identity permission layers.⁴
- Each participant within a network is identifiable with changes broadcast to the entire network.
- Hacking of data would require breach on the individual layer via hack of individual private keys, markedly limiting adverse damage.
- Organizations can maintain and update their own health care ledger – if a historical block were adjusted it would require 51% of network participant approval, therefore the integrity of a blockchain is proportional to the networks size.⁶
- Patients maintain control and responsibility of their own data.

Proposed Roles of Blockchain

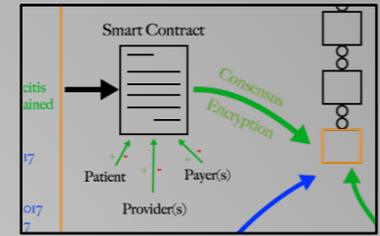
Information Security, Privacy and Integrity



- Shier et al. presents the Blockchain use case of the MIT *OPAL/Enigma* project which meets compliance with regulatory and ethical requirements without limiting scalability.
 - Peer-to-peer network encrypted at the level of the data repository node with legally binding Queried Smart Contracts, which, if executed, allow permissioned access to de-identified aggregate data with a tamper proof and auditable history of user identity and operation.
 - Overarching use case is a secure platform for large cohort precision medicine clinical trials with encrypted data sharing and analysis.
- Kuo et al. presents the ModelChain, a use case set to adapt Blockchain technologies for privacy-preserving machine learning.
 - Current centralized privacy preserving predictive modeling frameworks are centralized, constrained by institutional policies, single points-of-failure, limited participation, data dissemination and mutability.
 - ModelChain combats this by building upon existing health IT infrastructure and enacting a private blockchain with proof-of-work cryptographic algorithms and proof-of-information algorithms set on improving efficiency in large scale utilization of health information devoid of PHI for research and quality improvement.

Proposed Roles of Blockchain

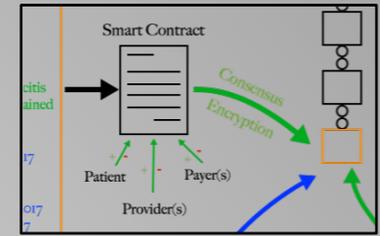
Reimbursement, Claims and Cost



- Billing and Insurance Related (BIR) activities are projected to exceed \$300 billion in 2018 demanding substantial provider time, patients are challenged with the complexities of health care costs demanding legislative and costly burden to payers, and regulators face an inefficient and barrier laden auditing process.⁹
- Culver et al. purposes integration of Fast Health Interoperability Resource (FHIR, i.e. HL7) compliant Application Programming Interfaces and Blockchain technologies.
 - Tokenized smart contracts with block data visible by all stakeholders.
 - Smart contracts can be standardized and further decrease overhead.
 - Improves transparency and patient knowledge of claims process.
 - Block data limited only to the minimum needed for the transaction with uniform resource locator (URL) to policy information and EMR, further increasing interoperability.
 - Process on the order of seconds vice days with ease of auditing.

Proposed Roles of Blockchain

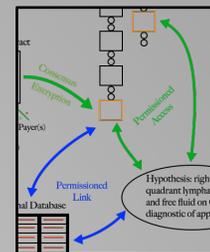
Reimbursement, Claims and Cost



- Yip et al. analyzes the use of Blockchain with alternative payment models in accountable care organizations.
 - ACOs are ripe for Blockchain implementation due to early absence of ACO specific IT platforms and a demand for linked technology to maximize quality and value, currently burdened by centralized legacy systems.
 - Establishing claims clearinghouse via Blockchain allows for real time and rapid analytics of the above metrics.
 - Large scale provider directory via Blockchain could be public in the absence of PHI - rapid payer contract interactions and service approval.
 - Encrypted patient directory via Blockchain may allow for quickly deployed services in accordance with patient care plans that may be updated via pre-implemented and real-time smart contracts.
 - Also allows for utilization analysis and intervention to control costs.
 - An example being frequent ED and imaging utilization.

Proposed Roles of Blockchain

Interoperability and Data Mining



- Perhaps the greatest potential of Blockchain is a new format of Health Information Exchange (HIE).
- Krawiec et al. presents the following **current HIE challenges** and potential

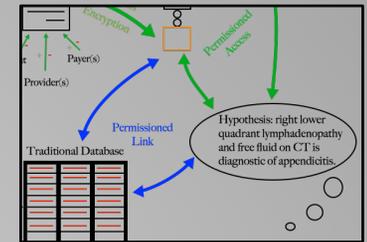
Blockchain solutions:

Centralized HIE Intermediary requiring trust	→	Disintermediation of trust with secure exchange and distributed ledger
Per transaction cost with low transaction volume	→	Efficient system with near-real time processing in decreased cost
Master patient index requiring intersystem synchronization	→	Public and private identifiers, cryptographically secure and distributed
Data standard incompatibility between systems	→	Shared data with near-real time updates
Limited access to population health data	→	Secure and distributed access to large scale and longitudinal data
Rule and permission inconsistency	→	Rule-based Smart Contracts

- Peterson et al. purposes a secondary layer of consensus known as *proof of interoperability*, a human-based process, based on FHIR profiles, of ensuing data exchanged over Blockchain networks are used appropriately within a large scale interoperable environment.
 - They conclude with an example case of leveraging Blockchain data to power machine learning processes of image interpretation, where cumbersome amounts of AI evaluated image data are collected and provided in *FHIR DiagnosticReports* to further aid radiologists in their diagnosis and expand the potential of role of AI in image interpretation and assistance.

Proposed Roles of Blockchain

Research



- Combining the theories and potential of Blockchain technologies, the reach of investigative efforts could see an exponential increase in cohort size and extent of research data sharing.
- Goldwater et al. investigates the integration of Blockchain technologies on improving patient-reported outcome measures via interface with smart phone based applications and mobile biofeedback devices.
 - Specific example cites the utilization of a Blockchain network to share and analyze real-time patient and provider specified anonymous utilization parameters for smartphone-based mental health assistance applications.
 - Allows for more efficient analysis of such applications while maintaining integrity of data and patient anonymity, in an area that has been challenged in investigative efforts to date.
- Ekblaw et al. presents MedRec, a novel Blockchain-based decentralized management system of more locally databased EHRs, allowing medical researchers access to population-wide data on treatments and outcomes.
 - While rooted in the interoperable functionality of Blockchain, MedRec, and models like it exist as “learning health systems” that can advance efforts of precision medicine and comparative clinical effectiveness research, a Patient-Centered Outcomes Research Institute (PCORI) goal.

Proposed Roles of Blockchain

Medical Imaging and Imaging Informatics

- While the ideal imaging interoperability landscape would allow for decentralized image sharing, the efforts in vendor-neutral archiving are better fit for this, but Blockchain has a potential role.
 - On chain data is measured on the order of kilobytes, however on chain permissioned Uniform Resource Locator (URL) access to traditionally archived, large volume data, such as DICOM files, is possible.
 - Smaller volume image related data may be shared on chain, such as DICOM metadata, dose, patient demographics, lesion characteristics, etc.
- Given its extent of readily available electronic data, the medical imaging sector is ripe for exploration of Blockchain with use case and pilot programs. Potential examples include:
 - Integrating CDS tools to monitor and maximize appropriate use.
 - Streamlining imaging billing and reimbursement processes.
 - Sharing low data volume imaging characteristics to strengthen cohorts of imaging biomarkers and the power of radiogenomics/radiomics.
 - Expanding machine learning capabilities.
 - Streamlining appropriate imaging follow up, such as RadPath correlation.
 - Long range and cumulative patient dose monitoring and outcomes research.

Challenges of Blockchain¹⁴

- Scalability – Public blockchains often require thousands of nodes, limiting transaction volumes, and private blockchains are often limited by number of involved nodes. Any proposed or implemented system would likely require significant stakeholder input with a network scaled to their demand while meeting network size requirements for security and data integrity.
- Limited performance – Not fit for low-value, high-volume transactions with continued questions about confidentiality and security of public blockchains.
- Hype - While Blockchain technologies have demonstrated disruptive performance within other industries, mainly the financial sector, its potential role in healthcare is at best in infancy with overall impact and potential yet to be seen.
 - Many point to the Gartner Industries Hype Cycle, a qualitative graphic representation used to describe the life cycle of a new technology, citing Blockchain in health care being in the early phase of innovation trigger possibly meeting a peak of inflated expectation. This may or may not be followed by a trough of disillusionment, slope of enlightenment and plateau of productivity.¹⁵

Conclusions

- While Blockchain is certainly not a panacea for Health IT challenges faced by systems today, it has potential to disrupt many aspects.
 - Rather than a replacement for legacy systems, Blockchain may serve as a supplemental tool for low data volume interoperability with an acceptable level of security, allowing for large scale cohorts, patient centered outcomes research, claims and reimbursement transparency, quality improvement and horizontal scaling.
 - Empowers patients to control and maintain their own health information.
- ONC Blockchain Challenge served to introduce the health informatic community to academic and industry pursuits as well as challenges.
- Not without hype and challenges, including scalability, performance and confidentiality concerns that may limit its wide scale use and implementation.
- Demand for Blockchain governance exists while maintain decentralization.
- Next Steps
 - Proof of concept pilot use cases are required to explore Blockchain's true and full potential.
 - Given excess of available data, imaging and imaging informatic sectors are ripe for these use case programs, including, but not limited to, appropriate use, imaging biomarkers and machine learning, imaging follow up, dose monitoring, imaging cost transparency and claims efficiency.

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*Submitted on the occasion of the ONC Blockchain Challenge and selected as a winning white paper.