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A new technology for medical and surgical data organisation: the WSES-WJES Decentralised Knowledge Graph

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Abstract

Background The quality of Big Data analysis in medicine and surgery heavily depends on the methods used for clinical data collection, organization, and storage. The Knowledge Graph (KG) represents knowledge through a semantic model, enhancing connections between diverse and complex information. While it can improve the quality of health data collection, it has limitations that can be addressed by the Decentralized (blockchain-powered) Knowledge Graph (DKG). We report our experience in developing a DKG to organize data and knowledge in the field of emergency surgery.

Methods and results The authors leveraged the cyb.ai protocol, a decentralized protocol within the Cosmos network, to develop the Emergency Surgery DKG. They populated the DKG with relevant information using publications from the World Society of Emergency Surgery (WSES) featured in the World Journal of Emergency Surgery (WJES). The result was the Decentralized Knowledge Graph (DKG) for the WSES-WJES bibliography.

Conclusions Utilizing a DKG enables more effective structuring and organization of medical knowledge. This facilitates a deeper understanding of the interrelationships between various aspects of medicine and surgery, ultimately enhancing the diagnosis and treatment of different diseases. The system's design aims to be inclusive and user-friendly, providing access to high-quality surgical knowledge for healthcare providers worldwide, regardless of their technological capabilities or geographical location. As the DKG evolves, ongoing attention to user feedback, regulatory frameworks, and ethical considerations will be critical to its long-term success and global impact in the surgical field.

Keywords Decentralized knowledge graph, Semantic model, Artificial intelligence, Blockchain in medicine, Electronic health records, Emergency surgery, World society of emergency surgery, World journal of emergency surgery, Education

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Background

In medicine, an increasing amount of information accumulates every day, making it essential to have effective tools for storing, structuring, and analyzing health data [1]. Moreover, healthcare professionals have an enormous amount of electronic health data to manage, analyse and share in a standardised way. One promising approach to address this issue is the use of Knowledge Graph (KG) technology, which creates a graphical (semantic, contextual) model of knowledge, reflecting the links between different entities and concepts [2].

The development of KGs is particularly relevant due to the lack of a unified, structured system for storing and presenting medical knowledge. This deficiency hinders access to high-quality information and complicates the process of making critical medical decisions [3]. Implementing KGs in medicine will create a unified user environment where information about medical concepts, their relationships, and their dynamics is presented in a convenient and comprehensible form [4].

However, centralized health data management systems often encounter issues related to security, privacy, and restricted access, necessitating innovative approaches to health information management [5].

A promising solution is the development of a platform based on blockchain technology and the KG, called the Decentralized Knowledge Graph (DKG). Blockchain provides secure and transparent information storage, ensuring data integrity [6]. The Knowledge Graph enhances the structuring of extensive medical data using artificial intelligence [7].

Our aim is to develop a DKG for the WSES-WJES bibliography to improve the systematization of data and knowledge in the field of emergency surgery and facilitate the dissemination of evidence-based guidelines.

Materials and methods

We utilized the Bostrom blockchain to develop the Decentralized Knowledge Graph (DKG) of the WSES-WJES bibliography [8]. Bostrom is a super space project based on the Knowledge Graph, built on the Cosmos-SDK blockchain, and utilizes the Interplanetary File System (IPFS) protocol for content addressing. IPFS is a distributed (decentralized) file system where files are stored on the computers of network members and are identified by their Content-ID (CID), which is a cryptographic hash referred to as a "particle" in Bostrom terminology. A Knowledge Graph is a directed weighted graph between CID particles, also known as content addresses [9].

We used the Cyb.ai platform, an application created using the Bostrom blockchain. Cyb.ai allows users to create "cyberlinks," perform graph searches, rank results using relevance algorithms, and share and store information [8]. The Bostrom Blockchain Knowledge Graph consists of pairs: each "source particle" is linked to a "recipient particle" through a "cyberlink," which includes additional neuron address and weight information [8, 10].

Cyb.ai features a search bar where users can enter queries. Upon entering a query, Cyb.ai calculates the CID of the IPFS text file containing the query content. Search results in Cyb.ai are files stored in IPFS, which are retrieved by the browser and displayed as IPFS hashes. These files are cyber-linked to the IPFS text hash entered in the search bar [10].

To input information, the full title of the article (the text of the target particle) was entered into the DKG, creating an IPFS hash for the target part. A file containing the article text in .pdf format was then attached to this hash using the "cyberlink" button [10].

The source code of Cyb.ai is available on GitHub at [https://github.com/cybercongress/cyb].

Results

The creation of the Decentralized Knowledge Graph (DKG) for the WSES-WJES bibliography involved three steps:

Data collection and input

A total of 394 articles from the World Journal of Emergency Surgery (WJES), covering topics in emergency surgery, were included in the DKG. These articles were published between January 2006 and March 2024. Using cyb.ai, we identified and constructed key entities, determining their properties and relationships (ontology) in the field of emergency surgery.

Construction

At this stage, the entered data was represented as a graph, where the nodes correspond to entities (keywords from the publications) and the edges represent relationships between them. The cyb.ai portal provided a convenient interface for working with the DKG, enabling efficient search, analysis, and interaction with the information.

Testing

We verified that the DKG accurately displays the entered information and allows users to access the full texts of the articles on emergency surgery by entering keywords in the search bar – https://cyb.ai/.

In the future, we plan to incorporate additional medical databases, clinical trials, medical references, and other sources of information related to emergency surgery beyond the scientific articles from WJES.

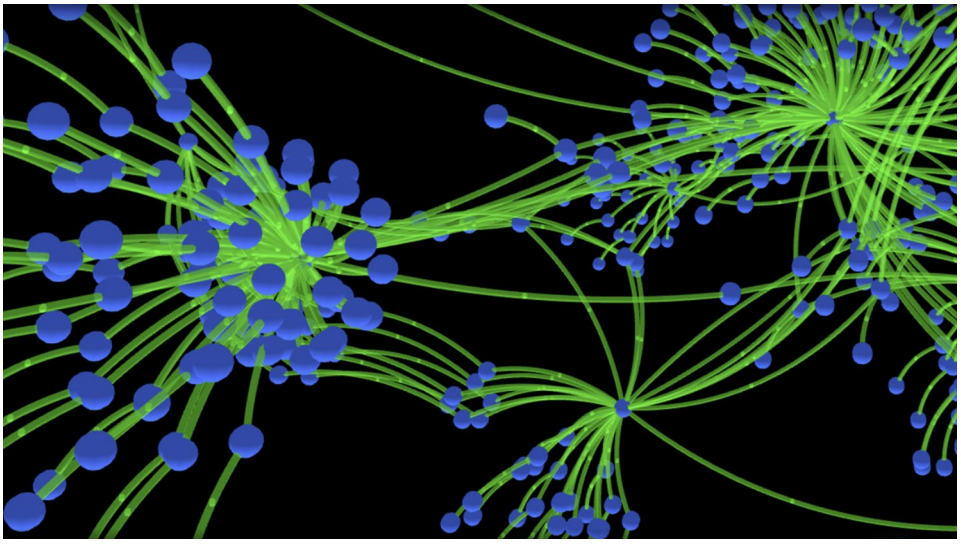

Fig. 1 Screenshot of the developed WSES-WJES Knowledge Graph

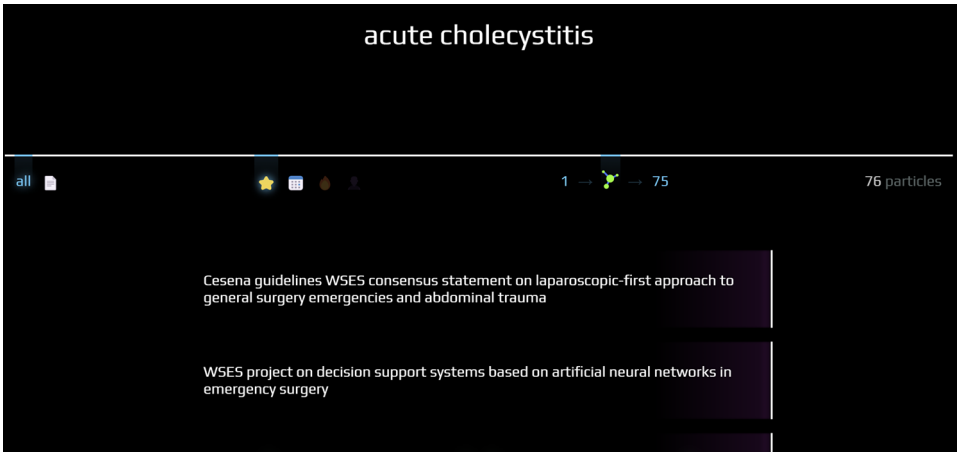

Fig. 2 Screenshot of WJES publications on "acute cholecystitis" (2 of 75)

Searching for articles in the DKG

There are two ways to search for articles in our DKG: the graphical Representation, the search bar and the direct links to specific topics.

Graphical representation

Users can use a graphical representation of the DKG with main nodes (keywords) and remaining nodes (full texts of publications in .pdf format). This can be accessed at https://cyb.ai/@aimedica/brain. A screenshot is shown in Fig. 1. When hovering over a node, such as "WSES guidelines," activating the node opens all related publications. Other topics and publications in emergency surgery can be accessed similarly.

Search bar

Users can enter keywords related to the section of emergency surgery they are interested in. For example, the Fig. 2 shows 75 WJES publications on "acute cholecystitis" in the search line on cyb.ai – https://cyb.ai/.

Direct links to specific topics

- Acute Appendicitis: https://cyb.ai/oracle/ask/acute%20appendicitis;
- Acute Pancreatitis: https://cyb.ai/oracle/ask/acute%20pancreatitis;
- Acute Cholecystitis: https://cyb.ai/oracle/ask/acute%20cholecystitis;
- Incarcerated Hernia: https://cyb.ai/oracle/ask/incarcerated%20hernia;
- Bleeding Peptic Ulcer: https://cyb.ai/oracle/ask/bleeding%20peptic%20ulcer;
- Perforated Ulcer: https://cyb.ai/oracle/ask/perforated%20ulcer;

- Intra-Abdominal Infections: https://cyb.ai/oracle/ask/intra-abdominal%20infections;
- WSES Guidelines: https://cyb.ai/oracle/ask/WSES%20guidelines;
- Abdominal Trauma: https://cyb.ai/oracle/ask/abdominal%20trauma;
- Acute Mesenteric Ischemia: https://cyb.ai/oracle/ask/acute%20mesenteric%20ischemia;
- Adhesive Small Bowel Obstruction: https://cyb.ai/oracle/ask/adhesive%20small%20bowel%20obstruction;
- Thoracic Trauma: https://cyb.ai/oracle/ask/thoracic%20trauma.

We plan to continually update the Knowledge Graph with new data, expand its functionality, and adapt it to the evolving needs of users. This will ensure the DKG remains a valuable tool for organizing and accessing medical knowledge in emergency surgery.

Discussion

A Knowledge Graph (KG) is a semantic network that stores information about various entities and their interrelationships. In a KG, an entity or "node" can represent anything, such as a person, object, date, concept, or any other material object or abstract idea. Predicates or "edges" illustrate the connections and relationships between different entities within the KG [11]. The concept of KGs gained attention when Google incorporated it into their search algorithm in 2012 [12].

KGs are used to consolidate vast amounts of data from different sources into a single knowledge repository. They can be either comprehensive, covering a wide range of data types, or specialized, focusing on a specific subject area. For example, Wikidata [13] is a broad knowledge graph that includes a diverse range of information, while BioPortal [14] is a specialized graph containing over 140 billion facts related to biotechnology and medicine. These repositories are publicly accessible, and the number of open data sites on the internet continues to grow, forming a cloud of interconnected data known as the Linked Open Data Cloud [15].

Traditional databases excel at storing structured data but struggle to capture the links between different pieces of information. In contrast, KGs are designed to handle unstructured data and visualize complex interrelationships between data nodes [16]. Traditional databases rely on tables with rows and columns, suitable for structured data divided into predefined categories. In contrast, graph databases are built around nodes (entities) connected by edges (relationships), enabling them to efficiently manage complex interrelationships between objects [16].

Blockchain is a decentralized database where information is stored as a chain of blocks, each containing information about the previous block, ensuring data integrity and security [6]. In medicine, blockchain can store medical records, analysis results, research data, and facilitate the transparent and secure exchange of information among system participants [5]. A Decentralized Knowledge Graph (DKG) integrates blockchain technology into KG technology, providing reliable data protection from unauthorized access and tampering, crucial in the medical field where privacy is paramount [17].

The fundamental principles of constructing a DKG in medicine include several key aspects. First, it is necessary to identify the primary medical entities to be represented in the graph, such as diseases, symptoms, medications, procedures, and patients [18]. Next, the relationships between these entities should be defined to build a comprehensive understanding of medical knowledge and its interrelationships. Another important principle is structuring the data in the graph, identifying attributes for each entity that store additional information. For instance, for a disease, attributes could include symptoms, causes, diagnosis methods, and treatments. Structured data helps organize information effectively, making it more accessible for analysis [18].

Integrating data from various sources is another critical aspect of building a DKG. Medical information is often diverse and spread across different databases and sources. Integrating this data into the graph creates a single point of access, improving its quality and completeness [19]. Additionally, updating the KG is crucial. Medical information is constantly evolving, with new research and discoveries altering our understanding of diseases and treatments. Therefore, it is essential to develop mechanisms for automatically updating the data in the graph and monitoring its relevance [19]. DKG improves the security and confidentiality of medical data and addresses the issue of constant updates through the inherent economic incentives of blockchain technology [20] .

Various blockchain platforms can be used to create a DKG, such as Bitzenzor [21], Cortex [22], and Cyber [9, 10]. These platforms enable the decentralized improvement of automatic text processing methods, semantic analysis, machine learning, and more by automatically extracting, structuring, and analyzing information from various sources [23].

We used the Cyb.ai platform to create the DKG for the WSES-WJES bibliography. Cyb.ai's key feature is the extremely low cost of adding information to the global knowledge graph while ensuring security. Additionally, Cyb.ai offers unmatched flexibility, allowing any structured data to be entered into the DKG. Therefore, we utilized the capabilities of Cyb.ai, a decentralized protocol in the Cosmos network [10], to begin creating the WSES Knowledge Graph based on WJES publications.

Our tasks included collecting and systematizing articles on the diagnosis and treatment of emergency surgical diseases, developing a semantic network schema based on Cyb.ai, and subsequently testing it. These steps enabled us to create a unified user environment for storing and presenting information about medical entities, their interrelationships, and the dynamics of changes in emergency surgery.

During this study, we identified significant advantages and prospects that DKG can offer for a new type of information storage, easy search, extraction, and utilization of medical Big Data. We believe that our "local" emergency surgical DKG based on WSES-WJES publications can be a first step toward creating a blockchain-based general medical knowledge base.

Regulatory and ethical implications of the WSES-WJES decentralized knowledge graph

The implementation of the WSES-WJES Decentralized Knowledge Graph (DKG) introduces new approaches for organizing and sharing knowledge, specifically focused on the WSES bibliography and related surgical literature, rather than patient data. Although this system leverages blockchain technology, which is often associated with privacy concerns in healthcare, in this case, there are no sensitive or confidential patient data involved, reducing the regulatory complexity typically associated with such systems.

Since the WSES-WJES DKG does not handle patient data but focuses on academic and clinical publications, concerns about data privacy and confidentiality—which are common with decentralized healthcare systems—are not directly relevant. This avoids issues related to GDPR or HIPAA compliance, as the system does not need to protect personal health information (PHI) [24]. Instead, it focuses on securely organizing medical knowledge from published sources.

One ethical consideration, even in a decentralized knowledge-sharing system, is ensuring equitable access to the platform. The system's reliance on blockchain and decentralized technology may create challenges for users in under-resourced regions or those with limited internet connectivity or advanced technological infrastructure. To promote global inclusion, efforts should be made to design the platform in a user-friendly manner that is accessible to a wide array of healthcare professionals, regardless of their location or resources.

The legal and ethical responsibility for maintaining decentralized systems remains a challenge, even when patient data is not involved. Ensuring the accuracy, validity, and reliability of the medical information shared through the DKG is crucial, as incorrect or outdated data could affect clinical decision-making [25]. Therefore, establishing clear governance protocols to oversee the information added, updated, or removed from the knowledge graph is essential to maintaining trust within the medical community.

For widespread adoption, the user experience must be intuitive and facilitate quick access to the relevant academic materials. If users struggle to navigate the system or access the right information efficiently, this could undermine the effectiveness of the DKG. Therefore, ongoing user feedback and iterative improvements in the system's interface and usability are vital to achieving the project's goals.

Although regulatory concerns are less critical compared to systems managing patient data, the ethical sharing of academic knowledge still requires clear guidelines to ensure transparency and the proper attribution of published work. Additionally, open access policies should be considered, especially for low-income regions, ensuring that healthcare professionals from various backgrounds can benefit from the organized knowledge within the DKG.

Conclusion

The development of the WSES-WJES Decentralized Knowledge Graph represents a transformative advancement in how medical and surgical knowledge is organized and shared. By creating a decentralized and blockchain-powered system focused on the WSES bibliography, this initiative is setting a precedent for more structured, transparent, and equitable access to academic resources in emergency surgery.

By promoting equitable access to medical knowledge, the DKG addresses ethical concerns about potential disparities in resource availability. The system's design aims to be inclusive and user-friendly, providing access to high-quality surgical knowledge for healthcare providers worldwide, regardless of their technological capabilities or geographical location.

The WSES-WJES DKG platform has the potential to significantly enhance the quality of diagnosis and treatment for a wide array of conditions. As the DKG evolves, ongoing attention to user feedback, regulatory frameworks, and ethical considerations will be critical to its long-term success and global impact in the surgical field.

Abbreviations

DKG	Decentralised Knowledge Graph
WJES	World Journal of Emergency Surgery
WSES	World Society of Emergency surgery
KG	Knowledge Graph
AI	Artificial Intelligence
EHRs	Electronic health records

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Not applicable.

Author contributions
A.L. and S.R. conceived the project, collected data and wrote the manuscript. B.DS checked the literature, critically read and revised the manuscript and edited it. B.DS wrote the paragraph "Regulatory and ethical implications of the WSES-WJES decentralized knowledge graph". F.C. read and approved the final manuscript. All the authors read and approved the final manuscript.

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