Transforming Clinical Information Systems: Empowering Healthcare through Telemedicine, Data Science, and Artificial Intelligence Applications

An Overview of the CIS Section of the IMIA Yearbook of Medical Informatics 2023

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Summary

Objective: In this synopsis, the editors of the Clinical Information Systems (CIS) section of the IMIA Yearbook of Medical Informatics overview recent research and propose a selection of best papers published in 2022 in the CIS field.

Methods: The editors follow a systematic approach to gather relevant articles and select the best papers for the section. This year, they updated the query to incorporate the topic of telemedicine and removed search terms related to geographic information systems. The revised query resulted in a larger number of identified papers, necessitating the appointment of a third section editor to handle the increased workload. The editors narrowed the initial pool of articles to 15 candidate papers through a multi-stage selection process. At least seven independent reviews were collected for each candidate paper, and a selection meeting with the IMIA Yearbook editorial board led to the final selection of the best papers for the CIS section.

Results: The query was carried out in mid-January 2023 and retrieved a deduplicated result set of 5,206 articles from 1,500 journals. This year, 15 papers were nominated as candidates, and four were finally selected as the best papers in the CIS section. Including telemedicine in the query resulted in a substantial increase in the number of papers found. The analysis highlights the growing convergence between clinical information systems and telemedicine, with mobile health (mHealth) technologies and data science applications gaining prominence. The selected candidate papers emphasize the practical impact of research efforts, focusing on patient-centric outcomes and benefits, including intelligent mobile health monitoring systems and AI-assisted decision-making in healthcare.

Conclusions: Looking ahead, the field of CIS is expected to continue evolving, driven by advances in telemedicine, mHealth technologies, data science, and AI integration, leading to more efficient, patient-oriented, and intelligent healthcare systems and overall improvement of global healthcare outcomes.

Keywords

International Medical Informatics Association Yearbook; clinical information systems; artificial intelligence; data science; telemedicine

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1 Introduction

As editors of the Clinical Information Systems (CIS) section, we annually apply a systematic approach to gather articles for the International Medical Informatics Association (IMIA) Yearbook of Medical Informatics. Over the past eight years, we have consistently employed a specific query to identify relevant publications in the CIS field, resulting in over 2,400 papers each year. These publications undergo a rigorous selection process to identify the best CIS papers.

During this period, we have observed a notable shift in CIS from primarily focusing on clinical documentation to a greater emphasis on generating patient-focused knowledge and facilitating informed decision-making. CIS have evolved beyond being mere tools or infrastructure for healthcare professionals and hospitals, becoming the foundation for a complex trans-institutional information logistics process. The patient has taken center stage, and patient data is utilized to create value for their benefit. Consequently, research in the CIS domain has increasingly focused on trans-institutional information exchange, data aggregation, and analysis [1–5].

The COVID-19 pandemic has significantly influenced scientific research in the CIS field, as evident from its extensive impact [6]. However, in the past year, we also observed no notable breakthroughs or innovative changes regarding methodologies, algorithms, tools, or applications for diagnostic or therapeutic purposes. This prompted us to question whether our long-standing query had become outdated [7].

With the change in our editorial team and the new section editor BP, we took the opportunity to update our query. Recognizing the significance of trans-institutional data exchange and patient-centeredness, we noticed that "telemedicine" was not explicitly included or adequately addressed in our existing systematic query. To rectify this, we conducted a thorough investigation by searching PubMed using the MeSH Major Topic "telemedicine," resulting in nearly 30,000 publications. These publications were subjected to bibliometric analysis [8]. Based on our findings, we decided to include terms related to telemedicine, such as "Telemedicine [MeSH Major Topic]", "Telemedicine majr/OT", "Telehealth [OT]" and "Telemonitoring [OT]" in our PubMed query. Conversely, we removed the term complexes surrounding "geographic information systems", as they were increasingly nonspecific in relation to CIS.

By incorporating these new search terms, we anticipate a significant increase in the number of identified papers, subsequently increasing our workload. To manage this challenge, we have appointed a third section editor (SBN) to ensure efficient handling of the expanded number of papers during the systematic selection process for the best CIS papers.

Each year, the IMIA Yearbook editorial board defines a special topic to highlight current aspects relevant to medical informatics. Each section focuses on these aspects when reviewing the past year's literature. For the 2023 edition, the special topic is "Informatics for One Health". Consequently, we were eager to assess whether this topic is reflected in the papers found during our selection process.

Table 1 Number of retrieved articles for Top-15 ranked journals.

Rank	Journal	Number of papers
1	Telemedicine journal and e-health: the official journal of the American Telemedicine Association	274
2	Journal of medical Internet research	155
2	International journal of environmental research and public health	155
4	Journal of telemedicine and telecare	134
5	PloS one	79
6	BMJ open	60
6	International journal of medical informatics	60
8	JMIR MHEALTH AND UHEALTH	57
9	BMC medical informatics and decision making	54
10	BMC health services research	53
11	Frontiers in public health	44
12	JAMA network open	43
13	Journal of the American Medical Informatics Association: JAMIA	40
13	Sensors (Basel, Switzerland)	40
15	Applied clinical informatics	36

About the Paper Selection

The process of searching for relevant publications and selecting the best papers in the CIS section follows a well-defined systematic approach. After using the same query for eight years, we decided this year, following an extensive analysis [8], to incorporate the topic of telemedicine in our queries and remove search terms related to geographic information systems. In mid-January 2023, we conducted the queries. We retrieved 5,206 unique papers, with 5,020 from PubMed (1,543 from the legacy query and 3,477 from the telemedicine-related search terms) and an additional 186 papers from Web of Science® (WoS). These articles were published in 1,500 journals, and Table 1 presents the Top-15-ranked journals with the highest number of resulting articles.

Despite changing the query, we noticed that the relative frequencies of publications from different countries remained similar to previous years. Most of those papers whose publication records included location information came again from the United States (45%, n=2,327). England was again second (26%, n=1,351), followed by Switzerland (6%, n=329), Canada (4%, n=222), Germany (3%, n=179), the Netherlands (3%, n=176), Ireland (2%, n=111) and Australia (2%, n=96).

Following our annual practice, we proceeded to categorize all the papers we found systematically through multiple rounds, resulting in a shortlist of up to 15 potential contributions. External experts and yearbook editors then reviewed these selected papers. Subsequently, the IMIA Yearbook Editorial Board conducted a selection meeting to choose a maximum of four best papers for each section. To comprehensively understand the articles' content in the CIS section, we employed text mining techniques and term combination mapping.

We used RAYYAN[1], an online systematic review tool for the multi-stage selection process of the best papers. The legacy query results from PubMed and WoS (n=1,729) were reviewed independently by two section editors (WHO and BP), and the telemedicine-related search results (n=3,477) were reviewed separately by all three section editors (WHO, BP, SBN).

During the first pass of screening, articles were excluded based on their titles and abstracts. The agreement rate for "exclude" decisions between WHO and BP was 95.5 percent, resulting in 4,970 articles being excluded out of the total 5,206 articles in consideration.

For the telemedicine-related search results, there was a 95.6 percent agreement rate (n=3,324) between BP and SBN regarding article exclusions out of the total of 3,477 articles. Between WHO and SBN, the agreement rate for "exclude" decisions was 96.8 percent, leading to the exclusion of 3,368 articles out of the total of 3,477 telemedicine-related articles.

[1] https://www.rayyan.ai

These agreements reflect the level of consensus among the section editors regarding the exclusion of articles based on title and abstract review. From this first selection pass, 350 papers remained for the next screening rounds, in which consensus was jointly reached to narrow down the selection further. The second selection pass yielded 136 possible candidates which were reduced to 52 in a third and 25 in a fourth pass. For these potential candidates, the full texts were obtained and reviewed.

Finally, we selected 15 candidate papers for the CIS section on mutual consent. Six candidate papers stemmed from the legacy query and nine were among the telemedicine-related articles. Each candidate paper underwent a rigorous review process, with at least seven independent reviews collected for each paper.

The selection meeting took place on May 5, 2023, in Bordeaux, France, and was conducted in a hybrid format, allowing both online participation and in-person attendance. The meeting involved the IMIA Yearbook editorial board, which decided on the final selection of papers. After careful deliberation and discussion during the meeting, four papers were ultimately chosen as the best papers for the CIS section. Content summaries of these four best CIS papers can be found in the appendix of this synopsis.

2 Findings and Trends: Clinical Information Systems Research 2022

During the selection process, the increase in the number of publications in the CIS field, particularly with the inclusion of telemedicine, posed a challenge in keeping track of the content of all the relevant literature. To cope with this abundance of publications, we employed additional methods such as text mining and bibliometric network visualization for several years in our section [9, 10]. These techniques allow for the efficient extraction of relevant information from a large corpus of articles and help us obtain a quick understanding of the content of the articles, enable meaningful comparisons between them, and provide us with a visual representation of the relationships between publications and their content. The visualizations also assist in identifying clusters of terms and emerging trends within the field.

2.1 Overview of the Content of All Found CIS Papers

First, we extracted the authors' keywords (n=38,184) from all articles and presented their frequency in a tag cloud (cf. Figure 1). We found 5,393 different keywords, of which 3,200 were only used once and 728 were used twice. As in the previous years, the most frequent keyword was "Humans" (n=3,914). This year "Telemedicine" was the second most frequent keyword (n=2,209), followed by "Pandemics" (n=1,030), COVID-19 (n=705), "Female" (n=683), "Child" (n=571) and COVID-19/epidemiology (n=546). "Electronic Health Records" is ranked 8th (n=546) versus 2nd last year.

In contrast to the keyword tag cloud, a bibliometric network can reveal more details on more items and interrelationships between the publications. We used VOSviewer [9] to create a clustered co-occurrence map of the keywords depicted in Figure 2.

Cluster 1 (in red) indicates the clinical perspective. Both in application and in research. The most common keywords in this cluster include "electronic health records", "technology", "hospitals", "(health) communication", "medical records", or "information systems". Terms such as "machine learning" or "artificial intelligence" suggest current research activities in this area. Cluster 2 (in green) contains as most frequent keywords terms like "humans", "telemedicine", "pandemics", "covid-19", "covid-19/epidemiology", "telemedicine/methods", "sars-cov-2", "cross-sectional studies", "delivery of health care", "referral and consultation", "patient satisfaction", or "primary health care". The most common keywords in cluster 3 (in blue) are "mobile applications", "quality of life", "pilot projects", "feasibility studies", "randomized controlled trials as topic", "telerehabilitation", "chronic disease", "exercise", and "treatment outcome". Cluster 4 (in yellow) contains general contextual factors of the studies with keywords such as "female", "adult", "male", "aged", "retrospective studies", "middle aged", or "adolescent". More specific context factors of the studies can be found in cluster 5 (in pink) with keywords such as "point-of-care systems", "prospective studies", "reproducibility of results", "emergency service", "hospital", "only child", "emergencies", "infant", "infant", "newborn", "child", "preschool", and "point-of-care testing". Finally, the keywords in cluster 6 (in turquoise) reflect specific application perspectives in the country with

Table 2 Best paper selection of articles for the IMIA Yearbook of Medical Informatics 2023 in the "Clinical Information Systems" section. The articles are listed in alphabetical order of the first author's surname.

Section
Clinical Information Systems

- Bialke M, Geidel L, Hampf C, Blumentritt A, Penndorf P, Schuldt R, Moser FM, Lang S, Werner P, Stäubert S, Hund H, Albashiti F, Gührer J, Prokosch HU, Bahls T, Hoffmann W. A FHIR has been lit on gICS: facilitating the standardised exchange of informed consent in a large network of university medicine. BMC Med Inform Decis Mak 2022 Dec 19;22(1):335. doi: 10.1186/s12911-022-02081-4.
- Guardiolle V, Bazoge A, Morin E, Daille B, Toublant D, Bouzillé G, Merel Y, Pierre-Jean M, Filiot A, Cuggia M, Wargny M, Lamer A, Gourraud PA. Linking Biomedical Data Warehouse Records With the National Mortality Database in France: Large-scale Matching Algorithm. JMIR Med Inform 2022 Nov 1;10(11):e36711. doi: 10.2196/36711.
- Poelzl G, Egelseer-Bruendl T, Pfeifer B, Modre-Osprian R, Welte S, Fetz B, Krestan S, Haselwanter B, Zaruba MM, Doerler J, Rissbacher C, Ammenwerth E, Bauer A. Feasibility and effectiveness of a multidimensional post-discharge disease management programme for heart failure patients in clinical practice: the HerzMobil Tirol programme. Clin Res Cardiol 2022 Mar;111(3):294-307. doi: 10.1007/s00392-021-01912-0.
- Zou Y, Pesaranghader A, Song Z, Verma A, Buckeridge DL, Li Y. Modeling electronic health record data using an end-to-end knowledge-graph-informed topic model. Sci Rep 2022 Oct 25;12(1):17868. doi: 10.1038/s41598-022-22956-w.

Fig. 1 Tag cloud illustrating the frequency authors' keywords (top 250 keywords out of n=38,184 are shown) within the 5,206 papers from the CIS query result set. Font size corresponds to frequency (the most frequent keyword was "humans" n=3,914).

the most frequent publications, the USA. The most frequent terms in this cluster are: "united states", "medicare", "prescriptions", "pharmacists", "analgesics", "opioid/therapeutic use", "drug prescriptions", "practice patterns", "physicians'", "opioid", "prescription drug monitoring programs", "electronic prescribing", "opioid-related disorders/drug therapy", "medicaid", "buprenorphine/therapeutic use", and "nonprescription drugs".

To ensure consistency with previous years' investigations, a parallel analysis was conducted using the terms extracted from all publications' titles and abstracts. The resulting co-occurrence map of the top-690 terms is visualized in Figure 3.

Compared to the analysis of the keywords, a different picture emerges here. The cluster analysis of titles and summaries resulted in four distinct, similarly large clusters. Cluster 1 (in red) is heavily populated with terms related to the COVID pandemic. But also, terms from the field of telemedicine, its application, and research are strongly represented. For example: "video", "appointment", "encounter", "patient satisfaction", "telehealth service", "telephone", "telemedicine visit", "telehealth visit", "telemedicine use", "teleconsultation", "care delivery", "phone", "telemedicine service", "telehealth use", "healthcare delivery", "video visit", "virtual visit", "virtual care", "video consultation", or "patient portal". Cluster 2 (in green) and cluster 3 (in blue) again contain various contextual factors, objectives, and methodological aspects of the studies. The remaining cluster 4 (in yellow) also includes such terms. Here, however, we also find numerous terms that can be attributed to the outcomes of the studies.

The impact of the COVID-19 pandemic continues to be profoundly felt in the field. Modifying the query with an increased emphasis on telemedicine has notably influenced the results. Nevertheless, the trends and research focus observed in recent years are still evident in the generated maps. The selection process for the best papers has yielded a substantial number of captivating and high-quality contributions. In the following sections, we will briefly introduce the candidates and highlight the best CIS papers chosen for recognition.

2.2 Insights into the Candidate Papers and Best Papers

Secondary use of clinical data is still an essential and prominent research field within CIS. Although the term "data science" is not yet often explicitly mentioned in the keywords or the titles or abstracts of the found CIS publications, we found many examples and inspiring, promising data science applications. One of them is one of the best papers, a contribution by Guardiolle *et al.* [11], which is about linking biomedical data warehouse records with the national mortality database in France using a large-scale matching algorithm. The algorithm was found to be reliable for both sensitivity and specificity evaluation, and it was able to link a large number of records with a high degree of accuracy. The paper also discusses the potential benefits of linking these two data sources for medical research and public health decision-making.

Another contribution from the field of data science, specifically about using machine learning and natural language processing techniques to analyze electronic health record (EHR) data is the best paper by Zou *et al.* [12] who use an end-to-end knowledge-graph-informed topic model. They discuss the challenges of extracting clinical knowledge from EHR data and propose a new method called the Graph ATtention-Embedded Topic Model (GAT-ETM) to address these challenges. The paper also compares GAT-ETM to other methods in terms of topic

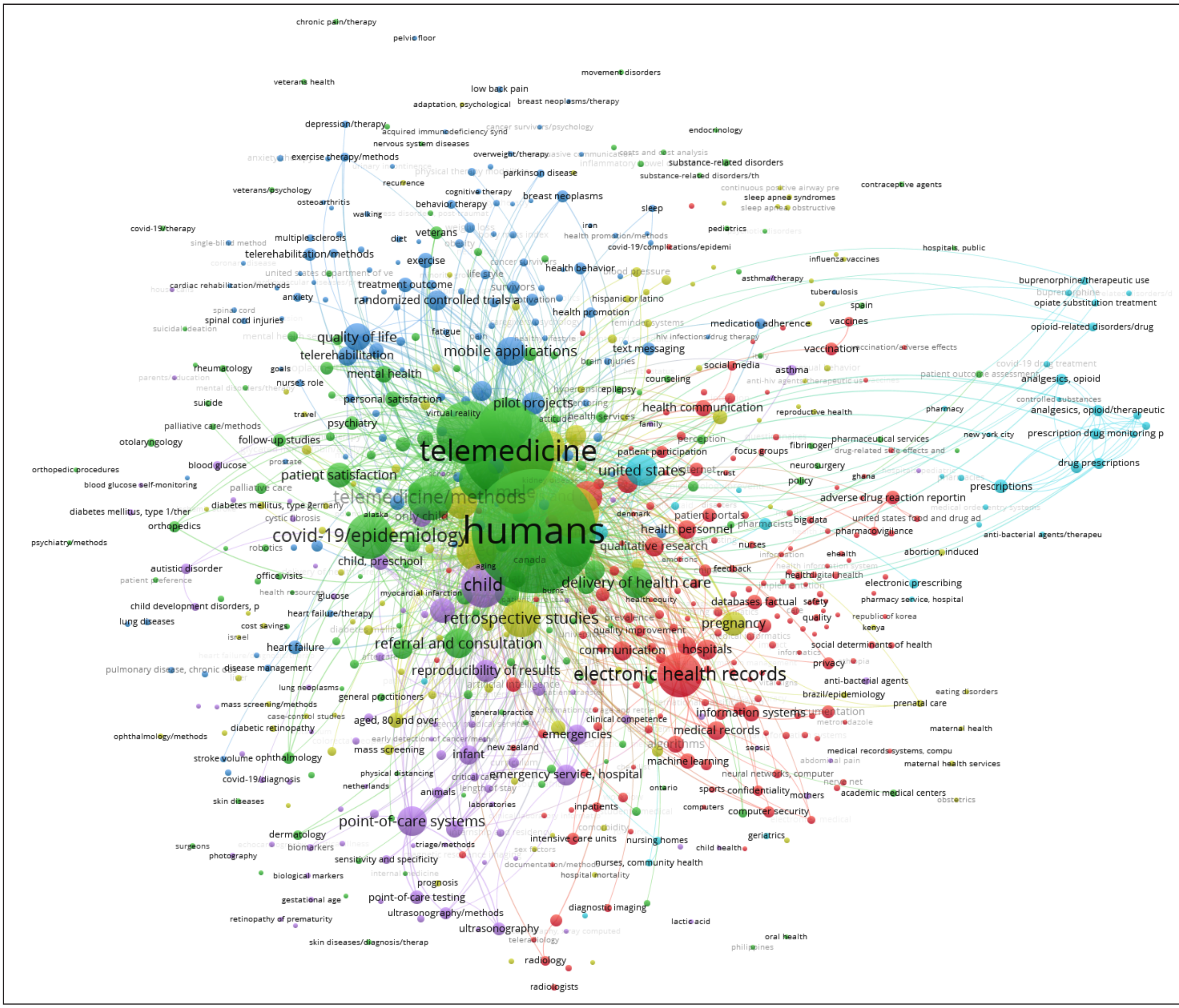

Fig. 2 Clustered co-occurrence map of the Top-690 keywords (keywords with the greatest total link strength n=690 of 5,393 distinct keywords) from the 5,206 papers in the 2023 CIS query result set. Only keywords that we found in at least six different papers were included in the analysis. Node size corresponds to the frequency of the keywords ("humans" n=3,914). Edges indicate co-occurrence (only the top 1,000 of 22,262 edges are shown). The distance of nodes corresponds to the link strength between the keywords. Colors represent the six different clusters. The network was created with VOSviewer [9].

quality, drug imputation, and disease diagnosis prediction, and explores how GAT-ETM can be used to discover interpretable and accurate patient representations for patient stratification and drug recommendations.

Information exchange between different stakeholders or institutions has become a core CIS topic in recent years. In the past years, we always had papers from the FHIR (Fast Healthcare Interoperability Resources) context in our selection. This year, a contribution by Bialke *et al.* [13] on the topic of standardized exchange of informed consent in an extensive network of university medicine made it into the best paper selection. The authors discuss the use of FHIR in facilitating the exchange of informed consent and provide insights into the potential implications of using FHIR for informed consent in the field of university medicine. Another interesting contribution to the FHIR context comes from Ayan Chatterjee *et al.* [14]. The paper is about achieving semantic and structural interoperability in personal health data through the use of HL7 FHIR with SNOMED-CT. It presents a proof-of-concept study that explores innovative

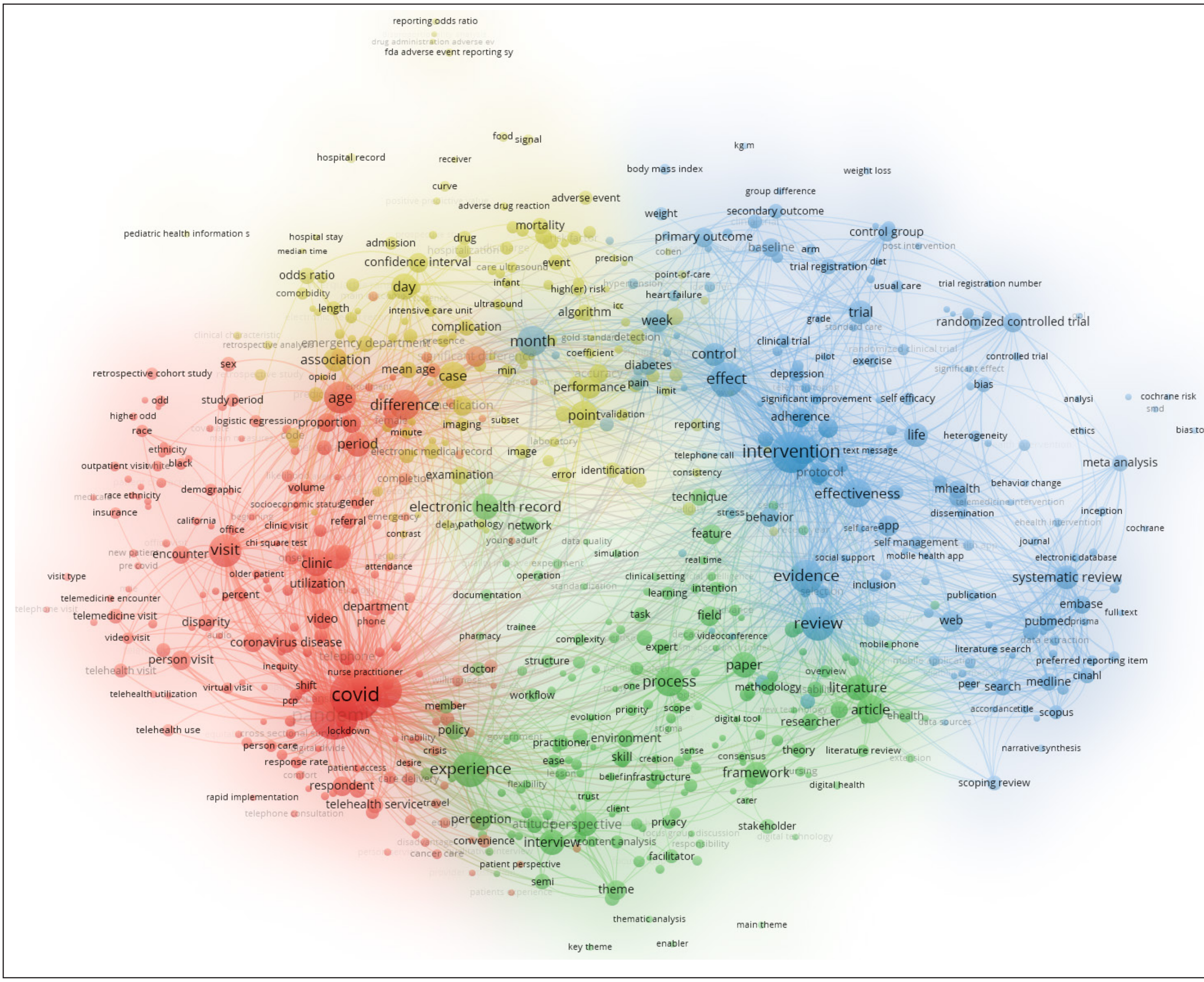

Fig. 3 Clustered co-occurrence map of the Top-690 terms (top 60 percent of the most relevant terms: n=690 of 95,937) from the titles and abstracts of the 5,206 papers in the 2023 CIS query result set. Only terms that we found in at least 25 different papers were included in the analysis. Node size corresponds to the frequency of the terms (binary count, once per paper, "covid": n=1,627). Edges indicate co-occurrence (only the top 1,000 of 131,853 edges are shown). The distance of nodes corresponds to the association strength of the terms within the texts. Colors represent the four different clusters. The network was created with VOSviewer [9].

solutions to the problem of heterogeneity in digital health information systems. The study focuses on designing and implementing a structurally and logically compatible tethered personal health record (PHR) that allows bidirectional communication with an electronic health record (EHR).

For a successful, seamless exchange of information, not only technical aspects are relevant. The publication by Pylypchuk *et al.* [15] provides valuable insights into the significance of EHR developers in facilitating hospital patient sharing, which involves the seamless transfer of patients between different healthcare facilities.

In another candidate paper worth reading, Kryszyn *et al.* [16] explore the question of how the performance of an openEHR-based hospital information system can be compared with a proprietary system. They evaluate the benefits and drawbacks of using the openEHR standard and suggest that the benefits of using openEHR may outweigh the found performance issues, especially for more complex hospital information systems.

Based on our observations, there is a growing convergence between clinical information systems and telemedicine. This overlap is leading to not only the exchange of data between different healthcare facilities but also the development of increasingly beneficial applications that leverage this data for the well-being of patients. Particularly, the term "mHealth," which refers to mobile health technologies, is gaining prominence within this context. As a subset of eHealth, mHealth focuses on utilizing mobile technologies to improve healthcare delivery and patient outcomes. Integrating mHealth solutions with CIS and telemedicine is driving innovations and advancements in patient-centric healthcare. In their candidate paper, Alenoghena *et al.* [17] provide a comprehensive review of trends and advancements in three aspects of an eHealth system and service delivery: contemporary architectures for eHealth designs, mHealth technologies, and security concerns. It is recommended to all who want to refresh their knowledge in these areas since reading this article.

Also an interesting read is the candidate paper by Li and You [18] who propose an intelligent mobile health monitoring system and establish a corresponding health network to track and process patients' physical activity and other health-related factors in real-time. The authors state that this system can help patients monitor their personal health in real time and can help healthcare providers identify potential health issues early on and intervene before they become more serious. This can lead to improved patient outcomes and better overall health management.

The focus on patient-centric outcomes is crucial in driving meaningful advancements in healthcare informatics. To emphasize the practical impact of research efforts, the selection process included concrete examples of applications that directly benefit patients. A truly impressive example of this is the fourth paper in the best papers roundup. Poelzl *et al.* [19] demonstrate the feasibility and effectiveness of a multidimensional post-discharge disease management program for heart failure patients in clinical practice. The study evaluated the benefits of a telemedical monitoring system incorporated into a comprehensive network of heart failure nurses, resident physicians, and referral centers. The study found that the multidimensional post-discharge disease management program was feasible and effective in clinical practice, resulting in a significant reduction in the primary endpoint of death from any cause and readmission for acute heart failure at six months, as well as improvements in patient empowerment.

Graetz *et al*. [20] could demonstrate that video telehealth improves access to healthcare for people with diabetes by offering them a new, convenient way to access healthcare without arranging transportation or taking time off work. Video visit access was associated with a statistically significant reduction in HbA1c levels among people with diabetes. This is particularly important for people with chronic conditions, who require ongoing monitoring and adjustment by patients and their clinicians. Video telehealth gives people real-time access to clinicians, which can help them manage their condition more effectively. Moreover, this approach contributes to reducing a patient's environmental impact by reducing the need for travel. Consequently, this article is relevant to the Special Topic "One Health" as it highlights the potential benefits of telehealth in improving patient outcomes and reducing environmental impacts, as shown in [21]. In addition to reducing the time and travel burden associated with participation, remote technology, and decentralization tools can also help increase patient enrollment in cancer clinical trials as suggested by the findings of Adams *et al.* [22].

Also for hospitals, it may be beneficial to have telehealth services. According to the candidate paper of Zhao *et al.* [23], hospitals with one or two telehealth services were found to have higher total performance scores compared to hospitals with no telehealth services. However, the study did not specify which specific telehealth services were associated with improved hospital performance.

In any case, the future will bring more mHealth applications, and it will be important to prepare both patients and hospital operators as well as possible. In their article, Hamberger *et al.* [24] explore central questions here, like What are some specific challenges that mHealth apps can help address in the healthcare system? How can patient-centered approaches be implemented through mHealth apps? What are some potential benefits and drawbacks of integrating mHealth apps into the healthcare system?

In our opinion, artificial intelligence (AI) can play a significant role in the context of mHealth apps and the healthcare system. AI can assist in decision-making, data analysis, and personalized treatment plans. However, the integration of AI into digital healthcare solutions also poses ethical challenges, such as transparency, accountability, and bias, such as biased data sources, which are often based primarily on male subjects and usually do not include minorities, possibly limiting the validity of the data and derived results. However, before we drift too deeply into such a discussion – there will be enough to discuss in detail in the coming years – let's take a look at the last two candidate papers. They exemplify what is already possible with artificial intelligence now. First, an interesting contribution by Humayun *et al.* [25] about an agent-based medical health monitoring system. Such a system is a group of intelligent agents that gather patient data, reason together, and propose actions to patients and medical professionals in a mobile context. The proposed system combines data mining techniques with a wireless medical sensor module to gather real-time sensory data from the patient's body and historical data obtained in the past. The system then categorizes the data into normal and emergency categories and declares an emergency by comparing the previously described data groups. Of course, there are numerous challenges here. If you are interested in this, you should read the paper. And last but not least, we have a paper from Hah and Goldin [26] in our selection. It is on AI-assisted decision-making in healthcare. In this article, the authors explore how clinicians currently use multimedia patient information (MPI) provided by AI algorithms and identify areas where AI can support clinicians in diagnostic decision-making.

This year's survey article of the CIS Section fits in perfectly with this. Farah Magrabi, David Lyell, and Enrico Coiera from the Centre for Health Informatics, Australian Institute of Health Innovation, Macquarie University, Sydney, present a very interesting overview of automation in contemporary clinical information systems [27]. Their survey explores the use of AI technologies in healthcare settings, including their clinical application areas, level of system autonomy, and reported effects on user experience, decision-making, care delivery, and outcomes. We would like to warmly recommend it to our readers, as we do every year at the end of our review of the results and trends of the Clinical Information Systems Section.

3 Conclusions and Outlook

The inclusion of telemedicine as a search term in our query turned out to be positive. Of course, this led to a substantial increase in the number of papers found. But we could compensate for that by adding a third section editor. On the other hand, we also found a large number of very substantial papers, which was also reflected in our selection. Nine of the 15 candidate papers came from this new query part.

The analysis highlights the growing convergence between clinical information systems and telemedicine, with mHealth technologies gaining prominence as a subset of eHealth. Data science applications, particularly in the secondary use of clinical data, are increasingly making a mark in CIS research. Additionally, the integration of artificial intelligence (AI) in healthcare informatics, mainly through mHealth apps, shows promising potential for decision-making, data analysis, and personalized treatment plans.

The selected candidate papers underscore the practical impact of research efforts, focusing on patient-centric outcomes and benefits. They cover a range of topics, from intelligent mobile health monitoring systems to AI-assisted decision-making in healthcare, all contributing to the improvement of patient care and outcomes.

As we move forward, it is evident that the field of CIS will continue to evolve, driven by advances in telemedicine, mHealth technologies, data science applications, and the integration of AI. This ongoing convergence between various disciplines will pave the way for transformative innovations in patient-centric healthcare. It will be crucial to address ethical challenges surrounding AI, ensure transparency, accountability, and eliminate biases to harness its full potential in improving healthcare delivery.

We think that the ongoing efforts in CIS research will undoubtedly lead to the development of more efficient, patient-oriented, and intelligent healthcare systems, contributing to the overall improvement of global healthcare outcomes. The next few years will show whether we are correct in this assumption.

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Appendix: Content Summaries of Selected Best Papers for the IMIA Yearbook 2023 Section "Clinical Information Systems"[1]

Bialke M, Geidel L, Hampf C, Blumentritt A, Penndorf P, Schuldt R, Moser FM, Lang S, Werner P, Stäubert S, Hund H, Albashiti F, Gührer J, Prokosch HU, Bahls T, Hoffmann W

A FHIR has been lit on gICS: facilitating the standardised exchange of informed consent in a large network of university medicine

BMC Med Inform Decis Mak 2022 Dec 19;22(1):335. doi: 10.1186/s12911-022-02081-4

Overview:

The article discusses the technical implementation of patient consent management in the context of the NUM-CODEX project, which aims to enable cross-site data exchange via FHIR in the area of consent. The authors describe the use of globally unique object identifiers (OID) and semantic statements to develop a common representation of the MII Broad Consent, which was extended with NUM-specific extensions. They also highlight the challenges of implementing complex FHIR consent profiles and the need for extensive practical experience and quality control to ensure syntactically and semantically correct implementation.

Detailed Description:

Goal

The goal of the text is to describe the implementation of a FHIR-compliant and interoperable nationwide exchange of consent information using gICS and TTP-FHIR Gateway.

Methods

The solution covers requirements identified in NUM-CODEX setting, which is part of a network of university medicines (NUM) to support COVID-19 and pandemic research at national level.

All 34 participating university hospitals work upon harmonized infrastructural as well as legal basis for their data protection compliant collection and transfer.

Informed consent from patients is required for processing their health data at NUM sites, transfer to CODEX, use & access procedure based on GDPR Art. 6(1) lit. a).

Findings

A reliable consent management system was successfully implemented by University Medicine Greifswald using MII broad consent in mid2020.

Current developments in the FHIR community must be considered when implementing cross-site data exchange via FHIR consents.

Steps were taken towards conception/implementation standardized solutions for provisioning consents through gICS with TTP-FHIT gateway serving as an intermediary between external infrastructure components.

Implications

Technical prerequisites have been achieved with help from gICS/TTP-FHIT Gateway enabling FHIT compliant provision info about patient's informed consents across multiple sites while maintaining compliance w/GDPR regulations.

Customised templates simplify assurance technical interoperability among all NUM/MII sites.

Guardiolle V, Bazoge A, Morin E, Daille B, Toublant D, Bouzillé G, Merel Y, Pierre-Jean M, Filiot A, Cuggia M, Wargny M, Lamer A, Gourraud PA

Linking Biomedical Data Warehouse Records With the National Mortality Database in France: Large-scale Matching Algorithm

JMIR Med Inform. 2022 Nov 1;10(11):e36711. doi: 10.2196/36711

Overview:

The paper describes a large-scale matching algorithm that links biomedical data warehouse (BDW) records with the French National Mortality Database (FNMD) to determine vital status after discharge, which is crucial for medical research. The algorithm uses advanced data cleaning and knowledge of the naming system, along with the Damerau-Levenshtein distance (DLD), to overcome challenges such as absence of unique common identifiers, name changes, and clerical errors. The algorithm's performance was evaluated using BDW data from three university hospitals, and the results showed that the DLD-based algorithm outperformed the direct algorithm in terms of sensitivity/recall by 11%.

Detailed Description:

Goal

The goal of the text is to present a study that developed and evaluated two algorithms for linking patient records between local biomedical data warehouses (BDWs) and the French National Mortality Database (FNMD).

Methods

The study utilized record linkage techniques, advanced data cleaning, knowledge of naming systems, Damerau-Levenshtein distance calculations, and blocking techniques.

Two algorithms were developed: a direct-matching algorithm and a deterministic matching algorithm based on DLD.

Findings

Matching large-scale BDW records with FNMD is challenging due to absence of unique common identifiers between databases.

The use of an advanced deterministic matching algorithm such as the DLD-based algorithm showed higher sensitivity/recall than direct matching algorithms.

Specificity was ≥98%, reducing risk differential biases between groups.

The execution time per patient decreased as total number increased but blocking technique reduced required comparisons by at least 40k times.

Implications

The findings have implications for medical research using open-source external data sources like FNMD in improving usage value BDWs.

The proposed method can be used routinely update vital status in BDW records from FNMD on large scale

Deterministic methods are more efficient when dealing with datasets without unique common identifiers

Poelzl G, Egelseer-Bruendl T, Pfeifer B, Modre-Osprian R, Welte S, Fetz B, Krestan S, Haselwanter B, Zaruba MM, Doerler J, Rissbacher C, Ammenwerth E, Bauer A

Feasibility and effectiveness of a multidimensional post-discharge disease management programme for heart failure

patients in clinical practice: the HerzMobil Tirol programme

Clin Res Cardiol 2022 Mar;111(3):294-307. doi: 10.1007/s00392-021-01912-0

Overview:
The HerzMobil Tirol program is a multidimensional post-discharge disease management program for heart failure patients that incorporates a telemedical monitoring system and a comprehensive network of specialized heart failure nurses, resident physicians, and referral centers. In a non-randomized study of 508 acute heart failure patients, the program was found to be feasible and effective in reducing the primary endpoint of time to HF readmission and all-cause mortality within 6 months by 46% compared to usual care. The program also showed a reduction in the composite of recurrent HF hospitalization and death within 6 months and a lower mortality rate after 1 year.

Detailed Description:
Goal
To evaluate the feasibility and effectiveness of a multidimensional post-discharge disease management program for heart failure patients using telemedical technology.
Methods
The study included 508 acute heart failure (AHF) patients managed by HerzMobil Tirol or usual care after discharge from hospital.

Patients in the HMT group underwent standardized evaluation, received structured follow-up, and were provided with a blood pressure and heart rate monitor, weighing scale, and smartphone for daily data acquisition.

Logistic regression models were used to calculate hazard ratios for primary outcomes including 6-month HF hospitalization and all-cause mortality at 6 months.
Findings
Management by HerzMobil Tirol was associated with a significant reduction (46%) in time to HF readmission within six months compared with usual care.

The composite endpoint was significantly lower with HMT than UC indicating that the program is effective.

Patients compliance among participants remaining in the HMT programme was high; only six out of two hundred fifty-one patients were found negligent on data transfer but remained until completion after three months.
Implications
Results suggest that specific disease management programs should be implemented widely following an acute heart failure event as they can prevent readmissions while improving clinical outcomes such as self-care behavior among patients.

Zou Y, Pesaranghader A, Song Z, Verma A, Buckeridge DL, Li Y

Modeling electronic health record data using an end-to-end knowledge-graph-informed topic model

Sci Rep 2022 Oct 25;12(1):17868. doi: 10.1038/s41598-022-22956-w

Overview:
The article describes a novel approach for modeling electronic health record (EHR) data using an end-to-end knowledge-graph-informed topic model called Graph ATtention-Embedded Topic Model (GAT-ETM). The GAT-ETM method leverages a medical knowledge graph to learn clinically meaningful disease topics from EHR data, and demonstrates superior performance over alternative methods for tasks such as drug imputation and disease diagnosis prediction. The approach has potential applications in computational phenotyping, patient stratification, and drug recommendations, and provides a promising avenue for refining disease phenotypes and discovering novel disease comorbidities from large-scale EHR datasets.

Detailed Description:
Goal
The goal of the text is to present Graph ATtention-Embedded Topic Model (GAT-ETM), an end-to-end taxonomy-knowledge-graph-based multimodal embedded topic model that distills latent disease topics from EHR data by learning the embedding from a constructed medical knowledge graph.
Methods
GAT-ETM assumes a generative process for each patient in the EHR corpus, where topic mixture membership is drawn from logistic-normal and categorical distributions.

To extract meaningful and interpretable disease topics, a linear decoder is used to reconstruct EHR data such that the linear projections can directly map to individual latent topics.

A graph augmentation strategy was proposed by connecting nodes with their ancestry nodes along taxonomy in order to maximize information flow among EHR nodes on the graph.

An ICD-ATC knowledge graph is leveraged to learn code embedding.

Empirically, it was found that mini-batch stochastic gradient descent worked well for updating models with large datasets.
Findings
GAT-ETM demonstrated superior performance over alternative methods on all tasks including drug imputation and disease diagnosis prediction.

GAT-ETM learned clinically meaningful embeddings of codes and discovered accurate patient representations for stratification purposes as well as drug recommendations.

The study evaluated model performance using expert-derived rule-based labels across 12 chronic diseases; results showed high accuracy classification scores across all diseases tested.
Implications
Incorporating multiple views through integrating knowledge graphs brings complementary information which improves phenotyping accuracy quantitatively & qualitatively.

Attention mechanism enables tracking input feature contributions which will be useful in understanding connections between different diseases.

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[1] We are convinced that artificial intelligence in the clinical setting will become more and more important and helpful. So, this year we asked an artificial intelligence to create the content summaries for our best papers. We used the tool Explainpaper (https://www.explainpaper.com/dashboard, Subscription Plus Mode) and did the following:
- Marke Headline and EXPLAIN IN EXPERT STATUS using EXPLAIN MODEL MODEL GPT-4 (costs 19 $ in addition)
- Use Explain COMPLETE PAPER using DETAILED SELECTION OF PAPER.

We present the unmodified original texts as supplied by the AI tool (only formatting was added afterwards).