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The Use of AI to Analyze Process-based Data in Hospitals: Opportunities, Limits and Ethical Considerations

By Thiemo Grimme and Ellen Hohma

Data driven environments are enabling and profiting from recent developments in Machine Learning and Artificial Intelligence (AI). Hospitals are one such setting that already produces vast amounts of data, leading themselves to optimization through AI-based technologies such as process mining. Process mining systems use AI to analyze process data with the goal of increasing efficiency and identifying potential bottlenecks that hinder smooth process flows. While this can improve clinic procedures, save time and ultimately positively impact medical care, their widespread deployment creates the need to understand ethical and social effects of the process mining technology for important stakeholders, mainly clinical staff, patients and broader society.

A hospital's primary concern is the health of its patients, with the goal of providing the best medical treatment possible. However, just like companies in any other industry, hospitals experience cost pressure and the need to be profitable, often operating with profit margins just around 5% (Asklepios, 2020). Consequently, there is a high need for efficient processes and the optimal use of resources. In 2019, 67% of doctors in Germany claimed that they had to postpone a treatment for cost-related reasons, an increase of 8% compared to 2016 (MLP, 2019). Moreover, 58% of the doctors named high cost pressure as one of the main issues in their clinic (MLP, 2019). In Germany, 84-92% of a hospital's annual revenue is spent on human resource and material costs (PWC, 2020). Subsequently, the remaining small revenue margins of 8-16% need to be sufficient to cover all additional costs, including investments in future technologies. These numbers highlight the importance for hospitals to improve their process efficiency in every way possible.

One major potential lies in the improved usage of data to understand mechanisms and measures that can accelerate and optimize hospital processes. In particular, the use of Artificial Intelligence enabled process mining for clinical use cases can effectively and continuously secure ways of processing data, contributing to the overall aim of enhanced efficiency. This brief outlines main opportunities of process mining in German hospitals. We provide relevant use case scenarios, as well as discuss potential ethical and social concerns that may arise with the implementation of AI-enabled process mining systems in medical facilities. The brief is part of a larger collaborative study by Celonis[1] and TUM IEAI, investigating the potential and impact of process mining for hospitals.

A needed transformation in hospital processes

Hospitals are increasingly embracing digitization in daily tasks. However, there are differences in terms of hospital use of digitization based on geography. In Germany, for instance, the adoption to digital solutions in hospitals is slower compared to most of its European neighbors. Germany ranks in the lower midfield, far behind countries like Denmark or the Netherlands in the use of digital data storage or processing and scores especially low in use of information logistics (Meister et al., 2020). This slow adoption can be linked to the traditionally highly authoritative and fragmented systems in German hospitals, leading to an organizational structure that is dominated by bureaucratic and administrative tasks (Siess, 1999). Thus, a dramatic change is needed in hospitals' digital infrastructure, particularly in Germany, to enable benefits from digitization and support the fundamental goal of efficient and effective patient care (Meister et al., 2020).

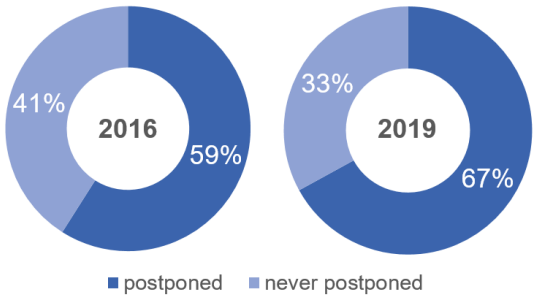

Figure 1: Postponement of patient treatments due to cost issues.
Source: Own representation based on MLP (2019).

The need for change was recognized by the German government in 2020 with the "Krankenhauszukunftsgesetz" (KHZG). The KHZG aims to increase the ability to innovate through the supply of investment capital (Meister et al., 2020). Hospitals can request funding for their digital projects through the KHZG, helping them to achieve a higher digital maturity[2]. The KHZG can be seen as important first step, especially signaling the government's awareness of challenges tied to a digitalization of the healthcare system, even if

[1] https://www.celonis.com/

[2] Project topics can include information technology (IT) in the emergency department, digital discharge management, Electronic Patient Record (EPR), implementation of automated decision assisting systems, digital medication management, digital processes to request services, secure IT-Infrastructure, online proof of care, implementation of network infrastructure needed for telematic medicine, technical systems needed to ensure data protection and changes to patient rooms regarding special requirements in the case of an epidemic

offered funding is limited. However, while the KHZG targets problems present today, it lacks a long-term strategy for shaping the future of hospitals which is needed for Germany to catch up with its European neighbors.

Rise of AI and process mining in hospitals

AI-enabled tools are fast-growing technologies and their potential in medical settings has already been acknowledged. According to the industry report "Sizing the Price" by PwC, AI based technology solutions are expected to increase the global GDP up to 14% by 2030. Specifically in hospitals, major cost savings are expected to be realized through AI (PWC, 2017). Not limiting impacts to monetary improvements, patient benefits are predicted from increased accessibility to information about care processes. It is shown in the TUM IEAI Research Brief discussing the issue of Ethical Implications of the Use of AI to Manage the COVID-19 Outbreak, that not only many AI-based tools are already in use, but that the interest in the use of AI-enabled technology has further been bolstered by the Covid-19 pandemic (TUM IEAI, 2020). This has increased public awareness, as well as academic and political discussion around the topic (PWC, 2017).

While clinicians can advance understanding of diseases, efficiency of diagnostics and treatment methods, AI has further potentials to decrease a hospital's administrative work

Besides potential benefits of AI for hospitals, challenges have to be taken into consideration. New risks related to impact, trustworthiness and ethical compliance present new regulatory questions that are often insufficiently investigated or in need of new or updated legal frameworks. This is complicated by the fact that "users" of AI in healthcare, specifically, are twofold: clinicians using the technology and patients experiencing the consequences of AI-based decisions. These potential risks still need further examination in order to mitigate them.
While clinicians can advance understanding of diseases, efficiency of diagnostics and treatment methods, AI has further potentials to decrease a hospital's administrative work. Striving for enhanced quality and profitability in each hospital, governments hope to create a more efficient healthcare system as a whole using AI (Katzenmeier, 2019).
The technology of process mining has the potential to help saving administrative costs and reduce time burdens in hospital settings. It is a relatively young technology that emerged with the progressing mega trend of digitalization. The technology allows processes to be digitally reconstructed and analyzed on the basis of event log data from IT systems. Process mining aims to improve process flows by reducing unwanted deviations from desired process models and identifying bottlenecks. In most industries, process mining is primarily used to make process flows more efficient, faster and more cost-effective (van der Aalst, 2011). Moreover, the extraction and analysis of existing event logs, storing information and meta-data on observed processes, enables detailed mechanism insights and transparent overviews, resulting in more informed decisions and process improvement for the organization using such a system (van der Aalst, 2012).
While, in general, AI systems can take a variety of forms, Jarrahi (2018) categorizes them along four superordinate categories: (1) generic analytical algorithms, (2) neural networks, (3) pattern recognition software and (4) deep learning. Embedding process mining in this classification, two predominant features are decisive. Process mining combines data analytics with pattern recognition capabilities, creating a machine learning algorithm that automatically extracts data out of the enterprise's (event log) system and conducts algorithmic investigation and process optimization. Moving beyond traditional data mining, AI is used in process mining to continuously analyze, enhance and monitor investigated processes (van der Aalst, 2012). Thus, we use the term process mining throughout the brief with the understanding that this is an AI-enabled tool (van der Aalst, 2012).
The data needed for process mining are compiled in so-called event logs. Every event log consists of chronologically listed events. Each event must consist of three different data logs. First the case ID, e.g. the identification number of a patient in the hospital, which allows its tracking. Second, the associated activity is described, e.g. administrative admission in the hospital, and third the timestamp of the activity. Additionally, information may be

stored in optional columns of the event log, for instance the age of patients, responsible physicians, cost of treatment etc. (van der Aalst, 2011). Based on the event logs, a digital twin[3], representing the hospital's actions, is generated — constantly monitored and analyzed in real-time by the AI. This enables AI-powered process mining solutions, like the Celonis Execution Management System (EMS)[4], to autonomously detect and evaluate data patterns (Russell & Norvig, 1995). Comparing these real-life processes to their digital counterpart allows the technology to provide decision-making guidance and detect hidden value by visualizing bottlenecks and discrepancies in practices in order to increase optimization (Rovani et al., 2015). Therefore, a major benefit of process mining compared to traditional data mining techniques is its power to establish a big picture and unveil inherent structures that consider the data's evolution and context. While data mining rather focuses on data available at the time of analysis, process mining includes past information to depict process development, empowering process mining to derive advanced predictions.

The capability to analyze large sets of event data and visualize them in a user-friendly way is especially beneficial as we experience a rapid growth in production, collection and storage of data across all industries (van der Aalst, 2012). Analyzing process data can contribute valuable insights for an organization's structure and actions, opening room for informed process decisions and improvement. Feasibility in this context of big data is enhanced because event logs can be retrieved from a variety of IT systems. This is particularly implementable in the healthcare context, as most event logs in hospitals are available, but stored in several, rarely linked source systems, like the Hospital Information Systems (HIS) or the Patient Data Management System (PDMS) (Rovani et al., 2015). With the ongoing (even if slow) trend of digitization in hospital environments, process mining could enable hospitals to overcome profit pressure and contribute to mitigating the high dependency on cost efficacy (van der Aalst, 2012). AI-based process mining systems and their power to investigate process data can be useful throughout many applications in a hospital. To depict the impact of process mining in hospitals, and its limits, it is useful to classify healthcare processes in two categories. (1) Primary processes, including all kinds of medical treatment like diagnostic and therapeutic activities, refer to the actual medical tasks and duties of a hospital. (2) Secondary processes cover organizational and administrative tasks required for an efficiently managed clinic (Rovani et al., 2015). As of now, process mining is strictly limited to secondary processes and every impact or direct effect on primary processes is avoided. Process mining is not being used to change medical treatment methods or interfere with any patient-doctor relationship, rather an optimization of the environment in which primary process take place is targeted to strengthen and advance medical care. Secondary processes are often not visible to the patient. They, however, ensure smooth process flows and increase the effectiveness and efficiency of a hospital.

Figure 2: Simplified example process flow for hospital billing.
Source: Celonis (2020).

[3] Digital twins mirror physical objects or processes, their characteristics and functions to create a virtual representation or counterpart.

[4] The Celonis EMS is the market leading process mining solution, capable of providing a comprehensive real-time picture of the analyzed processes with full transparency. Conformance checking functionality can be used to verify that processes conform to the process model. The Action Engine enables processes to be controlled in real time and inefficiencies to be counteracted. Lastly, the event data and models can be used in the EMS to make predictions about the process flow

The example of surgery management

Potential applications for AI-enabled process mining include purchase planning and organizational or accounting tasks, such as patient admission or patient billing. In general, benefits of process mining include a reduction of manual work, a lower error rate and a more efficient usage of the existing resources. Economically, however, the most important application is in surgery management, as 38% of stationary patients in hospitals underwent surgery in 2019, resulting in 17.2 million surgeries (Statistisches Bundesamt, 2020) and making the surgery the most important revenue source. Thus, we will use this case as an example to display the potentials for AI-enabled process mining in hospital settings.

While a surgery is performed by a doctor, its preparation and aftercare is responsibility of surgery managers. Their tasks include, for instance, confirming that a hospital's capacity of surgery rooms is used as efficient as possible. Common challenges include ensuring that a scheduled surgery starts on time or managing an effortless supply chain of surgical instruments. However, it is usually almost impossible for surgery managers to identify the cause of a delay, as multiple departments need to mutually collaborate. For instance, doctors often blame transportation services for delays and transportation services blame a care unit for not preparing the patient on time. At the same time, the surgery manager might criticize the whole team for a delay in requesting the transportation of the patient at all.

Evaluating the transportation service, for instance, several sub-events are investigated: the initial request of the patient, the order acceptance by the transport service and the delivery until the patient reached the respective surgery room. In this example, required data is extracted from the HIS and a smartphone app used by the transport service. As a result, the surgery manager gains a detailed overview of every single step involved in the process (Johnson, 2020). When evaluating the transportation service, several sub-events are investigated: the initial request of the patient, the order acceptance by the transport service and the delivery until the patient reached the respective surgery room. In this example, required data is extracted from the HIS and a smartphone app used by the transport service. This enables the surgery manager to gain a detailed overview of every single step involved in the process.

A study conducted by Celonis, which used data in a hospital setting, found the following insights about the process: (1) both, doctors and transport service were responsible for delays, (2) a clear pattern in the behavior became visible, unveiling that transports are steady in the morning, unreliable in the afternoon and (3) the transport service is considerably slower on Wednesdays and Fridays due to significantly higher workload per employee on these days. Mitigating actions, such as need-based trainings for affected surgery teams or adjustments in transportation staff according to workload peeks, can be proposed based on these insights. These optimizations can lead to increased efficiency and, thus, cost reductions for the hospital, time savings and reduced workload for clinical staff, as well as transparent knowledge and detailed, illustrated overviews about the efficacy of actions for administrative teams (Koch, 2019).

Benefits of process mining include a reduction of manual work, a lower error rate and a more efficient usage of the existing resources

Ethical considerations of AI-based process mining in hospitals

The healthcare sector has always been closely linked to questions of trust, ethics and, since the beginning of the digital era, data protection. In hospitals the impact of technology on the individual and its social legitimacy can only be ensured by a publicly accessible ethical dialog to meet the social standards and avoid threats to society. With the use of AI in hospital processes, and the excelled speeds at which it can use and process data, these questions become even more pertinent.

Process mining in hospitals concerns two main stakeholders, equally affected by the system's decisions and mechanisms: clinic staff and patients. Therefore, an ethical analysis needs to consider mutual interests and a balance of burdens. In an effort to initiate this important discussion, we highlight major ethical issues related to the application of AI in the analysis of

process-based healthcare data along the five ethics principles5 for a good AI society developed by Floridi et al (2018).

Beneficence

The principle of beneficence entails fostering well-being, respecting and preserving dignity and at the same time sustaining the planet. AI systems should pursue this principle to promote social good and sustain human comfort, an aim that corresponds to the overall goal of introducing process mining in hospitals. Process mining bears great potential in terms of optimizing the hospitals' secondary processes, like administration, procurement or logistic processes. Gained time consequently leads to cost reductions. Standardized and efficient processes help avoiding mistakes. Improved purchase and allocation of medical devices (e.g., for surgeries) and the ensuring of efficient internal supply, reduce medical drug waste. Besides the resulting impact on economic and environmental issues, freed-up financial resources can further be reinvested for the actual welfare of patients. Simultaneously, process mining can lead to improvements of social concerns related to the hospital staff. With its aim to achieve operational excellence, as shown above in the use case of surgery management, process mining and its increase in process efficiency especially reduces and accelerates administrative tasks. The reduced workload for clinic staff induces multiple benefits, including stress reduction and further opportunities for physical and mental recovery, potentially leading to increased employee motivation (Carayon et al., 2003).

Process mining bears great potential in terms of optimizing the hospitals secondary processes, like administrative, procurement or logistic processes

However, profits are not limited to the clinical context, patients can benefit from optimized processes, as well. A reduction of administrative workload for the clinical staff and the resulting extra time can be reinvested for medical treatment of patients ensuring quality of care. Particularly in the hospital environment, time for individual patient care is constantly scarce (MLP, 2019). More efficient secondary procedures can consequently yield higher standards of medical treatment and increase the quality and reliability of established processes.

Non-Maleficence

In addition to the ethic imperative to improve lives where possible, there is also an obligation to minimize harm in introducing new AI-based technology. Especially in the discussion about AI for the healthcare sector, where highly sensitive data, like previous or current diseases, or the general health condition of a patient is processed, non-maleficence is strongly tied to privacy protection and data security. As in any other industry, respecting and applying data protection standards following the General Data Protection Regulation (GDPR) is a prerequisite for the ethical conduct and deployment of AI-based systems in hospitals. Yet GDPR is often not precise enough to ensure and guide sufficient protection of all patient data. Besides GDPR, three essential legal frameworks with the goal to provide guidance for data processing in hospitals have been established in Germany: (1) the industry specific data protection laws "Landeskrankenhaus-gesetze", (2) the social data protection law (SGB §69ff) and (3) the medical confidentiality stated in §203 SGB (Katzenmeier, 2019). Even the latest initiatives, such as the 2020 "Patiendaten-Schutz-Gesetz" and the April 2021 European Commission draft of the "Artificial Intelligence Act," aim to guide the healthcare system into a more digital environment (Bundesgesundheitsministerium, 2020). However, the high amount of individual regulatory frameworks across Germany is precisely the opposite of what should have been achieved with the GDPR, aiming towards one consistent and comprehensive guidance, resulting in a mutual impediment of coexisting legal frameworks for data processing in German hospitals. Thus, hospitals may be left in an ambiguous position when it comes to the use of AI and data protection (Katzenmeier, 2019).
On the one hand questions of use and availability of data is one concern, on the other hand

prevention of unauthorized access to the obtained and stored data is likewise a critical aspect to ensure patient data protection. As suitable data security principles are undoubtedly required, process mining systems often propose further methods to minimize potential damage. This includes, for example, a pseudonymization of personal data. However, even if reasonable data security measures can be ensured, potential technical difficulties remain related to if and to what extent users can or should be able to reclaim their data. Concerns on the system's feasibility, functioning and usefulness might arise if patients do not consent to the analysis of their data, a question tightly linked to the user's autonomy of choice and data sovereignty.

Respecting and applying data protection standards following the General Data Protection Regulation (GDPR) is a prerequisite for the ethical conduct and deployment of AI-based systems in hospitals

A central aspect of non-maleficence of process mining in hospitals is limiting its use to 'secondary processes'. To prevent negative impacts on the medical treatment quality, any acceleration and optimization of 'primary processes', such as the surgery itself and the time needed to perform it properly and securely, should be avoided. Only secondary tasks, referring to patient administration or surgical preparations, that do not have a direct or indirect negative impact on medical care, should be subject to optimization respecting and ensuring patient well-being at all times.

Autonomy

Respecting the principle of autonomy means giving people the power to make decisions for themselves. Like many AI-systems already in use, AI-based process mining in clinic applications should always consult, but never fully replace a human decision. While such systems could, for example, guide medical staff with the ordering and distribution of medication, the ultimate decision for which medical supplies to stock should still be based on the experience and, thus, the final decision of the employees. While human oversight, on the one hand, should be required, it can simultaneously increase acceptance of such systems, particularly in the context of healthcare and clinics. Given the highly authoritarian structure in which hospitals still operate and the often low willingness of higher-ranked personnel to delegate decision-making tasks, maintaining human autonomy and decision power might support acknowledgement, and hence an uptake, of such systems. Together with limiting the AI-system's influence to rather routine, administrative tasks, process mining bears the potential to increase efficiency and decrease clinicians' workload, while augmenting human workforce and protecting human autonomy to decide how best to spend their time.

Autonomy and freedom of choice needs to likewise be maintained for the patient whose data is processed when applying process mining systems to healthcare institutions. This can especially be challenging since AI-based applications need user data to enable the system's operation and functioning. Therefore, the question remains of how such systems can be designed to respect patient consent to usage of their data as well as enable the procurement of answers to the questions of when, why, how and by whom the patient data has been used. This is an important question especially given the increasing trend of patient empowerment. The latest example of this is the introduction of the Electronic Health Record (EHR), which gives patients the opportunity to see and trace back all related health data, by showing whom it has been used by, therefore enabling a more informed consent (Johnson, 2020). While still not fully developed, the EHR is a step in the right direction to decrease the imbalance of information between patient and clinicians and hand some data sovereignty back to the patient.

Justice

The principle of justice implies eliminating unfair discrimination, ensuring justice, equity, and solidarity, as well as promoting shared prosperity throughout society. While human decisions and perceptions are often prone to bias, guidance through machine learning applications can to some extent avoid prejudices and discrimination, as

decisions are no longer subject to the potential arbitrariness of a single person but made by "neutral machines".
For example, overarching processes, such as patient billings, are optimized via process mining and not linked to a specific patient. Considering the example of patient registration automation illustrates potential fairness disputes in non-automized structures. In traditional systems, scope of actions is determined by clinic staff. Hence, scheduling and treatment of patients can to some extent be influenced by the administrative staff's feeling toward that patient or their mood that day. Automated AI-based systems have the potential to avoid these unfair decisions by merely basing them on facts instead of emotions. Different treatment during patient admission due to gender, origin, or simply personal feelings are thus largely excluded.

AI-based process mining in clinic applications should always consult, but never fully replace a human decision

However, clearly, assurance needs to be guaranteed, that these same biases do not creep in to the data being used to develop the solution. Indirect discrimination through one-sided data collection, poor representation of needs of certain groups or unbalanced data processing without a suitable and reasonable fairness mindset might cause unequal treatments and needs to be prevented.
Another issue is the equity of access to process mining technology. Equipping a hospital with an AI-based process mining system requires a certain degree of pre-existing digitalization. Consequently, there is a risk that understaffed or underfinanced hospitals might have a lack of knowledge and expertise or cannot afford the technology. This will increase an already existent divide in quality of hospital care between certain geographic areas or between private and public clinics. Further, while possibly contributing to health disparities between socio-economic classes within countries or regions (Lago et al., 2018), the health system gap between richer and poorer countries will likewise be affected. Therefore, the need to ensure that benefits and burdens of such systems can be equally distributed arises. There are several first approaches to mitigate these effects, for instance by using cloud-based systems, allowing access to the technology for anyone with internet without the need to deploy expensive servers. While this allows transfer necessary technology and know-how to less developed countries, fairness concerns potentially hindering the deployment and wide-spread adoption of process-mining systems for hospitals cannot be entirely avoided.

Concerns could include that it may be ethically questionable if a person can be made responsible for a decision that they confirmed, but never fully understood

Explicability

The aim of ensuring explicability is to enable the other ethical principles by increasing intelligibility and accountability through enhanced transparency, as higher degrees of explainability reinforces acceptance and trust in AI systems (Shin, 2021). Especially in highly authoritarian systems with rigid structures, like hospitals, introducing transparent and reproducible AI decisions that users can easily follow and understand will promote the uptake of such systems. Hence, including mechanisms in AI-enabled tools that explain how the new technology can support users, provide proof that a decision is made carefully and allow the option to trace back the justifications for a proposed action, it can be beneficial to increase acceptance. This can be helpful, for example, in the use of process mining for medicine ordering in that it could support the clinic staff in their decision, while allowing for adaptions based on their previous experience and domain knowledge.
Furthermore, transparency in AI mechanisms can contribute to solving the issue of responsibility and accountability for these systems. From a legal standpoint, where an AI-enabled tool can only consult or suggest (Intersoft Consulting, 2019), the

system could not be held accountable as a clinic employee would always be needed to confirm a final decision. However, beyond the legal scope, it may be ethically questionable if a person can be made responsible for a decision that they confirmed, but never fully understood. Consider the case that a process mining system proposes to order a certain amount of medicine without providing further explanation. It is morally arguable who is to be held responsible if harm arises from incorrectly ordered and administered medication, if the clinic staff was to purely trust the system. Clarifying this difficulty might be especially important given the area of operation, the healthcare sector and the potentially high level of harm a wrong decision may cause. Increasing the explainability and transparency of AI-enabled process mining can give valuable insights to users and, hence, enhance understanding and comprehensibility to promote more informed decisions.

Concerns can be raised as to how informational obligations for patients are actually implementable

For process mining systems in hospitals, explainability also needs to be directed towards the patient. Patients should always have the option to know which personal data is used and how. Some researchers even advance information obligation demands, claiming that all parties involved need to be informed about consequences of AI, for example potential harms related to its usage (Kushnick et al., 2019). However, in the context of process mining, this presents two challenges. First, concerns can be raised as to how informational obligations for patients are actually implementable, since the patient is not the system's actual user and, moreover, does not directly see or interact with the system at all. Second, in dealing with highly sensitive health data, there are heightened privacy concerns that complicate the disclosure process. Therefore, a suitable balance between transparent decisions and de-identifiable, secure data disclosure needs to be assessed to weigh both the hospital staff's need for transparent and traceable process flows, as well as the patient's concerns about security and use of their sensitive data.

Final thoughts and conclusions

AI will have widespread ramifications that revolutionize the practice of medicine, as well as transform the patient experience and clinician's daily routines. More specifically, AI-enabled process mining offers a big chance for hospitals to increase their efficiency and, hence, profitability, while relieving workload of clinic staff. This brief, however, depicts remaining issues and concerns in practical applicability, specifically highlighting the importance of using process mining for administrative, routine tasks, without negatively impacting actual medical treatments and decisions. Priorities must remain patient centered to emphasize and strengthen medical care and the patient's well-being at all times. Still, a suitable balance must be found concerning potential ethical trade-offs and the ability to lower burdens and improve the healthcare system.

Priorities must remain patient centered to emphasize and strengthen medical care and the patient's well-being at all times

AI ethics frameworks enable us to judge how the society can profit from the opportunities provided by AI and highlights undesirable consequences that need to be avoided. However, further evidence-based research in this field is needed to handle the manifoldness of this research topic, given that every hospital is unique and respective use cases can differ depending on the context. Despite major challenges regarding infrastructural prerequisites in hospitals (Siess, 1999), AI-based process mining offers a great potential to strengthen and support the healthcare industry and initiate a wide-spread application in hospitals (Siess, 1999

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