Implementing Process Mining in Indonesia Health Care: Challenges and Potentials

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A R T I C L E   I N F O

A B S T R A C T

Indonesia has become one of the countries having the biggest single-payer national insurance with a population-based membership. The insurance had helped up to 217 million patients since its inception in 2014. Capturing insights from a large-scale electronic health record has the potential to give a valuable improvement to the health care processes quality. Process mining is an emerging approach to "bridge" between the domain of data science and process science. It has also been recognized to contribute to the domain of health care where complex and multi-discipline processes are happening. The BPJS Kesehatan data containing routinely collected medical records becomes a valuable source of knowledge to improve the quality of health care. In contrast to its benefits, exploiting and managing population-based health care data for research brings challenges and potential. This paper presents the challenges of conducting process mining projects in the perspective of diversity, data quality, ethics, and security. Process mining in health care also brings potentials in care process comparisons, precision medicine, audit and compliance, and the opportunities of using virtual research environment to conduct research using a population-based data set based on unique characteristics of human biology.

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1. Introduction

Indonesia health care strategy is switching from a multi-payer health insurance to a single-payer national health insurance [1]. As the fourth   most populous country in the world, Indonesia is expected to be the biggest single-payer national health insurance in the world. The consequence of being the 'biggest' is that the initiative requires a substantial resource and an immense size of data. It is also recognised that the biggest spending is happening at the hospital-based care where strengthening the care processes in the hospitals is recommended [2].

Indonesia is facing a tremendous demand in managing a large amount of electronic health records (EHR) since the number of populations keeps growing. This routinely collected medical record could play an important role in supporting the care process. Insights from medical records can be used to support precision intervention, promoting better care through procedures given based on unique characteristics of human biology. The EHR may contain evidence of care and have the potential in promoting research to improve care [3][4].

Process mining is a relatively new method to identify processes from a generated event log, check the agreement of the factual event to the pre-defined guideline. It has been mostly implemented in the business domain [5] and relatively recent for implementation in the health care domain. We provide, for the first time, a critical review of process mining implementation in Indonesia health care to improve the quality-of-care processes. We reviewed three areas in relation with process-oriented health care improvement:

1. What data resource exists for process mining studies in Indonesia?
2. What are the challenges to conduct process mining studies in Indonesia's health care?
3. What are the potentials of such study that can be implemented?

This paper is in a position to inspire and encourage the contribution of future researchers who have interest in this domain.

1.1. Indonesia Initiatives of Improving Health Care Services

The vision of the Ministry of Health Republic of Indonesia is to create a healthy, independent, and fair society. This "grand vision" can be achieved through initiatives to improve public health status, assure healthcare availability, and ensure good health governance. The initiatives are written as legislation products, including the Minister of Health Regulation Number 97/ 2015 on Health Information System (HIS) Roadmap [6], Government Regulation Number 39/ 2019 on One Data Indonesia [7], Regulation of the President of Indonesia Number 72/ 2012 on the National Health System (SKN) [8], and the Minister of Health Regulation Number 21/ 2020 on the Strategic Plan of the Ministry of Health for 2020-2024 [9].

The regulations have potential to improve Indonesia's health services if all participating stakeholders are willing to comply and implement them to achieve the grand vision. One important implementation of those regulations is through research projects. Research projects on health data were mostly limited by the number of available data to work with because of the confidentiality nature of the health data [10][11]. Research projects may incorporate simulated or artificial data, but a significant impact may be achieved through the incorporation of the actual data, which Indonesia has an abundant resource of data.

1.2. Health Data Resource in Indonesia

Indonesian healthcare data are fragmented and decentralized [12][13]. Each healthcare provider has its own patient records. Some of the records are available in non-digital forms, and the sharing among them is very limited. This situation is a result of the decentralization reform in 1999 where the governance of the health care system is separated under each government system: central, provincial, and district/ municipality governments. In the central government, health care is managed by the Ministry of Health as the center of policies, regulations, and standards for the country. The ministry has subordinate representatives under the provincial and district governments. Together with the respective governments, they serve technical guidelines of the regulations and the standards, manage the hospitals and other healthcare facilities under their jurisdiction, to serve coordination to health issues, and provide reports to their superior government or the Ministry of Health. Following the decentralization reform, regional autonomy has been given to the provincial and district governments. This autonomy allows each region to develop itself without necessarily asking permission from the central government. The HIS development was done arbitrarily depending on the capability of each regional government including the HIS development of private health care providers. The lack of orchestration at the beginning of the HIS development produces fragmented and decentralized health data. More information on Indonesia's health system can be found in [14].

The national healthcare insurance program suggests all healthcare providers use a similar system to claim reimbursement although the current regulation suggests that healthcare providers are not obliged to provide reports to the central government [15]. The national health care insurance program gradually shifts the fragmented data storage into centralized data under the BPJS. The number of variables for reports is limited, but as the system evolves, the number of variables will be increased to reach the optimal numbers. The potential of using the BPJS health data samples for clinical pathway analysis has also been explored in previous research [16].

The primary care and secondary care providers are suggested to use the *Pcare* system [17] and the *Vclaim* system [18] respectively. Using those systems, the BPJS can collect data from providers even though the number of variables is limited. Additionally, the Center of Data and Information (*Pusat data dan informasi/ Pusdatin*) of the Ministry of Health of the Republic of Indonesia also collects data from other previously developed systems such as the tuberculosis information system (*Sistem Informasi Tuberkulosis/ SITB*) [19], the HIV information system, the regional health information system (*Sistem Informasi Kesehatan Daerah/ SIKDA*), etc. Periodic surveys are also conducted by the research and development department of the Ministry of Health. Those include the following but not limited to the basic health research (*Riset kesehatan dasar/ Riskesdas*), the health care facility research (*Riset fasilitas kesehatan/ Risfaskes*), and the national health survey (*Survei kesehatan nasional/ Surkesnas*). The various kinds of information systems and research data collection under the Ministry of Health suggest that the ministry has abundant health care records. These data are decentralized even if they are under the same ministry.

There are 3,099 hospitals in Indonesia [20] which are categorised based on class and ownership status. According to [21], four classes (A, B, C, and D) are used to identify a hospital based on the number of specialist services. Specialist service includes primary (e.g., internist, pediatric, surgeon, and obstetrics and gynaecology), other specialists (e.g., ophthalmology, neurology, cardiology, etc.), and supporting specialists (e.g., anaesthesia, radiology, microbiology, pathology,

etc.). Class-A hospitals provide all primary specialist services and have more other and supporting specialist services than those in other classes. Indonesia has 69 hospitals in class-A, 431 hospitals in class-B, 1,649 hospitals in class-C, and 925 hospitals in class-D. The other 25 hospitals are yet to be determined by the time this article is written. Based on the ownership status, the hospitals are categorized into private hospitals (836 hospitals), company-owned (514 hospitals), social organizations (323 hospitals), Islamic organizations (118 hospitals), individuals (75 hospitals), Catholic organizations (45 hospitals), Protestant organizations (28 hospitals), Hindu organizations (3 hospitals), and the rest are public-owned. All hospitals share their bed availability through Online Hospital Information System (SIRS Online) managed by the Directorate General of Health and Safety of the Ministry of Health [20]. The SIRS Online also has an integrated referral information system. In addition, BPJS Kesehatan also collects data related to hospitals through the process of credentialing and contracts every year at hospitals, including hospital services data of the claim process, limited to JKN patients.

Twelve secondary health data are available in Indonesia and published by several institutions. The data comes from four different sources, six datasets from the National Institute of Health Research and Development, the Indonesian Ministry of Health (*Litbangkes Kemenkes*), and three datasets from the BPS-Statistics Indonesia (*Badan Pusat Statistik*). The rest of the datasets are from the BPJS Kesehatan, Gadjah Mada University, and one dataset is a collaboration between the Ministry of Health, *Badan Pusat Statistik*, the National Population and Family Planning Board Due, and the United States Agency for International Development (USAID). The list of these secondary data is provided in Table 1.

Table 1 Secondary Health Data in Indonesia.

#	Dataset Name	Institution
1.	BPJS Kesehatan sample data (2015-2018 [22], 2015-2020 [23], 2015-2021 [24])	*BPJS Kesehatan*
2.	Basic Health Research (*Riset Kesehatan Dasar*) [25]	*Litbangkes Kemenkes*
3.	Health Facility Research (*Riset Fasilitas Kesehatan*) [26]	*Litbangkes Kemenkes*
4.	Health Funding Research (*Riset Pembiayaan Kesehatan*) [27], [28]	*Litbangkes Kemenkes*
5.	Non-communicable disease cohort study (*Studi kohort penyakit tidak menular*) [29]	*Litbangkes Kemenkes*
6.	National health survey (*Survei kesehatan nasional*) [30]	*Litbangkes Kemenkes*
7.	Utilisation of health operational funds 2010 (*Pemanfaatan dana bantuan operasional kesehatan 2010)* [31]	*Litbangkes Kemenkes*
8.	Indonesia Demographic and Health Survey (*Survei demografi dan kesehatan Indonesia*) [32]	*Badan Kependudukan dan Keluarga Berencana nasional; Badan Pusat Statistik; Kementerian Kesehatan; USAID*
9.	National Social and Economy Survey (*Survei sosial ekonomi nasional*) [33]	*Badan Pusat Statistik*
10.	Village potential data collection (*Pendataan potensi desa*) [34]	*Badan Pusat Statistik*
11.	Basic health indicator (*Indikator dasar kesehatan*) [35]	*Badan pusat statistik*
12.	Health and Demographic Surveillance System/HDSS (*Surveilans Demografi dan Kesehatan*) [36]	Universitas Gadjah Mada

Besides the above datasets, other sources of data are from outside Indonesia, such as the World Health Organization (WHO) providing Indonesia Data Completeness Index (*Index Kelengkapan Data Indonesia*) and the Research and Development (RAND) Corporation providing the Indonesia Family Life Survey.

Access to the raw format of those datasets requires an official request process through their respective institutions with pre-defined terms and conditions. When

access is granted, the data provided has gone through a cautious data management process to make sure that it is ready to be analyzed with anonymity.
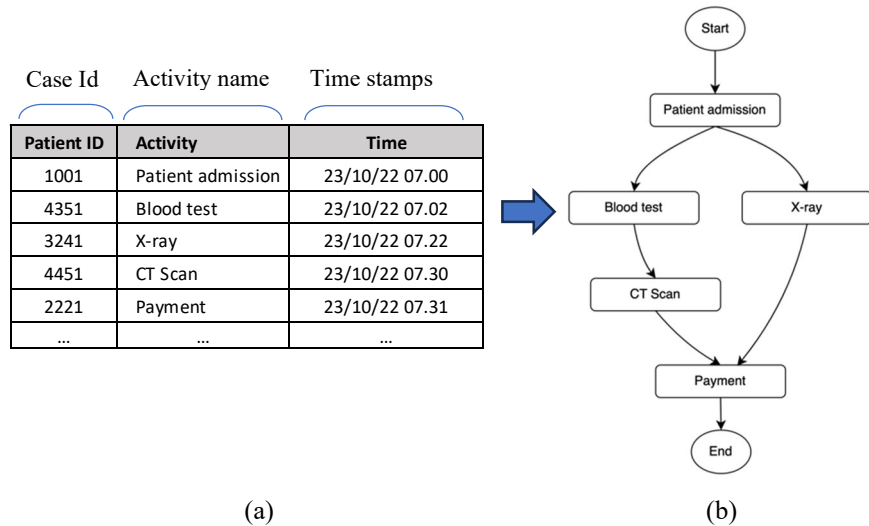
1.3. Why health Care?

Providing health care services requires collaborative work between clinicians, clinical specialists, nurses, laboratories, pharmacies and many more across the organization [37][38]. Each department may have its own limitation in handling cases, but the ability to provide a high-quality care process is paramount. Keep in mind, the patient's safety awareness which requires real action needs to be in place at the system level [38][39].

The care pathway had helped in providing guidelines on how to orchestrate multidisciplinary teams to provide care, not only for the patients but also for their relatives [40]. Care pathways provide a guideline for how a patient should be treated. It contains a series of care activities for a variety of conditions of patients [6] which are then acknowledged as the business process of the health care setting.

Process mining may offer the benefit of discovering knowledge from the evidence stored in the EHR, comparing the evidence with the pre-designed guideline and providing the performance measurement and outcome [41]–[43].

2. Process Mining

Process mining has been implemented in organisations for more than two decades ago and could help in analyzing the digital trace of any organisation's executed processes [5], [44]. The sequence of activities and all related data are stored within the organisation's information system. To enable the process mining technique, the required input needs to be extracted to create an event log as the input. There are at least three variables that should be present in the event log: the case identifier, activity name, and the timestamp to mark when the activity happened. The illustration of an event log is presented in **Figure 1**(a).

Patient ID	Activity	Time
1001	Patient admission	23/10/22 07.00
4351	Blood test	23/10/22 07.02
3241	X-ray	23/10/22 07.22
4451	CT Scan	23/10/22 07.30
2221	Payment	23/10/22 07.31
...	...	...

(a)   (b)

Figure 1 An Event Logs (a); A Process Model

There are three types of process mining that can be done. First, the discovery process produces a process model using the discovery algorithms. The obtained process model represents the evidence which is captured in the event log (see **Figure 1** (b)). Depending on the complexity of the process, the algorithm may produce a 'spaghetti-like' process model which is hard to interpret or analyze. Discovering a process model is a very complex task, therefore the second type,

conformance checking is needed to see if the obtained process model is representative of the event log [45]. The third type is enhancement where the potential of improvement to the processes is analyzed.

The process mining approach lies between data science and process science [44][46]. Data science mainly covers the area of data analytics and how to learn from data using a range of approaches including machine learning, data mining, query analysis, statistics, and artificial intelligence. On the other hand, process science is learned through observation and other fact-finding approaches to analyze business processes, manage, and systematically improve them. Process mining sits in between those two sciences, by analyzing data to learn and analyze business processes, and in turn, using the results of those analyses to improve the business processes' executions.

3. Process Mining in The Indonesia Health Care

3.1. Literature Study

We conducted a targeted literature review to see how process mining had been utilized to solve health care problems in Indonesia. We defined the following research questions as a guidance to identify challenges and potentials of process mining implementation in the Indonesian health care:

Q1: What cases in the health care domain have been investigated by process. mining?

Q2: What data, process mining types, algorithms, tools, and methods were incorporated in the studies, including the results?

We used Google Scholar with a combination of keywords: "process mining", "hospital", "health", and "Indonesia" including the Indonesian version of the keywords. A set of selection criteria has been applied to make sure that we analyzed credible literature. The selection criteria are as follows.

1. A peer-reviewed literature.
2. Written in English or Bahasa.
3. The study incorporates process mining extensively, not just mentioned.
4. The process mining approach was applied in the Indonesian health care setting.

The literature searching process was done using a web browser in the "incognito mode" or "private mode" to avoid getting a biased result due to the history of our other previous searching activity.

The results of the literature review were then combined with our previous literature reviews to get more insights in terms of the challenges and potential. The results are described in the following sections.

3.2. Investigated Process Mining Cases

Process mining has been applied to investigate cases that related to the health care setting whether directly or indirectly impact the care process of the patient. In the final selection of the literature, we found five works of literature containing reports of process mining exploitation from the perspective of *the process*. Anggrainingsih et al. [1] investigated the waiting time for the BPJS-covered patients' contact with the outpatient service at a local hospital in Sukoharjo. Outpatient care processes for a patient diagnosed with cardiovascular diseases are investigated in [47]. A care processes audit using process mining at a central

hospital in Sanglah, Bali is presented in [48], and conformance checking of a private hospital's financial administration process is presented in [49]. One study has also applied process mining for disease trajectory analysis on the Indonesia health insurance data [50]. One study presents a conformance check on drug production in the pharmacy industry [51].

For the *organisational* perspective, two studies had been conducted to identify and model the interaction among speciality doctors [52], and between doctors and the other actor in providing care to patients with diabetes [53]. There are two studies that present process mining in the pre-processing step: event log extraction from a hospital's information system [54], and the identification of imperfection patterns in an event log [55].

3.3. Process Discovery Algorithms, Tools, and Methodologies

In the discovery of a process model from an event log, four studies used inductive miner [1][47][53][56], two studies used the heuristics miner algorithm [49][51], one study used both inductive miner and heuristics miner [54], and one study used the genetic algorithm [48]. Conformance checking was also conducted in the mentioned studies.

The selected literature contains a report on the use of process mining tools to perform process mining analyses. From the nine selected literature, five studies are using both ProM tools and Disco, [49][51][52][54][57] and there are three studies that only used ProM tools [1][48][53]

We identified an indication where the recognition of process mining methodologies is still low. All investigated literature was published between 2015 and 2022 but none of them reported the use of process mining methodologies as a guidance to conduct process mining projects. The process mining methodologies has been introduced as early as 2009 [58][59] and since then many methodologies were proposed including the ClearPath method which combines process mining and simulation that is specifically designed for the healthcare domain [60]. The use of a methodology has benefits in promoting reproducibility and indicating high-quality research as required for grant applications and manuscript submission to journals [61].

4. Challenges for Conducting Process Mining Study

Despite all the benefits process mining technique could provide, the implementation of process mining would face several challenges. Based on the literature review, we identified five areas of challenges: diversity, data quality, ethics, security, and infrastructure.

4.1. Diversity

Indonesia is one of the largest countries by land area, at 1,910,931 square kilometers (737,814 square miles), consisting of more than 273 million people living in more than seventeen thousand islands [62]. This condition serves a wide range of challenges, mostly caused by the diversity/ disparity/ inequality in the governance and utilization of health care services between regions. Citizens living in the urban area around the center of economic and development regions are likely to use higher health care services than those living in rural areas [63]. Indonesia's health care system is a mixture of public and private health care delivery systems, with an increasing trend of the size and role of the private health care services. The government has introduced the National Health Insurance (NHI) program in 2014 to support equal access to basic health care services [14]. However, over the years,

the NHI universal health coverage has been unequally implemented in different regions.

Another consideration is the diversity in socioeconomic status (SES) that was indicated by different levels of educational background and income [14][64]. It is important to note that while some Indonesians have easy access to health services and facilities, others are at a disadvantage. It leads to the first challenge of data collection for process mining studies. Even if health care data of the whole country can be collected, some health care services might not be utilized in some regions, not because there were no casualties in those areas but because of the limited access to health care services and facilities.

The diversity of health care providers could also be challenging in some ways, especially when creating conclusions after conducting the process mining analyses using hospital's data. The size of the hospital and the complexity of the process can be determined from the classification status. Hospitals in class-A categories are more likely to have more variations compared to the other classes. The number of specialist services is higher than the hospitals in class B, C, or D. Patients under the care of hospital in class-A may have a better chance to receive treatment from specialist services. Thus, patients admitted in lower class hospitals will require referral to receive certain specialist services only available in the class-A. The obtained results from class-A hospitals could not be used to represent hospitals in general. Another challenge is the patient's movement between hospitals to seek treatment that is suitable for them. The event log of a patient hardly contains a complete sequence of treatment.

4.2. Data Quality

Weiskopf and Weng [65] introduced five common dimensions of health care data quality, which are: completeness, correctness, concordance, plausibility, and currency. Those five dimensions can be used to (1) measure suitability of health care data, (2) make sure that the data represent the complete truth about the patients, (3) agree between elements in the EHR and other data sources, (4) are making sense from the domain knowledge, and (5) are representing the patient state at a given point in time.

Care pathways can be found in each local hospital or other health care providers, thematically for a specific disease, or nationally in a data repository collected by a specific health care government institution. Some studies have been done to analyze care pathways of patients locally in Indonesia hospital [37][39][41] or thematically for a specific disease [47][66][67]. However, to the best of our knowledge, none has been done in national or country-wide health data. In terms of process mining studies, country-wide health data are potentially useful to ensure better data quality, specifically in the aspect of completeness.

There are initiatives to collect country-wide health care data in Indonesia that are potentially useful for a secondary analysis based on process mining approaches. First is the Indonesia Family Life Survey (IFLS) [68]. The IFLS is a survey in Indonesia which conducted in a longitudinal fashion. The survey is known to have a large collection including self-reported assessments including biomarker assessments, pain, symptoms, pattern of physical workouts, chronic conditions. The second initiative is a sample dataset collected by the Indonesia Social Security Agency for Health Care (*Badan Penyelenggara Jaminan Sosial/ BPJS Kesehatan*) [53]. *BPJS Kesehatan* focuses on organizing health insurance programs in Indonesia, which covered more than 217 million members (81.8% of Indonesia citizens) in 2019 [69]. The Health Care BPJS data center provides open-access data to be used by regional governance, other institutions, researchers, and policy

makers. The dataset consists of a sample of health care variables during 2015-2016.

Both IFLS and *BPJS Kesehatan* data are less likely to have enough detail for process mining study, especially on the presence of timestamps. Process mining analyzes rely on timestamps to identify the sequence of activities. Thus, the missingness of timestamps should be handled carefully to maintain the results to stay in quality. Another issue is that the patients' treatment data in primary and secondary health facilities are separately available. This can be addressed by linking the two separate data to obtain richer end-to-end analyses.

4.3. Ethics

Before any research can obtain access to the required data, two things are required: an ethical clearance from the respective ethics commission who is also the data provider and permission from the health facility to use the data. There are variations between hospitals regarding the administrative processes and the time it takes to get permission.

The next concern to be taken care of when retrieving data at a hospital is regarding the type of data. The available data might be in the manual form, either in a printed form or handwritten document, so researchers must invest more time to look through the medical records and key in the data into a digital form. One particular concern is when handwritten data are hard to read, this may reduce the quality of the produced data.

Patient consent can be neglected if secondary hospital data are used. In the event of researchers need primary data through direct interviews with the patients, then patients' consent is required.

Internationally, ethical issues regarding the secondary use of health data are regulated based on the Declaration of Helsinki (DoH), developed by the World Medical Association (WMA) [70]. The DoH is a statement of ethical principles for medical research involving human subjects. Based on the DoH, medical research involving human subjects is conducted to promote better medical care. Medical research should follow ethical standards respecting all human subjects and their health and rights. In Indonesia, health research has been regulated by the Health Minister Decree Number 7/ 2016 [71] on the National Health Research and Development Ethics Committee. This decree required health research to apply principles of good research governance, which are respect for persons, beneficence, non-maleficence, and justice. The National Health Research and Development Ethics Committee (KEPPKN) assists the Minister in regulating, fostering, and enforcing research ethics and health development. Locally, the health research ethics committee in every health research institution adheres to the Decree of the Minister of Health of the Republic of Indonesia Number 1031/Menkes/SK/VII/2005 [72] concerning National Guidelines for Health Research Ethics.

4.4. Security

The concern of protecting personal health data is growing as displayed by the increasing number of countries who introduce their regulation. There are the Health Care Insurance Portability and Accountability Act (HIPAA) from the USA [73], the General Data Protection Regulation (GDPR) in the EU [74], the Australian Privacy Act in Australia [75], and the Advisory Guidelines for the Health care Sector in Singapore [76].

Such regulation in Indonesia is still distributed in 30 different ordinances [71]. At the time of writing, a bill of personal data protection is under discussion in the Indonesian Parliament. The bill contains the amalgamation of the existing 30 ordinances including the protection of patient and healthcare data [72].

According to a report by the Indonesia National Cyber and Crypto Agency (BSSN), the security index of the health sector's information system (*Keamanan Sistem Informasi/ KAMI*) in 2018/2019 is measured as "not feasible" [77]. The KAMI index is a tool to evaluate the readiness level to secure information in an organization by measuring seven parameters. Among them, three out of seven areas of evaluation with the lowest average score. The three areas are risk management of information security, information security framework, and information security governance. For the full report and understanding of the KAMI please see [77].

As a protection to the healthcare data including the data privacy, there is a proposed framework to keep the data secure while conducting process mining [78]. By providing an adequately secure research environment will minimize the risk of the data being stolen.

5. Potentials of Process Mining Implementation

5.1. Care Process Comparison

Delivering care processes requires a multidisciplinary collaboration among entities within the health care provider. Patients with similar conditions are likely to be treated similarly. Using process mining, the delivery of care for a specific disease between two or more healthcare providers is comparable and enables the clinicians to see the whole process and the outcomes, which may encourage better care [79]. Care process comparison can also be used to analyze changes over time [80].

Despite the growing number of process mining studies in health care [81]–[84], any study using the Indonesia health care data is still interesting for exploration. Looking at the broad spectrum of the health care practice in Indonesia and the wealth of data, the study will bring benefit in many aspects, such as identifying the patterns of service, duration of care processes, the differences of care processes including the respective outcomes.

Process mining analysis based on specific diseases has been used and shows some interesting topics. Process mining analysis using cardiac data from a hospital in Egypt reveals the patient's journey from admission until discharge through many different specialist services [85]. In the domain of diabetes, process mining is used to predict the mortality of ICU patients using readily available data from Medical Information Mart for Intensive Care III (MIMIC-III) [86]. Process mining was also used to improve the prediction of ICU patients diagnosed with paralytic ileus 24 hours after admission [87]. Hospital expenses for chronic renal failure patients can be predicted using process mining [88]. More examples of process mining analysis in various domains be found from the initial literature review [89] until the most recent literature review [90]. Researchers in Indonesia could learn from the previous works and reproduce the same analysis but using the Indonesian dataset.

5.2. Human Biology in Indonesia and Precision Medicine

Process mining may also help in identifying the common characteristics of patients based on many different aspects (e.g., age, sex, location, etc.). One characteristic that can be identified is the common pattern of disease sequences among patients, also known as the disease trajectories [91]. The common

trajectories provide information on how diseases progressed temporally for each patient. This information becomes a valuable source for clinicians to design interventions for their patients so any potential diseases that may come afterwards can be avoided.

The disease trajectory study has been incorporated to support the development of precision medicine [92]. With the potential of becoming the largest single-payer health insurance in the world, identifying the common disease trajectories using Indonesia's nation-wide EHR may improve the capability of the pharmacy industry in developing the medications that are specific to the characteristic of the Indonesian population.

5.3. Audit and Compliance

The conformance-checking feature of process mining has been adopted to identify how the actual care processes deviate from the established guideline standards [93]. Following the vast area and the variety of health care providers in Indonesia, monitoring the establishment of standards in each health care provider may turn out to be challenging.

By examining the evidence that is available in the EHR, the monitoring process can be done electronically and remotely. Electronic data can be made available for limited access in the event of the auditing process. With the process mining equipped in the health information system, monitoring care processes can be done in a more efficient way.

5.4. International Comparison

Process mining is supported by a rich collection of tools from both open-source and propriety tools. It widens the opportunity of conducting comparison studies around the world. The comparison of the acute-myocardial-infarction (AMI) survival between the UK and Sweden helped in improving the policy of AMI survival of both countries [94].

In terms of the actual care, the comparison of care processes from three different countries may involve the outcome variable to see the effectiveness of the interventions [95]. Another potential of doing the comparison is opening more research fields to be explored.

The Indonesia BPJS Kesehatan data set contains distinct Indonesia human-biology and may attract collaboration of comparison studies. One of the challenges in the comparison study is finding comparable data within the participating countries. Having the population wide EHR and the accessible tools could increase the chance of Indonesia being involved in international comparison studies. Using the range of international comparisons may help in understanding the quality of healthcare services. Furthermore, a comprehensive report for a certain disease from the perspective of process mining can be created and will be updated annually.

5.5. Virtual Research Environment

Conducting research using a large scale EHR is considered to have many benefits, including the cost-effectiveness and the only chance to get samples that representatively adequate [42]. Looking at the size of the BPJS Kesehatan dataset and adopting the comparative illustration by Hemingway et.al [96], we placed the Indonesia BPJS Kesehatan as the largest population based EHR (Figure 1).

Having the collection of a massive population-based health care data will allow numerous opportunities for research. To store and process such a massive dataset for research will require adequate computing power. A Virtual Research

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Environment (VRE) has the potential to be one of the many solutions to manage research activities using a large dataset. One example of VRE for biomedical research is the CRISTAL software that can support collaborative and reproducible research work powered by the Grid or Cloud computing [97]. The VRE may support cost effective research projects to promote innovations as collaborative work is made possible.
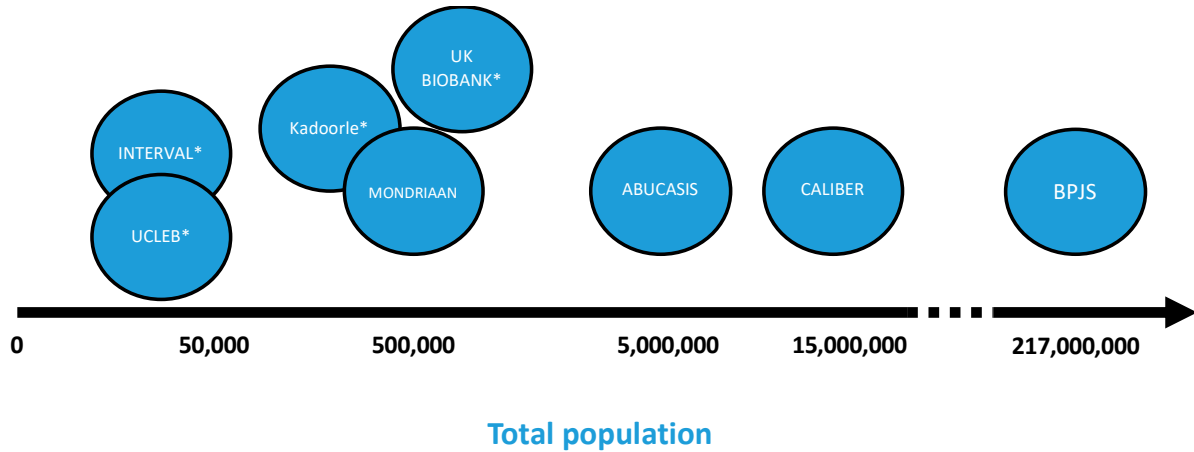

Total population

Figure 2 Size comparison of Population Based EHR (redrawn from [96]).

6. Conclusions

In this article, we have reviewed a limited number of pieces of literature on process mining implementation for Indonesian health care. It can be seen as a great opportunity for researchers to explore more in this domain. The healthcare system in Indonesia is dynamically evolving and has not reached its mature point yet. Therefore, innovations based on a process-mining approach are needed to improve the quality of care. Process mining is relatively new in Indonesia and these challenges and potentials can be used as a guideline to conduct process mining analysis specifically for Indonesia health care.

The rich source of datasets and the massive amount of data can play an important role in continuous improvement. The knowledge in the domain of Indonesian health care is still relatively untapped knowing that the distribution of health care service into more than 17,000 islands is still not optimal.

A population-based EHR, if properly managed and utilized could bring a valuable improvement in understanding the current healthcare processes, disease comorbidities and classification, and bring contribution in more pragmatic solutions to process-oriented healthcare difficulties. Despite the positive benefits, the challenges need proper addressing to allow more conceivable results and quality.

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