University of Twente

Process Mining in Healthcare: Gaps between protocol and clinical practice of critical side findings in radiology

Master Thesis

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The completion of this thesis is the end of my study at the University of Twente. A year and a half ago, I started the pre-master in a period where I took care of my terminal mother. It was a rollercoaster full of emotions, but I still managed to complete my courses.

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Lastly, I would like to thank the interview respondents that have made this thesis possible.

Abstract

All hospitals are forced to reduce costs while improving the quality of healthcare. Protocols have been drawn up in order to improve healthcare processes based on the most advanced knowledge and practice. According to the literature, various factors cause deviations from the protocol, but to date, there is no research into these deviations within the process of critical side findings in radiology. Therefore, the following research question has been formulated: *What is the adherence to protocols in critical side findings processes in radiology?* The processes are divided into acute and semi-acute, and in non-acute critical side findings.

To analyze these deviations, a case study was conducted at two Dutch hospitals. This research is conducted according to the FRAM method and uses three data sources. The work-as-imagined was based on the protocols and guidelines. Subsequently, process mining analyzed the adherence to the protocol. Ultimately, the influencing factors were identified by semi-structured interviews.

Process mining shows that the protocol deviations are workarounds. The documentation of communication is omitted, and many findings are not followed up. Process mining shows a global view of the processes but does not show the causes and consequences. Therefore, process mining cannot be used as a sole method for gaining an in-depth view of healthcare processes. To optimize healthcare processes, it is crucial to conduct qualitative research.

Various factors explain workarounds. Medical practitioners omit the documentation, as they do not consider it relevant to patient care. The confirmation of communication is also interpreted differently by each polyclinic. Problems that appear in the follow-up of critical side findings are mainly caused by the lack of a protocol and the fact that medical practitioners perceive no clear responsibilities.

The factors lead to a model, which visualize the relationships between the factors and the workarounds. The factors are divided into organizational, personal, and patient-related. The organizational factor, lack of personnel, causes that activities are carried out by unauthorized medical practitioners. The second organizational factor is the lack of the polyclinic’s understanding of the IT applications. This dearth of knowledge obstructs the third organizational factor; the adoption of IT. In addition, the personal factor, lack of perceived relationship between the protocol and patient health, causes workarounds to bypass administrative activities. The patient-related factor, exceptional patient symptoms, causes those critical side findings are not communicated if follow-up does not stimulate health.

The results of this study emphasize the importance of a reduction in the administrative burden on medical practitioners: identify the critical activities and eliminate unnecessary activities. Future research should focus on smart technologies for administrative activities to reduce effort.

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1 Introduction

Hospitals experience income reductions but are forced to improve their quality. Moreover, hospitals are forced to implement clinically responsible, cost-effective interventions. A new approach, called Safety II, is introduced to improve the quality and safety of patients (Hollnagel et al., 2015). Safety II focuses primarily on methods and activities that are effective in a process under varying conditions. It is assumed that the variability in care provides insight into the adaptions that are needed in the treatment of exceptional cases (Hollnagel, 2018). The purpose of this approach is that an explanation of how things go right; things are going wrong are also explained (Damen et al., 2018). This need has ensured that continuous worldwide research is conducted to improve the quality of healthcare and, reducing its costs. More effective managing processes in healthcare could aid these goals of better and cheaper healthcare (Helfert, 2009).

Healthcare processes are medical treatment processes that aim to improve a patient's health, while organization processes are focused on administrative activities (Kaymak et al., 2012). Medical treatment processes are carried following protocols that have been drawn up based on literature studies, discussions among medical practitioners and scientific research. A protocol describes which actions must be performed to achieve a specific result (Damen et al., 2018). It goes without saying that these guidelines must be realistic and feasible. Differences between protocols and the clinical practice are known as gaps, and often caused by workarounds. Explaining and managing these gaps and workarounds comprises a crucial challenge for healthcare.

Lack of understanding processes results in poorer process outcomes (Hysong et al., 2005). In the past, several techniques have been used to analyze healthcare processes, such as business process redesign, evidence-based medicine, and process mining (Rojas et al., 2016). This paper focuses on process mining. Through process mining, hospitals can scrutinize their *in situ* processes, verify whether protocols and guidelines were followed and gain insight into bottlenecks, allowing them to redesign a process if needed (Kaymak et al., 2012). This technique extracts knowledge from event logs based on the data available in the Hospital Information System (HIS). The HIS includes all databases, systems, protocols and events within a hospital. Several studies have applied process mining, yet they did not explain the gaps.

According to previous studies, there are various reasons why medical practitioners do not adhere to the protocol. For example, in medical treatment processes, clinical decisions for various patient-related aspects can differ. In addition, education, previous experiences and background can also influence the clinical decisions that are made. Furthermore, workarounds can arise in the interest of the medical practitioner. However, gaps and workarounds can influence the outcomes of the process. Therefore, it is important to analyze reasons for these gaps and workarounds.

According to Towbin et al. (2011), gaps between protocol and clinical practice in the field of radiology are mainly caused by poor communication. The communication and classification of diagnostic radiology are crucial in transferring critical patient information to the relevant medical practitioner (Tiwari et al., 2017). Certain findings from diagnoses can be urgent and can require immediate attention (McElroy et al., 2013). If this is not done correctly, the patients' wellbeing can fall victim to medical errors and patient harm.

This research aims to identify the gaps between protocol and clinical practice in the field of radiology by using process mining. Subsequently, the factors that explain these gaps need to be investigated. Based on this aim, the following research question is formed: *What is the adherence to protocols in critical side findings processes in radiology?* Critical side findings are unexpected findings where delays in reporting or lack of reporting may result in adverse consequences for the patient.

To answer this research question, the protocol must first be described. Based on this protocol description a model is created, to which process mining is then applied. The application of process mining provides insight into the extent to which the data from clinical practice correspond to the protocol. In order to explain the gaps and workarounds, various employees involved in the process will be interviewed.

Most process mining studies only focus on process discovery, conformance and enhancement. It is arguable that process mining is a valid method to optimize complex healthcare processes. Therefore, this research focuses on combining process mining with qualitative research to be able to conclude if process mining is an effective method for process analysis in healthcare. Additionally, this study extends on previous literature by analyzing influencing factors in a decade in which medical practitioners are more often expected to document in the HIS. This study also extends previous literature because process mining has not yet been applied for critical side findings in radiology.

We aim at multiple practical contributions. First, process mining shows if hospitals are adhering to their protocols. This information can be used for inspection purposes. The combination of process mining and qualitative research will thereby give an in-depth view of the process. This view can hereafter be used for process optimization. In addition, this study shows if process mining is a useful tool to visualize a healthcare process. These results may be used for lifetime monitoring that could decrease incidents.

2 Theoretical framework

Before describing the research methods, it is important to conduct a literature review on the topic of processes in general and processes in healthcare. Appendix A describes the literature research method. Section 2.1 describes the concept of process and process management. Subsequently, the literature review narrows down at processes in healthcare in section 2.2. The various process analyzes are then described in section 2.3. Section 2.4 describes the theory of workarounds, and section 2.5 describes the factors causing the gaps and workarounds.

2.1 Theory of process management

According to Davenport and Short (1990), a business process in an organizational setting is a set of logically related tasks performed to achieve a defined business outcome. However, Hammer and Champy (1993) emphasize that a business process ultimately creates an output that is valuable for the organization by adding value to the end customer. Business processes can be influenced by actors, such as customers and suppliers.

Business processes can be distinguished into managing, operating, and supporting processes (Armistead et al., 1999). The managing type of business process concerns all strategic and tactical planning of activities (Childe et al., 1994). It concerns all management activities that convert business and environmental information into strategies, goals and performance measures. Support processes concern all activities that are carried out to support the operational processes. For example, this entails HRM activities and marketing activities. The operating processes are a set of activities that ultimately converts the customer's needs or wishes into a service or product. For example, the production, delivery and installation of a product.

Business processes are cross-functional, and often there is not one single person responsible for the entire process. Elzinga et al. (1995) define Business Process Management (BPM) as 'a systematic, structured approach to analysis, improve, control, and manage processes to improve the quality of products and service' (p.119). Quality means the extent that the product or services meet the established specifications and client expectations (Dotchin & Oakland, 1992). Zairi (1997) emphasizes the analysis and continuous improvement of all activities within a company. However, the demand for BPM is emphasized by growth in complex environments where costs, quality and adaptivity are becoming increasingly important (Caputo et al., 2019). A business process can be divided into sub-processes, which consist of a subset of activities (Dani et al., 2019). However, it is crucial to optimize the information flows and to eliminate activities that do not add value (Klun & Trkman, 2018). In short, the main strands of BPM are structural analyzing activities and processes to improve them continuously.

There are a few requirements to ensure the successful implementation of BPM. First of all, business processes must be able to be measured (Armistead et al., 1999). Secondly, it must be documented how processes should be carried out to ensure consistency and discipline. According to

Harrington (1995), critical processes must be defined, and process owners should be designated. Also, employees must be empowered to find the most efficient and effective way to carry out and improve their activities (Prior-Smith & Perrin, 1996). The employees and process owner should continually monitor the process and search for potential improvements (Lee & Dale, 1998).

A study by van Assen (2018) demonstrates that the implementation of BPM results in operational performance. However, several studies show that there are challenges and issues potentially hampering the implementation of BPM. A study by Lee and Dale (1998), the characteristics of the activities of the actual processes were not documented. In addition, the employees suffered an excessive workload, meaning they did not have the time to improve processes.

Incorrect implementation of BPM causes employees to deviate from the process. Deviations could be divided into conscious and unconscious (Andrade et al., 2016). Conscious deviations lead to positive effects on further activities in the process. On the other hand, unconscious deviations lead to negative consequences on follow-up activities and the process outcome. Unconscious deviations are often characterized by forgetting particular activities.

Furthermore, the collaboration between IT and the management department appears to be the biggest challenge in BPM. A weak alignment between the two departments causes misunderstanding (Khaiata & Zualkernan, 2009). Similarly, according to research from Luftman (2003), IT employees know too little about management, and management employees know too little about IT. In addition, collaboration is hampered by different cultures and skills. Either way, the implementation of process management can be influenced by organizational and environmental actors (Heravizadeh et al., 2008).

2.2 Theory of healthcare processes

Business processes are every set of activities organized by people, materials and procedures to reach a specific goal. In healthcare, the emphasis lies in the series of activities that focus on diagnosing, treating, preventing diseases, and aftercare, to improve health. These activities are carried out by all involved medical practitioners. Healthcare processes are complicated due to the extent of medical practitioners involved, various circumstances, and various outcomes (Homayounfar, 2012; Kaymak et al., 2012). For example, a patient's treatment plan deviates from protocol when the treatment needs to be tailored to patient-specific needs, named personalization (Hawe et al., 2009; Zhang et al., 2005). The variability of these processes concerns the process variability (Molnau et al., 2001).

Healthcare processes can be divided into medical treatment processes and administrative processes. Medical treatment processes are operating processes, and the administrative processes are supporting processes. The medical treatment processes are specified to observation, reasoning and treatment, comprising every step in the process of treating a patient's ailments (Kaymak et al., 2012). This process starts with observing the patient and determining the treatment based on medical history and symptoms.

The administrative processes concern the division of labour, work planning, and preparations for an operation (Kirchner et al., 2012). These processes can be divided between elective care and acute care. Elective care processes are activities that can be planned, while acute care processes include activities that must be undertaken immediately.

Protocols have been drawn up to improve process outcomes in healthcare. A protocol is a document to support care providers, enabling to carry out all the actions involved in the process (Kirkpatrick & Burkman, 2010). Protocols are based on literature studies, discussions among medical practitioners, and healthcare scientists (Chassin et al., 1986). Patient safety is central to the preparation of a protocol. Patient safety concerns the prevention, reduction and analysis of medical implication that leads to undesired harmful effects (Fadahunsi et al., 2019). Despite economic factors not being taken into account while developing the protocol, several studies show that their implementation ultimately results in lower costs (Darmstadt et al., 2005). However, every hospital has to adapt the protocol to environmental factors (Reichert et al., 2005).

BPM is also implemented in healthcare to streamline services and processes. Research by Kohlbacher (2009) showed that BPM increases transparency, leads to clear responsibilities, and improves productivity. For example, a case study by Buescher et al. (2004) showed that the implementation of BPM had reduced the residence period in the concerning hospital by 33 per cent. BPM can analyze clinical practice to measure waiting times, identify bottlenecks in the process, and to predict treatment methods based on previous data (Rojas et al., 2016).

The process observations, named clinical practice, is collected in the HIS (Homayounfar, 2012). The HIS covers all computer systems and networks that are used within a hospital. Every activity in a hospital that is carried out by a person is registered in the HIS. It is necessary to optimize the HIS to integrate digital data into facilities and equipment for interdepartmental treatment processes.

2.3 Theory of process analyzes in healthcare

In the past, the methods business process redesign, evidence-based medicine, lean and process mining have been used to analyze healthcare processes. Business process redesign focuses on redesigning the process to reduce costs and increase efficiency. The application of recurring redesign practices is central during business process redesign (Jansen-Vullers & Reijers, 2005). The second method, evidence-based medicine, is a method used to optimize decision making in medical treatment processes based on scientific research (Woolf et al., 1999). The third method, lean, is a management method based on the continuous improvement of business processes by increasing their quality or reducing activities that add no value (Radnor et al., 2012). However, these methods are not aimed at analyzing clinical practice compared to the protocol. This research paper focuses on the fourth method, process mining, which is a relatively young method aimed at analyzing processes based on data from the HIS.

Process mining is increasingly feasible in healthcare due to an increase in data used for process discovery, process conformance and process enhancement (Rojas et al., 2016). The data are extracted into event logs to apply process mining. Several studies analyzed whether the clinical practice was in accordance with the protocol (Erdogan & Tarhan, 2018). In most studies, the protocol is translated to a Petri net, which visualizes the workflow from start to end. Based on the Petri net, the event logs can be compared to the protocol to check conformance and to identify bottlenecks.

Several points need to be considered before applying process mining. There is no general solution to apply process mining (Rojas et al., 2016). Research should be done on how process mining can be applied in the current HIS in a straightforward way, but without the necessary knowledge of process mining techniques and algorithms (Santos et al., 2013). In addition, process mining tools lack a clear visualization of the processes and their results, especially in complex processes like healthcare (Islam et al., 2018).

The most used tool for process mining is ProM. Yasmin (2019) conducted a study about the state of the art practices in the process mining field, which led to different insights. Novice process mining users will encounter an infinite number of ways to apply process mining. Research by Yasmin (2019) indicates that higher ease of use ultimately leads to higher perceived usability. For this reason, the Eindhoven University of Technology has set up a free four-week online course that provides insight into various interfaces and plug-ins in ProM. However, limited attention is given to user-friendliness and information on how to carry out a complete project.

The data collection and preparation are also a challenge for process mining in healthcare. In previous case studies, missing values and outliers were eliminated (Islam et al., 2018). However, these data are precious while extracting information about unique diseases or exceptional cases. Researchers should include outliers and find a better method to estimate missing values rather than eliminating them. In addition, studies should include knowledge of medical practitioners for the integration of process mining in actual work environments (Duan et al., 2011).

Researchers argue about the shortcomings of BPM and process mining. An ontological analysis of BPM and business process modelling shows that the lack of ontological completeness leads to problems for the usage of BPM and business process modelling (Recker et al., 2005). Ontology concerns the nature of the world and attempts to describe what exists in terms of the characteristics of, and the interactions between real things (Shanks et al., 2003). However, research by Recker et al. (2005) states that the usage of a Petri net achieves a high degree of ontological completeness because of its flexible usability. Limited research is done to review evidence and validity of its ability to improve healthcare processes. In short, process mining is a promising method to integrate into healthcare. However, process mining must be accessible and easy to use for medical practitioners, its data quality and preparation must be improved, and specialists must be involved in order to integrate process mining into hospitals.

Alternatively, the Functional Resonance Analysis Method (FRAM) focuses on identifying risks and explaining emergencies by analyzing the influence of process variability. During studies in the aviation sector, the perceptions and attitudes of the cockpit, ground crew, crew and the mutual relationships were examined (Hollnagel, 2012). Accordingly, safety indicators that should prevent such emergencies in the future were drawn up. The main drive behind the FRAM is unfolding and managing the performance of certain processes in complex and dynamic structures (Patriarca et al., 2020).

The aim of the FRAM are divided into retrospective and prospective. Retrospective FRAM obtains insight based on previous data, while prospective FRAM identifies risks (Patriarca et al., 2020). In most cases, the FRAM is performed after a calamity, in order to find out what went wrong and to prevent this from happening in the future. The application of the FRAM consists of four steps. The first step describes the system functions, the second step identifies the potential variability, the third step defines the functional resonance, and the fourth step monitors the resonance and mitigation. However, the fourth step was not performed in 45% of previous FRAM applications (Patriarca et al., 2020). It is necessary that the influencing factors of each activity of the process are analyzed.

Data collection could be done via investigating reports, surveys, protocols, interviews, and observations. There is no universal solution of FRAM because it can be used for a wide range of purposes. More than 50% of the FRAM studies have three or more data sources (Patriarca et al., 2020).

In healthcare, the FRAM is used to redesign processes, identify essential functions, and to compare clinical practice with the protocols. A study by Clay-Williams et al. (2015) shows that the use of the FRAM in healthcare results in alternative solutions to specific working methods, while improving safety and quality. Furthermore, the FRAM was used to map emergency care pathways, which showed that it was complicated to map the worst-case scenarios. In addition, a study by Pereira (2013) shows that even simple activities in a complicated situation could have very undesirable consequences.

However, the studies focusing on comparing clinical practice to protocols, were only conducted by consulting the protocols and conducting interviews. For this reason, there is a gap in the literature. At present, no research has been conducted in which clinical practice was quantitatively analyzed (Damen et al., 2018; Schutijser et al., 2019). This case study investigates whether process mining can be used in combination with the FRAM to analyze healthcare processes.

To sum up, the FRAM focuses on analyzing the variability of process activities that result in calamities and risks, while BPM focuses on streamlining processes to improve their quality and reduce costs.

2.4 Theory of workarounds

A gap between protocol and clinical practice may result in not delivering appropriate care (Ebben et al., 2013). Research by Donnellan et al. (2013) shows that the adoption of protocols has a positive impact on the effectiveness and quality of healthcare. Also, protocols are made to reduce variation by providing recommendations on the best scientific researches and practices (Slade et al., 2016). Gaps are closely related to workarounds. Workarounds can be seen as a method to accomplish something that the system does not let you do easily (Ash et al., 2003). Equally, Kobayashi, Fussell, Xiao and Seagull (2005) define workarounds as ‘informal temporary practices for handling exceptions to normal workflow’ (p. 1561). The most comprehensive definition of workaround comes from Alter (2014), who describes a workaround as a goal-driven adaptation, improvisation, or other change to one or more aspects of an existing work system in order to overcome, bypass, or minimize the impact of obstacles, exceptions, anomalies, mishaps, established practices, management expectations, or structural constraints that are perceived as preventing that work system or its participants from achieving the desired level of efficiency, effectiveness, or other organizational or personal goals (p. 1044).

A workaround represents a gap in the protocol and guidelines (Halbesleben et al., 2008). However, this does not mean that the output of the process is adversely affected. In some cases, a workaround improves output (Warren, 2003). Thus, workarounds are similar to gaps, but are motived to bypass activities in order to complete a task. Also, the definitions in the literature make little distinction between workarounds and gaps. Table 2.1 shows an overview of various workarounds.

Processes	Doing the work differently (skipping, adding steps)
Participants	Assigning different practitioners to do the work
Information	Doing work with different information
Technologies	Working around bugs
Services	Service deviates by expectation from customer and management
Customers	Withhold products/services from customer to minimize work
Environment	Workarounds depending on the situation, like emergencies
Infrastructure	The bypass uses of infrastructure

Table 2.1 Workarounds (Alter, 2014)

Current research into healthcare workarounds is mainly conducted in the Electronic Health Record (EHR) protocol (Rushton & Stutzer, 2015). Research by Halbesleben et al. (2013) shows that nurses consider the new electronic medication administration record an obstacle because they find the system inefficient. New information systems can be seen as bottlenecks in the workflow due to inefficiency, low user-friendliness and limited training (Mula et al., 2019). For this reason, practitioners look for alternative methods to achieve their goal. The factors that can cause workarounds are closely aligned with the factors described in section 2.5. On the other hand, workarounds allow medical practitioners to develop more effective processes and creative solutions (Lalley & Malloch, 2010).

While workarounds in healthcare reduce complex tasks, they can eventually lead to an increase in medical errors (Yang et al., 2012). Crucial activities or steps may be removed from a part of the process, which may put the patient in harm. For example, workarounds can lead to medication being administered to the wrong patient or in the wrong doses (Halbesleben et al., 2008). However, some workarounds only have an impact after a certain period. For example, in one case, the medical practitioner found that a patient had a swollen foot (Blijleven et al., 2019). ‘Swollen’ or ‘swelling’ gave no results in the system, so he eventually ticked ‘arthralgia’. Thus, this workaround allowed the physician to progress further into the system. However, the system does not provide a representative picture of the patient.

2.5 Theory of gaps between protocol and clinical practice

Understanding the reasons for the gaps and workarounds are one of the most critical challenges in healthcare (Bansal et al., 2012). Three different types of factors can cause gaps and workarounds, varying from personal, organizational and patient-related (Donnellan et al., 2013).

2.5.1 Personal factors

The first personal factor is a lack of agreement (Cabana et al., 1999). Medical practitioners may not agree with the protocol because they rely on their own experiences and their medical knowledge (Gagnon et al., 2014; Mahé et al., 2016; Mickan et al., 2011). In addition, medical practitioners may not agree when the protocol is not practical (Slade et al., 2016). Research by Cabana et al. (1999) shows that more than 10% of the respondents described the protocols as inconvenient or difficult to use.

The second factor is the lack of awareness and knowledge. 10% of the medical practitioners were not aware of the protocols, according to a case study from Cabana et al. (1999). Medical practitioners get an overload of information, which could be overwhelming in terms of reading and using it in practice (Slade et al., 2016). Also, a study by Donnellan et al. (2013) showed that some protocols were not clearly described.

The third factor is the relationship between protocol and patient outcome (Donnellan et al., 2013). A clear relationship between protocol and outcome is the strongest motivator for the medical practitioner to adhere to the protocol (Ebben et al., 2013; Slade et al., 2016).

The fourth factor is the lack of self-efficacy (Zwolsman et al., 2012). Self-efficacy concerns the belief that a person can perform a specific activity. Low self-efficacy may lead to limited adherence (Donnellan et al., 2013). Research shows that a lack of self-efficacy is commonly caused by a lack of education and counselling (Cabana et al., 1999).

The last factor is the belief of medical practitioners that the expected behaviour is not part of their job description (Mickan et al., 2011). The medical practitioner may deviate from the protocol if he is convinced that performing specific actions within the protocol is not his responsibility.

2.5.2 Organizational factors

Medical practitioners are also affected by organizational factors (Lau et al., 2015). These factors could eventually affect personal factors. The first factor concerns the degree of training and knowledge transfer between colleagues and management (Cabana et al., 1999). According to Gagnon et al. (2014), training and participation of medical practitioners were the main reasons for adherence to the protocol.

The second factor is the lack of time. Medical practitioners perceive that the time to adhere to the protocol could exceed the time that is allocated to a specific task (Slade et al., 2016). Research by Lam et al. (2016) shows that nurses deviate from the protocol because of a lack of time. Nurses indicated that they would prefer to have more time for the critical activities that are directly related to the patient (Lam et al., 2016). Healthcare management also experiences a lack of time for managing medical practitioners (Dulko, 2007).

The third factor is the lack of resources. It is not always possible to provide the required facilities because of the costs. Resources can be divided into various types, such as the amount of medical staff, medical equipment and surgery rooms. For example, the absence of the anesthesiologist may influence adherence to protocol because medical decisions are more likely to be made by an unauthorized medical practitioner (Cabana et al., 1999).

The fourth factor is the adaption of IT systems. The utility and ease of use can be a stimulator or a barrier (Gagnon et al., 2012). A medical practitioner may deviate from the protocol if he thinks that the activities of the IT systems offer no added value. Knowledge about IT systems must be optimally distributed to ensure effective IT adoption.

2.5.3 Patient-related factors

Clinical decisions are also affected by patient-related factors. In most circumstances, medical practitioners have to work with exceptional patient conditions. For example, adherence to the protocol may harm the patient if he has heart defects in combination with diabetes (Rovani et al., 2015).

The medical practitioner may deviate from the protocol when the patient does not agree. Patients can be resistant or not in need of protocol recommendations (Slade et al., 2016). In addition, medical practitioners can deviate from the protocol because of patients' previous experiences, fears, behaviours, family preferences, language barriers or cultural characteristics. (Slade et al., 2016). It must be borne in mind that the gaps in the needs of the patient can have a negative influence on his health. Table 2.2 summarizes the various factors influencing adherence to a protocol.

PERSONAL FACTORS	ORGANIZATIONAL FACTORS	PATIENT-RELATED FACTORS
Degree of agreement	Knowledge transfer	Exceptional patient conditions
Degree of awareness	Degree of workload	Degree of agreement patient
Degree of knowledge	Facility of resources	
Relationship between protocol and outcome	Adoption of IT	
Degree of self-efficacy		

Table 2.2 Factors influencing adherence

3 Methodology

The methodology starts from the point that the FRAM is the best method to get insight into the process. The FRAM is used in healthcare to redesign processes, identify essential functions, and to compare clinical practice with the protocols (Patriarca et al., 2020). This research focused on analyzing the clinical practice against the protocols, which is why not all steps of a standard FRAM application were performed.

The first step was to describe the functions by identifying all activities in the process. The protocols were analyzed and visualized in process models. The next step was to map the variability of the clinical practice with process mining. Process mining also analyzed the conformance and identified the gaps and workarounds. The last step was to conduct interviews to identify the factors influencing clinical practice. The implemented methodology is visualized in figure 3.1 below.

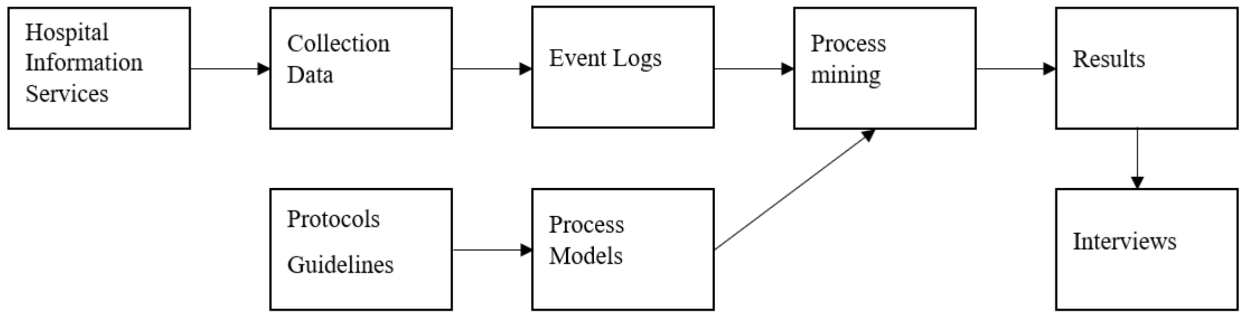

Figure 3.1 Methodology

3.1 Process Model

In the process model phase, a visual representation of the process from critical side findings in radiology was created using the clinical guidelines and protocols (Rovani et al., 2015). A Petri net has been used to visualize the process model. A Petri net (figure 3.2) contains four simple concepts, but still allows for complex constructs and also it has clearly defined semantics. For this reason, Petri nets are most commonly used for applying process mining, especially for analyzing conformance as described in subsection 3.2.3.

A Petri net is a structure consisting of a set of four parts, three of which are static, and one part moves through the other parts (Mans et al., 2008). The three static parts are places, arcs, and transitions. A place is indicated as a circle and may contain a token that moves to another place by executing actions. The transition in a Petri net represents an action that has been performed and is displayed by a box. An arc is indicated as an arrow and connects the places with transitions. The tokens are indicated as black dots in the places, which can be executed to the next part.

The Petri net also has three rules. Arcs can only go from place to transition and vice versa. Secondly, transitions 'fire' consuming one token from each incoming arc, and producing one on each outgoing arc. Lastly, the Petri has one start place and one end place. The goal is to get the token from the start place to the end place. To sum up, the Petri net is used to create the process model of the clinical guidelines and protocols. The Petri net was constructed in WoPeD (Workflow Petri Net Designer) because this software is compatible for with ProM, which will be explained further.

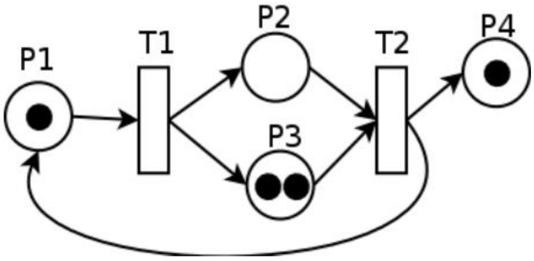

Figure 3.2 Petri net

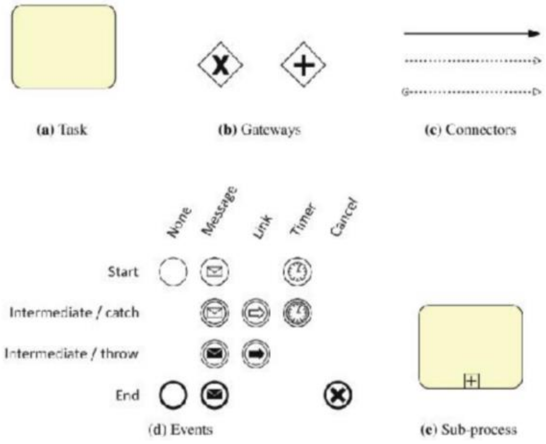

Figure 3.3 Components BPMN (Burattin, 2015)

Business Process Model and Notation (BPMN) is also widely used for process analysis. BPMN can visualize internal processes and communicate them in a simple manner (Burattin, 2015). Figure 3.4 shows an example of a BPMN model; the components of the model are visualized in figure 3.3. The difference between Petri net and BPMN is that the Petri net contains three static elements and therefore cannot be used to discover a process by data, while BPMN can be used for process discovery (Van Der Aalst, 2012).

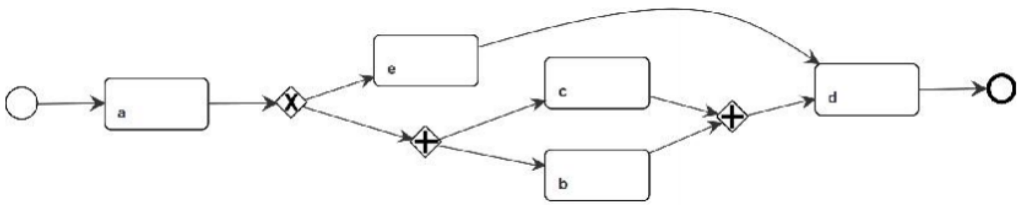

Figure 3.4 BPMN Model

3.2 Data analysis

3.2.1 Data extraction

Data were extracted from the HIS, including information about the patient's diagnosis, medications, and treatments established by different medical practitioners (administrative staff, nurses, physicians). Subsequently, the data were converted into event logs containing at least a case ID, performed activity, timestamp, and the relevant medical practitioner. Furthermore, the data were extracted as a CSV file for easy access and potential adjustments.

3.2.2 Event log creation

The data extracted from the HIS was called ‘raw data’. Then, the data were converted into event logs. Event logs contain information about the process activities, medical practitioners, timestamps, from the beginning to the end of a process. Figure 3.5 visualizes the process from raw data to event logs. The first step was to ensure that activities, resources, and timestamps match the case IDs to create events. Subsequently, the data were transformed into a structured table, making it easier to convert to event logs. The last step was to convert the CSV file to an XES file, making the event logs usable for process mining.

Figure 3.5 Event log creation

3.2.3 Process mining

Process mining is a relatively young method that focuses on extracting knowledge of data from information systems (Rojas et al., 2016). Process mining plays an important role between traditional process analyses and data mining. It allows for an objective view on clinical practice in contrast to traditional ways of process analyses (Mans et al., 2015). In addition, medical practitioners generally have a biased or limited view on clinical practice (Mans et al., 2015). Therefore, there is a growing demand for data scientists who can relate data to operational processes. This stimulates healthcare organizations to analyze their data in order to optimize their processes. As a result, process mining has received growing attention in the literature (Ghasemi & Amyot, 2016).

Process mining creates various opportunities to transform data in valuable information (Rovani et al., 2015). Process mining is mainly useful in healthcare because of an abundance of data in the HIS. In addition, data quality is expected to increase in the future, allowing process mining to play a more important role in healthcare (Rovani et al., 2015). Compared to many other sectors, there is a lot of room for improvements in healthcare processes (Mans et al., 2015). For example, process mining can identify the behavior of patients and resources to redesign processes. Process mining can also identify bottlenecks in the process.

Process mining can be divided into three types: discovery, conformance checking, and enhancement (Van Der Aalst, 2012). Process discovery was used to create an abstract model of a particular process using event logs. This model, therefore, describes the activities and their sequence. Process conformance checking analyzes how the actual clinical practice corresponds to the process models. Process enhancement focuses on analyzing turnaround times and identifying bottlenecks.

This research focused on analyzing conformance to map the gaps and workarounds. Due to an increase of attention from academia and industry, different software tools have been developed to apply process mining. The software tool ProM is used for this research. ProM supports various plug-ins that can be used for any type of process mining. Before the analysis was executed, filtering tools were applied to remove data noise.

The conformance is then analyzed using the Conformance checker tool. This tool evaluated the event logs based in the Petri net from WoPeD. Due to the characteristics of the extracted data, it was not possible to apply a resource analysis. The concerning medical practitioners were identified with a code, which could not be converted into the job description because of the General Data Protection Regulation (GDPR). Therefore, possible workarounds concerning authorizations of medical practitioners are analyzed by the interviews.

3.3 Qualitative research

Before conducting qualitative research among the personnel involved, it was crucial to identify the gaps. However, it was not guaranteed that there were gaps. The purpose of qualitative research was to identify the factors influencing the adherence to the protocol, and workarounds. Instead of conducting Critical Incident Interviews (CIT's), anonymous semi-structured interviews were conducted. In this study, a conscious decision was made not to perform CIT's because of ethical dilemmas. It was communicated to the respondents that the results of the interviews gave a more in-depth look at the clinical practice. Furthermore, it was communicated that the results might be used for process optimization.

This research focuses on conducting a small set of high-quality in-depth interviews rather than surveys aimed at generalizing observations. Many researchers recommend small samples to engage with the respondents and to maintain close interaction in a natural setting (Crouch & McKenzie, 2006). In addition, this research focuses on the factors that can influence behavior, rather than determining how often this occurs.

Three respondents were selected, based on the following criteria, 1) each respondent should be involved differently in the process of creating such a versatile view, 2) each respondent should be at least three years working in the hospital group. The topics discussed during the interviews were the influencing factors, communication, evaluation, implementation, bottlenecks, workarounds, and gaps from the protocol. The follow-up questions are dependent on the answers given by the respondent. The interview scheme can be found in Appendix B.

The interviews were conducted and recorded via Starleaf. Subsequently, the audio recordings were transcribed. However, the transcriptions resulted in lots of text, which needed to be analyzed. First, open coding was used to highlight and code essential quotations. Then, axial coding is done to interrelate the codes. Finally, selective coding led to a codebook in Appendix C. There was little variability in the results, increasing the reliability.

4 Case Study

This chapter describes the application of the methodology, as described in chapter 3. Section 4.1 explains the case and context. Subsequently, the process models are drawn up in section 4.2. Section 4.3 describes the data extraction and preparation. Based on the process models, data analysis is performed in section 4.4. Subsequently, the findings of the interviews are described in section 4.5.

4.1 Context

The methodology is carried out for the radiology department of a hospital group consisting of two hospitals with a catchment area of over 390,000 inhabitants. The group focuses on optimizing processes and increasing patient safety. The radiologist should ensure that the referrer has up-to-date knowledge of the critical side finding and document them.

Three different urgency categories can be distinguished in critical side findings. The first category, acute concerns findings that are potentially life-threatening and may necessitate an immediate change in patient policy. The second category semi-acute concerns findings that can result in mortality in the short term if no action is taken. The final category non-acute concerns findings that can result in morbidity if no action is taken but that are not directly life-threatening.

4.2 Process Model

Each urgency category has specific guidelines, making it impossible to work out one process model. The process models are based on four different guidelines and protocols:

- Guideline document National Association of Radiology (NVvR) from 2017, contains guidelines for the practical implementation of radiology in general
- the NVvR Critical Findings Guideline from 2016, which is aimed at the implementation of a system for communicating critical findings
- Protocol imaging techniques unexpected findings from 2020, descriptions of action, based on the national guidelines
- Record unexpected findings in the Healthcare Information X-change (HIX), work instruction from the hospitals from 2020, describes how critical side findings must be documented in the HIS.

The guidelines and protocols lead to two process models for medical practitioners. The first process model (figure 4.1) relates to the acute and semi-acute critical side findings because these are not distinguished in the protocols. The process starts with the referrer, who requests the diagnostic examination. The findings of the diagnostic examination are worked out after the diagnosis has ended. Since these findings require urgent action, they should be communicated to the referrer face to face or by telephone within 60 minutes. The date and time of the communication must be documented in the radiology report.

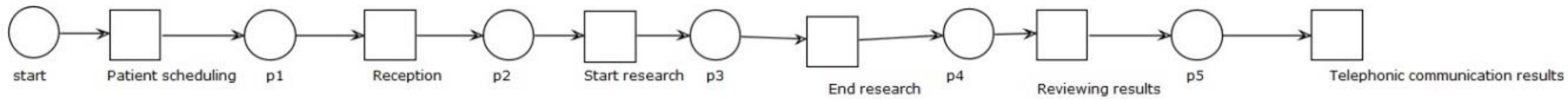

Figure 4.1 Process model urgency categories acute and semi-acute

The second process model (figure 4.2) concerns the non-acute critical side findings. The findings are incorporated into the radiology report and must be sent within three days. The referrer must be informed of the critical finding, which allows the referrer to tick the box after reading the report. The radiologist may also send the findings automatically from the Electronic Health Record (HER). The radiologist documents the follow-up in HIX. There are two other guidelines the two hospitals need to comply with. The waiting time between the referrer and the actual diagnostic examination should not exceed four weeks, and 90% of all reports should be available within 24 hours.

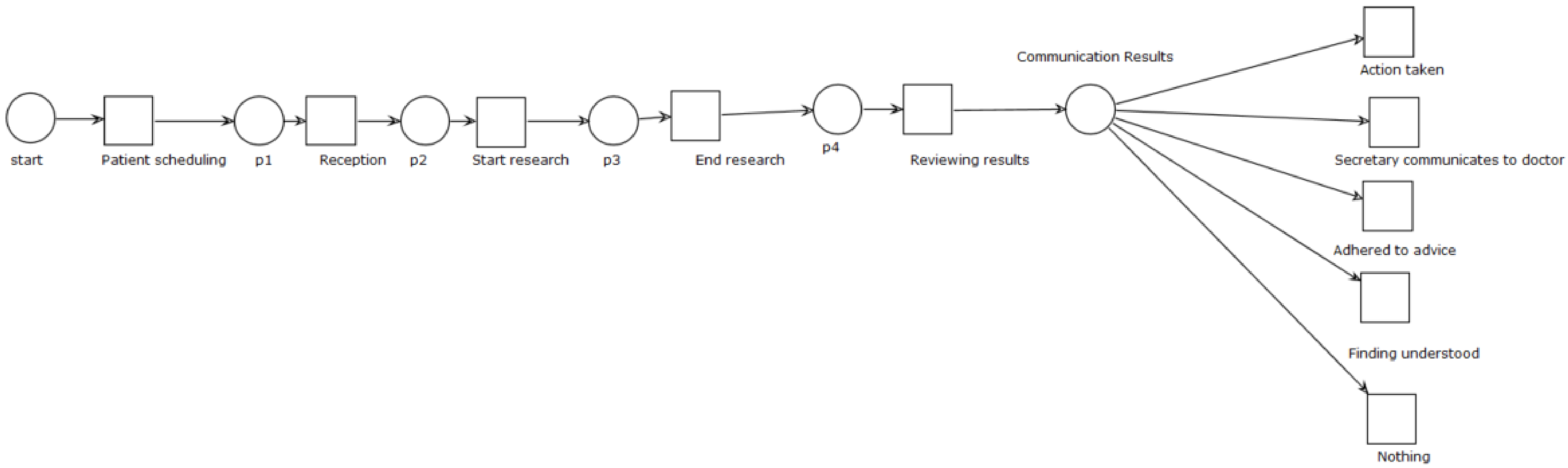

Figure 4.2 Process model urgency category non-acute

4.3 Data extraction and preparation

This section describes all the steps that are taken to execute process mining. Subsection 4.3.1 describes the data extraction, 4.3.2 describes the data preparation and 4.3.3 describes the data cleaning.

4.3.1 Data extraction

The required data were extracted from the HIX. The data came from various tables and information from critical side findings in the period from January first, 2019 to April 2020. Only necessary data were extracted, this excludes privacy-sensitive data. The period from January first, 2019 up to and including April 2020 was chosen because there were limited data available from the previous years. The raw dataset included 76 cases and was then exported to XLSX format. However, not all the necessary data were available to perform a conformance analysis. The sample size tends to be small, which may affect the statistical power. However, a small sample size is reasonable for specific purposes with data mining. According to Clifton (2000), small samples can be used for optimizing and visualizing specific processes. Currently, there is no rule of thumb for sample size in process mining.

The data for the first step of the process models ‘research request’ could not be found in the HIX. According to the document, Unannounced visit of critical radiology findings, carried out by the healthcare inspection, the hospital group does not have a standard format for applications for diagnostic research (Helthuis-Oude Groote Beverborg, 2018).

Furthermore, the extraction of the data showed that the urgency categories acute and semi-acute could not be distinguished in the HIX. As stated in the guidelines, communication of critical side findings must take place face-to-face or by telephone. This should also be stated after the conclusion in the radiological report; however, in all cases, this was not the case. On the other hand, it has been documented whether the referrer has read the results. If this has not been done, it is challenging to analyze whether and when the findings are communicated.

As stated in the literature, a gap may occur in favour of the patient. For this reason, it was examined whether new care programs have been started. Based on this information, it was analyzed whether the critical side findings are being communicated and followed up. New care programs were also extracted for the non-acute critical side findings.

Two datasets were constructed, the first dataset is related to acute and semi-acute critical side findings, and the second dataset is related to the non-acute critical side findings. The datasets were prepared in order to create event logs.

4.3.2 Event logs preparation & creation

The data were pseudonymized to ensure the anonymity of patients and medical practitioners. This was done by assigning a random number between 1111 and 9999 to each study. Table 4.1 displays an example of several columns in the dataset.

ONDERZDAT	CASE ID	SPECIALISM	INVOERDAT	INVTIJD	MUTDAT	MUTTIJD
2019-02-20 00:00:00.000	3377	RAD	2019-02-14 00:00:00.000	09:59	2019-02-20 00:00:00.000	15:24
2020-02-05 00:00:00.000	5574	RAD	2019-02-14 00:00:00.000	09:59	2020-02-05 00:00:00.00	12:23

Table 4.1 Fragment of the raw dataset

By creating a Case ID for the study, it was possible to identify each case for process mining. The datasets contained many columns that could not be traced back to assigning activities, which is why the columns were linked to activities, renamed and validated with the consultant. In order to create the different steps of the event logs, the columns were divided into separate worksheets in Excel. Furthermore, timestamps were constructed based on date and time. Table 4.2 shows an example of one activity.

CASE ID	ACTIVITY	TIMESTAMP	RESOURCE
4043	Start Research	2019-02-14 09:59	Secretary
8770	Start Research	2020-01-08 10:39	Secretary

Table 4.2 Example one activity

The datasets were exported to CSV files to create event logs in ProM. Table 4.3 shows an example of one case. As stated in the event log, there was no contact by telephone, and the email was not confirmed. However, a new care program was started. Contact has been made in some other way. In ProM, the CSV files were converted to XES files to be able to apply process mining. The XES file ‘Event log 1 and 2’ concerns the studies with acute and semi-acute critical side findings. The XES file ‘Event log 3’ concerns the studies with non-acute critical side findings.

CASE ID	ACTIVITY	TIMESTAMP	RESOURCE	LOCATION	SPECIALISM
1690	Patient Scheduling	2019-09-30 09:13	Secretary		
1690	Patient Reception	2019-09-30 09:13	Secretary		
1690	Start Research	2019-09-30 09:13	Radiologist	HE	CAR
1690	End Research	2019-09-30 09:34	Radiologist	HE	CAR
1690	Reviewing results	2019-09-30 11:11	Radiologist		
1690	Email Communication	2019-09-30 11:11	Radiologist		

Table 4.3 Event log example

4.3.3 Event logs cleaning

The event logs were cleaned via the Filter simple heuristics in order to remove cases that did not meet the requirements for process mining. In event log 1 and 2, cases were removed that did not start with the activity ‘patient reception’, ‘patient scheduling’ or ‘start research’. Eventually, 31 cases remained. In event log 3, 34 cases remained.

4.4 Data analysis

Subsection 4.4.1 demonstrates the results of process mining for the acute and semi-acute critical side findings. Subsequently, subsection 4.4.2 demonstrates the results of process mining for the non-acute critical side findings.

4.4.1 Acute and semi-acute critical side findings

First of all, the tool Interactive data-aware heuristic miner discovered the process to show possible gaps or workarounds. Figure 4.3 shows the discovered process model of the acute and semi-acute critical side findings. The model shows that communication by telephone is not documented. The documentation of ‘reviewing results’ and the ‘mail communication results’ is carried out simultaneously. This could be explained by the results being sent directly to the referrer if the findings are reviewed. It is also remarkable that new care programs have been started without having documented confirmation of the communication. Most worrying is that in some cases no new care programs have been started, while a critical side finding requires immediate follow-up. However, this does not mean that the critical side findings are not followed up. The findings may have been followed up within the referrer’s care process.

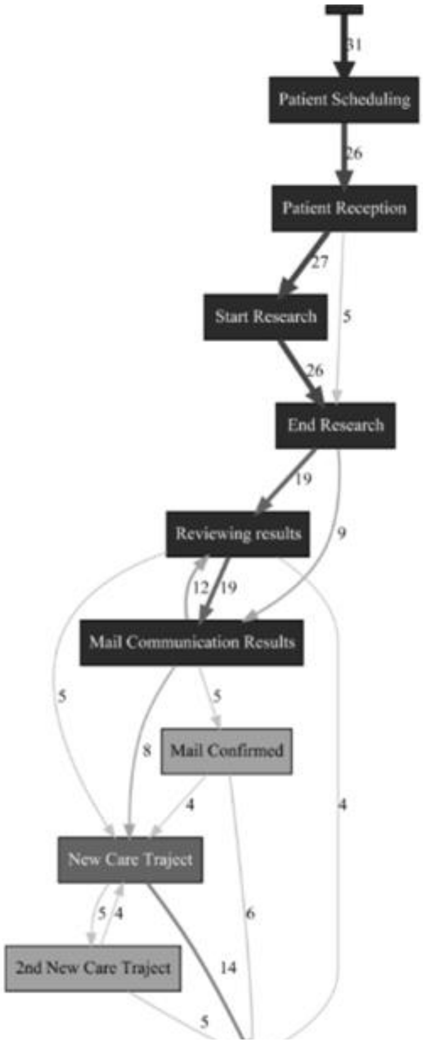

Figure 4.3 Heuristic miner acute and semi-acute findings

Secondly, the Inductive visual miner obtained more insight into the process of communication and the follow-up process. Figure 4.4 shows that the findings of the email have only been confirmed in nine cases. The small amount is possible because this confirmation is not in the protocol. The mails may be read, but not confirmed. Also, in eleven cases, no new care programs were started. The returning arrow indicates an activity which could not be displayed in the model. The number ‘7’ at the last returning arrow, means that in 7 cases a second new care program was started.

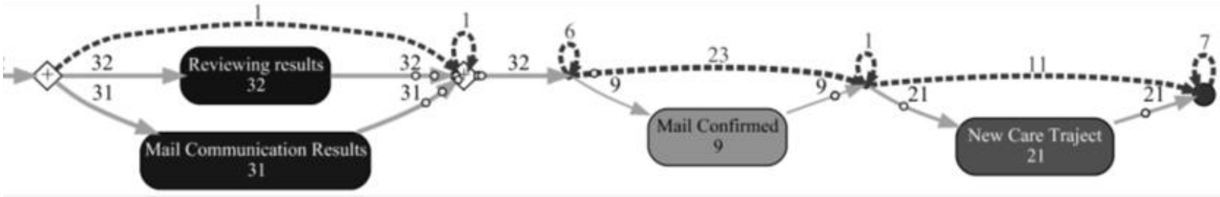

Figure 4.4 Inductive visual miner acute and semi-acute findings

To get a closer look at possible workarounds, the Inductive visual miner was also used to exclude the activity ‘email confirmed’. Figure 4.5 shows that in 16 cases, a new care program was started without confirmation of the email. There must have been contact without documentation, presupposing a workaround. It is assumed that there has been telephone contact.

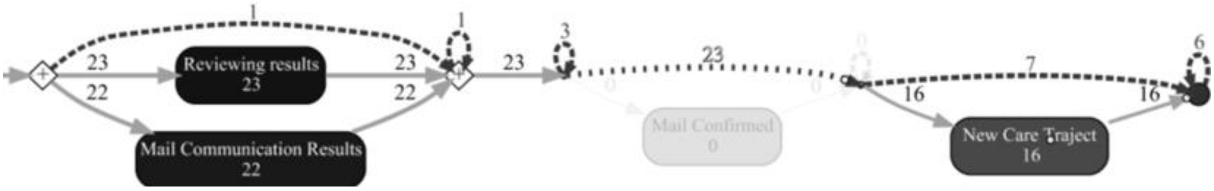

Figure 4.5 Inductive visual miner acute and semi-acute findings, excluding email confirmed

Both tools demonstrate deviations from the process model. Considering the most common process pattern in Figure 4.6, it is evident that communication by telephone and confirmation of emails are not documented in most cases.

Figure 4.6 Most common trace acute and semi-acute findings

The Conformance checker is used to measure the fitness, which describes how good the event log fits the process model. The average trace fitness is 0.6847, indicating that the clinical practice is not close to the process model. Because communication often takes place via email and emails can be confirmed, the process model (Appendix D) has been adapted to perform a conformance check in which the email communication is involved. This model indicates a fitness of 0.869, which is an improvement in comparison to the original process model.

Subsequently, the Multi-perspective process explorer has been applied to the event log to analyze the amounts of time between activities. Figure 4.7 shows the average times between activities. The median is used to acquire a more accurate representation of the event log. The average and median time from planning to the reception is on average less than the maximum of 28 days according to the guidelines. Further on in the process, it takes on average 1.1 hours for the results to be known and 1.2 hours for the results to be communicated to the referrer. The email is confirmed on average 28.4 days after, but this is due to an outlier of 88.6 days. Nevertheless, a median of 8.8 days is an exceptional value for confirmation. These times also indicate that the confirmation of the mail is not interpreted correctly, because these findings must be followed up on the same day.

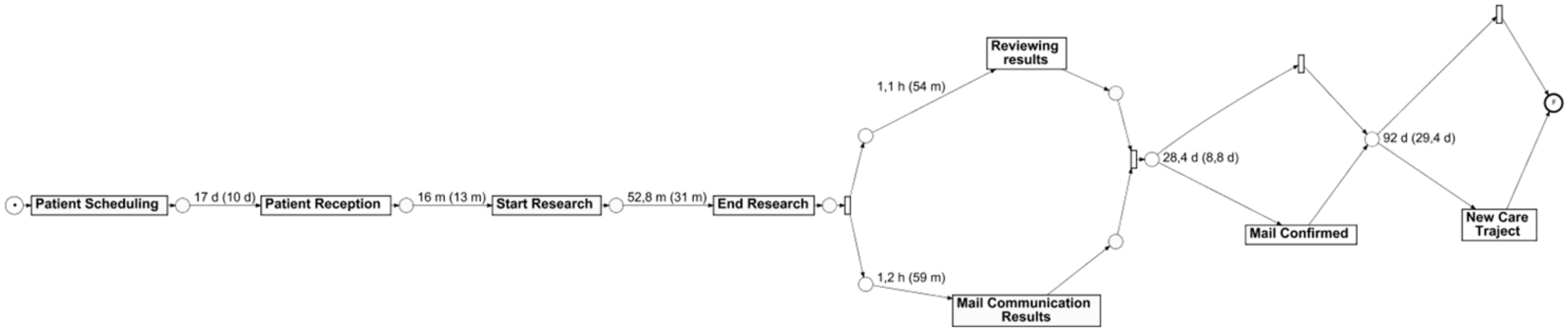

Figure 4.7 Multi-perspective process explorer acute and semi-acute findings

Subsequently, table 4.4 provides insight into the confirmation, time of confirmation and new care programs per specialism. The reliability of the small sample is limited, but the results are striking. No department confirms every finding and the percentage of new care programs varies per department. It is noteworthy that the cardiology department, in particular, confirms the finding after no more than 82.85 days. The findings may presuppose that the purpose of the confirmation is not clear to every department.

SPECIALISM	% CONFIRMED	AVG. CONFIRMATION TIME IN DAYS	% NEW CARE PROGRAM STARTED
Rheumatology	50%	7.83	100%
Surgery	0%	N.A.	66.66%
Cardiology	57.15%	82.85	85.71%
Lung department	50%	7.36	50%
Orthopedics	33.33%	9.29	55.56%
Urology	50%	9.22	75%
Neurology	50%	0.67	100%
Internist	0%	N.A.	100%

Table 4.4 Statistics specialisms acute and semi-acute findings (n=31)

4.4.2 Non-acute critical side findings

Just like the previous process, the process of the non-acute critical side findings is discovered with the Interactive data-aware heuristic miner (figure 4.8). In this process, communication and follow-up action are documented. These times also indicate that the confirmation of the mail is not interpreted correctly, because these findings must be followed up on the same day. The average trace fitness is 0.8262, which indicates that the process is close to the process model. Similar to the previous process model, no new care programs were started in thirteen cases. This is not remarkable because non-acute findings from 2019 may needs to be followed-up in 2020. It is also possible that these findings are followed up at another hospital.

Figure 4.8 Heuristic miner non-acute findings

According to the protocol, there must have been contacted within nine days. The Multi-perspective process explorer shows that on average, the communication with the referrer takes place within one day. Also, the average time between scheduling and patient reception is 11 days in figure 4.9. Table 4.5 provides insight into the new care programs per specialism. The percentages of new care programs are diverse.

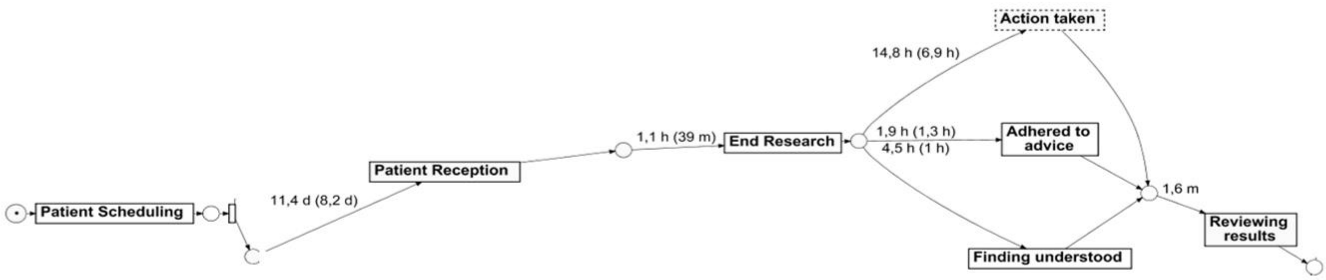

Figure 4.9 Multi-perspective process explorer non-acute findings

SPECIALISM	% NEW CARE PROGRAM STARTED
Surgery	25%
Cardiology	33.33%
Lung department	0%
Orthopaedics	33.33%
Urology	100%
Neurology	33.33%
Internist	75%
Pain policlinic	100%
ENT Specialist	0%
Gastroenterology	100%
Paediatrician	0%
Not available	66.66%

Table 4.5 Statistics specialisms non-acute findings (n=34)

In conclusion, process mining led to various insights into both processes. However, it was not possible to apply a resource analysis.

4.5 Qualitative research

Three semi-structured interviews were conducted to validate the gaps, workarounds, and to identify the influencing factors. The interviewees were a radiologist, quality researcher and quality manager. Coding the interviews led to 40 codes, and six code groups in Appendix C. In this section, the insights and interpretations will be discussed.

4.5.1 Workarounds

The results of the interviews also led to various workarounds. The first workaround is face-to-face communication instead of digital communication. An application for an appointment must be submitted digitally, but this is also done face-to-face. In the past, this led to an appointment that was not scheduled, and for this reason, the finding was not followed up.

The second workaround is the assessment of diagnostic images by employees who are not authorized to do so. Fewer radiologists are present during the evenings and weekends, and for this reason, the imaging staff assesses the images themselves. The radiologists ultimately also assess the images. However, changes in the assessment are often not communicated to the referrer. Similarly, diagnostic images are also assessed by the polyclinics, but the radiology reports are then not read. As a result, side findings can be overlooked. Polyclinics may send patients home while the radiology report has not yet been sent.

The last workaround is that polyclinics purposefully search for specific findings. The medical practitioners can filter by type of disorders, which means that side findings may not be seen and followed-up.

4.5.2 Personal factors

According to the respondents, two personal factors influence the process. The responsibility of the radiologist is the first personal factor. Medical practitioners always have patient safety in mind and are committed to not endangering it. The quality manager indicates that patient safety has never been put at stake on purpose. However, responsibility may also be a barrier. The radiologist does not contact the referrer after six months, to prosecute the non-acute finding, while he knows that this is desirable. However, this is not his responsibility.

'Every doctor has his own graveyard. Yes, you will have to learn to deal with that, and that is difficult.'

The second personal factor is the relationship between protocol and patient outcome. According to the respondents, medical practitioners like to engage in actions that stimulate patient safety. Documenting communication is not seen as a contribution to patient safety. According to all respondents, administrative tasks have risen more than desirable. Therefore, this gap can be seen as a workaround because this activity is perceived as a burden and therefore skipped.

'We often have a fear of noting things down, but not doing them.'

The hospital group attempts to identify the most critical tasks in the process and to eliminate those tasks that offer no added value. Therefore, according to the radiologist, research must also be conducted into the relationship between a checklist and patient safety. Currently, the documentation of communication is only consulted when a calamity occurs, not to analyze or optimize the processes. As a result, the radiologists see no connection between documentation and patient safety.

'I made the call, and it is now just a kind of legal administrative act that I am performing. Come on. I'm not looking forward to this. I called someone, I communicated it.'

4.5.3 Organizational factors

However, gaps are mainly caused by organizational factors. The first organizational factor is the facility of resources. The quality researcher states that a radiologist needs his office room to be able to concentrate fully. However, the radiologists work in pairs in a room, and because of this, they are easily distracted. Also, radiologists frequently get called or interrupted while working and therefore forget their administrative work.

'I get a call while walking in that hallway and then I can't record anything and meanwhile, before I get to a computer, I already get ten other calls, and the radiologists experience this as well.'

The adoption of IT systems is the second organizational factor and related to the personal factor the relationship between protocol and patient outcome. Radiologists fear that they have to document too much in HIX. For this reason, medical practitioners are quickly inclined to check everything off their list. Also, new IT applications are not interpreted in the same way by everyone in the hospital. The radiology department makes work instructions for HIX and shares them in work meetings within the department. However, the quality researcher indicates that it is a shadowy construction in which the working method for other departments is not precisely explained.

The third organizational factor is the degree of knowledge. Critical side findings may not be followed up because polyclinics do not have a handling protocol for these findings. According to all respondents, this mainly concerns the non-acute critical side findings. The focus lies on the urgent and expected findings.

4.5.4 Patient-related factors

The radiologists also deviate from the protocol in case of exceptional symptoms. For example:

'You know when you tell a ninety-five-year-old with metastatic breast cancer that they should prosecute that aneurysm in the abdomen. It has no added value.'

Thus, a non-acute critical side finding is not followed-up when this has no added value. For this reason, a radiologist must always map the clinical context of the patient.

4.5.5 Other factors influencing patient safety

Protocol and guidelines focus on timely communication to ensure patient safety. However, the problems also occur at the referrer and polyclinics. Process mining showed that in several cases, the finding had been communicated, but no new care programs had been started. This problem lies in the responsibility and interests of every medical department. Currently, there is no handling protocol of critical side findings, causing polyclinics looking for findings within their specialism. According to the quality researcher, a hospital can be seen as a:

'Collective building with all kinds of small companies, which are medical specialist companies. They all have a self-interest and that is very difficult.'

Figure 4.10 provides an overview of the relationships between the influencing factors, gaps and workarounds.

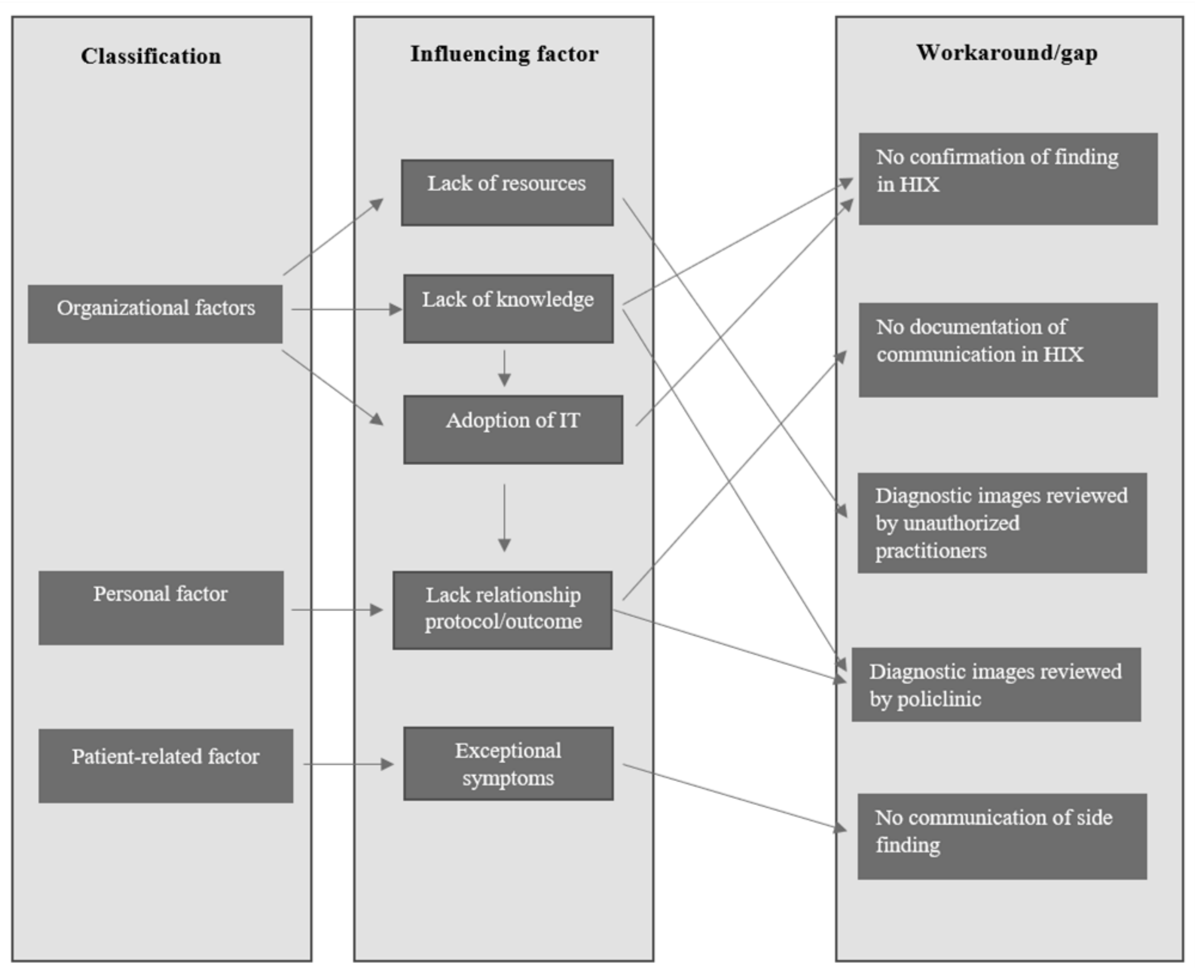

Figure 4.10 Relationship model between influencing factors, gaps, and workarounds

4.6 Summary case study

This study focused on analyzing the adherence to the protocol for the processes of critical side findings. Literature research revealed different methods to analyze healthcare processes and described various factors influencing processes. Previously, researchers used process mining to discover, analyze, and improve healthcare processes. An emerging approach is the FRAM method to analyze complex processes based on multiple data sources. However, previous studies have not employed this method in combination with process mining. For this reason, process mining was used to measure the adherence to the protocol, and then interviews were conducted to identify the factors influencing the adherence.

Previous literature showed that deviations often occur in the form of workarounds. Medical staff perform workarounds to skip certain activities or perform activities by unauthorized personnel. Personal, organizational and patient-related factors cause these workarounds. This study confirmed that there are workarounds by skipping activities and not following up all critical side findings. Process mining showed a global overview of the processes but did not provide enough depth to analyze the process further or to draw definite conclusions. The analysis further indicates a ‘fitness’, but this measure is not useful for critical healthcare processes. According to the literature, a fitness of 0.8262 is a good number, but this still leaves much room for deviations that can have critical consequences. To gain more insight into the processes, it was necessary to conduct interviews among those involved.

The interviews indicated that workarounds result from personal and organizational factors. The personal factor refers to medical practitioners not seeing the benefit in the documentation, as described by previous literature. The organizational factors, lack of resources and knowledge, and the adoption of IT lead to unauthorized employees carrying out activities and forgetting some activities.

This study shows that workarounds and deviations are more common in acute cases than in non-acute cases. There are several reasons for this. First, medical practitioners perceive documentation in acute cases as a cumbersome and unnecessary activity. Second, medical practitioners do not see this workaround as a problem. In non-acute cases, there is documentation because previously, the medical practitioners reported multiple calamities due to errors in communication. For this reason, this activity has been brought to attention with an explicit work instruction.

5 Discussion

This chapter discusses the conclusion, limitations, theoretical and practical implications, and the generalizability of this study.

5.1 Conclusion

This study aims to investigate the adherence to protocols, which raised the following research question: *What is the adherence to protocols in critical side findings processes in radiology?* The analysis was divided into a process for acute and semi-acute critical side findings and a process for non-acute critical side findings. The study administered the FRAM method by consulting the protocols, applying process mining, and conducting interviews. Process mining showed that adherence to the protocol is limited. The adherence to the protocol for non-acute critical side findings is acceptable because the practitioners documented the communication, and the average lead times are following the guidelines. However, the personnel did not document their communication for the acute and semi-acute critical side findings. Process mining indicates workarounds, as in most cases, new care programs started. Process mining shows a global view of the processes but does not show the causes and consequences. Therefore, process mining, as the sole research method, is not suitable for an in-depth analysis of a healthcare process.

Various factors explain the gaps and workarounds. Skipping documentation of communication is a workaround and radiologists perceive these as an administrative burden that, in their view, has no relation to the health of the patient. In addition, documentation is only consulted during calamities or inspections, which means that they have no benefit for medical practitioners. Referrers and polyclinics point to the lengthy processing time of the confirmation, being unaware of the purpose and the usage of the confirmation application. Calamities may arise if the findings are not communicated and have no follow-up.

This study visualizes the organizational, personal, and patient-related factors in a model. The first organizational factor, lack of personnel, leads to unauthorized medical practitioners carrying out activities. The second organizational factor, the lack of knowledge, refers to the polyclinic's misunderstanding of the IT applications, which obstructs the third organizational factor, the adoption of IT. The personal factor, lack of perceived relationship between protocol and patient health, also causes workarounds as medical practitioners bypass administrative activities. The patient-related factor, exceptional patient symptoms, causes those critical side findings are not communicated if follow-up does not stimulate health.

This study emphasizes the reduction of the administrative burden on medical practitioners. The implementation of a software and hardware platform for automating medical reporting makes it possible to convert speech to text, which requires less effort and time for administrative work. However, it is crucial to continually identify critical activities while eliminating unnecessary activities, especially in acute cases, where there is limited time for administrative work.

5.2 Limitations

The first limitation was obtaining data. The data could not by the researcher himself be extracted from the HIS for this study. Therefore, it was not possible to obtain data from the referrer and polyclinics, which might have provided more insight into the follow-up of critical side findings. This also makes it impossible to investigate whether the gaps and workarounds have a positive or negative influence on the follow-up process, according to the FRAM.

Another limitation was analyzing the medical practitioners with process mining. In the HIS, the employees are identified with a code. Due to the GDPR, it was not possible to convert the codes to job descriptions. Therefore, individual gaps and workarounds could not be explained by conducting CIT's. However, this could have been valuable information to analyze.

The last limitation is the small amount of sample characteristics, for a limited number of medical practitioners was interviewed. There could be a certain degree of bias, which could be explained by the difference in responsibilities and experience of the interviewees. Therefore, the research was aimed at describing the influencing factors for the process in general.

5.3 Theoretical implications and future research

Process mining proved to be an effective method of identifying gaps and workarounds in a process. These gaps and workarounds can be partly explained by shortcomings of BPM. Previous literature indicates that a process must be measurable, continuously monitored and that all stakeholders must be empowered for effective process management (Armistead et al., 1999; Klun & Trkman, 2018; Lee & Dale, 1998). However, the interviews prove otherwise because they show that the gaps and workarounds are caused by an administrative burden and the missing relationship between activity and patient safety. It can be questioned if process mining is the right method to analyze hospital processes as mentioned by Recker et al. (2005) because gaps and workarounds are often in the interest of the patient. Follow-up research should focus on the validity of the application of process mining as the sole research method of a case study. However, this method can serve as a starting point for process analysis in order to get a global overview of processes. Process mining is, therefore, an effective method to integrate into the FRAM, whereby process mining provides insight into any risks and bottlenecks. However, it remains challenging to determine the influence of process variability.

It is also interesting to research how medical practitioners should be motivated to comply with their mandatory administration. As mentioned by Donnellan et al. (2013), gaps can be explained by a perceived missing relationship between activities and patient safety. Previous literature shows that workarounds are performed to bypass an activity due to the effort and time. However, this research shows that in acute cases workarounds are caused because the activity is not perceived in relation to the health of the patient. Therefore, future research could focus on the relationship between administrative activities and patient safety, especially in acute cases. Furthermore, future research could investigate the relationship between administrative activities and workarounds. An increase of administrative obligations could lead to more workarounds. A follow-up study could also focus on the usefulness of lifetime visualization of process mining in preventing incidents.

In order to identify the main activities, it is interesting to investigate the entire process of critical side findings. Because every department involved has its interests and responsibilities, it is crucial to investigate how the entire process should be managed as a whole. Follow-up research could, therefore, focus on the influence of sub-processes and individual responsibilities on patient safety.

5.4 Practical implications

The results of this research are relevant for several stakeholders, the inspection and the radiology and quality department of the hospital group. The main focus of the recommendations is to decrease incidents caused by no or late follow-up. First of all, the hospital group needs to ensure that telephonic communication is documented for acute and semi-acute cases. In non-acute cases, everything is documented because it is mandatory to document communication in the HIX by ticking a box. This working method should also be applied to acute and semi-acute findings. To ensure this, a performance indicator could be created in which the radiologists, but also the quality department, can check whether it is going well. For this, it is necessary to investigate how data in the HIS can be converted into event logs.

It is also essential that each polyclinic interprets a working method in the same way. The quality researcher indicated that the IT applications are not interpreted in the same way by every polyclinic. All polyclinics involved should be informed of the purpose of this construction.

All respondents indicated that calamities were the result of late follow-up. These calamities can be reduced by introducing a standard handling protocol for critical side findings, whereby referrers and policlinics are obliged to read radiology reports and changes in radiology reports are explicitly communicated.

5.5 Generalizability

The generalizability of this research is limited for several reasons. A relatively small sample was chosen, which decreases the generalizability of the research. Furthermore, this research was a case study, which means that the characteristics may only apply to this particular hospital group. In addition, the process can be influenced by workload, but also, for example, by the type of hospital. To be able to say more about the process of critical side findings in general, it is crucial to research different hospitals. However, this research design did gain an in-depth insight into the process of critical side findings and the influencing factors in radiology.

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Appendix A. Method of literature research

Before the literature search has been carried out, it was necessary to identify which literature is useful and put into perspective with the research objective and central question. The literature review had three main objectives:

- Describing process management (in healthcare).
- Identifying deviations in healthcare.
- Identifying the influencing factors on processes in healthcare.

The search process was a manual search of journal papers. Figure A.1 gives an overview of the statistics of the literature search and selection for this review. The first stage was acquiring papers in three databases, Google Scholar, Scopus, and Web of Science using the search terms below:

- Business process management, process management
- Healthcare processes, medical processes, healthcare process management
- Process mining, process mining in healthcare, FRAM
- Healthcare deviations, gap healthcare, gap protocol, clinical guidelines, clinical gaps
- Workarounds, workarounds healthcare

The second stage was to review the articles based on the keywords and title, abstract. The third stage was assessing the articles based on the abstract and conclusion. In addition, the below criteria were also used to assess articles.

- Date
- Question and purpose of the research
- Relation to other studies
- Number of citations
- English literature only
- Last version only

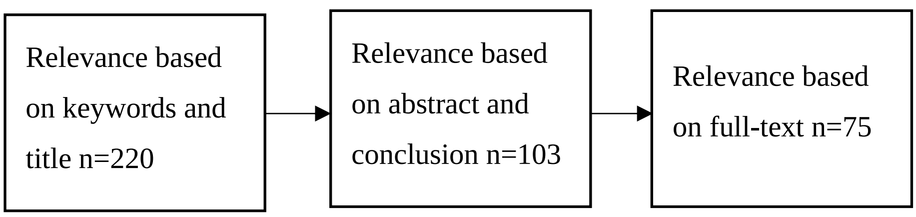

Figure A.1 Statistics literature search

Appendix B. Interview scheme

Introduction

- Introducing myself and a brief explanation of the research
- Brief explanation of data mining and process mining
- Introduction of respondent: brief function in the hospital and responsibilities. define interfaces with the department

Questions regarding protocols and guidelines

- How are protocols and guidelines communicated to those involved in the process?
    - How is it ensured that the above protocols and guidelines are read and understood?
    - Are the medical practitioners involved in drawing up these protocols and guidelines?
    - What happens if medical practitioners disagree with new protocols and guidelines?
    - How is it ensured that the protocols and guidelines are adhered to?
    - How do u experience that medical practitioners should document their communication in the HIX?

Communicating what is going good in the process. Describing the results of the application of process mining

Questions regarding research

- What do u think of the current working method?
- How do u think these deviations can be explained?
- Do u think these deviations are a problem for steps further in the process?
- Which factors do u think that have the most impact on the adherence of protocols and guidelines?

Questions regarding process mining

- What do u think about the usability about techniques like process mining?
- What limitations do u see in the usage about these techniques?

Appendix C. Codebook

CSF = Critical side finding

CSF – Unknown how it will develop	Stimulators – Personal - Checking each other
CSF – Unaware of CSF	Stimulators – Personal - Culpability creates sharpness
CSF – Non-acute most underrated	Stimulators - Personal – Responsibility own victims
CSF - Calamities discovered afterwards	Barriers – Personal - Resistance
Problems – Communication - No timely communication	Barriers – Personal - Lack of agreement
Problems – Communication - Forgetting documenting communication	Barriers – Personal - Own opinion
Problems – Communication - Changes in the report not seen	Barriers – Organizational - Workload
Problems – Communication - Not received	Barriers – Organizational - Unclear construction
Problems – Calamities discovered afterwards	Barriers – Organizational - New IT System
Problems – Pointing fingers	Barriers – Organizational - IT system not understood
Problems – Balance between checklist and safety	Barriers – Organizational - Protocol unclear
Problems – Differences in weekend	Barriers – Organizational - Concentration
Problems – Referrer does not take action	Barriers – Organizational - Financial
Problems - No adequate handling CSF	Barriers – Organizational - Peripheral matters
Workaround – Only own responsibilities & interests	Barriers - Organizational - Interruption
Workaround – Referrer reviews scan by themself	Barriers – Organizational - Lack of rooms
Workaround – Not certified practitioners	Barriers – Organizational - Technical failures
Communication protocol – Portal	Barriers – Organizational - Innovation may be challenging to deal with
Communication protocol – Meeting	Barriers – Organizational - Most essential tasks need to be identified
Communication protocol - Email	Barriers – Patient-related - Symptoms

Table A.1 Codebook

Appendix D. Repaired process model

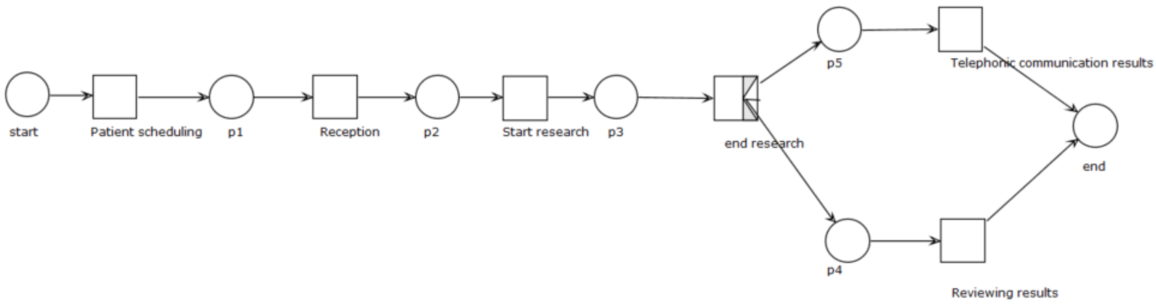

Figure A.2 Repaired process model acute critical side findings