MASTER

From paper-based care pathway to executable workflow process model

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From paper-based care pathway to executable workflow process model

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Preface

This master thesis is the result of a graduation project fulfilled in order to obtain the degree of Master of Science in Operations, Management & Logistics at the Eindhoven University of Technology. This graduation project is done in cooperation with Philips Research in Eindhoven.

First of all, I would like to thank my first supervisor, Pieter Van Gorp. My meetings with him were fruitful, his inputs helped me stay motivated throughout the process and he always helped when I had questions. It was very pleasant to have Pieter not only as my first supervisor, but also as my mentor over the past two years. I would also like to thank Oktay Türetken for being my second supervisor and providing me with useful advice. In the third place, I would like to thank my supervisor from Philips Research, Richard Vdovjak, for making it possible to work together with such a great organization for the past half year. Next I would like to thank Juby Joseph Ninan, who assisted me with his knowledge in the field of computer engineering. Fifthly, I would like to thank my friends for their support, advice and sympathy, not only during this project but throughout my whole student career.

Above all, I want to express my gratitude to my family for their support and interest throughout this project. My sincere appreciation goes to my parents, sister, brother-in-law and girlfriend, for helping wherever they can. They made me lift my thesis to the next level.

Wesley van Renswouw
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Management Summary

Nowadays there are major issues in the healthcare related to quality, performance and costs. Even in countries where the healthcare is well developed and resourced there is clear evidence that the quality remains a serious concern. Too many errors and incidents happen in the clinical working practices, resulting in unnecessary suffering, use of resources, and even deaths. In the USA at least 210,000 deaths each year are a result of preventable hospital errors. In National Health Service hospitals in the UK this number is estimated on 40,000 deaths a year due to medical errors. On top of that the cost of healthcare is increasing each year. It is clear that something has to change in the way healthcare is currently practising its business.

In the 1980s care pathways were introduced for the first time. A care pathway is a description of a care process from an organization point of view for a specific disease and for a specific group of patients. It is based on evidence and on (clinical) guidelines and it is designed to improve efficiency and patient outcomes. The aim of care pathways is to enhance the quality of care across the continuum by improving risk-adjusted patient outcomes, promoting patient safety, increasing patient satisfaction, and optimizing the use of resources. That this aim is getting achieved is demonstrated by many studies on this subject. Using care pathways can significantly improve the quality of care, shorten the length of stay of a patient, and lower the costs of care.

However the majority of care pathways that are developed and implemented are used manually by filling predefined paper documents. In this day and age where other industries have adopted workflow management systems with e.g. automated tasks, decision support, and compliance checking, the usage of paper-based documents seems obsolete. The few studies that are performed on workflow applications that integrate the care pathways show promising results. Key performance indicators like quality of care, length of stay of patient, use of resources, and costs of care are improved by these new systems.

As mentioned these systems are still in development and mature systems are not yet widely introduced and adopted in the market. The current mismatch between medical research and research done within the field of Information Systems might be the problem. Where the medical research is aimed primarily at developing the care pathways on a clinical level, the research in the Information Systems field is mainly focused on specific technical aspects of implementing care pathways into executable workflow applications. The part which describes how text-based care pathways can be modelled into executable workflow process models in a structured way is still missing in current research. Therefore in this thesis a methodology is derived which can be followed to transform paper-based care pathways to executable workflow process models in a structured and reproducible way.

The intention behind this methodology is to increase the usability of and compliance with care pathways in the healthcare field. By using the steps proposed in this methodology it is easier for hospitals and industrial partners to develop workflow process models based on paper-based care pathways. Also the developed process models will have a similar structure which would make the models more understandable in the long run since stakeholders will recognise the structure of the models.

The methodology consists of three phases. In phase one the paper-based care pathway is annotated in order to extract the information that is presented in the paper-based care pathway.

Phase two describes the steps how the annotated paper-based care pathway can be modelled in a conceptual process model in a structured and reproducible way. First the sunny day scenario is modelled in the main process. Next the subprocesses are modelled. It is likely that there are multiple child levels in the process model; therefore it is important to follow the structured approach, given in the methodology, to get a consistent model. Business rules should be added in order to comply with the procedures stated in the care pathway. Next extended BPMN constructs and exception handling patterns can be used to model the variance that can occur in the care pathway.

Finally the third phase provides a step-by-step description on how to perform the transformation from a conceptual process model to an executable workflow process model. Topics that are included in these steps are: the soundness and correctness of the conceptual model, the link between the two modelling languages, adjusting the conceptual model, modelling the required data, flexibility, roles and users, forms, business rules, integration with health information systems, and verification and execution of the process.

In order to give a proof of concept the methodology is used in a case study which uses the paper-based unstable angina care pathway as starting point. This care pathway is distributed by the Chinese Ministry of Health and its use is mandatory for all Chinese hospitals. In this case study first the care pathway is annotated. Next the whole case pathway is modelled to a conceptual model. In the last phase a section of the conceptual model is transformed to an executable workflow model.

An internal evaluation by Philips Research states that the annotation phase is an essential step in the methodology because it helps the modeller to get better acquainted with the care pathway he/she wants to model. The annotation steps provide a deeper understanding of information and the structure of the care pathway. The conceptual model is quite suitable for clinical practice and particularly useful for understanding the care pathway and communicating the necessary details among the relevant stakeholders. However the case study performed on the third phase of the methodology is quite limited; therefore the executability of the workflow process model should be tested more extensively and the outcomes should be communicated with the stakeholders before the real value of this phase can be determined. Also the intended use of the workflow process model needs to be further investigated.

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1. Introduction

In this chapter first the problem statement in § 1.1 will introduce the topic of this thesis. The research goal in § 1.2 is built upon the problem statement. Finally the layout of the rest of the report will be explained in 1.3.

1.1. Problem statement

In this section issues in the healthcare will be addressed. These issues relate to the quality, performance and costs in clinical practices. In order to tackle these issues care pathways were introduced in the healthcare, multiple meta-analyses show that implementing care pathways in the healthcare has positive results. However there are still problems with the current way in which care pathways are implemented. Furthermore, this section reveals a gap between medical research and the research done within the field of Information Systems, but also in the Business Process Management field as a whole. The problem statement discussed in this section is used as input for the research goal in § 1.2.

1.1.1. Quality and cost issues in healthcare

Even in countries where the healthcare is well developed and resourced there is clear evidence that quality remains a serious concern, expected outcomes are not achieved and there are still wide variations in standards of healthcare delivery (World Health Organization 2006).

Too many errors and incidents happen in the clinical working practices, resulting in unnecessary suffering, unnecessary use of resources, and even deaths (Kohn, Corrigan and Donaldson 2000). In the USA at least 210,000 deaths each year are a result of preventable hospital errors. When deaths related to diagnostic errors, errors of omission, and failure to follow guidelines are included this number increases to an estimated 440,000 preventable hospital deaths each year (James 2013). This is more than four times higher than the estimates of deaths due to preventable hospital errors in 1999 (Kohn, Corrigan and Donaldson 2000). When looking at the estimated percentage of patients that die due to preventable hospital deaths the percentage rose from 0.292% in 1984 to 0.614% in 2008 (James 2013). Studies on medical errors that occur in National Health Service (NHS) hospitals give an estimation of 850,000 medical errors a year, resulting in some 40,000 deaths (Aylin, et al. 2004), besides that 974,000 patient safety incidents and near misses were recorded on the NHS trusts' reporting systems in 2005 alone (O'Dowd 2006).

Another important issue in the Health Field is the cost of care. With the cost of healthcare increasing each year, it is important to find solutions to cut on these costs and make healthcare more affordable again (TIME Magazine 2013), (Health Care Cost Institute 2013), (Social Security Advisory Board 2009), (McKinsey 2008), (America's Health Insurance Plans n.d.). Some suggestions to lower the costs are using checklists, reduce the fragmentation in the delivery of care with better coordinating care among specialists, and improve the performance by quick dissemination and adoption of best practices (Reuters 2010).

1.1.2. Care pathways as a solution

One way of improving the quality and the performance of clinical practices and cutting costs is by developing and implementing care pathways. After a literature survey of Dalinghaus et al. (2012) the following definition was derived: "A care pathway is a description of a care process from an organization point of view for a specific disease and for a specific group of patients. It is based on evidence and on (clinical) guidelines and it is designed to improve efficiency and patient outcomes." Other terms that are used with similar meanings are: nursing care pathways, integrated care pathways, critical pathways, clinical pathways, etc. but following the arguments of Vanheacht, De Witte, & Sermeus (2007) care pathway is the preferable term used in this report.

Care pathways were first introduced in healthcare in the early 1980s in the USA. The care pathways came to Europe in the early 1990s where they were first used in the UK. Ten years later, from late 1990s to the beginning of the 21st century care pathways spread all over the world. Although in most countries the prevalence of care pathways is still rather meagre (Vanhaecht, et al. 2010).

The aim of care pathways within the healthcare field is to "enhance the quality of care across the continuum by improving risk-adjusted patient outcomes, promoting patient safety, increasing patient satisfaction, and optimizing the use of resources" (Vanhaecht, De Witte and Sermeus 2007, 154). Multiple meta-analyses were performed to evaluate the use of care pathways based on multiple key performance indicators (KPIs). KPIs that are often found in literature are: the length of stay (LOS) of a patient, costs during hospital stay, and complications in the treatment process.

In 2008 a systematic review was performed by Rotter et al. about the effect of using care pathways on LOS, hospital costs and patient outcomes. Only randomised controlled trials and controlled clinical trials were included, which resulted in a total of 17 trials, representing 4,070 patients, that were used in the meta-analysis. A significant shortening of LOS, especially with invasive procedures, was reported when care pathways were used. Also there were significantly lower costs for the pathway group. In this study no significant effects were found on readmission to hospitals or in-hospital complications (Rotter, Kugler, et al. 2008).

Twenty-two studies were used in a meta-analysis performed by Barbieri et al. in 2009. This meta-analysis evaluated the use of care pathways for hip and knee joint replacements when compared with standard medical care. Significantly fewer patients suffered from postoperative complications in the care pathway groups when compared to the standard group. Also a shorter LOS and lower costs during hospital stay were associated with the care pathway group (Barbieri, et al. 2009).

A third meta-analysis was performed on twenty-seven studies involving 11,398 patients. Statistical pooling of the results of the different studies was not possible due to the variation in study design and settings. However most studies showed a significant decrease in LOS and a reduction in hospital costs, next to that a reduction in in-hospital complication and improvement of the documentation was indicated (Rotter, Kinsman, et al. 2010).

These three meta-analyses show that using care pathways can significantly improve the quality of care, shorten the LOS of a patient, and lower the costs of care.

1.1.3. Current state of care pathways

The majority of care pathways that are developed and implemented are used manually by filling predefined paper documents (Wakamiya and Yamauchi 2006), which can lead to the following problems (Du, Jiang and Diao 2008):

- Limits to the capacity of data recording and collection.

- The simple description in term of forms can not represent complex logical and timing relationships of different activities.
- Lack of necessary [automated] timing monitoring.
- Lack of support for identifying and handling variations.
- Isolated from hospital information system (HIS).

These problems can be resolved by introducing workflow applications that integrate the paper-based care pathways. An extra opportunity when using care pathways integrated in workflow applications is the availability of decision support to the user. Although introducing workflow applications might seem like a logical next step in the future of care pathways, when conducting a literature review on this topic not many of the systems that can be found in the academic literature have past the prototype phase. The method of the literature review including the different search queries used is shown in Appendix U: Literature review method.

In the literature three cases were found where care pathways were successfully modelled into a workflow management system which was implemented and tested in a medical setting. In two of these cases the system was implemented and tested in a hospital/medical centre, in the third case an experiment was conducted where clinicians used the system. All the found systems that support workflow for care pathways are shown in Table 1. As stated by Song et al. “computer-aided workflows need to be evaluated in a real healthcare setting to ensure their efficiency and usability” (Song, et al. 2006, 932). Therefore only the three systems that were tested in a medical setting are further discussed.

The first example where a care pathway is successfully modelled in a workflow system is the i.s.h.med pathways (Graeber, et al. 2007), which was implemented in the department of General Surgery, Abdominal and Vascular Surgery, and Paediatric Surgery of the Saarland University Hospital. The i.s.h.med pathways include complete workflow integration where links to medical functions (e.g. order, access to electronic patient record, documentation) are directly available. The physician can assign the relevant pathway, execute this pathway stepwise, and control the workflow with a minimum of navigation. Especially for high complex pathways the length of stay (LOS) decreased significantly. Also the mean number of laboratory tests, consultations, and number of imaging procedures (x-ray, CT, NMR, ultrasonography) decreased significantly. Besides that the patient satisfaction was the same before and after the implementation of the system. The results of this implemented care pathway workflow system show that using these systems results in a positive financial outcome (shorter LOS and a lower number of laboratory tests, consultation, and imaging procedures) while keeping the same level of patient satisfaction.

The second found example, where a care pathway is implemented into a clinical workflow system, which also includes computer-based decision support, is developed by Blaser et al. (2007). This system is used in the daily routine of the Department of Trauma, Reconstructive and Hand Surgery at the University Medical Center in Marburg and shows very positive user feedback. The feedback indicates that using the IT-supported clinical pathway, in comparison with the pre-clinical pathway and the non IT-supported clinical pathway situation, results in significant improvements in pathway compliance and clinician performance and in less further inquiries and delays due to illegible documents.

Table 1: Systems that support workflow for care pathways

Name	Functions	Tested	References
Stateframe	Pro-active system with actions as alert, notify, refer, schedule and set timers; routing options which were only made with user's approval or suggestion; task automation; and information extracting and filtering	Prototype for proof of concept, not tested in a hospital environment	(AlSalamah, Gray and Morrey 2012)
Extended Workflow-nets	Workflow support with execution steps and automatic recognition of exceptional situations	Prototype for proof of concept, not evaluated	(Du, Jiang and Diao 2008)
Clinical Pathway Ontology	Workflow support with real-time monitoring of the patient's status and a SWRL rule engine for decision support	Prototype with part of a care pathway for proof of concept, not tested in a hospital environment	(Ye, et al. 2009), (Yao and Kumar 2012),
SEMPATH	Workflow support with real-time adaptation to the patient's status	Prototype for proof on concept, not tested in a hospital environment	(Alexandrou, Xenikoudakis and Mentzas 2009)
UML 2.0	Workflow support with automated communication and coordination between actors	Only theoretically supported, no prototype	(Mauro, et al. 2010)
METEOR	Workflow support with dynamic processes, error and exception handling, recovery, and Quality of Service management	The project died in 2005 without any tests	(Anyanwu, et al. 2003)
OLGA project	Executable process fragments for workflow management systems	Developed in a test bed environment, not tested in a hospital environment	(Sedlmayr, et al. 2007)
PROforma	Workflow and decision support	An experiment was conducted on the prototype, resulting in a significant decrease of (critical) deviations from the care pathway	(Fox, Patkar and Thomson 2006), (Patkar and Fox 2008)
i.s.h.med	Complete workflow integration with links to medical functions (e.g. order, access to EPR, documentation)	Implemented in a hospital, resulting in a significant decrease in length of stay, number of laboratory tests and consultations, and number of imaging procedures	(Graeber, et al. 2007)
Orbis/ OpenMed	Workflow and decision support for imaging diagnostics, procedures and medication, and operation planning	Implemented in a hospital, resulting in significant improvement in pathway compliance and clinical performance, and a decrease in further inquiries and delays	(Blaser, et al. 2007)

The third case that tested a care pathway based workflow system with decision support was the Triple Assessment Decision Support (TADS) system in the CREDO project (Patkar and Fox 2008), which used experiments to test the effect of the system on patient outcomes. The impact of the TADS system was measured by the compliance of clinicians with guidelines for breast related symptoms that raise suspicion of breast cancer. When clinicians were using the TADS system only 16 out of 120 patient journeys deviated from the guidelines, without the TADS system 60 out of 120 patient journeys deviated from the guidelines. Critical deviations dropped from 16 to 1 patient journey when the TADS system was used. No significant difference was found in the mean time taken by clinicians to diagnose a patient. The results from this experiment show that implementing care pathways into a workflow management system can improve the patient outcomes in healthcare.

These three workflow systems show the positive effect that care pathways, transformed into workflow applications, can have on KPIs as LOS, use of resources, costs of care, and quality of care. Based on these results and the results of the meta-analyses on care pathways, discussed in §1.1.2, the conclusion can be drawn that it is beneficial to transform existing paper-based care pathways into workflow applications that can be used by care givers.

1.1.4. Lack of methodology

As mentioned in §1.1.3 these systems, that integrate care pathways in workflow management, are still in development and mature systems are not yet introduced and adopted in the market. In the current research on care pathways there is a mismatch between the medical research and the research done within the field of Information Systems. Where the medical research is aimed primarily at developing the care pathways on a clinical level (Vanhaecht, et al. 2010), the research in the Information Systems field is mainly focused on specific technical aspects of implementing care pathways into executable workflow applications (AlSalamah, Gray and Morrey 2012), (Du, Jiang and Diao 2008), (Ye, et al. 2009), (Yao and Kumar 2012), (Alexandrou, Xenikoudakis and Mentzas 2009), (Mauro, et al. 2010), (Anyanwu, et al. 2003), (Sedlmayr, et al. 2007), (Fox, Patkar and Thomson 2006), (Patkar and Fox 2008), (Graeber, et al. 2007), (Blaser, et al. 2007). The part which describes how text-based care pathways can be modelled into executable workflow process models in a structured way is still missing in current research. From both practical and academic perspective there is a lack of methodology regarding the transformation phase from paper-based care pathways into executable workflow process models that can be implemented in hospitals and medical centres.

The lack of methodologies in Business Process Management (BPM) is seen over all industries. In general both experts in the BPM field (Bandara, et al. 2007) and BPM vendors (Sadiq, et al. 2007) indicate that there is a need for BPM methodologies that are focused on specific types of BPM projects. When searching online on Google[1] (not Google scholar[2]) it is found that the community is tackling this lack of academic BPM methodologies by business books and how-to tutorials. The topic of developing guidelines and methodologies that also include the workflow modelling part is emerging, as can be seen by the recent master thesis of Derrick (2012) in which conceptual-to-workflow model transformation guidelines are examined.

[1] http://www.google.com
[2] http://scholar.google.com/

In this thesis the process of transforming paper-based care pathways into workflow process models is further developed. Therefore this thesis acts on the found gap between medical research, Information System and BPM research, and practice.

1.2. Research goal

The goal of this research is to derive a methodology that can be used to model care pathways as executable workflow applications. By deriving a methodology that can be used to model care pathways in executable workflow process models, the usability of and the compliance with care pathways by medical staff will be increased. As discussed in §1.1.2 and §1.1.3 increasing the usability of and compliance with care pathways is expected to result in an improvement of the quality of care while costs are being decreased. The research questions and objectives are further discussed in §2.1.

1.3. Thesis structure

This thesis is structured as follows. Chapter 2 describes the research design; this includes the research questions and objective, scope, research method. Chapter 3 describes the proposed methodology to transform a paper-based care pathway to an executable workflow application. Chapter 4 follows with a case study where a paper-based care pathway is modelled into a conceptual process model and as proof of concept the conceptual process model is partly transformed into a workflow process model. Chapter 5 discusses the evaluation of the proposed methodology and the developed models. Finally chapter 6 concludes with the conclusion, practical implications, limitations of the research, and suggestions for future research.

2. Research design

The research design will be discussed in this section. First the research questions are given together with the research objective. Next the scope is described, followed by the research method and model. After this the modelling language and tools chosen for this research will be introduced.

2.1. Research questions and objective

Based on chapter 1 the following scientific research questions are defined. The main scientific research question is formulated as follows.

How can paper-based care pathways be transformed to executable workflow process models in a structured and reproducible way?

In order to answer this question it can be broken down to different sub questions. One way to do this is by looking at the different phases of the transformation process, each phase has its own key deliverable that is needed before the next phase can be entered. The phases of the transformation process and how they are related to the research questions are shown in Figure 1.

The first phase is understanding which information is presented in the paper-based care pathway, without this understanding it is futile to start modelling the pathway. The key deliverable of this phase is an annotated paper-based care pathway in which all the information in the pathway is labelled. This deliverable is not only necessary to get grip on the information that is presented in the care pathway from the perspective of the business analyst that is modelling the executable workflow process model, but it can also be used to verify or explain the understanding of the pathway to different stakeholders that might be involved (e.g. physicians, nurses, information managers, health information system vendors). This results in the following sub question.

- *How can the information that is presented in the paper-based care pathway be extracted?*

The next phase will be to model a conceptual process model from the annotated paper-based care pathway. A conceptual process model is a high level overview of different activities that are to be executed in a current or envisioned business process, this overview is usually a graphical description (Wedemeijer and de Bruin 2004). Typically it presents an abstract view of the business process with very minimal technical details. Because of this high level of abstraction conceptual process models are independent of the future software implementation packages, since technical implementation decisions are not yet made. The conceptual process model fills the gap between the paper-based care pathway and the workflow application, which makes the conceptual process model a good key deliverable for this phase. This results in the following sub question.

- *How can paper-based care pathways be modelled in a conceptual process model?*

The last phase is to transform the conceptual process model to an executable workflow process model. Workflow process models aim to model and control the execution of processes in business, scientific, or other applications. In workflow process models workflow-relevant information is captured in order to have a controlled execution by a workflow management system (Weske and Vossen 1997). The key deliverable of this phase is of course the executable workflow process model of the care pathway. This results in the following sub question.

- *How can a conceptual process model of a paper-based care pathway be transformed to an executable workflow process model?*

The scientific research objective of this thesis is defined as:

Deriving a methodology which can be followed to transform paper-based care pathways to executable workflow process models in a structured and reproducible way and additionally apply this framework to a paper-based care pathway example.

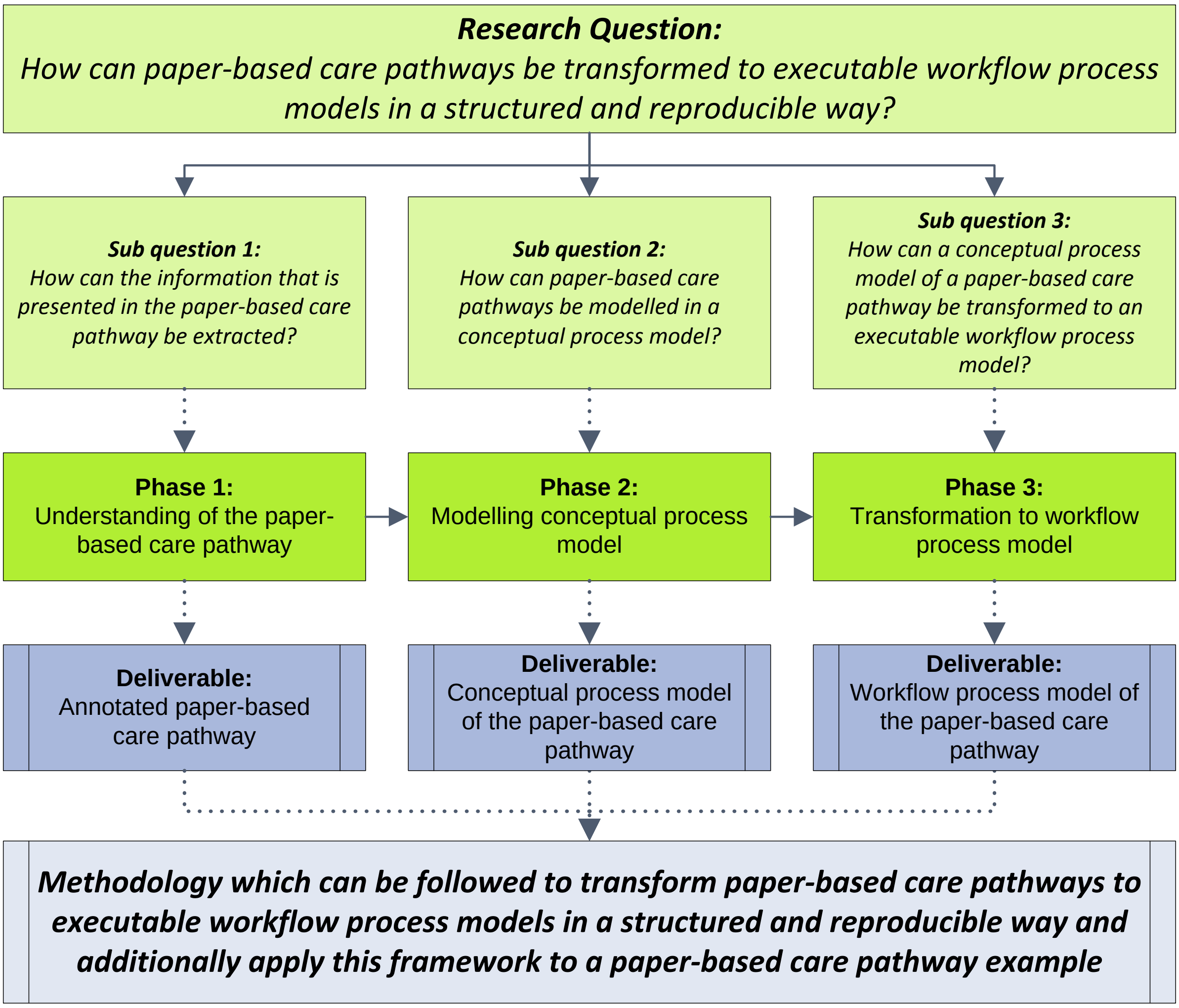

Figure 1: Phases of the transformation process

2.2. Scope

The scope of this thesis is defined by multiple dimensions which are: starting point of the methodology, type of care pathway, position in the BPM lifecycle, and the level of implementation of the example.

2.2.1. Starting point of the methodology

It is out of the scope of this thesis to design a care pathway; the methodology assumes that a paper-based care pathway is available to be used as starting point. The proposed methodology is focussed on transforming the paper-based care pathway to an executable workflow process model.

2.2.2. Type of care pathway

The methodology that is proposed in this thesis uses paper-based care pathways as basis to start from and is not aimed, and therefore probably not fit, to be used on other types of care pathways that are found in practice. The paper-based care pathway that is used in the case study of this thesis is provided by the Chinese Ministry of Health. Currently the Chinese government is executing a medical reform plan in order to assure that every citizen has equal access to affordable basic health care (Yip and Hsiao 2009). As part of this reform plan very detailed and structured paper-based care pathways are implemented in the Chinese hospitals (NICE - National Institure for Health and Care Excellence n.d.). With the implementation of these care pathways the Chinese Ministry of Health aims to standardize prescriptions, the length of stay of patients in the hospital and doctors' therapies, and increasing the turnover ratio for the hospital's beds (National Health and Family Planning Commission of the Peopl's Republic of China 2011). The Chinese paper-based care pathway that is used in the case study is shown in Appendix A: Unstable angina care pathway. Another example of a Chinese paper-based care pathway is the clinical pathway for surgical treatment of primary lung cancer (2012 Edition) (Zhi, et al. 2012).

Care pathways that are scattered in various reports, together with care pathways that only consist of flow chart figures, are not considered to be paper-based care pathways and are therefore not in the scope of this thesis. Parts of the proposed methodology might be useful when transforming other types of care pathways to executable workflow process models; however this is not in the scope of this thesis and will thus not be discussed.

2.2.3. Position in the BPM lifecycle

Since the starting point of the proposed methodology is a paper-based care pathway, the position of this methodology within the BPM lifecycle (La Rosa, Mendling and Reijers 2013) is to first understand which information is presented in the paper-based care pathway and to model this information in a conceptual process model; this is done in the Process discovery phase. After this phase the conceptual model is the As-is process model. The last step in the methodology is equal to the Process implementation phase of the BPM lifecycle. Therefore the scope of this thesis within the BPM lifecycle is in the Process discovery and the Process implementation phase. The Process analysis and Process redesign phases are not included in the methodology because in this thesis it is assumed that the process described in the paper-based care pathway needs to be implemented without any modifications. Also the phase after Process implementation is out of the scope of this thesis, however research on process monitoring and controlling of care pathway workflow systems are a logical next step for future research. The BPM lifecycle is shown in Figure 2. In order to give a better understanding on where the proposed methodology is positioned within the BPM lifecycle the phases and deliverables of Figure 1 are added to the BPM lifecycle in Figure 3.

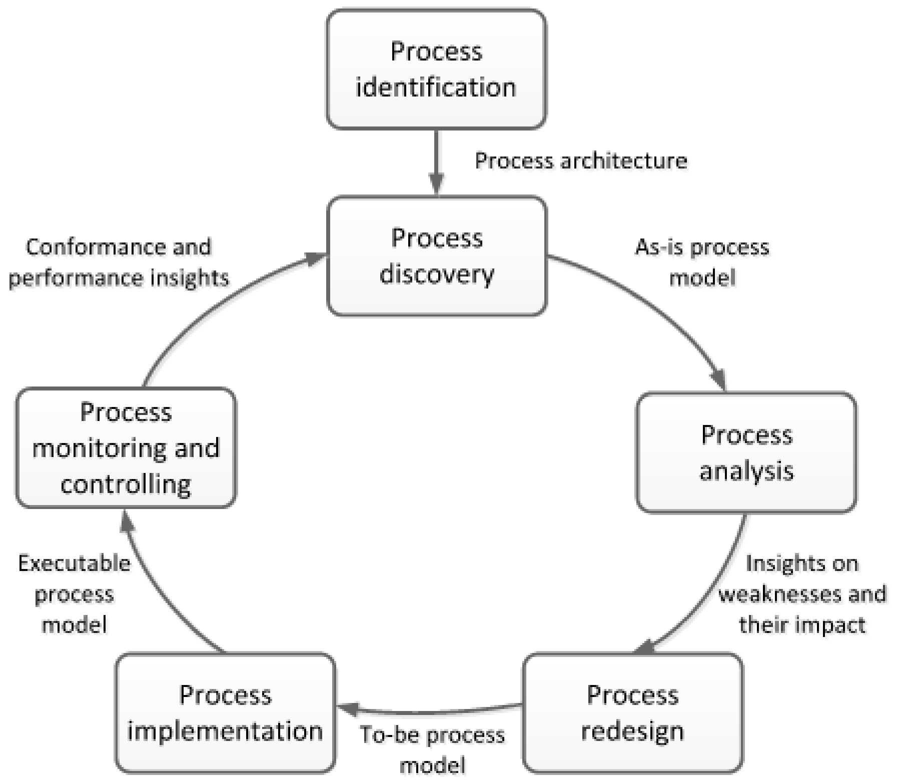

Figure 2: BPM lifecycle (La Rosa, Mendling and Reijers 2013)

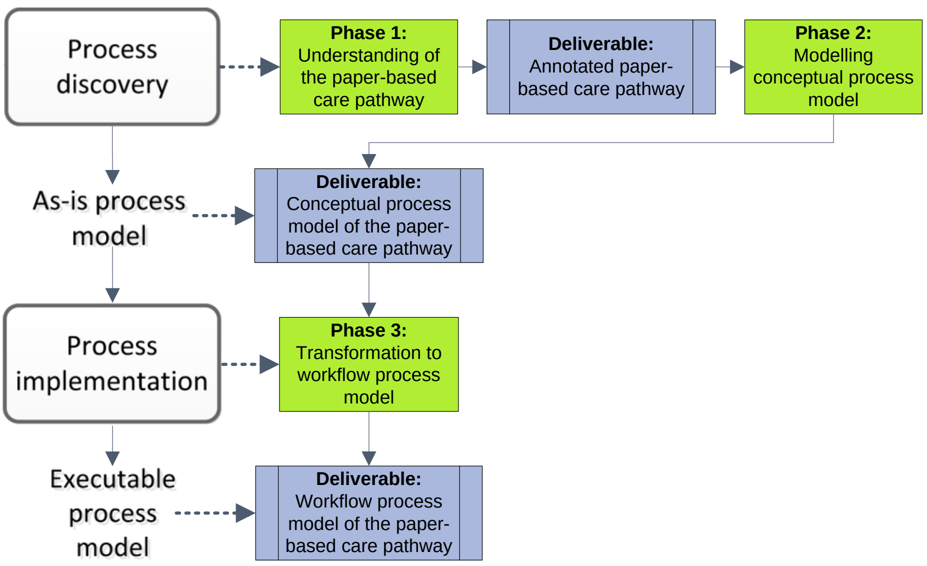

Figure 3: Methodology phases and deliverables with BPM lifecycle phases

2.2.4. Level of implementation of the example

The actual development of the example as a fully executable workflow process model implemented within a Medical Centre is outside the scope of the research; however the Unstable Angina care pathway[3] that is used as an example is fully modelled in a conceptual process model. Next the

[3] "The clinical pathway of intervention treatment for unstable angina (UA) 2009" provided by the Ministry of Health of the People's Republic of China

conceptual process model is also partly transformed to a workflow process model. An executable workflow application of this workflow process model is made as a proof of concept.

2.3. Research method and model

In this section the different research stages, which were applied in this thesis project, are introduced. Figure 4 shows an overview of the four different research stages, together with the key deliverables of these stages and the chapters in which these stages are discussed.

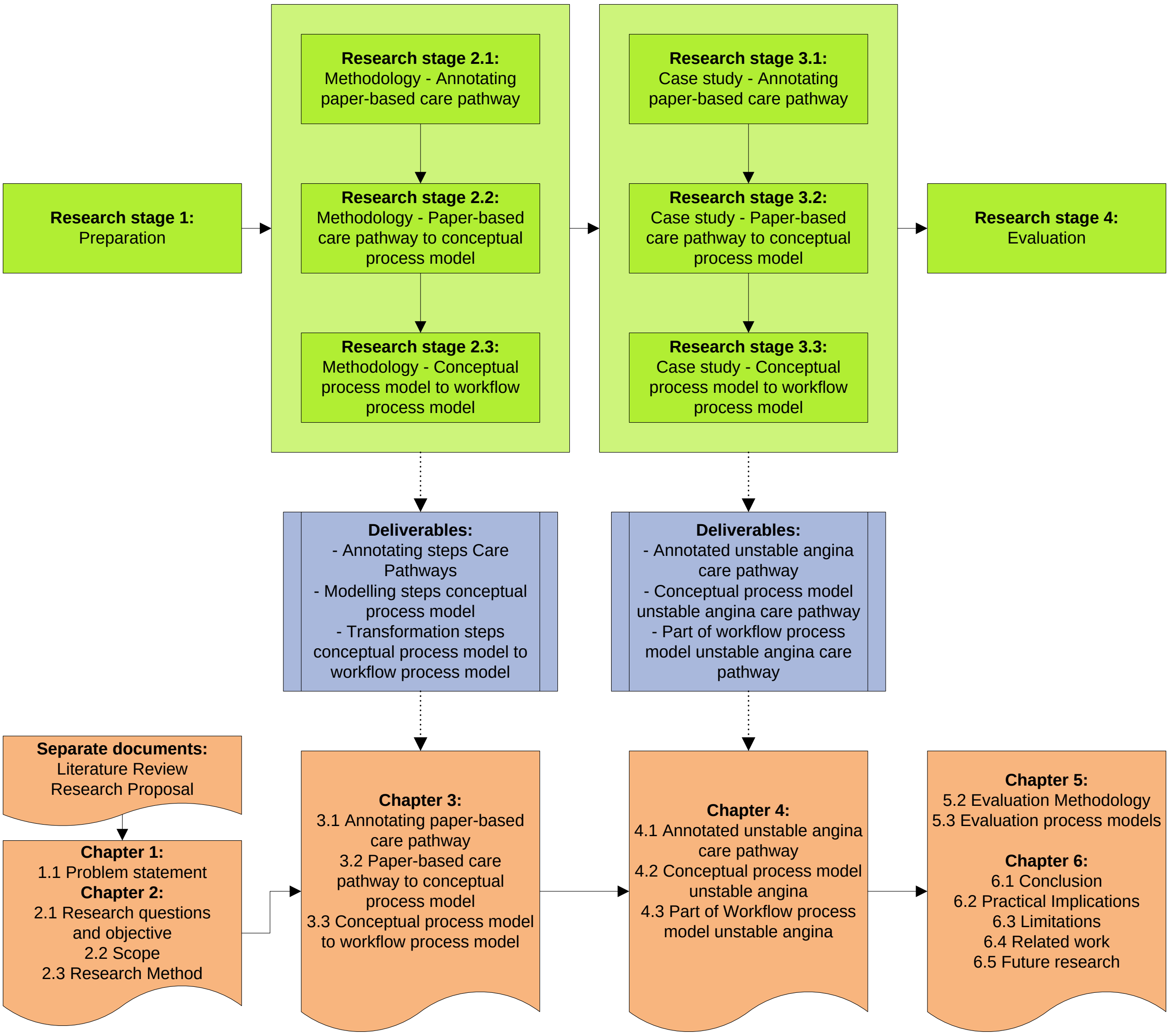

Figure 4: Research model

2.3.1. Research Stage 1

Preparation

The first stage of the research was the preparation stage. In this stage a literature review was conducted to gain an in-depth understanding concerning the domain, trends, ideas, and visions on care pathways and the workflow systems that are developed to implement care pathways. The research proposal was used to define the goals of this research, the research method, scientific background, and planning.

2.3.2. Research Stage 2.1

Methodology - Annotating paper-based care pathway

In stage 2.1 the first phase of the methodology (see Figure 1) is derived. The deliverable of this phase of the methodology is to describe the steps that should be followed to annotate the care pathway. These steps are determined by decomposing the paper-based care pathway and analysing the different information aspects that are presented in the pathway.

2.3.3. Research Stage 2.2

Methodology – Paper-based care pathway to conceptual process model

In stage 2.2 the second phase of the methodology (see Figure 1) is derived. In this phase the general modelling guidelines are explained and the specific modelling steps to model a conceptual process model from a paper-based care pathway are derived. The deliverable of this phase is a step-by-step description of the modelling process.

2.3.4. Research Stage 2.3

Methodology – Conceptual process model to workflow process model

In stage 2.3 the third phase of the methodology (see Figure 1) is derived. In this phase the specific transformation steps to transform a conceptual process model of a paper-based care pathway to an executable workflow process model are derived. As foundation for these transformation steps the conceptual-to-workflow model transformation guidelines are used that were proposed by Derrick (2012).

2.3.5. Research Stage 3.1

Case study - Annotating paper-based care pathway

In this stage a case study is performed where the annotating steps of phase 1 (see Figure 1) are followed to annotate the unstable angina care pathway.

2.3.6. Research Stage 3.2

Case study - Paper-based care pathway to conceptual process model

In this stage a case study is performed where the conceptual process modelling steps of phase 2 (see Figure 1) are followed to model the conceptual process model of the unstable angina care pathway.

2.3.7. Research Stage 3.3

Case study - Conceptual process model to workflow process model

In this stage a case study is performed where the transformation steps of phase 3 (see Figure 1) are followed to transform the conceptual process model of the unstable angina care pathway to a workflow process model. Of this workflow process model a small workflow application is made to provide proof of concept that the steps described in the methodology can deliver an executable workflow process model that can be used to manage a workflow in a clinical setting.

2.3.8. Research Stage 4

Evaluation

This stage includes the evaluation of the methodology and the unstable angina care pathway models. The evaluation is done internally by Philips Research, however also an evaluation tool is developed which could be used to evaluate the methodology.

2.4. Modelling language

There are many different modelling languages that can be used for different kinds of process models. Graphical modelling languages are widely used because the graphical aspect makes it more human-readable and easy to comprehend without prior technical training than other non graphic languages. For non-technical business users the graphical notations like the Unified Modeling Language Activity Diagrams (UML AD) and Business Process Model and Notation (BPMN) are easy to understand (Ko, Lee and Lee 2009). Together these graph-based languages are the two most expressive, easiest for integration with the interchange and execution level, and possibly the most influential in the near future (Ko, Lee and Lee 2009). However a literature review by Dassen (2012) found several other studies (Fernández Fernández, et al. 2010), (Allweyer 2010), (Chinosi and Trombetta 2012), (Eloranta, Kallio and Terho 2006) that conclude that BPMN has the most potential and is emerging as a de facto standard language for capturing business processes.

For the redesign phase in the BPM lifecycle (see Figure 2) graphical standards are leading. For the next phase it is different to find a widely used standard because of the differences in Business Process Management Systems and their underlying system infrastructure (Ko, Lee and Lee 2009).

When modelling the conceptual process model the BPMN 2.0 standard will be used. For the workflow process model also the BPMN 2.0 standard will be used to model the graphical part of the model, this is one of the industry requirements that were given by Philips Research. In addition to the graphical part of the model also other workflow-relevant information will be captured in the workflow process model. When developing a workflow system this information is used for the controlled execution of the model.

2.5. Business Process Modelling Tools

For the conceptual process model the Business Process Modeler[4] is used. This process modeller is a free tool that is easy to use and which uses the BPMN 2.0 standard. It also has a simulation option which is not used in this thesis.

For the workflow process model the Drools platform[5] is used. In the Drools platform there are multiple projects that can be combined to be used on the Business Logic Integration Platform. Functionalities of the drools platform are rules, workflow and event processing. This platform was recommended by Philips Research to be used for the workflow process model part of the thesis.

These tools are not obligatory when using the proposed methodology. The methodology is created in such a way that users of other tools and platforms should be able to use the methodology as well.

[4] http://bizagi.com/index.php/en/products/bizagi-process-modeler
[5] https://www.jboss.org/drools/

3. Methodology: Paper-based care pathway to executable workflow process model

In this chapter the proposed methodology is described. The methodology is split into three sections that represent research stage 2.1, 2.2, and 2.3 in the research model (shown in Figure 4 and described in §2.3). The components of the methodology are shown in Figure 5.

In order to model a paper-based care pathway it is of high importance to verify the models with medical specialists. Care pathways can use medical terms that might be confusing or unknown to non-specialised business analysts. Also the medical processes that are used during the treatment of a patient might be hard to follow for an outsider. Whenever additional information is needed or a step needs to be checked by a medical specialist, this is shown in the methodology with *italic*. In some steps BPMN constructs are used to explain the steps in more detail, however the methodology is aimed to be neutral in respect to the used modelling language.

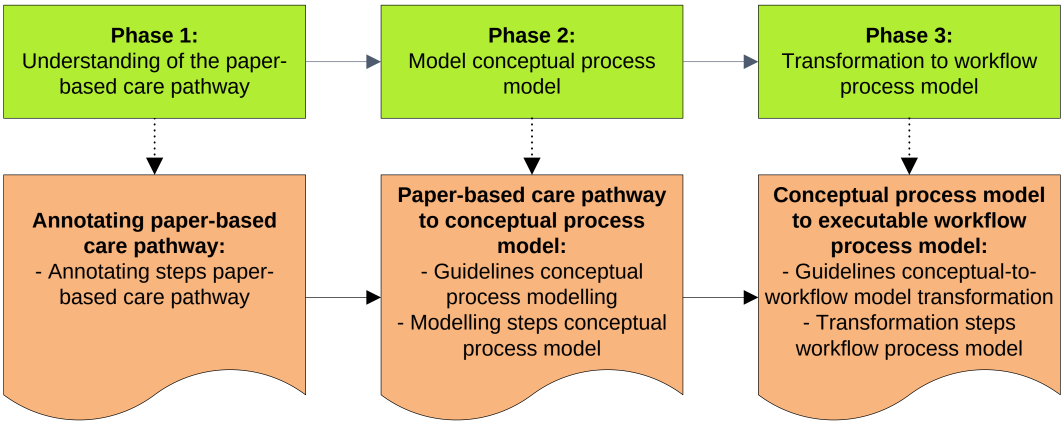

Figure 5: Methodology components

3.1. Annotating paper-based care pathway

In this section the steps are described that should be followed to get a better understanding of the paper-based care pathway. In these steps the information in the paper-based care pathway is annotated. An example of how a paper-based care pathway should be annotated is given in §4.1.

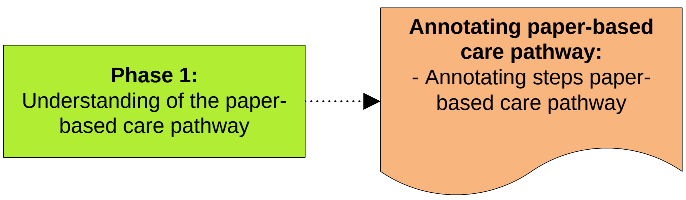

Figure 6: Methodology components phase 1

3.1.1. Annotating steps paper-based care pathways

1. Annotate the care pathway in different categories, in an analysis of the example care pathway (Appendix A: Unstable angina care pathway) the following categories are found: Clinical guidelines, Patient categories/symptoms, Treatment decisions, Specification of Patient group, Test orders, Operation guidelines, Patient status for discharge, Variation symptoms, and Checklists.
2. Annotate the time aspects that are mentioned in the Care Pathway.

3. Define what the beginning of the process is. What triggers or initiates the process of the care pathway? At which points can patients enter the care pathway? *Consult a medical specialist if the Care Pathway is not clear about the points at which patients can enter the care pathway.*
4. Define what the ending of the process is. What signifies the end of the process? *Consult a medical specialist if the Care Pathway is not clear about the points at which patients can exit the care pathway.*

3.2. Paper-based care pathway to conceptual process model

In this section the modelling guidelines and steps are explained that are used in the modelling of a conceptual process model. First the seven general modelling guidelines of Mendling, Reijers & van der Aalst (2010) are explained. These guidelines can be used as recommendations on how to build a process model. Afterwards the specific modelling steps which should be used are explained to model a conceptual model from a paper-based care pathway. An overview of all components of this section of the methodology can be found in Figure 7.

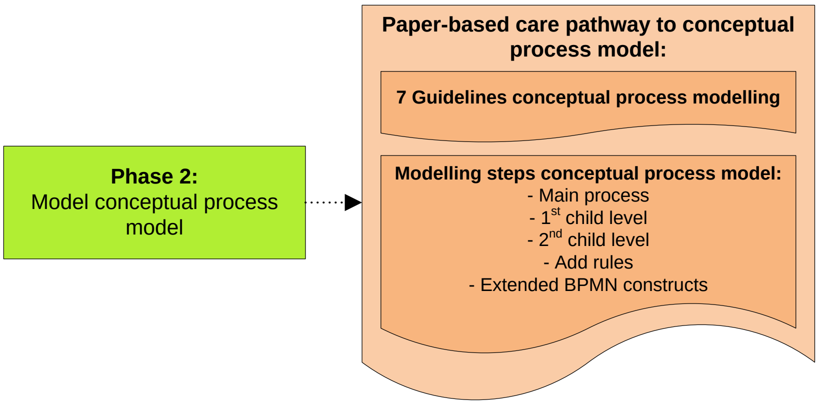

Figure 7: Methodology components phase 2

3.2.1. Guidelines conceptual process modelling

1. ***Use as few elements in the model as possible*** (Mendling, Reijers and van der Aalst 2010). Larger models tend to be more difficult to understand (Mendling, Reijers and Cardoso 2007) and have a higher error probability than small models (Mendling, Neumann and Van Der Aalst, Understanding the occurrence of errors in process models based on metrics 2007).
2. ***Minimize the routing path per element*** (Mendling, Reijers and van der Aalst 2010). The higher the degree of an element in the process model, i.e. the sum of the number of input and output arcs, the harder it becomes to understand the model (Mendling, Reijers and Cardoso 2007).
3. ***Use one start and one end event*** (Mendling, Reijers and van der Aalst 2010). There is a strong correlation between the number of start and end events with error probability (Mendling, Neumann and Van Der Aalst 2007). Process modellers will easily lose track of several start and end events due to our limited cognitive capability as humans. Models satisfying this requirement are easier to understand (Mendling, Reijers and van der Aalst 2010).
4. ***Model as structured as possible*** (Mendling, Reijers and van der Aalst 2010). A process model is structured if every split connector matches a respective join connector of the same type (Mendling, Reijers and van der Aalst 2010). Unstructured models are more likely to include errors and are hard to understand (Mendling, Reijers and van der Aalst 2010), (Mendling, Neumann and Van Der Aalst 2007).

5. ***Avoid OR routing elements*** (Mendling, Reijers and van der Aalst 2010). Models that have only AND and XOR connectors are less error-prone.
6. ***Use verb-object activity labels*** (Mendling, Reijers and van der Aalst 2010). The verb-object labelling style, like "Inform complainant", is considered as significantly less ambiguous and more useful than action-noun labels or labels that follow neither of these styles (Mendling, Reijers and Recker 2010).
7. ***Decompose the model if it has more than 50 elements*** (Mendling, Reijers and van der Aalst 2010). For models with more than 50 elements the error probability tends to be higher than 50%. Therefore, large models should be split up into smaller models (Mendling, Reijers and van der Aalst 2010), (Mendling, Neumann and Van Der Aalst 2007).

3.2.2. Modelling steps conceptual process model

When modelling the conceptual process model it is important that there is traceability between the model and the care pathway. In this methodology no tool is explicitly used to support this traceability. However during the naming of the elements in the model it is recommended that the names that are used are the same as used in the original text of the care pathway. If one decides to deviate from this and use different names for the elements in the model than used in the original text of the paper-based care pathway, matching annotations can be made in both the paper-based care pathway and the conceptual process model in order to increase the traceability between these two.

3.2.2.1. Main Process

This section discusses the steps to model the main process of the paper-based care pathway. The result of these steps in the case study can be seen in §4.2.1.

1. Start with adding the Start and End Events of the Happy Path. The points where patients can enter the care pathway are already determined in §3.1.1 Step 3. In case of a care pathway this can be when a patient enters the department and wants to register him/herself. Also the points that signify the ending of the care pathway are already determined in §3.1.1 Step 4. This will often be the discharging of the patient.
2. The next step is to model the checklist part of the care pathway. This part of the care pathway is used to create the subprocesses in the main process, each subprocess includes the tasks of a particular time frame. First add a subprocess for each timeframe given in the checklists. Name the subprocesses after the title of the checklist they are related to. Next connect the subprocesses in chronologic order.
3. When the subprocesses for the different checklists are added to the model the milestones can be added to the process. In the care pathway a milestone is reached after a checklist is completed. In case of the Unstable Angina there are 9 different milestones: beginning with 0-10 minutes after the patient reaching the Emergency Department, till the day the patient is ready to be discharged.
4. Check if sequence of the subprocesses matches the sequence flow of the process described in the care pathway. If this is not the case use AND split/join gateways and exclusive OR split/join gateways to reconnect concurrent and conditional steps in the process. It can occur that a specific subprocess can be performed multiple times until a patient is ready to go to the next milestone, this situation can be modelled with an exclusive split where the flow can continue

with the subprocess in the following milestone or the flow can be looped back to the specific subprocess that has to be performed again.

3.2.2.2. 1st child level

In this section the steps are included to model the 1st level of subprocesses. The case study example of these steps can be seen in §4.2.1, e.g. Figure 18 shows the subprocess of the first milestone in the main process.

1. Open the first subprocess (cf., step 2 in §3.2.2.1) in order to start modelling the activities within the first checklist.
2. In order for the nurses and physicians to perform the different kind of activities in parallel and without a pre-determined order it is recommended to add an AND split gateway after the Start Event. This makes it possible for the physician to perform diagnostic activities while a nurse is filling in the orders or performing care tasks.
3. In order to create an easy to follow structure it is recommended to add lanes when modelling in BPMN (or a similar construct when modelling in a different language) for the different kind of activities in the checklist.
4. Add in every lane a subprocess and connect the gateway with the subprocess. Name the subprocess after the different activities, tasks or orders that are checked in that part of the checklist. If the checklist items have another level of separation then more subprocesses can be added within the lane. Name the subprocesses after the kind of tasks that take place within this subprocess.
5. Add a new gateway and connect the subprocesses with this gateway. Next connect the gateway to the End Event.
6. Repeat steps 1 to 5 for all the subprocesses on the parent level of the process.

3.2.2.3. 2nd child level

In this section the steps to model 2nd level subprocesses are explained. An example of such a subprocess is the subprocess Main activities for diagnosis and treatment 0-10 minutes in §4.2.1 Figure 19).

1. Open the first subprocess in the child level (cf., step 4 in §3.2.2.2) and add a None Start and End Event.
2. After the None Start Event add a gateway, the specific type of gateway depends on the different tasks that are preformed in this part of the checklist. For parallel activities use the AND split gateway, if there are also activities that should be performed in a specific pre-determined order exclusive OR split gateways can be used. *Consult a medical specialist if the Care Pathway is not clear about the way exceptions are handled within the process.*
3. Add the tasks that are associated with this part of the checklist and connect the gateway with the added tasks. It is possible that for some activities on the checklist reusable subprocess are required. This is for example when the same group of activities is used in multiple milestones. See for instance the subprocess Operation in the case study (§4.2.1 Figure 22) which is used in multiple milestones.
4. Add a new gateway and connect the tasks with this gateway. The type of gateway depends on the sequence of flow that is modelled in the previous step (cf., step 2 in §3.2.2.3). Next connect the gateway to the End Event.

5. Repeat step 1 to 5 for all the subprocesses on the 1st child level of the process.

3.2.2.4. Add rules

Business rules can be used to define the sequence of flow for a specific patient. An example of such a business rule is shown in the case study §4.2.1 Figure 19 where it is checked if the diagnosis of the patient is clear.

1. Locate the areas in the annotated care pathway that can be used as business rules in the model.
2. Locate these parts in the conceptual model of the care pathway.
3. Use inclusive gateways and conditional expressions to model the sequence flows as it is described in the care pathway. It is possible to take multiple paths, however the process should be designed in such a way that at least one path can be taken for each (type of) patient.
   When using BPMN 2.0 a new option is to use Business Rule tasks, these tasks evaluate a business rule at a particular point in the process, the gateway following the Business Rule task can test the variable and route the process to perform any actions required by the business rule (Silver 2009).

3.2.2.5. Extended BPMN constructs

Extended BPMN constructs can be used to add flexibility in the conceptual process model. Example of extended constructs are shown in §4.2.1 Figure 21 where sending and catching intermediate Signal events are used before and after the operation subprocess. If another modelling language is used it is recommended to look up similar extended constructs for this language.

1. Refine the exception handling patterns and how it should be handled. *Consult a medical specialist if the Care Pathway is not clear about the way exceptions are handled within the process.*
   When using the BPMN standard for modelling there are a set of patterns that can be used to handle specific exceptions (Lerner, et al. 2010). These patterns are shown in Table 2.
2. If the process needs to wait for something to happen the catching Message or Signal intermediate event (or Receive task) can be used. Message events can be used within one process; however when events need to communicate between subprocesses a Signal event can be used. A Signal event broadcasts to any listening process. Notice that when using a Signal event the broadcaster or publisher is not aware which receiving (catch) signal events are receiving the broadcast. Also because the Signal event has no defined target the communication lines cannot be shown graphically in the diagram by using message flows, which makes it more difficult to follow in the diagram (Silver 2009).
3. If an information request has a deadline, put the Timer event on receive (catch) not send (throw).
4. Use matching labels for paired throw-catch events (Condition, Error, Escalation, Signal), in addition to any non-visual linking attributes.

Table 2: Exception handling patterns

Pattern	Description
Immediate Fixing	When a nonnormative situation is noted, an action is taken to address the problem that caused this situation before continuing with the remainder of the process. This is done by representing the nonnormative situation as an Intermediate (catch) Event attached to the boundary of a task. A multiple event can be used if there are multiple triggers that can lead to a nonnormative situation. When one of the specified triggers is detected the flow of the process is instantly redirected through the Intermediate Event, the new process path is called Exception Flow (Lerner, et al. 2010). The structure of this pattern is shown in Figure 8.
Deferred Fixing	When a nonnormative situation is noted, an action is taken to record the situation and possibly address the situation either partially or temporarily (because an immediate full fix is either not immediately possible or not necessary). This fix is done by representing the nonnormative situation as an Intermediate (catch) Event attached to the boundary of a task. When one of the specified triggers is detected the flow of the process is instantly redirected through the Intermediate Event where a temporary fix is performed. Later on in the process a XOR Gateway is used to check if there is a problem report, if yes then a full fix is performed (Lerner, et al. 2010). The structure of this pattern is shown in Figure 9.
Retry	When a problem is detected immediately after the execution of the task causing the problem, an action is taken to address the problem. After the problem is addressed the task that caused the problem is performed again to check if the problem is resolved. This fix is done by representing the nonnormative situation as an Intermediate (catch) Event attached to the boundary of a task. When one of the specified triggers is detected the flow of the process is instantly redirected through the Intermediate Event where the fix is addressed, the flow loops back to try the initial task where the problem occurred. In case the problem occurs again there is a additional Exception Flow that is defined for giving up retry and propagating the exception to be handled elsewhere (Lerner, et al. 2010). The structure of this pattern is shown in Figure 10.
Reject	When an exception occurs where the patient is forced to leave the care pathway. This is done by representing the nonnormative situation as an Intermediate (catch) Event attached to the boundary of a task. When one of the specified triggers is detected the flow of the process is redirected to an End Event that throws a Message of notification (Lerner, et al. 2010). The structure of this pattern is shown in Figure 11.
Compensate	When there is an exception that occurs and a task is cancelled it is often necessary to undo work that has already been completed. This pattern addresses the need to determine what work must be undone and then executes the compensating actions needed in order to undo it. This pattern makes use of the Compensation construct of BPMN which rolls back some of the effects of a Transaction. In this case a transaction is based on a formal business relationship and unanimous agreement among two or more participants. A Cancellation Event is attached to the boundary of a subprocess. When this Cancellation event is triggered the Compensation task is performed before the subprocess is actually cancelled (Lerner, et al. 2010). The structure of this pattern is shown in Figure 12.

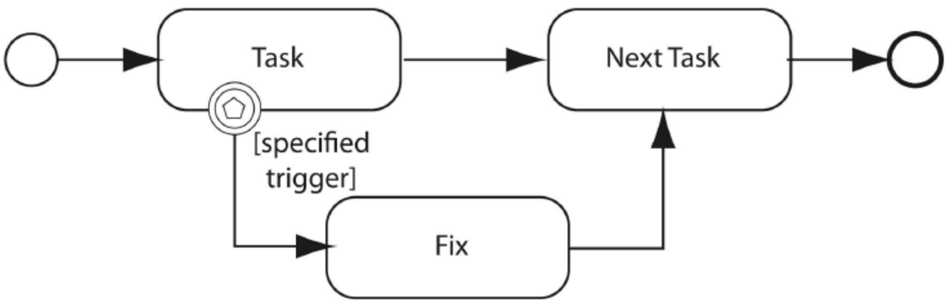

Figure 8: Immediate fixing pattern

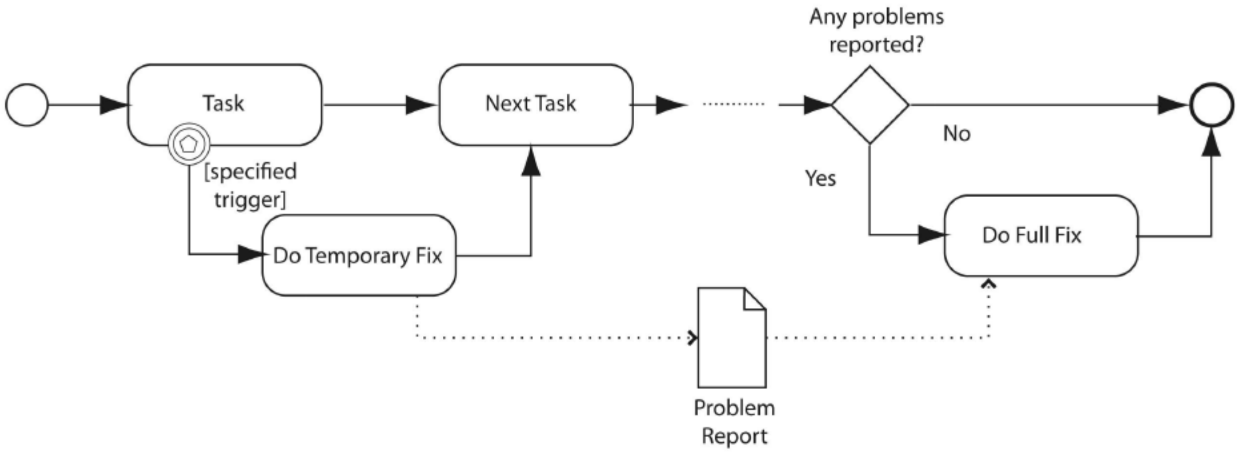

Figure 9: Deferring fixing pattern

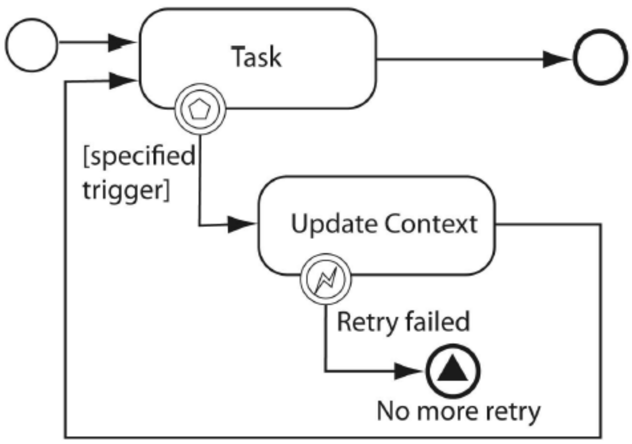

Figure 10: Retry pattern

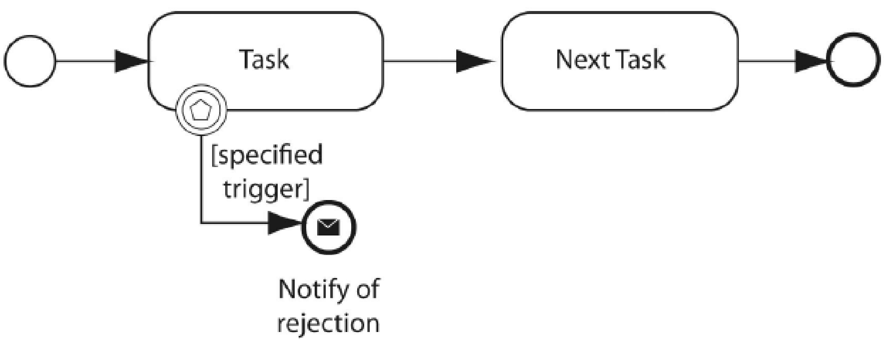

Figure 11: Reject pattern

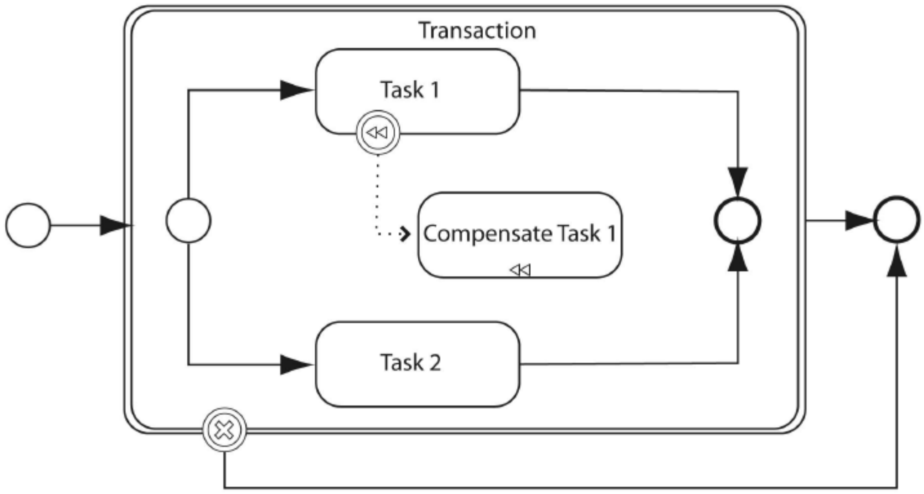

Figure 12: Compensate pattern

3.3.Conceptual process model to executable workflow process model

In this part the modelling guidelines and steps are explained that are used in the transformation of a conceptual process model to a workflow process model. First the conceptual-to-workflow model transformation guidelines of Derrick (Derrick 2012) are explained. These guidelines were partly found in literature and partly proposed by Derrick himself. Afterwards the transformation steps are explained. In these steps the abbreviations of the conceptual-to-workflow model transformation guidelines are used to link the steps to the matching guidelines. An overview of all components of this section of the methodology can be found in Figure 13.

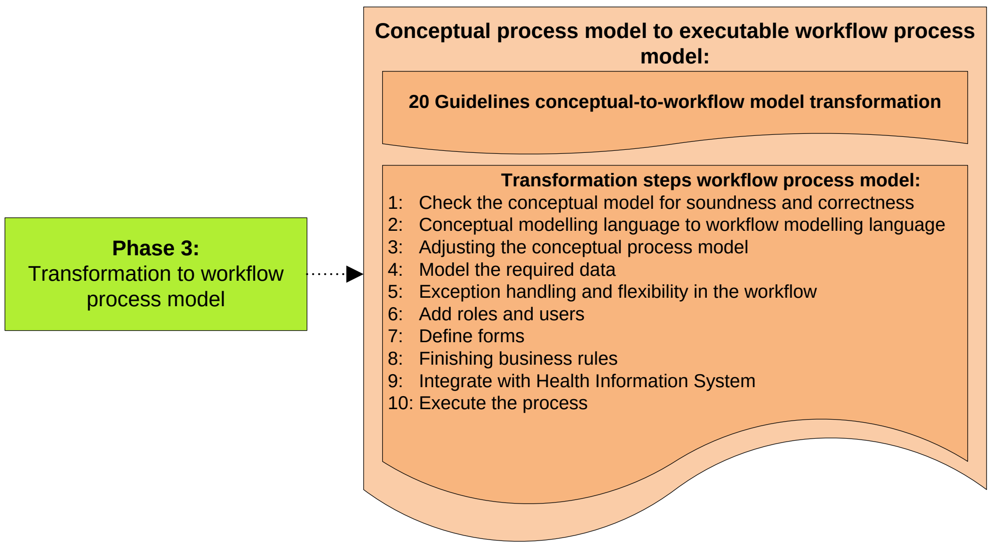

Figure 13: Methodology components phase 3

3.3.1. Guidelines conceptual-to-workflow model transformation

The conceptual-to-workflow model transformation guidelines of Derrick (Derrick 2012) are shown and explained in Table 3.

Table 3: Conceptual-to-workflow model transformation guidelines

Abbr.	Guideline
G1	***Decompose all abstract/composite tasks in the conceptual process model*** Typically in conceptual process models, a complex sub-process could be represented as a single abstract task. When transforming a conceptual process model to a workflow process model, such abstract tasks will then have to be identified and decomposed into several atomic/discrete tasks (tasks which cannot be decomposed any further).
G2	***Complete the process model*** Common often missing control flow information includes missing time-out, inappropriate behaviour when requesting revision, inappropriate end of (sub) process, sunny day scenario, impossible workflow patterns, and alternatives due to different applications.
G3	***Check the conceptual process model for semantic correctness*** When transforming a conceptual process model into a workflow process model, it is important to assess the correctness of the workflow process model (Dreiling, et al. 2008). When checking for correctness of a process model, our main focus is to ensure that it is sound. 1) For each token put in the *start* place, one (and only one) token eventually appears in the *end* place; 2) When the token appears in the *end* place, all the other places are empty; and 3) For each transition (task), it is possible to move from initial state to a state in which that transition is enabled i.e. there should be no dead tasks.
G4	***Examine the constructs of both the conceptual and workflow modelling language based on the BWW ontology*** Ontological examination of both the conceptual and workflow modelling languages is advantageous in that it clearly brings to light the difficulty of mapping constructs of the two languages that typically feature a different level of abstraction. The BWW model has five fundamental and core ontological construct namely; thing, property, state, transformation and stable state (Green and Rosemann 2010).
G5	***Assess the degree of workflow pattern support offered by both the conceptual and workflow modelling languages*** Identify which workflow patterns are directly, indirectly or not supported by a particular modelling language.
G6	***Normalize the conceptual process model*** During this stage, additional information associated with the different elements of the process model required for its successful execution is incorporated. These include: • Data necessary for process routing such as routing probabilities of the different alternative paths associated with exclusive gateways and/or workflow attribute. The three major classes of routing are conditional, rule-based, and parallel routing [26]. • Priority attributes that should be added to the tasks.
G7	***Refine the granularity of tasks/functions*** In a workflow implementation, the granularity of tasks is typically driven by the characteristics of the workflow actors, of the assignment criteria, and by the performance and tracking requirements (Casati, et al. 2002). Choosing tasks of the right size is a key issue in workflow modelling because a workflow engine sends work orders. A task is of the right size if it encompasses the work that a single person can perform uninterrupted.
G8	***Every task should have temporal aspect/constraints if it is dictated by the underlying business logic*** These can be: Deadline constraint, wait constraint, obligatory constraint, iteration constraint, and minimum, maximum and average execution time of tasks.

G9	***Integrate the process model with existing tools and application programs to be invoked by the WFMS*** These applications cover mainly general applications such as text editor or spreadsheet editor, and include special applications developed for the given task.
G10	***Configure exception handling and flexibility information in the workflow*** Technology supporting business process automation should allow the process models to adapt to changing requirements.
G11	***Map similar constructs of both modelling languages*** The main focus is to create a translation of pairs of constructs, one from the conceptual modelling language, and another from the workflow modelling language earlier determined from BWW ontology examination.
G12	***Specify a trigger for every task in the workflow process model*** There are four different types of triggers, automatic, user, message, and time. Note that the type of trigger is not the same as the task type (automated, manual or user). A user task could be triggered by a message trigger for instance when waiting for tests results before diagnosing a patient.
G13	***For every not manual task, specify the workflow engine/service that is responsible for executing the work represented in the task at runtime*** Different task may require different services to successfully execute it.
G14	***Always make a distinction between explicit and implicit OR-splits*** For explicit OR-split, workflow attributes is solely used to determine which process path among the possible process paths will be followed during the execution of a case. For the implicit OR-split, the moment of choice is made at the latest possible time.
G15	***For every task in the workflow process model, it should be explicitly specified whether it is an automated, manual or user task*** An automatic task is entirely performed by an application/computer program and does not require any intervention by human being. To the contrary, a manual task is entirely performed by human without the aid of any business process execution engine or any application. A user task is when a user performs a certain task with the assistance of a software application and is scheduled through a task list manager.
G16	***All user triggered atomic tasks must be allocated resources authorized to execute it*** Resources include roles and/or participants. Roles can be seen as a group of participant with similar characteristics. Resources therefore refer to an actor or group of actors authorized to execute a particular task. These resources will be offered work items of the task to which they are associated at runtime.
G17	***For every XOR split task, critically determine the evaluation sequence of the different flow expressions specified for the outgoing flows of the task*** Only the first flow expression that evaluates to true will be activated and subsequently all other flows will be automatically disregarded.
G18	***Add all the necessary case variables associated with every atomic task in the process model*** Variables should be key attributes of the object(s) being manipulated by a particular atomic task.
G19	***Specify the mechanism to be used to select a resource to execute a work item from a set multiple resources allowed to execute the same work item*** There are two different mechanisms. Push-driven, the workflow engine makes a decision on which resource should execute a particular work item and subsequently sends the work item to that specific resource. Pull-driven, the workflow engine sends to each resource that is authorized to execute a particular work item a copy of the work item.

G20	***Set the queuing principle to be used to order multiple work items*** FIFO, LIFO, SPT, LPT, SRPT, LRPT, EDD, or PRIO.

3.3.2. Transformation steps workflow process model

In order to model a structured and reproducible workflow process model it is important to add a sequence to the conceptual-to-workflow model transformation guidelines shown in Table 3. Next to the sequence the guidelines might also need additional explanation to make them better suited for this particular kind of process that is described in a paper-based care pathway. The steps in this part of the methodology are grouped in ten sections, these sections and the guidelines which are in each section are shown in Table 4.

When modelling the workflow process model it is important that there is traceability between the workflow process model and the conceptual process model. In this methodology no tool is explicitly used to support this tractability. However during the naming of the elements in the model it is recommended that, where possible, the names that are used are the same as used in the matching elements of the conceptual process model.

Table 4: Sections transformation steps and guidelines

Section transformation steps		Guidelines
1	**Check the conceptual model for soundness and correctness**	G3
2	**Conceptual modelling language to workflow modelling language**	G4, G5, G11
3	***Adjusting the conceptual process model***	G1, G7, G8, G15, G12, G16, G18, G19, G14, G17
4	***Model the required data***	G6
5	***Exception handling and flexibility in the workflow***	G10
6	***Add roles and users***	G20
7	***Define forms***	
8	***Finishing business rules***	
9	***Integrate with Health Information System***	G9, G13
10	***Execute the process***	G2

3.3.2.1. Check the conceptual process model for soundness and correctness

In this section the conceptual process model is checked for soundness and correctness.

1. G3: Before starting with transforming the conceptual process model into a workflow process model it is important to assess the correctness of the conceptual process model. When checking for correctness of a process model, our main focus is to ensure that it is sound. 1) For each token put in the *start* place, one (and only one) token eventually appears in the *end* place; 2) When the token appears in the *end* place, all the other places are empty; and 3) For each transition (task), it is possible to move from initial state to a state in which that transition is enabled i.e. there should be no dead tasks.
2. Even if a model is sound, this gives no indication that the model is semantically correct. *In order to verify whether the model does what the clinicians behind the care pathway (and the guidelines) intend the model needs to be discussed with a medical specialist.*

3.3.2.2. Conceptual modelling language to workflow modelling language

This section used examines the languages used for the conceptual process model and for the workflow process model. This section can be skipped if the same modelling language is used for both models.

1. G4: Examine the constructs of both the conceptual and workflow modelling language based on the BWW ontology: thing, property, state, transformation and stable state.
2. G5: Assess the degree of workflow pattern support offered by both the conceptual and workflow modelling languages: identify which workflow patterns are directly, indirectly or not supported by a particular modelling language.
3. G11: Create a translation of pairs of constructs, one from the conceptual modelling language, and another from the workflow modelling language.

3.3.2.3. Adjusting the conceptual process model

In this section the conceptual process model is adjusted to meet the needs and requirements of a workflow model (i.a. arranging and composing/decomposing tasks, check temporal aspects/constraints, define the kind of tasks and which roles can perform each task). The case study example of the results of these steps is discussed in §4.3.3.

1. G1 + G7: Arrange and compose/decompose the tasks in such a way that the sequence flows for each subprocess can end with a checklist. Sometimes one checklist in the subprocess is enough, but it can also be the case that there is a particular order in which the tasks need to be executed and there is a need to have one or more intermediate checklists. Also tasks in which the user (physician or nurse) puts data in the process should be defined; forms should be used for data input or data extraction. *Consult a medical specialist if the Care Pathway is not clear about the order in which tasks need to be performed.*
2. G8: Check which tasks are dictated by the underlying business logic to have temporal aspect/constraints. This means that for every task it should be checked if there is a need for a deadline constraint, wait constraint, obligatory constraint or iteration constraint. Deadline constraints should be used on checklist tasks in order so the user gets a reminder when a pending checklist task is not performed. Wait constraints can be used for monitoring tasks where certain patient values are monitored for a defined period of time.
3. G15: Check for every task if it is automated, manual or user task. Automated tasks are entirely performed by an application/computer program without any intervention by human beings, where manual tasks are performed by humans without using any software application. User tasks are performed by humans with the assistance of a software application. Not all workflow languages/engines can handle manual tasks, check with your workflow language/engine if this is possible or else use user tasks instead.
4. G12: Specify a trigger for every task in the workflow process model. There are four different types of triggers, automatic, user, message, and time. A trigger shows when an activity is ready to be performed.
5. G16: For user and manual tasks, define which resources can perform this task. Resources include roles and/or specific users. Some tasks can only be performed by a certain role, for instance a physician, where other tasks might only be performed by nurses. It is also possible that a task can be performed by either a physician or a nurse; in this case a group of users can be assigned to a task. It can also occur that tasks should be performed by the same user, for instance if test 1

is performed by physician 1, than test 2 should also be performed by physician 1 (and not by the other available physicians). *Consult a medical specialist if the Care Pathway is not clear about which resources are allowed to perform a particular task.*

6. G18: Make a data model of all the necessary case variables that are used in the process model. In every task there are key attributes of the patient or the treatment, these key attributes can be changed in the treatment process of the patient. For each task in the process model it should be checked that the attributes that are used in the task are included in the process model. This data model is used in §3.3.2.4 step 1.
7. G19: If there are multiple resources available to perform a task, specify the mechanism to be used to select a resource to execute a work item from a set multiple resources allowed to execute the same work item. There are two different mechanisms that could be chosen. Push-driven, the workflow engine makes a decision on which resource should execute a particular work item and subsequently sends the work item to that specific resource. Pull-driven, the workflow engine sends to each resource that is authorized to execute a particular work item a copy of the work item. *Consult a medical specialist if the Care Pathway is unclear about the mechanisms to select a resource to execute the work item.*
8. G14: While arranging and composing/decomposing the tasks check if the selection between explicit or implicit OR-splits is made correctly for each OR-gateway.
9. G17: For exclusive OR-splits, critically determine the evaluation sequence of the different flow expressions specified for the outgoing flows of the task. Only the first flow expression that evaluates to true will be activated and subsequently all other flows will be automatically disregarded.

3.3.2.4. Model the required data

This section is used to model the data that is required in the process. If a data model of the hospital is used it is always important to check if all necessary data and process variables are included in the data model. The data model of the case study example is discussed in §4.3.4.

1. G6: Model the data that is necessary to execute the process. It is normal that when implementing a workflow management system in a hospital the data model from the hospital is used (Health Information System/Electronic Medical Records). In order to check if all necessary data that is used in the model is present in the data model of the hospital all the necessary data from each activity should be checked.
2. If there are process data/variables that are useful for the execution of the care pathway but are not part of the data model already present in the hospital they should be added to the data model of the hospital.

3.3.2.5. Exception handling and flexibility in the workflow

The exception handling and flexibility aspects of the workflow process model are implemented in this section. In the conceptual process model exception handling patterns are already used, however it is important to check if these are transformed correctly in the workflow process model. Some examples of exception handling and flexibility of the case study are discussed in §4.3.5.

1. G10: During the treatment of a patients there are numerous events that can occur which will make the patient deviate from the care pathway. These are too many to be included in the paper-based care pathway; however these exceptions from the ideal treatment (also known as

"happy path") should be correctly handled in the workflow. *Therefore it is important to discuss with a medical specialist which exceptions can occur during the execution of the process and how these exceptions should be handled.* Unforeseen situations that arise during the execution of the workflow will require a flexible mode of reaction. The level of flexibility of the workflow depends on the workflow language and the workflow management system that is being used. The exception handling patterns discussed in section 3.2.2.5 Table 2 can also be used in the workflow process model.

3.3.2.6. Add roles and users

In §3.3.2.3 step 5 for each manual task the resources/roles that can perform the tasks were determined, in this section these resources and roles are added to the workflow process model. The roles and users in the workflow process model are discussed in §4.3.6.

1. Add the roles, groups, and the users (from §3.3.2.3 step 5) in the workflow process model.
2. G20: Specify in which order the resources will execute multiple work items. This of course depends highly on the particular situation. However it might be helpful for medical personal to see which work items are more important because they are for instance related to high-risk patients or to more important tasks. The work items could be ordered for instance on the importance of the tasks that are performed in the work items. This queuing principle is called Task with Priority go First (PRIO). *Consult a medical specialist if the Care Pathway is not clear about which resources can perform a particular activity.*

3.3.2.7. Define forms

In this methodology electronic forms are used in to translate the paper-based checklists in the workflow process model. There is however no standardized methodology yet to develop medical checklists (Winters, et al. 2009). Therefore this section gives some advice on the design and use of electronic forms in care pathways. The forms which were developed for the case study example are discussed in §4.3.7.

1. Define the forms that are used as checklists or as intermediate forms within the tasks of the model. Recommendations on the use of care pathways in practice are (Lenz, et al. 2007):
    - Forms should not be overloaded, core messages highlighted, scrolling should be avoided
    - It should be easily recognizable when pathway recommendations are not strict and when variance is needed
    - There should be carefully use of default selections

    Some points that require special attention when using electronic forms (Wakamiya and & Yamauchi 2009):
    - Displaying:
        - Improving visibility of checklists
        - Switching views alternately between electronic medical or care records and electronic cape pathways
    - Variance:
        - Reporting variance
        - Checking the occurrence of variance

2. The needs and workplace of the users of medical checklists are important when developing the checklists (Winters, et al. 2009). *Check with a medical specialist if the checklist items are correct and described in a clear and understandable way for the users.*
3. Seven principles that are applied in human factors engineering and that can be used when developing a checklist are shown in Table 5 (Winters, et al. 2009).

Table 5: Principles of human factor engineering

#	Principle
1	Design checklists based on caregivers' needs and the realities of their work by doing ethnographic studies of the clinical work and involvement of potential users.
2	List the most critical items at the beginning of the checklist whenever possible.
3	Avoid long checklists if possible. Subdivide long checklists into small meaningful sections or group checklists in time and space (for example, one checklist for this moment in time).
4	Pay close attention to usability, including the time it takes to complete the checklist, potential negative effects on caregivers' work and patient safety, and feedback from potential users.
5	Perform rigorous pilot testing and validation of the checklist before full-scale implementation.
6	Include potential users, content experts, and human factors/ usability experts on the design team.
7	Re-evaluate and update checklists periodically based on new literature and organizational experiences.

3.3.2.8. Finishing business rules

In the conceptual process model business rules are annotated in the process. In this section these rules are implemented in the workflow process model. The rules that were used in the case study are discussed in §4.3.8.

1. Add the business rules that were specified in the conceptual process model in a rules engine (like Drools).

3.3.2.9. Integrate with Health Information System

One of the benefits for workflow support for paper-based care pathways is the possibility to integrate the health information system in the workflow of the care pathway. This section discusses this integration. Since the case study was not performed within a hospital these steps are not included in the case study example.

1. Integrate the Health Information System with the workflow system. For this stage HL7 is an international standardisation organisation on interoperability of health information technology. It is used to exchange medical data between systems within a health institution itself, but can also be used to exchange data between health institutes. HL7v3 is a standardised methodology and is intended to be used for automated processing of the data by applications. Here for it can be used for workflow applications. There are multiple domains that are developed like Patient Care, Patient Administration, Medical Records and Pharmacy (Nictiz 2012).
2. G9: Integrate the process model with existing tools and application programs to be invoked by the workflow system: These applications cover mainly general applications such as text editor or spreadsheet editor, and include special applications developed for the given task.
3. G13: Specify every task that is executed by other workflow engines/services.

3.3.2.10. Execute the process

It is important to check the workflow process model with a medical specialist in detail before it can be used in practice.

1. G2: Check for the completeness of the model. Test the workflow process model by launching the application. *Consult a medical specialist to check all the elements of the workflow process model and the application.*

4. Applying methodology to case study

In this chapter a case study will be given for the use of the methodology for modelling text-based care pathways to workflow process models. The care pathway used in this case study is: *the clinical pathway of intervention treatment for unstable angina*. This document is provided by the Ministry of Health of the People's Republic of China. For this thesis the translated English version will be used which was provided by Philips Research. This version of the unstable angina care pathway can be found in Appendix A: Unstable angina care pathway. Since the by Philips Research translated English version of Chinese unstable angina care pathway is owned by Philips Research it is not included in the public available version of this thesis. In order to get an idea of how a paper-based care pathway is structured the paper-based care pathway for surgical treatment of primary lung cancer (2012 Edition) by Zhi et al. (2012) can be accessed.

The first section shows the annotated unstable angina pathway. Next the conceptual process model of the unstable angina pathway will be discussed. The last section of this chapter will discuss a part of the workflow process model of the unstable angina pathway.

4.1. Annotating the Chinese unstable angina pathway

First the Chinese paper-based unstable angina pathway is annotated. For this annotation own categories were created that were found when analysing the structure of the care pathway. The following categories were found: Clinical guidelines, Patient categories/symptoms, Treatment decisions, Specification of Patient group, Test orders, Operation guidelines, Patient status for discharge, Variation symptoms, Time aspects, and Checklists. A part of the annotated unstable angina pathway is shown in Figure 14; the full annotated unstable angina pathway can be seen in Appendix B: Annotated unstable angina pathway.

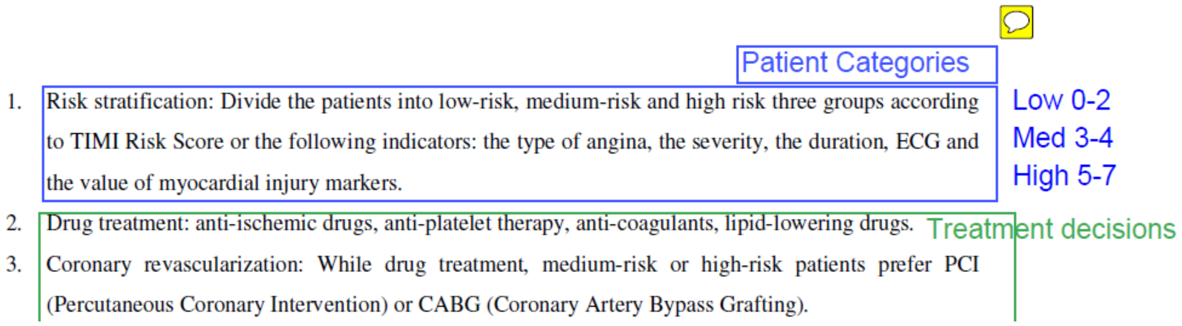
1. Risk stratification: Divide the patients into low-risk, medium-risk and high risk three groups according to TIMI Risk Score or the following indicators: the type of angina, the severity, the duration, ECG and the value of myocardial injury markers.
2. Drug treatment: anti-ischemic drugs, anti-platelet therapy, anti-coagulants, lipid-lowering drugs.
3. Coronary revascularization: While drug treatment, medium-risk or high-risk patients prefer PCI (Percutaneous Coronary Intervention) or CABG (Coronary Artery Bypass Grafting).

Figure 14: Part of annotated unstable angina pathway

4.1.1. Beginning of the unstable angina process

The beginning of the process is when a patient arrives at the hospital with symptoms of an unstable angina. Presentations of the unstable angina are:

a. New-onset angina: New-onset angina which occurred in the last month of at least CCS class III severity.
b. Increasing angina: Previously diagnosed angina that has become distinctly more frequent, longer in duration, or lower in threshold in the past month (i.e. increased by 1 or more CCS class to at least CCS class III severity).
c. Rest angina: Angina occurring at rest and prolonged, usually greater than 20 min.

d. Post infarction angina: Angina occurring after 24 hours to 1 month of acute myocardial infarction.
e. Variant angina: Angina occurring at rest or common activities, with ECG ST-segment elevation. Most patients could relief spontaneously, while a few patients will have myocardial infarction.

The standards to enter the pathway are:

- The main disease is unstable angina (ICD-10: I20.0/20.1/20.9)
- Except following diseases: myocardial infarction, aortic dissection, acute pulmonary embolism, acute pericarditis.
- For the patients who also suffer from other non-cardiovascular diseases, if no more testing and treatment needed and the diseases does not affect the first diagnosis, the patients could enter the clinical pathway.

4.1.2. End of the unstable angina process

The end of the process is when the patient leaves the clinical pathway. This can be when he or she is discharged (the sunny day scenario where there are no drastic exceptions) or when drastic variations occur whereby the patient is forced to leave the clinical pathway. Standards for discharge are:

- Stable vital signs.
- Hemodynamic stability.
- Symptoms of myocardial ischemia have been effectively controlled.
- No other complications needed continued stay.

Variations can be:

- After coronary angiography, the patients are transferred to surgical department to be performed emergency surgery coronary artery bypass grafting.
- Waiting for another PCI or coronary artery bypass grafting.
- Critical condition.
- Serious complications.

4.2. Conceptual process model of the unstable angina pathway

The conceptual process model consists of a main process model and a large amount of subprocesses. The levels of the conceptual process model are shown in Appendix C: Structure of the conceptual model.

4.2.1. Main process

The main process model is show in Figure 15, a close-up of the main process model can be found in Appendix D: Close-up Main process model. The structure of the process model is determined by the steps of the methodology in §3.2.2.1, this can be seen for instance in the subprocesses which are each in their own milestone.

In the main process model the nine different milestones in the unstable angina pathway are modelled as subprocesses. The checklist part of the care pathway is used to create the subprocesses; each subprocess includes the tasks of a particular time frame. In the case of the unstable angina the checklists can be found on the last four pages of the text-file of the unstable angina pathway. There are nine checklists in the unstable angina pathway; the subprocesses are named after the title of each of the checklists:

- 0-10 minutes activities
- 0-30 minutes activities
- 0-60 minutes activities
- Day 1 after admission (CCU) activities
- Day 2 after admission (CCU) activities
- Day 3 after admission (CCU) activities
- Day 4-6 after admission (CCU) activities
- Day 7-9 after admission (CCU) activities
- Day 8-14 (Discharge Day) activities

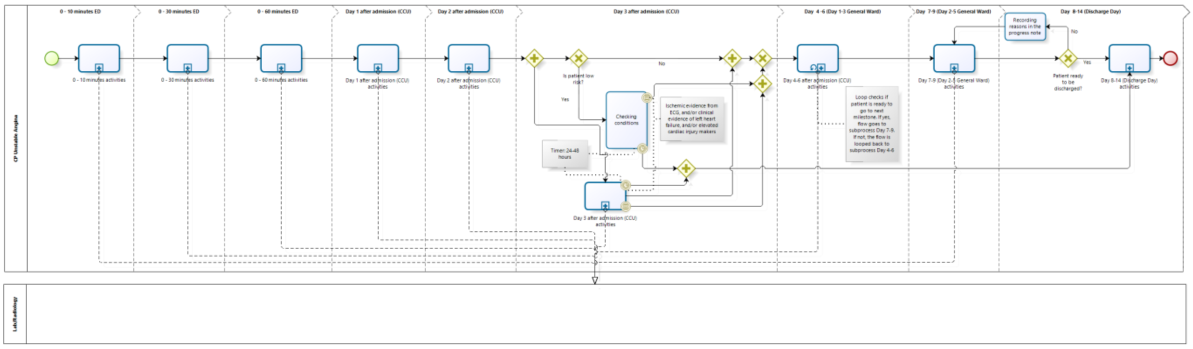

Figure 15: Main Process Unstable Angina

In Figure 16 a close-up is shown of the milestone Day 3. In this close-up the observation period for early discharge is shown. The early discharge option is for low risk patients. Low risk patients are monitored for 24-48 hours, if during this time the patients conditions stay within a certain range the patient can be discharged; this is modelled with timer events on the boundary of the Checking conditions task and the Day 3 subprocess. However if during the 24-48 hours the conditions of the patient indicate a higher risk, the conditional events on both the Checking conditions task and the subprocess Day 3 will be triggered and the patient is not up for early discharge.

There are two stages in the main process where a patient can be looped back to a subprocess; these are in the last three milestones of the process (close-up in Figure 17). The first loop is after the subprocess Day 4-6 after admission (CCU) activities is performed, an exclusive split gateway checks if the patient is ready to go to the next milestone, if this is not the case the patient is looped back to subprocess Day 4-6 after admission (CCU) activities. The same pattern is used to check after subprocess Day 7-9 (Day 2-5 General Ward) activities if the patient is ready to be discharged.

4.2.1. Subprocesses

The nine subprocesses that are in the main process are all modelled in the same way, in Figure 18 the diagram of subprocess 0-10 minutes activities is shown. In the unstable angina care pathway there are three different kinds of tasks in the checklist: Main activities for diagnosis and treatment, Main Orders, and Main care tasks. Since the checklists involve activities that are possibly performed by the same role there are three lanes created. In these lanes subprocesses are made for Main activities for diagnosis and treatment, Main Orders, and Main care tasks. The Main Orders can be separated into Long-term orders and Temporary orders, these results in two subprocesses that are added to the Main Orders lane.

Table 6 shows in which appendices the subprocesses can be found. The full conceptual process model of the unstable angina care pathway was modelled in Bizagi. How to get access to this model is explained in Appendix T: Getting access to the models through SHARE.

When the activities that are in the checklists of the care pathway are modelled it is unclear if there is a particular sequence in which these activities are performed. This results in most cases in tasks that can be performed in parallel with the use of AND gateways. An example of such a subprocess is the subprocess Main activities for diagnosis and treatment 0-10 minutes, which is shown in Figure 19.

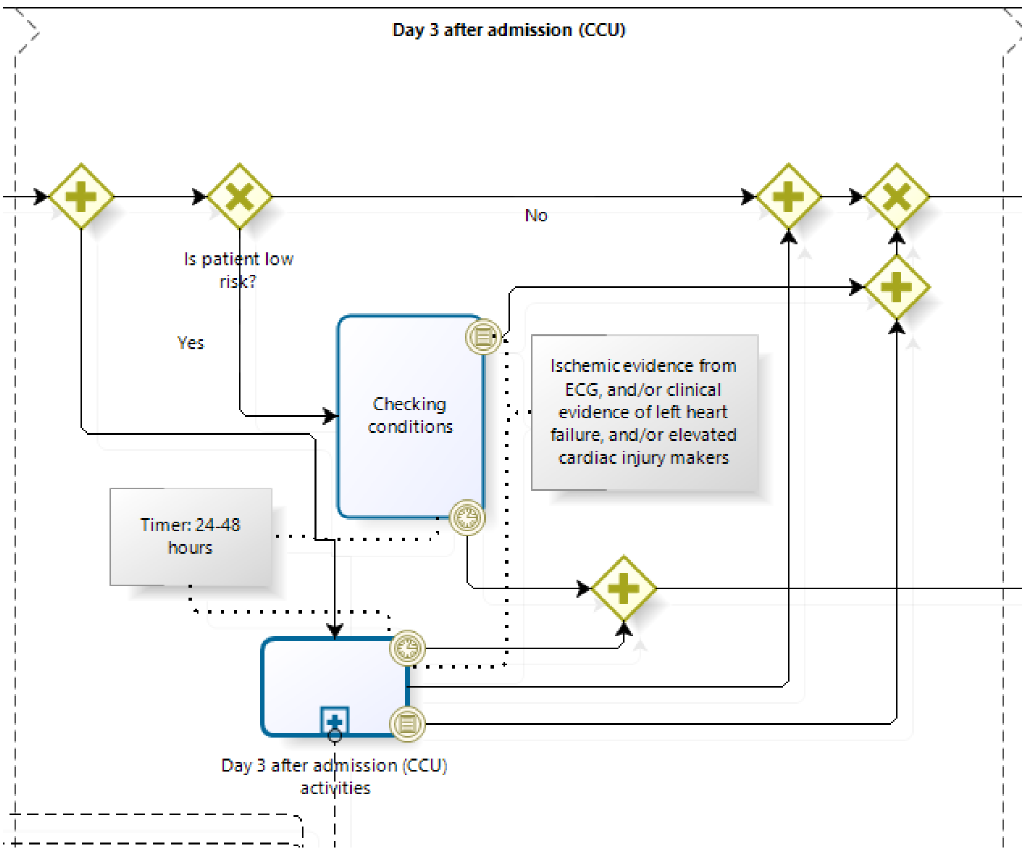

Figure 16: Close-up Day 3

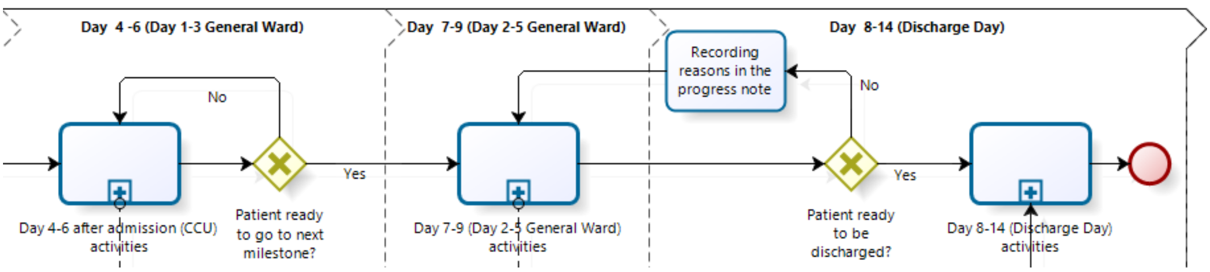

Figure 17: Close-up last three milestones

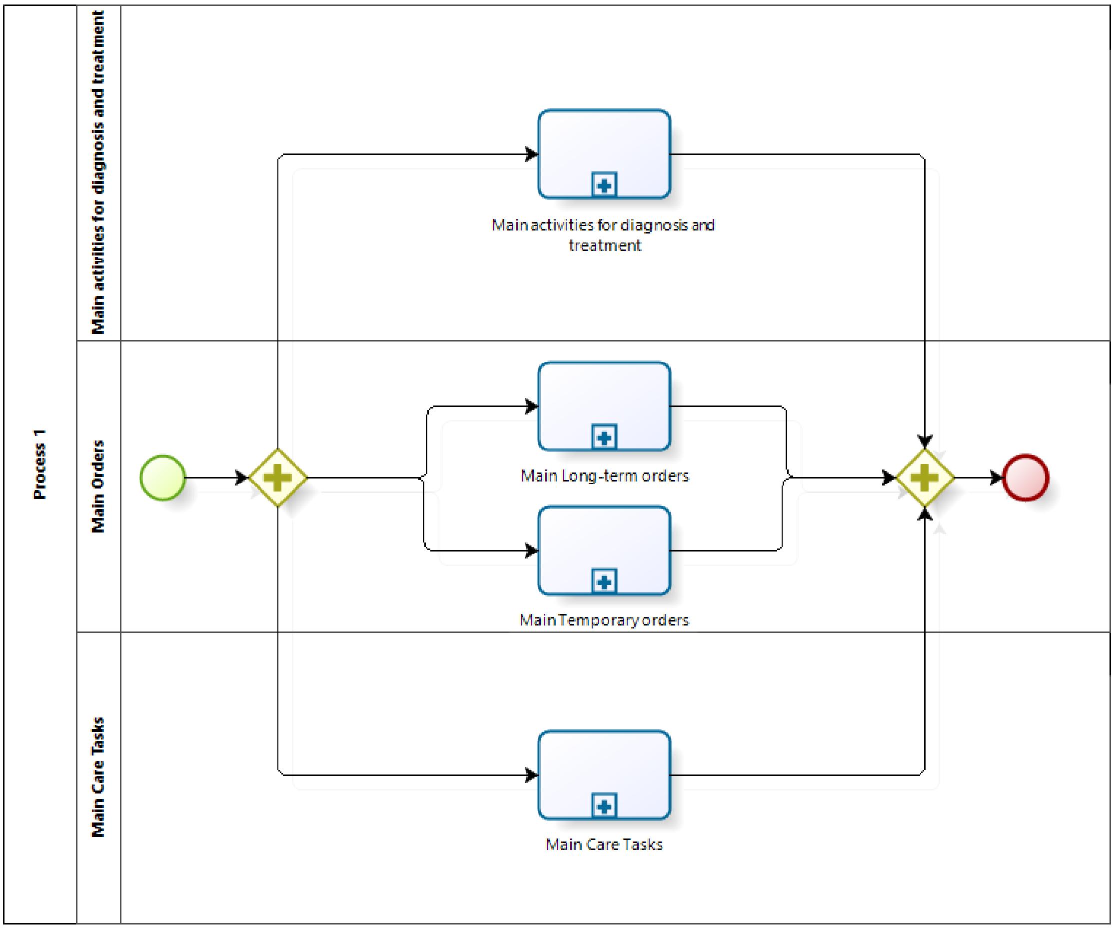

Figure 18: Subprocess 0-10 minutes activities

Table 6: Location of subprocesses in the appendices

Subprocess	Appendix
0-10 minutes activities	Appendix E: Subprocess 0-10 minutes activities
0-30 minutes activities	Appendix F: Subprocess 0-30 minutes activities
0-60 minutes activities	Appendix G: Subprocess 0-60 minutes activities
Day 1 after admission (CCU) activities	Appendix H: Subprocess Day 1 after admission (CCU) activities
Day 2 after admission (CCU) activities	Appendix I: Subprocess Day 2 after admission (CCU) activities
Day 3 after admission (CCU) activities	Appendix J: Subprocess Day 3 after admission (CCU) activities
Day 4-6 after admission (CCU) activities	Appendix K: Subprocess Day 4-6 after admission (CCU) activities
Day 7-9 after admission (CCU) activities	Appendix L: Subprocess Day 7-9 (Day 2-5 General Ward) activities
Day 8-14 (Discharge Day) activities	Appendix M: Subprocess Day 8-14 (Discharge Day) activities

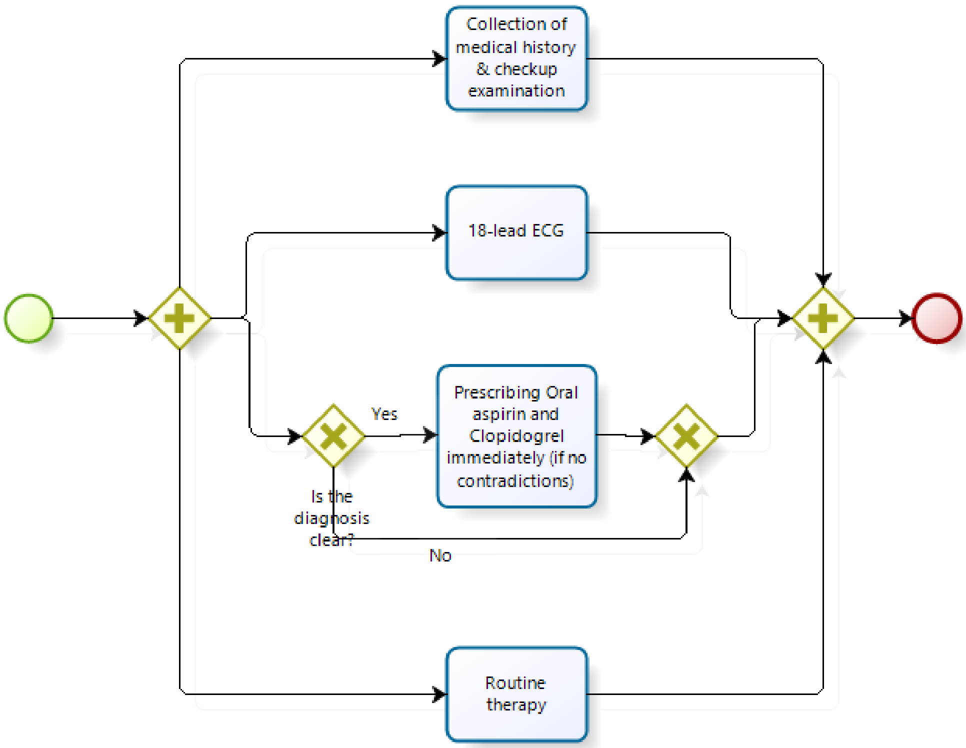

Figure 19: Main activities for diagnosis and treatment 0-10 minutes

However with some activities it is clear that there is a particular order in which the activities are performed. An example is shown in subprocess Main activities for diagnosis and treatment 0-30 minutes, which is shown in Figure 20. In this subprocess it is a logical argument that the rapid risk stratification and the urgent consultation of CVD specialists are performed before a choice is made on the treatment. Also it is clear from the pathway that only after the patient is transferred to the CCU the outcomes and risks of early coronary revascularization are again assessed. Of course these decisions on the sequence of tasks should be verified by a medical specialist. Another noticeable aspect in this subprocess is the extra information that is annotated in the diagram. This is done because there is a high chance that this information is used when transforming the conceptual process model to an executable workflow process model.

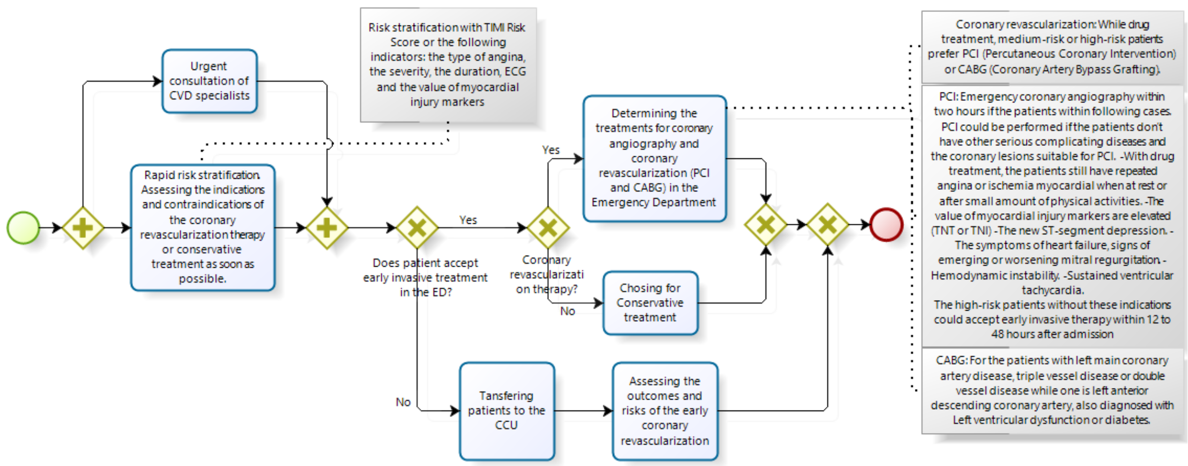

Figure 20: Main activities for diagnosis and treatment 0-30 minutes

The next exceptional subprocess is Main activities for diagnosis and treatment (operation) which is shown in Figure 21. In this subprocess the preparation and handling is modelled, the actual operation is performed in the subprocess Operations (Figure 22). Before the operation can start the preoperative preparation testing and examination must be complete, these tasks are modelled in another subprocess (Figure 23), however with the use of Signal (throw) event and a Signal (catch) event the operation can only be triggered at the moment that the tests and examinations are finished. The same principle is used to model when the postoperative tests and examinations (Figure 24) can start.

In the postoperative test and examinations subprocess there are optional tests for which no specific order is determined in the care pathway, these kind of activities can be modelled with an ad-hoc subprocess (Figure 25). An ad-hoc subprocess does not contain sequence flows to specify the defined order of activities (although sequence flows in ad-hoc processes are allowed in BPMN 2.0) but it contains a list of activities that could be performed, it is not necessary to complete all of the activities in order to complete the ad-hoc subprocess (Silver 2009).

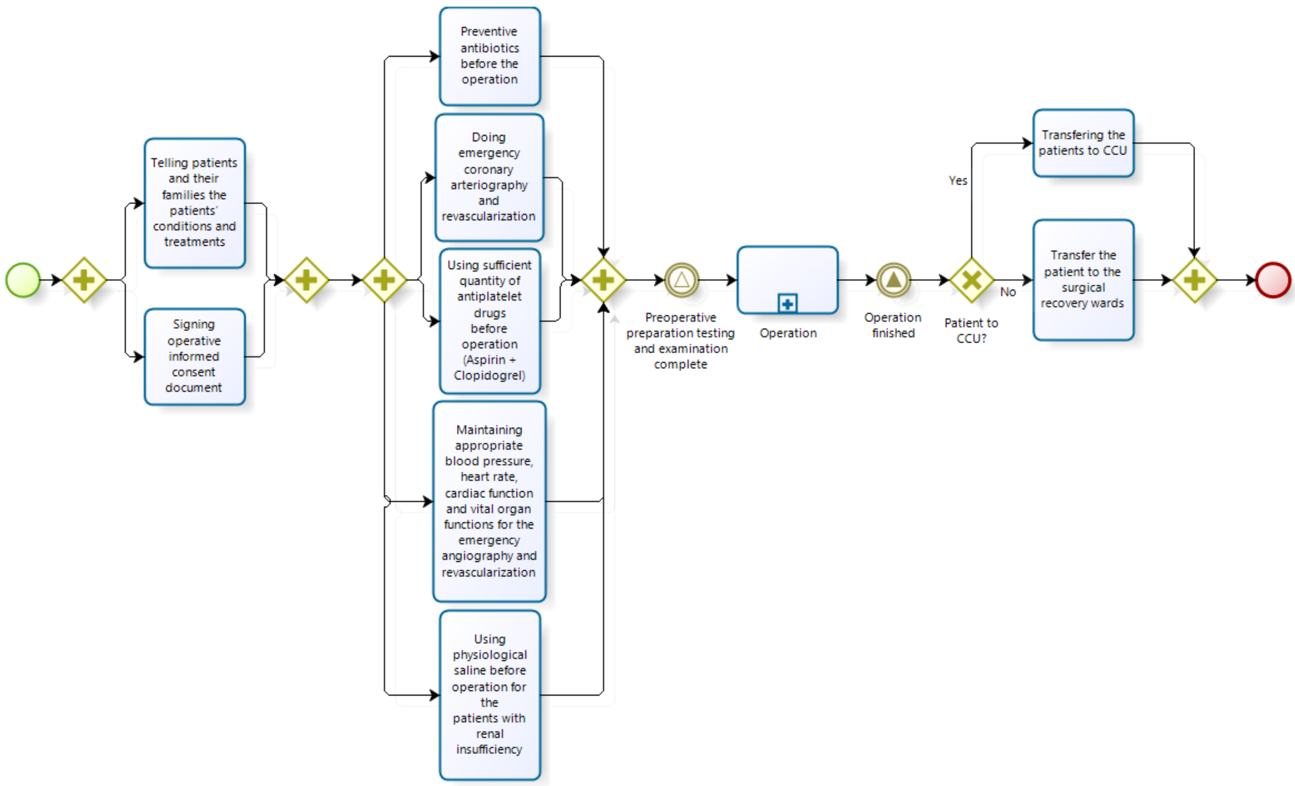

Figure 21: Main activities for diagnosis and treatment (operation)

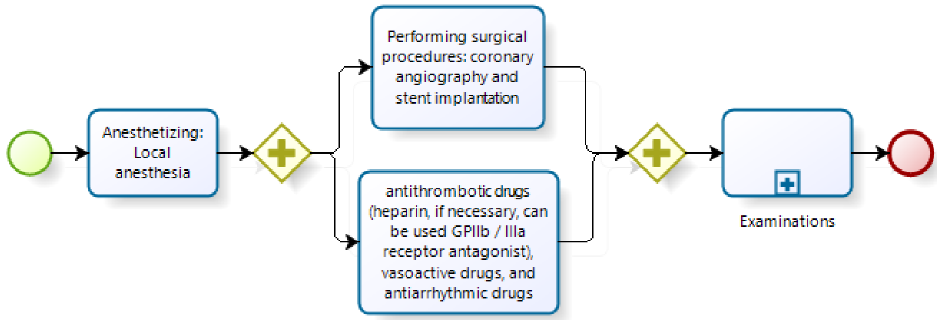

Figure 22: Subprocess Operation

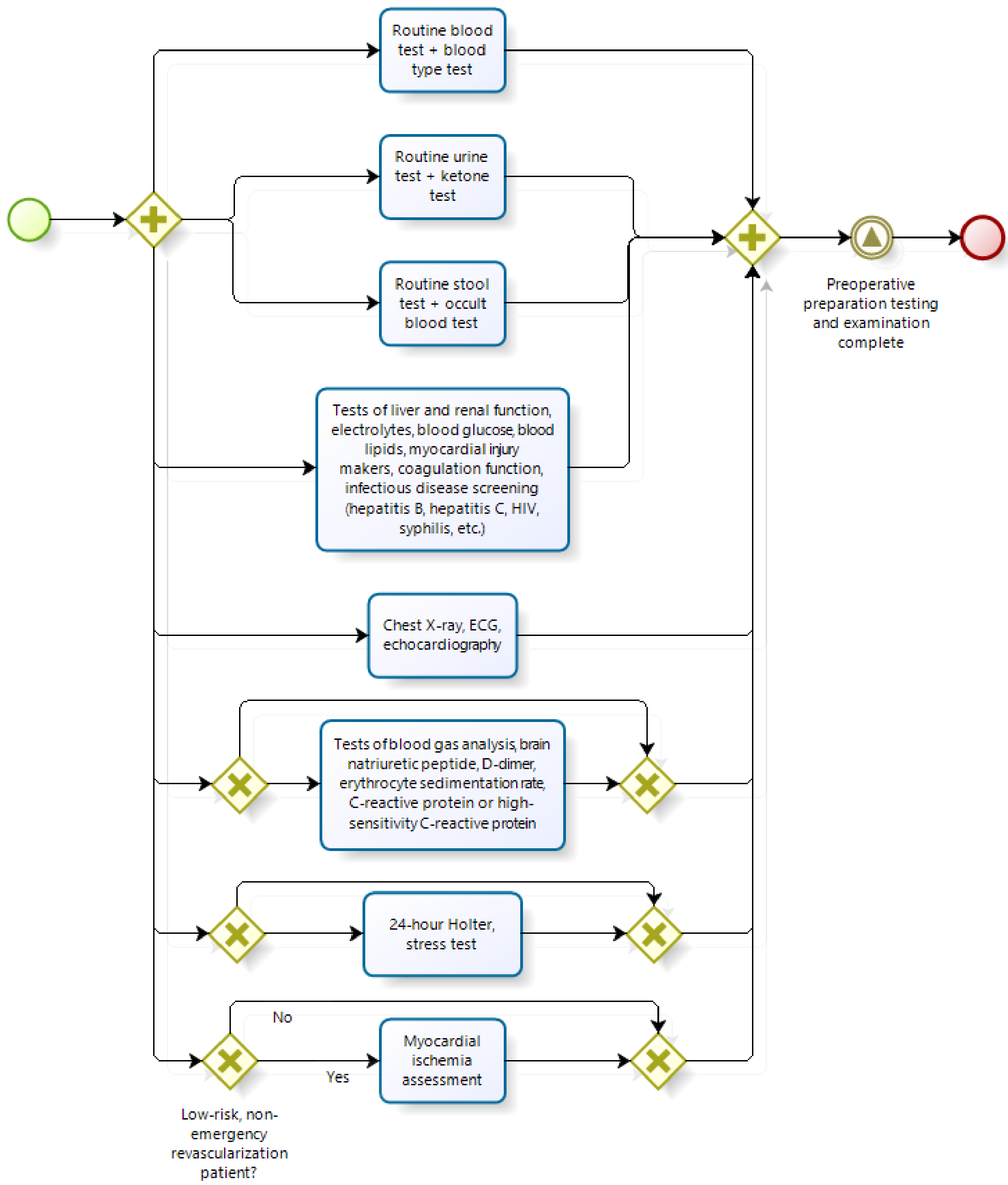

Figure 23: Subprocess Preoperative preparation testing and examination

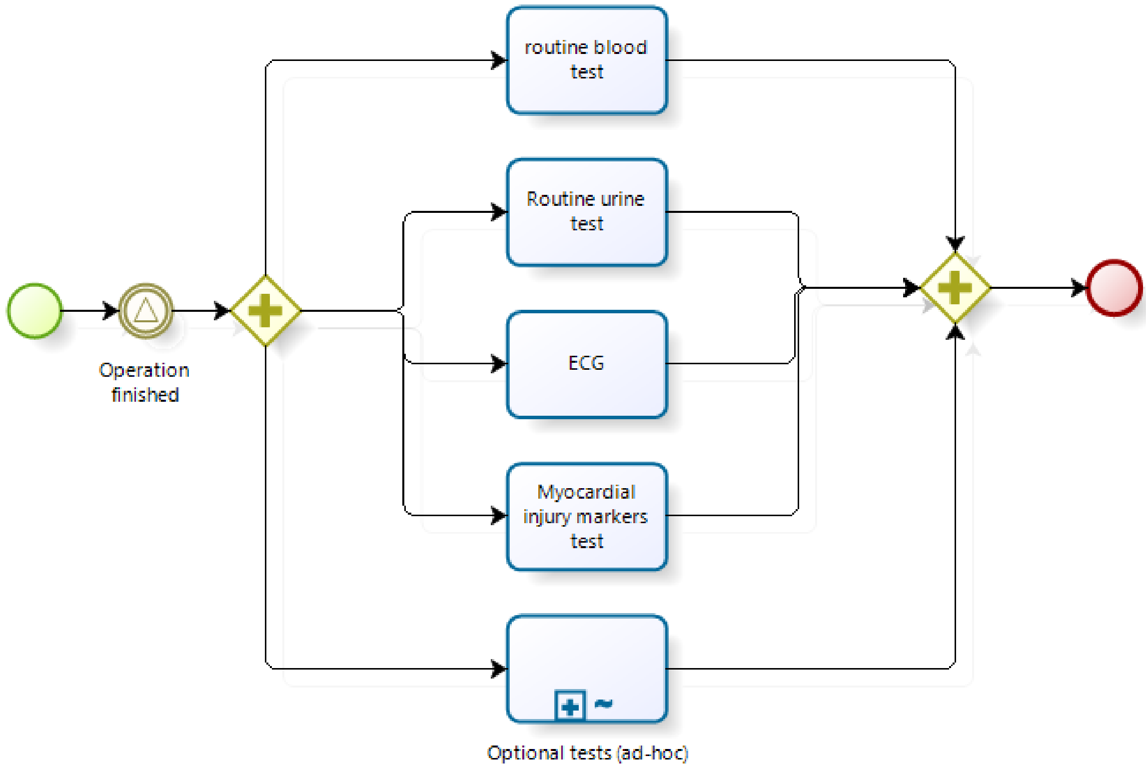

Figure 24: Subprocess Postoperative tests and examination

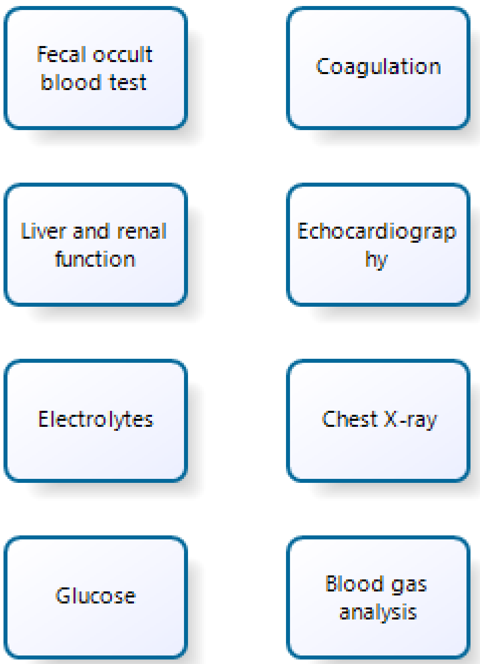

Figure 25: Subprocess Optional tests (ad-hoc)

4.3. Workflow process model of the unstable angina pathway

In this chapter a part of the workflow process model of the unstable angina care pathway is discussed. Due to time limitations the modelling of the full workflow process model is beyond the scope of this thesis. However by modelling the first two subprocesses a proof of concept of the proposed methodology is presented. While modelling these two subprocesses it was not possible to check the workflow process model with Chinese medical specialists that are familiar with the unstable angina care pathway. Therefore the verification steps, which needed a medical specialist, were not performed in this case study.

The workflow process model is build-up in such a way that each user task consists of a form that is shown to the user. Which user can perform the task is defined by a specific role or a group; a group can consist out of multiple users that have same or different roles (e.g. a group that exist of all users with the role nurse and all users with the role physician). The forms can have data already on it for the user to read (input data) or empty fields where the user can add data (output data).

In the following sections the different elements of the workflow process model are discussed. First the soundness and correctness of the conceptual process model are discussed. The next sections discuss the analysis of the modelling languages, BPMN diagrams, data model, exception handling, roles and users, forms, and the business rules.

4.3.1. Soundness and correctness

The soundness of the conceptual process model (G3) was validated by the process modelling tool Bizagi which was used to model the conceptual process model in BPMN 2.0. The semantically correctness of the conceptual process model was not performed since this needs to be done with a medical specialist.

4.3.2. Analysis of the modelling languages

Since BPMN 2.0 is used as modelling language for both the conceptual process model and the workflow process model the steps including G4, G5 and G11 from §3.3.2.2 were left out of this case study.

4.3.3. BPMN diagrams

Figure 26 shows the main workflow process which consists of the subprocess 0-10 minutes activities and 0-30 minutes activities. In order to make it easier to trace back to the conceptual model where possible the same names for the process elements are used.

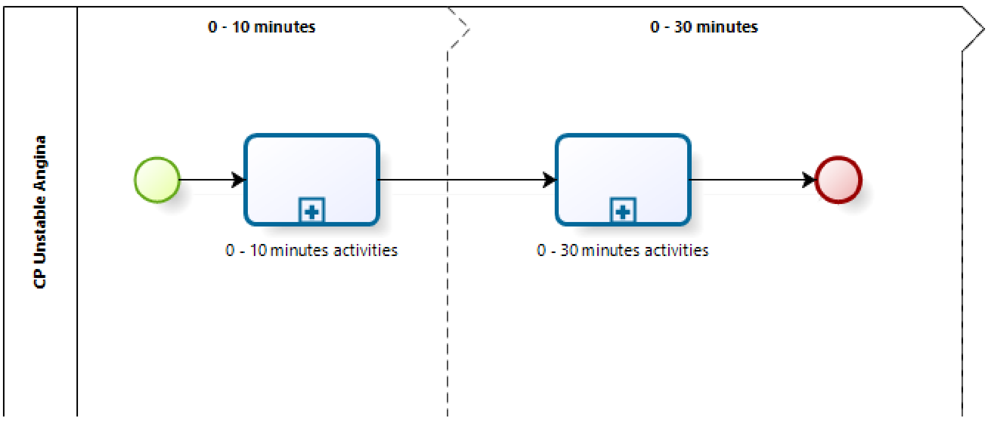

Figure 26: Main workflow process

The choice is made to model the first two subprocesses because the activities in this part of the care pathway are easier to understand for non medical trained readers than other subprocesses. Also all aspects of the workflow process model are represented in the first two subprocesses while still being compact enough to get a good overview of the process. The workflow process aspects that are modelled include e.g. user tasks, automated tasks, timer events, conditional events, business ruled, roles, and process variables. Workflow information that is not visible in the graphical representation of BPMN 2.0 are annotated and linked to the associated process elements. This is can, for example, be seen in subprocesses of 0-10 minutes activities (Figure 27) where the extra workflow information, necessary for the workflow engine to execute the process correctly, is annotated and associated to the timer events. These timer events on the boundaries of the subprocesses are the result of following G8. The full information on the subprocesses of 0-10 minutes activities can be found in Appendix N: Subprocess 0 – 10 minutes activities. For the subprocesses of 0-30 minutes activities this information is presented in Appendix O: Subprocess: 0 - 30 minutes activities.

The user tasks are modelled in the subprocesses Main activities for diagnosis and treatment 0-10, Main Orders 0-10, and Main care tasks 0-10. The first subprocess, Main activities for diagnosis and treatment 0-10, Main Orders 0-10, is shown in Figure 28. The usage of G1 and G7 can be seen in the arranging and composing/decomposing of the tasks in this subprocess. Defining if a task is an automated, manual or user task and defining which role can perform for this task is related to G15, G16 and G14. While arranging and composing/decomposing the tasks also all the necessary case variables were listed (G18), these are shown in Appendix P: Process data/variables. Most of the tasks are triggered by a user (nurse or physician) that selects a task from its task list which includes the work items, however some takes are triggered by time or automatically (G12). It was chosen to use a pull-driven mechanism (G19) to select a resource to execute a work item because this gives the possibility for the caregivers to select ad-hoc which patient they treat based on their own judgement.

The rest of the diagrams can be found in the appendices, the location of workflow subprocesses in the appendices is shown in Table 7.

Table 7: Location of workflow subprocesses and business rules in the appendices

Subprocess	Second subprocess & business rules	Appendix
0-10 minutes activities	Main activities for diagnosis and treatment 0-10	Appendix N: Figure 81
	Long-term orders 0-10	Appendix N: Figure 86
	Temporary orders 0-10	Appendix N: Figure 88
	Main care tasks 0-10	Appendix N: Figure 90
0 - 30 minutes activities	Main activities for diagnosis and treatment 0-30	Appendix O: Figure 94
	Long-term orders 0-30	Appendix O: Figure 100
	Main care tasks 0-30	Appendix O: Figure 102

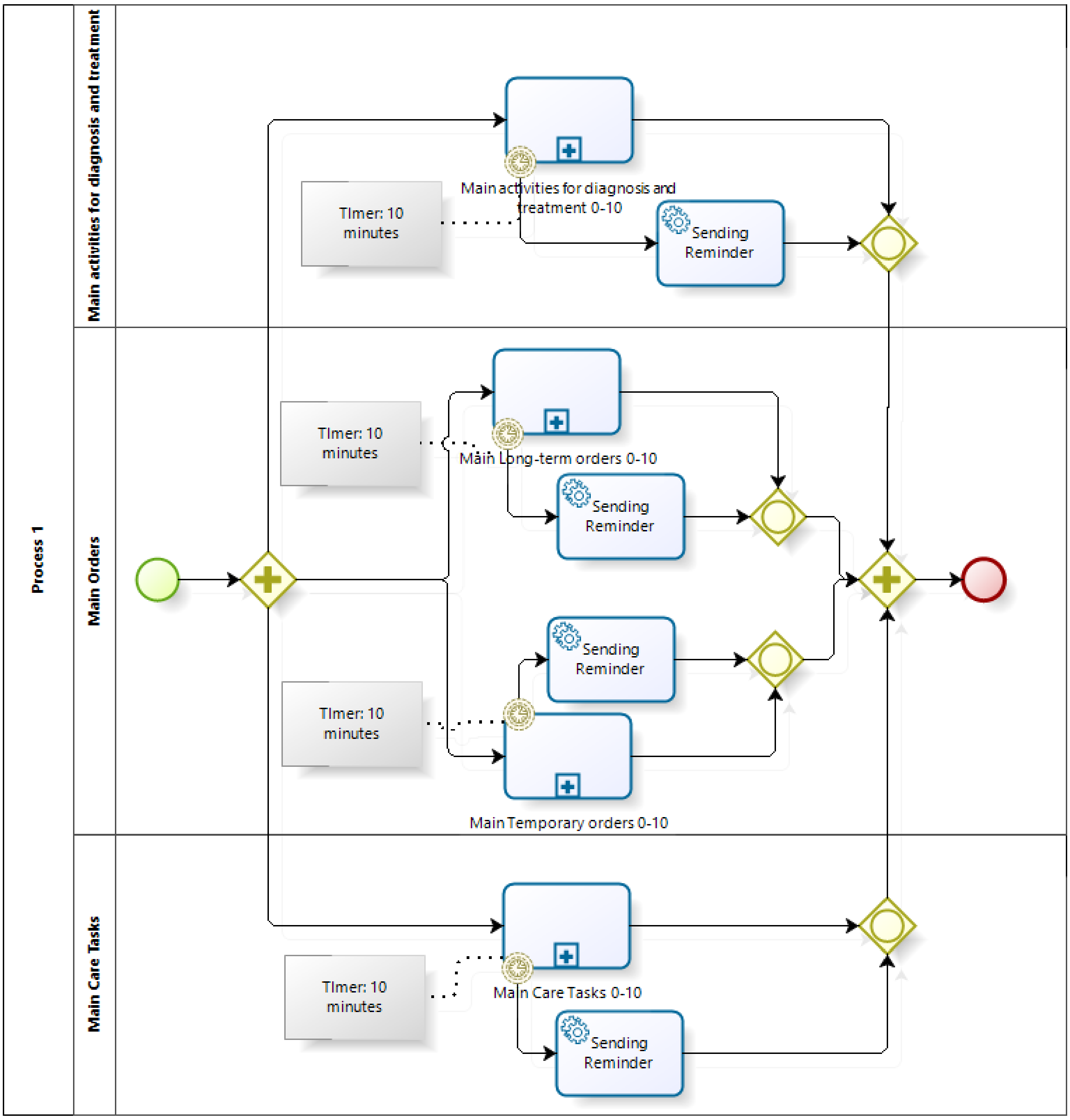

Figure 27: Subprocess 0-10 minutes activities

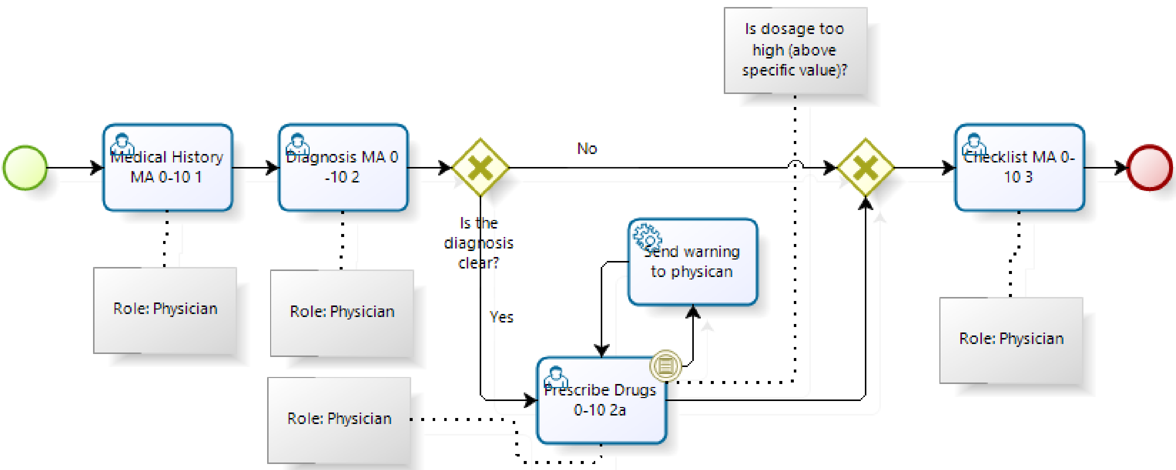

Figure 28: Subprocess Main activities for diagnosis and treatment 0-10

4.3.4. Data Model

When implementing a care pathway it is generally the case that the date model of the hospital is implemented in the workflow engine (G6). This applies to (most) patient data, however there might be process data/variables that are useful for the execution of the care pathway but are not represented in the existing data model of the hospital. When transforming the conceptual process model to a workflow process model it is important to map which process variables are needed to perform the tasks correctly. An overview of the data used in the different tasks of the model is given in Appendix P: Process data/variables. An example of a data model that could be present in a hospital is shown in Appendix Q: Example of data model[6].

4.3.5. Exception handling and flexibility

This section relates to the configuration of exception handling and flexibility information in the workflow (G10). An exception that could occur during the treatment of the patient could be that a nurse or physician forgets to perform the tasks within a certain time. In order to tackle this exception intermediate Timer events are used on the boundaries of the 2nd level subprocesses in the milestone subprocesses, as shown in Figure 27. Also in case of a variation during the treatment of a patient the nurse or physician can type a comment on every electronic form they fill in, this is further discussed in §4.3.7.

4.3.6. Roles and Users

In the workflow process model two types of roles are used, physicians and nurses. For tasks that could be performed by either a physician or a nurse a group is created which includes both the physicians and the nurses. For each user task the role is defined, this is presented in both the BPMN diagrams (found in Table 7) and in the forms (Table 8). In this case study the order in which the resources will execute multiple work items is not included (G20), however it seems logical to use a Priority go First queuing principle since the level of risk and the acuteness of risk of the patient and the importance of the task should determine the queuing of the patients.

4.3.7. Forms

For each user task a form is created. The form in which the nurse is registering the patient is shown in Figure 29. In this form the nurse fills in the patient information that is necessary for registration. In each form a section is created for comments. If there is any variation in the treatment process of the patient the physician or nurse can use this section to insert information about the variation. The majority of the forms are checklists in which the user can check the boxes of the tasks that are performed. In order to give the nurse and physician freedom in their work it is in this workflow process model not yet required to check all the tasks in the checklist before the form can be submitted. The reasoning behind this is that if it is required for the user to check all the tasks before he/she can continue the user is more inclined to check off all the boxes without looking what tasks are mentioned. By giving the user the opportunity to leave boxes open it is aimed that the user takes more time to actually look at the items and thinks about if he/she actually did perform the task. Another reason why this option is chosen, where boxes can be left open, is because it can occur that the specific condition of a patient requires skipping some tasks.

In the forms used in this case study it is not required for a user to check all the boxes of

[6] Provided by Philips Research

The complete set of forms can be found in the appendices, the location of each form in the appendices is shown in Table 8.

Table 8: Location of workflow forms and associated roles & date elements in the appendices

Subprocess	Form, roles & data elements	Appendix
Main activities for diagnosis and treatment 0-10	Medical History MA 0-10 1	Appendix N: Figure 82
	Diagnosis MA 0-10 2	Appendix N: Figure 83
	Prescribe Drugs 0-10 2a	Appendix N: Figure 84
	Checklist MA 0-10 3	Appendix N: Figure 85
Main Long-term orders 0-10	Long-term Orders List 0-10	Appendix N: Figure 87
Main Temporary orders 0-10	Temporary Orders List 0-10	Appendix N: Figure 89
Main Care Tasks 0-10	Registration Patient CT 0-10 1	Appendix N: Figure 91
	Checklist CT 0-10 2	Appendix N: Figure 92
Main activities for diagnosis and treatment 0-30	Assessing TIMI Risk Score 0-30 1	Appendix O: Figure 95
	Determining Early Invasive Treatment 0-30 2	Appendix O: Figure 96
	Checklist MA 0-30 3a early invasive treatment	Appendix O: Figure 97
	Checklist MA 0-30 3b no early invasive treatment	Appendix O: Figure 98
	Showing Treatment info 0-30 4	Appendix O: Figure 99
Main Long-term orders 0-30	Long-term Orders List 0-30	Appendix O: Figure 101
Main care tasks 0-30	Checklist CT 0-30	Appendix O: Figure 103

4.3.8. Business rules

The business rules that are used in the workflow process model are described in Table 9.

Figure 29: Form Registration Patient

Table 9: Business rules of the workflow process model

Subprocess	Name	Business rule
0 - 10 minutes activities (Figure 80)	Reminder	Non-interrupting timer events are modelled on the boundaries of the subprocesses in order to send a reminder when the subprocess is not finished at the predefined time. The non-interrupting timer event allows the subprocess to continue in parallel while the reminder is send. Because the reminders need to be send to the users that have the appropriate role it is chosen to set the non-interrupting timer event in this subprocess level and on in the main process.
Main activities for diagnosis and treatment 0-10 (Figure 81)	Gateway rule	The gateway "Is the diagnosis clear?" checks if the value of Diagnosis Clear is True, if this is the case than the process sequence flows to the task Prescribe Drugs 0-10 2a, if the diagnosis is not clear this task will be skipped. The value for Diagnosis Clear is given by the physician in the task Diagnosis MA -10 2.
Main activities for diagnosis and treatment 0-10 (Figure 81)	Dosage rule	This rule checks after the task Prescribe Drugs 0-10 2a is performed if the dosage of the prescribed medication is not above a certain number, hence controlling for (lethal) over dosage errors. This is modelled with an Intermediate (catch) Event that is attached to the boundary of the Prescribe Drugs 0-10 2a task, when the condition is met that the dosage is above a certain number a warning is send.
Main activities for diagnosis and treatment 0-30 (Figure 76)	Gateway rule	The gateway "Is the diagnosis clear?" checks if the value of Diagnosis Clear is True, if this is the case than the process sequence flows to the task Prescribe Drugs 0-10 2a, if the diagnosis is not clear this task will be skipped. The value for Diagnosis Clear is given by the physician in the task Diagnosis MA -30 2.

4.3.9. Integration with Health Information System

Since this case study is not performed in cooperation with a hospital this part of the methodology (including G9 and G13) were not performed.

4.3.10. Execution of the process

The checking of the completeness of the model (G2) is not included in this case study since there was no medical specialist consulted in this case study. However an executable workflow process model was made in Drools/jBPM. How to get access to this model is explained in Appendix T: Getting access to the models through SHARE. There are also screen casts of the executable workflow application available on screencast.com[7].

[7] http://www.screencast.com/t/I8ShWPynn; http://www.screencast.com/t/pOfuq9MwaY; http://www.screencast.com/t/yXCzJ41z

5. Evaluation of methodology

The evaluation of this methodology was performed internally by Philips Research. Besides this internal evaluation also an evaluation tool was developed, this tool was used by the Philips Research CPO team to complement the internal evaluation performed by Philips Research.

5.1. Philips internal evaluation

In general the methodological approach based on existing workflow literature and recommendations is liked very much. Also the case study on the unstable angina care pathway is valued. There were some points of improvement in the methodology and the models, these points are already implemented in the versions that are presented in this thesis. Besides that there were also some directions for future work provided:

- The annotation of the paper-based care pathway is an essential step in the methodology before the real modelling takes place. It might be useful to expand the annotation part of the methodology with steps that explicitly map each of the annotated categories to one pattern of a model.

- The two-stage modelling methodology is quite suitable for clinical practice. The conceptual process model of the unstable angina pathway is particularly useful for understanding the care pathway and for communicating the necessary details among the relevant stakeholders. The steps for translating the conceptual process model to an executable workflow process model are also of use, but the actual executability of the workflow process model should be tested more extensively and communicated with the stakeholders.

- In the proposed methodology the use of checklists is assumed. For the scope of this thesis it is fine to make this assumption, however in a clinician's real workflow it should be taken into account whether the clinician (or the nurse) has time to interact with the computer. Especially in critical time periods it is not very likely that the clinician/nurse will have much time to interact with the care pathway management system, unless they can get something they want/need e.g. an automated TMI risk score calculation or something similar. Another example could be, for the hospitals with advanced infrastructure, that the clinical pathway application can recommend the orders at the right time and the clinician does not need to fill in the checklist.

- It would be realistic to assume that checklists will most likely need to be combined and 'reported' ex-post when the user has the time and it fits in a natural way in his/her workflow. Therefore Philips Research thinks that care pathway management systems have the most benefits in longer lasting parts of the care pathway, not in the "mission critical" moments. It would be good to focus the workflow process model more to that direction, or to elaborate how to combine the checklist(s) into likely moments of interaction with care pathway management systems.

- A good point of the methodology is that the rules of how to validate the process model are described. Included in workflow process designer tools like Drools designer there are tools provided to validate some basic logic of the process. Such tools can be leveraged and other steps for rule validation can be added in the future.

5.2. Evaluation tool

For the evaluation of the proposed methodology an evaluation tool is developed. This tool consists of a questionnaire; in this questionnaire there are 16 criteria in which the questions are divided. The paper of Filipowska et al. (2009) about procedure and guidelines for evaluation of BPM methodologies is used to develop this questionnaire.

The criteria's that are used are:

- Flexibility
- Ease of applicability
- Utilisation of/compatibility to/contribution to open source tools and standards
- Popularity
- Domain Coverage
- Procedural completeness
- Ease of extendibility
- Ease of adaptation
- Step by step examples
- Quality of the presentation
- Conciseness
- Correctness of assumptions
- Correctness of steps
- Consistency
- Coherency
- Correctness from IT and business point of view

The questions should be answered in both quantitatively and qualitatively. The quantitative answer is given on a 5-point Likert Scale (Linkert 1932) where 1 corresponds to "not at all" and 5 to "very". The quantitative measurement will be used to get an absolute scoring of the proposed methodology, where the qualitative answers will be used to get a more in-depth understanding of the improvement points. The evaluation tool is shown in Appendix R: Evaluation tool.

5.2.1. Evaluation tool results

The questions in the evaluation tool are almost all answered quantitative and a large part is also answered qualitatively, these answers are used to complement the internal evaluation by Philips.

The qualitative answers together with the quantitative scoring give a good indication of how the methodology performs and elaborates on the directions for future research provided in the internal evaluation. The complete qualitative answers and quantitative results of the methodology can be found in Appendix S: Results of evaluation tool Table 12 and Table 13.

The quantitative results of this evaluation tool show a high number, the average of all answered quantitative questions is 4.4 on a scale from 1 to 5 (with 5 being the best option). The category ease of adaptation scores the lowest with a 3. However this category is about the adaptation of the methodology in different business environments, since the methodology is meant to be health care specific there is no need for the methodology to score high in this category. The methodology is rated the highest in the consistency and coherency categories with a score of 5.

In order to strengthen the evaluation results of the evaluation tool it is advised to distribute the evaluation tool in future research among more domain experts.

6. Conclusions, Related work, Implications, Limitations and Future Research

In this chapter the final conclusions of the thesis are presented. Furthermore practical implications of this conclusion are discussed. Also the limitations of this thesis are mentioned together with propositions for future research.

6.1.Conclusion

This thesis started with addressing the issues in today's healthcare system. Quality issues manifest themselves with a high numbers of preventable hospital deaths, medical errors that result in unnecessary suffering of patients and unnecessary use of resources, whereby the cost of care is increasing every year. In order to get a grip on these issues the healthcare field is searching for ways to improve their aging way of doing business.

6.1.1. Related work

In the early 1980s a new concept was introduced, care pathways. In numerous studies care pathways have proven themselves to be able to improve the quality of care, shorten the length of stay of patients and lower the cost of care. Now, 30 years later, the majority of care pathways are still paper-based without any form of workflow management while other industries gained large progress in the field of workflow management systems. The workflow managements systems that were found in the literature, which implement care pathways, were still in an early stage of maturity. Although the possibilities of these systems, such as decision support, complex logical and timing relationships that can be modelled in workflow management systems, and data recording and collection, make a strong case for the use of workflow management systems in care pathways.

As stated in the problem statement in §1.1 there was, at the time of the literature review, not much research that proceeded beyond the development of untested prototypes. Only three studies were found where care pathways were successfully modelled into a workflow management system and where these systems were tested in a medical setting. However these systems show that workflow support for care pathways can result in a positive effect on KPIs as LOS, use of resources, costs of care, and quality of care. One of the reasons why not many of these implemented systems can be found could be the lack of a proper methodology which can be followed to transform paper-based care pathways to executable workflow process models.

6.1.2. Research questions

In order to improve the support of workflow management for care pathways a research question was defined:

How can paper-based care pathways be transformed to executable workflow process models in a structured and reproducible way?

This research question was broken down to different sub questions.

- *How can the information that is presented in the paper-base care pathway be extracted?*

Paper-based care pathways can be build-up out of clinical guidelines, patient categories/symptoms, treatment decisions, specification of patient group, test orders, operation guidelines, patient status for discharge, variation symptoms and checklists. The first part of a paper-based care pathway consists out of information about the treatment process, including the different guidelines. The second part is a collection of checklists which are passed on as the patients goes through the care pathway.

The annotation step is an essential step in the methodology because it helps the modeller to get better acquainted with the care pathway he/she wants to model. The annotation steps provide a deeper understanding of information and the structure of the care pathway.

- *How can paper-based care pathways be modelled in a conceptual process model?*

When modelling a conceptual process model of a paper-based care pathway it is important to take notice of the seven general modelling guidelines. In this thesis the steps are described how to model a conceptual model (from a paper-based care pathway) in a structured and reproducible way. First the sunny day scenario is modelled in the main process. Next the subprocesses are modelled, it is likely that there are multiple child levels in the process model; therefore it is important to follow the structured approach, given in the methodology, to get a consistent model. Business rules should be added in order to comply with the procedures stated in the care pathway. Next extended BPMN constructs and exception handling patterns can be used to model the variance that can occur in the care pathway.

The conceptual model that is the key deliverable of this phase of the methodology is quite suitable for clinical practice and particularly useful for understanding the care pathway and communicating the necessary details among the relevant stakeholders.

- *How can a conceptual process model of a paper-based care pathway be transformed to an executable workflow process model?*

The transformation process of a conceptual process model to an executable workflow process model can be hard. There are a lot of steps that need to be taken and it is easy to lose grip on this process. In order to smoothen the transformation process there are conceptual-to-workflow model transformation guidelines. In the proposed methodology these guidelines are used in a step-by-step description on how to perform the transformation. Topics that are included in these steps are: the soundness and correctness of the conceptual model, the link between the two modelling languages, adjusting the conceptual model, modelling the required data, exception handling and flexibility, roles and users, forms, business rules, integration with health information systems, and verification and execution of the process.

This case study performed on this phase of the methodology is quite limited; therefore the executability of the workflow process model should be tested more extensively and the outcomes should be communicated with the stakeholders before the real value of this phase can be determined.

6.2.Practical Implications

The aim of this thesis is to increase the usability of and compliance with care pathways in the healthcare field. This is done by deriving a methodology that can be used to model care pathways as executable workflow applications. By using the steps proposed in this methodology it is easier for hospitals and industrial partners to develop workflow process models based on paper-based care pathways. Also the developed process models will have a similar structure which would make the models more understandable in the long run since stakeholders will recognise the structure of the models.

As explained in §2.2.2 the Chinese health reform plan distributes very detailed and structured paper-based care pathways to the Chinese hospitals, this makes the market for workflow support on these kind of care pathways very interesting. This gives great opportunity for companies like Philips Research to develop a product for certified support on the development and implementation of these care pathway workflow systems.

6.3.Limitations and future research

The most important limitation of this thesis lies in the correctness of the paper-based care pathway that is used as fundament for the conceptual process model and the workflow process model. In the proposed methodology it is assumed that all information presented in the paper-based care pathway is correct. It is important to always verify and test the correctness of a care pathway before implementing it in a hospital; this applies not only to paper-based care pathways but also for every other type of care pathway that can be found in practice.

In this thesis it is also assumed that all paper-based care pathways have the same structure and therefore the methodology is based on this specific structure. However it is possible that paper-based care pathways from different countries are structured in a different way. In the case study a Chinese care pathway was used because Philips Research is developing care pathway support specifically for the Chinese market and they have access to the Chinese paper-based care pathways. Case studies with care pathways from different countries should be performed to test the suitability of the proposed methodology to paper-based care pathways in other countries.

Another limitation of this thesis is the limited testing of the executable workflow process model. There is more testing necessary to sufficiently validate the steps proposed in this part of the methodology. Future research should focus on performing more case studies in order to validate the proposed methodology in a higher extent. In this research only one case study was performed and only a part of the provided paper-based care pathway was modelled in a workflow process model.

Also the intended use of the workflow process model needs to be further investigated. A market research should be performed on the intended users of the workflow application in order to identify and analyze the specific needs of these users. It is necessary to identify which parts of the care pathway should benefit the most from workflow support and what functionalities the physicians and nurses want in the different parts of the care pathway. An emerging research topic at this moment is the creation of dynamic checklists which makes the checklists seamlessly integrated in clinical workflow and more context aware. Research on this topic is done by the Information Systems department of Eindhoven University of Technology; publications on this topic by Shan Nan (among others) are expected in 2014.

The traceability between the deliverables of the different phases of the methodology (paper-based care pathway, conceptual process model, and workflow process model) is another limitation in the current thesis. Research should be done to develop a tool that supports the annotation of the care pathway, ideally model-driven engineering can be used to generate a flowchart from the annotated care pathway. Such a tool would not only be beneficial in reducing human errors while modelling, but could also increase the traceability between the paper-based care pathway and the conceptual process model. Research on this topic is already started by Van Gorp et al. (MDE support for process-oriented health information systems: from theory to practice 2012) & (Towards Generic MDE Support for Extracting Purpose-Specific Healthcare Models from Annotated, Unstructured Texts 2013).

The traceability is also effective when checking the compliance of the modelled models with rules stemming from the guidelines in the care pathway. Currently no tools are used to check this compliance of the models. However in the banking and e-business practices there is research performed on methods validating business processes to compliance requirements. An example is the research performed by Türetken et al. (2012), they present a new pattern-based framework that captures and manages business process compliance requirements by acting as a springboard to fully automate and continuously audit business processes. Another example of such research proposes a method that validates a model based on simulation of the execution of process instances based on specific scenarios (de Moura Araujo, et al. 2010). Next to that there is also research that provides an approach to extend visual compliance rule languages with the ability to consider data, time, resources, and partner interactions when modelling business process compliance rules (Knuplesch, et al. 2013). In future research on workflow support for care pathways it might be useful to follow the progress of these methods on compliance requirements validation.

The final deliverable of the proposed methodology is an executable workflow process model that can be used by caregivers during the treatment process of a patient. In this thesis the input and interaction of patients with such a system is not included. Although the essential part of the workflow system is support for the medical staff, in some care pathways it might be useful/practical if there is also an interaction possible between the patient and the system. A project which aims to provide such a patient-centric decision support system based on clinical guidelines and in a mobile environment is the MobiGuide project (García-Sáez, et al. 2013), (Sacchi, et al. 2013). In future work, research on decision support systems for patients where the “system helps patients manage their illness by monitoring disease parameters and providing appropriate feedback personalized to patients’ preferences and context” (García-Sáez, et al. 2013, 1) could be used to explore the interaction between a patient and the workflow system.

In the case study the drools jBPM BPMN web designer and the Drools platform are used to model the flow and the business rules of the care pathway. However the functioning of the Drools platform when modelling paper-based care pathways is not yet proven and can therefore be seen as a limitation in the thesis. Hence it is recommended to follow research on other options to model rules of the paper-based care pathway. A new rule-based process modelling language called rBPMN (rule-based BPMN) (Milanovic, Gasevic and Wagner 2008) was developed to improve the support of business rules in the BPMN language. Another study showed that a combination of the languages Simulation Reference Markup Language (SRML) and BPMN appears to be better suited for combined process and rule modelling than any of the other tested modelling languages used independently (Zur Muehlen and Indulska 2010). Since the functioning of the Drools platform when modelling paper-based care pathways is not yet proven, it is recommended to follow the progress of these kinds of initiatives.

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Appendix A: Unstable angina care pathway

This part of the thesis is deleted for privacy reasons.

Appendix B: Annotated unstable angina pathway

This part of the thesis is deleted for privacy reasons.

Appendix C: Structure of the conceptual model

Different levels of the Conceptual Model

- Level 1
    - Level 2
        - Level 3
            - Level 4
                - Level 5

Levels of the Unstable Angina Conceptual Model

- Main Process
    - Subprocess 0-10 minutes activities
        - Subprocess Main activities for diagnosis and treatment 0-10 minutes
        - Subprocess Main Long-term orders 0-10 minutes
        - Subprocess Main Temporary orders 0-10 minutes
        - Subprocess Main care tasks 0-10 minutes
    - Subprocess 0-30 minutes activities
        - Subprocess Main activities for diagnosis and treatment 0-30 minutes
        - Subprocess Main Long-term orders 0-30 minutes
        - Subprocess Main care tasks 0-30 minutes
    - Subprocess 0-60 minutes activities
        - Subprocess Main activities for diagnosis and treatment (operation)
            - Subprocess Operation
                - Subprocess Examinations
        - Subprocess Main Long-term orders 0-60 minutes
        - Subprocess Main Temporary orders 0-60 minutes
            - Subprocess Preoperative preparation testing and examination
            - Subprocess Postoperative tests and examination
                - Subprocess Optional tests (ad-hoc)
        - Subprocess Main care tasks 0-60 minutes
    - Subprocess Day 1 after admission (CCU) activities
        - Subprocess Preparation and Operation
            - Subprocess Operation
                - Subprocess Examinations
            - Subprocess Preoperative preparation testing and examination
            - Subprocess Postoperative tests and examination
                - Subprocess Optional tests (ad-hoc)
        - Subprocess Main activities for diagnosis and treatment Day 1
        - Subprocess Main Long-term orders Day 1
            - Subprocess Giving ACEI or ARB drugs
        - Subprocess Main Temporary orders Day 1
        - Subprocess Main care tasks Day 1
    - Subprocess Day 2 after admission (CCU) activities
        - Subprocess Preparation and Operation
            - Subprocess Operation

            - Subprocess Examinations
        - Subprocess Preoperative preparation testing and examination
        - Subprocess Postoperative tests and examination
            - Subprocess Optional tests (ad-hoc)
    - Subprocess Main activities for diagnosis and treatment Day 2
    - Subprocess Main Long-term orders Day 2
        - Subprocess Giving ACEI or ARB drugs
    - Subprocess Main Temporary orders Day 2
    - Subprocess Main care tasks Day 2
- Subprocess Day 3 after admission (CCU) activities
    - Subprocess Preparation and Operation
        - Subprocess Operation
            - Subprocess Examinations
        - Subprocess Preoperative preparation testing and examination
        - Subprocess Postoperative tests and examination
            - Subprocess Optional tests (ad-hoc)
    - Subprocess Main activities for diagnosis and treatment Day 3
    - Subprocess Main Long-term orders Day 3
    - Subprocess Main Temporary orders Day 3
        - Subprocess Giving ACEI or ARB drugs
    - Subprocess Main care tasks Day 3
- Subprocess Day 4-6 after admission (CCU) activities
    - Subprocess Main activities for diagnosis and treatment Day 4-6
    - Subprocess Main Long-term orders Day 4-6
    - Subprocess Main care tasks Day 4-6
- Subprocess Day 7-9 (Day 2-5 General Ward) activities
    - Subprocess Main activities for diagnosis and treatment Day 7-9
    - Subprocess Main Long-term orders Day 7-9
    - Subprocess Main Temporary orders Day 7-9
    - Subprocess Main care tasks Day 7-9
- Subprocess Day 8-14 (Discharge Day) activities
    - Subprocess Main activities for diagnosis and treatment Day 8-14
    - Subprocess Discharge orders
    - Subprocess Main care tasks Day 8-14

Appendix D: Close-up Main process model

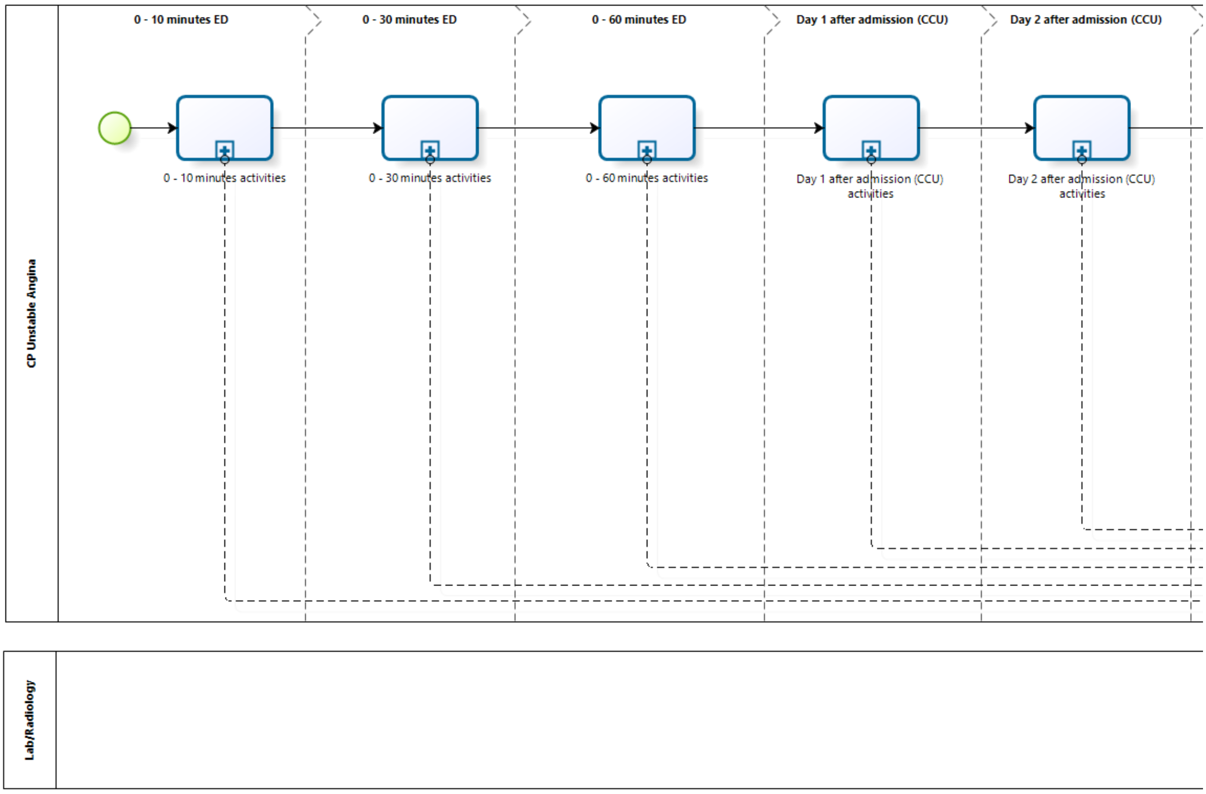


Figure 30: Close-up Main Process Unstable Angina 1

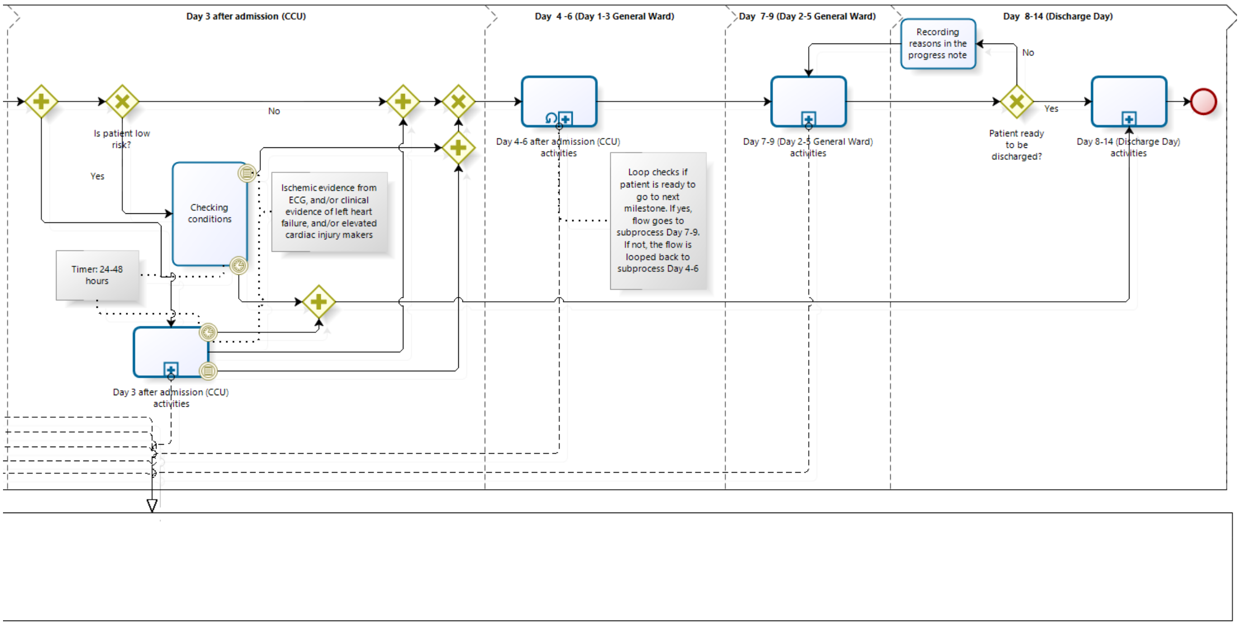


Figure 31: Close-up Main Process Unstable Angina 2

Appendix E: Subprocess 0-10 minutes activities

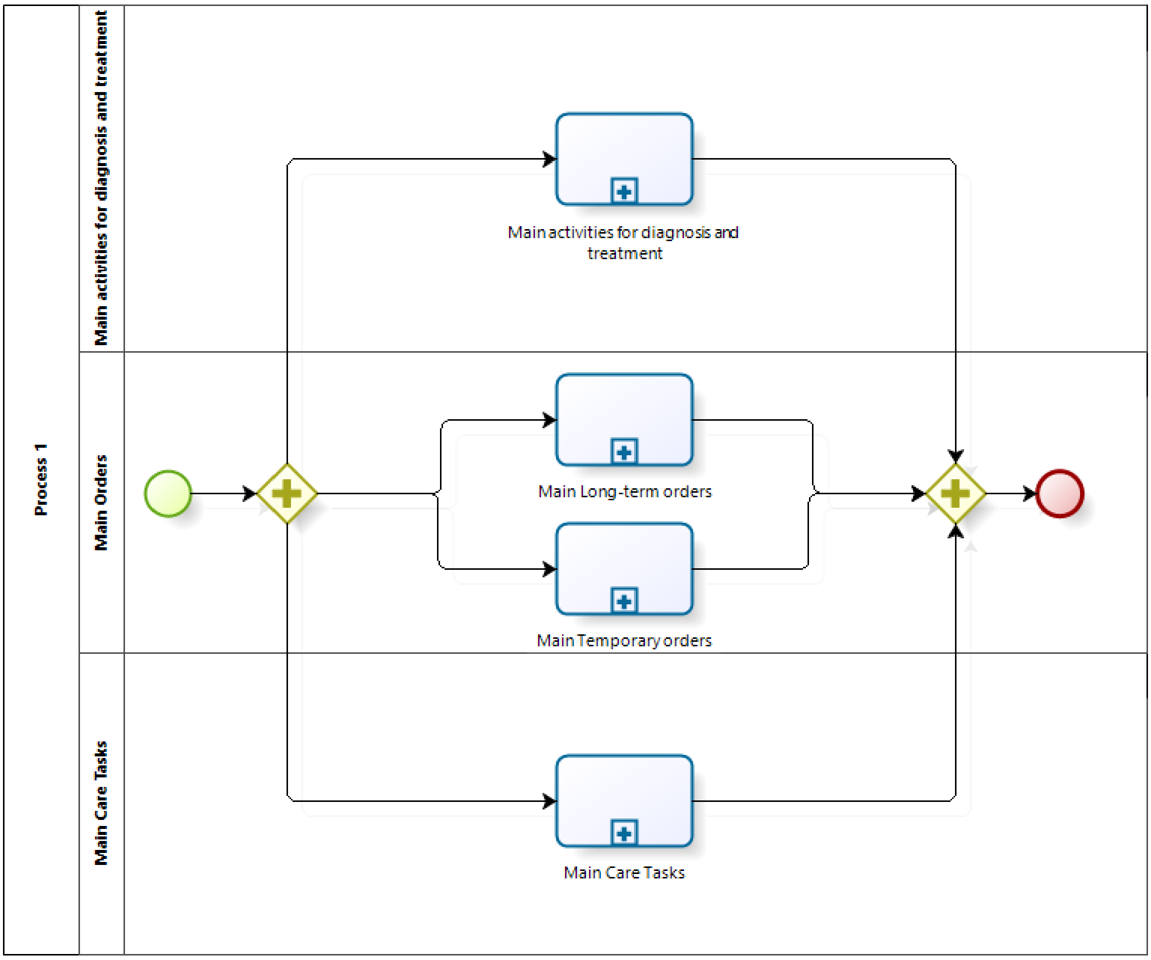


Figure 32: Subprocess 0-10 minutes activities

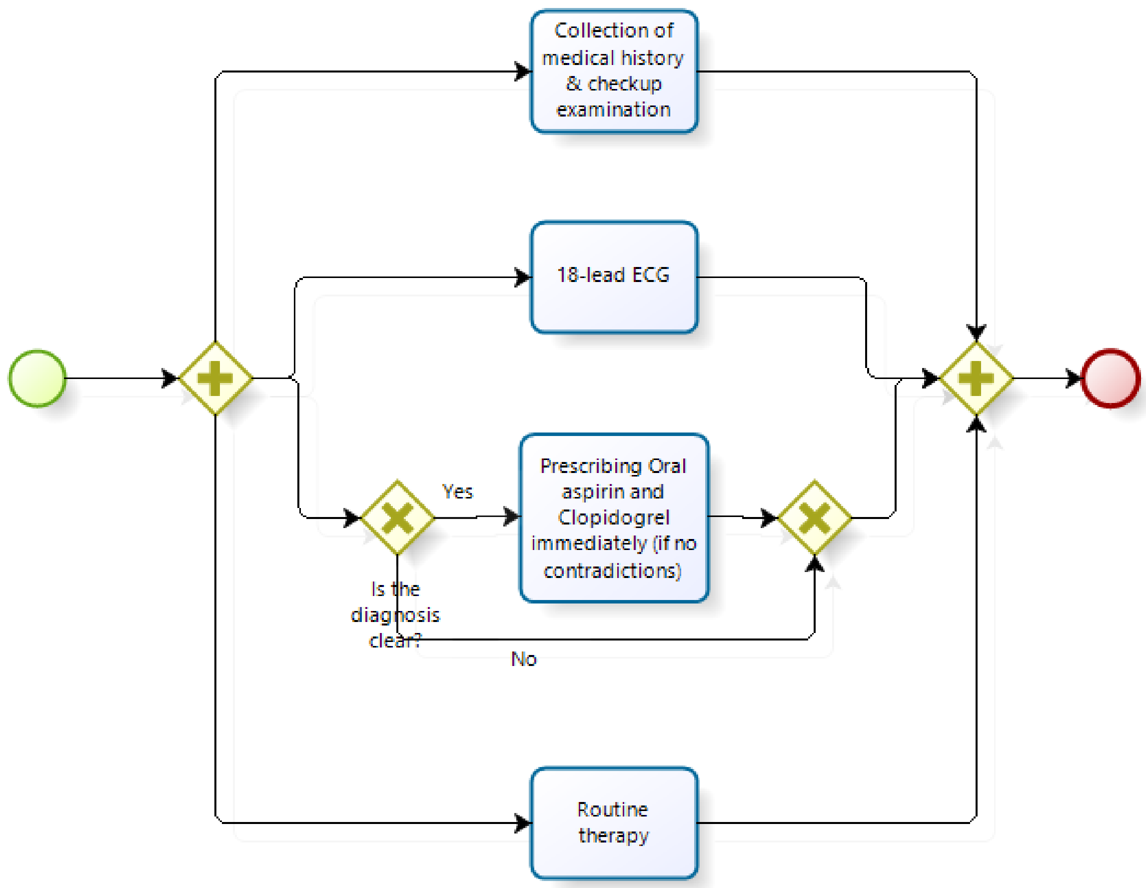


Figure 33: Main activities for diagnosis and treatment 0-10 minutes

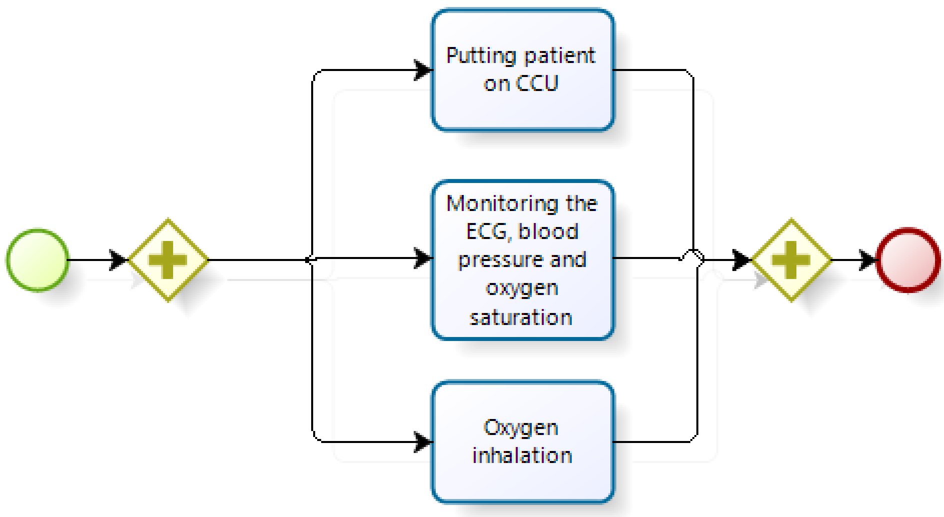


Figure 34: Main Long-term orders 0-10 minutes

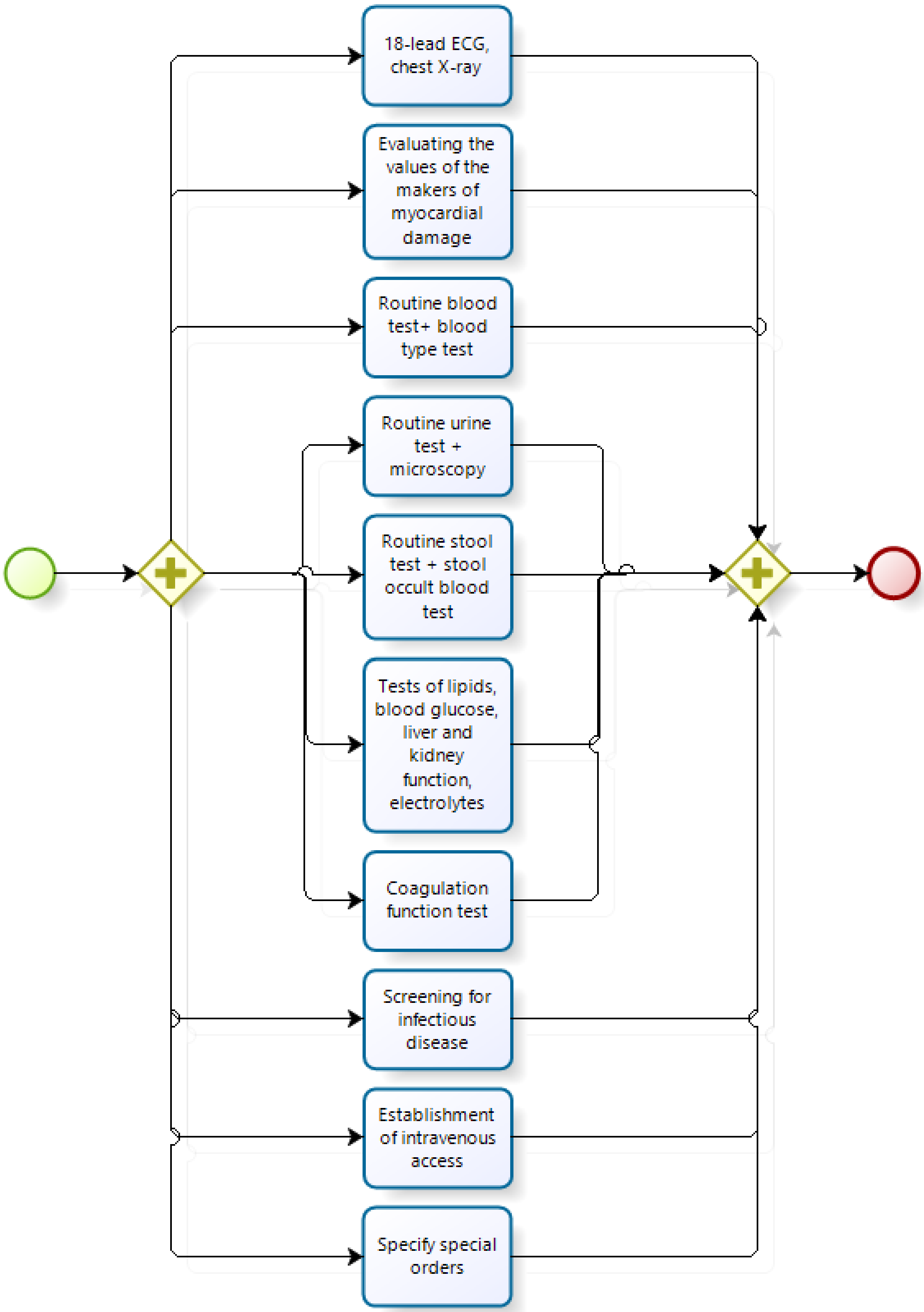


Figure 35: Main Temporary orders 0-10 minutes

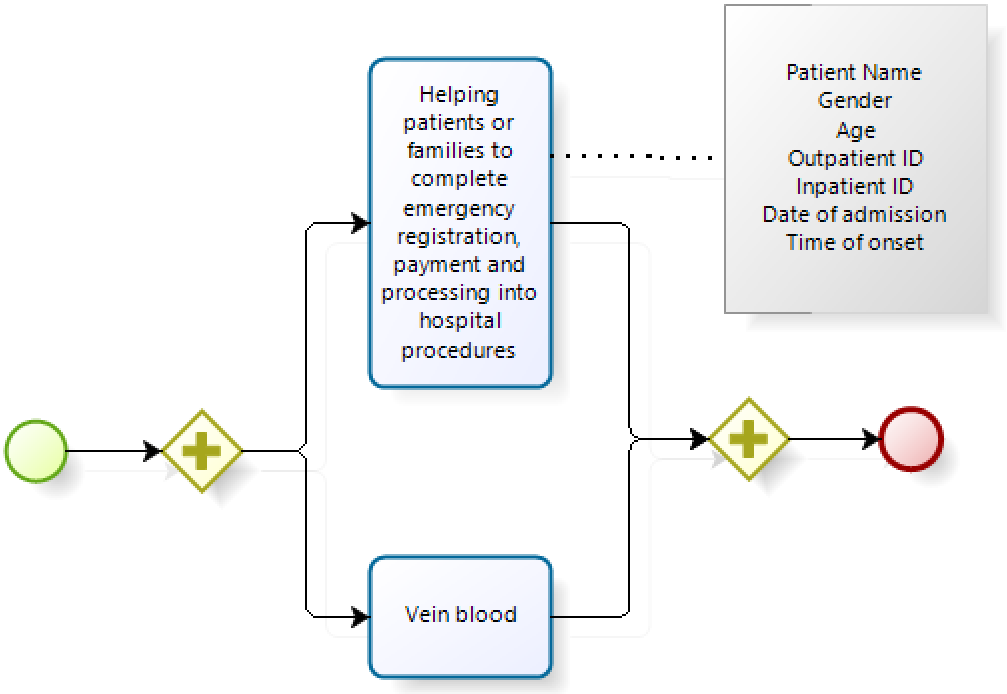


Figure 36: Main care tasks 0-10 minutes

Appendix F: Subprocess 0-30 minutes activities

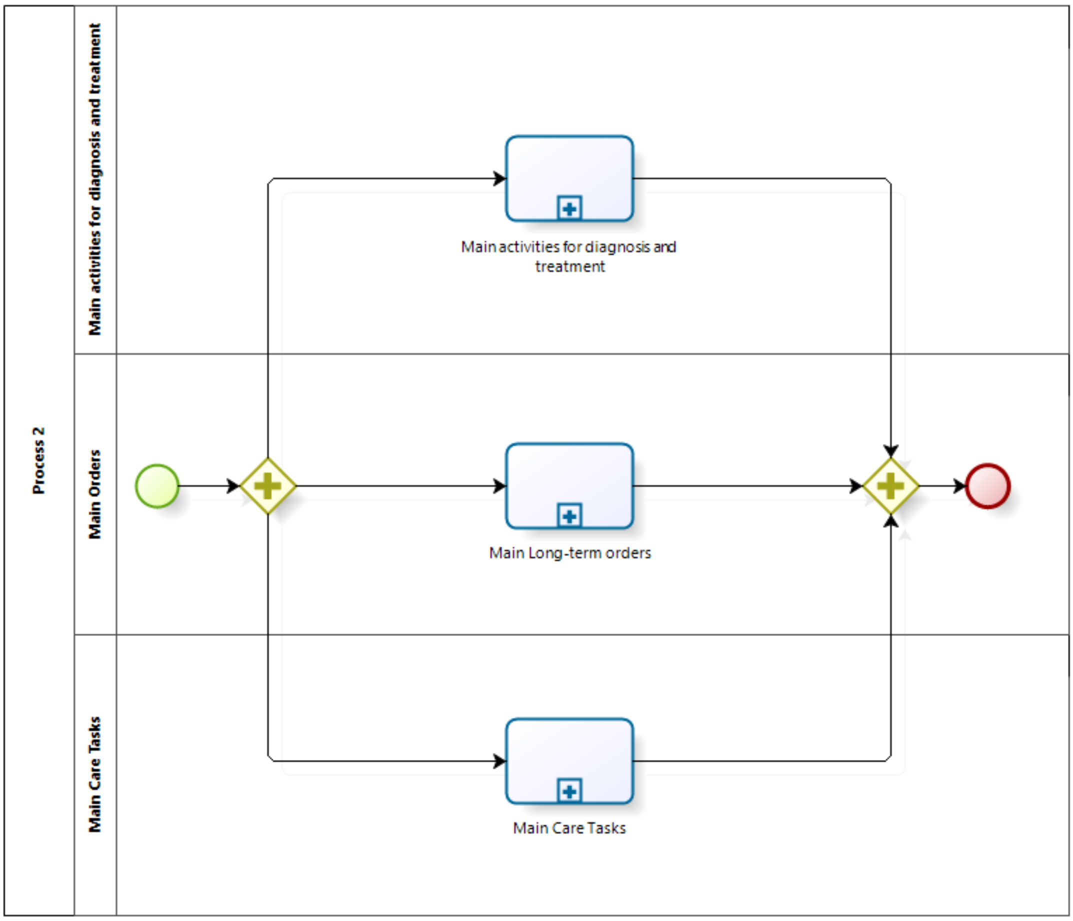


Figure 37: Subprocess 0-30 minutes activities

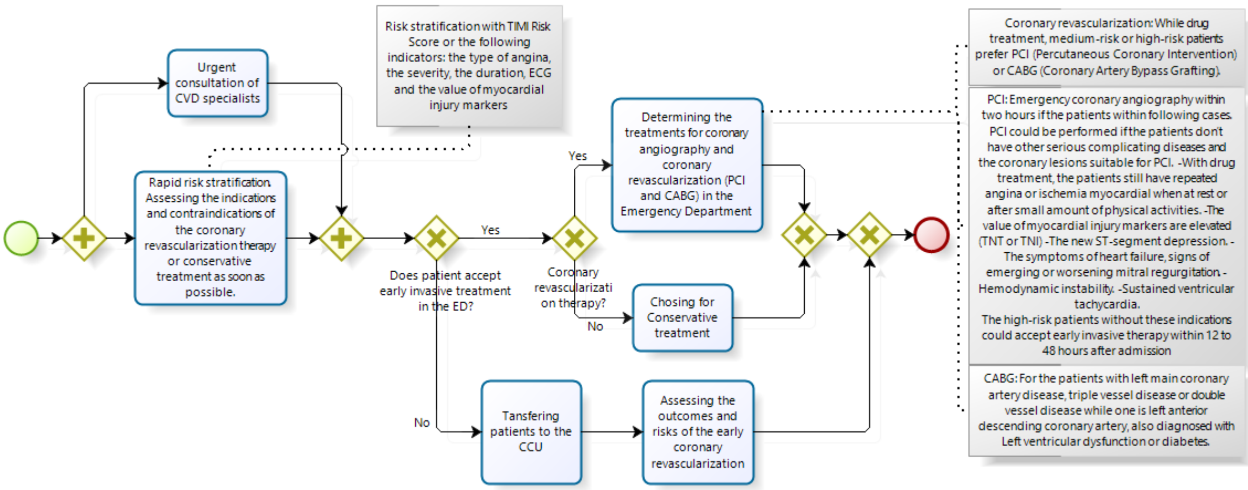


Figure 38: Main activities for diagnosis and treatment 0-30 minutes

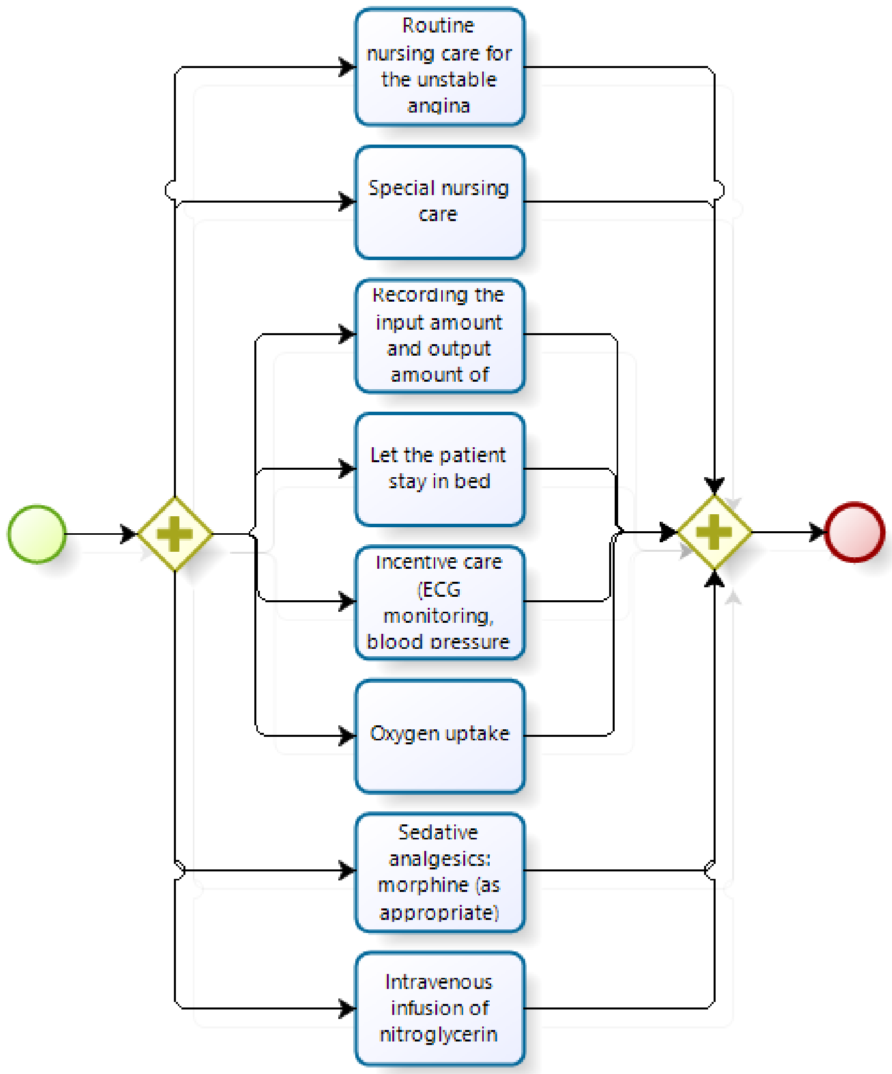


Figure 39: Main Long-term orders 0-30 minutes

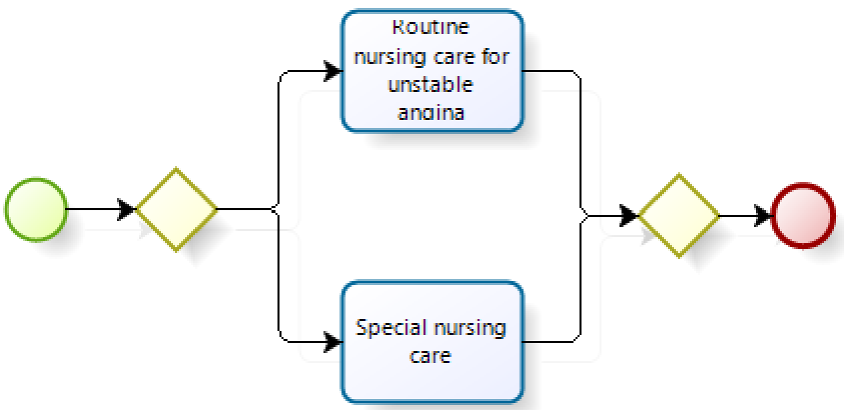


Figure 40: Main care tasks 0-30 minutes

Appendix G: Subprocess 0-60 minutes activities

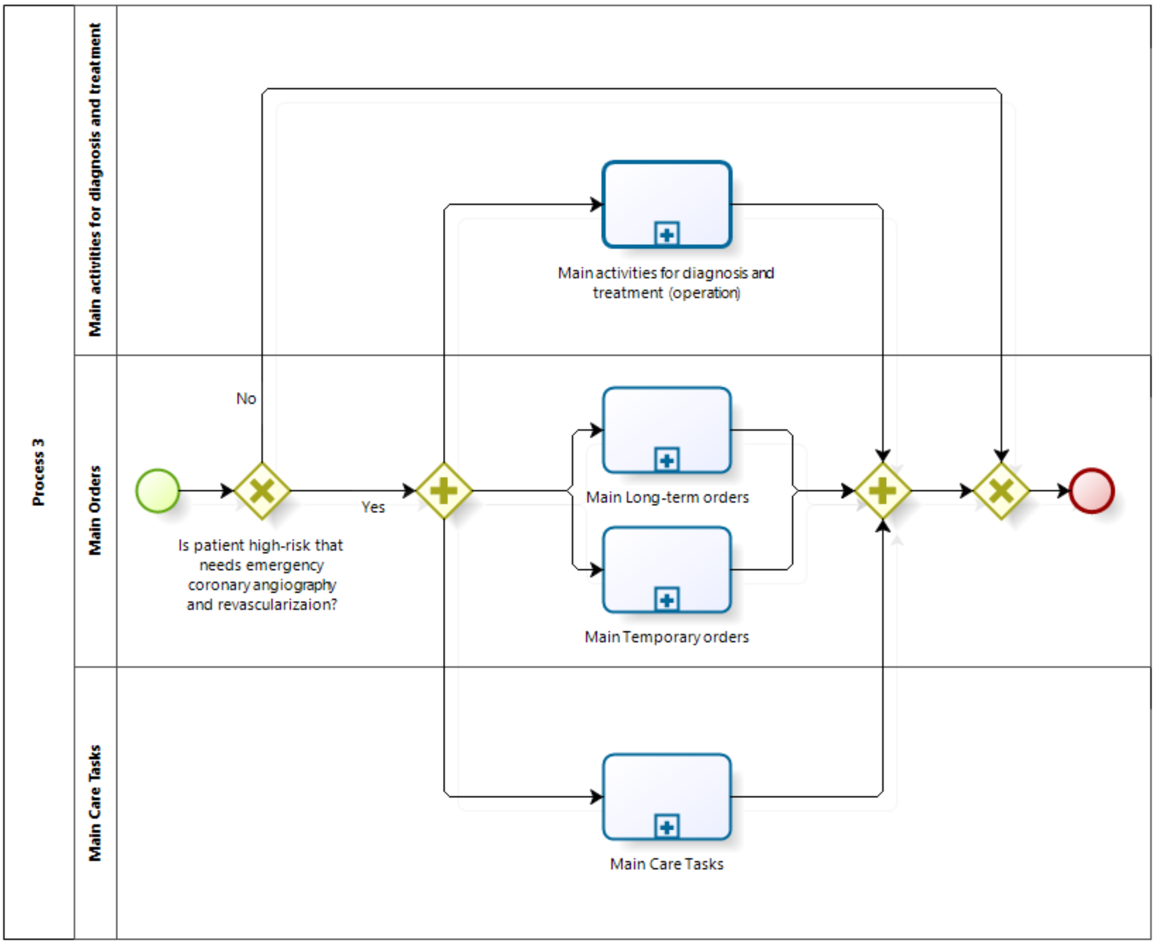


Figure 41: Subprocess 0-60 minutes activities

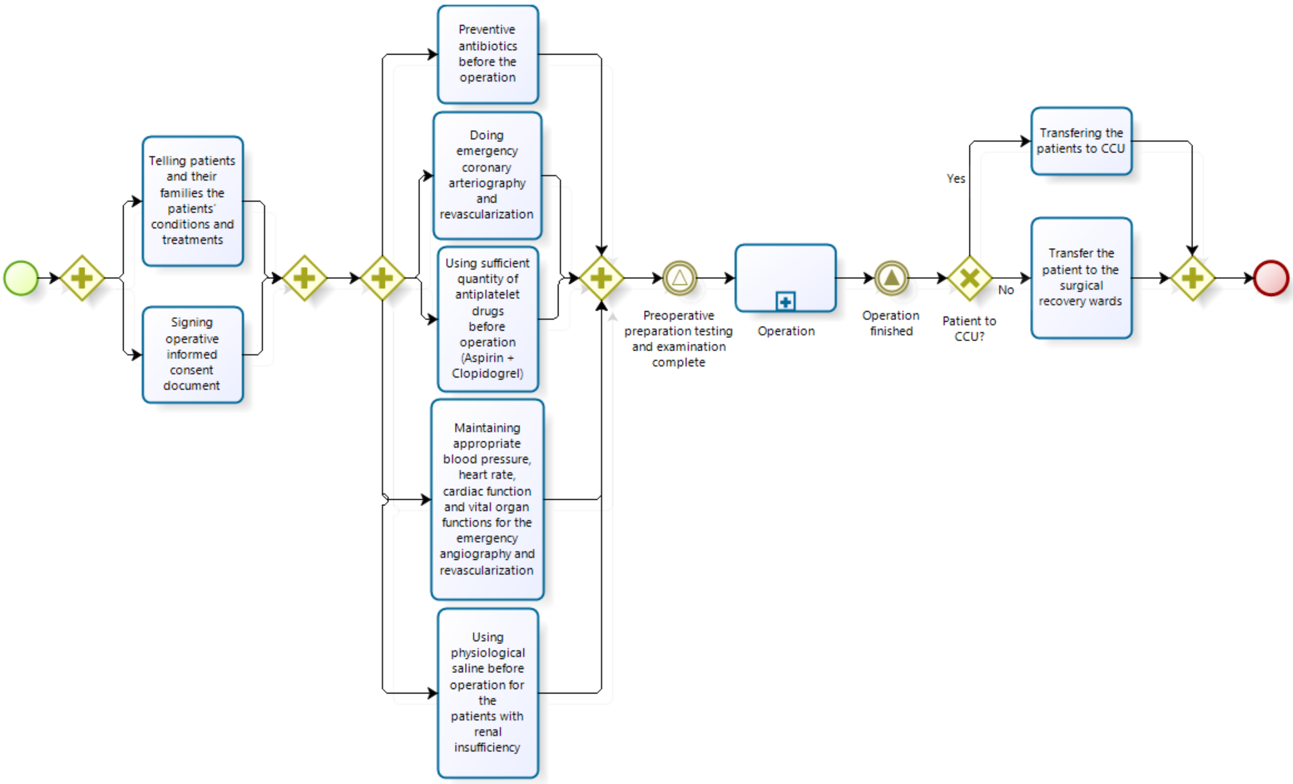


Figure 42: Main activities for diagnosis and treatment (operation)

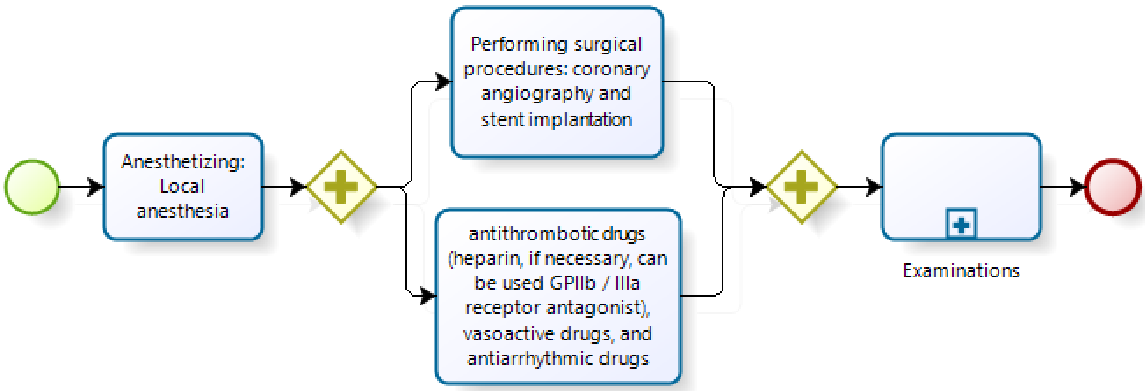


Figure 43: Subprocess Operation

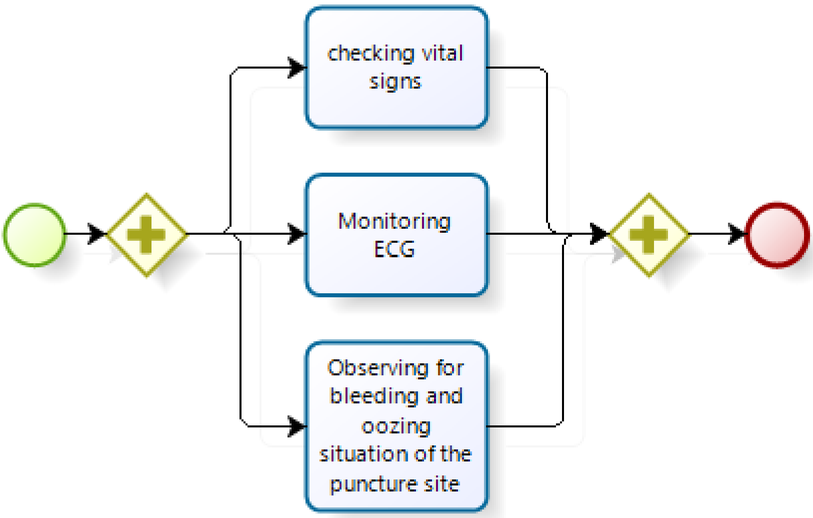


Figure 44: Subprocess Examinations

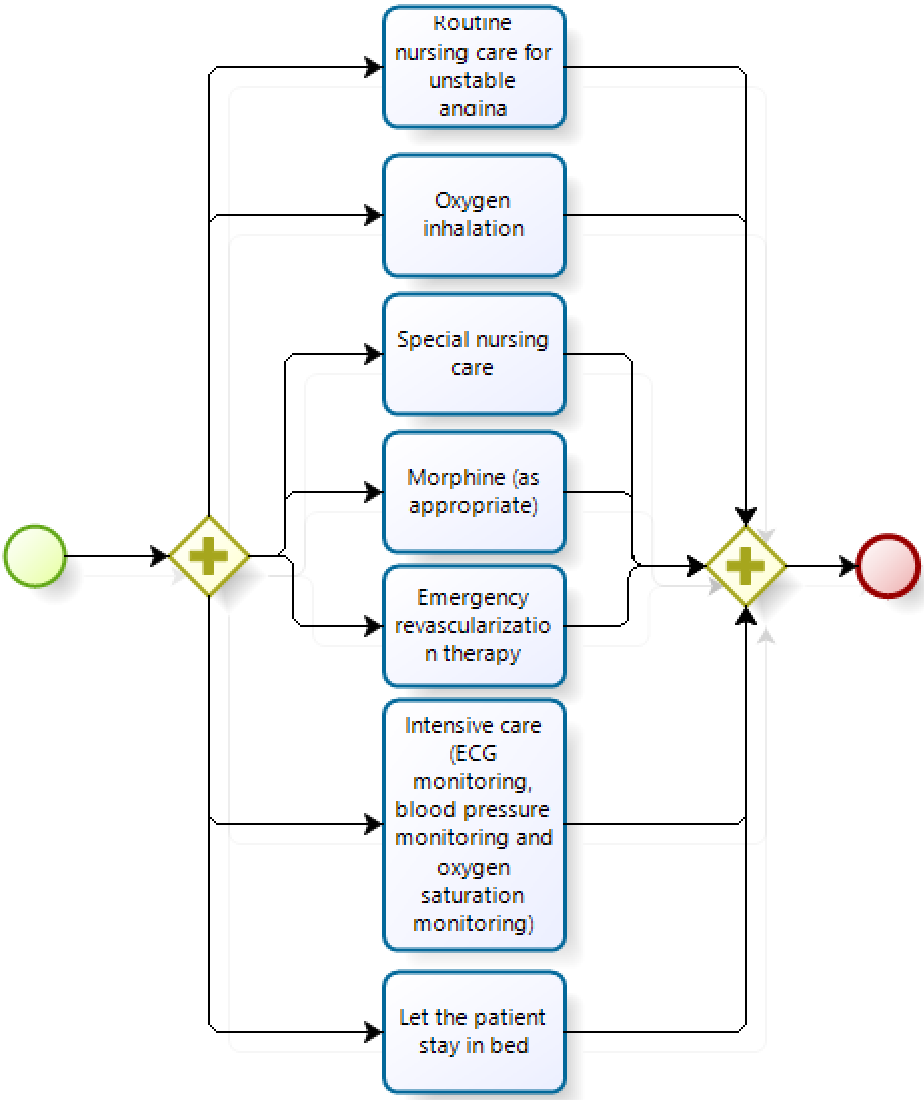


Figure 45: Main Long-term orders 0-60 minutes

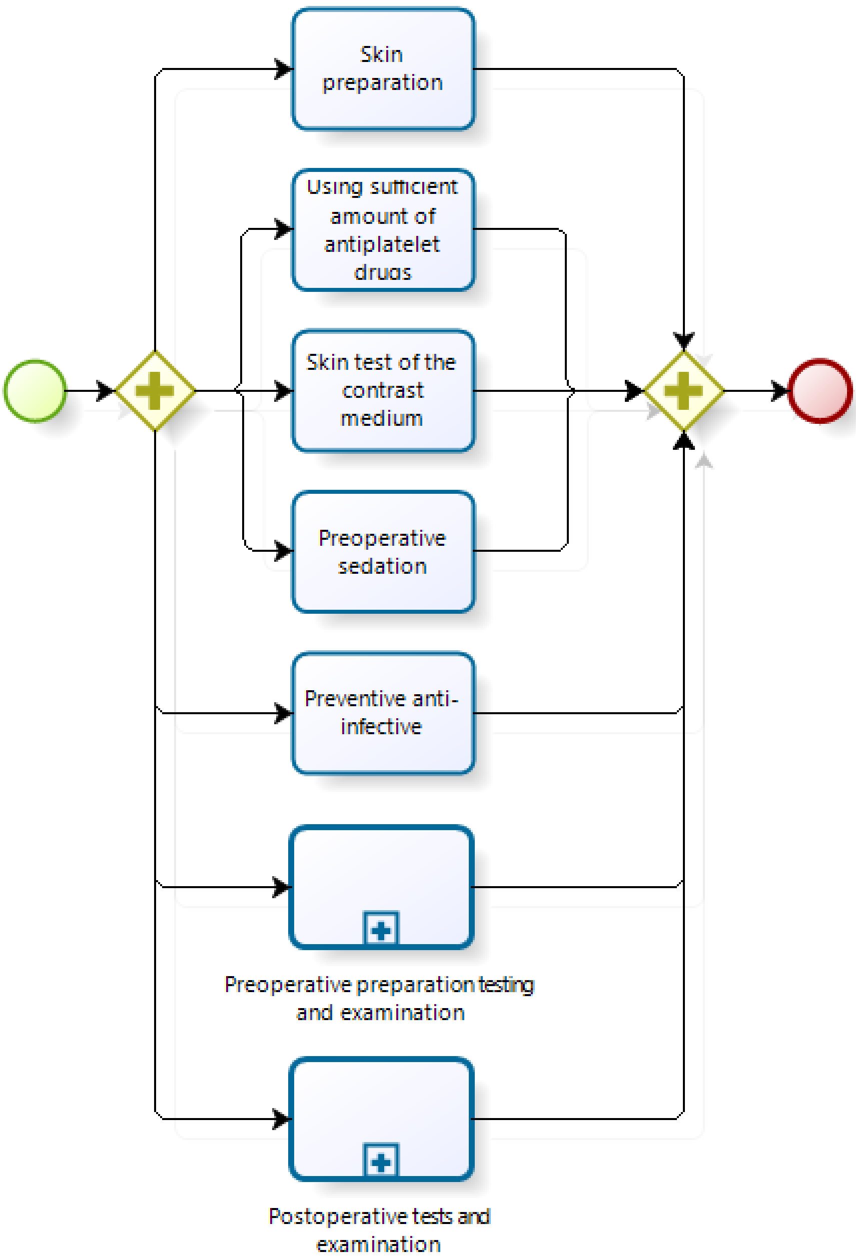


Figure 46: Subprocess Main Temporary orders 0-60 minutes

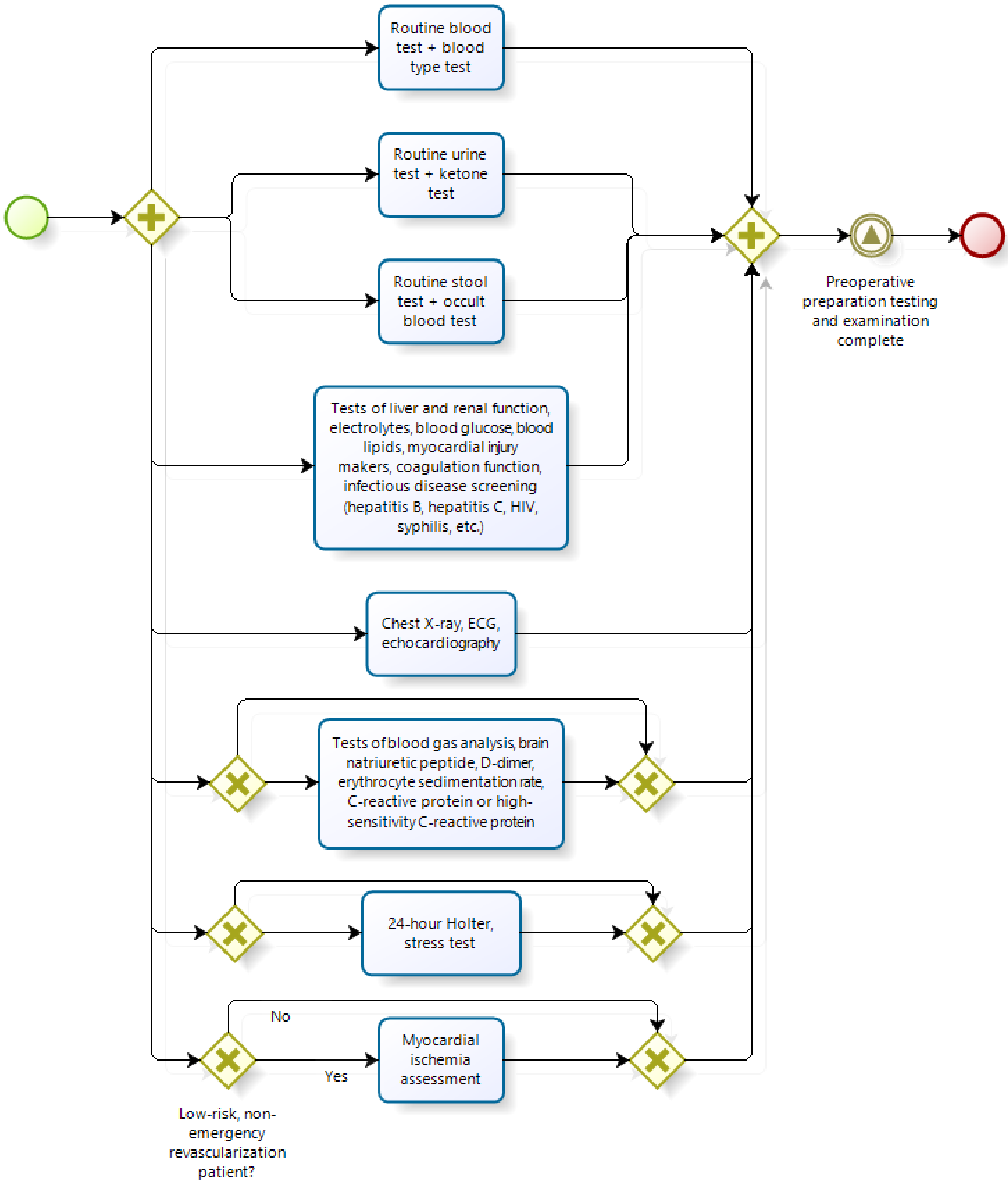


Figure 47: Subprocess Preoperative preparation testing and examination

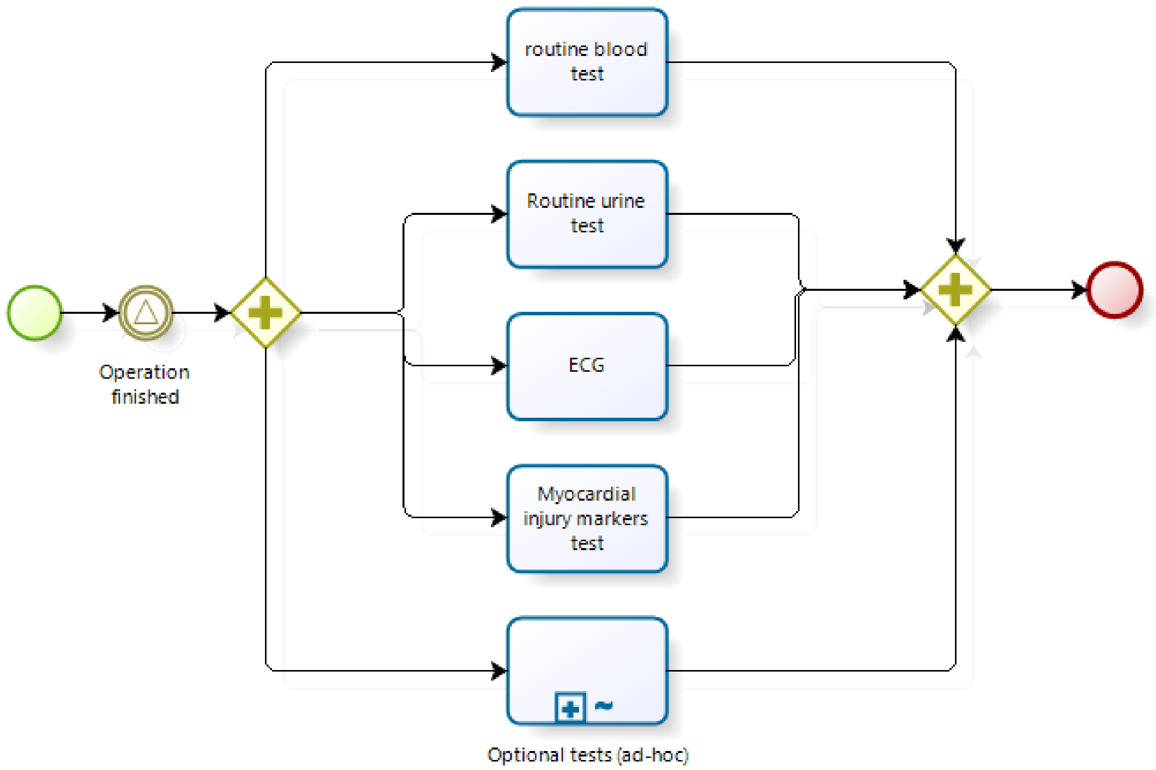


Figure 48: Subprocess Postoperative tests and examination

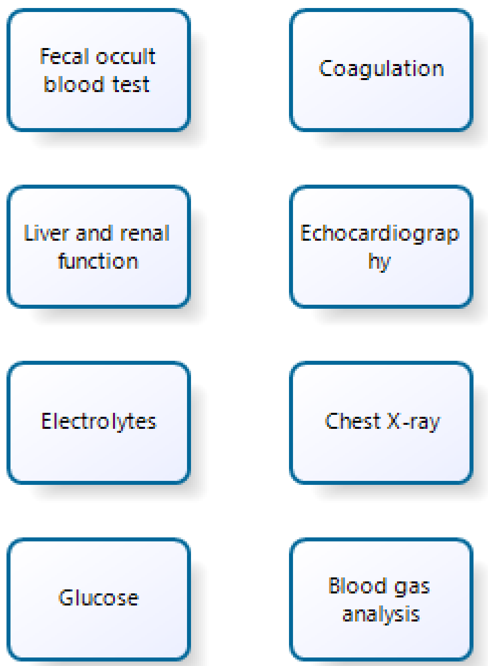


Figure 49: Subprocess Optional tests (ad-hoc)

Appendix H: Subprocess Day 1 after admission (CCU) activities

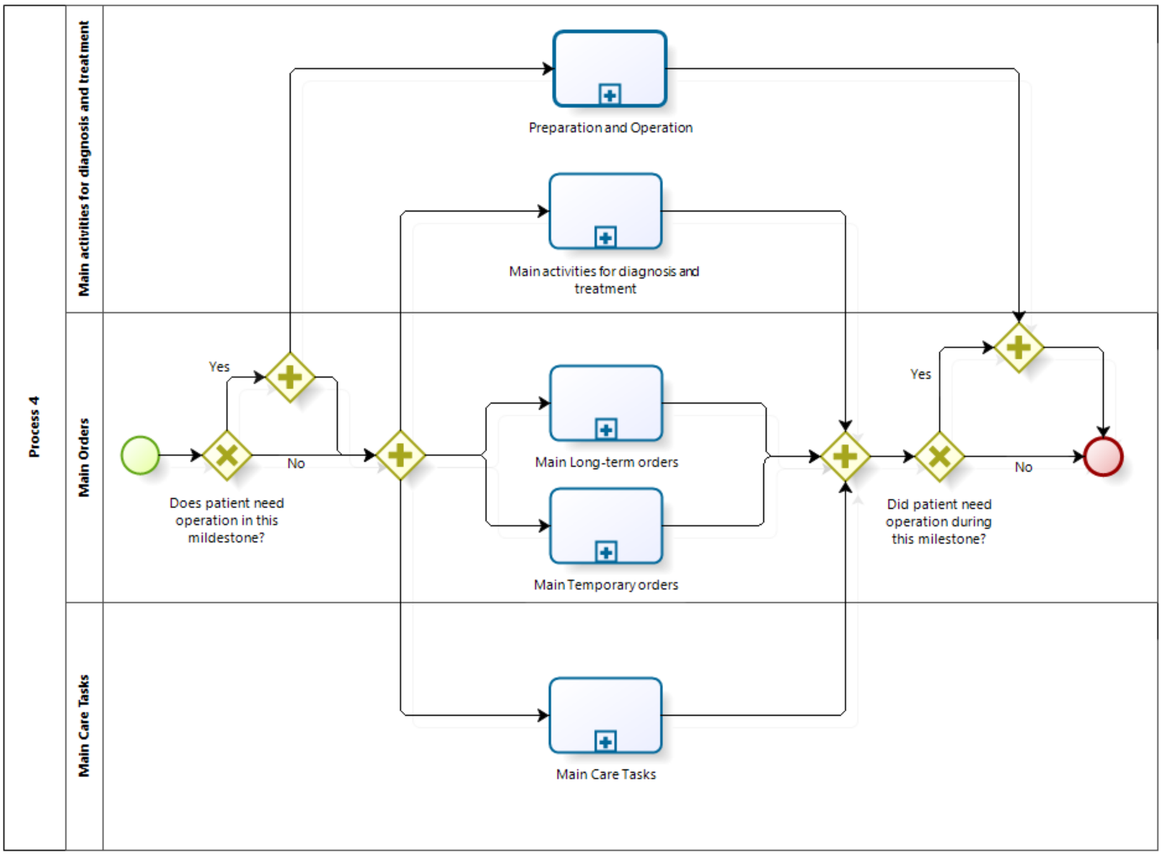


Figure 50: Subprocess Day 1 after admission (CCU) activities

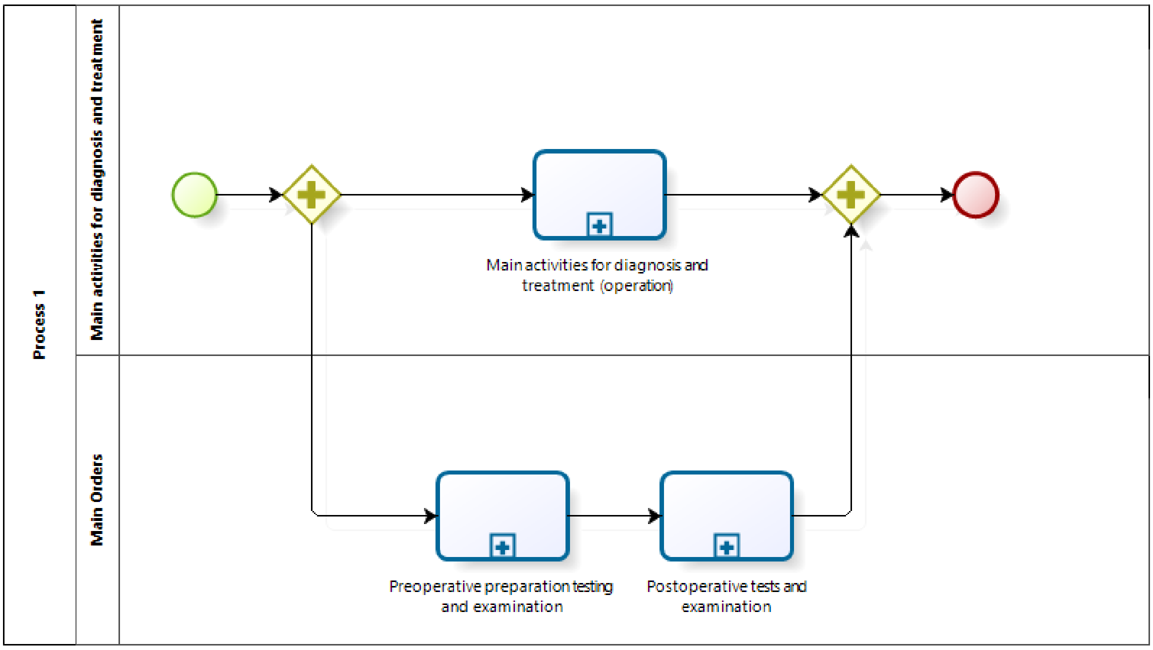


Figure 51: Subprocess Preparation and Operation

- Subprocess Main activities for diagnosis and treatment (operations) can be found on page 68.
- Subprocess Preoperative preparation testing and examination can be found on page 71.
- Subprocess Postoperative preparation testing and examination can be found on page 71.

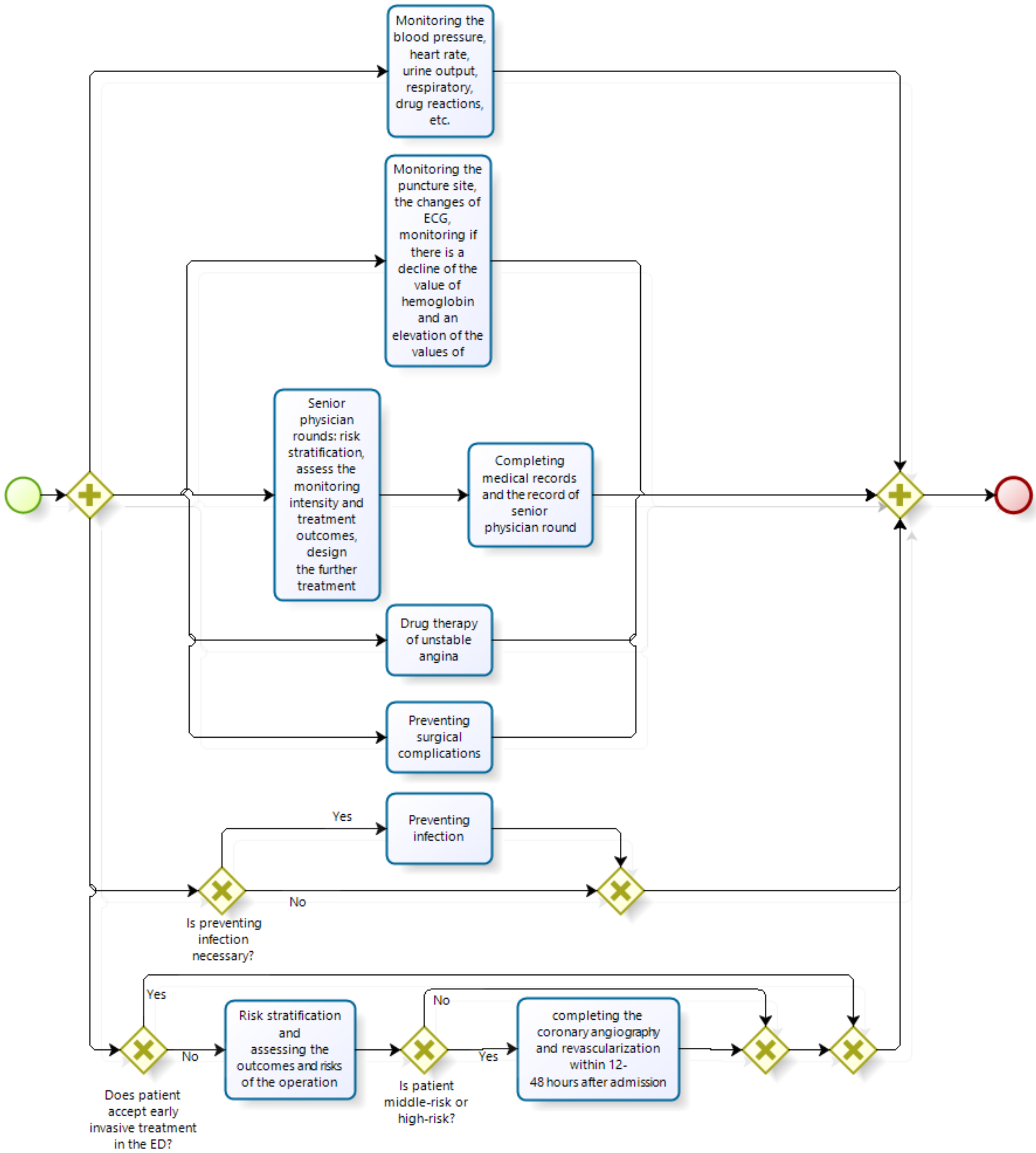


Figure 52: Subprocess Main activities for diagnosis and treatment Day 1

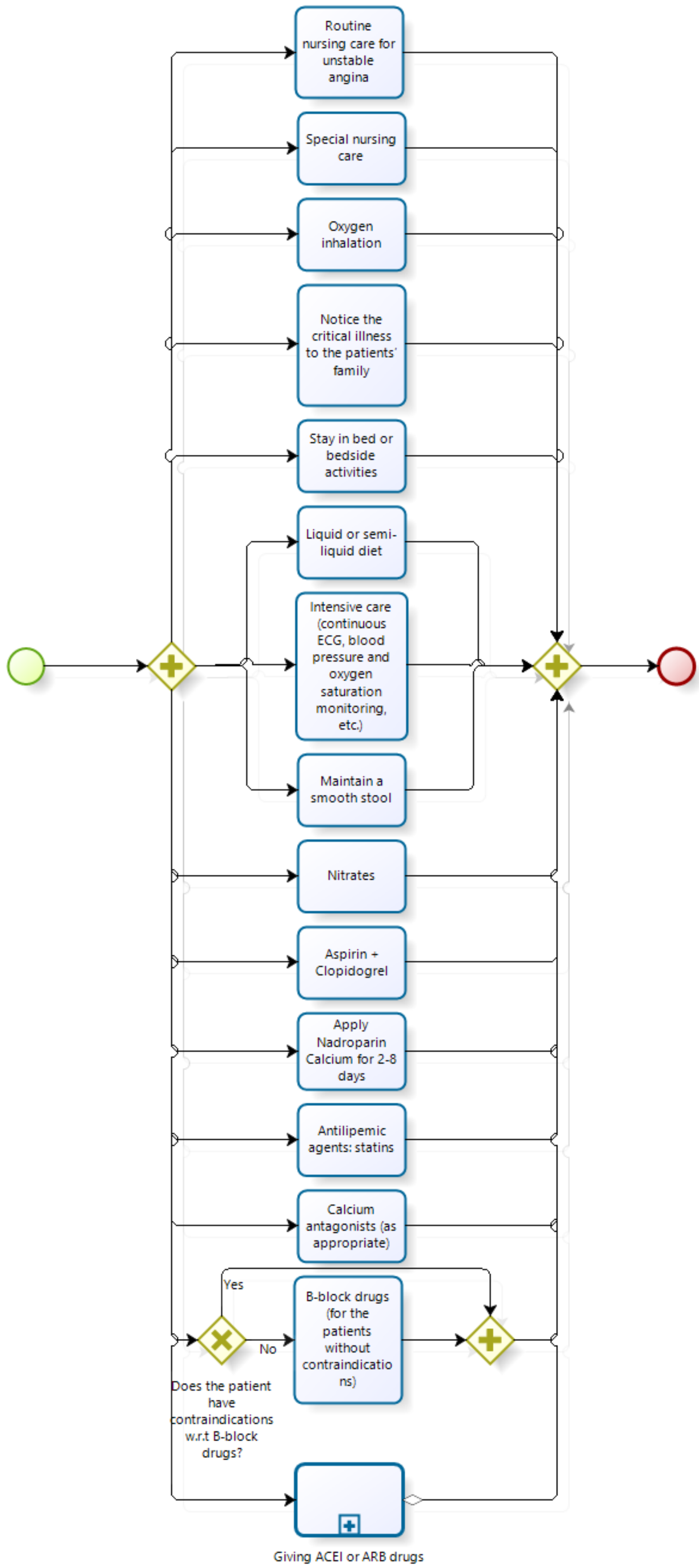


Figure 53: Subprocess Main Long-term orders Day 1

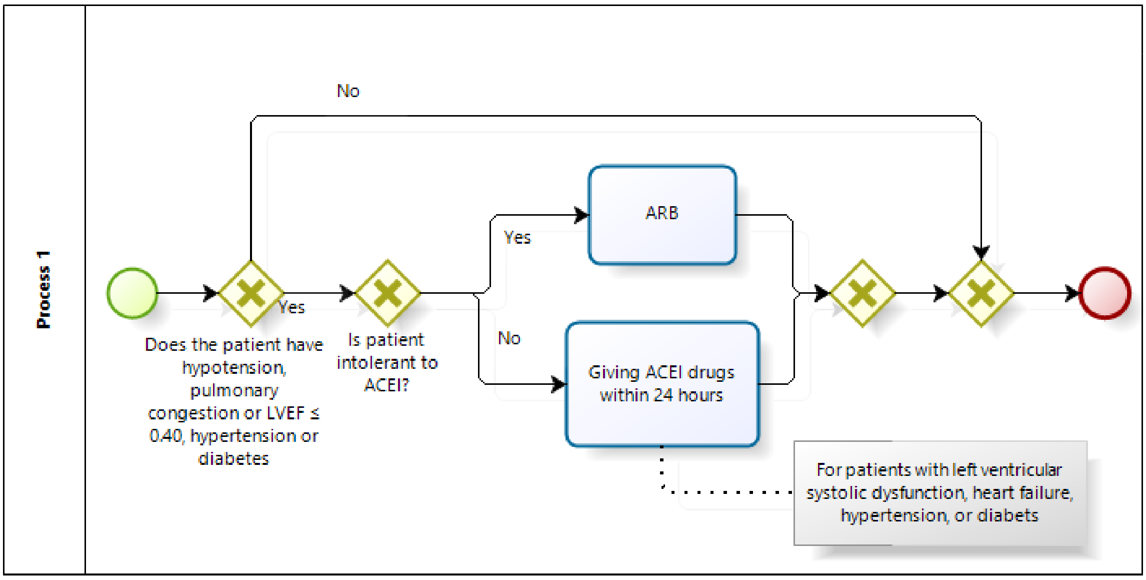


Figure 54: Subprocess Giving ACEI or ARB drugs

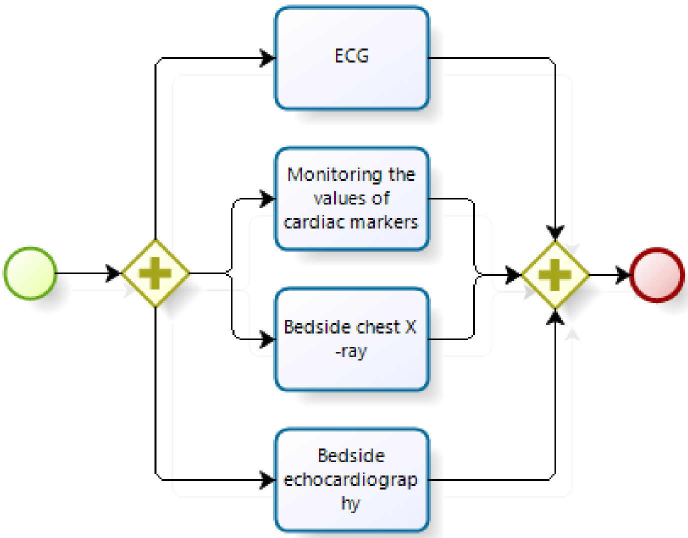


Figure 55: Subprocess Main Temporary orders Day 1

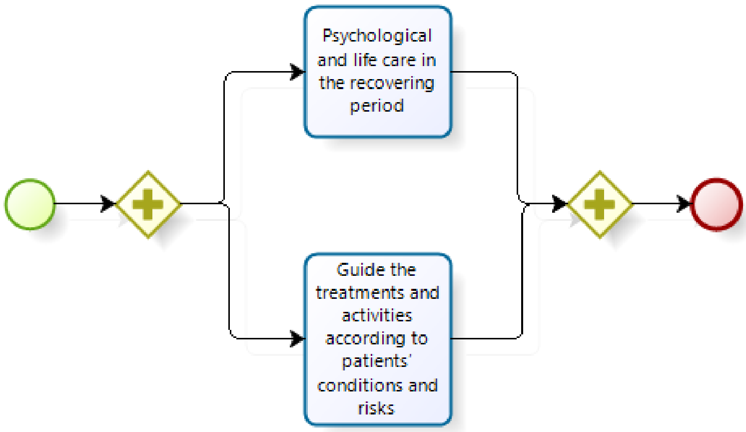


Figure 56: Subprocess Main care tasks Day 1

Appendix I: Subprocess Day 2 after admission (CCU) activities

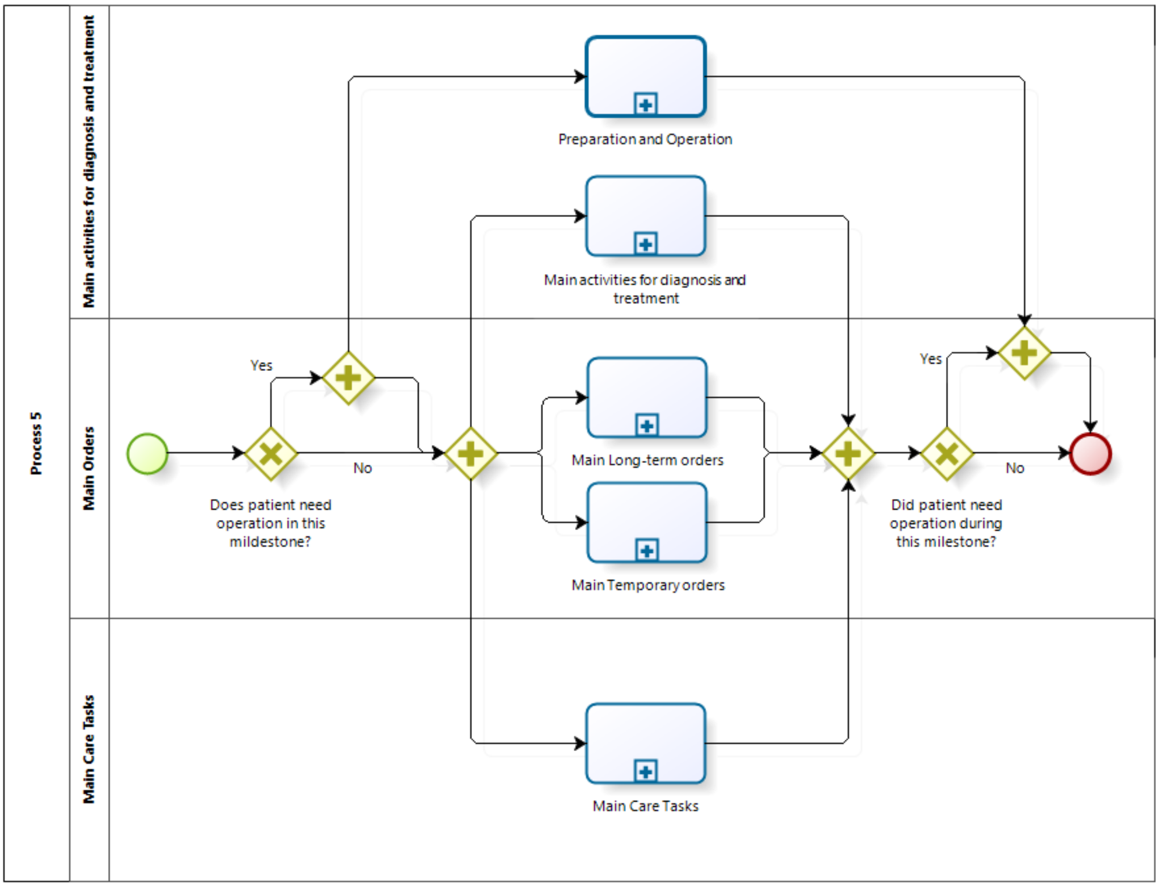


Figure 57: Subprocess Day 2 after admission (CCU) activities

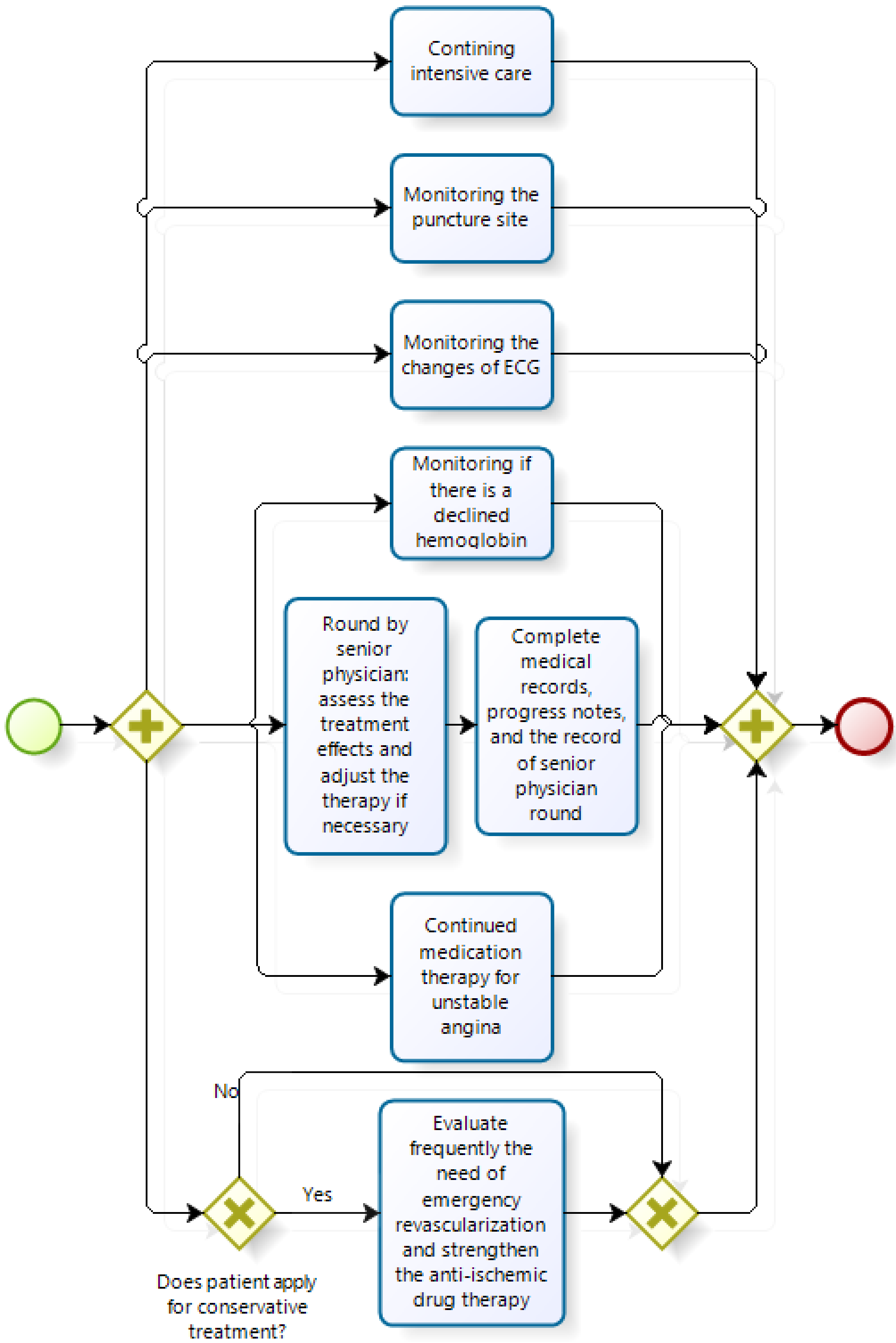


Figure 58: Subprocess Main activities for diagnosis and treatment Day 2

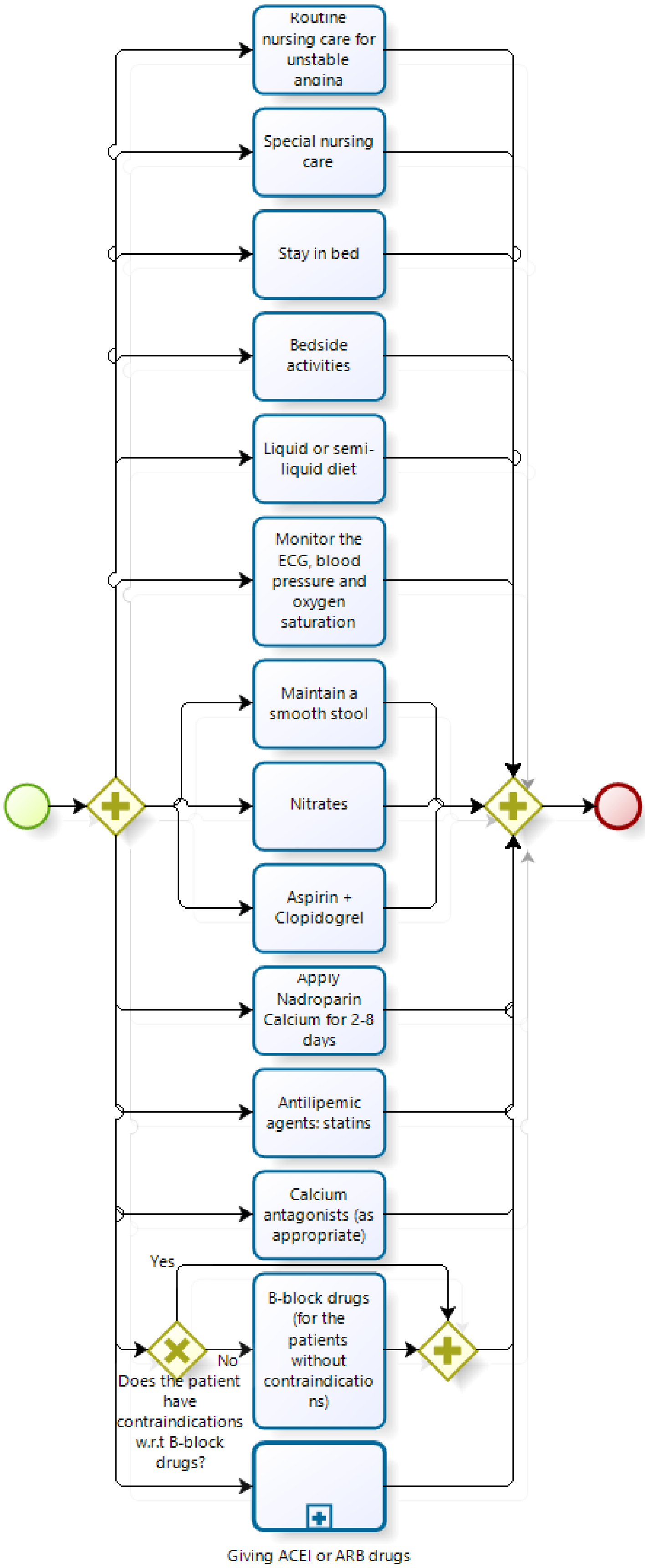


Figure 59: Subprocess Main Long-term orders Day 2

- Subprocess Giving ACEI or ARB drugs can be found on page 76.

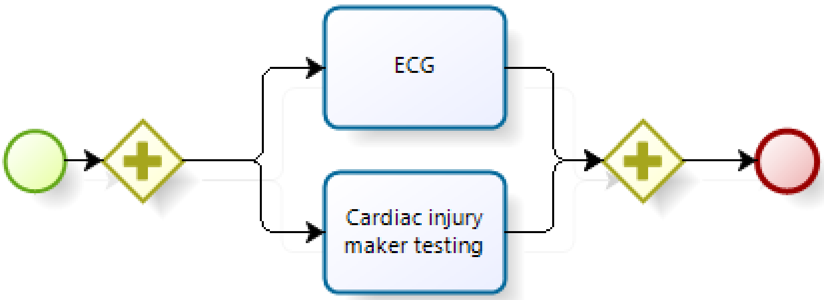


Figure 60: Subprocess Main Temporary orders Day 2

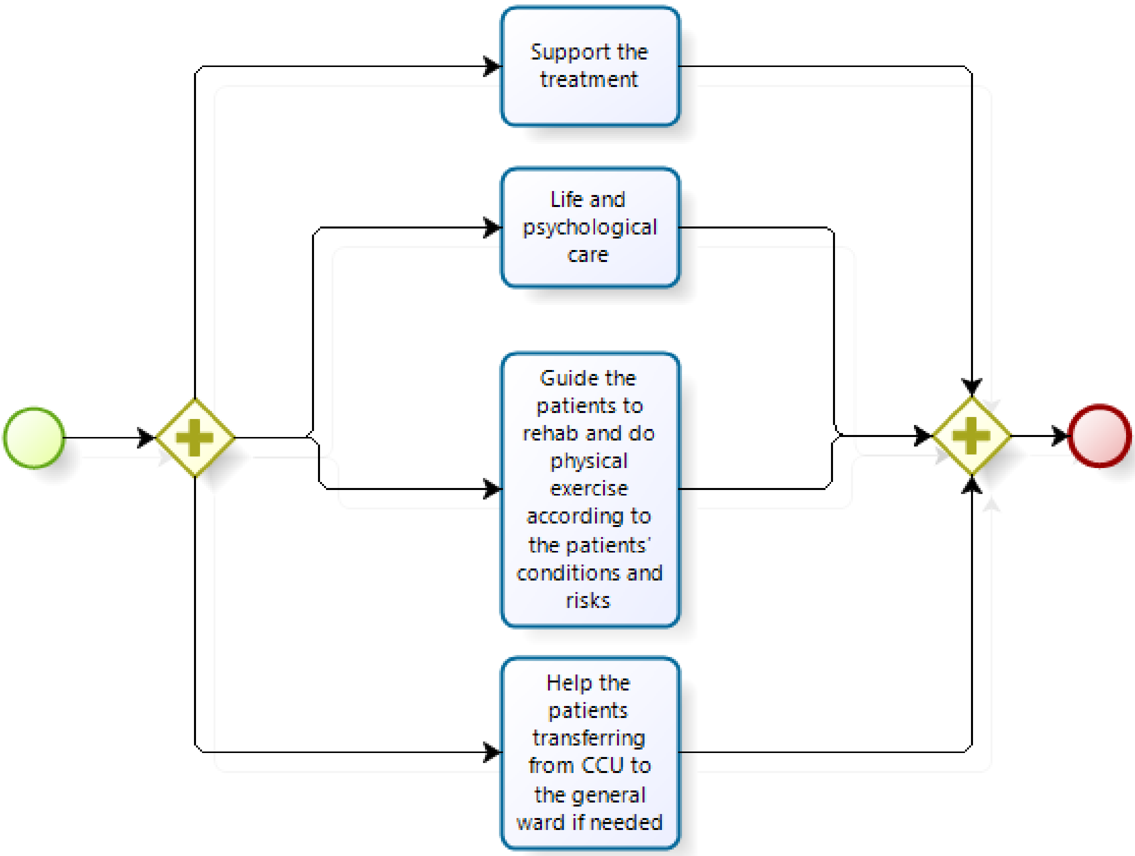


Figure 61: Subprocess Main care tasks Day 2

Appendix J: Subprocess Day 3 after admission (CCU) activities

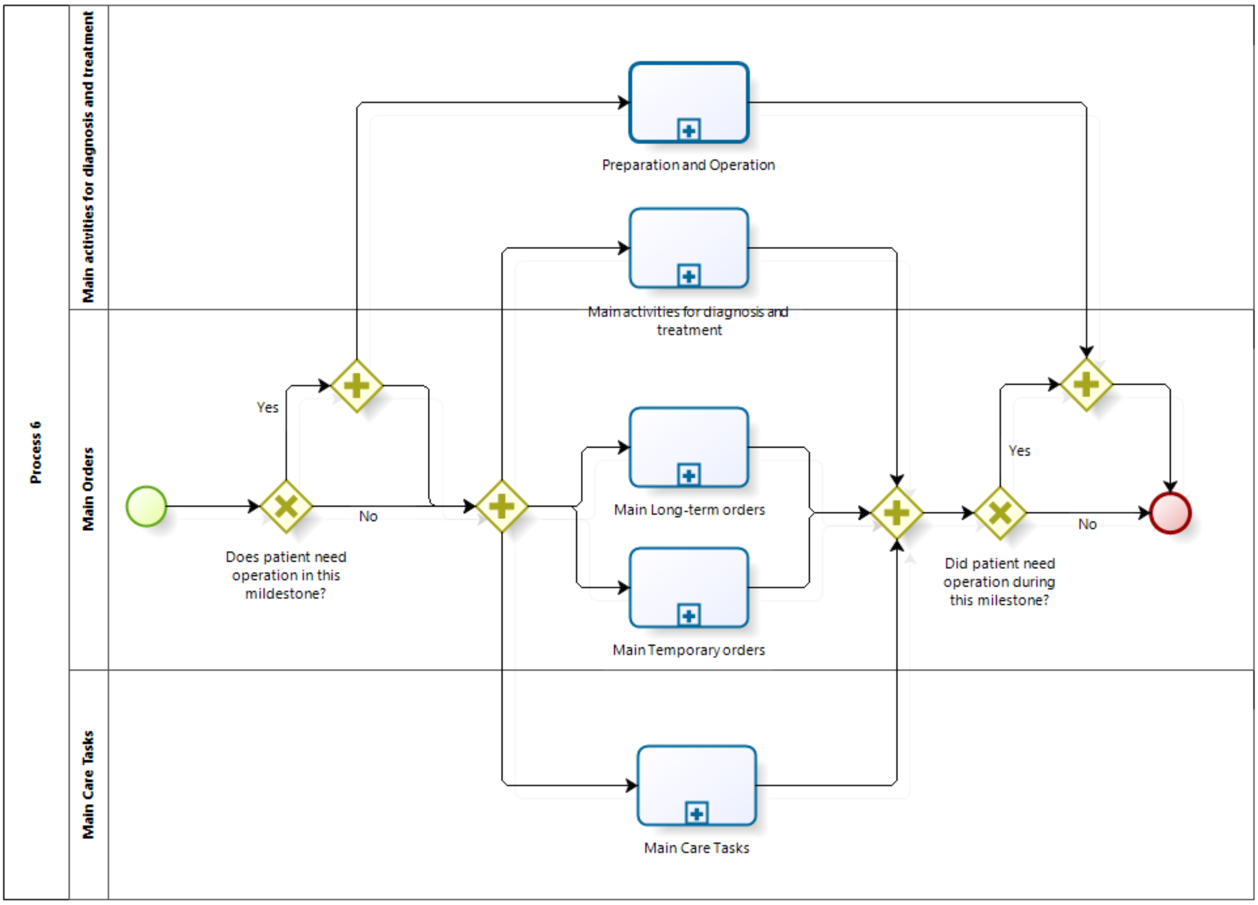


Figure 62: Subprocess Day 3 after admission (CCU) activities

- Subprocess Main activities for diagnosis and treatment can be found on page 73.

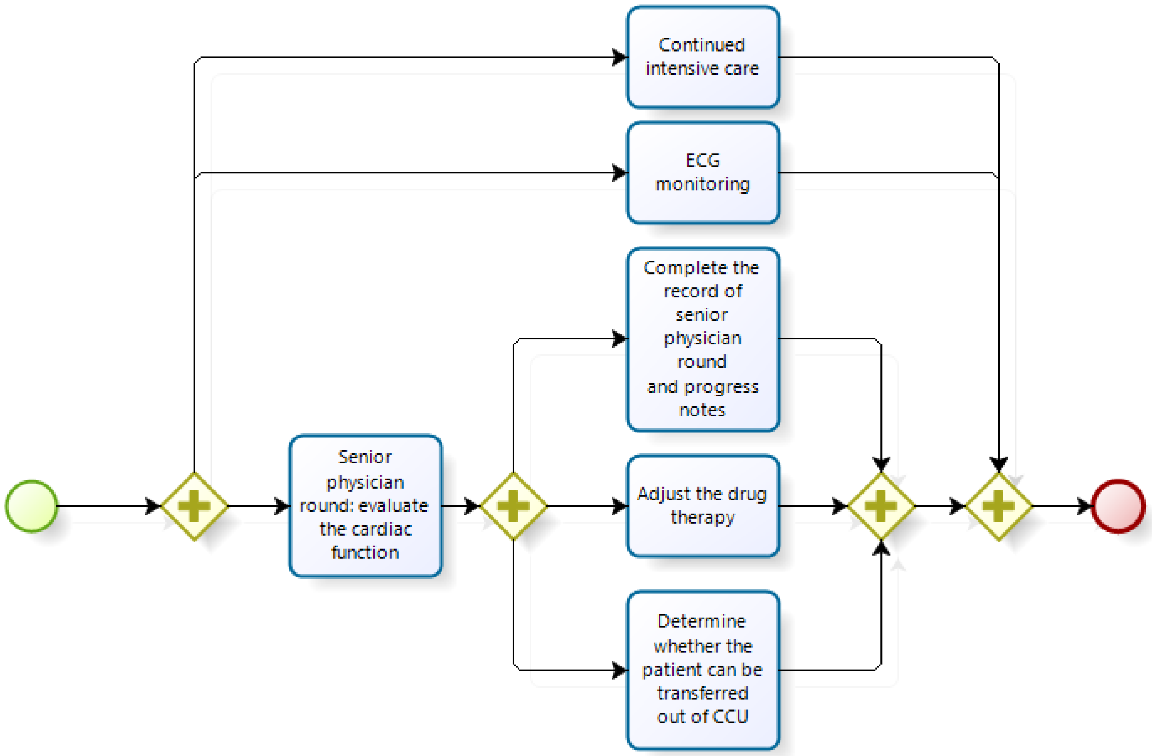


Figure 63: Subprocess Main activities for diagnosis and treatment Day 3

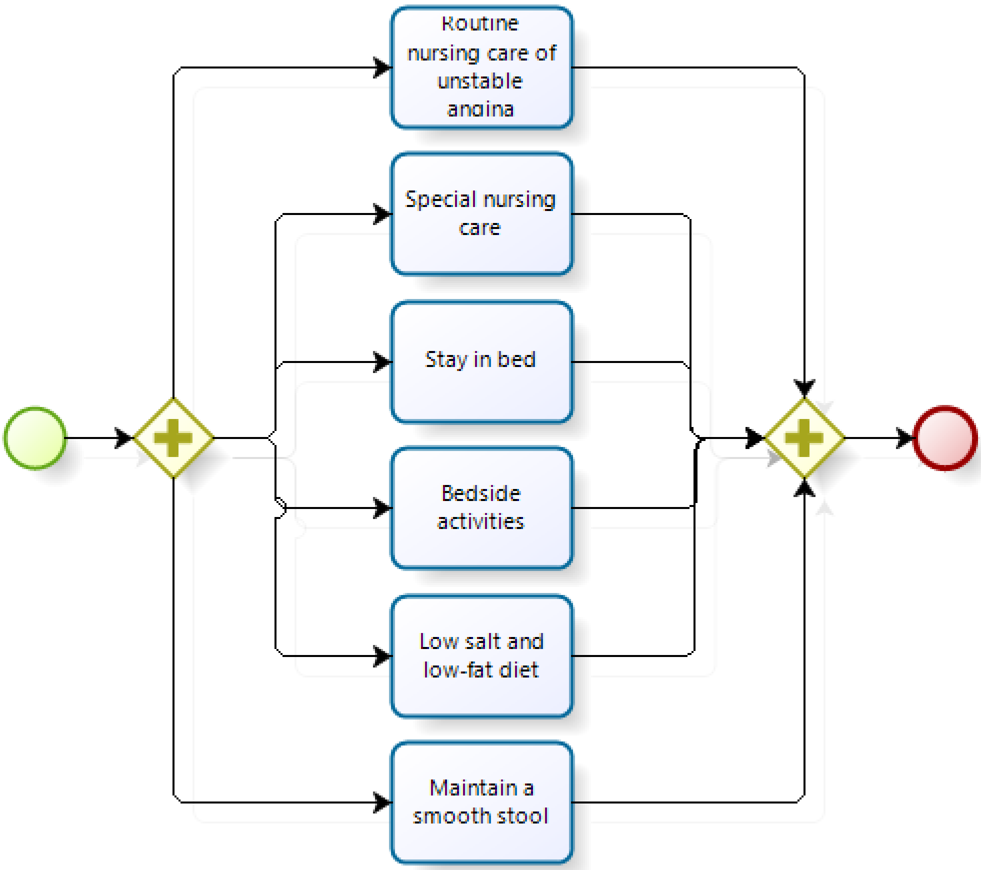


Figure 64: Subprocess Main Long-term orders Day 3

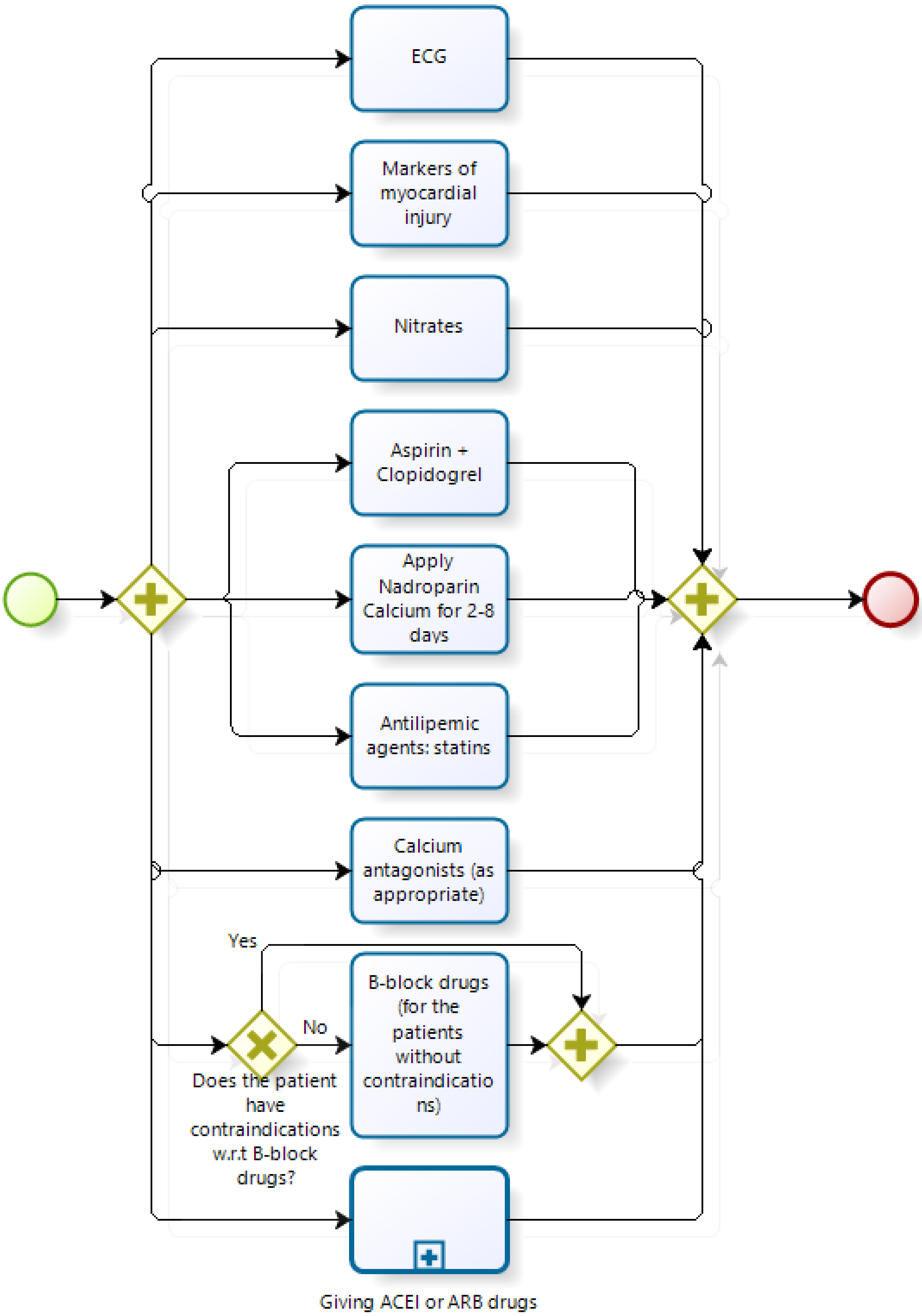


Figure 65: Subprocess Main Temporary orders Day 3

- Subprocess Giving ACEI or ARB drugs can be found on page 76.

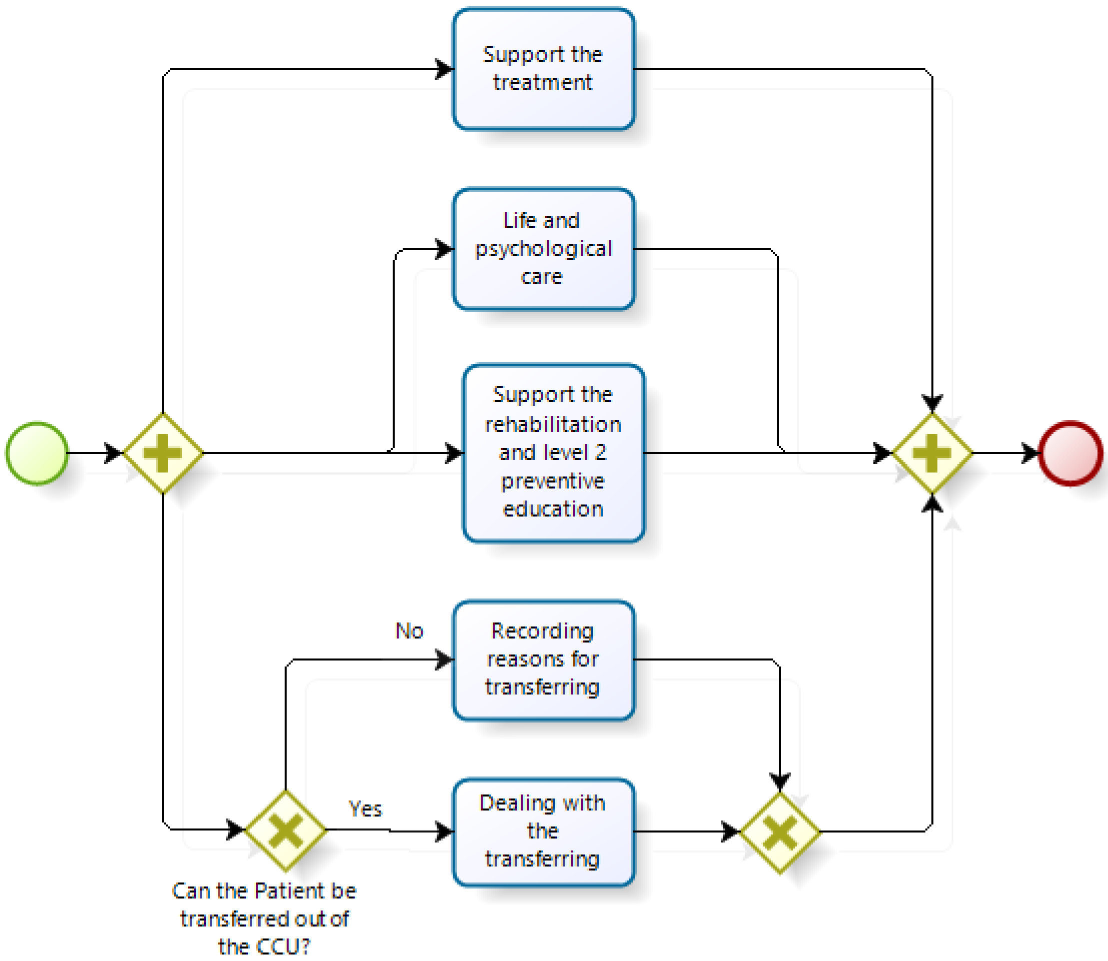


Figure 66: Subprocess Main care tasks Day 3

Appendix K: Subprocess Day 4-6 after admission (CCU) activities

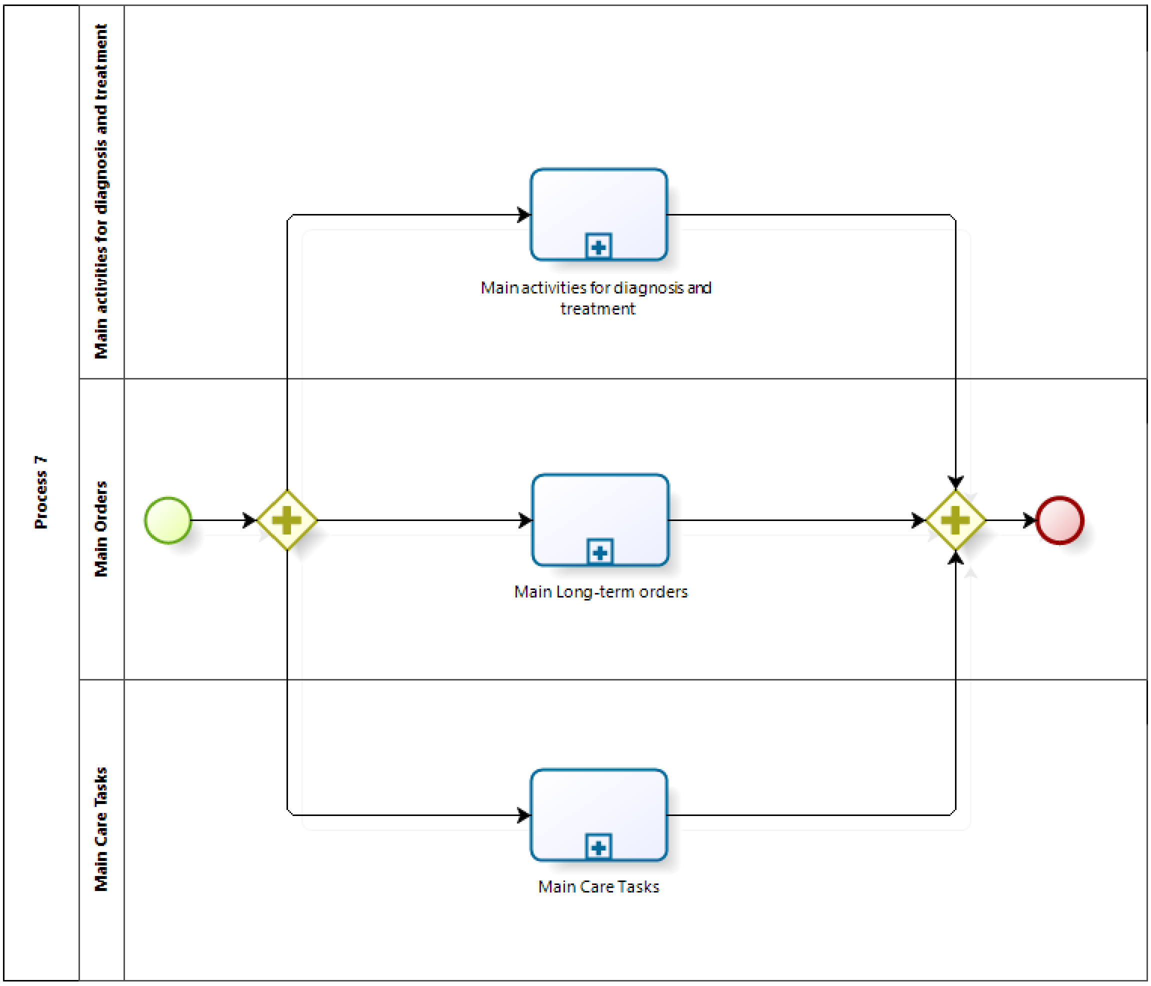


Figure 67: Subprocess Day 4-6 after admission (CCU) activities

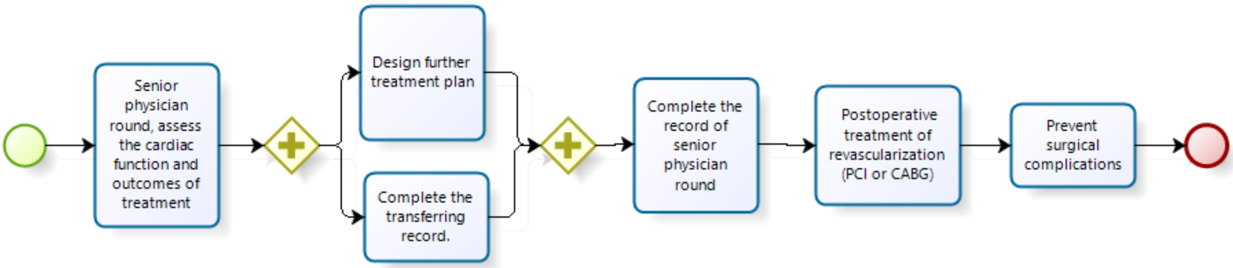


Figure 68: Subprocess Main activities for diagnosis and treatment Day 4-6

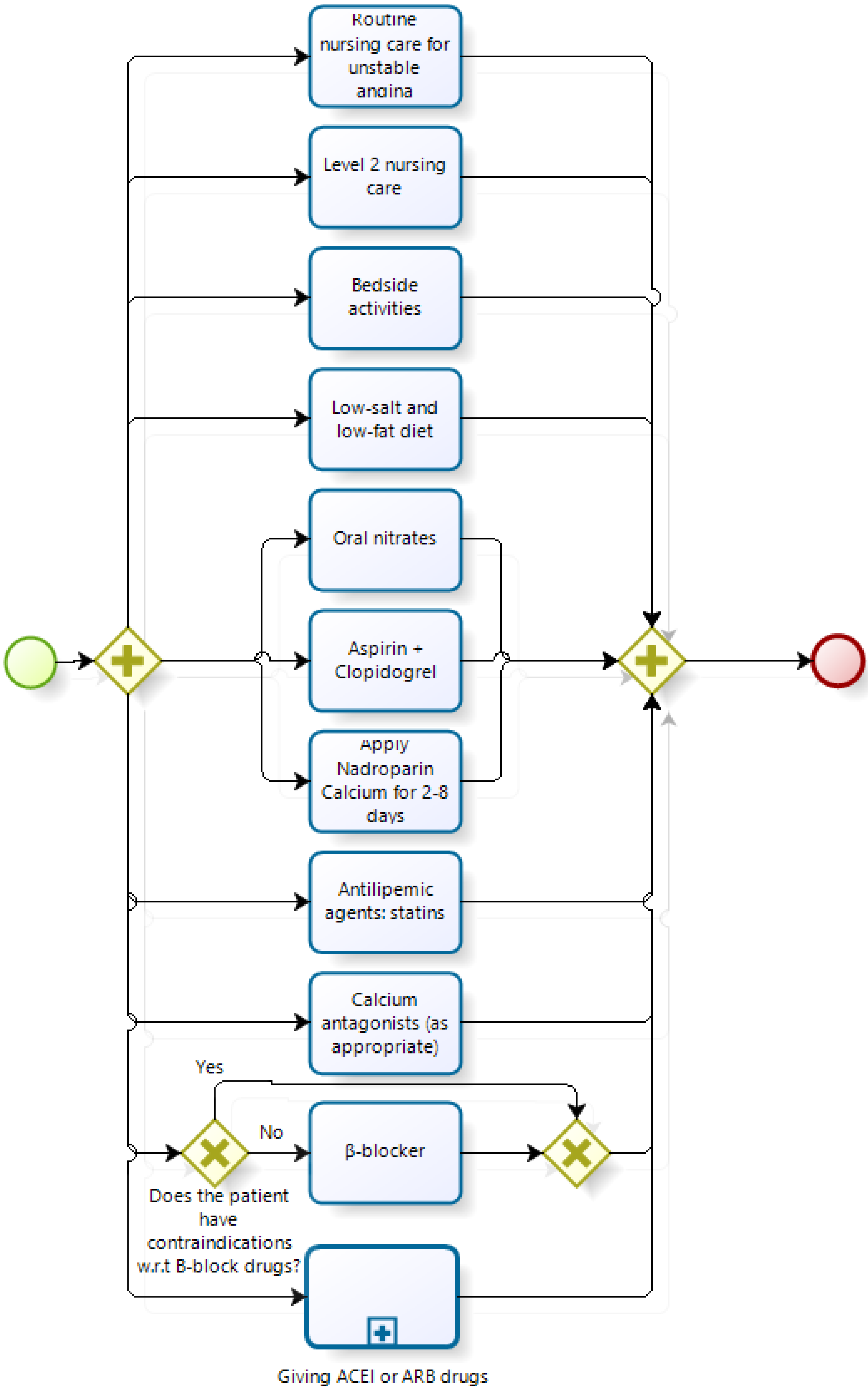


Figure 69: Subprocess Main Long-term orders Day 4-6

- Subprocess Giving ACEI or ARB drugs can be found on page 76.

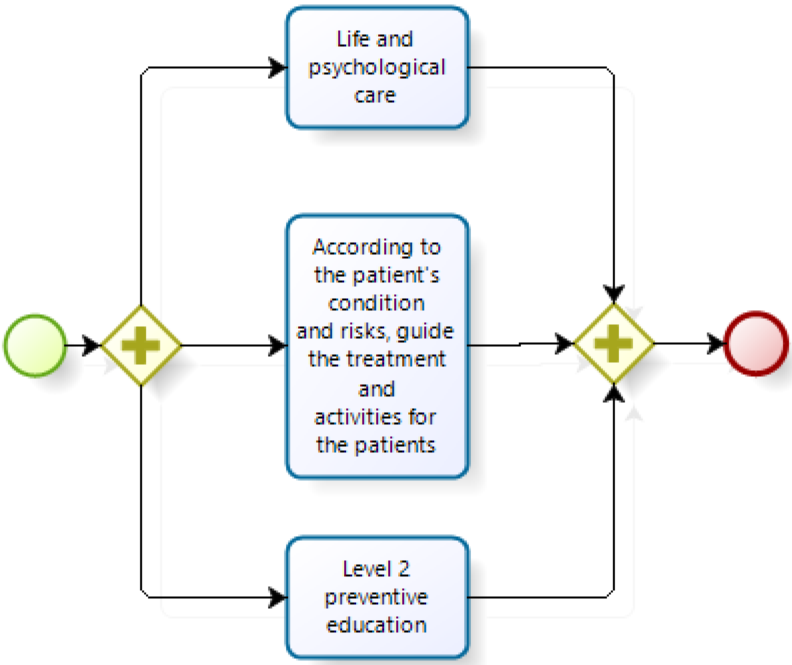


Figure 70: Subprocess Main care tasks Day 4-6

Appendix L: Subprocess Day 7-9 (Day 2-5 General Ward) activities

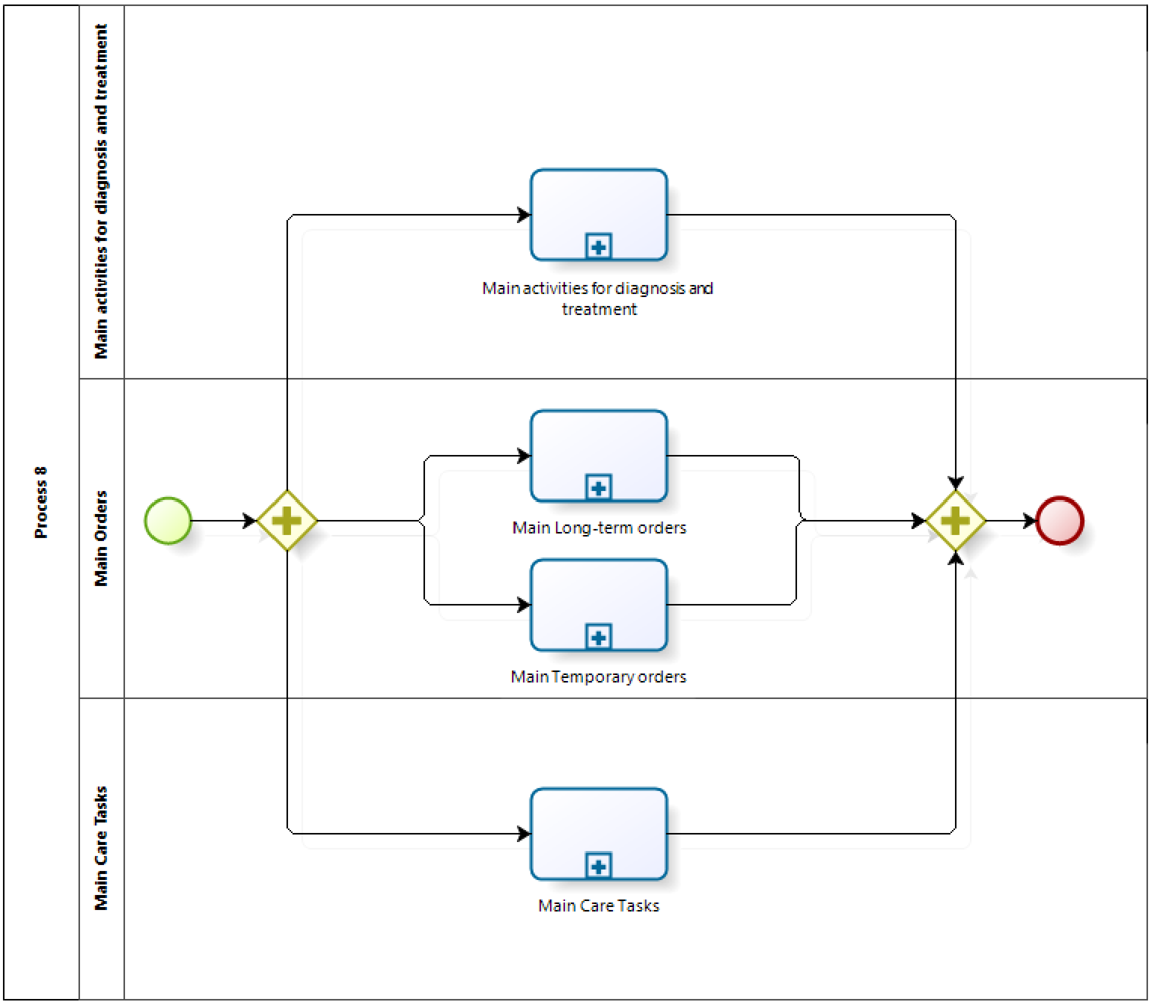


Figure 71: Subprocess Day 7-9 (Day 2-5 General Ward) activities

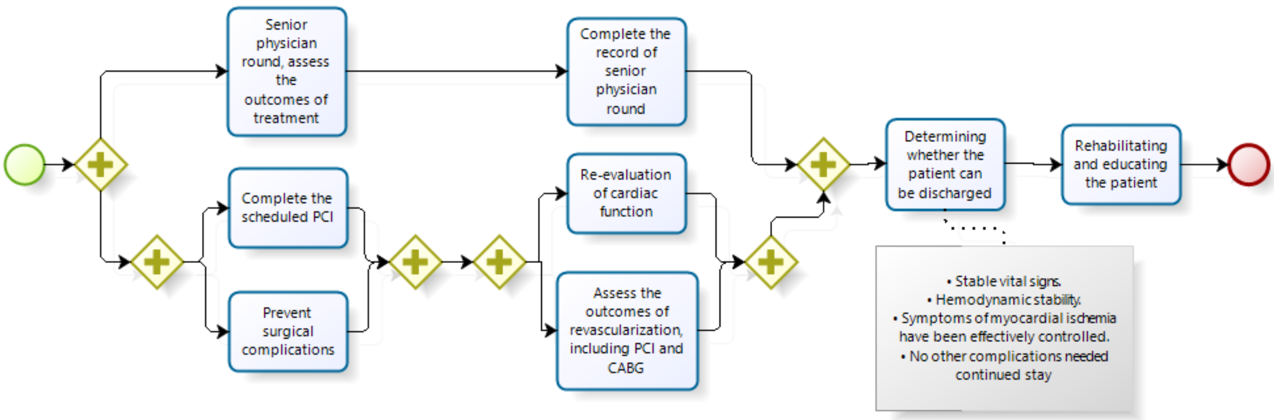


Figure 72: Subprocess Main activities for diagnosis and treatment Day 7-9

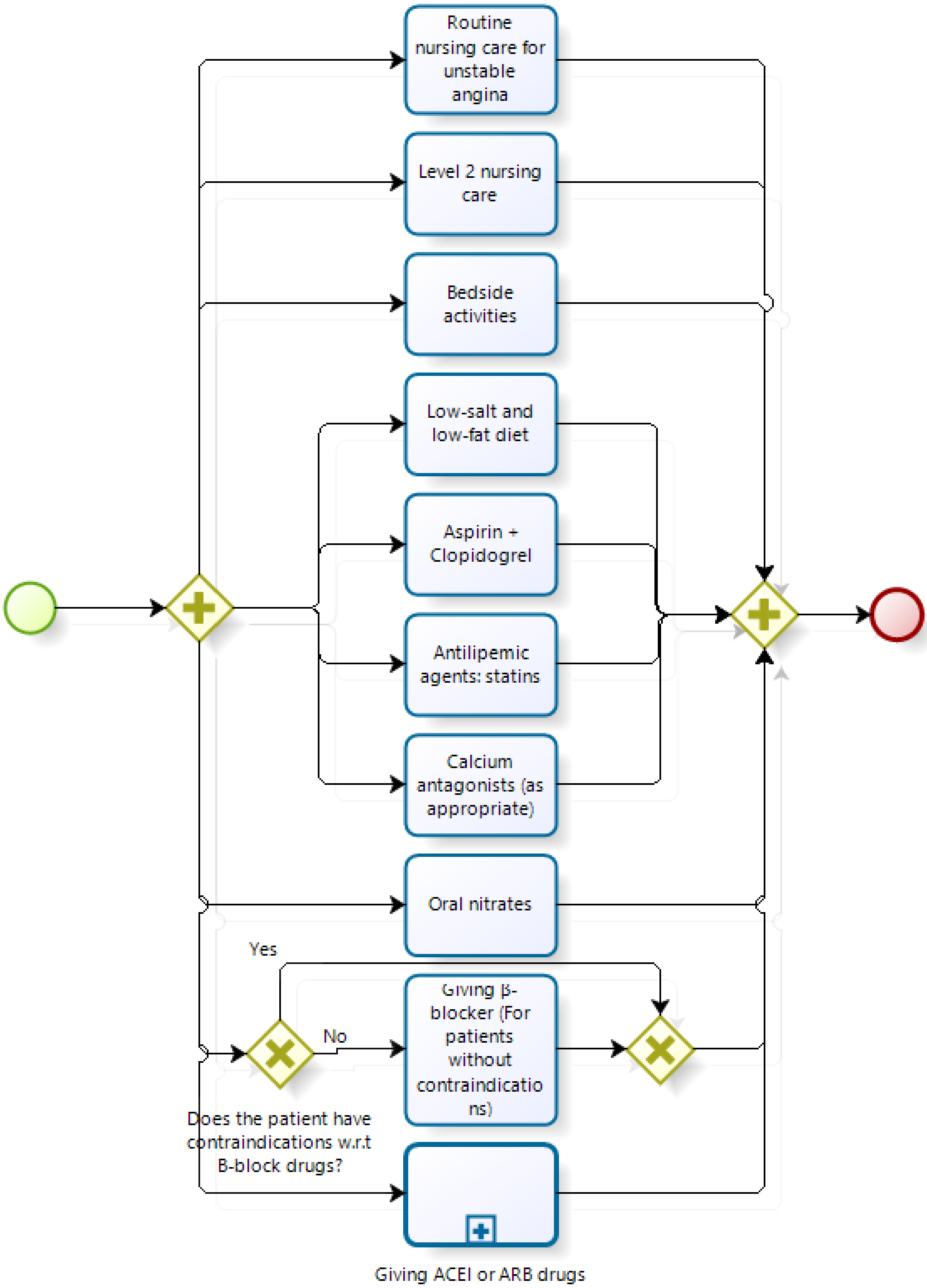


Figure 73: Subprocess Main Long-term orders Day 7-9

- Subprocess Giving ACEI or ARB drugs can be found on page 76.

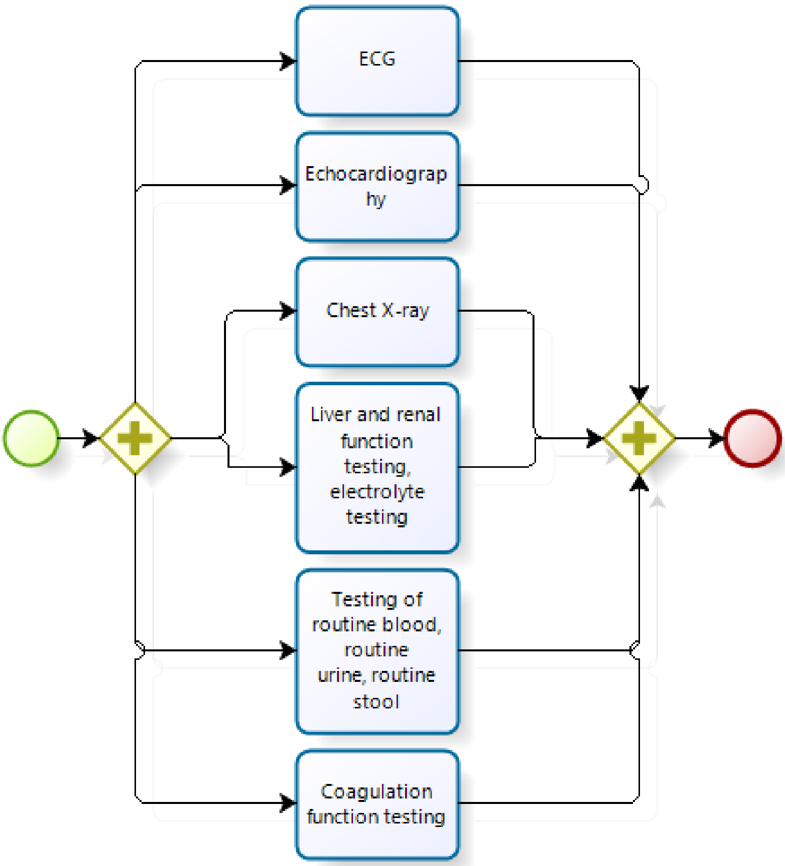


Figure 74: Subprocess Main Temporary orders Day 7-9

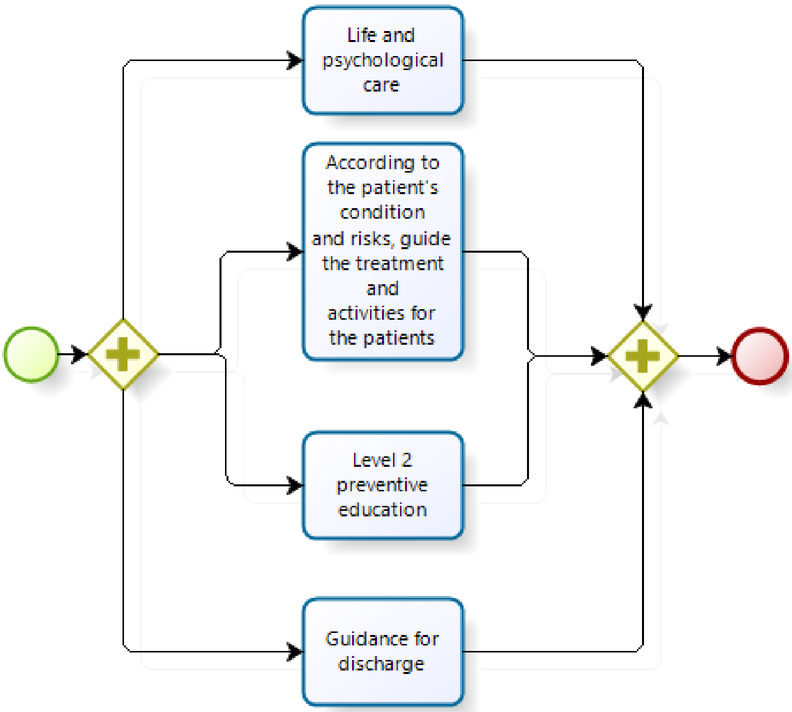


Figure 75: Subprocess Main care tasks Day 7-9

Appendix M: Subprocess Day 8-14 (Discharge Day) activities

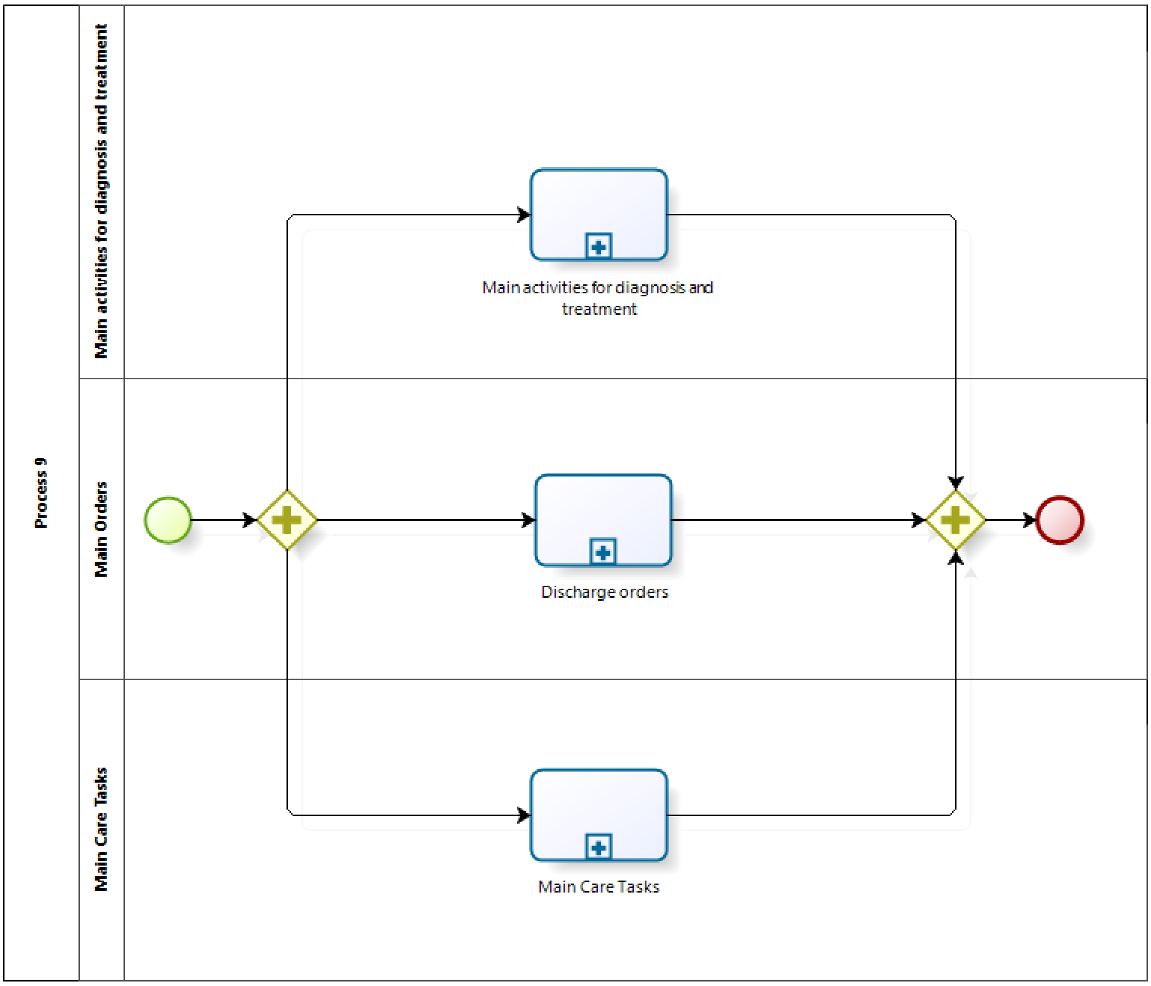


Figure 76: Subprocess Day 8-14 (Discharge Day) activities

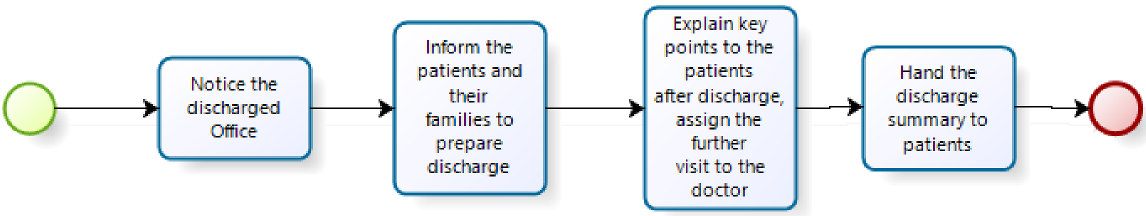


Figure 77: Subprocess Main activities for diagnosis and treatment Day 8-14

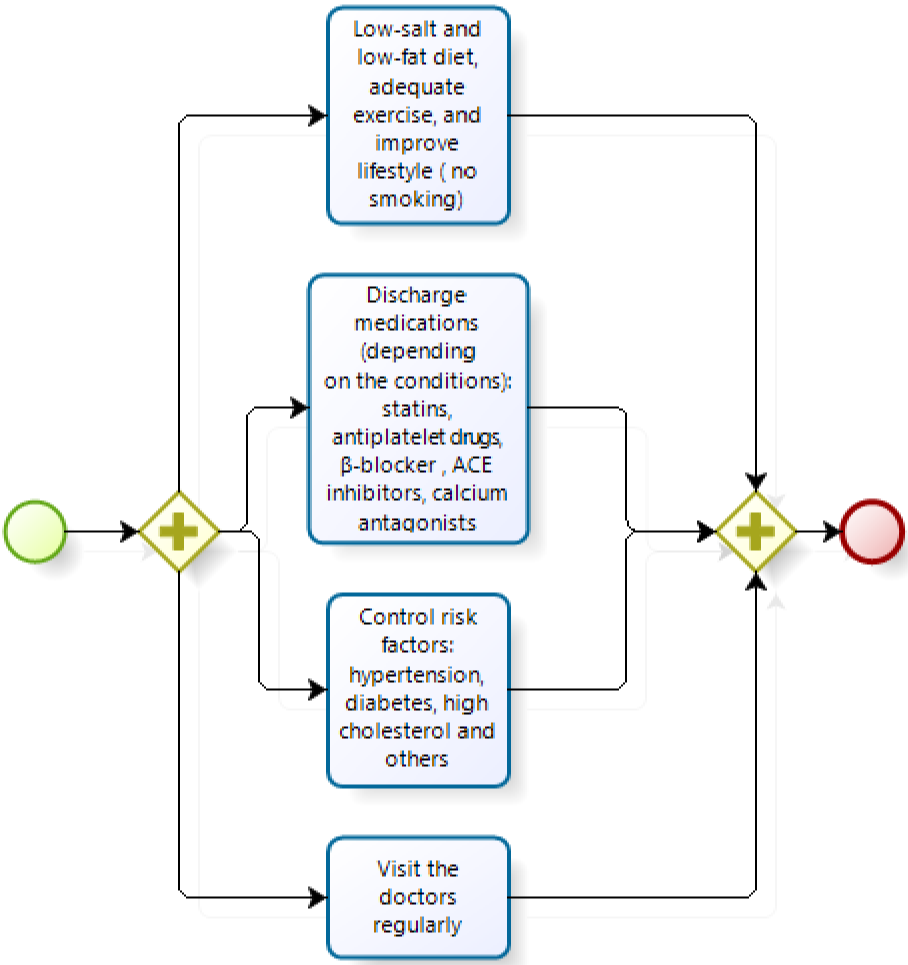


Figure 78: Subprocess Discharge orders

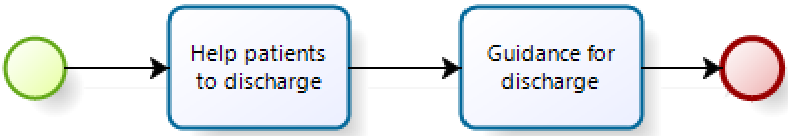


Figure 79: Subprocess Main care tasks Day 8-14

Appendix N: Subprocess 0 – 10 minutes activities

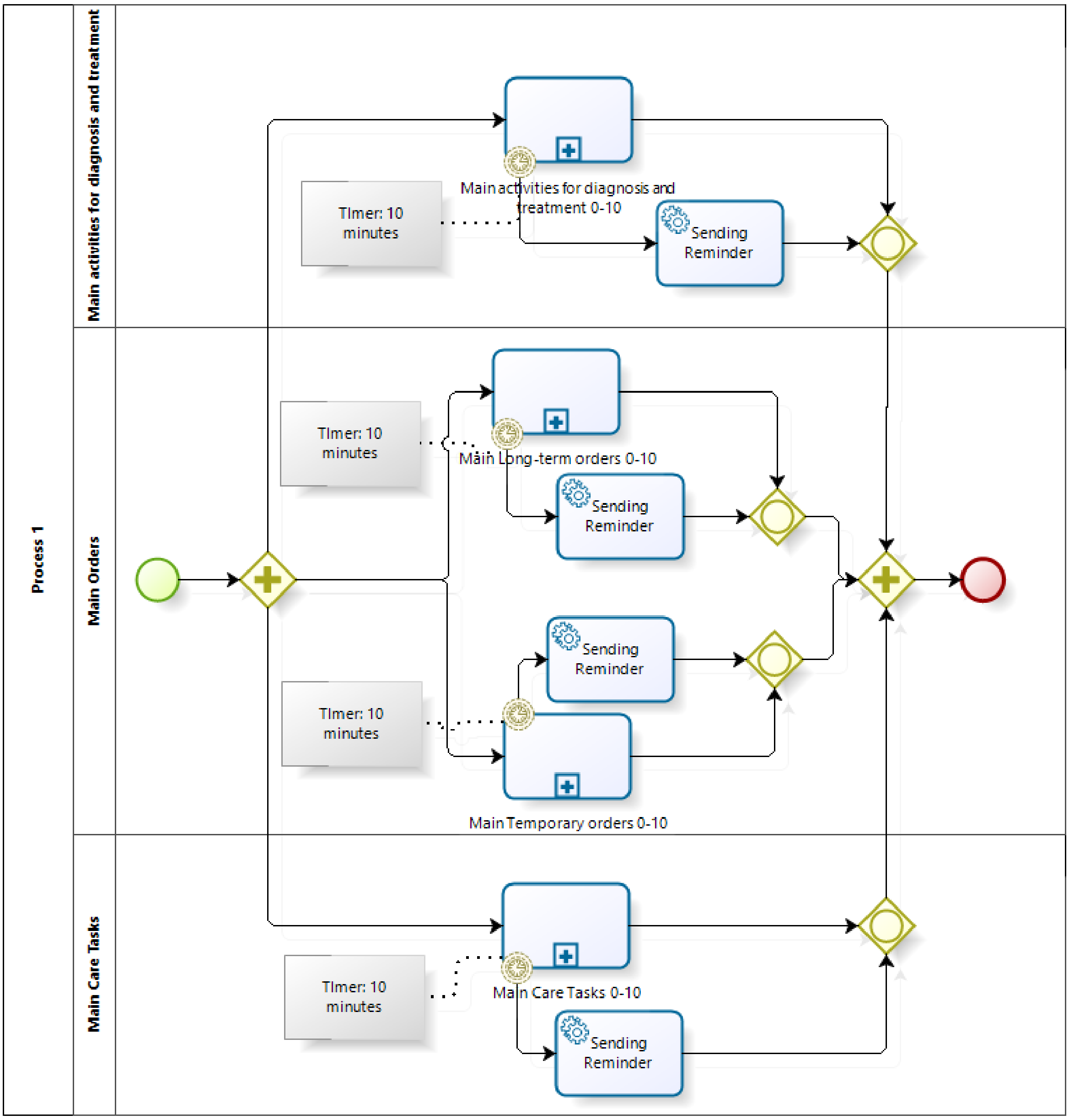


Figure 80: Subprocess 0-10 minutes activities

Business rules

Reminder

Non-interrupting timer events are modelled on the boundaries of the subprocesses in order to send a reminder when the subprocess is not finished at the predefined time. The non-interrupting timer event allows the subprocess to continue in parallel while the reminder is send. Because the reminders need to be send to the users that have the appropriate role it is chosen to set the non-interrupting timer event in this subprocess level and on in the main process.

Subprocess: 0 - 10 minutes activities

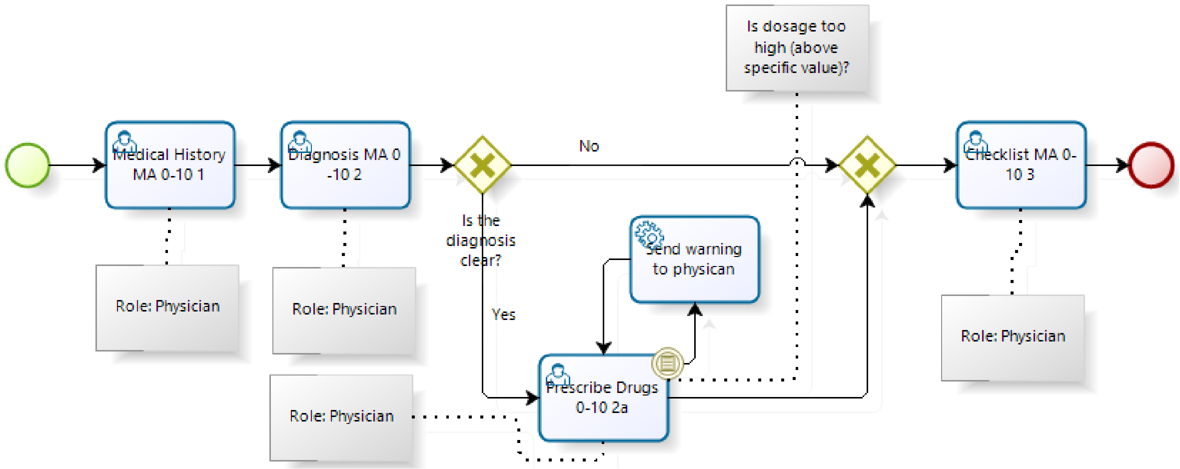


Figure 81: Subprocess Main activities for diagnosis and treatment 0-10

Business rules

Gateway rule

The gateway "Is the diagnosis clear?" checks if the value of Diagnosis Clear is True, if this is the case than the process sequence flows to the task Prescribe Drugs 0-10 2a, if the diagnosis is not clear this task will be skipped.

The value for Diagnosis Clear is given by the physician in the task Diagnosis MA -10 2.

Dosage rule

This rule checks after the task Prescribe Drugs 0-10 2a is performed if the dosage of the prescribed medication is not above a certain number, hence controlling for (lethal) over dosage errors. This is modelled with an Intermediate (catch) Event that is attached to the boundary of the Prescribe Drugs 0-10 2a task, when the condition is met that the dosage is above a certain number a warning is send.

Medical History MA 0-10 1

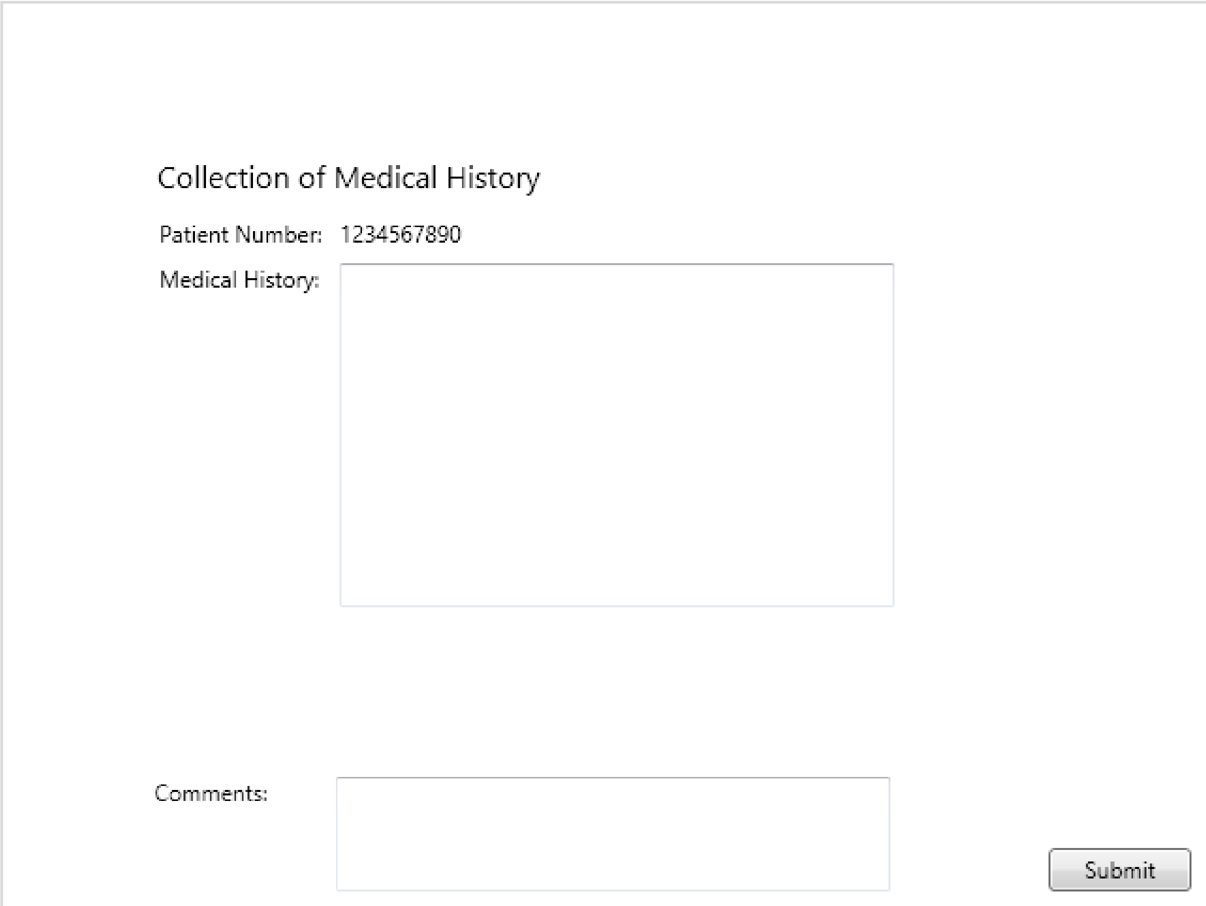


Figure 82: Form Medical History MA 0-10 1

Role: Physician

Data:

PatientID: String	Input
Medical History: String (Long)	Output (Compulsory)
Comment: String (Long)	Output

Diagnosis MA 0-10 2

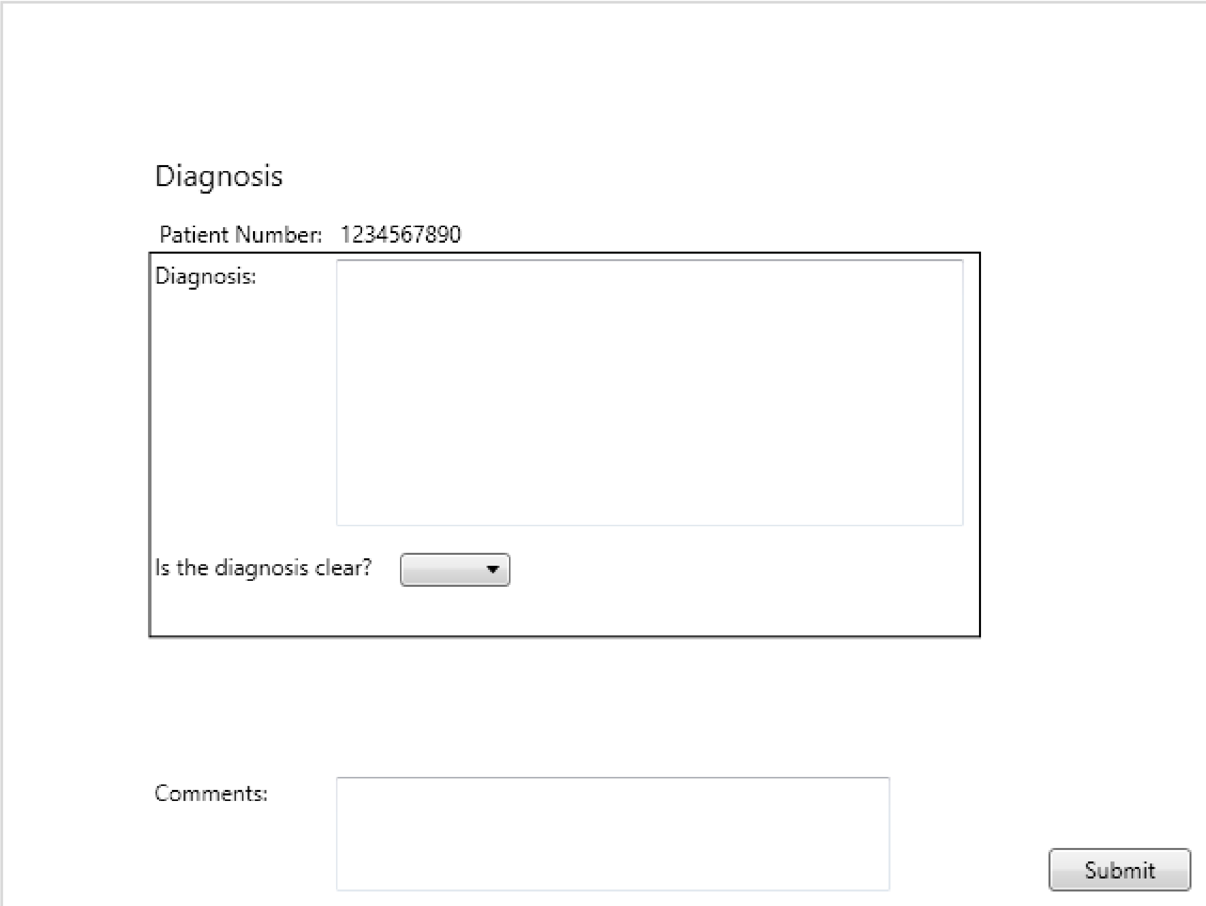


Figure 83: Form Diagnosis MA 0-10 2

Role: Physician

Data:

PatientID: String	Input
Diagnosis: String (Long)	Output (Compulsory)
Diagnosis Clear: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Prescribe Drugs 0-10 2a

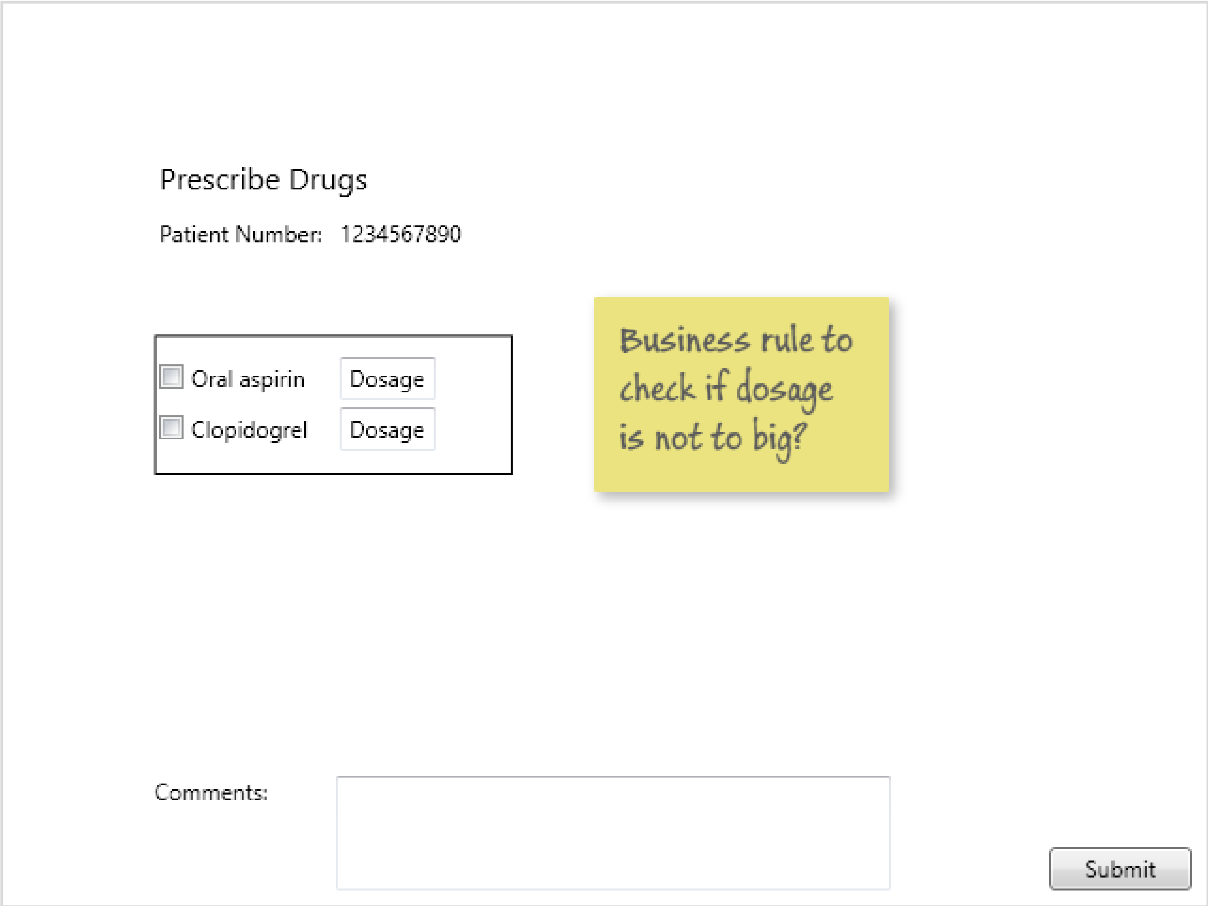


Figure 84: Form Prescribe Drugs 0-10 2a

Role: Physician

Data:

PatientID: String	Input
DrugsName: String	Input
DrugsCompulsory: Boolean	Output (Compulsory)
DrugsDosage: Integer	Output (Compulsory if DrugsCompulsory=True)
Comment: String (Long)	Output

Checklist MA 0-10 3

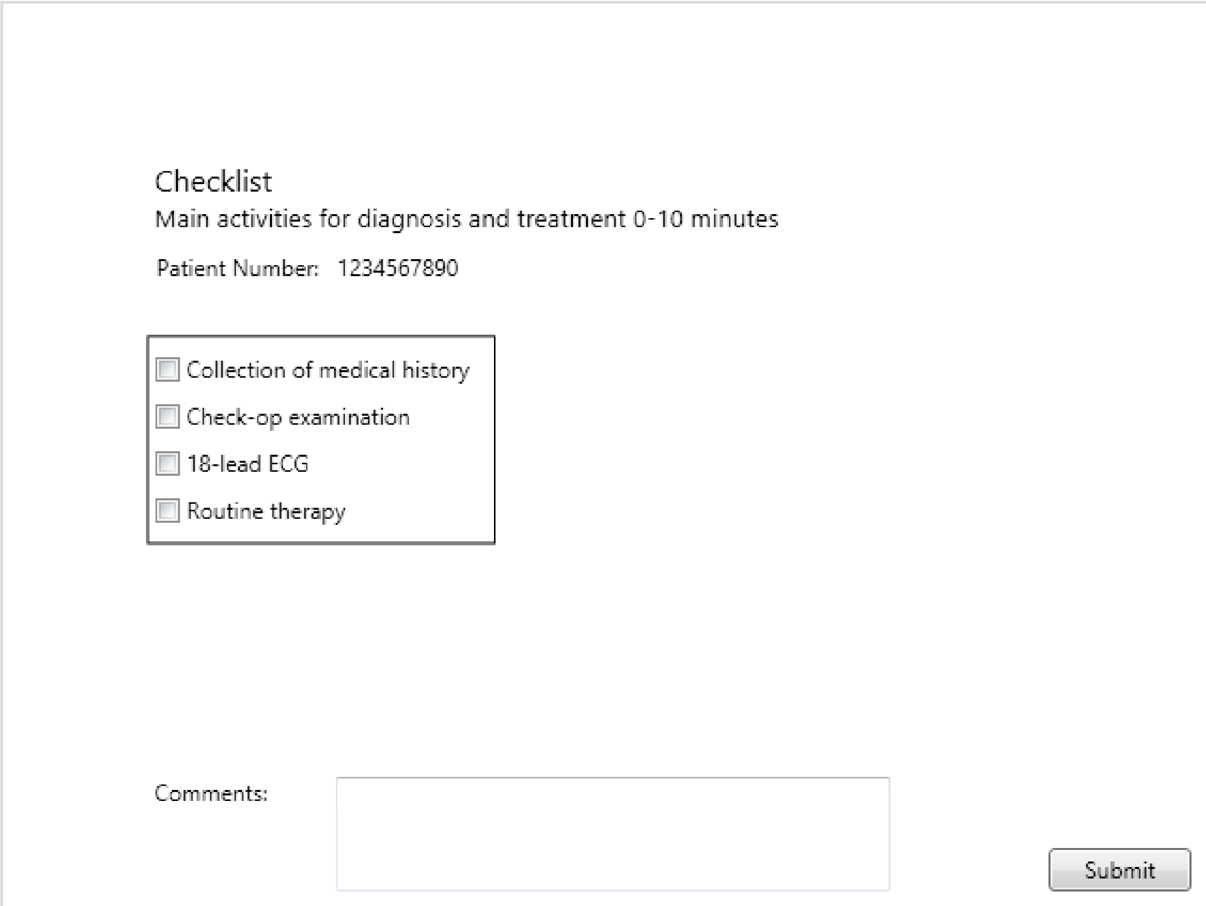


Figure 85: Form Checklist MA 0-10 3

Role: Physician

Data:

PatientID: String	Input
ChecklistItemName: String	Input
ChecklistItemDone: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Subprocess: Main Long-term orders 0-10

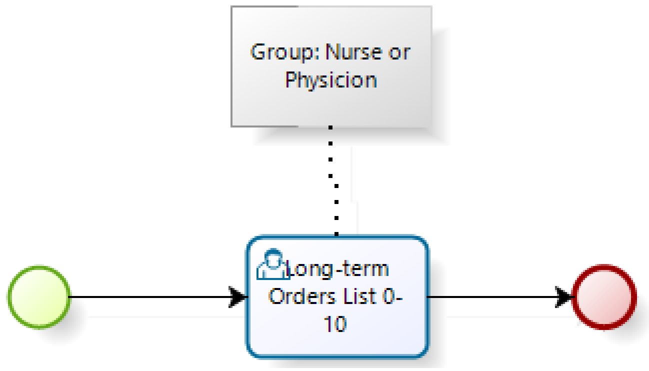


Figure 86: Subprocess Long-term orders 0-10

Long-term Orders List 0-10

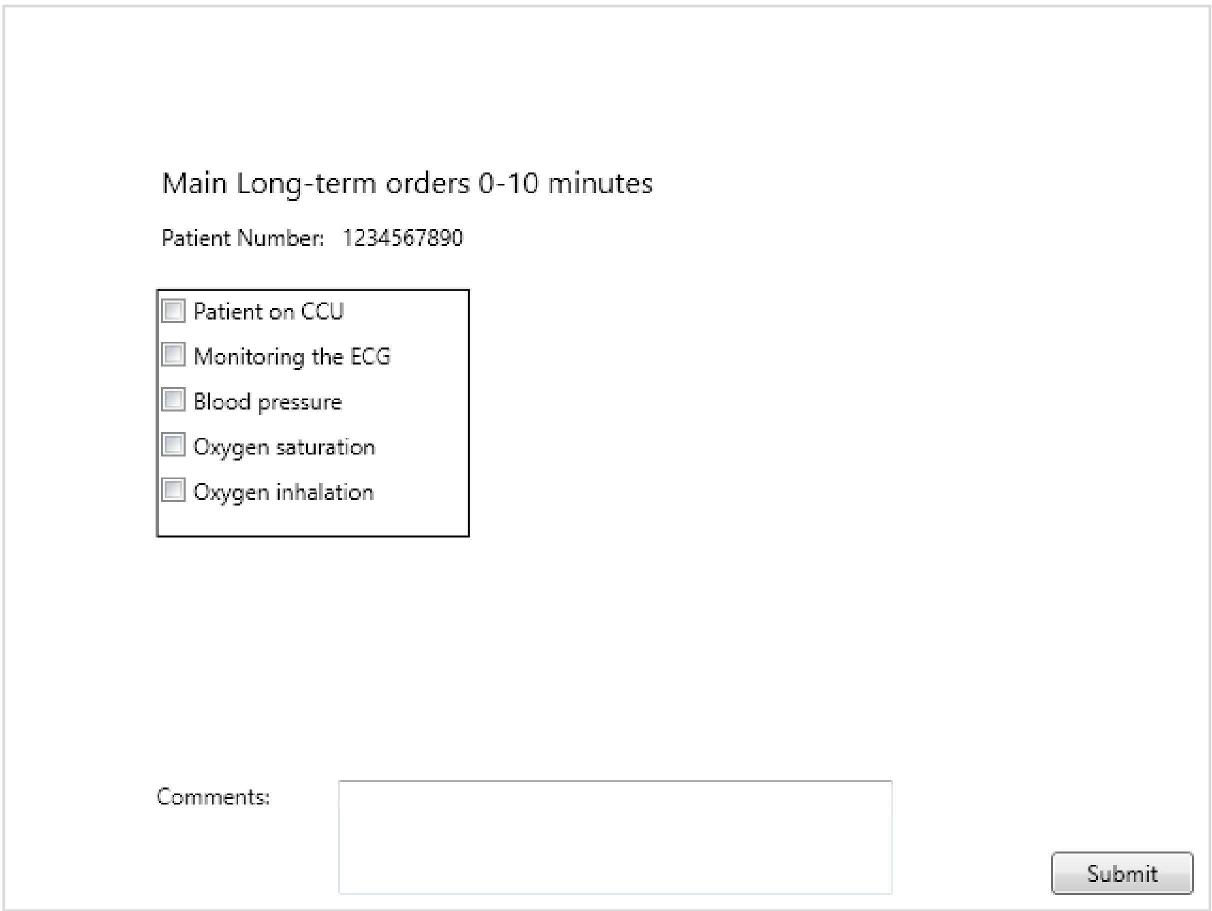


Figure 87: Form Long-term Orders List 0-10

Group: Nurse or Physician

Data:

PatientID: String	Input
OrderName: String	Input
OrderSelected: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Subprocess: Main Temporary orders 0-10

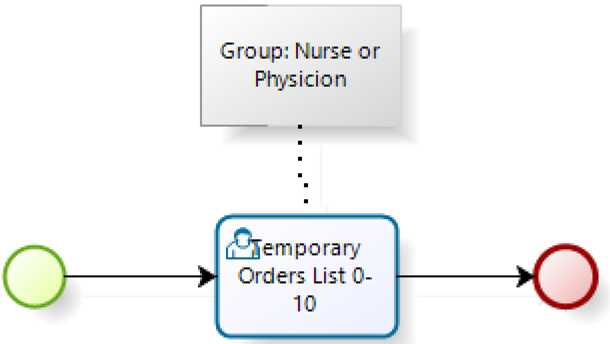


Figure 88: Subprocess Temporary orders 0-10

Temporary Orders List 0-10

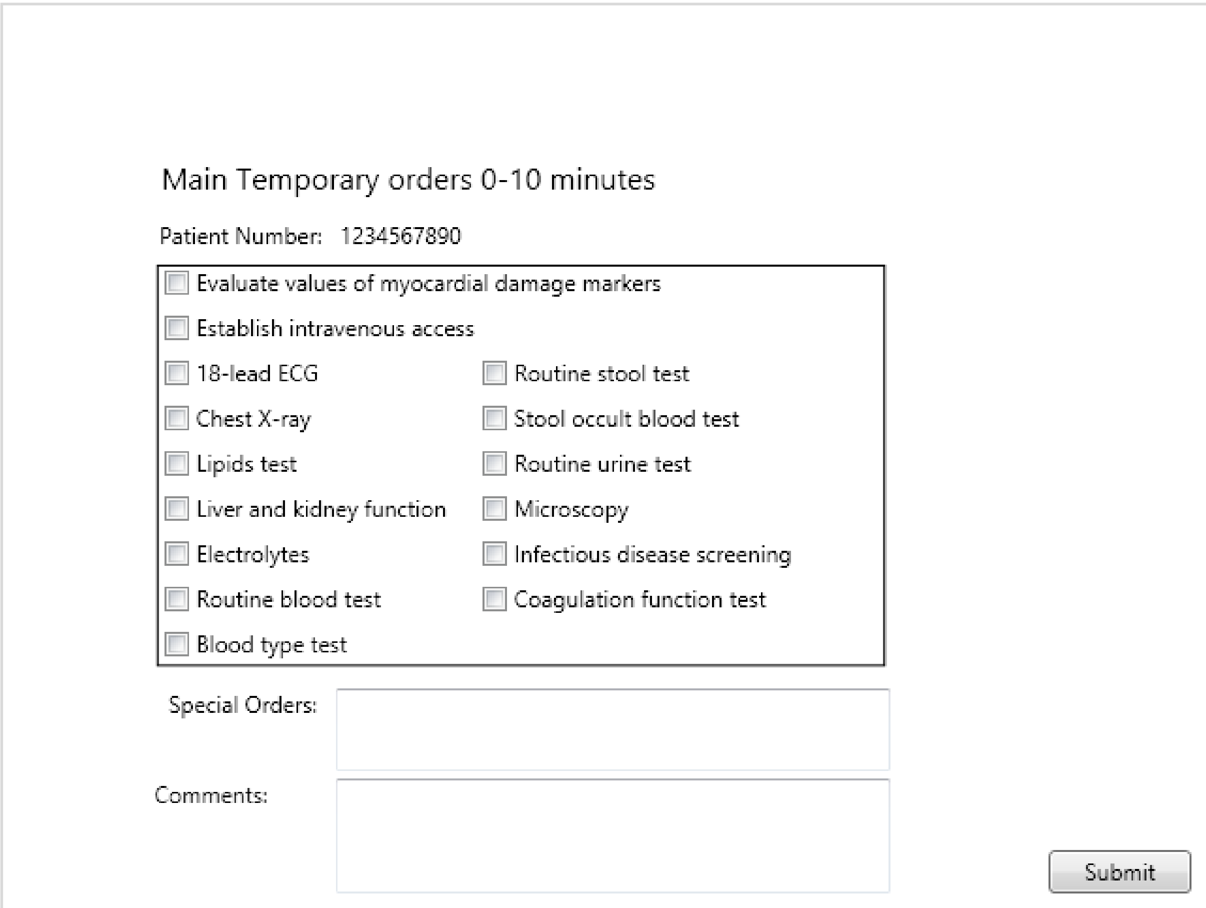


Figure 89: Form Temporary Orders List 0-10

Group: Nurse or Physician

Data:

PatientID: String	Input
OrderName: String	Input
OrderSelected: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Subprocess: Main Care Tasks 0-10

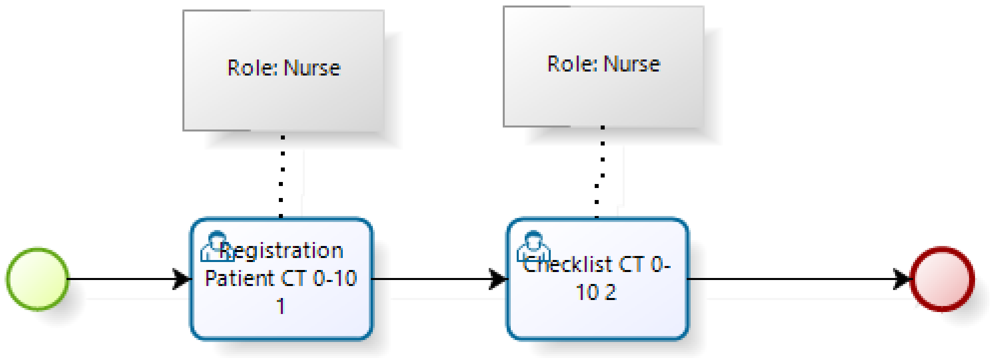


Figure 90: Subprocess Main care tasks 0-10

Registration Patient CT 0-10 1

Figure 91: Form Registration Patient CT 0-10 1

Role: Nurse

Data:

PatientID: String	Input
PatientFirstName: String	Output (Compulsory)
PatientMiddleName: String	Output
PatientLastName: String	Output (Compulsory)
Gender: String	Output (Compulsory)
Age: Integer	Output (Compulsory)
Outpatient ID: Integer	Input
Inpatient ID: Integer	Input
DateOfAdmission: Date	Output (Compulsory)
TimeOfOnset: Time	Output (Compulsory)
Comment: String (Long)	Output

Checklist CT 0-10 2

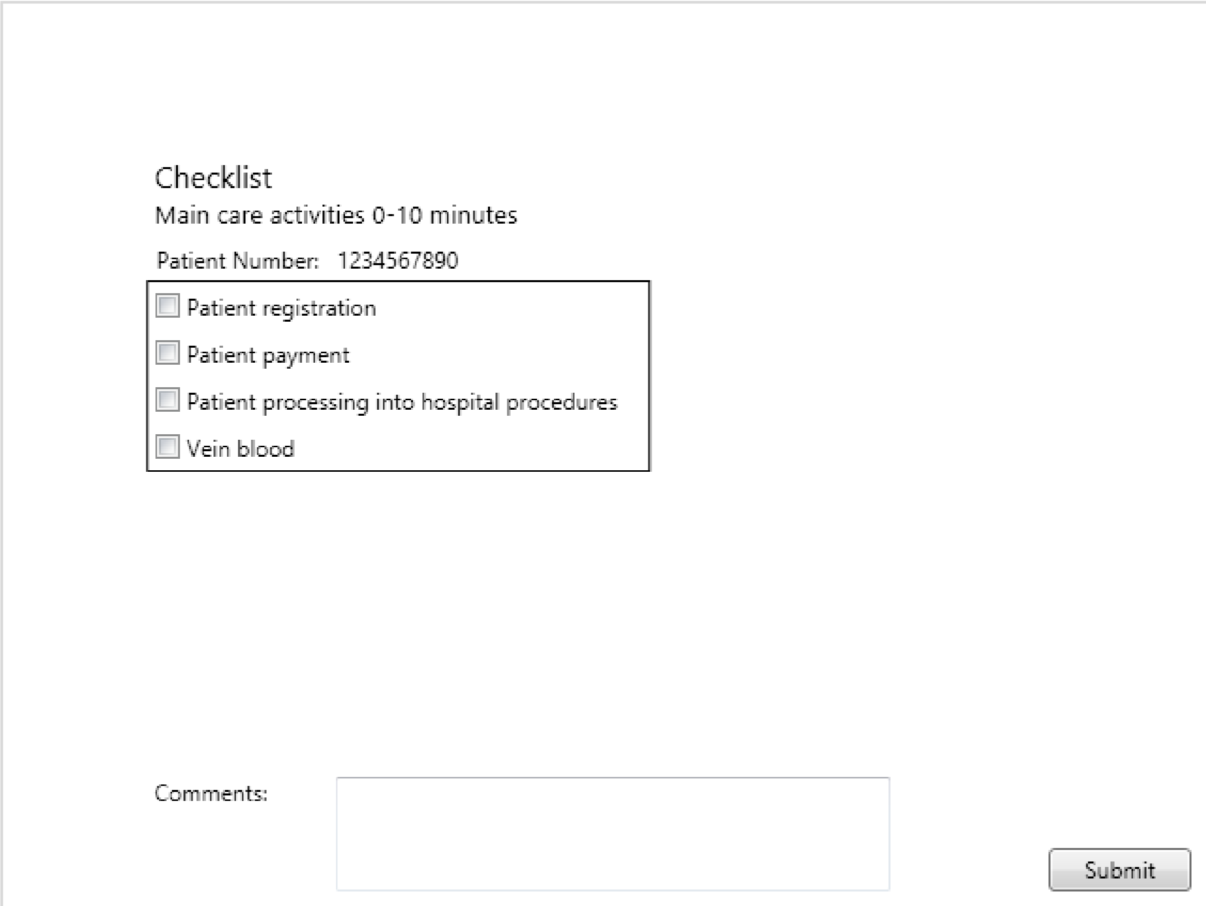


Figure 92: Form Checklist CT 0-10 2

Role: Nurse

Data:

PatientID: String	Input
ChecklistItemName: String	Input
ChecklistItemDone: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Appendix O: Subprocess: 0 - 30 minutes activities

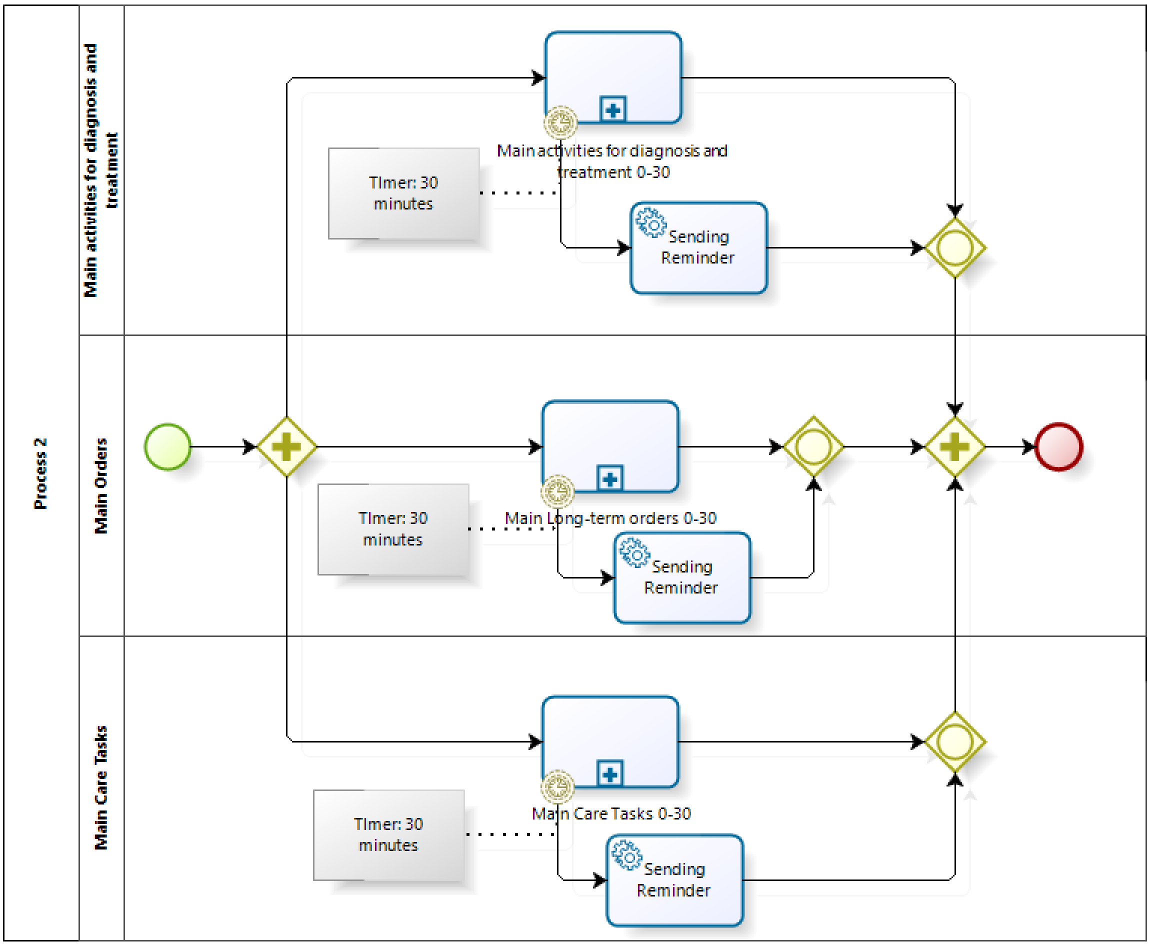


Figure 93: Subprocess 0-30 minutes activities

Business rules

Reminder

Non-interrupting timer events are modelled on the boundaries of the subprocesses in order to send a reminder when the subprocess is not finished at the predefined time. The non-interrupting timer event allows the subprocess to continue in parallel while the reminder is send. Because the reminders need to be send to the users that have the appropriate role it is chosen to set the non-interrupting timer event in this subprocess level and on in the main process.

Subprocess: Main activities for diagnosis and treatment 0-30

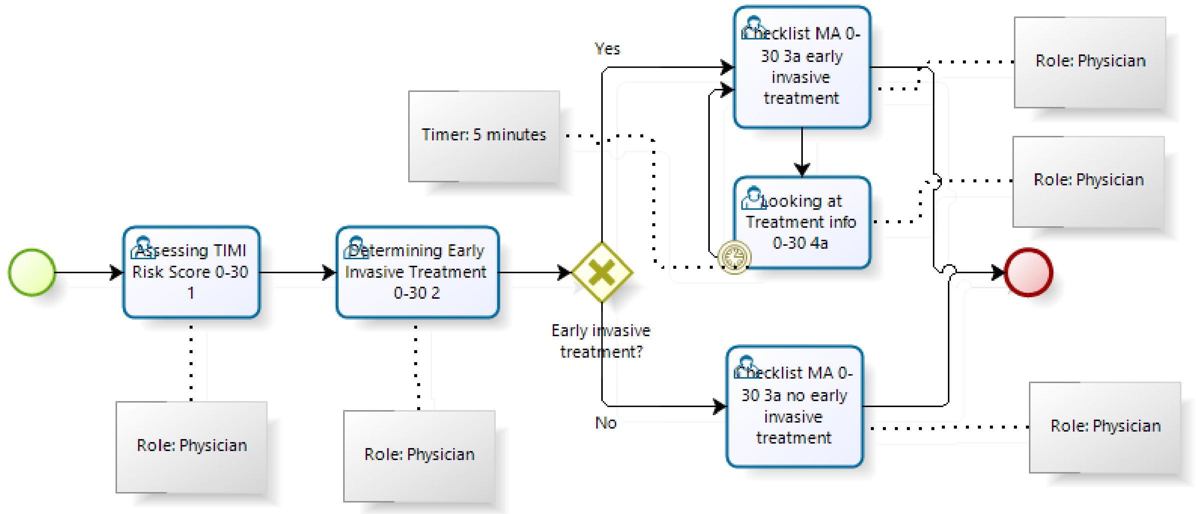


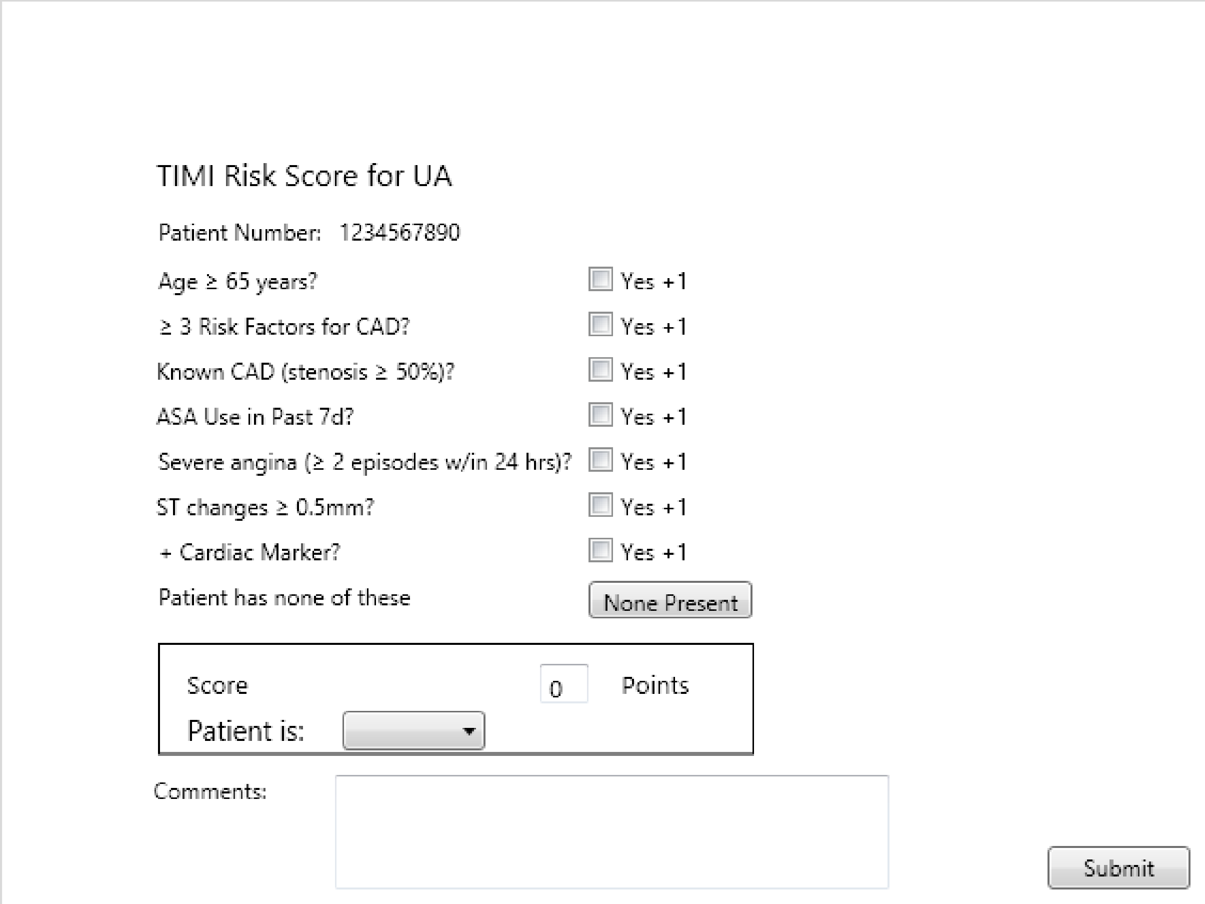
Figure 94: Subprocess Main activities for diagnosis and treatment 0-30

Business rules

Gateway rule

This gateway rule checks if the early invasive treatment that is selected in the task Determining Early Invasive Treatment 0-30 2 is true. If this is the case then it will proceed with the Checklist for early invasive treatment, if the EarlyInvasiveTreatment variable is false then the process sequence flow will go to the no early invasive treatment checklist, task Checklist MA 0-30 3a no early invasive treatment.

Assessing TIMI Risk Score 0-30 1



TIMI Risk Score for UA

Patient Number: 1234567890

Age ≥ 65 years? ☐ Yes +1

≥ 3 Risk Factors for CAD? ☐ Yes +1

Known CAD (stenosis ≥ 50%)? ☐ Yes +1

ASA Use in Past 7d? ☐ Yes +1

Severe angina (≥ 2 episodes w/in 24 hrs)? ☐ Yes +1

ST changes ≥ 0.5mm? ☐ Yes +1

+ Cardiac Marker? ☐ Yes +1

Patient has none of these [None Present]

Score 0 Points

Patient is:

Comments:

[Submit]

Figure 95: Form Assessing TIMI Risk Score 0-30 1

Role: Physician

Data:

PatientID: String	Input
TIMIName: String	Input
TIMISelected: Boolean	Output (Compulsory)
TIMIScore: Integer	Input (count formula of # TIMISelected=True)
PatientRisk: String	Output (Compulsory)
Comment: String (Long)	Output

Determining Early Invasive Treatment 0-30 2

Figure 96: Form Determining Early Invasive Treatment 0-30 2

Role: Physician

Data:

PatientID: String	Input
EarlyInvasiveTreatment: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Checklist MA 0-30 3a early invasive treatment

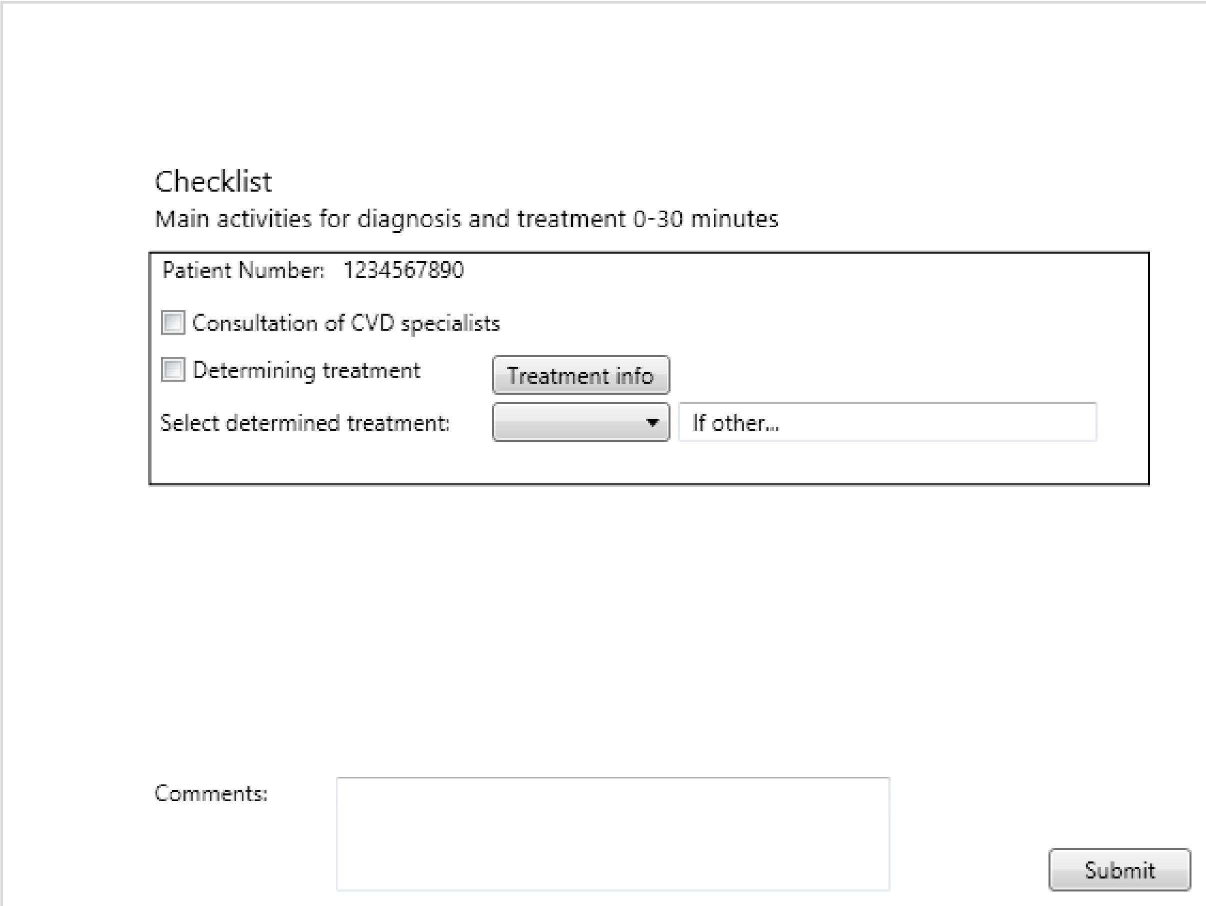


Figure 97: Form Checklist MA 0-30 3a early invasive treatment

Role: Physician

Data:

PatientID: String	Input
ChecklistItemName: String	Input
ChecklistItemDone: Boolean	Output (Compulsory)
Treatment: String	Output (Compulsory)
Comment: String (Long)	Output

Checklist MA 0-30 3b no early invasive treatment

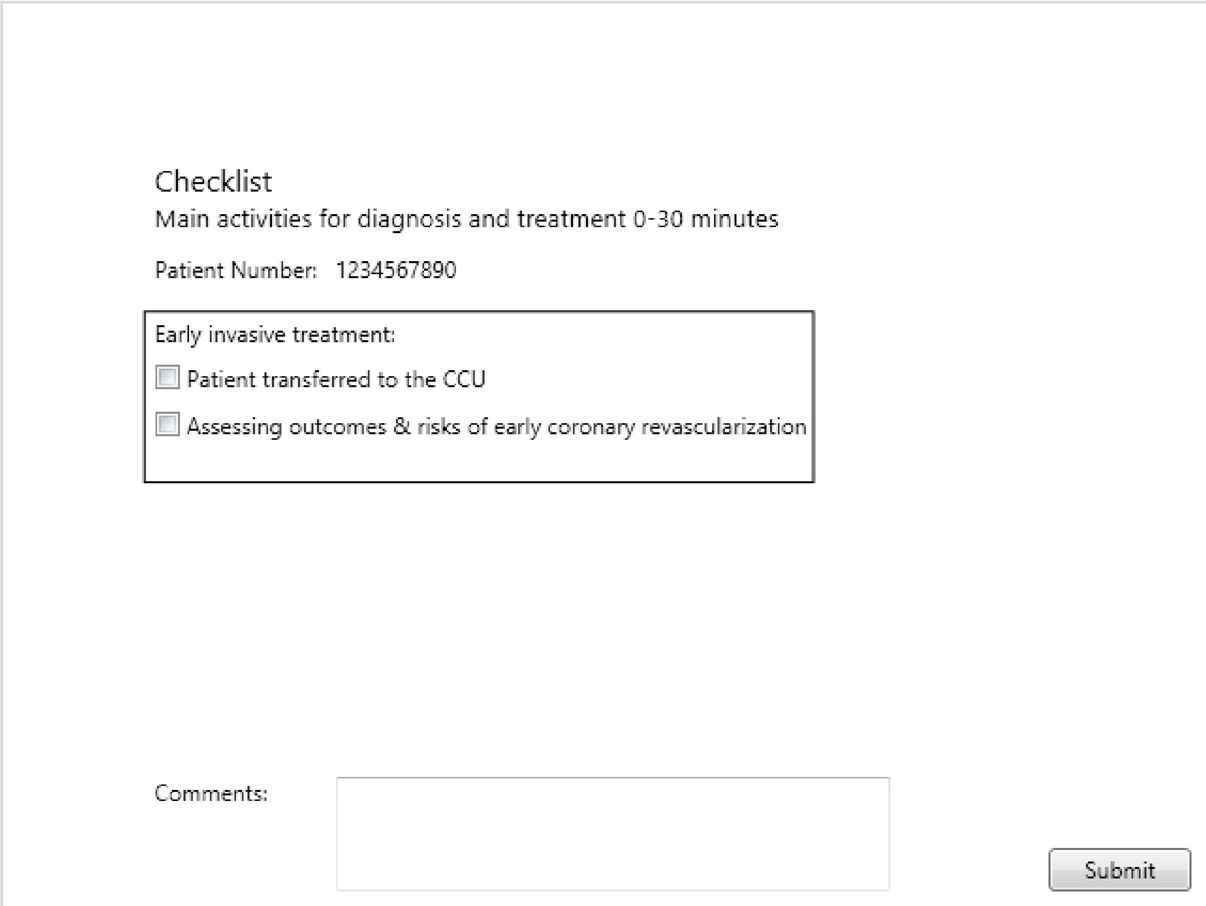


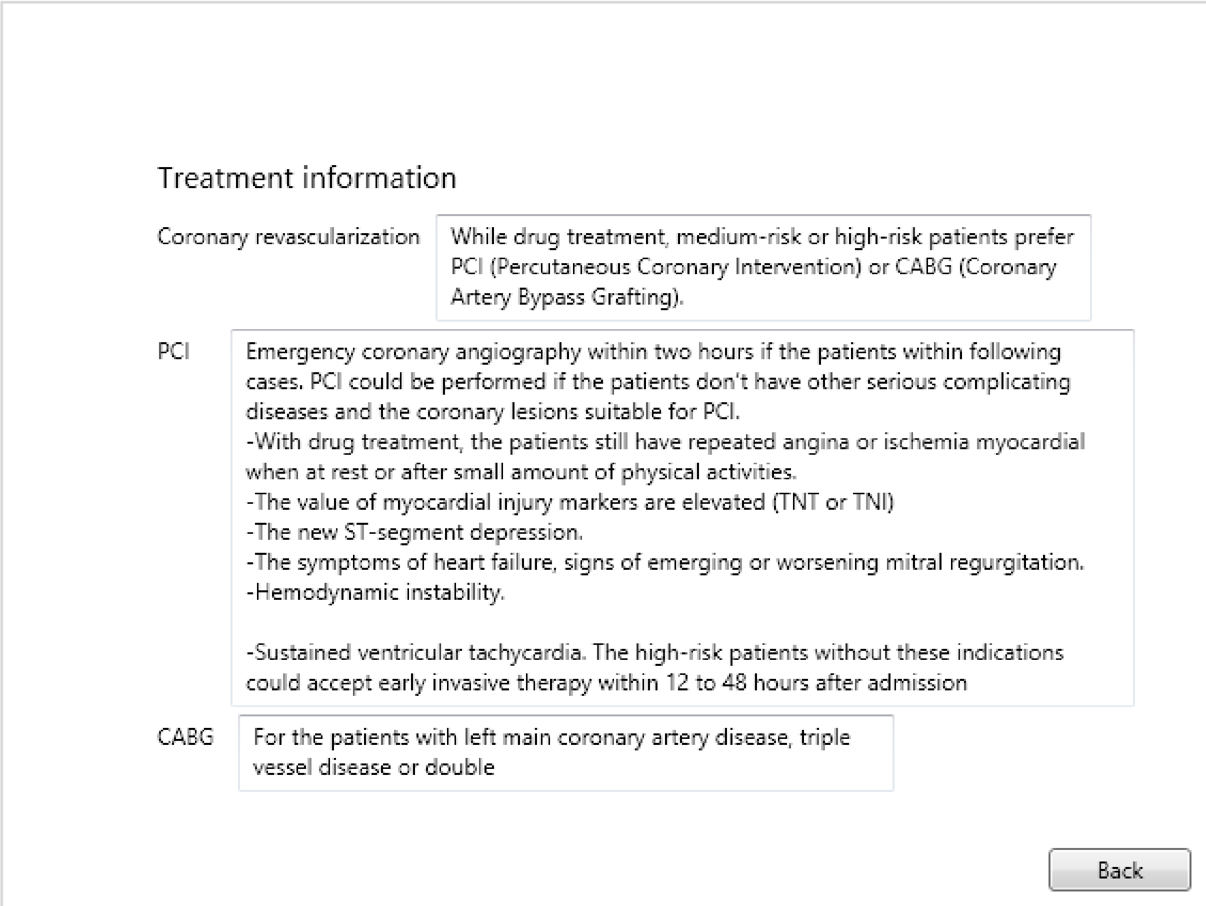
Figure 98: Form Checklist MA 0-30 3b no early invasive treatment

Role: Physician

Data:

PatientID: String	Input
ChecklistItemName: String	Input
ChecklistItemDone: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Showing Treatment info 0-30 4



Treatment information

Coronary revascularization: While drug treatment, medium-risk or high-risk patients prefer PCI (Percutaneous Coronary Intervention) or CABG (Coronary Artery Bypass Grafting).

PCI: Emergency coronary angiography within two hours if the patients within following cases. PCI could be performed if the patients don't have other serious complicating diseases and the coronary lesions suitable for PCI.
-With drug treatment, the patients still have repeated angina or ischemia myocardial when at rest or after small amount of physical activities.
-The value of myocardial injury markers are elevated (TNT or TNI)
-The new ST-segment depression.
-The symptoms of heart failure, signs of emerging or worsening mitral regurgitation.
-Hemodynamic instability.

-Sustained ventricular tachycardia. The high-risk patients without these indications could accept early invasive therapy within 12 to 48 hours after admission

CABG: For the patients with left main coronary artery disease, triple vessel disease or double

Back

Figure 99: Form Showing Treatment info 0-30 4

Role: Physician

Data: No variables

Subprocess: Main Long-term orders 0-30

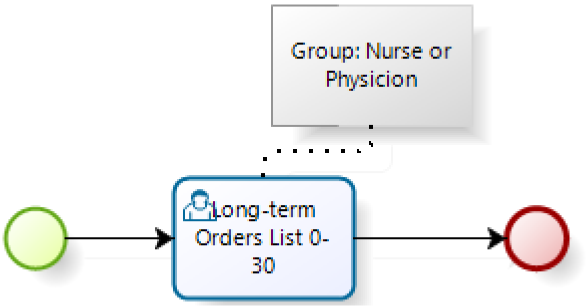


Figure 100: Subprocess Main Long-term orders 0-30

Long-term Orders List 0-30

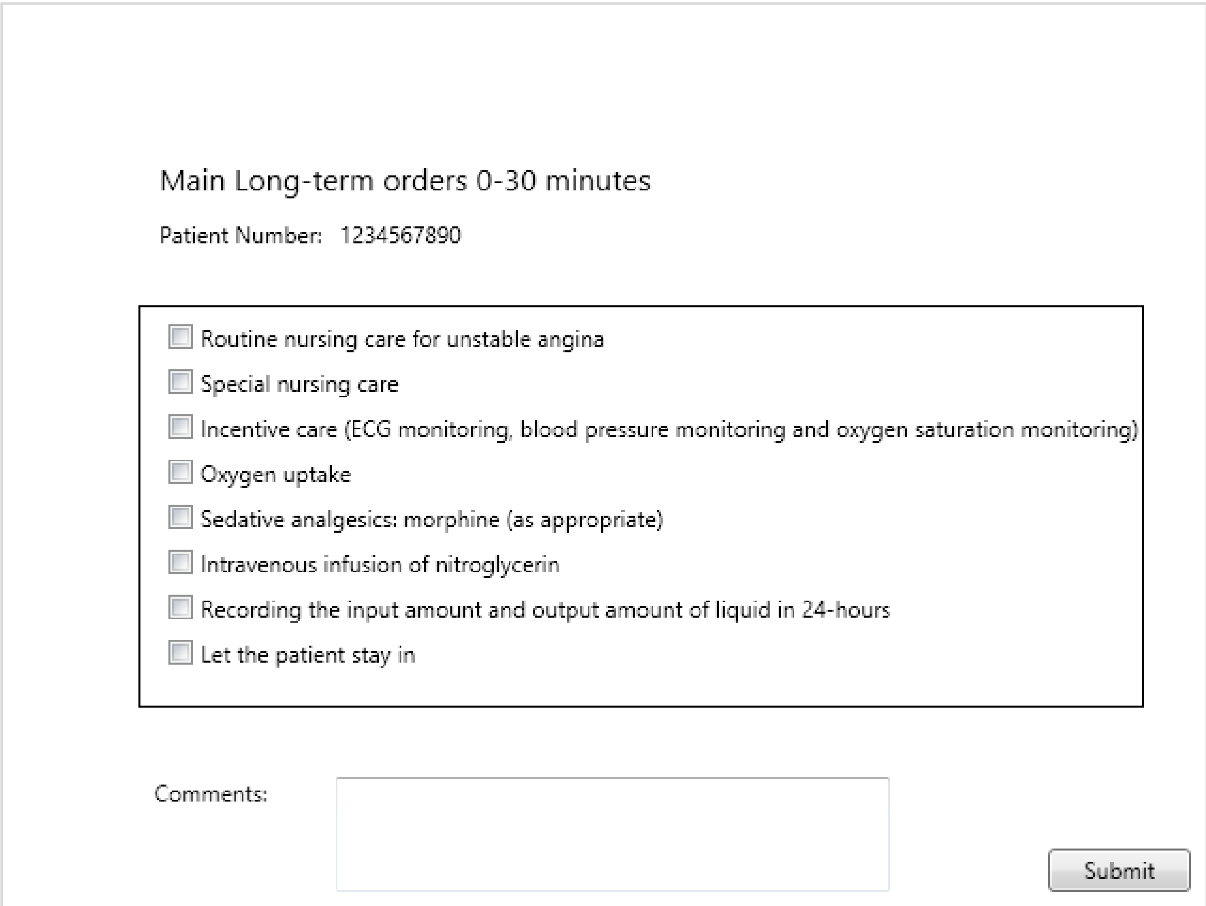


Figure 101: Form Long-term Orders List 0-30

Group: Nurse or Physician

Data:

PatientID: String	Input
OrderName: String	Input
OrderSelected: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Subprocess: Main care tasks 0-30

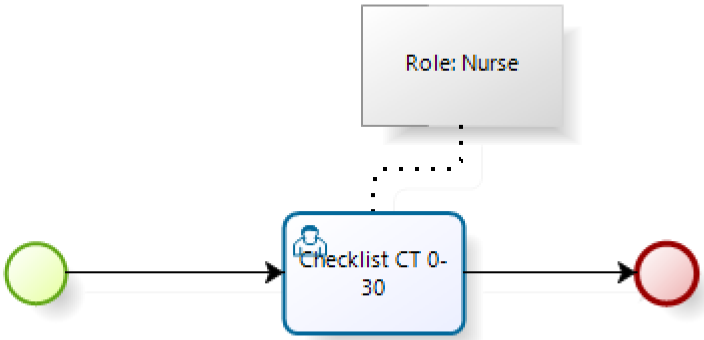
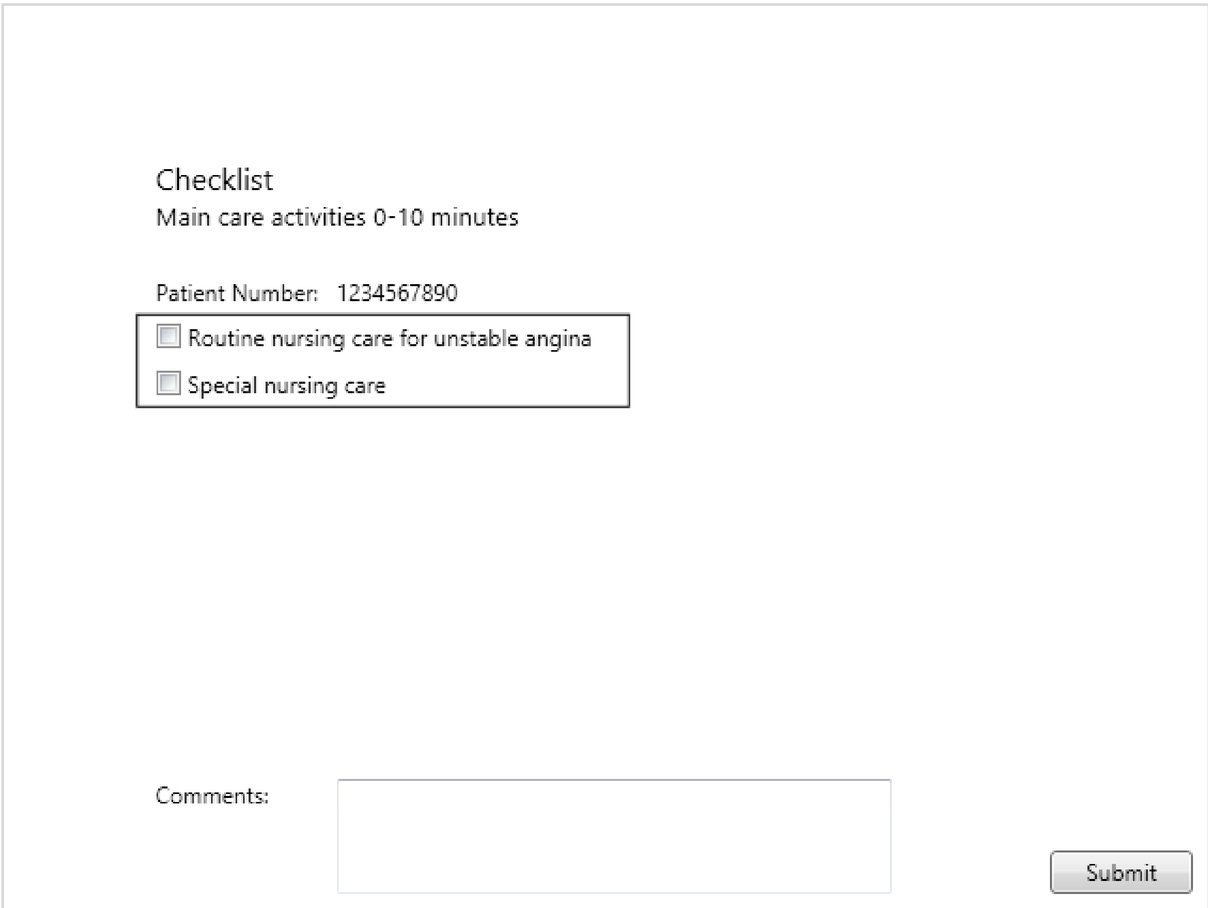


Figure 102: Subprocess Main care tasks 0-30

Checklist CT 0-30



Checklist
Main care activities 0-10 minutes

Patient Number: 1234567890

- [ ] Routine nursing care for unstable angina
- [ ] Special nursing care

Comments:

Submit

Figure 103: Form Checklist CT 0-30

Role: Nurse

Data:

PatientID: String	Input
ChecklistItemName: String	Input
ChecklistItemDone: Boolean	Output (Compulsory)
Comment: String (Long)	Output

Appendix P: Process data/variables

Table 10: Process data/variables

Milestone	Task	Data	
0-10	Medical History MA 0-10 1	PatientID: String Medical History: String (Long) Comment: String (Long)	Input Output (Compulsory) Output
	Diagnosis MA 0-10 2	PatientID: String Diagnosis: String (Long) Diagnosis Clear: Boolean Comment: String (Long)	Input Output (Compulsory) Output (Compulsory) Output
	Prescribe Drugs 0-10 2a	PatientID: String DrugsName: String DrugsCompulsory: Boolean DrugsDosage: Integer Comment: String (Long)	Input Input Output (Compulsory) Output (Compulsory if DrugsCompulsory=True) Output
	Checklist MA 0-10 3	PatientID: String ChecklistItemName: String ChecklistItemDone: Boolean Comment: String (Long)	Input Input Output (Compulsory) Output
	Long-term Orders List 0-10	PatientID: String OrderName: String OrderSelected: Boolean Comment: String (Long)	Input Input Output (Compulsory) Output
	Temporary orders 0-10	PatientID: String OrderName: String OrderSelected: Boolean Comment: String (Long)	Input Input Output (Compulsory) Output
	Registration Patient CT 0-10 1	PatientID: String PatientFirstName: String PatientMiddleName: String PatientLastName: String Gender: String Age: Integer Outpatient ID: Integer Inpatient ID: Integer DateOfAdmission: Date TimeOfOnset: Time Comment: String (Long)	Input Output (Compulsory) Output Output (Compulsory) Output (Compulsory) Output (Compulsory) Input Input Output (Compulsory) Output (Compulsory) Output
	Checklist CT 0-10 2	PatientID: String ChecklistItemName: String ChecklistItemDone: Boolean Comment: String (Long)	Input Input Output (Compulsory) Output

0-30	Assessing TIMI Risk Score 0-30 1	PatientID: String TIMIName: String TIMISelected: Boolean TIMIScore: Integer PatientRisk: String Comment: String (Long)	Input Input Output (Compulsory) Input (count formula of # TIMISelected=True) Output (Compulsory) Output
	Early Invasive Treatment 0-30 2	PatientID: String EarlyInvasiveTreatment: Boolean Comment: String (Long)	Input Output (Compulsory) Output
	Checklist MA 0-30 3a early invasive treatment	PatientID: String ChecklistItemName: String ChecklistItemDone: Boolean Treatment: String Comment: String (Long)	Input Input Output (Compulsory) Output (Compulsory) Output
	Checklist MA 0-30 3b no early invasive treatment	PatientID: String ChecklistItemName: String ChecklistItemDone: Boolean Comment: String (Long)	Input Input Output (Compulsory) Output
	Showing Treatment info 0-30 4	No variables	
	Long-term Orders List 0-30	PatientID: String OrderName: String OrderSelected: Boolean Comment: String (Long)	Input Input Output (Compulsory) Output
	Checklist CT 0-30	PatientID: String ChecklistItemName: String ChecklistItemDone: Boolean Comment: String (Long)	Input Input Output (Compulsory) Output

Appendix Q: Example of data model

This part of the thesis is deleted for privacy reasons.

Appendix R: Evaluation tool
Instructions

This questionnaire is used to evaluate the proposed methodology: *From text-based care pathway to workflow model*. In this questionnaire there are 16 criteria in which the questions are subdivided. It is asked to answer these questions both quantitative and qualitative. The quantitative answer is given on a 5-point Likert Scale[8] where 1 corresponds to "not at all" and 5 to "very" as seen in Table 11. The quantitative measurement will be used to get an absolute scoring of the proposed methodology, where the qualitative answers will be used to get a more in-depth understanding of the evaluated.

Table 11: Scale explanation

Value	Corresponds to
1	Not at all
2	Slightly
3	Somewhat
4	Quite a bit
5	Very much

Rationale - Applicability and usability of the methodology

Flexibility

1.
Is the methodology flexible enough to be applied in different scenarios (Care Pathways)? 1 2 3 4 5

If not, please explain why

2.
Is the methodology specific to the Healthcare domain? 1 2 3 4 5

Please provide examples

3.
Does the methodology allow for customization? 1 2 3 4 5

Why?

[8] R. Linkert, "Technique for the measurement of attitudes," *Archives of Psychology,* vol. 140, pp. 1-55, 1932.

Ease of applicability

4.
Do you think that it would be possible to apply the methodology in your company? 1 2 3 4 5

If not, why?

5.
Do you think that the methodology is optimal from the use case point of view? 1 2 3 4 5

If not, please explain why

Utilisation of/compatibility to/contribution to open source tools and standards

6.
Does the methodology take advantage of the open source tools, standards, and best practices? 1 2 3 4 5

Please provide points of improvement if necessary

7.
Does the methodology address already existing methods in the area of BPM? Yes No

If question 7 is answered with a yes, please continue with question 8.
If question 7 is answered with a no, please continue with question 10.

8.
To which level does the methodology already address existing methods in the area of BPM? 1 2 3 4 5

Should this be improved? If yes, how?

9.
To which level does the methodology try to define its approach on top of these existing methods in the area of BPM? 1 2 3 4 5

Should this be improved? If yes, how?

Popularity

10.
Is there public interest in the methodology? 1 2 3 4 5

Can you please explain your answer?

Structure – Completeness and support

Domain Coverage

11.
Does the methodology also include resources/roles and metrics/KPIs (besides the process steps)? 1 2 3 4 5

If not, which of these is missing?

12.
Does the methodology provide guidelines on how to coordinate different roles (responsibilities) throughout the entire process lifecycle? 1 2 3 4 5

If not, which are missing?

13.
Does the methodology provide concrete measures allowing for quantitative judgements? 1 2 3 4 5

If not, which could be added?

14.
Does the methodology cover a sufficient level of details? 1 2 3 4 5

If not, please explain why?

15.
Does the methodology define the scope, responsibilities, etc. of each process phase? 1 2 3 4 5

If not, what is missing?

16.
Does the methodology allow dealing with complex processes/projects? 1 2 3 4 5

Which level of complexity, do you think, should be covered by the methodology?

Procedural completeness

17.
Does the methodology cover all steps? 1 2 3 4 5

If not, which are missing?

18.
Are the steps in the methodology described in a correct level of detail? 1 2 3 4 5

If not, what should be improved?

19.

Is there a smooth transition between different steps/phases defined? 1 2 3 4 5

If not, please provide an example

Structure – Extendibility/adaptability

Ease of extendibility

20.

Is the methodology easy extendable? 1 2 3 4 5

Please provide examples

Ease of adaptation

21.

Can the methodology in question be easily adapted to the different business environments? 1 2 3 4 5

Is this necessary? Please explain your answer

Quality – Readability/understandability

Step by step examples

22.

Does it provide a sufficient number of application examples? 1 2 3 4 5

What number of examples would be sufficient? Please explain your answer

Quality of the presentation

23.

Is the way of the presentation adequate? 1 2 3 4 5

If not, please provide improvement points

Conciseness

24.

Does the methodology avoid useless definitions? 1 2 3 4 5

If not, please provide examples

25.

Are there redundancies in the methodology? 1 2 3 4 5

If yes, please provide examples

26.

Is the information provided by the methodology detailed enough for you to follow it? 1 2 3 4 5

If not, please provide examples

27.

Are the steps too specifically described and do not allow for flexibility or adaptation to different business environment? 1 2 3 4 5

Please explain if this is necessary

If applicable, please provide points of improvement

Correctness of assumptions

28.
Is the methodology based on assumptions? Yes No

If question 28 is answered with a yes, please continue with question 29.
If question 28 is answered with a no, please continue with question 31.

29.
Is the methodology based on the correct assumptions? 1 2 3 4 5

If not, please provide examples

30.
Are the assumptions used in the methodology realistic? 1 2 3 4 5

If not, please provide examples

31.
Does the methodology hold a correct balance between theory and practice? 1 2 3 4 5

If not, please explain your answer

32.
Does the methodology take into account industrial experience? 1 2 3 4 5

Please explain your answer

Correctness of steps

33.

Is the order of the steps correct? 1 2 3 4 5

If not, please explain which steps are in the wrong order

34.

Are the transitions between different steps correct? 1 2 3 4 5

If not, please explain which transitions are wrong

Consistency

35.

Are there some explicit or implicit contradictions within the methodology? 1 2 3 4 5

If yes, please explain the contradictions

Coherency

36.

Is the methodology in your point coherent? 1 2 3 4 5

If not, what are the problems?

Correctness from IT and business point of view

37.
Do you think that the methodology enables to bridge the gap between the IT and business representatives? 1 2 3 4 5

If not, why?

38.
Is the methodology correct from the business point of view? 1 2 3 4 5

If not, which parts are wrong?

39.
Is the methodology correct from the IT point of view? 1 2 3 4 5

If not, which parts are wrong?

40.
Is it well adjusted to these both worlds? 1 2 3 4 5

If not, which parts could be improved?

Appendix S: Results of evaluation tool

Table 12: Qualitative answers evaluation tool

	Question	Score	Explanation
1	**Is the methodology flexible enough to be applied in different scenarios (Care Pathways)?**	4	It needs to be validated to confirm this.
2	**Is the methodology specific to the Healthcare domain?**	5	The proposed methodology splits the care pathway modelling into two stages. The first stage aims to model the general clinical knowledge based on the text-based MOH clinical pathways and the second stage is intended to adjust all of these clinical activities and knowledge into real clinical practice. Both of these two stages are specific to the healthcare domain including the clinical knowledge and clinical workflow. In the model, clinical decision support is also used to check whether the dose of one drug is appropriate. CDS tools are also specific and useful in the healthcare domain.
3	**Does the methodology allow for customization?**	4	The proposed methodology annotates the care pathways into different categories and models each category into BPMN models. It is convenient for the users to add some items belongs to one of these key category based on the proposed method. The proposed methodology applies RIM-based data model which facilitates the care pathway deployment in the specific hospital by simple data mapping. However, it would be great if the proposed methodology include automatic generation of forms based on the data items (instead of using static forms).
4	**Do you think that it would be possible to apply the methodology in your company?**	5	Yes. It is valuable for the design of a clinical pathway system.
5	**Do you think that the methodology is optimal from the use case point of view?**	3	For the conceptual model the use-case works well, however, for the executable WF model you chose to focus on the first part of the CP i.e. 0-30 minutes: this is a very time critical period and as such it is not very likely that the clinician/nurse will have much time to interact with the CPMS. We need to be realistic in our assumptions on their availability – some checklists will most likely need to be combined and 'reported' ex-post when the user has the time and fits in a natural way in his/her workflow. In general, our feeling is that the CPMS has the most benefits in longer lasting parts of the CP, not in the "real-time applications" like in ER. It would be good to focus the WF model example to that direction, or elaborate how to combine the checklist(s) into likely moments of interaction with CPMS.

6	**Does the methodology take advantage of the open source tools, standards, and best practices?**	5	Yes. It leverages some open source tools, e.g. jBPM and Drools. The data model of this methodology is based on HL7 RIM which is a widely accepted approach in the healthcare domain.
10	**Is there public interest in the methodology?**	4	Clinical pathway is regarded as a useful tool to improve clinical quality and reduce medical cost. However, current market is lacking an electronic clinical pathway system which is well integrated with the existing hospital information systems and real clinical workflow. The proposed methodology explores how to translate the paper-based clinical pathways into executable workflow-based clinical pathways while using a standard based data model. It is an interesting exploration in this domain
11	**Does the methodology also include resources/roles and metrics/KPIs (besides the process steps)?**	4	It would be great if the proposed methodology covered inclusion of more KPIs including clinical outcomes, cost, etc.
13	**Does the methodology provide concrete measures allowing for quantitative judgements?**	4	Evaluation of clinical knowledge and clinical impact should also be considered.
16	**Does the methodology allow dealing with complex processes/projects?**	4	Complex projects usually involve a multitude of models which keep evolving in time. The two-phase approach proposed here may tackle the complexity of the first design decomposition, but it is questionable how would it address the natural evolution of (both) types of models in time and their mutual synchronization. It would be very useful if the methodology offered some traceability, e.g. maintain explicit mappings between the conceptual model into the original text, as well as between the CM and WF model refinement.
19	**Is there a smooth transition between different steps/phases defined?**	4	In general the transition is defined, but it is not quite clear/explicit how would one manage the model evolution and sync (see 16)
21	**Can the methodology in question be easily adapted to the different business environments?**	3	Not likely, it is meant to be HC specific.
22	**Does it provide a sufficient number of application examples?**	4	It would be great to see a more extensive executable WF models, which would also allow for exception handling etc.
29	**Is the methodology based on the correct assumptions? Are they realistic?**	4	Except of the real-time WF handling as mentioned above. There is also an assumption of “completeness” of the input (text based CP), while in reality there always will be exceptional cases – an interesting question is how to allow for justified CP deviation and yet support the clinical users with executable workflow.

37	**Do you think that the methodology enables to bridge the gap between the IT and business representatives?**	4	It would be great to see a realistic example of the executable WF model incl. a proof of concept demonstration.
39	**Is the methodology correct from the IT point of view?**	4	The methodology is correct, but to really make it practically applicable, a complete IT view/modeling needs to also include exception handling etc.

Table 13: Quantitative results evaluation tool (*inverted score)

Category	Sub-Category	Question		Score	
Rationale	Flexibility	**1**	4	4.33	4.25
		2	5		
		3	4		
	Ease of applicability	**4**	5	4	
		5	3		
	Utilisation of/compatibility to/contribution to open source tools and standards	**6**	5	4.67	
		7	-		
		8	5		
		9	4		
	Popularity	**10**	4	4	
Structure - Completeness and support	Domain Coverage	**11**	4	4.33	4.33
		12	5		
		13	4		
		14	4		
		15	5		
		16	4		
	Procedural completeness	**17**	5	4.33	
		18	4		
		19	4		
Structure – Extendibility/adaptability	Ease of extendibility	**20**	5	5	4
	Ease of adaptation	**21**	3	3	
Quality – Readability/ understandability	Step by step examples	**22**	4	4	4.57
		23	4		
	Conciseness	**24**	5	4.5	
		25*	4		
		26	5		
		27	4		
	Correctness of assumptions	**28**	-	4.67	
		29	4		
		30	-		
		31	5		
		32	5		
	Correctness of steps	**33**	5	4.5	
		34	4		
	Consistency	**35***	5	5	
	Coherency	**36**	5	5	
	Correctness from IT and business point of view	**37**	4	4.33	
		38	5		
		39	4		
		40	-		

Appendix T: Getting access to the models through SHARE

SHARE[9] stands for Sharing Hosted Autonomous Research Environments and can be used to provide access to a tool that is otherwise cumbersome to install or configure. In order to use SHARE to access the models of this thesis follow these steps:

1. Click on one of the links below

Conceptual process model	http://share20.eu/?page=ConfigureNewSession&vdi=Win7_Bizagi-in-Windows-7.vdi
Workflow process model	http://share20.eu/?page=ConfigureNewSession&vdi=Win7_Drools-Unstable-Angina.vdi

2. Request a new account and sign up
3. Request access to the bundle: TU/e Thesis W. van Renswouw
4. Request a new session for the conceptual model (Unstable Angina CP in Bizagi Process Modeler) or the workflow model (Unstable Angina WF in Drools/jBPM)
5. Connect via Remote Desktop Connection (note that you should use MS RDP Client v5.2)
6. Starting the conceptual model in Bizagi is straightforward
   Starting the workflow model in Drools/jBPM is a little more challenging; therefore screen casts[10] was made in order to help (these videos are also present in the virtual machine).

Further information on SHARE can be found on:

SHARE documentation website: https://fmt.ewi.utwente.nl/redmine/projects/grabats/wiki

SHARE how-to video: http://is.tm.tue.nl/staff/pvgorp/share/rsync-screencast/

SHARE paper (Van Gorp and Mazanek, SHARE: a web portal for creating and sharing executable research papers 2011): http://www.sciencedirect.com/science/article/pii/S1877050911001207

[9] http://share20.eu/?page
[10] http://www.screencast.com/t/N54QmIdjPI4; http://www.screencast.com/t/Joa8DXLOpq

Appendix U: Literature review method

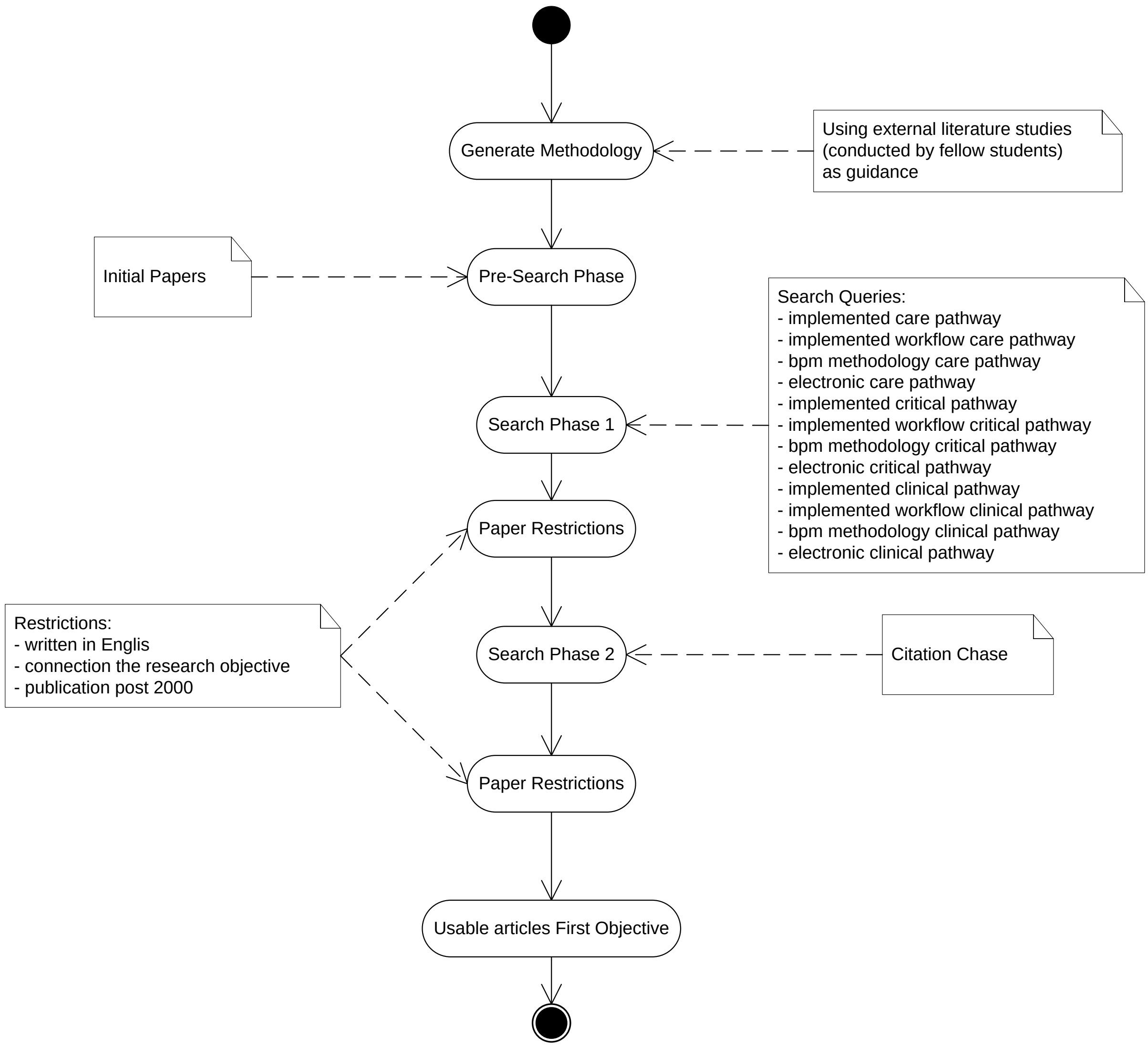


Figure 104: Method used for literature review