A process modelling method for care pathways

Vermeulen, L.R.E.

Award date:
2013

Eindhoven, November 2013

A process modelling method for Care Pathways

by
L.R.E. (Lonneke) Vermeulen

BSc Industrial Engineering and Management Science — TU/e 2011
Student identity number 0639690

in partial fulfilment of the requirements for the degree of

Master of Science
in Operations Management and Logistics

Supervisors:

Prof.dr.ir. U. Kaymak	TU/e, IS
Dr. P.M.E. Van Gorp	TU/e, IS
PhD H. Yan	TU/e, IS
Prof. dr. H.H.M. Korsten	CZE, Anesthesiologie
Dr. W.A.L. Tonino	CZE, Cardiologie

TUE. School of Industrial Engineering.
Series Master Theses Operations Management and Logistics

Subject headings: care pathways, health care, hospitals, method, process modelling

PREFACE

This report is a result of my graduation project, conducted in partially fulfilment for the degree of Master of Science in Operations Management and Logistics at the Eindhoven University of Technology. During the past months I have worked within the Brain Bridge Project on the development of a method to model Care Pathways and on the model of the Care Pathway of Unstable Angina at the Catharina Hospital Eindhoven. I would like to use this moment to thank the people surrounding me for their inspiration, advice and support.

First of all, I want to thank my first supervisor Uzay Kaymak for adopting me as his graduation student at the beginning of this year and embedding me in this inspiring project right away. His feedback and inspiration during our meetings was of great value to my work. Especially the brain teasers he would always give to think about after the meeting pushed me to improve my research. The second person I want to thank is my daily supervisor Hui Yan, who guided and supported me during the entire project and was always there for me whenever I had questions or just wanted to share my ideas. I would also like to thank Pieter Van Gorp for his valuable feedback during our few meetings, especially with regard to the modelling part of my project. In addition, I want to thank Shan Nan for his guidance and support and Parvathy Meenakshy for enjoying this adventure together. And of course all my teachers, friends and study buddies at the university throughout the years, who have formed me to the graduate student I'm today.

As I have conducted my project bilingual (English at the university, Dutch at the hospital), I will continue my acknowledgments in Dutch now.
Verder wil ik mij dank uitspreken aan iedereen van de afdelingen Cardiologie, Cardiothoracale Chirurgie, Intensive Care, Financiën en Kwaliteit en Veiligheid van het Catharina Ziekenhuis Eindhoven die mij geholpen hebben tijdens het uitvoeren van mijn case studie daar. In het bijzonder wil ik Erik Korsten bedanken voor zijn supervisie, inspiratie en de bijzondere en zeer waardevolle ervaringen die hij mogelijk heeft gemaakt. Daarnaast wil ik ook Pim Tonino, Inge Rongen en Corry Smeulders danken voor de vele uren die zij hebben geïnvesteerd in mijn onderzoek naar het zorgpad van Instabiele Angina Pectoris / ACS. Mede dankzij hun kennis, input en feedback is de case studie zo waardevol geweest voor mijn onderzoek, mijn onderzoeksteams, maar ook het ziekenhuis zelf.

Maar dit alles was nooit mogelijk geweest zonder de onvoorwaardelijke steun van mijn familie en de kans die zij me hebben gegeven om me persoonlijk te ontwikkelen. Ik ben ze enorm dankbaar voor alle steun, inspiratie en het warme nest dat ze me altijd hebben gegeven. Ook dank aan al mijn vrienden voor de gezellige en ontspannende momenten die we gezamenlijk hebben mogen genieten en de steun die jullie me hebben gegeven. Als laatste wil ik mijn vriend bedanken voor het luisteren naar al mijn verhalen, de vele discussies die erop volgde, zijn geduld en de leuke tijden die we samen hebben.

Thanks to you all!

Lonneke Vermeulen
November 2013

EXECUTIVE SUMMARY

Over the last decades Care Pathways (CPs) have been developed and globally accepted (Vanhaecht & Sermeus, 2002) and implemented, to face the worldwide healthcare challenge to provide cost-efficient care (Chu & Cesnik, 1998). *"A care pathway is a complex intervention for the mutual decision making and organization of care processes for a well-defined group of patients during a well-defined period."* (Vanhaecht, De Witte, & Sermeus, 2007, p. 137) In order to be able to keep ensuring the quality and efficient care of the pathway, it is important to implement a systematically feedback loop to evaluate and improve the pathway over time. In practice there is a lack of properly implemented feedback loops (Vanhaecht, et al., 2006), due to difficulties with the necessary data collection in complex hospital systems and unstructured patient files and a lack of good monitoring tools.

In order to help solve these problems, the Brain Bridge Project has started the research 'A toolkit for clinical pathway analysis', in which the aim is to analyse, optimize and compare pathways in Chinese and Dutch hospitals. Heretofore it is important that all included parties have a clear image of the pathway(s) in the form of a communication tool that can bridge the gap between medical professionals and technicians. This can be realized by using the technique of process modelling, that is developed to visualize processes such that they can be used for communication, analysis and optimization. Although a lot of research has already been conducted towards modelling pathways for different purposes, evaluation domains and modelling languages, it has not become clear yet how Care Pathway should be modelled for usage as a communication tool.

The goal of this research is then also to '*design a process modelling method for Care Pathways in hospital*', based on the existing literature of the field as well as experiences from practice that is applicable on any kind of pathway. The method needed to focus on setting the right requirements for the modelling language and tool such that the modeller can decide on the best possible model for the project leading from the goals (e.g. communication tool, mapping, checklists). Furthermore, special attention needed to be paid on the missing literature aspects of information gathering necessary to model the CP, the relationship between the goals of the model and the necessary granularity levels, and how to set those granularity levels.

In order to reach these goals, the first step of the research methodology was to conduct a literature study to capture the current knowledge on the Care Pathway concept and state of the art on similar methods/methodologies to model them. Based on the results of this study, it was possible to construct the method layout by comparing the different existing methods. This lead to the design method, which contained seven steps and the corresponding descriptions; *define project*, *plan project*, *make layout model and different views*, *fill in all details in the layout model*, *make stakeholders' perspectives*, *verify and validate model* and *refine model*, see Figure 1. In this design special attention was paid towards the setting of the requirements for the modelling languages and tool and the information gathering, but did miss some depth with regard to the granularity aspect as this is still an open point in the literature.

Case study

After that, the designed method was applied during a case study, with the goals to test if the method was also usable in practice and to be able to refine the method with insides from practice. As part of the Brain Bridge project, the objects was restricted towards the standardized care trajectory of Unstable Angina patients, hospitalized because of Acute Coronary Syndrome (ACS)

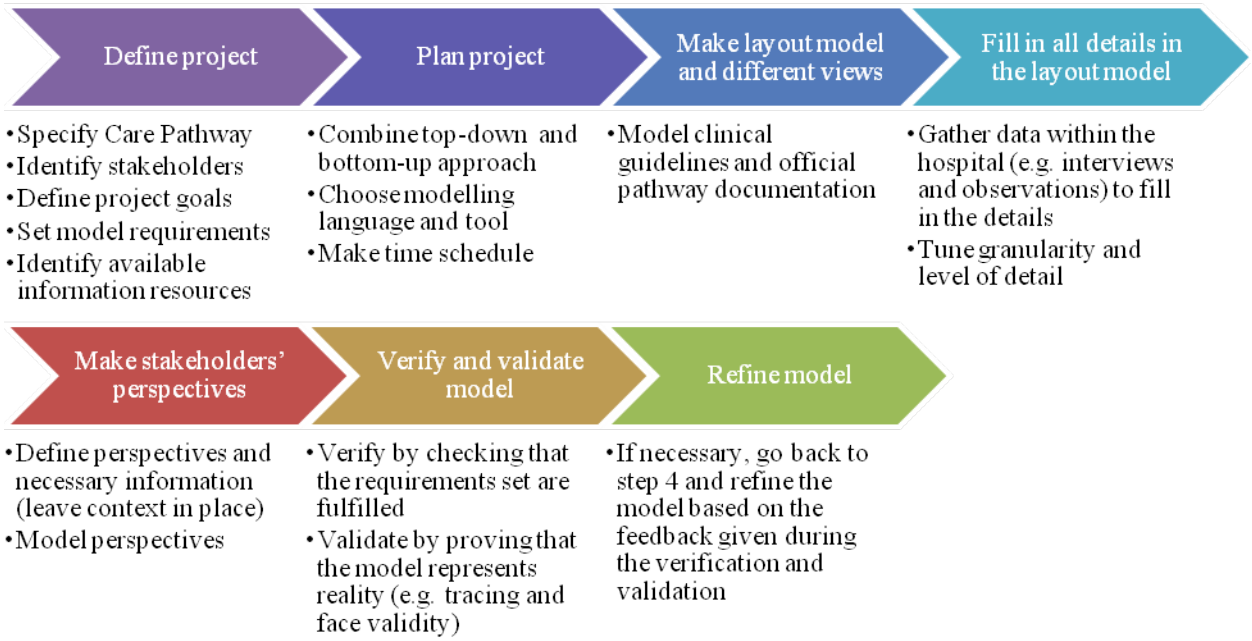


Figure 1 – Process modelling method for Care Pathways

at the Catharina Hospital Eindhoven. The goals of the modelling project were defined as a communication tool that could be used to align the different parts of the treatment and as the possible Key Performance Indicators for the further project towards clinical pathway monitoring. This led to the conclusion that the resulting model needed to provide an overview of the entire hospitalization period and show only the care activities conducted specifically for this patient group. After that, the model requirements were set with regard to the quality of the model, the process visualization, granularity and the modelling language. As the complexity of the process was not known yet, decisions with regard to the perspectives, visualization of roles and granularity were postponed. The available information resources were identified within the hospital, via associations and online, as clinical guidelines, documented work processes, patient brochures and (non) medical professionals.

According to the method, a top-down bottom-up modelling approach was chosen, in which the de-facto modelling language within the field, BPMN 2.0, and tool Signavio were used to work out the model. The official clinical guidelines and the ACS protocol were used for the model layout, but also served as a preparation for the modeller to get familiar with the medical terminology and the pathway. During the 'fill in all details in the layout model' phase data was gathered in the hospital by interviews conducted on the working floor, observations of the processes and the just made available work processes of the Cardiothoracic Surgery department. Here it was discovered that it is it important to be aware of the different used and existing names for tests and medicines (i.e. ATC-classification, nick and brand names). Besides that, it was found that the level of details are defined by the (sub) goals of the project, the clinical guidelines and/or the domain experts, but that the setting of the granularity levels is an art that needs to be done by the modeller. Based on the detailed model, seven perspectives were made for the direct key stakeholders within the hospital and it was found that it is important to keep the context in place here, due to the many alternations of the process.

After the perspectives were made, the verification was done by the modeller and medical professionals by looking if the model fulfilled the requirements set beforehand. As the original validation description (to test the model against historical data) was not applicable here, a second

literature study was conducted specifically to validate a communication tool without medical data. This resulted in the addition of the techniques of grouding (Carley, 1996), face validity and traces (Sargent, 1998), of which it was chosen to apply the traces, with eight self developed cases that covered extreme as well as normal patients and all different diagrams of the model, and the face validity by asking the medical professionals if the model represented reality. This lead to a couple of remarks, which were processed in the model, but overall the model was found to represent the complex treatment in place within the hospital.

Proof of concept

The last step of the research methodology was to validate the method, but due to time restriction it was not possible to conduct this. In order to get a first impression whether the method is indeed applicable to model Care Pathway, it was chosen to do a proof of concept with criteria based on the predetermined requirements;

(1) The method can be applied to any kind of pathway, not matter which treatment it covers and how well documented and/or worked out the pathway is;
(2) The method can result in different types of models.
(3) The resulting model can be used as a communication tool (e.g. is clear to medical staff and technici involved);
(4) The resulting model is a realistic image of the pathway in place;
(5) Medical staff and technicians see future benefit in resulting model;

As the method is such that the modelling approach can be adapted to the specific project, it can be used to any kind of Care Pathway (1) and will result in the optimal model type for that project (2). This was also proven during the case study in which the processes within the cardiology and cardiothoracic surgery department were very differently organized and documented and therefore required different modelling approaches. The method focused on the application as a communication tool (3) and also describes the goals of the project and the requirements of the modelling languages that need to be set during step 1 – 'Define project'. During the verification of the case study model, it was concluded that it could indeed be used as a communication tool. Besides that, it was also concluded that the resulting model was a realistic representation of the pathway in place in the hospital (4). By applying the method steps and refining the model until a success validation has been conducted, a realistic model can be ensured. The demonstrations of the patterns and checklists with the resulting model proved that the model is also of future benefit for technicians as well as medical professionals (5).

Future research

Future research must conclude that the developed method is indeed applicable to any Care Pathway. In order to be able to show this, the method should be extensively used in a variety of case studies. These case studies must reflect the diversity of Care Pathways existing, meaning that the factors of disease (different treatment approaches), hospital (different interpretations of CPs and available information resources), lengths (different time intervals) and goals must be varied. Aside from the validation of this method to model Care Pathways, it is interesting to research the applicability of this method on Care Pathways in other parts of the healthcare sector (like the mental health) and on Clinical and Transmural Pathways.

GLOSSARY

Abbreviation	Description
ACS	Acute Coronary Syndromes
ATC	Anatomical Therapeutic Chemical
BPM	Business Process Modelling
BPMN	Business Process Modelling Notation
BPR	Business Process Reengineering
CABG	Coronary Bypass Graft
CAG	Coronary Angiography
CCU	Coronary Care Unit
CHE	Catharina Hospital Eindhoven
CK	Creatine Kinase
COPD	Chronic Obstructive Pulmonary Disease
CP	Care Pathway
CPs	Care Pathways
CTC	*Cardiothoracale Chirurgie* Cardiothoracic surgery
DBC	*Diagnose Behandel Combinatie* DBC towards transparency
DM	Diabetes Mellitus
DOT	*DBC's op weg naar Transparantie* Diagnosis Treatment Combination
ECG	Electrocardiogram
EHH	*Eerste Hart Hulp* First heart aid
ENT	Ear, Nose and Throat
E-P-A	European Pathway Association
EPD	*Elektronisch Patiënten Dossier*
EPR	Electronic Patient Record
EuroSCORE	European System for Cardiac Operative Risk Evaluation
GOM	Guidelines of Modelling
GP	General Practitioner
GRACE	Global Registry of Acute Coronary Events
HC	High Care unit
HCK	*Hartcatheterisatiekamer* Heart catheterisation room
IAP **UA**	*Instable Angina Pectoris* Unstable Angina
IC	Intensive Care
ICC	Intercollegiate Consult
ICPs	Integrated Care Pathways
ItU	Intention to Use
KPI's	Key Performance Indicators
MEM	Method Evaluation Model
NKP	Netwerk Klinische Paden
NPA	National Pathway Association
NSTEMI	Non-ST Segment Elevation Myocardial Infarction
NVVC	*Nederlandse Vereniging voor Cardiologie* Dutch Association for Cardiology
OK	*Operatie Kamers*

OR	Operation Rooms
PACU	Post Anaesthetic Care Unit
PCI	Percutaneous Coronary Intervention
PEOU	Perceived Ease of Use
PM	Process Modelling
PU	Perceived Usefulness
7PMG	seven Process Modelling Guidelines
SOP	Standard Operation Procedures
STEMI	ST Segment Elevation Myocardial Infarction
TAM	Technology Acceptance Model
t.BPM	Tangible Business Process Modelling
TM	Telemonitor
TU/e	Eindhoven University of Technology
UA	Unstable Angina
VMS	*Veiligheidsmanagementsysteem* Safety management system

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1. INTRODUCTION

This research is about the development of a process modelling method for Care Pathways (CPs). Within this chapter background information will be provided about the link between the challenges of the healthcare sector and this research. After that, the research question(s) and methodology will be discussed, followed by the specification of the scope. Finally the structure of the rest of this report is explained.

1.1. Background information

Worldwide, the healthcare sector has two large ongoing challenges to deal with. On the one hand, the growing healthcare expenses needs to be controlled. In the Netherlands alone, the expenses grow with 3 to 4% for the last 3 years to €92,7 billion in 2012 (15,4 % of the Gross Domestic Product) (CBS, Centraal Bureau voor de Statistiek, 2013), of which the largest part, €23,9 billion, was for hospital care (CBS Statline, 2013). On the other hand, patients are demanding the best care possible. Dutch healthcare institutions are even required by law to deliver responsible care; top-class care that is given on an effective, efficient and patient-centred way and adjusted to the realistic needs of the patient [article 2 of the 'kwaliteitswet zorginstellingen']. This means "*that healthcare professionals and providers alike are under constant pressure to deliver evidence-based, high-quality treatment*" (Joosten, Bongers, & Meijboom, 2008, p. 472). From these two challenges it can already for years be concluded that cost-efficient care has become an important factor in healthcare processes (Chu & Cesnik, 1998).

1.1.1. Care Pathways

Over the last decades, Care Pathways (CPs), also called Clinical Pathways, have been developed to ensure quality and efficient care. "*A Clinical Pathway is a method for the patient-care management of a well-defined group of patients during a well-defined period of time*." (de Bleser, et al., 2006, p. 553) They have become a worldwide accepted (Vanhaecht & Sermeus, 2002) and adopted concept (Cardoen & Demeulemeester) and can be applied by between 60-80% of the patient groups in hospitals (Vanhaecht, Panella, Zelm, & Sermeus, 2010). Besides that, CPs are also interesting because of the desire to automate health records and involve patients and families in the process (Zander, 2002). The concept, if applied correctly, contains a systematically feedback loop to evaluate and improve the pathway in order to ensure the quality (including the effectiveness and patient safety) and efficiency of pathways in the rapidly evolving and highly dynamic healthcare sector.

Although the concept has become popular and the use is still growing (Hindle & Yazbeck, 2005; Vanhaecht, et al., 2006), difficulties with the implementation of a systematically feedback loop / evaluation have been recognized in practice. Research of Vanhaecht et al. (2006) confirms that not all pathways are evaluated or evaluated properly on all domains (of for example The Leuven Clinical Pathway Compass (Vanhaecht & Sermeus, 2003)). This seems to be caused by two aspects; difficulty with data gathering and the lack of proper analysis tools. In order to perform an evaluation, an extensive gathering of data needs to be done systematically. Until recently, many hospitals had paper-based patients' records/files, out of which the required data needed to be collected manually. This is a time consuming and error-prone process. With the introduction of the Electronic Health Record (EHR) and computerized systems in hospitals, data gathering should have become more easily. This is however often not the case due to the complexity of the systems (i.e. getting data from the system is a complex task) and because records are not always

clearly structured (i.e. the necessary data is placed in different fields and/or in free text). If hospitals are able to successfully collect the data, the next problem would be the analysis of it. This because Care Pathway analysis tools, which are tools that try "*to capture the actionable knowledge, which most commonly represents the best practice for most patients most of the time in their therapy and treatment processes*" (Huang, Lu, Duan, & Fan, 2013, p. 111) are only able to analyse basic information, like the average length of stay, while higher levels of analysis are required for substantial improvements of pathways. (Huang, Lu, Duan, & Fan, 2013)

1.1.2. Process modelling

From the field problems, it can be concluded that to make the feedback loop work, research needs to be conducted towards the data gathering and an advanced analysis tools. Therefore the Brain Bridge Project has started the research 'A toolkit for clinical pathway analysis', in which the aim is to analyse, optimize and compare pathways in Chinese and Dutch hospitals. In order to make and use this toolkit successfully (i.e. to be able to perform meaningful analyses in the future), it is important that the developers, end users and all different cooperating parties have a clear image of the pathway(s). This can be done by making a realistic model of the processes of the pathway that can serve as a communication tool to bridge the gap between medical professionals (the people doing the job) and technicians (the people who have to ensure the data gathering and clear records in the hospital system and the researchers that develop the analysis tool). The usage of CPs as a communication tool between professionals is very common and one of its top 10 characteristics (Vanhaecht, et al., 2006).

Process models are developed for this purpose, as they are used to visualize processes such that they can be used for communication, analysis and optimization. This means that a process model of a Care Pathway cannot only be used as a communication tool, but also to make an executable model that can perform simulations. Besides that, it could be used to identify Key Performance Indicators (KPI's), to make structured patients files, to create checklists or even a workflow and to determine the completed pathway (the pathway a specific patient has completed) of patients. The latter applies not only in the future, but is especially handy with the contemporary data. This data comes from unstructured files, from which it is not always clear which patients do and do not have followed a specific pathway. By mapping the care followed by these patients against (a part of) the model this distinguish can be made.

The process modelling technique has been used for many years in the industry and various modelling languages (e.g. IDEF, Petri-net, BPEL, and BPMN) and methodologies have been developed for different industries and purposes. (Rad, Benyoucef, & Kuziemsky, 2009) Although the process modelling technique is originally made for the industry, researches have successfully applied it in the healthcare sector since a few years. A lot of research has already been done towards modelling pathways for different purposes, evaluation domains and modelling languages. Nevertheless, it has not become clear how Care Pathway should be modelled for usage as a communication tool or for one of the other possible applications. Besides how to model a Care Pathway, an extra difficulty can be faced in practice as pathways are not always fully documented. In that case, the pathway first needs to be 'extracted' from the hospital before it can be modelled. This research will therefore focus on developing a process modelling method for Care Pathways from 'scratch'.

1.2. Research question(s)

Following from the background information, the goal of this research can be stated as '*design a process modelling method for Care Pathways in hospitals*'. This leads to the following central research question:

How to extract and model Care Pathways in hospitals?

With this question it should be possible to deliver a method to the scientific world that is specified for Care Pathways. In order to be able to answer the central research question and thus to develop the method, four sub questions have to be answered.

(1) What are Care Pathways and how are they applied in hospitals?

The first question that needs to be answered is about the central object of this research; Care Pathways. In order to be able to extract and model Care Pathway it is necessary to understand the object (i.e. what are CPs?) and how they are applied in hospitals (i.e. how are CPs used and evaluated?).

(2) Are there already, parts of, methods/methodologies that can be used to 'extract' and model Care Pathways?

To avoid 'reinventing the wheel' it is important to know how far the scientific world is with the development of such a method. Furthermore, lesions learned in the past by other researchers can be taken into account. (Business) Process Modelling is very common these days and has also been applied for a few years in the healthcare sector. So, it might be very well possible to apply (parts of) existing methods/methodologies from the (B)PM research field to 'extract' and model Care Pathways.

(3) Is the method usable in practice?

This method will be developed to actually model Care Pathways within hospitals. Therefore it is very important to test whether or not the theoretically method is also usable in practice.

(4) Is the developed method valid?

The last step of the development of the method is the validation process of it. Besides the actual validation, the main question here is how the method can be validated.

Following from this set of questions, the method will be based on the existing literature in the field and includes experiences from practice. This will allow that a detailed description of the steps to be taken can be described in this research, as well as a full Care Pathway model. Besides that, special attention can be paid to the information gathering necessary to model the CP, the relationship between the goals of the model and the necessary granularity levels, and how to set those granularity levels. Up till now, those aspects are missing in the literature even though they are quite important to make a good model of a pathway.

1.3. Research methodology

The research methodology for this research is divided in five stages, see Figure 2, in which the research question(s) will be answered. A description of every stage will be given here.

1.3.1. Stage 1 – Literature Study

The first stage of the research methodology is a literature study and was conducted in two parts; part A towards Care Pathways to answer sub question (1) and part B towards modelling methods to answer sub question (2). The search was conducted in the different search engines / databases with the keywords mentioned in Table 1. For part A, the keywords in the left column of Table 1, which are the primary synonyms for Care Pathways, were used in combination with the terms in the middle column to search for information about the Care Pathway concept, its development and evaluation. Important for this research was to find out if there are differences between CPs in the Netherlands and worldwide, therefore literature specific for the Netherlands was also searched. For part B, search results from part A could be used, but more information was search with the keywords from the right and left column of Table 1. In this way, it was possible to find specific methods/methodologies to model CPs, but also to find methods/methodologies of the business and healthcare process modelling fields. Besides keyword searching, literature was found by looking at the published work of pathway associations 'Netwerk Klinische Paden' (NKP), 'National Pathway Association' (NPA) and 'European Pathway Association' (E-P-A) and the KU Leuven and their members. Finally, in some cases search results were used to find more literature through their references (and citations).

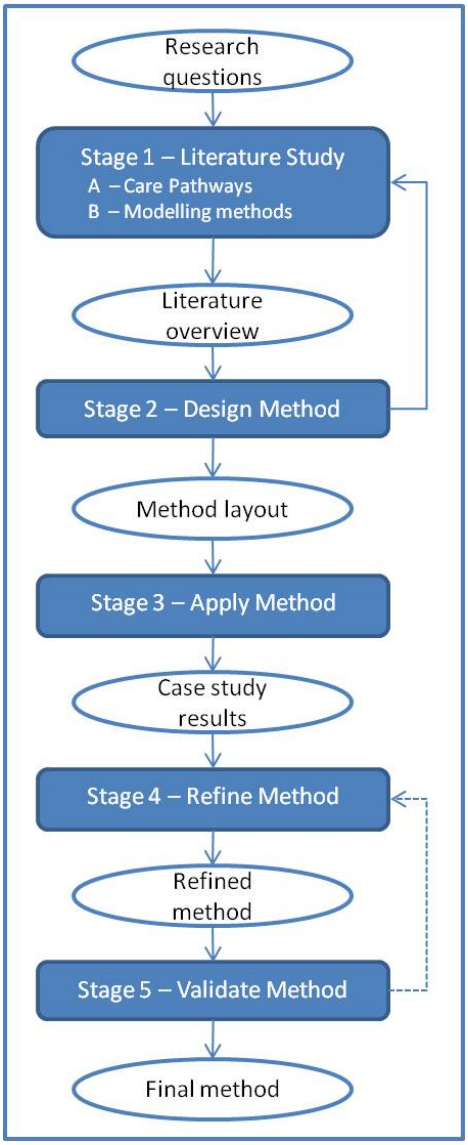


Figure 2 – Research Methodology

1.3.2. Stage 2 – Design Method

After the main part of the literature study was conducted, the designing of the method was started with the construction of the layout. The literature overview of stage 1B formed the basis for the construction of the method layout; from different researches the methods were compared and the results were used as a basis for this method. When needed the research returned to the first stage, to find more literature to continue the construction of the method. After the construction was done, the layout contained all the different steps and the corresponding description. Since the method needs to be applicable for all sorts of CPs, the method describes different options which can be chosen for a specific project. The only real vague step of the method at this stage was the granularity, because this is still an open point in the literature. Note that this stage answers sub question (3) from a literature point of view, the practice point of view will be answered in stage 3 and 4.

Search engines	Keywords		
ABI/Inform	Care maps	Development	Business Process Modelling
Inspec	Care Pathway	Dutch	BPMN
Focus	Clinical Pathway	Evaluate	Granularity
JStore	Critical Pathway	Evaluation	Healthcare process
Pubmed	Integrated Care Pathway	(Event) simulation	Level of detail
Scholar.google	Klinisch paden	Model	Methodology
Sciencedirect	Pathway	Modelling	Process model(ling)
Scopus	Zorgpaden	Netherlands	Stakeholders

Table 1 – Search engines and keywords used for the literature search towards Care Pathways

1.3.3. Stage 3 – Apply Method

Before the practical point of view of sub question (3) can be answered, first a case study needed to be conducted. Ideal would have been to apply the method layout to an existing Care Pathway in a Dutch hospital, but as part of the Brain Bridge Project the case study was restricted to the treatment Unstable Angina (UA) at Catharina Hospital Eindhoven (CHE). At the time of this research the CHE worked with Care Lines, in which the care of multiple diseases is bundled. Although there was no Care Pathway developed for UA, the care process was standardized by the Care Line, the Acute Coronary Syndrome (ACS) protocol and the clinical guidelines together. So, for the case study, we pretended that there was a CP for UA. This did however made the search for all required information (process, KPI's and stakeholders) about the treatment more difficult, since it was only partly documented and information was spread across different parts of the organization. The specific planning of the case study is described in chapter 4. During the modelling part of the case study more literature was search on the modelling language BPMN and the link between the goals of the model and the granularity levels.

1.3.4. Stage 4 – Refine Method

Already during the case study the method refinement started, as it was found that the method layout contained too few validation techniques. A second literature search was conducted specifically towards validation techniques for process models (and the method validation of step 5). The search engines and keywords used heretofore are note in Table 2. In total three useable articles were found and worked out in the refined method. After the case study was completed, the method was further refined with practical points and experiences resulting for the case study (see chapter 6).

1.3.5. Stage 5 – Validate Method

The last step taken in this research was to work out the method validation. Literature about this method validation was searched at the same time as the validation techniques, see Table 2, but it was very difficult to find literature about this subject. Eventually it was found that methods can be evaluated by the Method Evaluation Model (MEM) of Moody (2003) on their successfulness. In which success is defined as a combination between whether the method improves the task performance and is used in practice. In order to state how successful the method is, the five underlying constructs can be tested during experiments and/or field research. As measurements for these constructs need to be method specific, it was searched if already measurements have been developed that apply to this research. Through the snowball technique three useful articles were found about the measurements, but no directly applicable measurement set. So, in order to use the MEM measurements need to be developed first. Due to the time restrictions of this

Search engines	Keywords		
ABI/Inform	BPMN	process modelling methods	Validation method
JSTOR	Face validation	Validation	Validity
Scholar.google	process model	Validation model	

Table 2 – Search engines and keywords used for the literature search towards process models validation techniques and method validation

research this was not possible. Nevertheless, the layout of how this evaluation and measurements development should be done was worked out (see chapter 7) to answer sub question (4). In order to get a first impression whether the method is indeed applicable to model care pathway, a proof of concept was worked out based on the predetermined requirements set for the method. After the brief method evaluation, the research could be wrapped up; a conclusion was drawn and the report and presentation were written.

1.4. Scope

The goal of this research is to design a process modelling method for Care Pathway in hospitals. In the introduction of this research, it is already stated that the method should at least be applicable as a communication tool. Besides that, references for further usage of model should be included in the method. To conduct a dedicated research that fits in the time frame, the scope of this research needs to be further defined here.

First of all, the research question does not specify which type of process model will result from the developed method. This is because any type of process model can follow from the method, as the model type will be based on the requirements set for that specific project (i.e. the ideal model type leads from the project specifications). The focus here is therefore on setting the right requirements for the modelling languages and tool necessary to come to the best possible model of the Care Pathway. With the right requirements (and already conducted research towards this) modellers will be able to choose themselves. Note that the extra attention is paid towards the graphical process modelling type, as the corresponding goal of a communication tool will most likely obviously lead towards that type.

A second focus within this research it taken within the influence from practice. As the methodology already stated, there will be one case study performed towards the treatment of Unstable Angina in place in the Catharina Hospital Eindhoven, the Netherlands. Due to time restrictions it is not possible to conduct more (international) case studies.

1.5. Report structure

In the remaining seven chapters, the conducted research and its results will be discussed according to the different stages of the methodology. Chapter 2 explains the concept of Care Pathways (stage 1A) and chapter 3 the design of the method (stage 2), as well as the relevant literature where the method is based on (stage 1B). After that, chapter 4 describes the case study (stage 3) of the Care Pathway of Unstable Angina that has been done. The results of the case study are discussed and described in chapter 5, as well as two further applications of the model; patterns and checklists. Within chapter 6 the lessoned learned from the case study are used to refine the method (stage 4). In chapter7 the layout for the validation of the developed method is stated and a proof of concept is done (stage 5). Finally a conclusion is drawn and suggestions for future research are given in chapter 8.

2. CARE PATHWAYS

In order to develop a method to model Care Pathways (CPs), first a deep understanding of the concept and its use is required. This chapter will therefore provide an overview of the literature about of CPs. First, an overview of the history is given followed by the definition. Thereafter, the development, implementation and evaluation of CPs are discussed.

2.1. History

Care Pathways have emerged from industrial planning methods, such as Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT), which were developed in the 50s. The method was first used in the 70s, but only gains some foothold in the healthcare sector in the late 80s. (Sermeus & Vanhaecht, 2002) The New England Medical Center in Boston was between 1985 and 1987 the first systematically user. While the concept spread over the USA, the UK started with the development of Integrated Care Pathways (ICPs) from the beginning of the '90s. By the end of the 90s, 80% of the hospitals in the USA had implemented at least some pathways and the concept started to spread all over the world. (Vanhaecht, Panella, Zelm, & Sermeus, 2010) The upcoming popularity of the concepts is due to the fact that it is a relatively simple tool, can be drafted relatively easily and produce rapid results. It can among others things visualize the outcome criteria that drive clinicians and the complex structure of the healthcare activities, which shows the contribution of all involved practitioners and can bring patients and caregivers closer together. (Zander, 2002) Besides that, their popularity is due to the wide range of problems they can offer a solution for and "*their ability to align clinical, management and service user interests around a health-care quality agenda*." (Allen, 2009, p. 355) In the early 2000s, CPs had been introduced in at least 14 European Union countries with penetration levels between 1 – 40%. As the estimated penetration levels and the intended use are growing towards 10 – 90%, it can be concluded that CPs will become more and more important and widely used in Europe. (Hindle & Yazbeck, 2005; Vanhaecht, et al., 2006) The growth could however be constrained by challenging the medical autonomy under clinicians with the multi-disciplinary teamwork approach, lack of encouragement from purchasers, no rewarding from service purchasers and specifically in The Netherlands by the relative strength of the medical profession (Hindle & Yazbeck, 2005). According to Schrijvers, van Hoorn & Huiskes (2012) the creation of multidisciplinary guidelines has however been given an impulse to the development of Care Pathways in The Netherlands for the past ten years.

Due to the separated development of individual Care Pathways in organisations (de Luc, 2000) and across the world, there exists a difference in the name calling of the pathway concept. The following terms among others are in use in the literature; *Clinical Pathway* or '*Klinisch Pad*', *Care Pathway* or '*Zorgpad*', *Caremap*, *Critical Pathway* and *Integrated Care Pathway* (Sermeus & Vanhaecht, 2002; de Bleser, et al., 2006) and can also be used for database search (Shi, Su, & Zhao, 2008). Not only the name calling differs between countries and organisation, also the drivers of the pathway development. The development in the USA was driven by the international trend towards 'managed care', in which the costs are driven down by adopting protocols to control them. Integrated Care Pathways (ICPs), on the other hand, were in general driven from a need "*to improve the quality of patient care and the standards of associated documentation by systematically managing the processes of clinical care*". (Whittle & Hewison, 2007, p. 298) De Luc (2000) however discovered that a distinction could be made between four different drivers 'models' of care pathways (clinical effectiveness, continuity, efficiency and

patient focus), each with their own features regarding the development and operation. Grubnic (2003) added to this research that the interest and purpose of the manager developing the pathway is of significance influences. This is due to the fact that within the UK the development of care pathways is nationally stimulated, but the hospital managers are responsible for the way this is done.

Although the development of Care Pathways has expanded all over the world and in different healthcare settings (Hindle & Yazbeck, 2005), there are still mixed results of their effect. Every, Hochman, Becker, Kopecky & Cannon (2000) stated that there are no controlled studies showing that CPs result in reduced length of stay, resource use or improved patient satisfaction. More recently, Vanhaecht, De Witte & Sermeus (2007) stated that there is still uncertainty about their impact, literature shows positive as well as no change and negative results, and that only a few multicentre studies with proper design have been conducted. De Vries, van Weert, Jansen, Lemmens & Maas (2007) describe that there are positive effects found in literature on the domains of process, team and resource allocation, but that non positive effects will likely not be published. Furthermore, they state that not all pathways are evaluated on different domains than financial, while CPs are about improving multidisciplinary teamwork and care. According to Shi et al. (2008) it has been proven that CPs are effective in the way that they reduce the length of stay and charges and improve the quality of care (reducing the rate of complications, readmission and mortality). They furthermore note that research into the effects of CPs should be done with proper methods (i.e. most comparisons are made with pre/post χ^2 and t testing, while there might be other factors influencing the effect). From a meta-study conducted towards the effects of CPs on professional practice, patient outcomes, length of hospital stay, and hospital costs, it was concluded that CPs implemented in hospitals are associated with diminished complications and enhanced documentation without harming length of stay or costs (Rotter, et al., 2012).

2.2. Definition

As the Care/Clinical Pathways have developed over the years, so has the definition. It is changed many times since its earliest definition introduced in 1996 by the National Library Of medicine in the USA and is still subject of discussion. In this research, the latest definition used by the NKP (Netwerk Klinische Paden, n.d.) and the E-P-A (E-P-A, n.d.) is adopted here. This definition is based on a literature review of de Bleser et al. (2006) complemented with an E-P-A survey (Vanhaecht, et al., 2006) and online discussions and is as follows:

"A care pathway is a complex intervention for the mutual decision making and organization of care processes for a well-defined group of patients during a well-defined period. Defining characteristics of care pathways include:
(i) An explicit statement of the goals and key elements of care based on evidence, best practice, and patients' expectations and their characteristics;
(ii) the facilitation of the communication among the team members and with patients and families;
(iii) the coordination of the care process by coordinating the roles and sequencing the activities of the multidisciplinary care team, patients and their relatives;
(iv) the documentation, monitoring, and evaluation of variances and outcomes; and
(v) the identification of the appropriate resources.
The aim of a care pathway 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, & Sermeus, 2007, pp. 137-138)

Schrijvers et al. (2012) added to this definition that the leading expression is Care Pathway, as they are per definition integrated. Clinical Pathways are paths within clinics or 24-hour departments of hospitals and a Care Street is a pathway within a specific architectural setting. Compared to Clinical Pathways, Care Pathways are longer and include *"outpatient department's activities, discharge from the hospital and after-care."* (Schrijvers, van Hoorn, & Huiskes, 2012, p. 2) If also processes in primary care or other care facilities are included, the used terms are Transmural Pathways or disease management pathways.

2.2.1. Definition of the different uses of Care Pathways

Research has shown that four different uses of Care Pathways can be derived. CPs can be seen as a concept, process, method and/or as a product. (Sermeus & Vanhaecht, 2002) Later on, it was noticed that the different methods lead to different models being used and therefore method was replaced with model (Vanhaecht, Panella, Zelm, & Sermeus, 2010).

2.2.1.1. Care Pathways as a concept

Care Pathways as a concept are about the change needed in hospitals to realize the path. The CPs needs to replace the fragmented old work methods and become the new central axis were around the patient-focused organization processes are developed. (Sermeus & Vanhaecht, 2002) They further need to support "*the modelling of patient groups with different levels of predictability*" (Vanhaecht, Panella, Zelm, & Sermeus, 2010, p. 117).

2.2.1.2. Care Pathways as a Process

The Care Pathway as a process can be seen as the process to develop a CP with the involved caregivers. This development is maybe even more important than the CP as a product. (Sermeus & Vanhaecht, 2002) Some even state that the discussion about the process is more crucial than the product (de Vries, van Weert, Jansen, Lemmens, & Maas, 2007). The process is defined in the '*30-step scenario*' of Vanhaecht & Sermeus (2002) and will be described in section 2.3.1.

2.2.1.3. Clinical Pathways as a method (or model)

Care Pathways can be defined as methods in the field of continuous quality improvement and can be split up in three. The first and largest used (around 60%) method is *standardized CPs* according to *chain models*, which are developed for a highly predictable care process of a group of patients. The second (20%) is the *customized CPs* according to *hub models*, which are pathways that are drawn for an individualistic patient from standardized building blocks. The third method (20%) is *case-management* following *web models*, in which a case manager coordinates the multidiscipline care given to a patient and makes sure that the team is tuned and working according to the developed pathway. (Sermeus & Vanhaecht, 2002; Vanhaecht, Panella, Zelm, & Sermeus, 2010)

2.2.1.4. Clinical Pathways as a Product

The last use variant is the Care Pathway as a product, the daily used pathways in practice which have different aggregation levels, see Figure 3.[1] The highest aggregation level is the *model pathway*, which are available international and national evidence that is not organization specific

[1] Note that Sermeus & Vanhaecht (2002) made a similar distinguish in the different pathways, but spoke of a model pathway on the local level, here called operational pathway, as highest 'aggregation level'.

(e.g. guidelines with organization aspects). Clinical guidelines are not meant here, since they are systematically developed consensus statements to assist practitioners in making decisions in specific clinical circumstances (Every, Hochman, Becker, Kopecky, & Cannon, 2000). *Operational pathways* are organization specific CPs that are drawn for groups of patients with insights from the model pathway and the possibilities of the organization (Vanhaecht, Panella, Zelm, & Sermeus, 2010). It states who does what and when, which decision moments there are, the applications and regulation, information, etc. *Assigned pathways* are time-based pathway models, wherein for a specific patient is documented which different steps of the pathway will be conducted. (Sermeus & Vanhaecht, 2002) The basis for this pathway is the operational pathway. *Completed Pathways* note the pathway a specific patient has been completed and can been seen after discharge. Differences between the completed and operational pathway are variances and can be used for the improvement of the operational pathway. Note that the completed pathway is not the same as a patient file; a completed pathway is not empty at the beginning and only describes the decision point that influences the coordination and cooperation of the care, where the patient file is an empty document at first and notes all relevant information (Sermeus & Vanhaecht, 2002). The *patient version* is divided over two aggregation levels and is used to inform and involve the patient and family about the care process. (Vanhaecht, Panella, Zelm, & Sermeus, 2010)

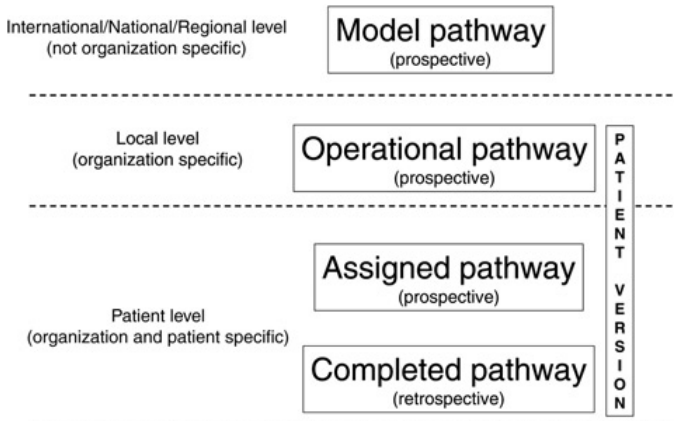


Figure 3 – Four aggregation levels of the Clinical Pathway product, source: (Vanhaecht, Panella, Zelm, & Sermeus, 2010)

As the healthcare sector is becoming more and more digitalized, so will CPs. "*Electronic care pathways are a newer form of process decision-making that is supported by specialist information technology and computer software.*" (Smith & Ross, 2007, p. 196) An example is the integrated digital clinical pathway for electrocardioversion in atrial fibrillation in the Medical Centre Alkmaar. This pathway is integrated in the hospital information system and combines the medical and nurse records. Furthermore, the digital pathway includes an option for variance analysis in which deviations from the pathway must be explained. (Zwaan & Umans, 2012) In the light of the aggregation levels, the operational pathway is present within the system and records, the assigned pathways and completed pathway are combined in the patient record where a comparison between these and the operational pathway is integrated.

2.3. Development, implementation and evaluation

As Vanhaecht et al. (2010) indicated, there are multiple ways to develop, implement and evaluate Care Pathways. Here, the 30-step scenario of the NKP, the Belgium-Dutch CP organization, will be shortly explained, while also indicating the important aspects that are shared between many methods.

2.3.1. 30-step scenario

The 30-step scenario of Vanhaecht & Sermeus (2002) has been developed in cooperation with the Centre of Case Management in Boston (USA) on basis of a literature study, pilot studies, and

from experiences within the NKP. The scenario is developed with the goal to guide teams by the evaluation of the current care, to strive for patient-focused primary processes and to systematically follow the primary processes. The scenario is a process of change, that has four mayor success factors; commitment of management (top-down), bottom-up ownership, the way the CPs are embedded in the organisation and to what extent the process of change has been systematically done. (Vanhaecht & Sermeus, 2002) The bottom-up ownership is also indicated by Every et al. (2000) as an important factor; practitioners and physicians are the key players in the development and implementation of pathways. Besides that, Ramos & Ratliff (1997) stated that physicians must strongly support the development.

The 30-step scenario is build on the basis of the Deming Cycle, Plan – Do – Check – Act (PDCA) cycle (see Figure 4), and will be summarized per phase here.

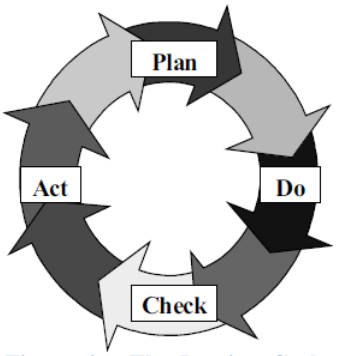


Figure 4 – The Deming Cycle, source: (Vanhaecht & Sermeus, 2002)

2.3.1.1. Plan phase

The development starts with the plan phase, in which the project is started up and a first version of the pathway is drawn.

One of the first steps is to *specify the patient group*, time interval of the pathway and to indicate the parameters (high volume, high risk, high costs and high predictability) of this patient group. The other steps in this phase are important according to Vanhaecht & Sermeus (2002) and are; the interdisciplinary *team composition* and the agreements they make about the organization and course of the project, *setting the goals* for the pathway and making them operational in measurable indicators such that evaluation can take place in the future, and *drawing the first version of the pathway* by the team by looking at the goals and how they can be reached.

The interdisciplinary team composition should include all people that are managing the disease processes and are responsible for patient care, which are all types of physicians (from General Practitioners (GPs) to specialists), nurses, social workers and administrators (de Vries, van Weert, Jansen, Lemmens, & Maas, 2007). Team composition is also indicated by Every et al. (2000) and Shi et al. (2008) as an important factor. Ramos & Ratliff (1997), add that an institutional leadership and the planning are important for the success of a pathway. Both Every et al (2000) and Ramos & Ratcliff (1997) furthermore state that the specification of the patient group is very important. Zander (2002) even stated that this is the most important step of the development. Also from Shi et al. (2008), it can be concluded that the patient group is important, although they state it from the reasoning that the disease should be a decent object for a pathway.

2.3.1.2. Do phase

The important Do phase is about testing the first version of the CP on feasibility and quality, and about getting a good indication of the current way of working and the quality of care. The 30-step scenario suggests seven steps to do so: a *file analysis* in which the feasibility of the CP is analyzed by looking at about twenty patient files; the important *pre measuring* in which the pathway is tested on the basis of the Leuven Clinical Compass; a *patient survey* (via interviews, walk-through or questionnaires) such that patient expectations can be used in the development process; a *document analysis* in which all documentation about or related to the pathway (also patient brochures) is reviewed and updated; *process mapping* in which the whole process for a

few patients is written out, including the time intervals, duration and nature of contact and decision moments, to find possible bottlenecks; a *peer review* to discuss indicators, goals and roles with consultants and supporting medical departments to test the feasibility; and *Compare with best-practice* by looking at the "best-practice" guidelines from leading organizations and for evidence based literature. (Vanhaecht & Sermeus, 2002)
Every et al. (2000) also indicate evaluating the current care processes and the use of evidence-based best practices as important. Vanhaecht et al. (2010) indicate that evidence-based key interventions and outcome indicators should be present. Scheuerlein et al. (2012) even developed a CP by using the current guideline as a guide for the development process.

2.3.1.3. Study phase

In this phase the information from the Do phase will be studied and used to review and further develop the pathway. Important is that the information gathered in the Do phase will lead to a *revised specification of the patient group* and *a second version of the pathway*. Besides that, the *planning and tuning of all processes* including the capacity and resources of the pathway will be worked out. For the latest, it is necessary to *evaluate the current capacity and resource plan* to come to an optimal patient flow in the future. Furthermore, *Service Level Agreements (SLAs)* about services of other practitioners and consultants need to be made such that the patient flow can be guaranteed and it must become clear who is going to *manage* the pathway.
The last and important part of the phase, is the *training* of all involved employees such that they are able to work according to the pathway and that it is clear to everybody how the path is used and when it needs to be followed. (Vanhaecht & Sermeus, 2002) Shi et al. (2008) furthermore state that the training is also to explain why the CP will be implemented and that the proper education method should be used. Every et al. (2000) also indicate the training as an important success factor.

2.3.1.4. Act phase

In this phase the pathway will become operational and a feedback loop will be made. It is important that the pathway is first *tested by a few patient*s, such that the test results can be processes into the *final implementable version*. This version can be *integrated in the information system and the patient files* (i.e. change the system such that the pathway is electronically supported). Note that the majority of the CPs are still paper-based, while there is a lot of potential for the faster and more efficient computerized CPs (Shi, Su, & Zhao, 2008). The necessary *agendas of supporting departments need to be centralized* (if not already), such that their services can be booked by the clinical departments. Furthermore, patients and employees need to have access to *information* about the pathway via the internet, intranet and/or brochures. (Vanhaecht & Sermeus, 2002)
It is important that pathways are *continuously evaluated by variance analysis and the initial indicators* (Every, Hochman, Becker, Kopecky, & Cannon, 2000; Vanhaecht & Sermeus, 2002; Vanhaecht, Panella, Zelm, & Sermeus, 2010)**.** Variances are documented by 'Charting by Exception', a method in which the variance from the pathway are documented using different codes that indicate the reason for the variance. Information about the feasibility and quality of the pathway can be obtained by this and used for improvements. (Graven & Hoekstra, 2006) Furthermore, data about the initiate indicators (set in the Plan phase) are measured, compared and given back to the clinical team for evaluation (Vanhaecht & Sermeus, 2002). The Leuven Clinical Pathway Compass, see Figure 5, can be best used here as a framework of pathway

indicators, since it is designed to be used at patient-group level. The Compass has five domains; clinical indicators including also functional indicators (pain, mortality, etc.) which can partly be found in evidence-based literature, service indicators (satisfaction, anxiety, etc.), team indicators (team effectiveness, job satisfaction, etc.) process indicators (waiting times, variances, etc.) and financial indicators (cost, length of stay, etc.). (Vanhaecht & Sermeus, 2003) The variance and indicator analysis together can be used for the *systematical feedback loop* to improve the care process. The specific feedback loop needs to be built by the owners. (Vanhaecht & Sermeus, 2002)

Also, de Vries et al. (2007) state that the effectiveness of the CPs is guaranteed by this feedback loop and recommend the use of the Compass. Shi et al. (2008) add that education should also be part of the continuously improvements. They furthermore state that attention should be paid to the psychological influence (i.e. it is important that patients and care providers recognize and trust CPs).

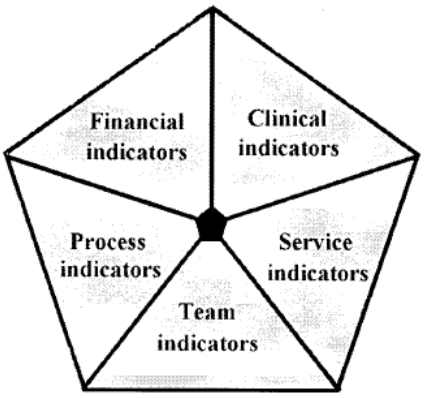


Figure 5 – Leuven Clinical Pathway Compass, source: (Vanhaecht & Sermeus, 2003)

3. DESIGN METHOD

Within this chapter the process modelling method for Care Pathways will be designed. First, an overview of the technique of process modelling will be given that describes why a new method is developed and at the same time notes which aspects of existing methods can be reused. Afterwards, the developed method layout will be discussed as well as the literature where the layout is based on.

Process modelling is a very broad concept and can be applied to all kinds of processes and result in many types of models. The technique is often used to solve problems, in which an AS-IS is modelled first and then the process can be improved by simulating a TO-BE, also known as Business Process Reengineering (BPR). This use of process modelling often has the same method structure, as all mathematical and computer modelling methods, and "*can typically be split into the steps of problem formulation, collection and analysis of data, model formulation, model construction, verification and validation, experimentation, analysis of results, conclusions and implementation. ... The modelling steps do not form a linear process but one which may involve many loops, and so the choice of model affects each of the steps."* (Brooks & Tobias, 1996, pp. 1-2) This approach cannot be followed for most pathways communication tools, since there is no problem to start with. Furthermore, these methods use properties of the process (e.g. processing times, arrival distribution) to build the model such that simulation can be run. Those properties need to come from the hospital data / patient file analysis, a very complex task to perform, as explained before. Besides that, our goal is not directly to simulate the model, but to use it as a communication tool. Therefore a different approach, than above, is needed to model Care Pathways.
Healthcare process modelling on the other hand wants models that are "*able to simultaneous track patients, resources and information, as well as model synchronous and asynchronous processes and their interactions.*" (Ramudhin, Chan, Benziane, & Mokadem, 2006, p. 1) Since Care Pathways are typically made for a specific patient group, one might ask if this tracking can be usefully used. If the tracking is for optimization, one needs to model all care pathways within a hospital (department) to make a good analysis. If it is to see where patients are located or by which step of the pathway they are, then it is useful information. However, then resources are not needed. The modelling of the processes and their interactions can be used in the same way for pathways as in healthcare modelling. Benyoucef et al. (2011) mentions the macro and micro level healthcare system modelling in which "*the macro-level represents system level processes such as patient flows through a hospital or through an emergency unit; while the micro-level represents processes at the individual patient care level. ... The micro-level is largely based on collaborative healthcare delivery consisting of multiple providers, locations, and information flows that span diverse organizations and groups".* (Benyoucef, Kuziemsky, Rad, & Elsabbahi, 2011, pp. 569, 573) According to them, it is quite important that the day-to-day clinical processes are adequately represented in process models. Since they are talking about systems, the link between processes and data flow are really important. But to make that link, first the process needs to be made clear. How that needs to be done is not described by Benyoucef et al. (2011).

Although the typical (healthcare) process modelling methods cannot be applied here, it is possible to use the knowledge they have developed. Especially, the specific healthcare sector characteristic and requirements regarding the process modelling method and model. The developed method layout exists of seven steps and will be explained below.

3.1. Define project

The first important aspect of a modelling method is to define the goals and objectives of the project to model a Care Pathway (Presley & Liles, 2001). This includes the specification of the Care Pathway, identify (key) stakeholders, defining the goals of the project, the translation of the goals into a set of requirements for the model and the indication of which resources are available for information gathering. In the next sections (3.1.1 to 3.1.5.), these five subjects will each be discussed.

3.1.1. Specify Care Pathway

As is the case for every process model that is going to be made, it is important to specify which process is going to be modelled. Within this method, that process is always a Care (or Clinical) Pathway and therefore the same specifications can be used as by the 30-step scenario (Vanhaecht & Sermeus, 2002); specify the patient group, time interval of the pathway and indicate the parameters (high volume, risk, costs and predictability) of the patient groups. The later specification can be used to control if the process is indeed a CP, but also to note which kind of CP as a method (or model) and as a product is meant here (see sections 2.2.1.3 and 2.2.1.4.).

3.1.2. Identify (key) stakeholders

Stakeholders are parties that have an interest in the project and are needed to define the goals of the project. Three kinds of stakeholders exist; direct, indirect and key. Direct stakeholders are "*people whose work processes, roles or vital interest are directly affected*" (van Aken, Berends, & van der Bij, 2007, p. 98) by the Care Pathway modelling project. Hospital staff within this category stakeholders are probably also the disciplines involved in the development of the CPs. According to Vanhaecht et al. (2006) this are mainly doctors and nurses, but due to differences per pathway and country also allied health professionals, (senior) management, GPs and/or patients can be part of the team. Indirect stakeholders are "*people who are to cooperate with the direct stakeholders"* (van Aken, Berends, & van der Bij, 2007, p. 98) and therefore are affected by the CP modelling project. These stakeholders need to cooperate with the direct stakeholder within the hospital, are cooperating outside organisations or have another indirect connection to the pathway and/or project. Key stakeholders are direct or indirect stakeholders that have a very high influence on the project.

An example of direct stakeholders can be found in the research of Hayward-Rowse and Whittle (2006) towards an electronic ICP for the Mother en Baby unit. The stakeholders were identified as all people of the disciplines service users or clients and their caretakers, nursing staff, allied health professionals, medical teams, administration staff, and students on placement in either the day, outpatient, inpatient or community service. The example of the Children's Obesity Care Pathway (0-4 years), where a broad development was chosen, shows a long list of direct and indirect key stakeholders (e.g. Paediatrician resp. director of Public Health), see Table 3.

3.1.3. Define project goals

After the pathway is defined and the stakeholders are identified, the goals of the project need to be set. Within this method, it is assumed that one of the goals is to use the model as a communication tool, as described in the introduction. For this, it needs to be defined which parts of the care pathway needs to be communicated. Is it only necessary to model the care activities of the pathway, or is it also necessary to include (bed) logistics, administration, and etcetera?

Key Stakeholders		
Public Health Strategists – Children and Young People	Head of Health Intelligence/Information	(Local Authority/Sport and Leisure Provider)
Managers of specific local obesity programmes	Public health dental health consultant/strategist	External providers of obesity services
Children's services commissioning lead	Professional Executive Committee representatives	Assistant/Associate Director of Public Health
Primary Care Trust Obesity Lead	Physical activity coordinator	Paediatrician
Director of Children's Services	General Practitioner	Community Food Team
Head of Maternity Services	Practiced Based Commissioning	Practice Nurses
Paediatric Dietician	Head/Director of Finance	PCT Social Marketing lead
Community Paediatrician	Head of Health Visiting	RPHG obesity lead
Physiotherapist	Head of Dietetics	Head/Director of Procurement
Infant Feeding Coordinator	Clinical Psychologist	

Table 3 – Key stakeholders of the Children's Obesity Care Pathway (0-4years), source: (Pheasant & Enock, 2010)

Other possible goals, also noted in the introduction, are to identify Key Performance Indicators (KPI's), to make structured patients files, to create checklists, to determine the completed pathway, to optimize the pathway or to make a workflow. For all these goals, it is necessary to specify sub goals, in order to be able to make a distinction what needs to be taken into account during the modelling project and what not.

3.1.4. Set model requirements

Based on the chosen pathway and the defined goals, the set of requirements for the model can be specified (Scheuerlein, et al., 2012). Part of the requirements are general for the sector and/or the purpose of modelling, the other part highly depends on the specific modelling case and its goals. The model requirements can be split into the quality of the process model, process visualization, granularity and the modelling language and will be discussed below. Note that the requirements of the different types can influence each other.

3.1.4.1. Quality of the process model

The quality of the process model can be determined using so called modelling guidelines. Depending on the goals of the model different guidelines are applicable. For a graphical model, the best fit for the goal of a communication tool, two basic guidelines can be applied. The first is of Becker, Rosemann and von Uthmann (2000), who recognized that modelling processes became more and more important and developed a framework for the evaluation of the quality of those process models from different viewpoints. The Guidelines of Modelling (GoM) consist of basic and optional Guidelines, see Table 4. A decade later, Mendling, Reijers and van der Aalst (2010) discovered that the usability of a model is strongly connected with the ease of comprehension (understandability, error probability and label ambiguity). They developed the seven process modelling guidelines (7PMG), see Table 5, as a recommendation on how to build a process model from scratch and/or for improvements. The goals of the guideline are that models are better understood by various stakeholders and contain less syntactical errors.

3.1.4.2. Process visualization

There is a lot of deviation in how processes are visualized. Theretofore, it is good to think about how the process should be represented with regards to the views & perspectives, the sequence and roles before the actual modelling starts. The results can be used as input for the decision of the language later on, see section 3.1.3.4.

Basic Guidelines	Optional Guidelines
Guideline of correctness This includes the syntactic correctness (consistent and complete against the meta model) and the semantic correctness (structure and behaviour of the model are consistent with the real world).	***Guideline of clarity*** The model must be readable, understandable and useful for the model user. This guideline is therefore very subjective.
Guidelines of relevance The model, modelling technique and objects need to be relevant.	***Guideline of comparability*** All guidelines within a modelling project should be used consistently, such that the model can be compared. This applies for example to layout and naming.
Guideline of economic efficiency This guideline forms a constraint to the other guidelines. For example the use of reference models, good modelling tools or the re-use of other models.	***Guideline of systematic design*** This guideline states that the relationships between the different model views should be well-defined. For example the relation between process and data models.

Table 4 – Guidelines of Modelling (GoM), source: (Becker, Rosemann, & von Uthmann, 2000)

Seven Process Modelling Guidelines
G1 - Use as few elements in the model as possible Larger models are harder to understand and the likelihood of errors becomes larger when models are larger. Therefore keep the model as small as possible.
G2 - Minimize the routing paths per element How more input and output arcs an elements contains, how harder it becomes to understand the model. Thus try to use as few routing paths per element.
G3 - Use one start and one end event If the model contains more start and/or ending points the risk of errors increases. Furthermore the understandability becomes more difficult. So, if there is only one start and one end event, the model is better understandable and the risk of errors is smaller. Furthermore, the model is then suitable for all kinds of analysis.
G4 - Model as structured as possible Every split connector needs to have a matching join connector, otherwise the model is unstructured and the change on errors is higher. Besides that, a structured model is easier to understand.
G5 - Avoid OR routing elements Having only AND and XOR-elements decreases the chance on errors. Aside from that, not all systems can deal with an OR-element.
G6 - Use verb-object activity labels The use of the verb-object style has proven to be more useful than other style (or no style at all).
G7 - Decompose the model if more than 50 elements This guideline relates to G1. The risk on errors is more than twice at large by models with more than 50 elements. Sub processes, according to G3, can be added and replaced with one activity in the main process.

Table 5 – Seven Process Modelling Guidelines (7PMG), source: (Mendling, Reijers, & van der Aalst, 2010)

3.1.4.2.1. Views and perspectives

The literature states that in order to clearly understand business processes, models should be made from different views (Lin, Yang, & Pai, 2002). At least four different distinctions between views can be found of which Presley and Liles (2001) mention three. The first one makes a distinction between the function, information, resource and organization views and originates from an article of Vernadat from 1992. The second one is quite similar and contains the four views defined in 1992 by Curtis et al. as the functional, which represents the process elements (consisting of objects, data, artifacts or products) that are performed. The behavioral which represents the allocating (e.g. sequencing) of the process elements and the related actions that are performed. The organizational view representing who and where in the organization process elements will be performed. The last view is the informational view representing the structure of information entities, which are produced by a process (like data or documents), and their relationships. (Lin, Yang, & Pai, 2002) The third version has five different views and was

developed in 1994 by Barnett et al.; "*The activity view defines the functions performed by the enterprise. The business process view outlines the time-sequenced set of steps making up the processes the enterprise uses to achieve its objectives. The organization view details how the enterprise organizes itself. The business rule view defines the entities managed by the enterprise and the rules governing their relationships. The resource view models the resources managed by the enterprise.*" (Presley & Liles, 2001, p. 568) The fourth distinction of views found is mentioned by Ramudhin, Chan, Benziane & Mokadem (2006) and note the function, information, organization, decision, economic and dynamic view.

Although the different views make sense, working according to them means adapting several modelling techniques and/or languages to make them (Presley & Liles, 2001; Ramudhin, Chan, Benziane, & Mokadem, 2006; Shen, Wall, Zaremba, Chen, & Browne, 2004). Men must thus ask if it is beneficial in achieving the project goals to model all the views. Ramudhin et al. (2006) coupled the views to the healthcare domain and concluded that it would be ideal if all relevant aspects, patients, healthcare providers, information and material, could be viewed in one view. Since there was no language that could combine these views, they developed a new language called MedBPM that could, see Figure 6. (Ramudhin, Chan, Benziane, & Mokadem, 2006)

Besides making different views, it is important to adjust them to the different stakeholders' perspectives. As the same model can be used for different purposes, different perspectives with other levels of details and representations would make the model more understandable (as in less complex) for the specific target group (Rad, Benyoucef, & Kuziemsky, 2009). Applying perspectives will also make the model more suitable as a communication tool, as redundant details can be left out. Note that the modelling language should be able to handle this feature and therefore the requirement '*Optimized models for different purposes*' is set in section 3.1.4.4.

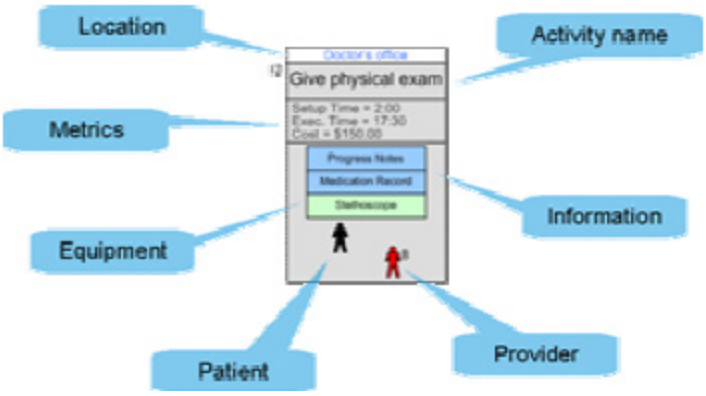


Figure 6 – A MedBPM activity; the activity 'give Physical Exam' occurs in the location 'Doctor's office', executed by a doctor (red stick figure) and the patient (black stick figure), with the use of the material, 'stethoscope' and two information documents 'progress notes' and 'medication record', source: (Ramudhin, Chan, Benziane, & Mokadem, 2006)

3.1.4.2.2. Sequence

The sequence of a model is the order in which events are put behind each other. In literature, many sequences can be found, of which only a few are applicable for the modelling of Care Pathways. Which one needs to be used depends on the specific CP and the goal of the project.

Care Pathways are standardized care trajectories that define what needs to be done, when, where and by whom. It is assumed that process steps in CPs have a causal predictable relationship, which means that "*activity A leads to activity B leads to activity C leads to a pre-known outcome*" (Joosten, Bongers, & Meijboom, 2008, p. 475). Theretofore, it is possible to make at least a chronological ordered model of a CP. If also the time aspect is taken into account, a time ordered sequence can be drawn. The business process view discussed above has a time ordered sequence, while by the behavioural view the type of sequence is not specified.

It can however be the case that there is no explicit chronological or time order in (parts of) the Care Pathway. For example, because the diagnosis part of the pathway has lots of options and/or different starting points. In that case a decision needs to be made between modelling the ideal pathway or to choose for the option to declare all (optional) elements separately and continue with the imperative model from the moment the pathway is similar for all patients. Another option is to define the imperative model on a day-to-day level with declarative activities per day. Although these combinations are hardly seen in CPs literature, it can provide the model more flexibility and a very realistic overview of the process.

3.1.4.2.3. Roles

The third important aspect of process visualization is about how to display the roles in the model. Care Pathways are teamwork and thus involve many different roles. All these roles have shared as well as individual tasks and tasks that can be done by other roles instead or involved additional roles. This means a high complexity of involved roles in the healthcare processes. The modelling language should be able to deal with all those different roles and their involvement in the process (see also peer-to-peer representation in Table 6). In BPMN for example, roles can be visualized by using pools, lanes or colours. Pools separate organizations and lanes organizational units. Colours are a newer visualization form, in which the different colours in activities indicate the involvement of different roles. Each role has its own colour and so the process can be visualized very clear. (Müller & Rogge-Solti, 2011)

3.1.4.3. Granularity

Granularity is "*the level of detail considered in a model .... The greater the granularity, the deeper the level of detail. Granularity is usually used to characterize the scale or level of detail in a set of data.*" (BusinessDictionary.com, 2013) In models the level of detail is about how detailed a system (e.g. a production line) is represented. The granularity or level of detail is indicated as an important aspect of the best model for the project and therefore of the successfulness of the project. (Brooks & Tobias, 1996) In practice there might be more than one perspective and/or view of the model for the project, as different actors involved in the Care Pathway require different views and levels of detail. For example, a model with a low level of detail gives a general view of the process for high level management, whereas a very high level of detail is needed for IT in case of system support. (Rad, Benyoucef, & Kuziemsky, 2009) Choosing the appropriate level is seen as a difficult thing to do and is more an art than a science (Brooks & Tobias, 1996). Nevertheless, there can be found indications how to choose the appropriate granularity.

The first indications found to determine the appropriate level of detail is to model as simple as possible while meeting all modelling requirements and goals (Brooks & Tobias, 1996; Jun, Jacobson, & Swisher, 1999). For example by starting with a very simple model and step by step adding more details until the model meets all criteria (Brooks & Tobias, 1996). In order words, exclude all details from the model that are of no interest to the model users (Presley & Liles, 2001). The level of detail wanted by the model end users can be found out by performing interviews with a beforehand created well-structured and comprehensive interview checklist. Based on the answers of the interviewees the appropriate level can be determined in the model formulation step, in which the conceptual model is made. (Shen, Wall, Zaremba, Chen, & Browne, 2004) Another way to determine the level of detail is to refer to other existing models, in which case comparison can be helpful by drawing the process (Brooks & Tobias, 1996).

In any case, the higher and lower level models parts should be aligned (Weidmann, et al., 2011). A way to do this, is to make use of sub-processes (Staccini, Joubert, Quaranta, Fieschi, & Fieschi, 2001), in which activities are split up in more details at higher levels of detail and bounded together at lower levels of detail. Besides that, it is important that the modelling language can deal with more levels of detail. Therefore, requirements related to the granularity and levels of detail are also included in the modelling language requirements.

3.1.4.4. Modelling language requirements

The last aspect of the model requirements is the modelling language requirements. The healthcare sector, as every other sector, has its own requirements regarding the characteristic of the modelling languages for meaningful usage. This is mainly due to the specific characteristics of the sector, but can also depend on the specific case and purpose of modelling. Although here predominantly the general requirements will be discussed, it is very important to properly set the specific case related requirements using literature and/or domain experts.

The general requirements for modelling healthcare processes are very well described by the following quotes. "*Processes span many disciplines, most involving complex sets of clinical activities. There is great variability from institution to institution depending on the clientele, the range of services offered and the technological infrastructure. Unlike a manufacturing production line, every patient has his or her own unique pathway through the system, which in most cases, cannot be entirely foreseen. Healthcare institutions are also subject to constant changes, for example, new clinical procedures, departmental reorganizations and new standards. Information is almost always spread across many systems, both paper and software based. Finally, a recent move towards integrated care has meant that processes are focused around the patient, while healthcare resources are in constant flow around this patient."* (Ramudhin, Chan, Benziane, & Mokadem, 2006, p. 1)

"In terms of business process modelling, healthcare is a rather complex sector of activity. Indeed, modelling healthcare processes presents special requirements dictated by the complicated and dynamic nature of processes as well as by the specificity and diversity of the actors involved in these processes." (Rad, Benyoucef, & Kuziemsky, 2009, p. 1)

"Micro-level models require explicit details about the data and communication flows that take place across processes and healthcare providers. ... Another requirement of BPM in healthcare is the need to design models to serve multiple purposes including systems design, education, evaluation of best practices, and communicating domain details between designers and stakeholders. ... Healthcare is a very dynamic domain and process exceptions are very common. So, models must be able to evolve through extensions to represent the changing needs of healthcare delivery. Finally, despite the automation of healthcare delivery, there are still numerous processes performed using multiple modalities (i.e. manual and automated). ... Those modalities will exist for the foreseeable future and therefore processes need to be modelled to represent them." (Benyoucef, Kuziemsky, Rad, & Elsabbahi, 2011, p. 571)

Further refinement of these descriptions into requirements has been done by Rad et al. (2009), who developed an evaluation framework for (service based business) process modelling languages (see Appendix B), and Benyoucef et al. (2011), who concluded with twelve features to assist with the selection of a methodology. The adopted requirements from these articles can be found in Table 6. Note that '*user understandability*' and '*easy of use*' are quite important by CP modelling, since the medical staff is the owner of the pathway and needs to be able to understand and work with the model. Besides that, '*exception handling*' is an interesting topic within Care

Pathways, because in practice deviations from the ideal pathway occur often. A realistic model of a CPs should therefore also deal with those deviations. Both, Rad et al. (2009) and Benyoucef et al. (2011) conclude that there is probably no language that meets all requirements. To solve this mismatch, two languages can be combined or the most suitable language can be chosen. Another option is to develop a new language, like Ramudhin et al. (2006) did.

General modelling language requirements	
Complexity of processes	Healthcare processes are complex because of the number of (sub) departments involved and the number of transactions between collaborating departments. Modelling these collaborations is rather difficult and not all languages are suitable for this.
User understand-ability	As in general the stakeholders need to be able to understand it. In the healthcare sector the medical staff is also stakeholder, since they are the ones working with the model and involved its optimization. Besides the modellers' creativity, the understandability of the model depends on the specific languages notations and representation of constructs.
Optimized models for different purpose	The modelling languages should be chosen such that the model can be adjusted to the different views/perspectives of stakeholders. This includes that the languages should be flexible in the level of detail and representation.
Evolution of processes	Healthcare processes are dynamic of nature and the modelling language should be representing this through exception handling.
Nested processes and integration	Different languages are often used for different departments, because the requirements fit better. It can be necessary to integrate or map different models. The language should be suitable for this.
Tool support	The use of modelling languages will increase if there is graphical tool support for them, especially within the healthcare sector.
Ease of use	The language should be understood by both the designers and the users (e.g. physicians, nurses, administrators, and other healthcare personal). Furthermore the language structure and syntax and the tool support determine how easy the language is to use.
Scalability	Complex processes between different groups and organizations, which involve various tasks, many data and lots of people, are in place in healthcare. Furthermore, the sector is very dynamic and changing constantly. So, the modelling language should be scalable to deal with the growing nature of the sector and to be able to add new features and components.
Abstraction	The language should have the ability to focus on abstract levels, while hiding detailed information.
Exception handling	Exceptions in healthcare are very common and therefore models should be able to deal with them. Note here that although there are ideally no exceptions within the pathway, deviation can occur.
Peer-to-peer representation	Collaborations are part of the healthcare sector and care delivery by teams is a characteristic of CP. The language should be able to represent these collaborations.
Reusability	The ability to model processes with a relatively small number of reusable modelling constructs will lead to less avoid needed when models need to be re-built and/or re-used for similar situations.

Table 6 – General requirements for the modelling language, adopted from: (Rad, Benyoucef, & Kuziemsky, 2009; Benyoucef, Kuziemsky, Rad, & Elsabbahi, 2011)

3.1.5. Identify available information resources

The last step of the project definition is to sum up all available information resources that can be used as input for the modelling. Information resources can be documents, systems, (medical) experts and patients. Five examples are given here to indicate which information resources there are and how they are used in the modelling process. See also the 30-step scenario discussed in section 2.3.1. for an overview of possible available information used or produced during the pathway development.

Example 1: Vissers (2006) developed a logistic demand-supply model for hospital processes, which has on the demand side descriptions of the trajectories of patient groups structured using the model as a process chart. These trajectories are described during the important 'mapping and analyzing the patient processes' step using input from (expert opinions of) medical specialists and information on examinations and treatments. He states that it is obvious that medical specialists play an important role in describing these processes, since it is about their core activities. Besides that, involving medical staff is needed to get all data, since the information systems will not provide systematic information on processes. In order to get the process, all steps taken by patients need to be followed (e.g. waiting times and diagnostic and therapeutic procedures during admission).

Example 2: During the development of pathways, a walk-through can be part of the patient survey during the Do-phase to map and evaluated the current situation in the hospital. During a walk-through the researcher will observe the patient during the whole process, and the observed data will be notated on an observation list. This gives the researches a good overview what happens during the process and if it is done by enough patients the figures will be representative. Hoekstra et al. (2006) used this walk-through method to improve the current pathway and therefore looked at the process during the admission, especially with regards to time. An observation protocol was made in advance which included the goals, focus points for patients and researchers, as well as a guideline, such that all observations were done similar. Researchers were not allowed to enter the examination room and could not intervene in the process (e.g. if the patient was send to the wrong clinic, this was not corrected). Also the observation list used here was made in advance and contained only the key interventions of the process. All process times where noted as well as the (subjective) experience of the patient. (Hoekstra, et al., 2006)

Example 3: Panis (2008) did research on the improvement of the clinical pathway of tube feeding in the VU University Medical Centre Amsterdam (VUmc). The VUmc uses their own 10-step plan, derived from the 30-step scenario of Vanhaecht & Sermeus (2002), for the development of all their CPs. This plan includes also a description of the current situation drawn as a flow chart to conclude the plan phase. Here this is done based on the file analysis and patient satisfaction questionnaire conducted in the 'objectify / baseline measuring' step. (Panis, 2008)

Example 4: Wit, Schaap & Umans (2011) developed a CP for frail elderly cardiac patients within the Medical Centre Alkmaar and theretofore took into account the guidelines of the Dutch VMS Public Safety program 'VMS veiligheidsprogramma' to ensure patient safety. Within the development process the current situation was accessed through a focus meeting including all multidisciplinary caretakers involved.

Example 5: A discrete event simulation model for ocular hypertension was built on the basis of the NICE (National Institute for Health and Clinical Excellence) guidelines, literature and in consultation with clinical experts, service users and the DCE (a Discrete Choice Experiment with an advisory panel and a focus group) by Burr et al. (2012).

3.2. Plan project

Based on the project definition, requirements and the available information resources, the project can be planned. The plan includes the modelling approach and the according timeframe of the different steps. The modelling approach includes a specification of the modelling language and tool used and which information resources will be involved.

The modelling approach can either be top-down or bottom-up or a combination of the two. By a top-down approach first the overall model will be drawn, before the details of the lower layers

will be filled in. The bottom-up approach starts with all detailed activities and builds from that the overall model. A combination of the two will start with the overall model of the top-down approach, but fills in the details from a bottom-up approach. In literature all three approaches can be found for modelling various healthcare processes.

3.2.1. Example of Top-down approach

Scheuerlein et al. (2012) developed a computerized BPMN model for the treatment of colon and rectal cancer with the use of the t.BPM method where possible. The development was done by a five-headed team trained on using BPMN. According to Scheuerlein et al. (2012), the use of the BPMN language and the t.BPM method in healthcare is similar to the use in industry. t.BPM is a method in which the BPMN symbols are made tangible and used to construct an outline or raw model, by putting the symbols on a paper sheet. The constructed model can later on be computerized. More information on the t.BPM method is explained in the articles of (Grosskopf, Edelman, & Weske, 2010) and (Edelman, Grosskopf, Weske, & Leifer, 2009).
The project started with defining the requirements, followed by the definition of the scenarios (specific cases) with the use of t.BPM. Then the structure and individual design were developed. During the development and for the fine-tuning, numerous interviews with medical, nursing and administrative staff were done. Depending on the situation outline models were developed by the core team or together with the staff using t.BPM. The interviews had a similar structure "*What is the content of the process step? Who is responsible? What pre-requisites and resources are required? Are there hiccups or peculiarities?*" (Scheuerlein, et al., 2012, p. 757). To make a realistic model, the modelled processes were continually reviewed to reach a consensus within the team. Afterwards the model was tested and if possible simulated (and optimized).

3.2.2. Example of Bottom-up approach

A simulation–based modelling framework to deal with Clinical Pathways was developed by Ozcan, Tàfani & Testi (2011) to identify critical activities and scarce resources to come to the process bottlenecks from both patient-centred and facility-centred points of view, see Figure 7. Besides that, the framework integrates different modelling techniques (project management, simulation and optimization) and is applied to a case study towards the thyroid surgical treatment.
For the modelling of a CP communication tool, the focus is on the upper part of the framework and the corresponding step. The goal of this step is to identify the flow process and the clinical pathway. First, the fundamental activities that make the process integrated need to be identified. This is done by making, with the clinicians and personnel involved, a flow chart of the clinical path of patients according to a given pathology. The gathered information can then be used to identify the CP and start the project management modelling. This contains four

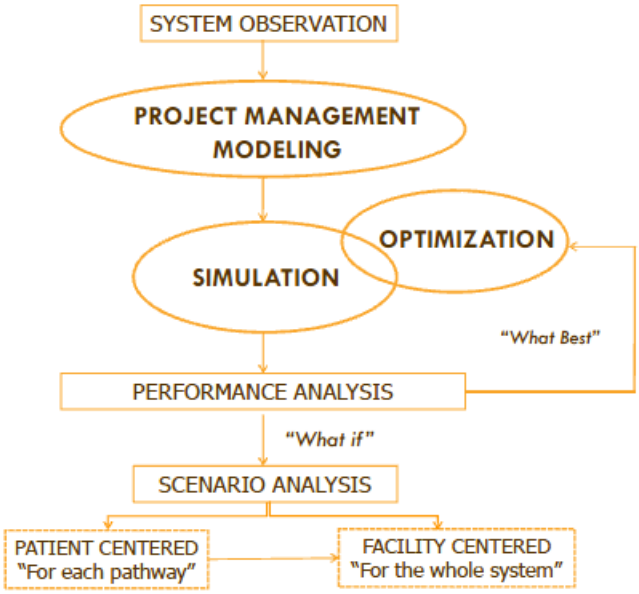


Figure 7 – Modelling framework to deal with Clinical Pathways, source: (Ozcan, Tànfani, & Testi, 2011)

parts; (1) identification of activities, (2) identification of relationships among activities, (3) identification of time requirements for the activities (deterministic and probabilistic), and (4) identification of the path(s) for care delivery and its duration. The researchers argue that the project management approach helps to conceptualise the pathway and align how patients flow through the treatment process. (Ozcan, Tànfani, & Testi, 2011)

3.3. Make layout model and different views

In this step a layout of the different views of the model will be made, as in the modelling approach that combines the top-down and bottom-up approach. So, the specification of the pathway and the identified available information can be used to make the layout model. Of the available information, the clinical guidelines and if present the official pathway documents are the most suitable for modelling the necessary care processes. In the Netherlands clinical guidelines are very common and often compulsory and will therefore be available and probably also be used as a basis for the CPs under investigation.

3.4. Fill in all details in the layout model

When the layout model is made, it is time to start filling in the details of the model. Note that some details can already be put in the model during the layout step. According to the project plan the information will be gathered and processed in the model. When the layout is made with the official pathway documentation and the clinical guidelines, details can be gathered through interviews with all involved disciplines and if available patient leaflets from or used by the hospital. Semi-structured interviews, well-structured and comprehensive interview checklists and/or t.BPM can be used here. Besides that, new information can lead to renewed decisions about the process visualization aspects.

3.5. Make stakeholders' perspectives

When the details are filled in, the different stakeholders' perspectives can be made. Which perspectives need to be made is defined in the project definition, including which information each perspectives requires. The perspectives are necessary for the goal as a communication tool, but also for the validation of the model and should easily lead from the entire model.

3.6. Verify and validate model

The last but one and perhaps most important step of the method is the verification and validation of the process model. This is so significant because the process model should represent a realistic picture of the real world.

There is no consistency in the literature concerning the definitions of verification and validation, but here the following definition will be used. "*Verification means the process of testing whether the model is working as intended, and validation means the process of comparing the model output with historical data."* (Brooks & Tobias, 1996, p. 2) Verification can thus be done by checking if the model fulfils all requirements. Validation on the other hand needs to be checked, according to this definition, against medical records. These records however are not always available or suitable for this purpose. In these cases, validity can also be proved in others ways; by asking medical staff if the model is correct, by running simulations and/or by conducting a walk-through with patients. Note that in case the goal of the project requires an executable model as an output, this step also contains experimentations to validate the model. Heretofore

knowledge of the BPR field can be use. No matter which validation technique is used, it is important that the process model defined from one information resource is also checked with another. This way it is possible to check whether the process model represents a realistic overall picture or a biased one (e.g. an individual view of a medical expert or of the whole discipline).
The research of Da-Hua (2009) clearly states how the validation and verification of their 8-tuple Clinical Path Net (CPN) model has been done. The authors note the importance of a good model, which they ensured by first applying modelling the clinical diagnosis and treatment path with a Petri-Net, where each step of the path is an activity of the workflow in the model with the corresponding role. Then they let medical personnel verify the model and afterwards the model was simulated to check the performance of the system. However, they stated that the establishment of the model is more crucial, since it provides "*a strong guarantee for qualitatively and quantitatively analyzing the hospital medical treatment processes, and optimizing the diagnosis and treatment programs, reducing health care costs and increasing the cure rate of patients*." (Da-Hua, 2009, p. 1132)

3.7. Refine model

It is very well possible that in the verification and validation process new information comes to light that shows incompleteness of the model. This feedback needs to be used to refine the current model. Refinement can be done by restarting the modelling process from step 4 – 'Fill in all details in the layout model' and continuing the cycle until the verification and validation shows that the model is complete and correct.

4. CASE STUDY

Based on the method describes above, a case study was conducted at the heart centre of the Catharina Hospital Eindhoven (CHE). In this chapter a broad description is given of each of the steps performed. The resulting model is explained in the next chapter.

4.1. Define project

The object of this case study is the treatment of patients with Unstable Angina (UA), also referred to as NSTEMI, at the CHE. Unstable Angina is a disease in which a stenosis of the coronary arteries has occurred (arteriosclerosis) that causes a reduced blood flow through the arteries. Because of this, a hypoxia (lack of oxygen) of the heart muscle occurs, which feels like a tiredness on exertion or chest pain. In the case of UA, chest pain can also appear during rest as sudden cloths in the arteries and/or spasm of the arteries can occur.

At the time of this study the Catharina hospital worked with five Care Lines[2], in which the treatment of UA was imbedded within the Coronary Care Line. Although there is no Care Pathway in place here, as defined in chapter 2, the case is representable as the care trajectory has been standardized through the Coronary Care Line and Acute Coronary Syndrome (ACS) protocol in place in the hospital and the (inter)national applicable clinical guidelines for NSTEMI. The Coronary Care Line covers agreements about the allocation of patients between the different departments and units of the heart centre and medical decision trees, like the ACS protocol. The ACS protocol covers the triage, start of medication, timeframe for the catheterization (CAG) and points for discharge of all ACS patients (patients arriving with chest pain) were either STEMI or NSTEMI has been confirmed (see Appendix I). The medical decision points between the CAG and discharge are however not documented, as well as many other medical activities. The official clinical guidelines (Hamm, et al., 2011) form a basis for the care given during the entire hospitalization by both the physicians and nurses. The medical staff strongly believes that they have developed a standardized way of working, based on these documents and their many years of experience.

4.1.1. Specify Care Pathway

The Care Pathway of UA starts upon the arrival of a patient with acute chest pain without a persistent ST-segment evaluation (NSTEMI) at the hospital and continues until departure. The typical UA patient can be defined as having *"rather persistent or transient ST-segment depression or T-wave inversion, flat T waves, pseudo-normalization of T waves, or no ECG changes at presentation."* (Hamm, et al., 2011, p. 3004) The entire hospitalization is between one and nine days, depending on the nature and severity of complains.

The parameters (high volume, risk, costs and predictability) of the UA patient group are not defined for this case study by the hospital, but can be found within the clinical guidelines and by the research done. The volume of the Care Pathway is approximately 2000 patients a year, leading from the facts that the annual incidence is ~3 per 1000 inhabitants (Hamm, et al., 2011) and the estimated service area of the CHE heart centre for UA as the area of Brabant-Southeast that counts over 720.000 inhabitants (Veiligheidsregio Brabant-Zuidoost (VRBZO), 2010; RIVM, 2010). The involved risks are rather high as cardiovascular diseases are the main cause of death in the western world, of which coronary artery disease (CAD) is the most common one.

[2] Care lines are a broader concept than Care Pathways, as one Care Line contains multiple Care Pathways.

"*Patients with chest pain represent a very substantial proportion of all acute medical hospitalizations in Europe. Distinguishing patients with acute coronary syndromes (ACS) within the very large proportion with suspected cardiac pain are a diagnostic challenge, especially in individuals without clear symptoms or electrocardiographic features. Despite modern treatment, the rates of death, MI, and readmission of patients with ACS remain high."* (Hamm, et al., 2011, p. 3003) UA and NSTEMI patients are furthermore also more vulnerable as they tend to be older and have more comorbidities, especially diabetes and renal failure. The general in-hospital mortality rate is 3–5%, but the 6 months mortality rate is 13%. (Hamm, et al., 2011). The involved costs of the treatment (see also Appendix C - Table 24) as well as the treatment plan itself, strongly depends on the nature and severity of complains. The treatment of UA patients is always foreseeable for the near future, as the next step within the treatment of a standard patient can be determined based on the already present information about the nature and severity of complains. This operational pathway is thus a form of the customized CP as a method. This is linked to a hub model in the literature, but here a chain model is wanted. For the treatment of non standard patients (patients with co-morbidities) adjustments of the standard care trajectory or even case management might be required.

The model that will be made in this case study will cover the care trajectory of the entire hospitalization for standard Unstable Angina patients (including both conservative and invasive treatments). Furthermore, where possible the standard adjustments for co-morbidities are taken into account, as well as indications to withdrawal patients from the pathway.

4.1.2. Identify (key) stakeholders

The direct stakeholders of the modelling project were identified as the two groups that needed to communicate; the small group of researcher of the Eindhoven University of Technology (TU/e) and the medical professionals of the Catharina Hospital Eindhoven. Which medical professionals belong to this group, was determined by a stakeholder analysis of the CP of UA. This same stakeholder analysis was also used to determine the indirect stakeholders of the project within the hospital. Aside from the hospital, the only indirect stakeholder is the 'scientific world'.

To identify the stakeholders of the CP, first information was gathered from the clinical guidelines, the 'VMS Safety program' and different patient brochures (see also section 4.1.5. for the used information sources). The resulting list was revised after talking to the different roles within the hospital during the information gathering. The direct stakeholders were identified as roles that are directly involved in the medical treatment of the patient group during the hospitalization (see Appendix D - Table 25). Note that not all departments are involved in every assigned pathway; cardiology is always involved, cardiothoracic surgery only in case of a (possible) bypass operation (CABG) and the operation rooms (OR) and intensive care (IC) only in case the CABG is performed. Beside these, a few additional departments are involved for specific sub groups of patients (noted with a star (*) in the list). Roles that support this medical treatment, like receptionists and department heads, and other types of stakeholders within and outside the hospital were noted as

	Key Stakeholders
Direct	TU/e researchers
	EHH nurse
	CCU nurse
	7 west nurse
	7 west nurse practitioner
	Cardiologist
	Intervention Cardiologist
	6 west nurse
	6 west nurse practitioner
	Cardiothoracic surgeon
	Anaesthetist
Indirect	Medical head of Cardiology
	Medical head of Cardiothoracic surgery
	Department manager EHH+ CCU+ HCK
	Quality and safety department

Table 7 – Key stakeholders of the Care Pathway modelling project of Unstable Angina at the CHE

indirect (see in Appendix D - Table 26). Note that the list of direct and indirect stakeholders is also very important for the modelling process itself, since representatives of roles can be used as an information resource and can assist with goal setting.
The key stakeholders were identified as the TU/e researchers and the key stakeholders, the most important roles involved in the medical treatment and behind the scenes, of the CP. An overview of the key stakeholders is provided in Table 7.

4.1.3. Define project goals

Within this research, the most important goal is to come to a model that is applicable as a communication tool between the involved medical professionals of the CHE and TU/e researchers. Between medical professionals the model can be used to provide an overview of the different care processes within the (sub) departments, such that the whole process can be understand and if needed aligned and/or optimized in the future. For the researchers the goal is to get a deep understanding of the entire care process. This because in the future, the same care trajectory will be used as a case study towards pathway monitoring. Theretofore, the model needs also to be applicable for the mapping of patients to the pathway, such that the completed pathway, the deviations from the pathway and the specific category of UA patients can be determined.
These goals are however very global and do not state anything about what needs to be in the model and what can be left out. In order to scope the project more, a deeper look was taken into the future monitoring usage. For this application, it is very important to define which performance needs to be measured. Since performance measurements, also called Key Performance Indicators (KPI's), can be linked to different processes in the care trajectory, it can tell us which processes are especially of interest to the researchers. Note that only KPI's that can be directly linked to the time frame of the hospitalization are taken into account here.
As stated before, pathways can be evaluated by KPI's set by the hospital based on the five domains of the Clinical Pathway Compass (Vanhaecht & Sermeus, 2003) and through the national and international (mandatory) indicators described. In order to find out which indicators where set by the hospital, information was gathered within the finance and quality and safety departments (see Appendix C) and the heart centre. It happens to be the case that there are no financial indicators set, but it is important to open and properly check the DOT[3]. At the moment of this research, the CHE only needed to measure the three criteria of the VMS safety program, of which two are applicable for UA (VMS Veiligheidsprogramma, 2010). Besides that, the hospital had defined five KPI's in the context of the 'Meetbaarbeter'-project for the procedures of PCI (catheterization) and CABG (bypass operation) that are measurable within the time frame of the hospitalization (van Veghel, van den Bosch, Dekker, & Tonino, 2012). Furthermore, notion was taken that KPIs were listed by the hospital for the development of the current operational Care Lines. Unfortunately, this list of KPI's was not available. From these sources a total number of seven KPI's were listed. Because this seemed an unrealistic small number, we adopted KPI's about UA/NSTEMI (pathways) from literature and stated by the direct stakeholders within the hospital. An overview of all included KPI's divided according to the Leuven Clinical Pathway Compass (Vanhaecht & Sermeus, 2003) and linked to the different phases of the process is provided in Appendix E – Table 27.

[3] DOT is in Dutch 'DBC op we naar Transparantie' literally translated 'DBC towards transparency', where DBC in Dutch stands for 'Diagnose Behandel Combinatie' and is translated in English 'Diagnosis Treatment Combination'.

Besides looking at the KPI's, a second look was taken to the concept of Care Pathway. CPs are about patient-focused organized care (instead of specialist-focused) and thus a patient perspective to represent the care trajectory within the model seemed a logical choice. Combining the listed KPI's with the patient perspective, lead to the inside that only the care activities (tests, medications, surgeries, rounds) that are specifically conducted for this patient group needed to be included in the conceptual model. This meant that the model will not be able to simulate and that all logistical operations (beds logistics, planning OR / HCK / research), nutrition moments, visiting hours and shift handovers will not be included. Logistical operations are influenced by multiple factors outside this pathway and thus can only be understood if the whole picture is given. Nutrition moments, visiting hours and shift handovers belong to the daily routine of the hospital departments and are therefore not included.

4.1.4. Set model requirements

With the specification of the pathway and the defined goals, it was now possible to set the model requirements. As the method describes, the model requirements can be split into the quality of the process model, process visualization, granularity and the modelling language. Each of the subjects will be discussed now separately.

4.1.4.1. Quality of process model

Since a conceptual process model needs to be made, no other guidelines are applicable then those of Beckers et al. (2000) and Mendling et al. (2010) described in the method.

4.1.4.2. Process visualization

The process visualization will be discussed here in the separate parts of the views and perspectives, sequence and roles.

4.1.4.2.1. Views & perspectives

The goals of the model state that a realistic overview of the care process needs to be made in the form of a conceptual model. This can be done by working out the behavioural view as defined by Curtis et al. in 1992 or the business process view as defined by Barnett et al. in 1994, since this type of views show the care steps of the process and their sequencing. For the healthcare sector, it is important to also know where process elements take place. So, the behavioural / business process view needs to be combined with the organizational view described by Curtis et al. in 1992. Besides that, it is good to also make the organization view defined by Barnett et al. in 1994 with regard to the involved medical professionals, such that it also becomes clear how roles are related to each other. Note that all involved roles are already listed as stakeholders.
Aside from the different views, different perspectives need to be made for the direct key stakeholders of the modelling project within the hospital, as the TU/e researchers need the entire model. Which perspectives needed to be made was decided during *step 5 – Make the different perspectives* of the method, since it was not clear yet how the different stakeholders cooperate. Note that the department manager and quality and safety department do not belong to the target group of this communication tool, as they neither belong to the medical professionals nor the researchers. Therefore, no separate perspective was made for them.

4.1.4.2.2. Sequence

For the sequencing of the care processes a chronological order was chosen, such that the standard building blocks of the customized CP as a method can be compound according to the actual timing. For example, a catheterization is done within 120 minutes by patients assigned to an urgent invasive treatment and within 72 hours by patients assigned to an invasive treatment. The timing of the care is different for the groups, but the treatment options afterwards are the same.

4.1.4.2.3. Roles

The decision how to represent the different roles within the model was postponed until step 4 of the method, because it was not yet known if all direct stakeholders are also of significant influence during the care trajectory (i.e. needed to be noted in the model). Furthermore, the complexity of the care process was not known yet.

4.1.4.3. Granularity

The granularity of the model was very hard to determine beforehand, because all details of the care process were still unknown. What could be set beforehand is that the model will contain a top-level, in which an overview of the different phases of the CP is given, and at least one sub-level, that shows the process within the different phases. Furthermore, it could be determined from the goals that it was not necessary to model until the level of detail of 'movements' (i.e. '*nurse y gives medicine x*' instead of '*nurse y walks to the medicine cabinet, picks medicine x, walks back to the patient, gives water and medicine x*'). For medicine, on the other hand, it is important to note specifically which medicine of a group of medicine is prescribed, as the KPI's clearly indicate usage percentage of different medicines. Besides this, no further details about the granularity could be and were set here.

4.1.4.4. Modelling language

The method already describes a good and complete set of modelling language requirements (see Table 6). The only requirement with a doubtful applicability for this research is '*Nested processes and integration*', since there is no goal to integrate or map the model. Furthermore, there were no models to map with and the EPR system was not included in this project. This does however not mean that the model should not be easy to work with for further applications. Aside from this, the most important requirements are those of the understandability of the process model.

4.1.5. Identify available information resources

The available information resources for this research can be split up into the categories of clinical guidelines, documented work processes, patient brochures, medical professionals, non medical professionals and hospital records and system. Each type of resources will be discussed here separately. Note that the category of patients is not mentioned here, as they were off-limits.

4.1.5.1. Clinical Guidelines

The Dutch association of Cardiology 'Nederlandse Vereniging voor Cardiologie (NVVC)' refers to the ESC Guidelines of NSTE-ACS (Hamm, et al., 2011) for the treatment of patients with UA. The guideline advises on the 'optimal' treatment of patients, based on their interpretation of clinical researches categorized in three classes of recommendations and three levels of evidence.

As the medical professionals state that they follow the guidelines, it can be assumed that at least the first class recommendations are implemented. The guidelines give no information regarding the involved roles, admission processes, (bed) logistics and finance. Note that guidelines for specific procedures (CAG, PCI and CABG) are not mentioned here, to avoid very specialistic details of the interventions and operation within the model of an entire care trajectory.

4.1.5.2. Documented work processes

There are two available documents about the work processes of this pathway; one of cardiology and one of cardiothoracic surgery. These are important resources for the modelling as they tell how the process works. The ACS protocol (see Appendix I) contains the important decisions needed to make during the triage and the process of the start of medication and catheterization scheduling. Furthermore, some general important notes are made on the last page, especially about the discharge. It however does not contain any roles, admission processes, (bed) logistics, finance and many details about how the process works. The work processes of the nursing ward of Cardiothoracic Surgery (CTC) are represented in basic flow chart for all CTC patients and show information about the flow of the process, tasks details, involved resources and the daily routine of medical professionals. Note that this document became only available during the information gathering within the CTC department during step 4.

4.1.5.3. Patient brochures

The goal of patient brochures is to inform patients about the treatment they will undergo and/or to advise them on the living rules after the operation. They often provide a general view of the care processes, but more importantly about the roles involved. Patient brochures can be found on the concerning departments and might also be available online. Aside from the hospital brochure, the national Dutch 'Heart Association' also provides a lot of information about heart diseases, treatments and living rules in patient brochures available in the hospital and online. A list of all included patient brochures from the Catharina Hospital Eindhoven and the 'Heart Association' and their sources can be found in Table 8. Note that the 'Heart Association' has many more brochures related to UA, which are quite similar to the hospital brochures and therefore not included. Besides the 'real' patient brochures, information about the disease can be searched on internet (for example via Google).

Document	Source
Brochure of *hartrevalidatie* of the CHE	(Catharina Ziekenhuis, 2012b)
Brochure of *hartkatheterisatie leefregels na het onderzoek* of the CHE	(Catharina Ziekenhuis, 2012c)
Brochure of *Coronary Care Unit* of the CHE	(Catharina Ziekenhuis, 2010a)
Brochure of *een hartoperatie informatie rond u opname* of the CHE	(Catharina Ziekenhuis, 2012a)
Brochure of *PCI-behandeling* of the CHE	(Catharina Ziekenhuis, 2010b)
Brochure of *opnamewijzer* of the CHE	(Catharina Ziekenhuis, 2013b)
Brochure of the '*hartstichting*' about Angina Pectoris	(Hartstichting, 2012)

Table 8 – List of included patient brochures for the care trajectory of Unstable Angina and their source

4.1.5.4. Medical professionals

For this case study the hospital has provided the opportunity to be a guest on the work floor of the Cardiology department for one week. This meant that the work 'behind the screens' on the nursing wards could be observed, since patients rooms and intervention labs were off limits, and that there was access to medical staff. Observations could thus give inside into all processes on the working floor of the wards; from clinical to logistics excl. any finance matters. Interviews

could provide detailed information about the processes and the decisions made within the treatment. Outside this week, medical staff of the cardiology could also be contacted for interviews.
From the cardiothoracic surgery department, responsible for the care trajectory of the bypass operation, one nurse practitioner from the nursing ward of this department was available. This nurse practitioner is also responsible for the CTC work processes and therefore has a lot of knowledge about the care trajectory. Besides that, an opportunity was provided to observe a bypass (CABG) operations from holding to intensive care, during which questions could be asked. Furthermore, an Anaesthetist was available for questions.

4.1.5.5. Non medical professionals

The non medical professionals of the quality and safety department and finance department could be important to gather information about the KPI's and the financial administration behind the care trajectory. As both these departments were not directly involved in the project, they needed to be contacted independently. This resulted in both cases in an appointment, of which a summary can be found in Appendix C.

4.1.5.6. Hospital records and system

The hospital system (EZIS and Gaston) that the Catharina Hospital uses is not made available for this research, although it could have been. This is because earlier research concluded that there is too limited information about the process decisions in the patient files and instead observation could be done (Peeters, 2013). Besides that, a short introduction of the complex system learned that many record fields of the cardiology department were free text and therefore information could be noted in several fields. This would have made it difficult to process the data, and in addition it was told that it is very hard to extract data from the records.

4.2. Plan project

Now the project is defined and all requirements have been set, it is time to make the project plan. As the method advises, a top-down combined bottom-up approach was used here and thus all described steps apply. A broad description of the execution of the steps is discussed in the next sections (sections 4.3 – 4.6). Before the planning is noted, first the choice of the modelling language and tool are discussed.

4.2.1. Modelling language and tool

First of all, the modelling language for this project is BPMN 2.0, as it fulfils all requirements set and is seen a de-facto standard within the field (Müller & Rogge-Solti, 2011). The language can deal with the *complexity of healthcare processes* and the *peer-to-peer representation* through the use of pools and swim lanes or choreography and with *evolution of processes*, *exception handling* and *scalability* through all different included (intermediate) events and artifacts. Besides that, with the use of sub processes and a proper tool the requirements of *optimized models for different purposes* and *abstraction* can be fulfilled. Furthermore, there is enough *tool support* for the language and it is also possible to translate the language to other standards (*nested processes and integration*). Last and most important, the *user understandability* and *ease of use* is very high, as the development of the language was focused on these aspects. "*BPMN by the OMG3 is designed to be understandable by both business professionals and IT-specialists. The explicit design for non-technical users makes it a promising candidate for healthcare*

process modelling, where medical staff needs to understand and discuss the process models." (Müller & Rogge-Solti, 2011, p. 66)

There are many tools that support the modelling of BPMN 2.0, but it is very important to choose a proper one. In this case, the tool needs to be user friendly, able to export the model and to support the work with sub-processes, intermediate events, different views and perspectives and pools and swim lanes. Aside from that, it would be nice if the tool can make an overall model and/or show sub processes on higher levels automatically, but this is not required. After an internet search, four tools were selected based on their online information and needed to be tested. The first tool *Altova Umodel* is according to their website very suitable for the creation of different views and perspectives, but was found to be not user friendly at all. *Interfacing BPMN modeler* is very strong in the generation of swim lanes and flat maps, but it is not possible to adjust the flowcharts to different perspectives. Furthermore, the tool always requires an attached resource and that hold backs the modelling of clinical guidelines. The last tool tested and also chosen to use, is *Signavio process editor academic initiative*. The tool can make business process, conversation and choreography diagrams and organization charts. Furthermore, it supports the use of sub processes, gateways, many event types and pools and swim lanes. Besides that, it is possible to make different perspectives with the tool, but not to make an overall view of the model automatically. The tool is very user friendly and is used before by Scheuerlein et al. (2012) to model healthcare processes. The fourth tool *Magicdraw business modeller plugin* was not installed, as it was already known to fit the requirements less (no perspectives features).

4.2.2. Project planning

Before the modelling project started an introductory meeting was held, in which the project supervisor within the hospital (an Anaesthetist specialized in cardiology) and the small group of researcher met. During this meeting, the main cardiologist regarding this pathway was also met. Shortly after the meeting an introduction to the medical record system was given by a cardiologist in training as part of the research preparations. After that, a couple of preparation meetings were held with the supervisor and the researchers. At the end of the preparation phase, the actual modelling project planning was made and discussed with the supervisor, see Table 9. Due to the summer season (holidays and work pressure) and a higher modelling workload, the project was eventually realized with a five weeks extension, see Table 10. Note that also the documentation of the model is included in the 'verify and validate final model' phase.

4.3. Make layout model and different views

The layout model was made on the basis of the clinical guidelines (Hamm, et al., 2011) and adjusted according to the ACS protocol of the CHE (see Appendix I), as the CTC work processes were not available yet. The clinical guidelines provide information about the entire care process, but also leave a lot of options for practitioners. The protocol provides specific information about

Planning		Tasks
Week 26-27	June 24 – July 5	Search for guidelines Make layout model
Week 30	July 22 – 26	Observation week at Cardiology and make detailed model
Week 31	July 29 – August 2	Make different stakeholders' perspectives
Week 32	August 5 – 9	Verify and validate model
Week 33-35	August 12 – 30	Refine model (over and over again)
Week 35-36	August 26 – September 6	Verify and validate final model

Table 9 – Original project planning of modelling project

Planning		Tasks
Week 26-27	June 24 – July 5	Search for guidelines, read guidelines and make layout model
Week 30	July 22 – 26	Observation week at Cardiology Appointment with finance department
Week 30-31	July 22 – 31	Make detailed model based on observation week
Week 32-33	August 8 –15	Appointment with quality and safety department Interview with main Cardiologist and refine model
Week 34-36	August 21 – September 6	Interviews and observation at Cardiothoracic Surgery and make detailed model
Week 37	September 9 – 12	Reduce size of the revascularization and hospital discharge diagrams and make different stakeholders' perspectives
Week 38-39	September 13 – 20 October 2 – 13	Verify and validate model and refine model

Table 10 – Realized project schedule of modelling project planning

parts of the process in this hospital. Therefore, the guidelines and the protocol complete each other; the guidelines can be used for the entire flow, the protocol to filter the applied options of the guidelines. For that reason, it was decided to start the layout modelling based on the clinical guidelines, while keeping in mind the protocol in order to prevent unnecessary modelling (i.e. if it was already known that certain aspects described in the guidelines were not applied in the hospital this was not modelled).

The guidelines, as already stated, contain aside from descriptions about the care activities a lot of discussion about the interpretation of clinical research, especially within the treatment chapter; very interesting for medical professionals, but hard to understand and follow for non medical professionals. Within this guideline, many tables are present containing the conclusions of these researches categorized according to the level of evidence and recommendation. So, instead of reading all those discussions the focus was on the conclusions and if more details were needed to be known a look was taken to the discussion. Furthermore, the management summary in the back of the guidelines was very useful and good to follow for non medical professionals.

The layout model (model version 1) did not contain any information about resources, as the protocol and guidelines do not state anything about that subject. In order to identify the status of the confirmation of tasks between the guidelines and protocol, colours were used. The different colours stated which tasks out of the guidelines were already confirmed with the protocol, which were highly recommended by the guidelines but not confirmed and which tests were recommended by the guidelines but of which it was doubted whether these belong to the pathway of UA. The granularity of the model at this time was three levelled for the processes; the top-level contained the overview of the five phases aligned with the management summary of the clinical guidelines (see Figure 8), the middle level showed an overview of all processes within the phase and the lower level contained details of certain tasks with the process overview (for example, the process of taking an ECG, to measure 'Troponin' within take blood test or give 'anticoagulation' within give medicine). Especially for the provision of medicine, two addition levels were made. The upper level of medicine note the specific type of medicine within the category and the lower level note the dose that needs to be given.

The organization view can be made based on the list of stakeholder of the CP. As it was already known that this list would be updated during the information gathering within the hospital, it was decided to postpone making this view. The list of stakeholders served as the organization view at this point in time. The final organization view can be found in Appendix J – Figure 21 and Figure 22.

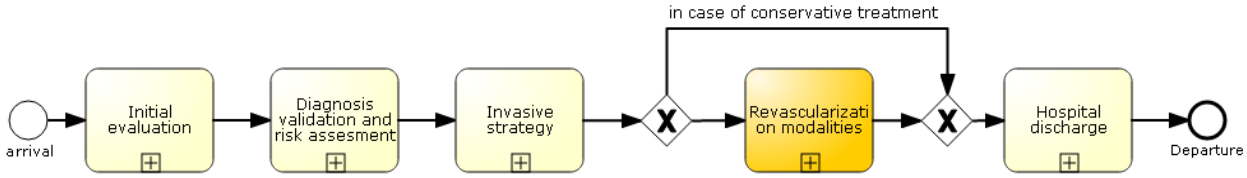


Figure 8 – Top-level of the model of Unstable Angina Care Pathway (model version 1)

4.4. *Fill in all details in the layout model*

After the layout was made, the information gathering within the hospital could start to fill in all details in the model. The description of the information gathering is split in a part about the cardiology department and a part about the cardiothoracic surgery department. After those descriptions, the final decisions made about the model aspects of granularity, role representation and exception handling will be explained.

4.4.1. Cardiology department

The information gathering within the cardiology department started with the observation week at the nursing wards, supervised by the team leader of the CCU. Beforehand, there was no concrete plan how to use this week, other than to speak to representatives of the different units and roles within the cardiology department. This was because there was no introductory meeting planned in advance and therefore no plan could be made in cooperation.

During the four days of this observation week eight interviews were conducted. During the first two day interviews were held with a nurse from the first heart aid (Eerst Hart Hulp EHH), two nurses from the Coronary Care Unit (CCU/hartbewaking) and a nurse from the nursing ward of Cardiology (7 west). During these interviews first the scope of the research was explained and afterwards the question was asked which care was provided to a typical UA patient from the moment they arrive at their department till they leave. After these two days, the gathered information was processed in the model (model version 2.1).

During the third day two interviews were conducted. The first interview was with a cardiologist in training at that moment located at the EHH, but knowledgeable about the whole pathway regarding the wards. During this interview the model so far (model version 2.1) was discussed, which lead to eliminations for part of the tasks resolving from the guidelines and a lot of new information about the care process. The next short interview was with the team leader of the heart catheterization room (in Dutch 'Hart Catheterisatie Kamer' HCK). Besides the question of what care and medicine were provided within the HCK, it was also asked which KPI's could be used to measure this part of the pathway. The interviewee mentioned two team indicators which were listed, see Appendix E. Afterwards, the CCU team leader gave feedback on the list of KPI's. The new gathered information was again processed in the model (model version 2.2) to use the next day.

During the fourth and last day the latest model (model version 2.2) was discussed broadly with the CCU team leader. During this discussion a number of necessary corrections came to the light, but overall the model was found quite complete and detailed. It was decided to conclude the week here, as an appointment with the main cardiologist of the pathway was scheduled a week later and he needed to decide whether or not the CABG path needed to be worked out. The interviewees so far, found the CABG path of the pathway not really important to include, as only a little percentage of the patients undergo this operation.

After the observation week two separated appointments were scheduled with the main cardiologist of the pathway. During the first meeting, the project goal and progress were discussed and a short introduction was given about the model. A printed version of the entire model (model version 2.3) was left behind for the cardiologist to look at. During the second meeting, this model was broadly discussed and feedback and necessary corrections were noted. One important point that was discussed was to work out the CABG path as part of the CP as well. Furthermore, the visualization of perspectives and granularity and the listed KPI's were discussed. One important aspect he mentioned was that for the use of the model in practice, the choices of medicine should be shown immediately and not be hidden in different diagrams. Besides that, the different roles should be provided with their own perspectives that contain only their activities.
After the meeting, the feedback was processed in the model (model version 2.4) and one more interview was conducted. This telephone interview was with the nurse practitioner of the heart rehabilitation policlinic, in order to check the policlinic's role within the pathway. As the current capacity of the policlinic is limited, only STEMI and open heart surgery patients are accepted into the program. The program starts after the hospitalization, but a cardiologist or cardiothoracic surgeon needs to refer the patient during discharge to the program. In some cases, the intake meeting of the program starts during the hospitalization, but this is left out of the model.
With this confirming interview, the model (version 2.4) regarding the cardiology part was considered ready for now.

4.4.2. Cardiothoracic surgery department

Via the CCU team leader contact was made with the nursing ward of cardiothoracic surgery (6west) to start the information gathering within that department. The team leader of 6west put forward a nurse practitioner as the best knowledgeable person about the whole process and thus the nurse practitioner became the contact person and source of this department. During the first appointment the goal and scope of the research were discussed and afterwards it appeared that this department had already for years been working on standardizing their processes and working them out in a Clinical Pathway. They had even a checklist within the hospital system for the intake procedure. The work processes of the cardiothoracic surgery (CTC) department were briefly discussed, before they were handed over as an information source to base the model on.
After the appointment, the work processes were studied and processed in the model. This was more difficult than it seemed. First of all, because the work processes covered all different types of patients within the department and thereof only the processes for patients with CABG were needed. This was made extra complicated as it was not always clear if UA patient exactly follow those standard CABG processes, as they are already hospitalized and treated with specific medicines. A second difficulty was converting the employee-like perspective of the work processes into the patient perspective of the model. After all information from the work processes was processed as good as possible, a second meeting was scheduled to clarify some uncertainties about the interpretation of the document and to gathering the last missing information about a few routings. During this meeting a printed version of the latest model (model version 2.5) was used to guide the discussion.
The only parts of the model that could not completely be filled in with the work processes were the processes around the surgery itself, because these takes place at the operation rooms (OR) and intensive care (IC). Heretofore, contact was made with an Anaesthetist and he provided the opportunity to observe the processes around a CABG operation from the transfer at the OR

holding up to the transfer to the IC. During this observation, questions could be asked to the operating team and another observer, a former CTC nurse. Aside from this observation, two discussion moments took place with the Anaesthetist. During the first moment, the subject was the granularity of the model with regard to the processes around the operation. Most important was the transfer of patients, following the pre and post OR checklist and the time out within the operation room. It was furthermore advised to model not too detailed, as all those procedures are laid down in so called standard operation procedures (SOP) which are quite often a subject to change. The second moment was used to gather the last missing information about which medicines are given and which test are performed at the IC. This information was provided in the presence of a nurse practitioner of the IC, which also showed the corresponding SOPs in the hospital system. Besides that, the model so far was discussed with the Anaesthetist. After this last meeting and information gathering, the new information was processed in the model (model version 2.6) and considered 'finished' for this part of the modelling.

4.4.3. Model aspects

Now that all pathway details are known, it is time to work out the final level of detail of the model, the granularity levels and the role visualization. Besides that, it was made possible to withdraw patients from the pathway, but this is explained in section 5.1 – Case study results.

4.4.3.1. Level of detail of the model

First of all, it needed to be defined how detailed the model needs to be, as the requirements only state that it is not necessary to model until the details of 'movements' and to specify the medicines used. It was found that the level of detail is defined by the clinical guidelines, the medical professionals and/or by the KPI's. During the model layout step, the clinical guidelines as well as the KPI's were used as guides, while during this step the medical professionals who are interviewed are added as a leading guide for the detail of the model. The interviewees are CP domain experts and can state the important activities and decisions taken. Furthermore, they decide how much detail is provided about the care processes. Of course the level of detail provided during interviews can be influence by the interviewer to a certain extent, who needs to keep the goals in mind (e.g. keep the model as simple as possible).

In order to provide a good overview of the care activities with the CP, it needed to be decided for each activity which level of detail was required. No 'movements' were drawn, but sometimes it was important to specify preparations, after care and interpretations that needed to be done or to note very important elements. Take for example the interventions CAG and PCI and the operation CABG, for which the preparation and after care is specified but not the procedure itself. The most important reason for this is the very specialistic nature of the work, which requires a lot of effort and time to model. Of course the 'big lines' of these procedures and the concerning safety rules are the same, but each patient is a unique case. As neither the goals and the KPI's nor the medical professionals required including the specialistic details, it was left out. Note that the KPI's concerning the procedures PCI and CABG are adapted from the project 'Meetbaarbeter' (van Veghel, van den Bosch, Dekker, & Tonino, 2012) and are therefore also less important to include in the future pathway monitor analysis. Examples in which important elements are noted are the monitoring and rounds, whereof it was mentioned either by the guidelines or medical professionals what was at least included. Also for blood tests it is always specified what values are requested, as the lab will otherwise perform a standard blood test where these values will not be included.

4.4.3.2. Granularity levels

During the process of information gathering, the granularity levels of the model (model version 2.1 to 2.6) had state the same as in the layout model (model version 1). After all details were filled in, the model diagrams of *Revascularization modalities* and *Hospital discharge* had exploded due to the addition of the CABG path. The CABG path on its own is already a complete Clinical Pathway and needed to be fit into the two phases of this Care Pathway.
In order to resize the two model diagrams, it was decided to add an extra granularity level only for these two sub processes. This was done first of all because it was not possible to either add more sub processes within the phase diagrams (i.e. replacing task from the middle to the lower level), due to the many alternations of roles within and between departments. Nor was it possible to consistently adjust the collapsed sub processes at the top-level to one for PCI and one for CABG, because of the interaction between the two processes within the *Revascularization modalities* phase (e.g. the 'urgent' path of CABG can be started after a heart team meeting, but also after a PCI). In addition, the top-level was considered as a very well defined level of which it was not desirable to change it. The second option, to add the extra granularity level consistently in the model, was seen as unnecessary as the three other phase diagrams already contained a small to reasonable amount of tasks.
Therefore, the exploded diagrams were studied and it was decided to build a new level between the processes noted in those diagrams and the top-level. The exploded diagrams were chopped up into groups of tasks based on their interrelationships and taking into consideration how the different groups needed to be placed in the sequence of the pathway. Furthermore, attention was paid to the optimal group size; small groups will lead to many diagrams and losing the overview of the pathway, while large groups will lead to complex and therefore unreadable diagrams. In order to solve this puzzle, it was necessary to violate the BPMN language rule that states that the pools or swim lanes in a child level need to be named as the swim lane where the mother level is located. It was seen more important to provide a clear overview of the process than to obey to this rule. The revision of the *Revascularization modalities* diagram is shown in Figure 9.
With the adjusted granularity levels, noted in Table 11, a new version of the model (model version 3) was made. Note that the different levels are not always related to the diagrams; if a collapsed sub process is used the lower granularity level is showed in a new diagram, but by an expanded sub process the lower level, elements of tasks, is shown on the same diagram. An exception of this general rule is made for the level 2 task 'give medicine', as defined in the granularity levels. The reason why there are in general two options for the modelling of medicine is due to the variety of use of the different names of medicines within and between the guidelines and the hospital. Medicines can be classified according to the five levels of the Anatomical Therapeutic Chemical (ATC) classification, see Table 12 (WHO Collaborating Centre for Drug Statistics Methodology, 2011), but are also called by their nicknames and/or brand names. In order to keep it comparable to the guidelines and to practice only the pharmacological or chemical subgroup is mentioned in the model if the guidelines especially state those, otherwise preferably the chemical substance name is used (e.g. '*hibiscrub'* is the brand name of a disinfectant, while '*mupirocino'* is the chemical substance name of a nasal cream).

4.4.3.3. Visualization of Roles

During this step, it became clear that the Care Pathway could be best represented by pools and lanes. Since most tasks could be assigned to a specific role and there were too many different roles involved to make good use of colours (e.g. many different colours make it also more

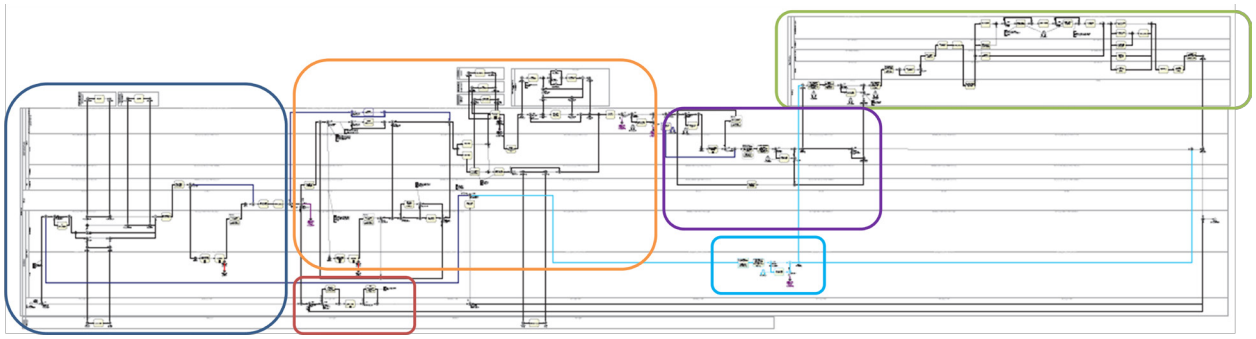


Figure 9 – Revascularization modalities diagram chopped up into groups of tasks

Granularity	Description
Level (1)	Top-level, providing the overview of the different phases of the CP
Level (1a)	Overview of the phase of the CP *Only applied in the phases Revascularization modalities and Hospital Discharge*
Level (2)	Process within the phase, containing collapsed and expended sub processes for tasks executed by the same role and belonging together (e.g. take blood test and take ECG).
Level (3)	View of the sub processes 1) The pharmacological or chemical subgroup of medicine is mentioned here as this is explicitly mentioned in the clinical guidelines (e.g. Aspirin and P2Y12 inhibitors). 2) The name of the chemical substance of medicine (e.g. paracetamol and lorazepam).
Level (4)	1) The name of the chemical substance of medicine (e.g. ASA en Ticagrelor). 2) Dose of medicine that needs to be given.
Level (5)	1) Dose of medicine that needs to be given.

Table 11 – Overview of the set granularity levels within the model (model version 3)

Code	Level	Example
B	1st level, anatomical main group	BLOOD AND BLOOD FORMING ORGANS
B01	2nd level, therapeutic subgroup	ANTITHROMBOTIC AGENTS
B01A	3rd level, pharmacological subgroup	ANTITHROMBOTIC AGENTS
B01AC	4th level, chemical subgroup	Platelet aggregation inhibitors excl. Heparin
B01AC24	5th level, chemical substance	Ticagrelor

Table 12 – ATC-classification of medicines, source: (WHO Collaborating Centre for Drug Statistics Methodology, 2011; WHO Collaborating Centre for Drug Statistics Methodology, 2012)

difficult to read the model quickly). For one type of task, the heart team meeting, it was required to make a joining swim lane, as cardiologists and cardiothoracic surgeons form together the heart team. For other tasks involving different roles, it was chosen to assign the task to the role that executes the tasks and not the role prescribing or responsible. For example, 'give medicine' is done by the nurse, while the corresponding task to prescribe medicines by the doctor is left out. It is possible to add an additional role by this task, but this was not done as it is general known that medicines need to be prescribed by doctors.

4.5. Make stakeholders' perspectives

In the beginning of the project, it was stated that perspectives needed to be made for the direct key stakeholders from the hospital that only contained their own tasks (swim lanes). Now the final model is made, this statement needs to be adapted as not all direct stakeholders have their own swim lane and the process knows many alternations.

Based on the direct key stakeholders and the model, a total of eight different perspectives were specified; EHH nurse, CCU/7west nurse, cardiologist, HCK team, 6west nurse, CTC nurse practitioner/physician/surgeon in training, CTC surgeon and Anaesthetist. The roles of the CCU

and 7 west nurses were taken together, because of the similarity of the standard care provided. The role of the 7 west nurse practitioner has not come back in the model and therefore also no perspective was made. The roles of the nurse practitioner, physician and surgeon at the nursing ward (6west) of cardiothoracic surgery are taken together, since their tasks are to a certain level exchangeable. Note that no perspectives are made for the other roles involved in the process, as their tasks mostly happen on request and are therefore placed within the perspective of the requestor. The process happening at the intensive care is entirely included in the Anaesthetists' perspective, as he/she has the final responsibility there.
The content of the different perspectives was made such that the roles see their own swim lane and the interacting swim lanes. This was done because the process knows many alternations and by showing them in the perspectives, the context of the tasks is maintained and thus the model is easier to understand. Of the final 26 diagrams of the model only two diagrams needed to be adjusted for the development of the perspectives, as it happened to be the case that most diagrams already contained a small amount of different roles. These two diagrams were adjusted to the perspectives by summarizing the tasks of the other roles that were not important for the context of their perspective. An overview of all diagrams of the model and the perspectives they apply to is given in Appendix F – Table 28.

4.6. Verify and validate model

After all interviews were conducted and the perspectives had been made, the model could be verified and validated. The verification process was done according to the method description; to test if the model fulfils the requirements set. To conduct the validation however additional validation techniques needed to be searched, as there was no medical data available. This search was part of the method refinement and therefore the results can be found in chapter 6 'Refine method'. Before the validation is explained, first the verification will be discussed.

4.6.1. Verification

For the verification all requirements set were tested. First of all, the quality of the process model requirements was tested by the modeller. Afterwards, the other requirements were tested by the medical professionals as the modeller already had argued the choices made.

4.6.1.1. Quality

The quality requirements set by modelling guidelines of Becker et al. (2000) and Mendling et al. (2010) stated in Table 4 and Table 5 will be discussed now, except for the *Guidelines of relevance* of Becker et al. (2000) as this is already broadly discussed in the project definition and plan. The first aspects are the *guideline of correctness* and the *guideline of comparability*; the model is made as consistenly as possible and when deviated this has been noted, see also chapter 5. This makes it very easy to compare the different model diagrams with each other. Besides this, no deadlocks were found in the model, but this does not mean that they cannot occure by a combination of possiblities. This will be tested during the validation, together with the semantic correctness of the model. The *Guideline of economic efficiency* has been applied by (re-)using the ACS protocol and the CTC work processes and working with a sufficient modelling tool. Overall the modelling tool was found nice to work with, but it does not supports all functions wanted; not all BPMN elements are supported (e.g. the call activity), the included best practices have some drawbacks and the simulation function is very limited. Note furthermore, that the model itself can be re-used to model related care and clinical pathways, for example the STEMI

protocol or elective CABG. The organization view and the business view are aligned so far as it was applicable (i.e. the organization view contains roles that are not mentioned in the business view model, as they do not conduct any care tasks) and therefore the *Guideline of systematic design* is also applied. The last aspect of the guidelines of Becker et al. (2000) is the *Guideline of clarity* and is about the readability of the model. This will be discussed together with the modelling language in the next section.
The guidelines of Mendling et al. (2010) were applied during the modelling. Therefore all diagrams have one start and end event (*G3*) for the sequence of the pathway, exception are made for the error end event. New departments outside the sequence have start- and end event every time a new test is requested. This is consistent with reality. The diagrams are made as structured as possible (*G4*), but at a few places AND and XOR joins were replaced by INCLUSIVE joins as there were many routings coming together. The INCLUSIVE join makes it here easier to follow the sequence. This also relates to the minimization of routing paths (*G2*); it was tried to keep the options as low as possible, but sometimes the reality is that a lot is done in parallel. OR gateways (*G5*) are not supported by Signavio and thus not applied. The *G1* and *G7*, to use as few elements per diagram as possible, are already discussed by the setting of the granularity levels. There is one diagram left that contains a too large number of tasks, but due to the sequencing of the tasks it is impossible to resize it. Last, *G6* to label tasks with verb-objects, is applied as good as possible for the activities that note a task and not for the top-level (sub) phase as well as the medicine related activities.

4.6.1.2. Process visualization, granularity and modelling language

The aspects of process visualization, granularity and modelling language have already been broadly discussed before from the perspective of the modeller. Now, the opinion of the medical professionals about the decision made needed to be asked. This was done during the validation round and earlier on during the information gathering by discussing the aspects of language, sequence, roles, level of detail and usefullness.
During the meetings with the medical professionals it was noted that it was relatively easy to follow and understand the model with a short introduction. During the validation a table with all symbols and their meaning was provided. The nurse practitioner added that the investment made to understand the model, was worth it. The sequence and roles set in the model were alright with the professionals. The level of detail of the model was assessed as just right, with a tendency towards too detailed. This is partly due to the fact that the model represents the complexity of the real process. Therefore, the process cannot be represented any easier without losing information. Another reason for this is that the model needs to be applicable as a communication tool, which makes that sometimes more details are required to make the process clear to somebody else than the domain expert of that particular process part. Both reasons were also noted by the medical staff. The usefullness of the model was confirmed by all medical staff, as they found that the model can be used within the hospital to communicate the processes of one department to the other. Explicit intentions to use the model have been expressed by the nurse practitioners and the main cardiologist wanted to include the CTC processes to be able to align them. Besides that, it has been stated that the 'model' could also be used for other applications. For example to model the STEMI protocol or to specify which patients are suitable for inclusion in clinical research.

4.6.2. Validation

Based on the validation part of the refined method, see section 6.2, it was decided to use the validation techniques of traces and face validity. Before this could be done, the model was first executed and thoroughly looked over to discover and remove modelling errors.

4.6.2.1. Execution

The execution of the model was done within the modelling tool, Signavio. First of all, the built in best practices were used to discover and remove modelling errors. A couple errors were noted and removed, but due to the large number of suggestions listed it is sometimes difficult to easily notice the errors and warnings. Therefore, it is very well possible that the modeller oversees comments that need attention. Furthermore, the best practices are done per diagram which makes it possible that mistakes are not recognized.

Afterwards, a copied version of the model without expanded sub processes was made to execute with the limited 'simulation' function of Signavio. Besides the expanded sub processes also inclusive gateways were not supported, but they could not easily be changed and therefore not all diagrams could be executed. Unfortunately, the simulation results of the executable diagrams were not really helpfull for the validation. The function executed only individual diagrams, could not detect the one right start event and spontanuously activated event-based gateways sequences (i.e. start and intermediate events could activate while the corresponding message or signal had not been send yet).

In order to be able to process the whole model, it was chosen to thorougly look over the complete model by hand. During this paper based 'execution' thirdteen remarks were made, of which nine were corrected in the model (model version 3.1); two remarks about wrong named swimlanes, one about a wrong placed tasks, one remark about two ICC processes that needed to be replaced in the diagram of the sub process, a remark about a possible deadlock because of two missing escape options, a remark about a wrong sequence of the process and three layout related remarks. Two of the remarks were about the questions '*are pre meds given in case of a acute or emergency CABG?*' and needed to be asked during the validation round. One remark was added to the description of the model, see chapter 5, and the last one was about a large diagram that could not be resize (as already discussed).

4.6.2.2. Traces

After the laboriously execution, the trace process could be conducted. As no medical data was available, cases needed to be developed by hand to trace artificial patients through the model. The goal here is to test if the model behaviour is correct with regard to reality and technically. In order to do this, the cases did not need to form a realistic reflection of the actual patient population, but needed to contain quite 'standard' types of patients (case I, III and IV) as well as some 'very complex' rarely seen patients (cases II and VI) to be able to test the entire model, see also Table 13 and Table 14. During the tracing twelve unique remarks were made, of which nine were processed in the model (model version 3.2), two were added to the description of the model in chapter 5 and one needed to be checked in the hospital during the validation round; '*is the contrast nefropathie protocol not applicable for CAG< 120 minutes?*'. The processed remarks were in two cases about missing line descriptions, two about missing tasks, two about correcting for possible deadlocks, one about a wrong gateway, one about a missing option and in one case the boundary error events on the mother sub process were missing.

Case	Description
I	Patient with hsTnT<30 @ T=0hrs, hsTnT>30 and ΔhsTnT≥8 @ T=3hrs. Patient needs CAG within 24hrs and afterwards a PCI. The sheath is removed at the CCU department and afterwards the patient is discharged from 7 west.
II	Patient needs nitrates, has typical ACS and has already NSTEMI medicine. The patient a CAG < 120 minutes and CK/CKmb measuring. After the CAG a PCI and acute CABG are conducted. After the operation, when the ECG is done on the IC it is decided that the patient needs case management.
III	The hsTnT level of this patient is not rising above 30 and therefore a stress test is conducted after the results of T=6hrs blood test are back. The patient is withdrawal from the pathway as ACS is not the reason of the chest pain.
IV	This patient has typical ACS and the hsTnT>30 @ T=0hrs. A CAG needs to be conducted within 120 minutes. The CAG shows that a CABG is a possibility and therefore a heart team meeting is schedule. The CABG path will be started, but with a delay in the transfer of the patient to 6 west. The patient will receive post operative care at the PACU.
V	The patient needs nitrates, has a hsTnT>30 and ΔhsTnT≥8 @ T=3hrs and the Ck/Ckmb needs to be measured. There is no emergency or CAG within 120 minutes needed, but the ECG the next morning indicates STEMI. So, the patient needs to change to the STEMI protocol and is therefore withdrawal from the pathway.
VI	This patient arrives with emergency at night. After the CAG and PCI are conducted, an emergency CABG incl. Valve needs to be conducted. The post operative care is provided at the IC.
VII	This patient has a positive hsTnT level @ T=6hrs and needs a CAG within 72 hrs. He has a GFR >6ml/min and needs also a FFR test. After the CAG a medical treatment is decided.
VIII	This patient has a hsTnT>30 @ T=0hrs and ΔhsTnT≥8 @ T=3hrs. As the patient has no further risk factors, a conservative treatment is initiated.

Table 13 – Description of the cases developed for the traces of the validation

Diagrams / Case	I	II	III	IV	V	VI	VII	VIII
0. CP UA @ CHE (Top Level)	x	x	x	x	x	x	x	x
1.1 Initial evaluation	x	x	x	x	x	x	x	x
1.1.1 Give nitrates		x			x			
1.2 Diagnosis validation and risk assessment	x		x		x		x	x
1.2 Diagnosis validation and risk assessment [EHH]		x		x				
1.2.1 Take ECG	x	x	x		x		x	x
1.2.2 Give medicine (ACS-NSTEMI)	x	x		x	x		x	x
1.2.3 CK/CKmb measuring		x			x			
1.3 Invasive strategy	x	x		x		x	x	
1.3.1 Perform CAG	x	x		x		x	x	
1.4 Revascularization modalities	x	x		x		x	x	
1.4.1 Prepare and conduct PCI	x	x				x		
1.4.2 Prepare, await and hold Heartteam meeting				x		x		
1.4.3. Await and conduct screening + intake CABG				x		x		
1.4.3.1 Screening + intake				x		x		
1.4.4 Await CABG				x		x		
1.4.4.1 Give medicine (ACS-NSTEMI-CABG)				x		x		
1.4.5. Prepare acute CABG		x						
1.4.6 Perform CABG		x		x		x		
1.5 Hospital discharge	x	x		x		x	x	x
1.5.1 Nurse and mobilize patient (at Cardio)	x						x	x
1.5.2 Discharge patient (at Cardio)	x						x	x
1.5.3 Provide post operative care		x		x		x		
1.5.3.1 Give medicine (ACS-NSTEMI-postCABG)		x		x		x		
1.5.3.2 Take ECG @ IC		x		x		x		
1.5.4 Nurse and mobilize patient (at CTC)				x		x		
1.5.5 Discharge patient (at CTC)				x		x		

Table 14 – Overview of the involved diagrams within the eight cases developed for the traces

4.6.2.3. Face validity

The last step of the validation is the face validity, in which it was asked to the CCU team leader and the CTC nurse practitioner if the model is a realistic representation of the care trajectory in place in the hospital. No other medical professionals were included as they were not available during this time period. Furthermore, previous versions of the model had already been seen and corrected by several persons, including the main cardiologist and aneasthetist, as described in the detailed modelling step. The CCU team leader is capable to judge the entire process at her department including that of the cardiologist. Her perspective did not include the EHH processes, but that part was already 'finished' during the interview with the cardiologist (i.e. only small changes in the order were made back then). The perspective of the Aneasthetits was already seen and confirmed during the last information gathering before the validation round.

The team leader of the CCU was asked first to validate the process. A printed version of her perspectives was provided including an introduction to the model and an explanation of the modelling language symbols used (see section 5.1 and Appendix G – Table 29). After looking over the model during an appointment, she concluded that the model contained all activities that needed to be undertaken by her role, as well as the other roles included in her model (HCK team and Cardiologist), within the 'standard' treatment. She made however one remark, to add the control of the groins to the rounds in the *nursing and mobilize patient (at cardio)* diagram. This because it is often forgotten and very important to trace bleedings. Another remarks made were about the incorrectly sequence of the process within the same diagram and an incorrect combination of options with regard to *'give Glycoprotein IIb/IIa receptor inhibitors'* , see Table 15. No remarks were made about the '*contrast nefropathie protocol not being applicable for CAG< 120 minutes'* and therefore it can be concluded that this is indeed the case. Also the assumption made that '*no pre meds are given in case of acute CABG'* was correct.

Also the CTC nurse practitioner was provided a printed version of her perspective including a introduction to the model and an explanantion of the modelling language symbols used (see section 5.1 and Appendix G – Table 29). She overlooked the model on her own and a meeting was sceduled afterwards to discuss her remarks. First of all, it was notices that there had been a misunderstanding about the different forms of CABG operations. In practice elective, urgent and emergency CABG operations exists, while the model showed a standard, emergency and acute option that did not fit reality. All tasks were there, only the sequence and naming needed to be adjusted. It is noteworhty, that this wrong sequencing of the acute CABG was not noticed by the CCU team leader of the CCU, although it was within her perspective. This might be due to the fact that while the patient is admissed to the CCU, they are not responsible for the screening and intake, but CTC is and therefore this was not recognized. Aside from this misunderstanding, eleven other remarks were made about missing and wrong sequencing, see Table 15. These remarks also relate to medicines given during the post operative care within the intensive care department. Although there were quite a couple remarks that needed to be processed, she was positively surprised by the overall correctness and completeness of the model. Especially as only two, one hour, meetings were held aside from the provided CTC work processes.

4.7. Refine model

Based on the feedback given during the face validity, see Table 15, the model now needed to be refined. As the project was already overrunned and needed to be round up, it was decided to only process the remarks made and not to gather any additional information. Besides that, it was not possible to execute a second full verification and validation of the model.

Therefore, during the processing of the remarks it was simultaneously looked if the diagrams kept its semantical correctness and thus its verification. Due to the fact that most remarks needed to be corrected very locally, it could be easily seen what the impact was for the semantic correctness. In a few cases non-local adjustments needed to be made (e.g. the emergency/acute CABG operation, the medical objection of the anaesthetist and blood pressure control). Due to the change of the acute/emergency pathway the cardiology perspective of the 'await and conduct screening + intake' also needed to be adjusted.
As the final model needed to be documented afterall, it was decided to used this process to simultaneously conduct the validation of the model. During the documentation, a few small errors were noted and directly corrected. Among them are mainly typing errors and additional text annotations, but also three missing line descriptions, two incorrect sequence flow and two missing boundary STEMI error events that were somehow not notices before. After the documentation, the final model (model version 3.4) was a fact. This model was considered valid as all elements and the correct sequence of the pathway were represented and the model was already found semantically correct. A full desciption of the model is given in the next chapter, section 5.1.

Diagram	Remark
Prepare and conduct PCI	The sheath needs to be in place if Glycoprotein IIb/IIa receptor inhibitors is given. The routing in case the sheath is remove needs to be adjusted.
Nurse and mobilize patient (at Cardio)	the order from *attach monitor* up to *mobilize patient*, needs to be *attach monitor, perform ECG, admit patient, blood test aPPT and Haemoglobin, remove sheath* and finaly *remove bandage*.
Nurse and mobilize patient (at Cardio)	Add the control of the groins to the rounds
Revascularization	In practice elective, urgent and emergency CABG operations exists, while the model showed a standard, emergency and acute option that does not fit reality. All tasks are there, but the sequence and naming needs to be adjusted.
Await and conduct screening+intake	The Anaesthesist needs to decide if there is a medical objection to not proceed with the operation at the end of his intake. This objection can be of short notice (e.g. the patient is not sober yet) or protracted (e.g. blood values need to be stabilized).
Await and conduct screening+intake ***Screening+Intake***	In case the Euroscore ≥ 10 the CTC surgeon needs to be consulted about the decision to proceed the pathway or withdrawal the patient from the pathway.
Await CABG	Hemodynamics needs to be added to the round
Give medicine (ACS-NSTEMI-CABG)	After the surgery the CTC restarts the Anticoagulation with the medicine Dalteparin (brand name Fragmin) instead of the medicine fondaparinux or Enoxaparin that is prescribed by the Cardiology department.
Give medicine (ACS-NSTEMI-CABG)	Hibiscrub and mupirocine need to be given 5 days in advance (instead of the 2 days noted), if that has not happend it needs to be continued after surgery till it is given for 5 days total.
Give medicine (ACS-NSTEMI-CABG)	Paracetamol is continued after the operation day, thrice a day untill discharge.
Give medicine (ACS-NSTEMI-CABG)	A text annotation needs to be added to the other meds, to think about Vitamin K antagonist. A medicine that is often prescribed by CABG patients, but is not related to ACS.
Nurse and mobilize patient (at CTC)	The blood pressure needs to be controlled every 8 hrs until discharge, and not until the telemonitor is detached.
Nurse and mobilize patient (at CTC)	At the same moment as the drains and catheter are remove, the infusion is also removed. This needs to be added to the model.
Nurse and mobilize patient (at CTC)	The INR test is only needed in case a Vitamin K antagonist is prescribed.

Table 15 – Remarks made during face validity by the medical professionals involved

5. CASE STUDY RESULTS

Within this chapter the communication tool model resulting from the case study performed will be described. Besides that, it is explained how the same model can be used in two other future applications; patterns and checklists development.

5.1. Model description

The Unstable Angina Care Pathway model involves the entire hospitalization period resulting from an admission because of acute chest pain (ACS). All patients arriving at the hospital with non STEMI chest pain can follow this path, but eventually only the 'standard' UA/NSTEMI patients will remain. All patients without UA/STEMI need to be withdrawn from the pathway, as well as complex patients that need case management. This can be done by one of the three included 'escape' options explained in Table 16**Error! Reference source not found.**. Patients that receive additional or deviated care, for example because of bleedings or allergies, can still be treated according to the pathway, as it is allowed to deviate for good reasons. Note that only care activities (tests, medications, surgeries, rounds) performed specifically for this group of patients are included[4] and that there are differences in the level of detail between diagrams, as a result from the information gathering and goals of the model. A specification of the granularity levels, as well as the ATC classification for medication can be found in chapter 4 – Table 11 respectively Table 12. An explanation of the used symbols of the Business Process Modelling Notation (BPMN) 2.0 is noted in Appendix G – Table 29 and the entire business view model (model version 3.4) can be found in Appendix K.

In this section a description of the model will be given, by explaining the care pathway process according to the sequence of the model; starting by the arrival of a patient within the top-level and following the process through the lower level diagrams until the patients' departure. Aside from a description of the process, also notes will be made concerning assumptions and choices that are made during the modelling.

	In case after an ECG is made and interprets by a nurse STEMI is confirmed, the patient needs to be switched to the STEMI protocol immediately. At that moment, this error will be thrown at the lowest level and cached by the mother levels, such that a cardiologist will be alerted and the patient will leave the pathway at the top-level through the corresponding error end event.
	In case patients have entered the pathway but have no chest pain resulting from ACS, they need to be withdrawn from the pathway by throwing the corresponding error. This option can only be applied during the 'Initial evaluation' and 'Diagnosis validation and risk management' phases.
	If a patient has UA, but cannot longer follow the Care Pathway due to circumstance (for example, serious complications or comorbidities), than case management needs to be applied. The corresponding error needs to be thrown and the involved medical professionals need to make a personal treatment plan for this patient at the top-level. This option is only present between the second and third phase and within the last two phases.

Table 16 – The three 'escape' options within the model of the 'Care Pathway' of UA

[4] All logistic activities (beds logistics, planning OK / HCK / research), nutrition moments, visiting hours and shift handovers will not be included.

5.1.1. Top–level

The top-level diagram, called *CP UA @CHE*, gives an overview of the entire care process from arrival to departure according to five phases aligned with the clinical guidelines. An overview of the involved departments and units per phase is given in Table 17 – Overview of the involved departments per phase of the pathway

.

The care process starts at the top-level with the *arrival* of a referred patient with chest pain at the hospital. The patient arrives either at the first heart aid (EHH) department or in case of emergency is directly send to the heart catheterization room (HCK) for the *Invasive strategy*. The distinction between emergency and non-emergency patients is made before the model starts, as the referrer, a policlinic, GP, ER or ambulance, contacts the cardiologist on duty (at the EHH) to discuss the case. Thereupon, the cardiologist decides if the patient can come to the hospital.

Most patients with Unstable Angina (UA) arrive at the first heart aid (EHH) and start with the *Initial evaluation* (see section 5.1.1.1). During this phase, as well as during the other phases, it is possible that the patient develops an infarction after all and thus the red coloured error end event *change to STEMI protocol!* is thrown. After which a cardiologist is alerted and the patient will leave the pathway through the end event *switched to STEMI protocol*. Patients can also be withdrawn from the pathway if not ACS but from another disease causes the chest pain. In this case, an orange coloured error end event *withdrawal from pathway (other disease)* is thrown and the patient will lead the pathway at the top-level to the corresponding end event. This can also be noted in the next phase in line; the *diagnosis validation and risk assessment* (see section 5.1.1.2). At the end of this phase a decision is made which of the three treatment plans will be followed. The first option is a *conservative* treatment, in which case the patient will receive a drug therapy and continues the care process within the *Hospital discharge* (see section 5.1.1.5). The second option is an *invasive* treatment, in which case the process proceeds with a catheterization within the *Invasive strategy* phase (see section 5.1.1.3), followed by the *Revascularization modalities* (see section 5.1.1.4) and the *Hospital discharge*. The last option is to apply *case management* because medical reasons indicate that will be the best treatment for this patient. The patient will leave the pathway through the purple coloured end event *withdrawal patient from the pathway (case management)*. Case management can also be applied in the *Revascularization modalities* and *Hospital discharge* phases, after an invasive treatment has been started. If the pathway is successfully walked through, the patient will leave the hospital through the *end event Departure*.

	EHH	CCU	7west	HCK	Heart team	CTC scr.	6west	POS	OR	IC	Lab	Radiology	ENT	Oral surgery	Internal medicine	Pulmonary medicine
Initial evaluation	X										X					
Diagnosis	X	X	X								X					
Invasive strategy	X	X	X													
Revascularization																
- **PCI/meds**		X		X												
- **(Possible) CABG**		X	X		X	X	X	X	X		X	X	X	X	X	X
Hospital Discharge																
- **CAG/PCI/meds**		X	X								X					
- **CABG**							X			X	X	X				

Table 17 – Overview of the involved departments per phase of the pathway

5.1.1.1. Initial evaluation

The *Initial evaluation starts* with the arrival of the patient, either by themselves or by ambulance. In case the patient arrives *by ambulance*, the *update by paramedic* is done between the first heart aid nurse and the paramedic. This includes a discussion of the paramedics' findings and the

handover of a print of the ECG performed in the ambulance. After the update or the arrival of the patient *by themselves*, the nurse will *attach patient to monitor* while starting a short *anamnesis*. The monitor measures the *saturation*, *pulse*, *respiratory rate* and *blood pressure*. In case the *saturation is smaller than 90%* or in case the medical professional finds it necessary, *Oxygen insufflation* is started. After that, the nurse performs an ECG (*make and interpretate ECG*) to judge the current condition and exclude STEMI. If STEMI has been developed the error end event *change to STEMI protocol!* is thrown and the patient will be switched to the STEMI protocol. If no STEMI is noted, the nurse needs to continue according to the pathway with two parallel processes. In case the patient has *chest pain and a systolic blood pressure > 100mmHG* (or on decision of the practitioner) nitrates are given (*give nitrates* see section 5.1.1.1.1). If this is not the case, only a blood test will be taken (*take blood test*) by drawing a blood sample and sending them to the laboratory with an order to determine the levels and values of *Troponin*, *hsCRP*, *Creatinine*, *Haemoglobin*, *Blood glucose*, *Blood cell count*, *Creatine Kinase (CK)* and *CKmb*. After arrival the laboratory will conduct the blood test, which takes about one hour.
In the meanwhile, the care process at the first heart aid will continues with the cardiologist, who interpret the ECG (*interpretate ECG*) and starts the *anamnesis*. After that, a *physical examination* is conducted and the *patients' history* will be judged. If the cardiologist finds it necessary, he/she will *compare ECG with previous one* made in the ambulance or earlier. Afterwards, it is possible that the cardiologist orders the nurse to *give nitrates* (see section 5.1.1.1.1) after all and/or decides to *do an echocardiogram*. The next step is to *make a working diagnosis* based on the gathered information and test results so far and is done by all patients. If the working diagnosis is not NSTEMI or Unstable Angina (UA), the patient will be withdrawn from the patient by throwing the error end event *withdrawal from pathway (other disease)*. For NSTEMI and UA patients, the pathway follows with the calculation of the GRACE score within the EPR (*calculate GRACE-score*) en the admission of the patient (*admit patient*) including the opening of a new DOT (*open DOT*) for the financial administration. After this is done, the cardiologist can decide to *give morphine* in case the patient has severe pain. The *Initial evaluation phase ends* here, and the treatment is continued within the *Diagnosis validation and risk assessment* phase (see section 5.1.1.2).
The Global Registry of Acute Coronary Events (GRACE) score is a very important risk score that predicts the in-hospital (see Figure 11) and 6 months death and death or MI (Myocardial Infarction) probability and is also used as an indicator to determine the treatment plan later on. The GRACE score is at admission based among others on the age heart rate (HR) in beats per minute (bpm), the systolic blood pressure (SBP), the creatinine level (Creat.) and which of the four killip class of Congestive Heart Failure (CHF) applies, see Figure 10.

Risk category (tertile)	GRACE risk score	In-hospital death (%)
Low	≤108	<1
Intermediate	109–140	1–3
High	>140	>3

Figure 11 – Mortality in hospital in low, intermediate, and high risk categories in registry populations, according to the GRACE risk score, source: (Hamm, et al., 2011, p. 3010)

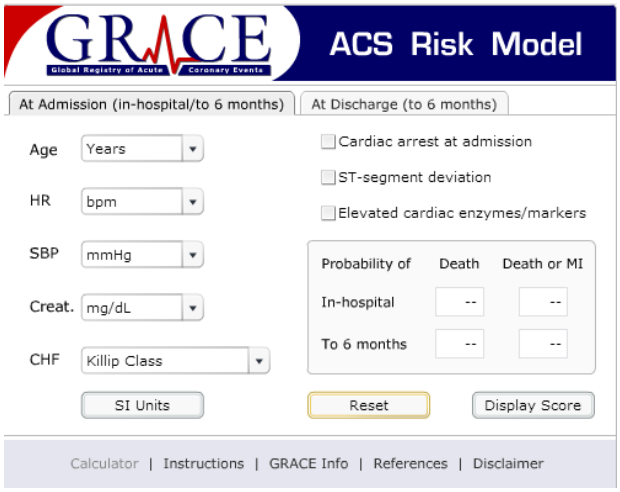


Figure 10 – GRACE ACS Risk Model At Admission, source: (GRACE, 2013)

5.1.1.1.1. Give nitrates

When it is initiated to *give nitrates*, the nurse will first *give sublingual nitrates* (sublingual means under the tong). It takes about 5 minutes time before the effect of the medicine can be evaluated. So therefore, the process is *put on hold for 5 minutes* before it is evaluated if the nitrates work. In case the nitrates work and/or in case the patient has still chest pain *intravenous nitrates* are given. If this is not the case, no more nitrates will be given. The sub process of give nitrates ends when the intravenous nitrates are given or when it is decided not to give them.

5.1.1.2. Diagnosis validation and risk assessment

After the *Initial evaluation*, the care process continues with the *Diagnosis validation and risk assessment* at the first heart aid unit (EHH) and might be taken over by the CCU or nursing ward of Cardiology (7west). Aside from the entire diagram, also two perspectives are made for the EHH respectively CCU and 7west, which include only the activities taken place at that department and the blood tests requested by the Laboratory.

With the information gathered during the first phase the cardiologist can determine if the patient has no STEMI and typical ACS. If this is the case, the patient is immediately treated with ***give medicine (ACS-NSTEMI)*** **at the EHH** without waiting for the results of the taken blood test (throwing signal *move on without hsTnT results*). The blood test will still be performed by the laboratory and the results will be uploaded to the EPR, but this is not explicitly used in the process anymore. In case patients do not have typical ACS, the treatment awaits the results of the blood test (*wait for hsTnT results*). When the results arrive (*results of blood test @T=0hrs in EPD*) the cardiologist needs to look at them (*look at results blood test @T=0hr*), especially to the value here troponin, also called hsTnT. If the hsTnT level is ≥ *30ng/L* and the patient *has typical ACS*, the treatment will continue with ***give medicine (ACS-NSTEMI)*** **at the EHH**. If the hsTnT level ≥ *30ng/L* and the patient has *no typical ACS* or in case the hsTnT level < *30 ng/L*, the treatment process will continue at *T=3hrs* with *Take ECG @T=3hrs* (see section 5.1.1.2.2). If there is no STEMI shown on the ECG, again a blood sample will be taken and a blood test is ordered (*take blood test @T=3hrs*) to measure at least the levels of *Troponin*, *Creatine Kinase (CK)* and *CKmb*. After about one hour the results will be uploaded in the EPR by the Laboratory (*results of blood test @T=3hrs in EPR*) and the Cardiologist can *look at results blood test @T=3hrs*. Afterwards, the ECG made a T=3hrs is interpret and compared (*interpretate and compare ECG of T=3hrs*). Based on the troponin level the pathway routing will be decided. If the troponin level has *not risen with 8 ng/L or more*, the cardiologist needs to either *perform an exercise ECG* to be able to exclude or include ACS as the cause of the chest pain or can directly exclude ACS as the cause and withdrawal the patient by throwing the error end event *withdrawal from pathway (other disease)*. If ACS is the cause of the chest pain, the next step of the treatment will be ***give medicine (ACS-NSTEMI)*** **at the EHH**. This step will also be next in line, in case the troponin level was at T=0hrs 30 ng/L or more and has risen with at least 8 ng/L between T=0hr and T=3hrs (sequence flow *yes and TnT @ hr=0 ≥ 30 ng/ L*) and in the case the troponin level has risen at least 8 ng/L and is 30ng/L or more at T=3hrs (sequence flows *yes and hsTnT@T=0hr <30ng/L* and *yes*). However, in case the troponin level has risen with at least 8 ng/L and is still below 30ng/L (sequence flows *yes and hsTnT@T=0hr <30ng/L* and *no*), the patient will be moved to the CCU or nursing ward of cardiology (7west) and the process will continue at ***T=6hrs***.

After ***give medicine (ACS-NSTEMI)*** **at the EHH** (see section 5.1.1.2.1), there is again a possibility to *do an echocardiogram* if the cardiologist finds this necessary. Thereafter, it needs

to be indicated if the CK and CKmb levels are decreasing yet. If they are not decreasing yet, a second measurement needs to be done in 8hrs (*measure CK/CKmb* see section 5.1.1.2.3). After this, the cardiologist decides if an *urgent invasive treatment* is needed or not, see Table 18. If an indication is given for an urgent invasive treatment the *Diagnosis validation and risk assessment* phase will end and the patient will continue the pathway within the *Invasive strategy* phase (see section 5.1.1.3). If there is no indication for an urgent invasive treatment, the patient will be moved to the CCU or to 7west and the treatment continues the next morning at ***8 a.m.***.
In case the pathway routing has lead to ***T=6hrs*** or to ***8a.m***., patients will be transferred to the CCU if they are unstable, have an infusion and vasodilator substances (e.g. intravenous nitrates) or in case there is no room at 7west. In all other cases patients are transferred to the 7west. The process at ***T=6hrs***, from *Take ECG @T=6hrs* to the assignment of an *urgent invasive treatment* or the routing to *8a.m.*, is almost identical to the process after T=3hrs at the EHH. The difference is that this process takes place 3 hours later at the CCU or 7 west and that there are only two options in the routing after the *results of blood test @ T=6hrs in EPD*; by *hsTnT ≤30 ng/L*, the cardiologist can choose to *perform an exercise ECG* and/or to throw the error end event *withdrawal from pathway (other disease)*, by *hsTnT>30 ng/L* or a positive exercise ECG, the next step is at ***8 a.m.*** the next morning, when a daily doses of medicine will be given (*give medicine (ACS-NSTEMI)* see section 5.1.1.2.1) at the CCU/7west. After this, a daily ECG will be taken (*take ECG* see section 5.1.1.2.2) and the cardiologist(s) will make their *rounds* together with a nurse, in which the *interpretate ECG* and *evaluate patients' status* will be done. Afterwards, the cardiologist *Determine treatment plan* based on the GRACE-score and the presents of risks factors, see also Table 18 and Table 19. Patients that are assigned to an invasive treatment will continue the pathway within the *Invasive strategy* phase (see section 5.1.1.3), patients that are assigned to a conservative treatment will continue the pathway within the *Hospital discharge* phase (see section 5.1.1.5) and patients that are assigned a case management treatment will be withdrawn from the pathway within the top-level.

Treatment	Indication	Plan
Urgent invasive	refractory angina, severe heart failure, ventricular arrhythmias and/or hemodynamic instability	CAG < 120 min
Early invasive	GRACE score > 140 or ≥ 1 primary risk factor	CAG < 24 hrs
Invasive	108 < GRACE score < 140 or ≥ 1 secondary risk factor	CAG < 72 hrs
Conservative	GRACE score < 108 No additional risk factors	Treatment with medicines
Case management		Withdrawal from pathway

Table 18 – Treatment plan options for ACS-NSTEMI/UA

Primary risk Factors
Increased troponin
Dynamical ECG changements
Secondary risk factors
Diabetes Mellitus
Renal insufficiency (GFR<60ml/min/1.73m^2)
Reduced LV function (LVEF<40%)
Early post infarction Angina
Recent PCI or prior CABG
Intermediate to high GRACE risk score

Table 19 – Primary and secondary risk factors for the indication of the treatment of ACS-NSTEMI/UA

5.1.1.2.1. Give medicine (ACS-NSTEMI)

The sub process *give medicine (ACS-NSTEMI)* shows the process of the medication provision during the morning rounds and also indicates if medicine needs to be given a second time on the same day. For the treatment of NSTEMI/UA six medicines are given by default during the entire hospitalization, started during the *Diagnosis validation and risk assessment* and continued until

the *Hospital Discharge* unless stated otherwise. Note that these default medicines still need to be prescribed by a cardiologist before the nurse can give them, although this is not modelled.
The first default medicine given is *aspirin* in the chemical substance of *ASA* (acetylsalicylic acid) in an *initial dose of 160mg* or in a *daily dose of 80mg*. The initial dose is only given in case the patient does not get this medicine yet. The second medicine that will be given is of the chemical subgroup *P2Y12 inhibitor*. By default the medicine *Ticagrelor* is given in an *initial dose of 160mg* or in a *daily dose of 90mg twice a day*. If this is not possible (e.g. because of allergy) *Clopidogrel* will be given instead in an *initial dose of 600mg* or in a *daily dose of 75mg*. It is possible that the P2Y12 inhibitors are stopped during the revascularization phase of the hospitalization when an intervention cardiologist decides to, because a CABG operation needs to be performed. The third medicine is a chemical substance of the type *Anticoagulation* (a type of the chemical subgroup Antithrombotic agents). The chemical substance *Fondaparinux* is given by default in a *dose of 2,5mg*, but if the patient *has a CrCl <30mL/min* than the chemical substance *Enoxaparin* is given in a *dose of 1mg/kg once a day* (i.e. 1mg Enoxaparin is given per kg weight of the patient). CrCl is the Creatinine clearance rate and can be found in the lab results in the EPR. It is used to determine the renal function (i.e. patients with a renal insufficiency will receive Enoxaparin instead of Fondaparinux). Anticoagulation is stopped just before the patient is discharged from the hospital. For the other three medicines that are given by default, no chemical substance names or doses are known, but they are referred to in practice as the pharmacological subgroups of *oral Beta-blockers* and *ACE inhibitor* and the nickname of *Statin*, which is used for the chemical subgroup HMG CoA reductase inhibitors. The provision of the *ACE inhibitor* and *Statin* can be postponed if the cardiologist finds that necessary. Aside from the default medicines for the treatment of ACS-NSTEMI, medicines can be provided for other diseases, like Diabetes Mellitus (DM) or COPD (Chronic Obstructive Pulmonary Disease, a long disease). Note also the medicine of the chemical subgroup Vitamin K Antagonist, that is prescribes for among others atrial fibrillation.

5.1.1.2.2. Take ECG

The sub process *take ECG* is done by nurses of the cardiology department and starts with the *perform ECG*. As patients at the cardiology department are attached to a (tele)monitor, taking a ECG is pushing a button. Afterwards, it is important to *interpretate ECG*, as it must been seen what the current state of the patient is. This is also the moment to see *if STEMI* has been developed. If this is the change the red colours error end event *Change to STEMI protocol!* will be thrown and the patient will leave the pathway at the top-level by switching to the STEMI protocol. Note that it is the nurse here that raises the alarm to switch, but this always needs to be confirmed by a cardiologist. Therefore, at the top-level a cardiologist will be alerted. If there is no STEMI, the nurse needs to *compare ECG with previous one* in order to be able to see the long-term state of the patients (i.e. is the patient in a stable condition, is the patient getting worse or better?). After the ECG is compared, this sub process is ending.

5.1.1.2.3. CK/CKmb measuring

The *CK/CKmb measuring* diagram is a strange diagram in the model, as it is not included in the sequence of the pathway, but continues in parallel. The *start event measure CK/CKmb* is activated when the corresponding escalation event is thrown in the *Diagnosis validation and risk assessment* phase. As the levels of CK (Creatine Kinase) and CKmb need to be measured *every 8 hours*, the process first waits for 7-8 hours before a new blood test will be done (*take blood test*)

to determine the values of *CKmb* and *CK*. Creatine Kinase is an enzyme that is present in the muscle cells and is seen in the blood if muscles damage has been done. The specific iso-enzyme of CK that is mainly present in the heart muscle is CKmb and thus a raised CK and CKmb indicate heart muscle damage. When the laboratory receives the order and blood sample, they will *Take blood test* to measure the levels of *CKmb* and *CK* and afterwards upload the *results blood test CK/CKmb* to the EPR. When the results are uploaded, the cardiologist needs to look at *results blood test* and will then see if the levels are decreasing or not. In case the levels are still increasing, a new blood test needs to be done in 7 hours. In case the levels are decreasing, no new test needs to be done and the diagram will end in its end event.
Note that the process in this diagram is a loop that starts when an escalation is caught and ends when the CK and CKmb levels are decreasing, no matter what happens in the rest of the model. This is semantically not correct, as it can be the case that a patient has already left the pathway while the measuring continues. In order to make it semantically correct the XOR gateway should be an event-based gateway that ends the loop when a patient is withdrawn and otherwise continues until the levels are decreasing. To realize this, a throwing signal needed to be added by all throwing end error events in the lowest sub processes, which could be caught by this diagram. This would not have made the model nor this diagram any clearer. As the diagram is not part of the sequence and the model is used as a communication, the incorrect semantics of this diagram is overlooked.

5.1.1.3. Invasive strategy

The *Invasive strategy* phase is initiated for patients that have been assigned to an *invasive treatment* and patients that have arrived at the hospital with *emergency*.
The phase starts for all patients with the *sign patient up for CAG* by the cardiologist of their residence or in case of emergency by the cardiologist located at the EHH at daytime (or by the cardiologist on duty at night). For emergency and urgent invasive patients, the CAG needs to happen as soon as possible. At daytime there are several HCK teams present to do this, but at night the HCK team on duty needs to be paged (*call HCK team*) and will arrive within 20 minutes. Patient with an urgent invasive treatment (*<120minutes*) are already remaining at the department and can therefore be prepared (*undress patient and put on theater clothing*) for the *perform CAG* (see section 5.1.1.3.1) on the nursing ward. Emergency patient however directly start with the *perform CAG* (see section 5.1.1.3.1), as they arrive at the hospital after the care pathway has been initiated. This is because the cardiologist on duty has already been informed by the ambulance about the future arrival of the patient, such that the HCK team can perform the CAG as soon as the patient arrives at the hospital.
The routing of the care process of patients assigned to an early invasive or invasive treatment depends on the timing of the scheduled CAG. If the CAG is scheduled today (most likely by an early invasive treatment (CAG<24hrs)), the patient will be prepared (*undress patient and put on theater clothing*) and in case of a present renal failure (*a GFR<60ml/min*) the kidneys will be purified by *follow "contrast nefropathie" protocol*, a hospital wide protocol that makes it possible for patients with renal failure to undergo certain diagnostic test. After that, the CAG is performed (*perform CAG* see section 5.1.1.3.1). In case the CAG is not scheduled today (likely in case of an invasive treatment, CAG<72hrs) the patient will await the day of the CAG while receiving 'the daily morning care'; at **8 a.m.** (the next morning) a daily doses of medicine will be given (*give medicine (ACS-NSTEMI)* see section 5.1.1.2.1), a ECG will be taken (*take ECG* see section 5.1.1.2.2) and the cardiologist(s) will make their *rounds*. It can be the case that patients

are transferred from the CCU to 7west while waiting or that the ECG shows that STEMI has been developed and thus the patient needs to switch to the STEMI protocol. The treatment within the *Invasive strategy* phase ends after the CAG is performed and continues in the *Revascularization modalities* phase (see section 5.1.1.4).

5.1.1.3.1. Perform CAG

The *perform CAG starts* after the patient has been prepared for the intervention or in case of emergency after the patient has arrived at the hospital. By emergency patients, first an *update by paramedic* is given, after which the patient is prepared for the intervention (*undress patient and put on theater clothing*) by the HCK team. All patients are *give UFH* (UnFractionated Heparin) in a dose of *5000* international *units*. After this, the HCK team *sterilize and anaesthetize groins* and *place sheath* by the patient. This because the CAG (Coronary Angiography), also called a catheterization, is done through the blood vessels in the groins under local anaesthesia. After the *execute CAG*, it might be possible to *execute FFR* (Fractional Flow Reserve), a technique that is used to decide if it is necessary to perform a PCI. Based on the results of the CAG, and FFR, it is decided if the sheath will be removed or not (*remove sheath and apply pressure bandage*). The sheath will be left in place if a PCI needs to be performed (or in case the heart team meeting might decide to perform a PCI). After this decision the sub process will end.

5.1.1.4. Revascularization modalities

The *Revascularization modalities phase starts* when patients have finished the *Invasive strategy* phase. Based on the information gathering during the performed CAG, it can be decided if either a bypass operation (CABG), a PCI or a medical treatment is the most suitable treatment option. Most patients will either be treated with a *PCI*, in which case the routing will lead to the start of the sub phase *prepare and conduct PCI* (see section 5.1.1.4.1), or a *medical* treatment is prescribed, in which case the *Revascularization modalities phase will end* and the patient will continue his/her treatment within the *Hospital discharge* phase (see section 5.1.1.5). After the PCI has been conducted the *Revascularization modalities phase will end* for most patients. It is however possible that an *urgent or emergency CABG is required*, in which case the sub phase *prepare, await and hold heartteam meeting* (see section 5.1.1.4.2) will starts. This sub phase will also start in case the HCK team finds the CABG option the most suitable option after the CAG is performed. In both cases the patient is transferred from the HCK to the CCU or 7west, where the preparation will be done.

The heart team meeting will decide the further treatment plan for the patient. The possible treatment plans for patients that only had a previous CAG are a *medical* treatment, a *PCI*, a *CABG* in the sub phase *await and conduct screening + intake CABG* (see section 5.1.1.4.3), or *case* management in which the purple colours error end event *withdrawal patient from the pathway (case management)* in thrown. For patients that had a previous PCI, the only routings options are those leading to the start of the sub phase *await and conduct screening + intake CABG* (see section 5.1.1.4.3) either because of an emergency CABG (sequence flow *yes*) or because of an urgent CABG (sequence flow *no* and *CABG*) and the routing to the withdrawal of the patient from the pathway (sequence flow *yes* and *case*). This is not explicitly mentioned in the model, but otherwise patients could have a PCI after a PCI instead of being assigned to a case management treatment. After the *await and conduct screening + intake CABG* (see section 5.1.1.4.3) has be conducted, the patients will continue their care process within the sub phase of *await CABG* (see section 5.1.1.4.4), except if an emergency CABG will be performed then the

sub phase *prepare emergency CABG* (see section 5.1.1.4.5) will be started. This distinction is made because emergency patients remain on the CCU during the shortened sub phase of *await and conduct screening + intake CABG*, while all other patients will be transferred to the nursing ward of Cardiothoracic Surgery (CTC, 6west). The responsibility to perform and coordinate the screening and intake of an emergency CABG operation remains with the CTC nurse practitioner and cardiothoracic surgeon, but the roles of nurse and secretary will be done by the CCU employees.[5] During the sub phases of *await CABG* (see section 5.1.1.4.4) and *prepare emergency CABG* (see section 5.1.1.4.5), it is possible that the Anaesthetist does not want to proceed with the CABG operation in which case the patient will be put back on the waiting list in case of an urgent or elective CABG or will be withdrawn from the pathway in case of an emergency CABG. In case the process can continue, the sub phase *perform CABG* (see section 5.1.1.4.5) will be started. After the CABG is performed the *Revascularization modalities phase will ends* and treatment continues within the *Hospital discharge* phase (see section 5.1.1.5).

5.1.1.4.1. Prepare and conduct PCI

The sub phase *prepare and conduct PCI starts* when a PCI treatment is initiated after a CAG or a heart team meeting. In most cases the *execute PCI* follows directly after the CAG, as the patient is already in the intervention room (at the HCK). In case the heart team meeting has decided to perform a PCI anyway, the nursing ward needs to *Undress patient and put on theater clothing* and transfer the patient to the HCK. There the patient will be given heparin (*give UFH* in a dose of *5000 units*), before the PCI is performed. Afterwards, the HCK team can *remove sheath and apply pressure bandage*. If the sheath is left in place, the patient needs to be transferred to the CCU and it is possible to *give Glycoprotein IIb/IIIa receptor inhibitors* to reduce blood clots or to prevent them. They go by the brand names of ReoPro and Aggrastat (chemical substance names abciximab and tirofiban). If the sheath is removed, the patient can be transferred to either the CCU or 7west. After the decision has been taken to remove the sheath or after the Glycoprotein has been given this sub phase will end. The treatment of the patient will continue in either the *prepare, await and hold Heart team meeting* (see section 5.1.1.4.2) or in the *Hospital discharge* phase (see section 5.1.1.5).

5.1.1.4.2. Prepare, await and hold Heartteam meeting

The sub phase *prepare, await and hold Heartteam meeting* is started in case the HCK team considers a CABG operation and the patient has been transferred to the CCU or 7west. In order to be able to *sign patient up for heart team meeting* an echocardiogram is required and thus it needs to be looked if the results of a recently conducted echocardiogram are available. If this is not the case, the cardiologist needs to *do echocardiogram*. Afterwards, additional tests need to be done if also one of the heart *valves* and/or the *aorta* needs to be operated on. In case of the heart *valves*, intercollegiate consults of the jaw by a dental surgeon (*ICC jaw*) and of the Ear, Nose and Throat (ENT) by an ENT specialist (*ICC ENT*) need to be done. In case of the aorta, a CT-scan needs to be made (*conduct CT-scan*) by a radiologist.
As regular *Heartteam meeting* are scheduled every morning at *10a.m.*, patients that have been indicated as elective[6] or urgent need to wait till the next morning before they are discussed. In

[5] Unstable elective and urgent patient also remain at the CCU and receive the same treatment as the stable patients at the 6west, but then from a combination of CCU employees and the CTC nurse practitioner and surgeon in training.
[6] Please note that these elective CABG patients are still hospitalized because of ACS and are not similar to the 'common' elective CABG patients who await their screening and operation at home.

the meanwhile, they will receive 'the daily morning care'; at *8 a.m.* a daily dose of medicine will be given (*give medicine (ACS-NSTEMI)* see section 5.1.1.2.1), an ECG will be made (*take ECG* see section 5.1.1.2.2) and the cardiologist(s) will conduct their *rounds*. In case of emergency, a *Heartteam meeting* is hold immediately as the patient needs to be operated on as soon as possible. After the Cardiothoracic surgeon and the Cardiologist have hold their meeting and decided on the further treatment, the EuroSCORE needs to be filled in (*fill in Euroscore*). After this the sub phase ends and the treatment of the patient is continued in either the sub phase *await and conduct screening + intake CABG* (see section 5.1.1.4.3), in the sub phase *prepare and conduct PCI* (see section 5.1.1.1) or in the *Hospital discharge* phase (see section 5.1.1.5) or the patient is withdrawn from the pathway.
The European System for Cardiac Operative Risk Evaluation (EuroSCORE) is a risk model that calculates the mortality probability after a heart operation, based on the 18 factors of age, gender, renal impairment, extracardiac arteriopathy, poor mobility, previous cardiac surgery, chronic lung disease, active endocarditis, critical preoperative state, diabetes on insulin, NYHA (indication of heart failure), CCS class 4 angina, LV function, recent MI, pulmonary hypertension, urgency, weight of the intervention and surgery on thoracic aorta, see also Figure 12. (EuroSCORE Study Group, 2011) As information about the different factors is gathered during different moments of the pathway, the EuroSCORE is updated at the end of each sub phase within the EPR. The first calculation of the score is done after the heart team meeting.

Patient related factors			Cardiac related factors		
Age [1] (years)	0	0	NYHA	select	0
Gender	select	0	CCS class 4 angina [8]	no	0
Renal impairment [2] *See calculator below for creatinine clearance*	normal (CC >85ml/min)	0	LV function	select	0
Extracardiac arteriopathy [3]	no	0	Recent MI [9]	no	0
Poor mobility [4]	no	0	Pulmonary hypertension [10]	no	0
Previous cardiac surgery	no	0	**Operation related factors**		
Chronic lung disease [5]	no	0	Urgency [11]	elective	0
Active endocarditis [6]	no	0	Weight of the intervention [12]	isolated CABG	0
Critical preoperative state [7]	no	0	Surgery on thoracic aorta	no	0
Diabetes on insulin	no	0			
EuroSCORE II	0				
EuroSCORE II					
Note: This is the 2011 EuroSCORE II	Calculate	Clear			

Figure 12 – EuroSCORE II interactive calculator, source: (EuroSCORE Study Group, 2011)

5.1.1.4.3. Await and conduct screening + intake CABG

The sub phase *await and conduct screening + intake CABG* will be started if the heart team initiates an elective, urgent or emergency CABG operation. A shortened screening and intake of emergency patients will start immediately by the CTC nurse practitioner and cardiothoracic surgeon in training while the patient remains at the CCU. For elective and urgent patients the sub phase starts with the order of the heart team to the CTC secretariat to place the patients on the waiting list for the CABG operations (*put patient on "klinische wachtlijst"*) After this, it would be ideal if the patient is transferred to the CTC nursing ward (6west), but if this is possible depends on the bed capacity there. At the cardiology department they hold on to the rule of thumb that patients can be transferred to 6west after the surgery date is made public (every Wednesday the operation planning for next week is made), until then patient remain at the CCU and/or 7west. At the cardiology wards they will receive the 'the daily morning care'; at *8 a.m.* a daily dose of medicine will be given (*give medicine (ACS-NSTEMI)* see section 5.1.1.2.1), an

ECG will be made (*take ECG* see section 5.1.1.2.2) and the cardiologist(s) will conduct their *rounds*.[7] In case the surgery is scheduled within 6 days (or might be scheduled within 6 days) and a stent has been placed within the last 12 months, the heart team *discuss discontinuing P2Y12 inhibitors* (and also vitamin K antagonist is this is prescribed). The P2Y12 inhibitors can cause bleedings during the operation, but they also prevent that any blood clots will get stuck on the stent. As both complications want to be avoided, the intervention cardiologist needs to look which specific type of stent is place and how long the medicine needs to be given (they are prescribe by default for 12 months). The decision to discontinue the P2Y12 inhibitors by a prior placed stent, therefore needs to be made by the intervention cardiologist. When no stent is place within the last 12 months, the medicine can be stopped without consulting the heart team. When the time is there, patients will be transferred to 6 west. At the CTC department only patients that will undergo a *surgery for main stem stenosis* are monitored. All other patient are therefore detached from the monitor when they arrive at 6west (*detach (tele)monitor*). Directly after their arrival it is check whether or not already a decision was made about discontinuing the P2Y12inhibitors. If this has not been done yet, this will be done as discussed above. Afterwards the one day screening and intake can be start.

The screening and intake of the CABG starts when an emergency CABG has been initiated or when the patient arrives at 6west. Normally, the screening and intake is done in one day, but in case of emergency this is done in a shortened form. First, the nurse needs to *make ECG* with an ECG device, as most 6west patients are not attached to a (tele)monitor. The movements of 'stuck the electrodes of the ECG device on the skin before the ECG device makes the ECG and remove them afterwards' are not worked out in a separated sub process. Besides that, the nurse needs to *take blood sample* and deliver that to the 6west secretary, who will order the blood test and send the blood sample to the laboratory (*request blood test*). All blood tests that are done at CTC are standardized and documented in their work processes, where the model refers to. The *"opname blok"* that is ordered here, asks for the levels of HB, HT, platelets, Leuco's, Glucose, ALAT, kalium, sodium, urea, creatinine, MDRD, INR and CRP and the blood group and irregular antibodies. The laboratory will start the *blood test "opname blok"* when the order is received and will upload the *results blood test "opname blok"* to the EPR within one hour. In the meanwhile, the *screening+intake* (see section 5.1.1.4.3.1) is already started by the nurse practitioner, physician and/or surgeon in training, in which also the ECG and test results will be looked at.

The process after the *screening+intake* continues in parallel. The 6west secretary starts the *NEC request "NEC protocol"*, which is used to indicate who many units of which type of blood need to be ordered for the operation and is not worked out here in detail. After the secretary has requested the NEC, an X-ray needs to be request (*request X-ray*) by the radiology department in case there is recent X-ray present, conducted in the last 3 month. If needed a Radiologist will *make an X-ray* and will upload the *result X-ray* in the EPR. In the meanwhile, the *intake: information/DVD+guided tour* is done by the nurse, followed by the start of the Anaesthetists *Intake: information* at the ward where the patient is remaining. It is possible that the Anaesthetist *request more info* because he/she needs that to base his approval, indication and pre medications on. It is the task of the Nurse Practitioner, Physician and Cardiothoracic surgeon to *gather info that is requested*. Within the Anaesthetic intake, at least an indication will be made for the provision of the post operative care on either the *PACU* (Post Anaesthetic Care Unit), which is indicated if it is expected that the patient can be transferred to 6west a few hours after the surgery

[7] Note that, in practice it might be needed to remove the sheath here as well (see section 5.1.1.5.1), but within this model it is assumed that this has been done directly after the CAG in case a CABG needs to be performed.

has been performed, or the *HC* (High Care), where patients need to remain for at least 24 hours after the surgery, followed by *prescribe pre medication*. The pre medication prescribed by default are included in the sub process *give medicine (ACS-NSTEMI-CABG)*, see section 5.1.1.4.4.1. After this, the Anaesthetist needs to end his intake either directly without any medical objection (sequence flow *no*) or after a short term objection (i.e. for a few hours), or the intake ends with a protracted objection in the error end event *withdrawal patient from the pathway (case management)*. After the Anaesthetic intake has been finished and the X-ray is present, the EuroSCORE will be updated (*update Euroscore*). If the EuroSCORE is *above 10* a *consult CTC surgeon* will be done, in which the CTC surgeon needs to decide to *proceed with the pathway* or *to withdrawal the patient* from the pathway because case management is required. In case the EuroSCORE is *below 10*, it is possible that there is *medical objection* in which case also a *consult CTC surgeon* and a corresponding decision takes place. In case there is *no medical objection* or the *CTC surgeon has decided to proceed*, this sub phase *will end* and the treatment continues for elective and urgent patients in the sub phase *await CABG* (see section 5.1.1.4.4) and for emergency patients in the sub phase *prepare emergency CABG* (see section 5.1.1.4.5).
Note, that there are two perspectives of this sub phase; one for the CCU/7west that contains only the first part of the process until transfer to CTC and one for 6west that contains the entire process at 6west with one task for the 'daily morning care' at cardiology.

5.1.1.4.3.1. Screening + intake

The sub process *Screening + intake starts* with the *data gathering* and *intake, patient history and information providing*, in which it is also noted if the patient has comorbidities like DM and COPD. In case the patient has DM, the *start "GIK schema"* needs to be done (a schedule for the provision of the DM medicines) and afterwards a *request ICC Internist* needs to be send. The *ICC Internist* will be done within short notice after the *request ICC Internist* has been received as it needs to be completed before 12.00hrs. If the patient has a COPD ≥ 3, a *request ICC Pulmonologist* will be send and the *ICC Pulmonologist* will take place. When all needed ICCs request are send, the Nurse practitioner, physician and/or cardiothoracic surgeon continues with the *physical examination and control blood pressure*. Afterwards the *results blood test "overname blok"* will be looked at and the *interpret ECG* will be done. If these test results are not acceptable, the patient will be *withdrawal from pathway (case management)*. Before the *enter medication + authentication, laboratory, X-ray, consultations* can be done, the *advice internist* and *advice pulmonologist* need to be given in case these were requested. After all information is entered to the EPR, the *update Euroscore* will be done. If this score is *above 10*, a *consult CTC surgeon* needs to be done to *proceed* or to *withdrawn* the patient from the pathway. If the pathway proceeds, *information, risk discussion and informed consent* will be done by the cardiothoracic surgeon in training according to the guidelines. Afterwards, it is possible that a reason from a medical objection is found which needs to be discussed with the CTC surgeon (*consult CTC surgeon*) to be able to *proceed* or *withdrawn* the patient from the pathway. The sub process ends when there is no medical objection or the CTC surgeon decides to proceed.

5.1.1.4.4. Await CABG

Patients that have finished the screening and intake and have been signed up for an elective or urgent CABG operation will continue their treatment within this sub phase. Also patients that

have been put back on the waiting list (*put patient back on "klinische wachtlijst"*) during the preparation of the surgery will continue their treatment here.
Until the day before the surgery is scheduled, patients will receive 'daily care' every morning at *7.00 a.m.* consisting of a daily dose of medicine (*give medicine (ACS-NSTEMI-CABG)* see section 5.1.1.4.4.1) followed by the *rounds* of the nurse practitioner, physician and cardiothoracic surgeon in training, in which the *check patient*, *hemodynamics* and *evaluate patients' status* will be done.
The day before the operation is scheduled the *introduction of CTC surgeon to patient* takes place and the next morning only medicines will be given (*give medicine (ACS-NSTEMI-CABG)* see section 5.1.1.4.4.1). Afterwards the *preoperative preparation patient* is conducted, including the *change patient into theater clothing* and *ensure patient has been fasting*. The fasting of the patient starts during the night and is very important to ensure, as it can be a reason to send patients back when it is not properly done. After the patient has been prepared the *follow "check operatieve patienten – PRE OPERATIEF – Verpleegafd. naar Holding"* is done. This is the first part of the checklist that is used for all patients undergoing an operation in the hospital (see Appendix H – Figure 18). If it is not possible to complete the checklist, the Anaesthetist needs to be informed (*discuss with Anaesthetist*) and decides if the patient can *proceed* according to the pathway or needs to be put back on the waiting list (*put patient on "klinische wachtlijst"*). If the checklist is completed or the pathway is proceeded the *await CABG sub phase ends* and the *perform CABG* sub phase (see section 5.1.1.4.5) will start.

5.1.1.4.4.1. Give medicine (ACS-NSTEMI-CABG)

The sub process *give medicine (ACS-NSTEMI-CABG)* shows the process of the medication provision during the morning rounds and later that day for ACS-NSTEMI/UA patients that will be undergoing an elective or urgent CABG operation. Note that the medicines given here are prescribes by the Cardiologist, Anaesthetist and/or Cardiothoracic surgeon/Nurse practitioner earlier in the process, see also *give medicine (ACS-NSTEMI)* in section 5.1.1.2.1.
Four of the six medicines that are given by default for the treatment of NSTEMI/UA are always continued during the CABG path. These are *Aspirin*, *Oral Beta-blocker*, *ACE inhibitor* and *Statin*. The *P2Y12 inhibitor* is preferably stopped, as it can cause bleeding during the operation. The decision to discontinue this medicine is taken during the sub phase *await and conduct screening + intake* (see section 5.1.1.4.3). The *Anticoagulation* chemical substance *Fondaparinux* (or *Enoxaparin*) prescribed by the cardiologist is continued until the day before the operation and is replaced after the operation with the chemical substance *Dalteparin* (brand name Fragmin) in a *dose of 2500units* or *5000units,* depending on the weight of the patient. Why different chemical substances of the same group are used is unknown, but it might have to do with the optimal medicine for ACS patient (essential for the treatment) and the choice for a similar but cheaper medicine for CABG patients. Also in this path the Anticoagulation is stopped prior to the discharge during the *nurse and mobilize patient (at CTC),* see section 5.1.1.5.4.
Aside from the default medicines for ACS, also default medicines for the CABG operation are prescribed. Five days before the operation is scheduled, the patient will receive two medicines used to disinfect the patient; the disinfectant with the brand name '*hibiscrub'* and a nasal cream of the chemical substance *mupirocino* (brand name bactroban). If the medicines are not given for 5 days in advance, it will be continue after the operation until it is used for 5 days total. The day before as well as the morning of the operation, the chemical substance *Lorazepam* is given in a *dose of 2mg* or in case the patient is older than 70 years in a *dose of 1mg* for its narcotic effect

(i.e. such that the patient can sleep well). The morning of the surgery the medication of the chemical substance *paracetamol* starts with a *dose of 1gram thrice a day* until discharge.
Aside from the default medicines for the treatment of ACS-NSTEMI and CABG, medicines can be provided for other diseases, like DM or COPD. Important here is the medicine of the chemical subgroup Vitamin K Antagonist, that needs to be discontinued prior to the operation (if possible) and restarted afterwards.

5.1.1.4.5. Prepare emergency CABG

Patients that have finished the screening and intake and have been indicated with an *emergency* CABG operation will continue their treatment within this sub phase. The sub phase starts with the *introduction of CTC surgeon to patient*. Afterwards, the *preoperative preparation patient* is conducted, including the *ensure patient has been fasting*. The fasting of the patient needs to starts as soon as the indication of emergency is given, as it can be a reason to send patient back when it is not properly done. As it is not known if emergency patients are *changed into theater clothing* during this part of the preparation or within the operation rooms department, it is left out of the model. After the patient has been prepared the *follow "check operatieve patienten – PRE OPERATIEF – Verpleegafd. naar Holding"* is done. This is the first part of the checklist that is used for all patients undergoing an operation in the hospital (see Appendix H – Figure 18). If it is not possible to complete the checklist, the Anaesthetist needs to be informed (*discuss with Anaesthetist*) and decide if the patient can *proceed* according to the pathway or not. This last option will hardly be taken, as the life of the patient is as stake here. In case the Anaesthetist decided to no proceed, the patient is *withdrawal from pathway (case management)*. If the checklist is completed or the pathway is proceeded the *prepare emergency CABG sub phase ends* and the *perform CABG* sub phase (see section 5.1.1.4.5) will start.

5.1.1.4.6. Perform CABG

The *perform CABG sub phase starts* after the *await CABG* or *prepare emergency CABG* have been successfully completed. A CTC or CCU nurse transfers the patient from the nursing ward to the holding of the Operation Rooms and hands over the patient by *sign "Checklist operatieve patienten – PRE OPERATIEF - Verpleegafd. naar Holding"* by both the nurse and holding employee, see Appendix H – Figure 18). After that, the second part of the checklist is followed (*follow "Checklist operatieve patienten – PRE OPERATIEF - Holding"*, see Appendix H – Figure 18) by the holding employee. In case it is not possible to complete this part, the Anaesthetist needs to be informed (*discuss with Anaesthetist*) and he/she needs to decide if the patient can *proceed* according to the pathway or needs to be put back on the waiting list (*put patient on "klinische wachtlijst"*). In case of emergency, the only option here is to proceed with the operation. If the checklist is completed or the pathway is proceeded, the *sign "Checklist operatieve patienten – PRE OPERATIEF - Holding"* is done by both the holding employee and anaesthetic employee. Afterwards, the anaesthetic employee will transfer the patient to the operation room, where the OR team will *place patient on OR table and connect to required equipment*. Then the *time out pre operative* will be done by the team (see Appendix H – Figure 19) and needs to be agreed on before the process can continue. The OR team exists of an anaesthetist, anaesthetic employee and one or more nurses, operation assistants and cardiothoracic surgeons.
After the time out agreement, the anaesthetist will *bring patient under anaesthesia* followed by the *insert urine catheter* and *sterilize patient* by the operation assistant. Next, the *prepare patient*

and room for surgery will be done by the OR team. Afterwards, the medical professionals will be working in parallel. While the anaesthetist and the anaesthetic employee keep on *control patients' status*, the cardiothoracic surgeon opens the chest of the patient (*open patient*) and the operation assistant *prepare vain from leg or arm for CABG*. The routing afterwards depends on the type of bypass operation decided on. During the intake, the operation approach is discussed with the patient, but this might change when the patient is opened up. In case a CPB technique is used, the patient is attached to a CPB machine during the CABG operation (sequence flow *CPB – attach patient to CPB machine – perform CABG – CPB – detach patient from CAPB machine*). A CPB, cardiopulmonary bypass, is a bypass technique whereby the heart function is (partly) taken over by a heart-lung or CPB machine, such that the blood circulation continues while the heart is brought to a (partly) standstill. The attachment of a CPB machine is the responsibility of the surgeon and the perfusionist, whereas the control of the machine is the responsibility of the perfusionist. In case the OPCAB (off-pump coronary artery bypass) technique is used, the bypass operation is done while the heart keeps beating (sequence flow *OPCAB – perform CABG – OPCAB*). Note that in case also one of the heart valves and/or aorta needs to be operated on, this will be done here as well (during the *perform* CABG). After the CPB machine is detached or the OPCAB is perform, the *place thorax drains* is done by the surgeon, such that fluids can be released from the chest when it is closed. Also pacemaker leads can be placed here, but this is not modelled. Afterwards, the OR team will round up the surgery and write the corresponding reports in parallel; the surgeon will *write and record OR-report* and *prepare closing patient* and afterwards *close patient*; the operation assistant will *count if all equipment is present* during the entire closing procedure; the anaesthetist will *write and record OR report* and keep controlling the patients' status; and the entire OR team needs to *record postoperative policy*. After that, the *debriefing* (see Appendix H – Figure 19) and *prepare patient for transfer* are performed. Before the patient can be transferred to the IC, the first part of the post operative checklist needs to be followed (*follow "Checklist operatieve patienten - POST OPERATIEF - Operatiekamer naar Recovery/IC"*, see Appendix H – Figure 20). After this task is done, the sub phase *perform CABG ends* and the treatment continues within the *Hospital discharge* phase (see section 5.1.1.5).

5.1.1.5. Hospital discharge

The *Hospital discharge* phase contains two possible successful routings, which are initiated based on their prior step within the patients' assigned pathway.

Most Unstable Angina patients are assigned to a *conservative treatment*, in which case the routing to this phase is done directly after the *Diagnosis validation and risk assessment* phase, or an *invasive treatment with or without a PCI*, in which case the routing to this phase is done after the CAG or PCI is performed in the *Revascularization modalities* phase. All these patients will be treated at the cardiology department according to the sub phases *nurse and mobilize patient (at cardio)* and *discharge patient (at cardio)* (see section 5.1.1.5.1 and section 5.1.1.5.2). During these sub phases it is possible that STEMI has been developed and the patient needs to *change to STEMI protocol!*. This does not mean that no other complications or comorbidities can cause problems during the treatment. In fact these can happen anytime during the phases and as it makes no sense to model a 'withdrawal from pathway (case management) option' after every activity; it was chosen to only model the STEMI notification.

All patients that have been assigned to an *invasive treatment with an elective, urgent or emergency CABG* are treated at the intensive care and the nursing ward of cardiothoracic surgery

according to the sub phases *provide post operative care*, *nurse and mobilize patient (at CTC)* and *discharge patient (at CTC)* (see section 5.1.1.5.3 to section 5.1.1.5.5). During these sub phases it is possible that patients either need to *change to STEMI protocol!* or are *withdrawal from pathway (case management)*.

5.1.1.5.1. Nurse and mobilize patient (at cardio)

The *nurse and mobilize patient (at cardio) sub phase starts* when patients have successfully completed either the *Diagnosis validation and risk assessment* phase and are assigned to a *conservative treatment*, or are assigned to an *invasive treatment with or without a PCI* and have completed the *Revascularization modalities* phase. In the first case, the patients will continue their treatment after they are moved to 7 west with the activity ***start mobilize patient***. In the other cases the treatment continues with the transfer of the patient to either the **CCU** or **7west**. The treatment at the two departments is similar, but some additional activities are performed the CCU. The process flow of the CCU activities until ***start mobilize patient*** will be discussed first, then those happening at 7west.

Patients that are unstable and/or have a sheath are transferred to the **CCU**, where they are attached to the monitor (*attach patient to monitor*) that measures their *pulse*, *respiratory rate* and their *blood pressure* (through the sheath). Besides that, pulsation needs to be checked every nursing round to indicate possible bleedings. Afterwards, an ECG is taken according to the sub process *take ECG* (see section 5.1.1.2.2). In case the patient has been brought in with *emergency*, the patient needs to be admitted (*admit patient*) and a new DOT needs to be opened (*open DOT*) (as is done for non-emergency patients in the *Initial evaluation* phase, see section 5.1.1.1). Approximately 6 hours after the 'installation' has been done, the next step is to *take blood test* to measure the *aPTT* and the level of *Haemoglobin*. The *aPTT*, activated partial thromboplastin time, is used to indicate how thick the blood is and need to be retested if the blood is still too thin. The *Haemoglobin* level is used to indicate if an internal bleeding has occurred; "*the lower the baseline haemoglobin the higher the risk, for both procedure-related and non-procedure-related bleeding.*" (Hamm, et al., 2011, p. 3036) As the haemoglobin level is also measured at T=0hrs during the *Initial evaluation* phase, it can be seen if the level is significantly decreased and if action is required. In case the *blood is thick enough*, the sheath will be removed and a pressure bandage will be put on (*remove sheath an apply pressure bandage*). When the sheath is removed and the patient is stable, he/she can be transferred to 7west on indication of the cardiologist to ***start mobilize patient***. In case no bed is available at 7west, it is possible to continue the remaining treatment or parts of it at the CCU.

Patient that are stable and have a pressure bandage are transferred to **7west**, where they are attached to a telemonitor that measures their *pulse*, *respiratory rate* and their *blood pressure*. Also here the pulsation needs to be checked every nursing round, to indicate possible bleedings, and an ECG is made. After 4 hours the pressure bandage can be removed again (*remove pressure bandage*) and the *start mobilize patient* can initiated. During the ***start mobilize patient***, the patient is supported to try to mobilize himself/herself again. This means that the patient needs to try to sit on the edge of the bed and walk around the ward for a minimum of one hour. After the mobilization has started, a cardiologist needs to decide when the patient is ready for discharge. This is normally the same or the next day (or another day in the future). In case the patient is discharged today, the anticoagulation will be stopped (*discontinue anticoagulation*) and treatment will continue in the *discharge patient (at cardio)* sub phase (see section 5.1.1.5.2). In case the discharge is not today, 'the daily morning care' will continue until it is possible to

discharge the patient; at *8 a.m.* a daily dose of medicine will be given (*give medicine (ACS-NSTEMI)* see section 5.1.1.2.1), an ECG will be made (*take ECG* see section 5.1.1.2.2) and the cardiologist(s) will conduct their *rounds*, in which also the *control groins* will be done. Besides that, the cardiologist can *discontinue anticoagulation*.

5.1.1.5.2. Discharge patient (at cardio)

When the cardiologist has stated that the patient can be discharged, the sub phase *discharge patient (at cardio) is started*. First of all, a pre-discharge ECG is performed (*Perform pre-discharge ECG*), which refers to the sub process *take ECG (*see section 5.1.1.2.2). Afterwards, the nurse will *give patient life style advice*, including *risk-factor counselling*, a discussion of the *living rules* and *what to do in case of new symptoms*. Afterwards, the cardiologist *make follow up appointments for patient*, which consist currently of a *control appointment by Cardiologist* and an *update letter for GP and/or Cardiologist* (in case the patient is normally treated within another hospital). Besides that, two future inclusions are modelled; *refer to cardiac rehabilitation / secondary prevention program* and the according *sign patient up for pre-rehabilitation x-ergometry*. This is done because patients need to be referred to the rehabilitation program and cardiologists also do this, but patients with NSTEMI/UA are refused due to capacity limitations. In the near future, it will be possible to also admit NSTEMI/UA patients to the program, as the capacity will be extended when the joint program with the Maxima Medical Centre is realized. After the appointments are made, the cardiologist needs to *prescribe medicine* for the long term treatment. By default the 'golden five medicines', *Aspirin – ASA 80 mg/day*, *P2Y12 inhibitor*, *Oral Beta-blocker*, *ACE inhibitor* and *Statin*, are prescribe that have also been given during the hospitalization (see also *give medicine (ACS-NSTEMI)* in section 5.1.1.2.1). Instead of the *ACE inhibitor* it can be chosen to prescribe *ATII*, which stands for the chemical subgroup of Angiotensin II antagonists. Besides that, a *proton pump inhibitor* is prescribed if the patient fulfils one of the following criteria; above ≥65year, stomach bleeding or uclus of H. Pylori in vg, steroid and/or combined anticoagulantia. The last task is to *discharge patient*, which includes that it is looked if the DOT is correct (*check DOT*), the GRACE score is recorded (*check GRACE*) and the golden five medicines are prescribe or that it is recorded why they are not prescribe (*check golden 5 medicine*). After that, the *sub phase of discharge patient (at cardio) will end* and the patient leaves the hospital at the top-level (end event *Departure*).
Note the differences and similarities between the discharge here and at CTC; the discharge letter is not modelled here, there is also no check build for the completion of the 'intervention' report and no referral is made by thrombotic patients. It is very well possible that this happens in practice, but where not mentioned during the information gathering.

5.1.1.5.3. Provide post operative care

All patients who have undergone an elective, urgent or emergency CABG operation within the *CABG* sub phase will afterwards continue their pathway within this sub phase. After the patient has been transferred by the anaesthetist and the cardiothoracic surgeon to either the HC (High Care) or the PACU (Post Anaesthetic Care Unit) unit of the Intensive Care, the patient is hand over and the checklist needs to be signed by the anaesthetist and the IC nurse (*sign "Checklist operatieve patienten - POST OPERATIEF - Operatiekamer naar Recovery/IC"* see Appendix H – Figure 20). After that, *attach patient to monitor* and *oxygen insufflation* will be done and the thorax drains (*control thorax drains*), drip policy and fluid balance (*control drip policy and fluid balance*) will be controlled hourly. The *oxygen insufflation* continues for a few hours until the

patient is stable, awake and breathing on his/her own. When that point is reached the insufflation stops and the tube is removed (*stop Oxygen insufflation and remove tube*).
In the meanwhile, the standard medications will be given (*give medicine (ACS-NSTEMI-postCABG)* see section 5.1.1.5.3.1) and an ECG will be made (*take ECG @ IC* see section 5.1.1.5.3.2). If the patient needs to be withdrawn from the pathway based on the ECG, also the other activities in the model are stopped. After an successful ECG, a standard blood test is taken (sequence flows *take blood test "standard"* and *results blood test "standard"* at IC and start message *request blood test "standard" – Take blood test "standard"* – end message *results blood test "standard"* at Laboratory) and an X-ray is made by a radiologist (sequence flow *Request X-ray* and *results X-ray* at IC and start message *request X-ray – Take an X-ray* – end message *results X-ray* at Radiology). It is unknown which levels are request with the "standard" blood test here. Based on both test results, it is again possible that the patient needs to be withdrawn from the pathway, but in case the test results are satisfying, it needs to be decided if the patient can be transferred to 6west today. Normally patients that are remaining on the PACU are transferred to 6west the *same day* and patients that are remaining on the HC are transferred the *next day* (24hours after surgery). Before the patient can be transferred the post operative checklist needs to be followed by the IC team (*follow "Checklist operatieve patienten - POST OPERATIEF – Recovery Verpleegafdeling"*) and signed by the IC team and a nurse from 6 west (*sign "Checklist operatieve patienten - POST OPERATIEF – Recovery Verpleegafdeling"* see Appendix H – Figure 20). Afterwards, the patient will be transferred by the 6west nurse to the nursing wards of CTC (6west) and this sub phase will end. The treatment continues within the sub phase *nurse and mobilize patient (at CTC)* (see section 5.1.1.5.4).

5.1.1.5.3.1. Give medicine (ACS-NSTEMI-postCABG)

The sub process *give medicine (ACS-NSTEMI-postCABG)* is only applied at the IC department and shows the process of the medication provision directly after the operation at both the PACU and HC (first and second group of medicines) and during the daily morning rounds at the HC (second and third group of medicines).
The first group of medicines consists of the *antibiotic* with the chemical substance name *Cefazoline*, which is given in a *dose of 2000mg/24hrs*, and the fluid *Lactated Ringer* in a dose of *240ml/24hrs*. If the patient is allergic to Cefazoline, *other type* of antibiotic will be given. The second group of medicines consists of the chemical substances *dalteparin*, *paracetamol*, *mupirocine* and if prescribed all *non ACS/CABG related medicine* (among others for DM, COPD and the medicine of the chemical substance vitamin K antagonist). *Dalteparin* is part of the *anticoagulation* group and is the replacement of the medicine 'Fondaparinux' or 'Enoxaparin' given prior to the operation. Note that the disinfectant with the brand name hibiscrub is not mentioned here, as it was not confirmed by the Anaesthetist that this indeed needed to continue after surgery until it is given for a total of 5 day. The third group of medicines are the 'golden five medicines' for the treatment of ACS-NSTEMI; *aspirin* in the chemical substance of *ASA*, the chemical subgroup *P2Y12 inhibitor* with *Ticagrelor* and *Clopidogrel* (if still given) and the pharmacological subgroups of *oral Beta-blockers*, *ACE inhibitor* and HMG CoA reductase inhibitors (*Statin*).
See for further explanation of the second group of medicines section 5.1.1.4.4.1 – *give medicine (ACS-NSTEMI-CABG)* and for the third group section 5.1.1.2.1 *give medicine (ACS-NSTEMI)*.

5.1.1.5.3.2. Take ECG @IC

The sub process *take ECG @ IC* is quite similar to the sub process *take ECG*, see section 5.1.1.2.2. The difference is that after the interpretation of the ECG, only a comparison with a previous ECG is made if there is a reason for. After a comparison is done, it is possible to *withdrawal from pathway (case management)*.

5.1.1.5.4. Nurse and mobilize patient (at CTC)

After the *provide post operative care* sub phase (see section 5.1.1.5.3) is successfully walk trough, patients continue their treatment within this sub phase. The routing of the care activities within this sub phase depend on the moment of transferring, as the monitor policy difference over time. First the routing for **PACU** patients will be explained and then that of **HC** patients.
Patients arriving from the **PACU** are attached to the monitor (*attach patient to monitor*) that measures their *saturation*, *pulse*, *respiratory rate* and their *blood pressure*. Furthermore, the hourly control of the thorax drains (*control thorax drains*), drip policy and fluid balance (*control drip policy and fluid balance*) is continued. Until the next morning the Anaesthetist is still responsible for the patient, who is remaining at 6west. The next morning at 7a.m., CABG day +1, a daily dose of medicine is given (*give medicine (ACS-NSTEMI-CABG)* see section 5.1.1.4.4.1), an ECG is made (*take ECG*) and a blood sample is taken (*take blood sample*) by the nurse. Afterwards, the secretary requests a blood test (*request blood test "overname blok"*) and an x-ray (*request x-ray*), which will be performed by the laboratory respectively radiology after the request has been received. The requested levels of the *"overname blok"* are those of HB, HT, platelets, Leuco's, Glucose, ALAT, kalium, sodium, urea, creatinine, MDRD, INR and CRP. During the daily *rounds* the test results will be reviewed (*review new test results*), the patient will be checked (*check patient*) and the patients' status evaluated (*evaluate patients' status*). Furthermore, it can be decided to request the additional Quickview test (*request Quickview*) by a cardiology laboratory assistant. Besides that, PACU patients will be switched to a telemonitor (TM) 24hrs after the operation (*switch or attach patient to telemonitor*) and therefore the nurse needs to start *check blood pressure* every *8hrs* until discharge. The models shows four options more here, but these are normally done as the process loops for a second, third or another time. For PACU patients the treatment continues at *7a.m.* on CABG day +2, as the daily medicine are given (*give medicine (ACS-NSTEMI-CABG)* see section 5.1.1.4.4.1). This time only *take blood for INR* needs to be done if vitamin K antagonists are prescribed[8]. If this is not the case, the *rounds* will directly follow and it can normally be decided to *detach TM* and to *remove drains, IV and catheter*, whereby the corresponding hourly controls also stop. Afterwards, the mobilization of the patient can be started (*start to mobilize patient*). It is furthermore possible that additional tests are needed (*request Quickview* and *request blood test "verblijf 6 west blok"*) and that the anticoagulation can already be discontinued (*discontinue anticoagulation*). There are three different types of *"verblijf 6west blok"*; the diuretics block requires the levels of kalium, sodium, urea and creatinine, the infection block requires the levels of the Leuco's, and CRP and the extended infection block requires the levels of HB, HT, platelets, Leuco's, kalium and sodium. The daily morning routine with the medicines, rounds and possible additional test continue until it is decided that the patient can be discharged. This will be done after the patient is mobilized and the anticoagulation has been stopped. The treatment of the patient continues within the sub phase *hospital discharge (at CTC)* (see section 5.1.1.5.5).

[8] The INR needs to be measured every 2 days until it is in range twice in a row.

Patients transferring from the **HC** to 6west will normally arrive on CABG day +1 and can be attached to the telemonitoring directly (*switch or attach patient to telemonitor*). Besides that, the nurse needs to *check blood pressure* every *8hrs*, and continue the hourly control of the thorax drains (*control thorax drains*), drip policy and fluid balance (*control drip policy and fluid balance*). After that, their treatment continues the next morning at 7a.m., as described above by the PACU patients; the daily meds will be given (*give medicine (ACS-NSTEMI-CABG)* see section 5.1.1.4.4.1), an ECG will be made (*take ECG*) and a *blood test "overname blok"* will be done before the daily *rounds* are made. As the HC patients first morning on 6 west is at CABG day +2, it is now already possible to *detach TM* and to *remove drains, IV and catheter*, whereby the corresponding hourly controls also stop and the mobilization of the patient can be started (*start to mobilize patient*). Besides that, it is possible to requests the additional Quickview and blood test (*request Quickview* and *request blood test "verblijf 6 west blok"*), and maybe to already *discontinue anticoagulation*. The daily morning routine with the medicines, rounds and possible additional test continues, as by the PACU patients, until it is decided that the patient can be discharged. This will be done after the patient is mobilized and the anticoagulation has been stopped. The treatment of the patient continues within the sub phase *hospital discharge (at CTC)*.

5.1.1.5.5. Discharge patient (at CTC)

When the nurse practitioner, physician, and/or cardiothoracic surgeon has stated that the patient can be discharged, the sub phase *discharge patient (at CTC) is started*. First of all, an ECG is made with an ECG device (*take ECG*) and a blood sample is taken (*take blood sample*) by the nurse. Afterwards, the secretary *request blood test "ontslag CABG blok"*, which includes the measurement of the levels of HB, HT, platelets, Leuco's, Glucose, ASAT, ALAT, kalium, sodium, urea, creatinine, MDRD and CRP and if needed also INR by the laboratory. In case of an operation on also the valve, the INR needs to be included in the test. After the lab results are back (*results blood test "ontslag CABG blok"*), the nurse practitioner, physician and/or cardiothoracic surgeon will *interpretate ECG and lab results* and can if needed decide to withdrawn the patient. If the discharge proceeds, there are four *documents to check, deliver and/or finish*; the *update letter for GP and/or Cardiologist* needs to be finished and delivered, the *Quickview report* and *OR report* need to be checked and the *survey* needs to be delivered. After that, the follow up appointments are made (*make follow up appointments for patient*), which consisted of *refer to cardiac rehabilitation* and the according *sign patient up for pre-rehabilitation x-ergometry*, a *control appointment by CTC*, a *control appointment by Cardiologist* and *sign patient up by intensive care for thrombotic patients*. Additional appointments are made in case also an operation is done on one of the valves (*schedule Echo cor + Doppler*) and/or the aorta (*schedule CT Thorax* and *schedule Echo Doppler*). After the appointments are made, the practitioner needs to *prescribe medicine* for the long term treatment. By default the 'golden five medicines', *Aspirin – ASA 80 mg/day*, *P2Y12 inhibitor*, *Oral Beta-blocker*, *ACE inhibitor* and *Statin*, are prescribe for the long-term treatment of ACS, which were also given during the hospitalization (see also *give medicine (ACS-NSTEMI)* in see section 5.1.1.2.1). If the P2Y12 inhibitor is discontinued before, it not prescribed here. Instead of the *ACE inhibitor* it can be chosen to prescribe *ATII*, which stands for the chemical subgroup of Angiotensin II antagonists. Besides that, a *proton pump inhibitor* is prescribed if the patient fulfils one of the following criteria; above ≥65year, stomach bleeding or uclus of H. Pylori in vg, steroid and/or combined anticoagulantia. The last task to be done is *discharge patient*, which includes that it is looked if the DOT is correct (*check DOT*), and the discharge letter is made and

given to the patient. When also that is done the *sub phase of discharge patient (at CTC) will end* and the patient leaves the hospital at the top-level (end event *Departure*).
Note the differences and similarities between the discharge here and at cardiology; CABG patients are by default admitted to the rehab program, but no life style advice is given here as this is already included in the intake of the CABG operation and there is no check on the EuroSCORE and medicine prescription.

5.2. Other applications of the model

The requirements of the CP modelling method state that the resulting model needed to be applicable on more aspects then only as a communication tool. During the case study two other applications of the resulting model were brought up, both within the Brain Bridge project. In the first application patterns will be build out of the model in order to categorize patients. For the second application the model will serve as an overview for the development of checklists. Both applications were roughly work out and will be discussed here.

5.2.1. Pattern development

The first application that will be demonstrated here is the pattern development. Patterns are model parts that can be used to compare the actual behaviour of the process against the model and is also known as backward conformance checking. This technique is normally used to detect non-conformant behaviour, but can also be applied to categorize patients according to their completed pathway. This can be used when performance analyses needs to be done, as KPI's can be patient category specific. Within the Unstable Angina patient this is also the case, as the applicable KPI's are different for the conservative and invasive treatment and even within the invasive treatment as a PCI or CABG might or might not be performed.
Yan et al. (2013) recently developed an analyzing conformance technique for Clinical Protocols that can also be used to Care Pathways and is based on the BPMN language. The technique compares CP patterns against the trace of the hospital data, in which a trace describes the sequence of the activities happened. With this technique it is thus possible to categorize patients based on their resulting trace. As there is no hospital data available, here the set of patterns and needed resulting traces for each category will be made.

5.2.1.1. Categories

Before the patterns and traces can be made it is important to define the different patient categories, as this defines the criteria were distinctions are going to be based on. The categories can be made based on the different possible standard completed pathways (i.e. different taken routings through the model). Looking very closely to the model, many possible completed pathways can be noted. For this demonstration, it is chosen to focus on the time until diagnosis validation and the treatment plan chosen afterwards, as in conservative or invasive and PCI, CABG or medicinal. Besides that, only successfully completed pathways are included.
Based on the focus, the categories can now be defined by analyzing the routings of the model. Based on the *top-level*, see Appendix K – Figure 23, it is possible to distinguish three types of categories; non-emergency patients assigned to an invasive treatment or a conservative treatment and emergency patients. These categories can be refined by taking a closer look into the model phases. The first refinement can be made in the *Diagnosis validation and risk assessment* phase (see Appendix K – Figure 26) between patients that receive medicines at T=0 (before the results of blood test T=0 is back), after T=1 (when the results of blood test T=0 are back), T=3 or T=6,

as also clearly indicated by the ACS protocol (see Appendix I). Further refinements can be made based on the *Revascularization modalities* phase (see Appendix K – Figure 32). These are the differences in treatment with regard to the PCI intervention, heart team meeting and CABG operation; only a PCI, a PCI followed by a CABG, a heart team meeting followed by a PCI, a heart team meeting followed by a CABG, a heart team meeting followed by a medicinal treatment, or nothing at all leading to a medicinal treatment. All together eleven different factors could be identified leading to 34 different categories, see Table 20.

Nr	Category description
1	Patient assigned to an conservative treatment, via T=0
2	Patient assigned to an conservative treatment, via T=1
3	Patient assigned to an conservative treatment, via T=3
4	Patient assigned to an conservative treatment, via T=6
5	Patient assigned to an invasive treatment, via T=0, with medicinal treatment
6	Patient assigned to an invasive treatment, via T=1, with medicinal treatment
7	Patient assigned to an invasive treatment, via T=3, with medicinal treatment
8	Patient assigned to an invasive treatment, via T=6, with medicinal treatment
9	Emergency patient with medicinal treatment
10	Patient assigned to an invasive treatment, via T=0, with Heart team meeting and medicinal treatment
11	Patient assigned to an invasive treatment, via T=1, with Heart team meeting and medicinal treatment
12	Patient assigned to an invasive treatment, via T=3, with Heart team meeting and medicinal treatment
13	Patient assigned to an invasive treatment, via T=6, with Heart team meeting and medicinal treatment
14	Emergency patient with Heart team meeting and medicinal treatment
15	Patient assigned to an invasive treatment, via T=0, with PCI
16	Patient assigned to an invasive treatment, via T=1, with PCI
17	Patient assigned to an invasive treatment, via T=3, with PCI
18	Patient assigned to an invasive treatment, via T=6, with PCI
19	Emergency patient with PCI
20	Patient assigned to an invasive treatment, via T=0, with Heart team meeting and PCI
21	Patient assigned to an invasive treatment, via T=1, with Heart team meeting and PCI
22	Patient assigned to an invasive treatment, via T=3, with Heart team meeting and PCI
23	Patient assigned to an invasive treatment, via T=6, with Heart team meeting and PCI
24	Emergency patient with Heart team meeting and PCI
25	Patient assigned to an invasive treatment, via T=0, with PCI and CABG
26	Patient assigned to an invasive treatment, via T=1, with PCI and CABG
27	Patient assigned to an invasive treatment, via T=3, with PCI and CABG
28	Patient assigned to an invasive treatment, via T=6, with PCI and CABG
29	Emergency patient with PCI and CABG
30	Patient assigned to an invasive treatment, via T=0, with Heart team meeting and CABG
31	Patient assigned to an invasive treatment, via T=1, with Heart team meeting and CABG
32	Patient assigned to an invasive treatment, via T=3, with Heart team meeting and CABG
33	Patient assigned to an invasive treatment, via T=6, with Heart team meeting and CABG
34	Emergency patient with Heart team meeting and CABG

Table 20 – Categories of patients for the patterns

5.2.1.2. Patterns

Now the categories are known, the needed patterns can be made. As the conformance technique will compare the patterns against an event-log, it is important to select those activities of which it can be expected that they are registered in such an event-log. These will be orders of tests, operations and medicines and tests results, as well as the admission and discharge of patients. In addition, it would be nice if the selected activities apply to all patients within that category. Otherwise, multiple traces would lead to one and the same category. If the same patterns are used for further refinement of the categories, then this would not matter of course.

Looking at the first phase of the model, the *Initial Evaluation*, the activities of *make and interpretate ECG*, *take blood test* and *admit patient* can be selected for the pattern, as the ECG is recorded in the EPR and the order of the blood test and the patient admission is done through the EPR. All other activities are either not category general, which can be noted by an XOR split and join, or might not be noted in an event-log although they are recorded in the patient file, like the *anamnesis*, *physical examination* and *calculate GRACE score*. This leads to a pattern consisting of three tasks in sequence for this phase, see Appendix L – Figure 49. Note that the name of the ECG tasks has been changed in *perform ECG*, as only this part will be found in the event-log. Furthermore, the message send about the blood test will be recorded in the event-log and not the test itself. Besides that, the pool for the unit of EHH is removed as the location is of no importance to the comparison of tasks here.
Within the *Diagnosis validation and risk assessment* phase the message flows *results blood test in EPD* and *take blood test* and the tasks *take ECG* and *give medicine* (the first time) are selected for the pattern. As only the actual perform ECG can be traced, the sub process of the model is replaced by the task *perform ECG*. The sub process of give medicine on the other hand is kept in place, as only the specific drugs can be traced. In this case, those are by default *aspirin ASA*, *ticagrelor* or *clopidogrel*, *fondaparinux* or *enoxaparin* and the *oral beta-blocker*. Besides that, the cycle of ECG and blood test are similar for T=3 and T=6 and therefore is only noted once, see Appendix L – Figure 50 and Figure 51. The daily morning care (meds, ECG, rounds) is left out of the pattern as no distinction is made here between the different invasive treatments and so this is redundant.
The same counts for the *Invasive strategy* phase, where the daily morning routing is also redundant. The corresponding pattern shows only the tasks *sign patient up for CAG* and *give UFH* and *execute CAG* out the sub process *perform CAG*, see Appendix L – Figure 52. From the *Revascularization modalities* phase, only patterns needed to be made for the sub phases *prepare and conduct PCI*, see Appendix L – Figure 53, *prepare, await and hold Heartteam meeting*, see Appendix L – Figure 54, *await and conduct screening + intake CABG*, see Appendix L – Figure 55, and *perform CABG*, see Appendix L – Figure 56. The other two sub phases contain no important activities for the categorization of patients specified here. Within the pattern of *prepare, await and hold Heartteam meeting* and *await and conduct screening + intake CABG*, the diagnosis test of *echocardiogram*, *X-ray* and *discontinue P2Y12 inhibitors* remain although they might not be conducted. This is because they are very specific for this group of patients. From the *Hospital discharge* phase, patterns were made of the sub phases to indicate that the patient has completed the pathway successfully, see Appendix L – Figure 57 and Figure 63.

5.2.1.3. Traces

With the developed patterns, it is now possible to specify the resulting trace of each category. As no two categories can have equivalent sequences, the trace is a unique identifier. In order to specify the traces, each unique activity is given a unique letter. For each of the eleven factors here the corresponding trace will be explained.
Starting from the arrival of the patient, the first seven factors are emergency, non emergency with T=0, T=1, T=3 or T=6 leading to an invasive or conservative treatment. For each of the non-emergency categories first the activities A, B and C need to be done. After that, the sequence of T=0 will directly go to give medicine (activities G-J). The sequence of T=1 first awaits the results of the blood test (D) before the medicines are given. The sequences of T=3 and T=6 await also the blood test results as well as a second respectively third ECG and blood test

before the medicines are given. Afterwards, patients assigned to an invasive treatment, as well as emergency patients, will undergo a CAG (activities K-M). Therefore, the traces are as follows;

$\sigma_{T=0}$ = <(A,B,C),(G,H,I,J)> in which H={H_1,H_2} and I={I_1,I_2}.
$\sigma_{T=1}$ = <(A,B,C),(D),(G,H,I,J)> in which H={H_1,H_2} and I={I_1,I_2}.
$\sigma_{T=3}$ = <(A,B,C),(D,A,E,F),(G,H,I,J)> in which H={H_1,H_2} and I={I_1,I_2}.
$\sigma_{T=6}$ = <(A,B,C),(D,A,E,F,A,E,F),(G,H,I,J)> in which H={H_1,H_2} and I={I_1,I_2}.
$\sigma_{emergency,invasive}$ = <K,L,M>

After a CAG is performed, the next factors that come across are the PCI, heartteam meeting, CABG and medicinal treatment. If directly a PCI follows, only activity N (PCI) is noted. In case of a heart team meeting (activity Q), first an echocardiogram needs to be performed (activity O) if not already done, followed by the sign up for the meeting (activities P). If after the meeting a PCI is performed, the heparin medicine needs to be given again (activity L). In case a CABG follows, the screening and operation needs to be performed (activities A, R-AA). Note that no distinction is made here between emergency CABG and non-emergency CABG patients, as a result of which there are options in the sequence of the trace. At least the activities of ECG, blood test and NEC protocol are done (activities, A, T, U and V). For a medicinal treatment, the hospital discharge is directly started (see below). The corresponding traces of the PCI, heart team meeting and CABG are as followed;

σ_{PCI} = <N>, $\sigma_{PCI\ after\ heartteam\ meeting}$ = <L,N>.
$\sigma_{\ Heartteam}$= <O,P,Q> or <P,Q>.
σ_{CABG}= <(A,T,U,V),(Y,Z,AA)> instead of (A,T,U,V) also (R,S,A,T,U,V,W,X), (R,S,A,T,U,V), (R,A,T,U,V,W,X), (R,A,T,U,V) or (A,T,U,V,W,X) can happen.

After the revascularization modalities have been performed, the last patterns are those of the hospital discharge. The discharge process for all CABG patients is similar and follows the patterns of provide post operative care, give medicine (ACS-NSTEMI-postCABG), nurse and mobilize patient (at CTC), give medicine (ACS-NSTEMI-CABG) and discharge patient (at CTC). The sequences of the process can vary due to parallel tasks. Note that the sequence of parallel activities is only noted from top to bottom, but in reality can differ. The conservative and medicinal treatments are only included in the discharge processes of cardiology, where the sequence of a medicinal treatment is the same as that of all PCI patients. The sequence of the conservative treatment skips the first two activities of the discharge, as these patients have not had a CAG. The corresponding traces are as follows;

$\sigma_{Conservative\ discharge}$= <(AB),(A,AC,G,H,AD,J,AE,AF)>,
$\sigma_{CAG/PCI/meds\ discharge}$= <(A,AB),(A,AC,G,H,AD,J,AE,AF)>,
$\sigma_{emergencyCAG/PCI/meds\ discharge}$= <(A,C,AB),(A,AC,G,H,AD,J,AE,AF)> in which H={H_1,H_2} and AE={AE_1,AE_2}.
$\sigma_{CABG\ discharge}$= <(AG,AH,AI,AJ,AK),(A,W,AL,X,AM,AB),(G,H,AI,AJ,J,AE_1,AD), (A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)> in which H={H_1,H_2}, AE={AE_1,AE_2} and AG={AG_1,AG_2}.

By combination all these different traces it is possible to get a unique trace for every category of patients. The corresponding traces are noted in Table 21.

Nr	Trace
1	σ_1= <(A,B,C),(G,H,I,J),(AB),(A,AC,G,H,AD,J,AE,AF)>
2	σ_2= <(A,B,C),(D),(G,H,I,J),(AB),(A,AC,G,H,AD,J,AE,AF)>
3	σ_3= <(A,B,C),(D),(G,H,I,J),(AB),(A,AC,G,H,AD,J,AE,AF)>
4	σ_4= <(A,B,C),(D,A,E,F,A,E,F),(G,H,I,J),(AB),(A,AC,G,H,AD,J,AE,AF)>
5	σ_5= <(A,B,C),(G,H,I,J),(K,L,M),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
6	σ_6= <(A,B,C),(D),(G,H,I,J),(K,L,M),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
7	σ_7= <(A,B,C),(D),(G,H,I,J),(K,L,M),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
8	σ_8= <(A,B,C), (D,A,E,F,A,E,F),(G,H,I,J),(K,L,M),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
9	σ_9= <(K,L,M),(A,C,AB),(A,AC,G,H,AD,J,AE,AF)>
10	σ_{10}= <(A,B,C),(G,H,I,J),(K,L,M),(P,Q)*,(A,AB),(A,AC,G,H,AD,J,AE,AF)>
11	σ_{11}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(P,Q)*,(A,AB),(A,AC,G,H,AD,J,AE,AF)>
12	σ_{12}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(P,Q)*,(A,AB),(A,AC,G,H,AD,J,AE,AF)>
13	σ_{13}= <(A,B,C),(D,A,E,F,A,E,F),(G,H,I,J),(K,L,M),(P,Q)*,(A,AB),(A,AC,G,H,AD,J,AE,AF)>
14	σ_{14}= <(K,L,M),(P,Q)*,(A,C,AB),(A,AC,G,H,AD,J,AE,AF)>
15	σ_{15}= <(A,B,C),(G,H,I,J),(K,L,M),(N),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
16	σ_{16}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(N),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
17	σ_{17}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(N),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
18	σ_{18}= <(A,B,C),(D,A,E,F,A,E,F),(G,H,I,J),(K,L,M),(N),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
19	σ_{19}= <(K,L,M),(N),(A,C,AB),(A,AC,G,H,AD,J,AE,AF)>
20	σ_{20}= <(A,B,C),(G,H,I,J),(K,L,M),(P,Q)*,(L,N),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
21	σ_{21}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(P,Q)*,(L,N),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
22	σ_{22}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(P,Q)*,(L,N),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
23	σ_{23}= <(A,B,C),(D,A,E,F,A,E,F),(G,H,I,J),(K,L,M),(P,Q)*,(L,N),(A,AB),(A,AC,G,H,AD,J,AE,AF)>
24	σ_{24}= <(K,L,M),(P,Q)*,(L,N),(A,C,AB),(A,AC,G,H,AD,J,AE,AF)>
25	σ_{25}= <(A,B,C),(G,H,I,J),(K,L,M),(N),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK), (A,W,AL,X,AM,AB),(G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
26	σ_{26}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(N),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK), (A,W,AL,X,AM,AB),(G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
27	σ_{27}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(N),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK), (A,W,AL,X,AM,AB),(G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
28	σ_{28}= <(A,B,C),(D,A,E,F,A,E,F),(G,H,I,J),(K,L,M),(N),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK), (A,W,AL,X,AM,AB),(G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
29	σ_{29}= <(K,L,M),(N),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK),(A,W,AL,X,AM,AB), (G,H,AI,AJ,J,AE$_1$,AD), (A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
30	σ_{30}= <(A,B,C),(G,H,I,J),(K,L,M),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK),(A,W,AL,X,AM,AB), (G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
31	σ_{31}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK), (A,W,AL,X,AM,AB),(G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
32	σ_{32}= <(A,B,C),(D),(G,H,I,J),(K,L,M),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK), (A,W,AL,X,AM,AB),(G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
33	σ_{33}= <(A,B,C),(D,A,E,F,A,E,F),(G,H,I,J),(K,L,M),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK), (A,W,AL,X,AM,AB),(G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>
34	σ_{34}=<(K,L,M),(P,Q)*,(A,T,U,V)**,(Y,Z,AA),(AG,AH,AI,AJ,AK),(A,W,AL,X,AM,AB), (G,H,AI,AJ,J,AE$_1$,AD),(A,AN,AO,AP,AQ,AC,AR,G,H,AD,J,AE,AF)>

Table 21 – Categories of patients and their corresponding traces; in all cases H={H$_1$,H$_2$}, I={I$_1$,I$_2$}, AE={AE$_1$,AE$_2$} and AG={AG$_1$,AG$_2$}, *= instead of (P,Q) also (O,P,Q) can happen and **=instead of (A,T,U,V) also (R,S,A,T,U,V,W,X), (R,S,A,T,U,V), (R,A,T,U,V,W,X), (R,A,T,U,V) or (A,T,U,V,W,X) can happen

5.2.2. Checklists development

Checklists in hospital are used aside from or besides Care Pathways to standardize care and to ensure the quality of the care given and safety of the patient. Their development starts with

making an overview of the medical procedures of the treatment, which serve as a basis for the identification of moments of use and their content. (Peeters, 2013) The communication tool made with the method can be used in this development as the required overview. In order to prove that the model can indeed be applied for this purpose, a demonstration is given here to determine the moments of use and checklist content for the Care Pathway of Unstable Angina.

5.2.2.1. Requirements and current state of the art

Before the first development steps can be done, it is important to note the requirements and the current state of the art of checklists in this pathway. The hospital and researcher are momentarily looking into the development of do-verify dynamical checklist. With do-verify checklists, the physician first needs to perform the actions before the check will take place (Peeters, 2013). The dynamical aspect lies in the fact that the checklists can be made patient specific based on their condition and assigned treatment (e.g. only the checklist for patients with renal failure will ask if enoxaparin is prescribe instead of fondaparinux). Besides that, the dynamical checklist can interact with the EPR and is shared with all involved medical professionals that can see and adapt their own but also view the other ones. For the development it is thus important that the content of the different groups of patient are identified together with its owner(s).
The current state of the art is that already five checklists are in place at the CABG side of the pathway. Two of them were already included in the model and will not be discussed here again. These are the paper based "checklist operatieve patient" (see Appendix H – Figure 18 and Figure 20) and the "time out" checklist within the EPR (see Appendix H – Figure 19). Another checklist, the discharge within the work processes of the cardiothoracic surgery department, is not specifically mentioned in the model but the associated activities were processed. From the other two checklists, the PPOS/Intake within the EPR and the clinical admission within the CTC work processes, it is not known if they completely apply to the UA patients. These three checklists will therefore be used as input for the development here. No checklists are in place within the cardiology side of the pathway, but Peeters (2013) recently did research towards the application of checklists here. The proposed checklists were based on the ACS protocol and could not be validated due to a lack of available data within the patient records. As the current model differs from the overview Peeters (2013) made, his checklists will be reviewed, reused and completed.

5.2.2.2. Checklist usage and content

For the identification of the checklist usage and content, the developed model of the Care Pathway stated in Appendix K will be used together with the five existing checklists and the research of Peeters (2013). Note that the EPR is not taken into account here, but it is important to align the EPR with the checklists before they are implemented. This because at some points it is assumed that the checklists are automatically adapted to the specific patient, based on the entered data in the EPR. All (created) checklists can be found in Appendix H.

5.2.2.2.1. Initial evaluation phase

The pathway starts with the arrival of the patient at the top-level, after which the *Initial evaluation* phase follows. The priority in this phase is to conduct the evaluation as soon as possible in order to determine the working diagnosis and risk. A logical point to use a checklist within this phase is at the end, as the patient needs to be admitted (task *Admit Patient*, see Appendix K – Figure 24). This checklist needs to automatically check if the most important tasks

within this phase have been done and ask the Cardiologist at the EHH or on duty to complete and agree. The first task to check is *attach patient to monitor* and is represented by IE1, see Appendix H – Table 30. After that, it must be checked if the ECG has been made and interpretated and if the blood test has been order, represented by IE 2 - IE4. Then the group of tasks, *interpretate ECG*, *anamnesis*, *do physical examination* and *judge patients' history*, conducted by the Cardiology needs to be check by IE5. Next, it must be checked if the working diagnosis is NSTEMI/UA (IE6) and if the GRACE score has been filled in (IE7). The last check to perform is about the start of the next phase (IE8).

5.2.2.2.2. Diagnosis validation and risk assessment phase

Afterwards, the treatment continues within the *Diagnosis validation and risk assessment* phase. As the treatment in this phase is different for each patient, it is important that the checklist is adapted to the specific condition of the patient. A total of four checklists can be created to check if the pathway is followed, see Appendix H – Table 31. The first three checklists, DV0, DV3 and DV6, concern the diagnosis validation with the measurement of the troponin level, the ECG and if necessary the exercise ECG. The checklists need to be completed after the results of the blood concerning their time are back and looked at. For DV0 this is before clock *T=3hrs* or the task *give medicine (ACS-NSTEMI)* at the EHH; for DV3 before clock *T=6hrs* or the task *give medicine (ACS-NSTEMI)* at the EHH; and for DV6 before the task *give medicine (ACS-NSTEMI)* at the CCU/7west, see Appendix K – Figure 26. Note that the checklist can also be completed before the patient is withdrawn from the pathway. The fourth checklist is about the risk assessment and needs to be completed after the task *Determine treatment plan* or in case of an urgent invasive treatment before *end of diagnosis validation and risk assessment*, see Appendix K – Figure 26. All checklists need to be completed and agreed on by a Cardiologist.

5.2.2.2.3. Invasive strategy phase

The next phase in line for patients assigned to an invasive treatment is the *Invasive strategy* phase (see Appendix K – Figure 30). In this phase one checklist is created consisting of different parts that need to be completed and agreed on by different medical professionals, see Appendix H – Table 32. The first important check to make is by the HCK if the CAG is scheduled within the timeframe (IS1). Besides that, it would be good to check the preparations and documentation of the intervention like that is done for operations. For all non emergency patients IS2 and IS3 need to be checked before the patient is send to the HCK by the nurse. IS4 and IS5 (and in case of emergency also IS3) need to be checked by the HCK before the CAG can start. Before the patient leaves the HCK the check IS6 needs to be done by the HCK team and in case no PCI is conducted directly afterwards also IS7.

5.2.2.2.4. Revascularization modalities phase

After the CAG is completed, the *Revascularization modalities* phase (see Appendix K – Figure 32) is initiated, in which three different checklists are made. Furthermore the two existing checklists are applied, see Appendix H – Figure 18 till Figure 20. The first checklist concerns the PCI intervention, see Appendix H – Table 33, and needs to be completed by the HCK before the patient leaves the HCK (see Appendix K – Figure 33). Note that in case a PCI is performed directly after a CAG, also IS6 still needs to be checked here. The second checklist is about the preparation and conducted heart team meeting, see Appendix H – Table 34, and is partly based on the already existing PPOS/intake checklist within the CTC work processes. The first part,

HT1 – HT4, needs to be checked by the CCU/7west nurse and then again by the CTC secretariat together with HT5. The second part, HT6–HT11, needs to be checked by the heart team at the end of their meeting (see Appendix K – Figure 34). The third and last checklist made for this phase is about the screening and intake, see Appendix H – Table 35, and is based upon the already existing PPOS/intake and clinical admission checklists within the CTC work processes. The first two items need to be completed before the patient is transferred from cardiology to 6west, or if the patient stays at cardiology before the screening is started. Items 3 and 4 are completed by the nurse before the screening and intake by the Nurse practitioner (NP) starts. During the screening and intake, the NP completed the numbers CABG3 till CABG11 before the task *information, risk discussion and informed consent is started* (see Appendix K – Figure 36). Note that CABG2 and CABG5 can be prematurely filled in with the information gathered during the *Initial evaluation* phase. After the nurse has completed the DVD and guided tour (CABG12), a CTC surgeon in training or a physician continues with the completion of the checklist items CABG13 till CABG17. This needs to be done before the screening + intake sub process is completed. Afterwards, the Anaesthetist needs to complete the items CABG18 till CABG21 before finishing the intake. The following two items CABG22 and CABG23 need to be completed by the secretary any time after CABG10/11 has been completed and before CABG24 till CABG29 is checked by the NP. The last item to be checked is CABG30, about the introduction of the CTC surgeon to the patient.

5.2.2.2.5. Hospital discharge phase

The next checklist will be that of the patient discharge at either the cardiology or CTC department. As it is doubted whether intermediate checklists for the nurse and mobilize patient sub phases add value, these possible checklists are left out of this demonstration.

The checklist for the *discharge patient (at cardio)* sub phase, can be made one on one with the model diagram, see Appendix K – Figure 43, but is also partly based on the research conducted by Peeters (2013). As the diagram already shows, the discharge process is conducted by two roles; the nurse and the cardiologist. Therefore, the checklist contains two parts, such that each role can check their own tasks, see Appendix H – Table 36. The first two items, HDC1 and HDC2, are about the tasks performed by the nurse, the other nine about the appointments, medication prescription and checks that need to be performed by the cardiologist. Both parts of the checklist need to be completed together with or after the task Discharge patient.

The *discharge patient (at CTC)* sub phase was made based on the CTC work processes including the checklist 'discharge' and completed with the specific ACS medications. Therefore, the checklist for this sub phase can be made one on one with the model diagram, see Appendix K – Figure 48. Also here two roles are shown in the model diagram, but the checklist only needs to be completed by one. This because it is clearly indicated that the Nurse Practitioner / Physician / Cardiothoracic surgeon in training have the finally responsibility and interpret the results of the tasks performed by the nurse. The checklist, see Appendix H – Table 37, needs to be completed before the patient is send home, so together with or after the task *Discharge patient*.

6. METHOD REFINEMENT

In this chapter the developed method will be refined based on the inside provided by the conducted case study. It was shown that most methods steps were sufficiently described and only needed to be completed with general points of interest and tips resulting from the case study. *Method step 6 – Verify and validate model* did however lacked a proper scientific basis and needed some additional research. Here only the refinements will be discussed, a summary of the final method can be found in appendix A.

6.1. General points of interest and tips

The general points of interest and tips resulting from the case study will be discussed according to the method steps up to step 5, but first one important general point is made.

It is very important to note that the method is not linear, in the sense that decisions can be postponed to future steps and/or decisions made in previous steps can be revised based on new insights. In the explanation of some aspects it is explicitly mentioned that the decisions can be made on different times within the project, but by other aspects this is not done. For example, the general goals of the project were defined within the 'project definition', but the listed KPI's were only confirmed during the interviews with the medical professionals of the detailed modelling phase. The general goals and the temporary list of KPI's could give the project enough direction at the beginning, but the final list of KPI's was needed to make more concrete modelling choices.

6.1.1. Define project

The case study has shown a few very practical points of interest about the '*granularity'* and '*identify the available information resources'* aspects to complete the project definition.

6.1.1.1. Granularity

The setting of the granularity levels and the levels of detail is very difficult and asks a lot of creativity from the modeller. It was found that the levels of detail are defined by the clinical guidelines, the KPI's and/or the medical professionals during the two modelling steps. During the model layout step, the clinical guidelines are used to guide the detail of the model as well as the KPI's, while during the detailed modelling the medical professionals who are interviewed are added as a leading guide. Within the project definition the granularity levels cannot be set as this is related to the levels of detail; how higher the level of detail, how more granularity levels are probably required. It is here thus important to state the already known requirements.

It can be advised to make a top-level that provides a very abstract overview of the pathway. This level automatically makes sure that the model is divided into sub processes given an overview of one phase of the pathway. The other granularity levels highly depend on the goals of the project and the levels of detailed set (later on). During the layout modelling temporal levels can be set that work best with the information present during this phase and with the knowledge what still needs to come. Within the detailed modelling phase, these levels need to be evaluated and if necessary revised. It is good to keep two things in mind concerning the granularity level setting. First of all, every time the granularity levels are reset the model needs to be revised. As revising the model takes a lot of time (how larger the model, how more time), it is good to limit the times it needs to be done. The other point is that there might be very good reasons to deviate from consistently set granularity levels. For example, the case study has shown that it is more

important to have a model that is understandable, then a model that has a very consistent granularity level.

6.1.1.2. Identify available information resources

Aside from the (official) information for hospital staff that might be available within the hospital about the care pathway, patient brochures and the internet can be really helpful with the information gathering. Patient brochures are available in the hospital and maybe on the hospital website. On the internet, information can be found from national associations concerning the disease or medical professionals of the care pathway. Via the medical professionals association clinical guidelines might be available or traceable. Furthermore, scientific literature about the pathway (developed) in other hospitals could be present (do not confuse this with the complex clinical researches available). This can be searched by the pathway associations (e.g. Centre of Case Management in Boston, E-P-A, NPA and NKP), but also in the International Journal of Care Pathways and through the annual conference (Allen, 2009).

6.1.2. Plan project

Three points of interest and tips can be noted for the project plan phase. The first one is about the choice of the modelling language that needs to be made based on the requirements. If the hospital already uses a specific language, consider than first if this language is sufficient. In case the hospital language is not sufficient or there is no language, look first into using the de-facto language within the field. At this moment BPMN 2.0 is seen as a de-facto standard within the field (Müller & Rogge-Solti, 2011). If this language is also not useable, search for literature related to the project goals to find a suitable language. The second point is a tip; keep in might during the scheduling of the project to leave room to get familiar with the modelling tool and language, if there is a lack of experience.

The last point of interest is concerning the combined top-down bottom-up approach advised for the modelling of care pathways. As a result of the case study an important argument from practice can be added to the motivation of this advice. On the one hand, the guidelines and further preparation can be used to make the layout model, but on the other hand it can serve as an introduction to the medical terms and their meaning. Especially for modellers that are not very familiar with the medical process and terms, it is good to read into the subject before starting the modelling. Medical staff often speaks in medical terminology, in which there are many terms used for the same test and medicine. If the modeller is not familiar with the terms and/or the meaning, it may be very difficult to link information about the same process. It could for example lead to double noted tasks due to different names. Besides that, information gathering with foreknowledge makes that the conversation between interviewer and interviewee takes place on a more equivalent level and makes it easier to continue asking questions.

6.1.3. Make layout model and different views

During this phase within the case study it was noted how the clinical guidelines can be used to gather information. As they contain a lot of interpretations of clinical research, the focus needs to be on the conclusions and if present tables and management summary. Besides that, it is helpful for the rest of the process to try to extract as much information about the process as possible, while keeping in mind the goals of the research.

6.1.4. Fill in all details in the layout model

During the "fill in details in the model" of the case study, information of each interview (day) was directly processed, such that during the next interview (day) this new information could be used to discuss. This makes that interviews are always based on all information gathered and that misinterpretation can be noticed early on. This way of working can also be seen as a continuously refining of the model, such that the validation will go smoothly.

Concerning the interviews two tips can be stated here. First of all, be flexible during the interviews. The conversations often happen during working hours and it can therefore happen that you need to wait for your appointment, because (s)he needs to finish something else first, and/or that the appointment is (temporarily) interrupted with work related issues. A second tip is to keep in mind a time delay when scheduling appointments with medical staff, due to their busy working schedules and the fact that they work in shifts.

A last point resulting from the case study was the difference in names used for medicine that the modeller needs to be aware of. This is because different names for medicines exist, due to the classification of medicine according to the five levels of the ATC (WHO Collaborating Centre for Drug Statistics Methodology, 2011) (see also Table 12). In practice, different names can be used for the same subgroups of the ATC-classification and/or medicines are called by their brand name. On the website of the WHO, medicines can be searched in the index (WHO Collaborating Centre for Drug Statistics Methodology, 2012), but for that one of the official names must be know (i.e. the index does not include any nicknames or brand names).

6.1.5. Make stakeholders' perspectives

The most important aspect of making different perspectives for a communication tool is to keep the context in place. The care process is team work and often alternates between roles, which makes that medical professionals also reflect on their processes in combination with the other roles tasks. Therefore, it is important to not only show the activities performed by the perspectives role, but also the tasks that interact with their own.

6.2. Method step 6 – Verify and validate model

During the case study is was discovered that the verfication and validation step described in the method lacked a proper scientific basis. The validation options describes were not entirely applicable in our case and alternatives were not provided. Therefore, a second search was conducted on the specific subject of validation of (conceptual) process models within the BPR fiels, as explained in the reseach methodology.

Within the simulation validation process different maturity levels exists. Harmon and Youngblood (2005) developed a model for simulation process maturity consisting of six levels from no validation at all to an automated validation process, see Figure 13. The first three levels of this maturity model can also be used for conceptual models. Level zero is the initial level, where no validation is conducted. The first level represents the subject-matter expert opinion, also called face validity, and within the second level the validation criteria set are tested by the subject-matter expert. Where simulation models need to reach a higher level of validation maturity to be considered valid, conceptual models cannot reach higher and therefore can be considered valid if they reach the first or second level.

In order to reach these maturity levels validation techniques are needed that can be applied to process models and specifically conceptual process models. Two papers were found that focus on techniques applicable for the validation process of simulation and their conceptual models.

Carley (1996) focused on the conceptual or theorectical and external or operational validaty of computational models. According to her, the external validaty can be distinguished into face, parameter, process, pattern, point, distributional, value and theoretical validity. "*Face validity requires that the computational model has an appearance such that taken at face value the model seems to jive with reality. Parameter validity occurs when the parameters of the model match reality - values observed for parameters in field, survey, archival or experimental settings. Process validity occurs when the process described by the computational model corresponds to real processes. Pattern validity requires that the pattern of results generated by the computational model matches real patterns of results. Point validity requires that the behavior of the model on each dependent variable, taken one at a time, has the same mean as the real data. In contrast, distributional validity requires that the distribution of results generated by the computational model has the same distributional characteristics as the real data; e.g., means, standard deviations, and shape of results are the same. Whereas, value validity requires that the specific results from the computational model match on a point by point basis the real data. Finally, theoretical validity occurs when the underlying theoretical constructs in the computational model provide a better predictive indicator of real data than does a linear model.*" (Carley, 1996, p. 10) The types of face, pattern and process are about the internal working of the model, while pattern, point, distribution and value test the model's result.

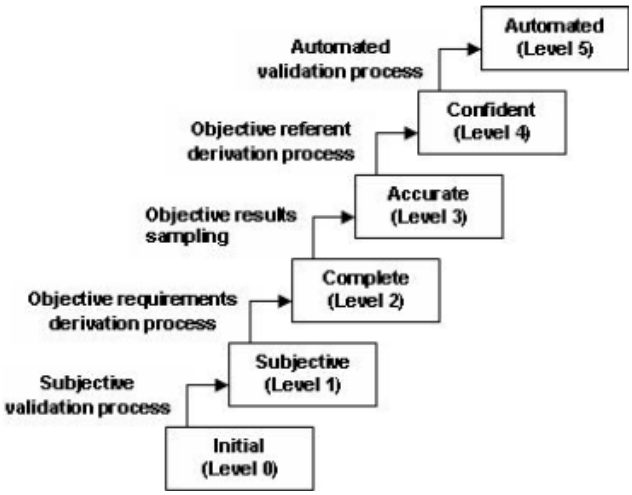


Figure 13 – Levels of validation process maturity and the processes needed to improve maturity, source: (Harmon & Youngblood, 2005)

In order to confirm the different types of validity, four techniques are mentioned. The first technique is grounding, which establishes the reasonableness of the model, and can be used for face, parameter, process and pattern validity. The technique involves story telling, initialization and evaluation. In story telling the validity claim of the modeller is accepted if there is no overclaim and the model is discussed on his limitations and scope conditions. The setting of initial or starting parameter or procedures for the model is called initialization and evaluation is used to see if the behavior of the model is according to expectations based on real data. Calibrating is the second technique and is used to tune the model to fit real data to establish pattern, point, distrubution and/or value validity. These types of validity can also be establish by the third technique called verification, which is here defined as "*a set of techniques for determining the validity of a computational model's predictions relative to a set of real data*" (Carley, 1996, p. 16). Not be confused with the definition of verification stated by Brooks and Tobias (1996) that is used within this method for the testing of requirements set. The fourth and last technique mentioned is that of harmonization, which is used to establish theoretical verification.

The techniques mentioned by Carley (1996) provide a lot of inside how to conduct a validation process, but are generally only applicable for simulation models and if data is available. In the article of Sargent (1998) another distinction is made in types of validations and new techniques are mentioned. According to Sargent (1998), validation can be distinguished into conceptual

model validity, computerized model verification, operational validity and data validity. "*Conceptual model validity is defined as determining that the theories and assumptions underlying the conceptual model are correct and that the model representation of the problem entity is 'reasonable' for the intended purpose of the model. Computerized model verification is defined as ensuring that the computer programming and implementation of the conceptual model is correct. Operational validity is defined as determining that the model's output behaviour has sufficient accuracy for the model's intended purpose over the domain of the model's intended applicability. Data validity is defined as ensuring that the data necessary for model building, model evaluation and testing, and conducting the model experiments to solve the problem are adequate and correct.*" (Sargent, 1998, pp. 122-123)

In order to establish all these kinds of validity sixteen validation techniques are mentioned. As the method lacks techniques specifically for conceptual model validity, only the techniques of face validity and traces are mentioned here. A description of the other techniques can be found in Sargent (1998) or a later version of the article. "*Face validaty is asking people knowledgeable about the system whether the model and/or its behavior are reasable.*" (Sargent, 1998, p. 123) This requires the examination of the flowchart or graphical model by the experts. "*Traces: The behavior of different types of specific entities in the model are traced (followed) through the model to determine if the model's logic is correct and if the necessary accuracy is obtained.*" (Sargent, 1998, p. 124)

7. METHOD VALIDATION

Now the method has been developed, tested and refined, the next step would be to validate the developed method. Due to time restrictions a validation could not be conducted and considering the fact that only one case study was performed with the method, it would also be not very generalisable if it had been done. Nevertheless, the set up of the procedure that should be done in the future is discussed here first. After that, the results of the proof of concept that has been done instead of the validation process will be shown.

7.1. Validation

Within the Information Systems (IS) field the Method Evaluation Model (MEM) of Moody (2003) is developed to evaluate all types of IS design methods. The model is also applicable for this method and could therefore be used here. In this section, first an introduction is given of the MEM. After that, the operationalisation of the model for this research is explained.

7.1.1. Method Evaluation Model (MEM)

The Method Evaluation Model (MEM) is based on two theories. The first theory is the Methodological Pragmatism from the philosophy of science field, which states that to validate a method it needs to be demonstrated that "*it is rational practice to adopt the method based on its pragmatic success"* (Moody, 2003, p. 3). Pragmatic success is "*the efficiency and effectiveness with which a method achieves its objectives*" (Moody, 2003, p. 3). In practice this means that the objective, to improve task performance, can be reach by efficiency improvement and/or by increasing the effectiveness, see also Figure 14. The Technology Acceptance Model (TAM) on the other hands is from the IS field and is about the user technology acceptance. Which states that 'no matter how strong the technology, a system is worthless if it is not used, because then the benefits are also not realised'. The three primary constructs of TAM are Perceived Ease of Use, Perceived Usefulness and Intention to Use. Moody states that there is a similarity between a user choosing a system and a practitioner choosing a method and therefore TAM can be used to explain and predict the adoption of methods. Besides the two described theories, the definition of what is meant by a 'successful' method is needed to complete the MEM. (Moody, 2003) These are actual efficacy, *"whether the method improves performance of the task"* (Moody, 2003, p. 4), and adoption in practice, "*whether the method is used in practice*" (Moody, 2003, p. 4). The complete MEM is shown in Figure 15 and the final definitions of the six constructs can be found in Table 22.

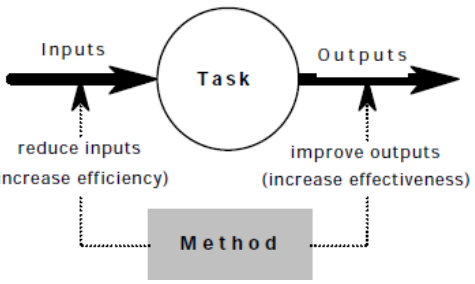


Figure 14 – Efficiency vs. Effectiveness, source: (Moody, 2003)

Construct	Definition
Actual Efficiency	the effort required to apply a method
Actual Effectiveness	the degree to which a method achieves its objectives (O)
Perceived Ease of Use	the degree to which a person believes that using a particular method would be free of effort
Perceived Usefulness	the degree to which a person believes that a particular method will be effective in achieving its intended objectives
Intention to Use	the extent to which a person intends to use a particular method
Actual Usage	the extent to which a method is used in practice

Table 22 – The definitions of the construct of the MEM source: (Moody, 2003, p. 5)

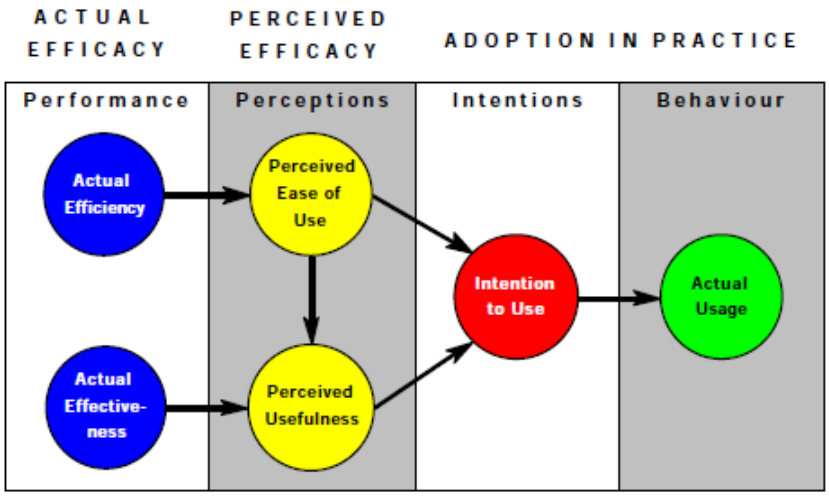


Figure 15 – Method Evaluation Model of (Moody, 2003)

7.1.2. Operationalisation of MEM

For the validation process the Method Evaluation Model (MEM) needs to be made operational. This means that for all constructs, measurements should be developed specific for the objectives of our method and tasks being evaluated. (Moody, 2003) The objective for this method is to construct a model of a care pathway that can at least be used as a communication tool between the medical professionals and the technicians. For this method, it is very important that both the medical professionals and the technicians are considered in the validation of the method. This because the method is only successful if the technicians can work according to it and the medical professionals can accept this way of working.

The Actual Efficiency can be measured with input measures as time and cost of effort and the Actual Effectiveness with output measures as the quantity and/or quality of the results (Moody, 2003). For our method, the objectives can be translated in the Actual Efficiency measures 'the time taken to make the model' and the 'time put in to help construct the model (for the medical professional)' and the Actual Effectiveness measure 'the quality of the model'. Note that these measures should be handled differently in laboratory and field experiments. Within Laboratories cases can be controlled and thus the results are comparable, where within the field cases are uncontrolled and therefore the results are not directly comparable.

There are four ways to come to measurements for Perceived Ease of Use, Perceived Usefulness and Intention to Use that all are based on TAM. The first one is to reuse the measures Davis et al. (1989) has developed and adjust them for our method. The six measures for Perceived Ease of Use, six for Perceived Usefulness and one for Intention to Use were on a 7 point scale from likely to unlikely. The last one from Intention to Use was also on a 7 point scale but then from improbable to probable. Reading the measurements of Davis et al. (1989) (see appendix M – Table 38), it can be concluded that they might not be very representable to our objectives and tasks. A second way to come up with the right measurements is to conduct a literature search to find already developed measurements specific for our type of methods. Since there was no process modelling method for Care Pathways yet, these need to be search within the healthcare or business process modelling fields. Unfortunately no measures could be found that fitted our objective and tasks. The third option is to use the measures from Davis et al. (1989) as a basis to make the measures such that they fit our objectives and tasks, like Moody (2003) did when

developing MEM. His final measures were partly negated and mixed and put into a post-task survey (see appendix M – Table 38).
The problem with all these three ways is that measurements are adopted from other research domains, which can lead to biased results (Recker & Rosemann, 2010). Therefore Recker and Rosemann (2010) developed the procedural model for the development of measures specific for the process modelling field. The fourth and last way is thus to use this framework to develop our own measures to evaluated our method. The model makes use of various techniques to develop the measurements and, more importantly in our case, it involves more users (experts, practitioners, students and end users). In the first stage of the model item creation takes place using relevant literature. After that, substrata identification is done, in which the items are sorted using an expert panel. In the third stage the item identification takes place through ranking the items by an expert panel. Next, the item revision is done with a practitioner panel to re-specify and further improve the set of items. Finally the instrument validation takes place by using a survey research method on the target population to obtain statistical evidence for reliability and validity of the created items.
In order to proof their procedural model, Recker and Rosemann (2010) did a case study towards the process modelling grammar BPMN. Based on TAM and the developed measurements for that method, they came up with a top three of measures for all three TAM constructs, see Figure 16. They furthermore found that PU3 and PU4 (see appendix M – Table 38) are not suitable for the domain of process modelling.

Theory Construct	No	Item Definition
Perceived usefulness	PU1	Overall, I find BPMN useful for modeling processes.
	PU2	I find BPMN useful for achieving the purpose of my process modeling.
	PU3	I find BPMN helps me in meeting my process modeling objectives.
Perceived ease of use	PEOU1	I find it easy to model processes in the way I intended using BPMN.
	PEOU2	I find learning BPMN for process modeling is easy.
	PEOU3	I find creating process models using BPMN is easy.
Intention to continue to use	ItU1	If I retain access to BPMN, my intention would be to continue to use it for process modeling.
	ItU2	In the future, I expect I will continue to use BPMN for process modeling.
	ItU3	I prefer to continue to use BPMN for process modeling over other process modeling grammars.

Figure 16 – Top Three Items of the TAM constructs, source: (Recker & Rosemann, 2010)

7.2. Proof of concept

As already stated above, conducting a validation process was neither possible in the timeframe of this research nor very meaningful. To obtain a first impression of the performance of the method, a proof of concept is done with criteria based on the predetermined requirements.
During the introduction of the research and the design of the method, requirements were stated with regard to the applicability of the method. The method needed to be applicable on any kind of Care Pathway within any hospital and the resulting model needed to be usable as a

communication tool to bridge the gap between medical professionals and technicians, but also for other purposes. Besides that, it was stated that the focus of the method needed to be on setting the right requirements for the modelling languages and tool necessary to come to the best possible model of the Care Pathway.
Based on these requirements, the following criteria were set to review the method and it result:

(1) The method can be applied to any kind of pathway, no matter which treatment it covers and how well documented and/or worked out the pathway is;
(2) The method can result in different types of models.
(3) The resulting model can be used as a communication tool (e.g. is clear to medical staff and technici involved);
(4) The resulting model is a realistic image of the pathway in place;
(5) Medical staff and technicians see future benefit in resulting model;

The method is designed such that the modelling approach can be adapted to the specific project. This makes that the method can be used on any kind of Care Pathway (1) and will result in the optimal model type for that project (2). It happened to be the case that the case study conducted towards the Unstable Angina Care Pathway included two departments with totally different documentations. The treatment within the cardiology department was documented very basically within the ACS protocol and based upon the clinical guidelines, but is mainly kept within the knowledge of the medical professionals. The treatment within the cardiothoracic surgery department, on the other hand, was worked out in great detail with their departments' work processes. As the method prescribes that the modelling approach should be determined among others upon the available information, it was possible to apply a different approach during step 4 – 'Fill in all details in the layout model' within the two departments. This indicates that the method can indeed be applied to different pathways, with different 'levels of documentation'. From the case study, it cannot be concluded that indeed different types of models can be resulting from the method. But the method clearly states that based on the modelling language requirements set, the optimal modelling language should be chosen. This makes that the choice of the model type is left open for the modeller to make.
In order to guarantee that the resulting model can be used as a communication tool (3), the goals of the project and the requirements of the modelling languages need to be set during step 1 – 'Define project'. Within the method description, as well as the conducted case study, this is also worked out. Especially the requirements for the modelling languages are important in this case, as the model cannot be used as a communication tool if the modelling language is too hard to understand for the medical professionals. During the verification of the model, it was already concluded that the resulting model of the case study could indeed be used as a communication tool. Besides that, it was also concluded that the resulting model was a realistic representation of the pathway in place in the hospital (4). By applying the method steps and refining the model until a success validation has been conducted, a realistic model can be ensured.
In general, the future benefit of the resulting model depends on the personal interests and intentions of the persons involved. In our case, the resulting model was found to be applicable in the hospital; the nurse practitioner as well as the main cardiology concerning the pathway stated that the model could be used for future alignment of the paths. It was furthermore stated that the model could be used for the inclusion of patients in clinical researched, related to the mapping application. Within chapter 5 two future application of the model are worked out, the pattern and

checklist development, that prove that the model is also of future benefit for technicians as well as medical professionals (5).

A last criterion that could be of importance to the evaluation of the method, is the time needed to present the results. In practice results are wanted within a reasonable time frame, as the model needs to be applied in a project or simply because men does not want to put too much time and effort into the modelling. It is very hard to indicate if this method can deliver 'within the a reasonable time frame'. This is because the modelling time depends upon a few factors; among others the specific care pathway complexity (i.e. the more complex the pathway, the harder it is to model), the 'level and quality of documentation' of the pathway (i.e. the clearer the pathway is documented, the easier it is to model), the availability of the medical professional involved in the pathway and the experience and medical knowlegde of the modeller. Note that the time needed to complete the case study, 12 weeks, cannot be used here as an indication, as other tasks were also conducted within this period. Furthermore, there was no time restriction stated here, other than that of the graduation project.

8. CONCLUSION AND FUTURE RESEARCH

To conclude this research a conclusion is drawn and future research is discussed.

8.1. Conclusion

The goal of this research was to '*design a process modelling method for Care Pathways in hospital*', that was applicable on any kind of care pathway. Besides that, the resulting model needed to be at least usable as a communication tool to bridge the gap between medical professionals and technicians. In order to reach the goal, first a literature study towards Care Pathways and process modelling methods has been done to answer sub questions (1) and (2). Based on the results, a method was designed consisting of the seven steps; *define project*, *plan project*, *make layout model and different views*, *fill in all details in the layout model*, *make stakeholders' perspectives*, *verify and validate model* and *refine model*. In this design special attention was paid towards the setting of the requirements for the modelling language and tool and the information gathering.

After that, the designed method was applied during a case study towards the Care Pathway of Unstable Angina at the Catharina Hospital Eindhoven, with the goals to test if the method was also usable in practice and to be able to refine the method with insides from practice. During the case study special attention was paid to the relationship between the goals of the model and the necessary granularity levels, and how to set those granularity levels. It was found that the level of detail are defined by the (sub) goals of the project, the clinical guidelines and/or the domain experts, but that the setting of the granularity levels is an art that needs to be done by the modeller.

After the case study was successfully completed, it could be concluded that the method was indeed applicable in practice. In order to evaluate the method a proof of concept was done, as a full validation could not be performed within the time frame. The method was evaluated based on the predetermined requirements (stated above) and it was concluded that the method should be applicable on any kind of care pathway as the modelling approach can be adapted to the specific project. This was also seen during the case study were the modelling approach applied in the two departments was different. Besides that, the resulting model of the method can be used as a communication tool and serve in other applications, as was proven by the demonstrations of the patterns and checklists.

The latest means that the method can be used in solving the open issues of Care Pathway usage with regard to the current lack of feedback loops. The method can deliver the model needed to conduct future research towards the difficulties with gathering data and the lack of proper monitoring tools. Aside from that, the method can also be of value for hospitals on its own. By applying it hospitals will gain a very good inside in their current pathways and will therefore be better able to evaluate, align and improve them medically as well as technically. The resulting model will thereby form the bridge between medical professionals as well as between medical professionals on one hand and supporting and management staff on the other. The method furthermore, can also be applied by them within the development of Care Pathways, as described by the 30-step scenario, to make an overview of the current and future processes.

8.2. Future research

During this research it has been shown that the developed method can be used to model Care Pathways, as least to model the Care Pathway of Unstable Angina in place in the Catharina

Hospital Eindhoven. Future research must show that the method can indeed be applied to any Care Pathway.

In order to be able to show this, the method should first be extensively used in a variety of case studies. These case studies must reflect the diversity of Care Pathways existing, meaning that the factors of disease, hospital, lengths and goals must be varied. The factor disease is about the way the method deals with the differences in the treatment approach due to the involved patient group, risk level and predictability. Every hospital has their own interpretation of Care Pathways, their development and how they should be documented. Furthermore, there might be differences in Care Pathways between hospitals due to their quality level (i.e. hospital with a high quality level might work more structured than hospitals that have a lower quality level). Another inside that could result from varying the hospitals is how to deal with a variety of available information resources. Special interest here is to include the hospital data as well, as it has been showed that it is very difficult to deal with. Also the current case study conducted can be supplemented with hospital data. The third factor, length, is about the time interval of the pathway. In the Unstable Angina case study the time interval was the entire hospitalization, while Care Pathways normally also include policlinic visits and after-care. Including these activities will mean that the patient enters and leaves the hospital multiple times, which must be reflected in the model. The last factor that must be varied are the goals of the case study. Not only to see that the method can deal with the different requirements and models leading from the goals, but also to notice how the method could help in improving the cost-efficient care that is so important for the world nowadays. In the introduction a number of possible goals have already been mentioned, of which the patterns and checklists have been shortly work out in this research.

Aside from the validation of this method to model Care Pathways, it is interesting to research the applicability of this method on Care Pathways in other parts of the healthcare sector (like the mental health) and on Clinical and Transmural Pathways. The application on Clinical Pathways, paths within clinics or 24-hours departments of hospitals, is probably quite similar to Care Pathways as it is still within the hospital, but the application on Transmural Pathways, pathways across different healthcare facilities including primary care, increases the complexity of the project as every part of the project should be tuned with all involved parties. Nevertheless, these Transmural Pathways might become very important in the future, as healthcare organizations more and more cooperate to optimize the treatment.

BIBLIOGRAPHY

Allen, D. (2009). From boundary concept to boundary object: The practice and politics of care pathway development. *Social Science & Medicine, 69*(3), 354-361.

Becker, J., Rosemann, M., & von Uthmann, C. (2000). Guidelines of Business Process Modeling. *Business Process Management, Lecture Notes in Computer Science (LNCS), 1806*, 30-49.

Benyoucef, M., Kuziemsky, C., Rad, A., & Elsabbahi, A. (2011). Modeling healthcare processes as service orchestrations and choreographies. *Business Process Management Journal, 17*(4), 568-597.

Brooks, R., & Tobias, A. (1996). Choosing the Best Model: Level of Detail, Complexity, and Model Performance. *Mathematical and Computer Modelling, 24*(4), 1-14.

Burr, J., Botello-Pinzon, P., Takwoingi, Y., Hernández, R., Vazquez-Montes, M., Elders, A., . . . Cook, J. (2012). Surveillance for ocular hypertension: an evidence synthesis and economic evaluation. *Health Technology Assessment 2012, 16*(29).

BusinessDictionary.com. (2013, May 22). *Granularity*. Retrieved from BusinessDictionary.com: http://www.businessdictionary.com/definition/granularity.html

Cardoen, B., & Demeulemeester, E. (n.d.). Evaluating the capacity of clinical pathways through. Leuven: Katholieke Universiteit Leuven, Faculty of Economics and Applied Economics, Department of Decision Sciences and Information Management.

Carley, K. (1996). Validating computational models. Retrieved Augustus 29, 2013, from http://www.casos.cs.cmu.edu/publications/papers.php

Catharina Ziekenhuis. (2010a, March 17). Cardiologie - Coronary Care Unit (CCU). Eindhoven: Catharina Ziekenhuis. Retrieved July 05, 2013, from http://www.catharinaziekenhuis.nl/files/Patient/Patientenfolders/Cardiologie/Coronary_Care_Unit.pdf

Catharina Ziekenhuis. (2010b, May 19). Cardiologie - PCI-behandeling. Eindhoven: Catharina Ziekenhuis. Retrieved July 05, 2013, from http://www.catharinaziekenhuis.nl/files/Patient/Patientenfolders/Cardiologie/PCI-behandeling.pdf

Catharina Ziekenhuis. (2012a, March 12). Cardiothoracale Chirurgie - Een hartoperatie, informatie rond uw opname. Eindhoven: Catharina Ziekenhuis. Retrieved July 05, 2013, from http://www.catharinaziekenhuis.nl/files/Patient/Patientenfolders/Cardiothoracale_chirurgie/Een_hartoperatie_informatie_rond_uw_opname.pdf

Catharina Ziekenhuis. (2012b, April 04). Cardiologie - Hartravalidatie. Eindhoven: Catharina Ziekenhuis. Retrieved July 05, 2013, from http://www.catharinaziekenhuis.nl/files/Patient/Patientenfolders/Cardiologie/Hartrevalidatie.pdf

Catharina Ziekenhuis. (2012c, September 21). Cardiologie - Hartkatheterisatie, leefregels na het onderzoek. eindhoven: Catharina Ziekenhuis. Retrieved July 05, 2013, from http://www.catharinaziekenhuis.nl/files/Patient/Patientenfolders/Cardiologie/Hartkatheterisatie_leefregels_na_het_onderzoek.pdf

Catharina Ziekenhuis. (2013a). *Prijslijst DBC DOT 2013*. Retrieved September 26, 2013, from Catharina Ziekenhuis: http://www.catharinaziekenhuis.nl/files/Patient/Praktische_info/Tarieven/Tarievenlijst_Catharina_Ziekenhuis_2013.pdf

Catharina Ziekenhuis. (2013b, January 11). Algemeen - Opnamewijzer. Eindhoven: Catharina Ziekenhuis. Retrieved July 05, 2013, from http://www.catharinaziekenhuis.nl/files/Patient/Patientenfolders/Algemeen/Opnamewijzer.pdf

CBS Statline. (2013, May 16). *Zorgrekeningen; uitgaven (in lopende en constante prijzen) en financiering*. Retrieved May 30, 2013, from www.cbs.nl: http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=71914ned&D1=0-23&D2=a&HDR=G1&STB=T&VW=T

CBS, Centraal Bureau voor de Statistiek. (2013, May 16). *PB13-037: Uitgaven aan zorg met 3,7 procent gestegen.* Retrieved May 30, 2013, from CBS.nl: http://www.cbs.nl/nl-NL/menu/themas/gezondheid-welzijn/publicaties/artikelen/archief/2013/2013-037-pb.htm

Chu, S., & Cesnik, B. (1998). Improving clinical pathway design: lessons learned from a computerised prototype. *International Journal of Medical Informatics, 51*, 1-11.

Da-Hua, X. (2009). Simulating on CIS based on Petri-Net. *International Symposium on IT in Medicine & Education. ITME '09.* (pp. 1132-1135). Jinan: IEEE.

Davis, F. (1989). Perceived Usefulness, Perceived Ease Of Use, And User Acceptance of Information Technology. *MIS Quartely, 13*(3), 319-340.

de Bleser, L., Depreitere, R., de Waele, K., Vanhaecht, K., Vlayen, J., & Sermeus, W. (2006). Defining pathways. *Journal of Nursing Management, 14*, 553–563.

de Luc, K. (2000). Are different models of care pathways being developed? *International Journal of Health Care Quality Assurance, 13*(2), 80-86.

de Vries, M., van Weert, J., Jansen, J., Lemmens, V., & Maas, H. (2007). Step by step development of clinical care pathways for older cancer patients: Necessary or desirable? *European Journal of Cancer, 43*(15), 2170-2178.

Edelman, J., Grosskopf, A., Weske, M., & Leifer, L. (2009). Tangible Business Process Modeling: A New Approach. *International Conference on Engineering Design, ICED'09*, (p. paper number 623). Stanford University, Stanford, CA, USA.

E-P-A. (n.d.). *Clinical / Care Pathways*. Retrieved February 26, 2013, from European Pathway Association: http://www.e-p-a.org/clinical---care-pathways/index.html

EuroSCORE Study Group. (2011). *EuroScoreII interactive calculator*. Retrieved October 12, 2013, from euroscore: http://www.euroscore.org/calc.html

Every, N., Hochman, J., Becker, R., Kopecky, S., & Cannon, C. (2000). Critical Pathways : A Review. *Circulation*, 461-465.

GRACE. (2013). *GRACE ACS Risk Model*. Retrieved October 12, 2013, from GRACE: http://www.outcomes-umassmed.org/GRACE/acs_risk/acs_risk_content.html

Graven, A., & Hoekstra, T. (2006). Variantieanalyse klinische paden – een eerste verkenning. *Cordiaal, 5*, 154-157.

Grech, E. D., & Ramsdale, D. R. (2003). ABC of interventional cardiology: Acute coronary syndrome: unstable angina and non-ST segment elevation myocardial infarction. *British Medical Journal (BMJ), 326*(7401), 1259-1261.

Grimm, W., & Maisch, B. (2006). Behandlungspfad „Akutes Koronarsyndrom“. *Internist, 47*(7), 699–706.

Grosskopf, A., Edelman, J., & Weske, M. (2010). Tangible Business Process Modeling – Methodology and Experiment Design. *Business Process Management Workshops, 43*, 489-500.

Grubnic, S. (2003). Care athways: conceptualising and developing a multi-skilling initiative. *International Journal of Health Care Quality Assurance, 16*(6), 286-292.

Hamm, C., Bassand, J., Agewall, S., Bax, J., Boersma, E., Bueno, H., . . . Zahger, D. (2011). ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. *European Heart Journal, 32*(23), 2999-3054.

Harmon, S., & Youngblood, S. (2005). A proposed model for simulation validation process maturity. *The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology, 2*(4), 179-190.

Hartstichting. (2012, November). Angina pectoris. Hartstichting. Retrieved July 5, 2013, from http://www.hartstichting.nl/9800/13341/15244/brochure_angina_pectoris

Hayward-Rowse, L., & Whittle, T. (2006). A pilot project to design, implement and evaluate and electronic integrated care pathway. *Journal of Nursing Management, 14*(7), 564-571.

Hindle, D., & Yazbeck, A. (2005). Clinical Pathways in 17 European Union countries: a purposive survey. *Australian Health Review, 29*(1), 94-104.

Hoekstra, T., de Boer, J., van den Elst, A., Holierhoek, M., Sprong, E., van Vliet, M., . . . de Wit, K. (2006). 'Walk Through' Cardiologie & Cardio-thoracale chirurgie. *Cordiaal, 27*(1), 10-13.

Huang, Z., Lu, X., Duan, H., & Fan, W. (2013). Summarizing clinical pathways from event logs. *Journal of Biomedical Informatics, 46*(1), 111-127.

Joosten, T., Bongers, I., & Meijboom, B. (2008). Care programmes and integrated care pathways. *International Journal of Health Care Quality Assurance, 21*(5), 472-486.

Jun, J., Jacobson, S., & Swisher, J. (1999). Application of Discrete-Event Simulation in Health Care Clinics: A Survey. *The Journal of the Operational Research Society, 50*(2), 109-123.

Kinsman, L., Rotter, T., James, E., Snow, P., & Willis, J. (2010). What is a clinical pathway? Development of a definition to inform the debate. *BMC Medicine, 8*.

Lin, F., Yang, M., & Pai, Y. (2002). A generic structure for business process modeling. *Business Process Management Journal, 8*(1), 19-41.

Mendling, J., Reijers, H., & van der Aalst, W. (2010). Seven process modelling guidelines (7PMG). *Information and Software Technology, 52*, 127-136.

Moody, D. (2003). The method evaluation model: a theoretical model for validating information systems design methods. *11th European Conference on Information Systems, ECIS.* Naples, Italy.

Müller, R., & Rogge-Solti, A. (2011). BPMN for Healthcare Processes. *the 3rd Central-European Workshop on Services and their Composition, ZEUS 2011* (pp. 65-72). Karlsruhe, Germany: CEUR-WS.org.

Netwerk Klinische Paden. (n.d.). *Definitie*. Retrieved Februari 07, 2013, from Netwerk Klinsche Paden: http://www.nkp.be/nederlands/wat-zijn-klinische-paden/definitie/index.html

Ozcan, Y., Tànfani, E., & Testi, A. (2011). A Simulation-based Modeling Framework to Deal with Clinical Pathways. *Winter Simulation Conference* (pp. 1190-1201). Grand Arizona Resort Phoenix, AZ: IEEE.

Panis, C. (2008). *Zorgpad transmurale voeding.* Rotterdam: Erasmus MC Rotterdam.

Peeters, A. (2013). Creating and validating an electronic integrated checklist for patients with unstable angina. Eindhoven: Eindhoven University of Technology.

Pheasant, H., & Enock, K. (2010). *Obesity Care Pathway support packages - Child Obesity workbook.* London: Public Health Action Support Team (PHAST).

Presley, A., & Liles, D. (2001). A holon-based process modeling methodology. *International Journal of Operations & Production Management, 21*(5/6), 565-581.

Rad, A., Benyoucef, M., & Kuziemsky, C. (2009). An Evaluation Framework for Business Process Modeling Languages in Healthcare. *Journal of Theoretical an Applied Electronic Commerce Research, 4*(2), 1-19.

Ramos, M., & Ratliff, C. (1997). The development and Implementation of an Integrated Multidisciplinary Clinical Pathway. *Journal of Wound, Ostomy and Continence Nursing, 24*(2), 66-71.

Ramudhin, A., Chan, E., Benziane, R., & Mokadem, A. (2006). Modeling and Optimization of Health Care processes. *The Institute of Industrial Engineers Annual Conference*, (pp. 1-7). Orlando, Florida.

Recker, J., & Rosemann, M. (2010). A measurement instrument for process modeling research : development, test and procedural model. *Scandinavian Journal of Information Systems*(22), 3-30.

RIVM. (2010, March 22). *Verwachte verzorgingsgebieden hartcentra*. Retrieved September 16, 2013, from National Atlas Volksgezondheid: http://www.zorgatlas.nl/zorg/ziekenhuiszorg/topklinische-zorg/verwachte-verzorgingsgebieden-hartcentra-2008/

Rotter, T., Kinsman, L., James, E., Machotta, A., Willis, J., Snow, P., & Kugler, J. (2012). The Effects of Clinical Pathways on Professional Practice, Patient Outcome, Length of Stay, and Hospital Costs: Cochrane Systematic Review and Meta-Analysis. *Evaluation & the Health Professions, 35*(1), 3-27.

Sargent, R. (1998). Verification and validation of simulation models. *28th Winter Simulation Conference. 1*, pp. 121-130 . Washington, DC, USA: IEEE Computer Society.

Scheuerlein, H., Rauchfuss, F., Dittmar, Y., Molle, R., Lehmann, T., Pienkos, N., & Settmacher, U. (2012). New methods for clinical pathways—Business Process Modeling Notation (BPMN) and Tangible Business Process Modeling (t.BPM). *Langenbeck's Archives of Surgery, 397*(5), 755–761.

Schrijvers, G., van Hoorn, A., & Huiskes, N. (2012). The care pathway: concepts and theories: an introduction. *International Journal of Integrated Care, 12*(Special Edition Integrated Care Pathways).

Sermeus, W., & Vanhaecht, K. (2002). Wat zijn klinische paden? *Acta Hospitalia*(3), 5-11.

Shen, H., Wall, B., Zaremba, M., Chen, Y., & Browne, J. (2004). Integration of business modelling methods for enterprise information system analysis and user requirements gathering. *Computers in Industry, 54*(3), 307–323.

Shi, J., Su, Q., & Zhao, Z. (2008). Critical Factors for the Effectiveness of Clinical Pathway in Improving Care Outcomes. *International Conference on Service Systems and Service Management* (pp. 110-115). Melbourne, Australia: IEEE.

Smith, E., & Ross, F. (2007). Service user involvement and integrated care pathways. *International Journal of Health Care Quality Assurance, 20*(3), 195-214.

Staccini, P., Joubert, M., Quaranta, J., Fieschi, D., & Fieschi, M. (2001). Modelling health care processes for eliciting user requirements: a way to link a quality paradigm and clinical information system design. *International Journal of Medical Informatics, 64*(2-3), 129–142.

van Aken, J., Berends, H., & van der Bij, H. (2007). *Problem Solving in Organizations - A Methodological Handbook for Business Students.* Cambridge: Cambridge University Press.

van Veghel, H., van den Bosch, W., Dekker, L., & Tonino, W. (2012). *Meetbaar Beter Boek - Catharina Ziekenhuis 2012.* Eindhoven.

Vanhaecht, K., & Sermeus, W. (2002). Draaiboek voor de ontwikkeling, implementatie en evaluatie van een klinisch pad. 30 stappenplan van het netwerk klinische paden. *Acta Hospitalia*(3), 13-27.

Vanhaecht, K., & Sermeus, W. (2003). The Leuven Clinical Pathway Compass. *Journal of Integrated Care Pathways, 7*, 2-7.

Vanhaecht, K., Bollman, M., Bower, K., Gallagher, C., Gardini, A., Guezo, J., . . . Panella, M. (2006). Prevalence and use of clinical pathways in 23 countries - an internationa survey by the European Pathway Association. *journal of Integrated Care Pathways, 10*(1), 28-34.

Vanhaecht, K., De Witte, K., & Sermeus, W. (2007). *The impact of Clinical Pathways on the organisation of care processes.* Leuven: KU Leuven.

Vanhaecht, K., Panella, M., Zelm, R. v., & Sermeus, W. (2010). An overview on the history and concept of care pathways as complex interventions. *International journal of Care Pathways, 14*, 117-123.

Veiligheidsregio Brabant-Zuidoost (VRBZO). (2010). *Veiligheidsregio Brabant-Zuidoost (VRBZO)*. Retrieved September 16, 2013, from Veiligheidsregio Brabant-Zuidoost (VRBZO): http://www.vrzob.nl/

Vissers, J. (2006). A Logistics Approach For Hospital Process Improvements. In R. Hall (Ed.), *Patient Flow: Reducing Delay in Healthcare Delivery* (pp. 393-427). New York: Springer.

VMS Veiligheidsprogramma. (2010). *Optimale zorg bij Acute Coronaire.* Utrecht: VMS Veiligheidsprogramma.

Weidmann, M., Alvi, M., Koetter, F., Leymann, F., Renner, T., & Schumm, D. (2011). Business process change management based on process model synchronization of multiple abstraction levels. *IEEE International Conference on Service-Oriented Computing and Applications (SOCA)* (pp. 1-4). Irvine, California, US: IEEE.

Whittle, C., & Hewison, A. (2007). Integrated care pathways: pathways to change in health care? *Journal of Health Organization and Management, 21*(3), 297-306.

WHO Collaborating Centre for Drug Statistics Methodology. (2011, March 25). *ATC - Structure and principles*. Retrieved September 27, 2013, from WHO Collaborating Centre for Drug Statistics Methodology: http://www.whocc.no/atc/structure_and_principles/

WHO Collaborating Centre for Drug Statistics Methodology. (2012, December 20). *ATC/DD index*. Retrieved from WHO Collaborating Centre for Drug Statistics Methodology: http://www.whocc.no/atc_ddd_index/

Wit, M., Schaap, A., & Umans, V. (2011). A Critical Pathway for the Frail Elderly Cardiac Patient. *Critical Pathways in Cardiology, 10*(4), 159-163.

Yan, H., Van Gorp, P., Kaymak, U., Lu, X., Vdovjak, R., Korsten, H., & Duan, H. (2013). *Analyzing conformance to clinical protocols involving advanced synchronizations.* Eindhoven: Technische Universiteit Eindhoven. Retrieved from http://www.tue.nl/publicatie/ep/p/d/ep-uid/288425/

Zander, K. (2002). Integrated care pathways: eleven international trends. *Journal of Integrated Care Pathways, 6*, 101-107.

Zwaan, E., & Umans, V. (2012). Step by step towards a clinical pathway. *International Journal of Care Pathways, 16*(1), 19-24.

APPENDIX A – OVERVIEW OF 'PM METHOD FOR CARE PATHWAYS'

The method for modelling Care Pathways consists of seven steps. It is very important to note that the method is not linear, in the sense that decisions can be postponed to future steps and/or decisions made in previous steps can be revised based on new insights. For each step an overview is provided of the most important points. A full description of the method and its development can be found in chapter 3 and chapter 6.

(1) Define project

The method starts with the definition of the goals and objectives of the Care Pathway (CP) modelling project. This includes the specification of the CP, identify (key) stakeholders, defining the goals of the project, the translation of the goals into a set of requirements for the model and the indication of which resources are available for information gathering. Each of these aspects will be shortly explained now.

- **Specify Care Pathway**

  Specify the patient group and time interval of the pathway and the parameters (high volume, risk, costs and predictability) of the patient group (Vanhaecht & Sermeus, 2002).

- **Identify (key) stakeholders**

  Stakeholders are parties that have an interest in the project, are needed to define the goals of the project and can be very helpful with the information gathering. Three kinds of stakeholders exist; direct, indirect and key. Direct stakeholders are "*people whose work processes, roles or vital interest are directly affected*" (van Aken, Berends, & van der Bij, 2007, p. 98) by the Care Pathway modelling project. These stakeholders are the project team and directly involved hospital staff, mainly doctors and nurses. Indirect stakeholders are "*people who are to cooperate with the direct stakeholders"* (van Aken, Berends, & van der Bij, 2007, p. 98) and therefore are affected by the CP modelling project. These stakeholders need to cooperate with the direct stakeholder, are cooperating outside organisations or have another indirect connection to the pathway and/or the modelling project.

- **Define project goals**

  The goals of the project need to be defined. Within this method, it is assumed that one of the goals is to use the model as a communication tool. Other goals of the project might be to identify Key Performance Indicators (KPI's), to make structured patients files, to create checklists, to determine the completed pathway, to optimize the pathway or to make a workflow. For all these goals it is necessary to specify sub goals, in order to be able to make a distinction what needs to be taken into account during the modelling project and what aspects can be ignored. Note that although it is ideal to defined all goals within this phase, it is very well possible to work with an temporal list of sub goals until the information gathering within the hospital will finalized it.

- **Set model requirements**

  Based on the chosen pathway and the defined goals, the set of requirements for the model can be specified. The model requirements can be split into the quality of the process model, process visualization, granularity and the modelling language, but can still influence each other. Part of the requirements is general for the sector and/or the modelling purpose, the other part highly depends on the specific modelling case and its goals. Each of the aspects will be discussed here shortly separately.

- ***Quality of process model***

The quality of the process model can be determined using so called modelling guidelines. Depending on the goals of the model, different guidelines are applicable. For the goal of a communication tool a conceptual graphical model will be probably made. For this purpose two basic guidelines are applicable; the Guidelines of Modelling (GoM) (Becker, Rosemann, & von Uthmann, 2000) and Seven Process Modelling Guidelines (7PMG) (Mendling, Reijers, & van der Aalst, 2010), see Table 4 and Table 5 in chapter 3.

- ***Process visualization***

The process visualization is about how the process should be represented in the model with regard to the views & perspectives, sequence and roles. Note that the decisions taken here also influence the modelling language requirements.

- *Views & perspectives*

  In order to clearly understand processes, models should be made from different views. At least four different distinctions can be found in literature, see Presley & Liles (2001) and Ramudhin, et al. (2006), but as every view requires a different modelling technique and/or language it is very important to define which views needs to be made. For a communication tool at least the business view needs to be made.

  Aside from the views, it is important to define which different perspectives need to be made of the model. As the model is used for different purposes, different perspectives with other levels of details and representation would make the model more understandable (as in less complex) for the target group. This also counts for the application of a communication tool, as redundant details will be left out.

- *Sequence*

  The sequence of a model is the order in which events are put behind each other. In literature many sequences can be found, but as Care Pathways have a causal predictable relationship the sequences of chronological order, time ordered and day-to-day planning are applicable for the business view. In case there is no explicit chronological or time order in (parts of) the Care Pathway, a combination of a declarative and prescriptive model could be very useful.

- *Roles*

  The third important aspect of process visualization is about how to display the roles in the model. Care Pathways are teamwork and therefore involve many roles that perform tasks separately and together. How the cooperation can be visualized depends on the modelling language, but pools, lanes or colours can help with this. Note the relation between the role visualization, the complexity of the process and the understandability of the model. As the complexity of the process is probably not known yet, a decision can be postponed till step 3 to 5.

- ***Granularity***

The granularity is about how detailed a process is represented. As different actors require different levels of detail, it is important to derive the required levels from the project goals, from interviewees with medical professionals and non-management personnel and/or by referring to other existing models. The setting of the granularity levels and the levels of detail is very difficult and asks a lot of creativity from the modeller, as there is only one rule of thumb; the appropriate level of detail is to model as simple as possible while meeting all modelling requirements and goals. It can be advised to make a top-level that provides a very abstract overview of the pathway. This level automatically makes

sure that the model is divided into sub processes given an overview of one phase of the pathway. Furthermore, the clinical guidelines, the KPI's and/or the medical professionals can be used to define the levels of detail during the two modelling steps. At this moment in the project, it is important to state the already known requirements, such that during the layout modelling temporally levels can be set with that in mind. As the project follows the details of the CP will become clear and the final levels can be set eventually. Note to minimize the times the levels are reset, as this is a quite time consuming task.

- ***Modelling language***

The healthcare sector, as every other sector, has its own requirements regarding the characteristic of the modelling languages for meaningful usage. Aside from the general requirements that can be found in Table 6, it is important to properly specify any case related additional requirements (using literature). Taken here also the requirements set for the other process visualization aspects into account. Note that '*user understandability*' and '*easy of use*' are quite important by CP modelling, since the medical staff is the owner of the pathway and needs to be able to understand and work with the model. Besides that, '*exception handling*' is an interesting topic within Care Pathways, because in practice deviations from the ideal pathway occur often. A realistic model of a CPs therefore should probably also deal with those deviations.

- **Identify available information resources**

The last step of the project definition is to sum up all available information resources that can be used as input for the modelling. Information resources can be documents (like pathway documentation, guidelines, brochures, charts or patients records), systems (HIS and EPD), (medical) experts and patients. Note that besides the (official) hospital information, a lot of information can be found on the internet and by the national associations concerning the disease or medical professionals of the care pathway. Furthermore, scientific literature about the pathway (developed) in other hospitals could be present (do not confuse this with the complex clinical researches available).

(2) <u>Plan project</u>

Based on the project definition, requirements and the available information resources, the project can be planned. The plan includes the modelling approach, in which the modelling language and tool and the information recourse used are chosen, and the according timeframe of the different steps.

The method advices to use a combined top-down bottom-up modelling approach, as the layout modelling based on the guidelines can also serve as a preparation for the information gathering within the hospital. This preparation is very important, as the modeller needs to get familiar with the medical process and terminology. Especially the terminology requires some attention as there are many different terms used for the same test and medicine. For medicines the official names of the ATC-classification, see Table 12, are used together with nicknames of medicine groups and brand names. The website of the WHO medicines contains an index, which can be consulted with one of the official names.

While choosing the modelling language keep in mind to look if the standard language used by the hospital and/or the de-facto language within the field (BPMN2.0) satisfy the requirements used. If there is no experience yet with the language and/or tool chosen, leave room in the project planning to get familiar with them.

(3) Make layout model and different views

In this step a layout of the different views of the model will be made as in the modelling approach that combines the top-down and bottom-up approach. This can be done based on the clinical guidelines and if present the official pathway documents. Clinical guidelines are often compulsory and probably also be used as a basis for the CPs under investigation, but are hard to read for non-medical professionals as they contain a lot of interpretations of clinical research. As it is for the rest of the process important to extract as much information as possible from them, it is good to focus on the conclusions and if present tables and management summary.

(4) Fill in all details in the layout model

After the lay out modelling is done, the details can be filled in and the information gathering within the hospital can start. Note that some details can already be put in the model during the layout. When the layout is made with the official pathway documentation and the clinical guidelines, details can be gathered through interviews with all involved disciplined and if available patient leaflets from or used by the hospital. Semi-structured interviews, well-structured and comprehensive interview checklists and/or t.BPM can be used here. During the information gathering it is very handy to update the model regularly, such that always the last available information can be used as input for the next interview. While conducting interviews during working hours, keep in mind that medical professionals are very busy and that it is very well possible that interruptions will take place, as the welfare of the patients stands above all else. During this phase, new information will and can lead to renewed decisions taken about process visualization and the final granularity levels.

(5) Make stakeholders' perspectives

When the details are filled in, the different stakeholders' perspectives can be made. Which perspectives need to be made is defined in the project definition, including which information each perspectives requires. The perspectives are necessary for the goal as a communication tool, but also for the validation of the model and should easily lead from the total model. The most important aspect of making different perspectives for a communication tool is to keep the context in place.

(6) Verify and validate model

The last but one and perhaps most important step of the method is the verification and validation of the process model. This is so significant since the process model should represent a realistic picture of the real world. Note that in case the goal of the model requires an executable model as an output, this step also contains experimentation to validate the model. Verification can be done by checking if the model fulfils all requirements, while for the validation it needs to be proven that the model represents reality. There are many validation techniques that can be used, depending on the goal of the model and the available information resources. Important is to keep in mind are the levels of validation process maturity defined by Harmon & Youngblood (2005), for which the highest achievable level can be derieved. To validate a communication tool, without medical data, the techniques of grouding (Carley, 1996), face validity and traces (Sargent, 1998) can be used. If the validation is not passed, then go on with step 7, otherwise the methodology stops here.

(7) Refine model

It is very well possible that in the verification and validation process new information comes to light that shows incompleteness of the model. This feedback needs to be used to refine the current model. Refinement can be done by restarting the modelling process from step 4 and continuing the cycle until the verification and validation shows that the model is correct.

APPENDIX B – EVALUATION FRAMEWORK OF RAD ET AL. (2009)

Figure 17 – Evaluation framework, source: (Rad, Benyoucef, & Kuziemsky, 2009)

Evaluation framework elements
Security and privacy Not applicable for conceptual process modelling.
Pattern representation On the one hand pattern representation reduces the complexity of models. On the other hand familiarity with patterns increases the understandability of the model.
Ontological completeness Evaluation of languages concepts is done with ontological constructs. Since incompleteness of the language can force the modeller to either ignore aspects of the model or construct it differently, this leads to a decrease in the understandability of the model. So how more complete the ontological of the language, how better the model can represent the situation.
Extendibility As stated with the requirement, the language should either be combinable with other languages or extendible such that it can meet the requirements itself.
Notations The notation of the language influences the understandability of the models by stakeholders. Because of different backgrounds model use can be improved by a coherent and standard language notation for all actors.
Modularity Using a modular design, abstraction of processes and sub processes, leads to less complex models. Furthermore it increases the ability to adjust the model for different users and uses.
Level of detail The level of detail is important because of the different actors and their views. Flexibility of the model makes this possible.
Exception handling Exceptions are very common in healthcare and the predictability of an adaptable model increases when those are foreseen.

Table 23 – Evaluation framework elements, source: (Rad, Benyoucef, & Kuziemsky, 2009)

APPENDIX C – SUMMARY INTERVIEWS SUPPORTING DEPARTMENTS

At the start of the project, both the finance department and the supporting quality and safety department were stated as indirect key stakeholders. Therefore contact was established via e-mail with the two departments, which led in both cases to an appointment. A summary of both meeting is given her.

The first appointment was with the finance department of the hospital. Beforehand it was made clear what the goal of the research was and that the scope of the meeting was about how the financial administration around the care pathway is arranged. The financial administration is arranged as follows: When the patient arrives at the hospital and is admitted a new so called DOT is opened. During the care treatment all care is noted in the hospital system and at discharge the doctor checks if the DOT registration is still correct (for example if the diagnosis is still correct). When the treatment is finished, the DOT will be closed by the financial department and all activities and information registered in the DOT is send to a grouper. This grouper decides which care product number the DOT gets. Every care product number is linked to a declaration code in the hospital.

Hospitals have a general price list, but make in addition also separate price agreements with healthcare insurance companies. A list of the relevant Cardiology care product numbers (provided by the financial department), declaration codes, label (in Dutch) & description and prices (Catharina Ziekenhuis, 2013a) can be found in Table 24. Note, that no care product numbers of the CABG treatment are included, as they were not provided by the financial department. As the financial administration and setting prices is a complex and difficult business, there are no KPI's set for individual care trajectories by the financial department. Furthermore, medical staff is not aware of the exact working of this administration. So, therefore no financial matters are taken into account in the model accept the opening and checking of the DOT.

The appointment with the Quality and safety department was about KPI's and the measuring of it within the hospital. The mandatory KPI's are measured and reported on by the different department and can be asked by the concerning departments, in this case the two KPI's noted in Appendix E from the VMS. In general, KPI's for care pathways are set by the concerning medical departments with some support of quality. Often the focus is on the process and outcome indicators. They experience that the evaluation of the KPI's by the department is hardly done. Often a small oral evaluation with the medical team is made, but the KPI's are not consistently evaluated. The most important reason for this is that the necessary data gathering needs to be done manually and is therefore found a too major effort. In the recently written new vision on care pathways, the evaluation of KPI's is taken to a higher level and will become an important part of the care pathway development. The implementation of this vision has been suspended because the IT department has not yet made it possible to measure KPI's within or through the hospital system.

Care product	Declaration code	Label *(in Dutch)* & Description *(in English)*	Total Price
099499015	15A610	**Label**: Cardiologie | Ischemie Met/ Zonder Schade | Ambulant Middel | Hart/Vaat Ischemische Hartziekte **Description**: Treatment or examination at the policlinic by a heart disease due to blocked blood supply (myocardial infarction) or signs of inadequate blood supply to the heart	€ 606,47
099499019	15A611	**Label**: Cardiologie | Ischemie Met/ Zonder Schade | Licht Ambulant | Hart/Vaat Ischemische Hartziekte **Description**: Consult at the policlinic by a heart disease due to blocked blood supply (myocardial infarction) or signs of inadequate blood supply to the heart	€ 239,42
099499026	15A613	**Label**: Cardiologie | Ischemie Zonder Schade | Dag/ Klin Cumulatief Kort | Hart/Vaat Ischemische Hartziekte **Description**: Up to 5 treatment and/or nursing days by signs of inadequate blood supply to the heart	€ 2.184,97
099499032	15A617	**Label**: Cardiologie | Ischemie Zonder Schade | Dag/ Klin Cumulatief Middel | Hart/Vaat Ischemische Hartziekte **Description**: 6 to 28 treatment and/or nursing days by signs of inadequate blood supply to the heart	€ 7.248,65
979001217	14D676	**Label**: Percutane Coronaire Interventie Klasse 5 | Met Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI (with nursing days) by a disease of the heart and / or lung (vessels)	€13.377,28
979001219	14D678	**Label**: Percutane Coronaire Interventie Klasse 4 | Met Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI (with nursing days) by a disease of the heart and / or lung (vessels)	€7.187,97
979001220	14D679	**Label**: Percutane Coronaire Interventie Klasse 4 | Zonder Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI by a disease of the heart and / or lung (vessels)	€ 5.345,08
979001221	14D680	**Label**: Percutane Coronaire Interventie Klasse 3 | Met Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI (with nursing days) by a disease of the heart and / or lung (vessels)	€ 6.008,60
979001222	14D681	**Label**: Percutane Coronaire Interventie Klasse 3 | Zonder Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI by a disease of the heart and / or lung (vessels)	€ 4.360,37
979001223	14D682	**Label**: Percutane Coronaire Interventie Klasse 2 | Met Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI (with nursing days) by a disease of the heart and / or lung (vessels)	€ 7.613,19
979001224	14D683	**Label**: Percutane Coronaire Interventie Klasse 2 | Zonder Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI by a disease of the heart and / or lung (vessels)	€ 6.003,85
979001225	14D684	**Label**: Percutane Coronaire Interventie Klasse 1 | Met Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI (with nursing days) by a disease of the heart and / or lung (vessels)	€ 5.413,80
979001226	14D685	**Label**: Percutane Coronaire Interventie Klasse 1 | Zonder Vpld | Hartoperatie/Hart-/Longtransplantatie **Description**: PCI by a disease of the heart and / or lung (vessels)	€ 3.875,13

Table 24 – List of UA related care product numbers, declaration codes, labels and descriptions and the price in place for treatment at the Cardiology department at the CHE, (source: (Catharina Ziekenhuis, 2013a)

APPENDIX D – STAKEHOLDER FOR THE CP OF UA

Department (*in Dutch*)	Direct Stakeholders
	Patient
Cardiology	Cardiologist (in training) (Hamm, et al., 2011)
Cardiologie	Co-assistant (Catharina Ziekenhuis, 2013b)
	Laboratory technician
First Heart Aid *Eerste Hart Hulp (EHH)*	EHH-Nurse
Coronary Care Unit (CCU)	Ward Doctor (Catharina Ziekenhuis, 2013b)
Hartbewaking	CCU Nurse (Hamm, et al., 2011; Catharina Ziekenhuis, 2010a)
	Team leader CCU
Heart Catheterization Room	Intervention Cardiologist
Hart Catheterisatie Kamer (HCK)	HCK Nurse (Catharina Ziekenhuis, 2010b)
	Team leader HCK
Nursing ward Cardiology	Ward doctor (Catharina Ziekenhuis, 2013b)
Verpleegafdeling Cardiologie (7west)	Nurse practitioner (Catharina Ziekenhuis, 2010b)
	Nurse (Hamm, et al., 2011)
	Team leader 7 West
Cardiothoracic Surgery *Cardiothoracale Chirurgie*	Cardiothoracic surgeon (in training) (Catharina Ziekenhuis, 2012a)
	Co-assistant (Catharina Ziekenhuis, 2013b)
	Secretariat
Nursing ward Cardiothoracic Surgery	Ward doctor (Catharina Ziekenhuis, 2013b)
Verpleegafdeling Cardiothoracale	Nurse practitioner (Catharina Ziekenhuis, 2012a)
Chirurgie (CTC/6West)	Nurse
	Secretary
	Team leader 6 West
Operation Rooms	Anaesthetist (Catharina Ziekenhuis, 2012a)
Operatie Kamers (OK)	Anaesthetist employee
	Operation assistant
	OR-nurse
Intensive Care	Anaesthetist-intensivist (Catharina Ziekenhuis, 2012a)
Intensive Care (IC)	Ward doctor
	IC nurse practitioner
	IC nurse
	Team leader IC
Laboratory	Laboratory staff
Algemeen Klinisch Laboratorium (AKL)	Specialist laboratory medicine
	Laboratory technician (Catharina Ziekenhuis, 2013b)
Radiology *Radiologie*	Radiologist
***Oral and maxillofacial surgery** *Mondziekten, kaak- en aangezichtenchirurgie*	Dental surgeon
***ENT** *KNO*	ENT specialist
***Internal medicine** *Inwendige geneeskunde*	Internist
***Pulmonary medicine** *Longgeneeskunde*	Pulmonologist
***Emergency Room (ER)**[9]	ER doctor (VMS Veiligheidsprogramma, 2010)
SpoedEisende Hulp (SEH)	ER nurse

Table 25 – Direct Stakeholders of the CP of UA at the CHE, with * for optional involved departments

[9] It is possible that patients arrive through the ER/SEH or are admitted there because the EHH is fully occupied.

	Indirect Stakeholders (*in Dutch*)
Catharina Hospital	Medical head of Cardiology
	Medical head of CCU
	Department manager EHH+CCU+ HCK
	Department secretary / receptionist EHH+CCU+HCK
	Department secretary / receptionist Cardiology (7west)
	Medical head of Cardiothoracic surgery
	Department secretariat Cardiothoracic surgery (CTC)
	Department secretary / receptionist Cardiothoracic surgery (6west)
	nursing Consultant Cardiothoracic Surgery (Catharina Ziekenhuis, 2012a) *Verpleegkundig consultant Cardiothoracale chirurgie*
	Physiotherapist (Catharina Ziekenhuis, 2012b; Catharina Ziekenhuis, 2013b) *Fysiotherapist*
	Dietician (Catharina Ziekenhuis, 2012b; VMS Veiligheidsprogramma, 2010) *Dietiste*
	Pharmacist (VMS Veiligheidsprogramma, 2010) *Apotheker*
	Social worker (Catharina Ziekenhuis, 2010a) *Maatschappelijk werker*
	Spiritual counsellor (Catharina Ziekenhuis, 2012a) *Geestelijk verzorger*
	Policlinic Heart Rehabilitation (Catharina Ziekenhuis, 2012b) *Polikliniek Hartrevalidatie*
	Quality and safety department *Afdeling kwaliteit en veiligheid*
	ICT department
	Bureau Patient interests (Catharina Ziekenhuis, 2010a) *Bureau patiëntenbelangen*
	Bureau Patient education (Catharina Ziekenhuis, 2010a) *Bureau patiëntenvoorlichting*
Local	General Practitioner (GP) (Catharina Ziekenhuis, 2012a) *Huisarts*
	Partners (Hartstichting, 2012)
	Family
National	Heart & Vascular Group (Hartstichting, 2012) *Hart &Vaatgroep*
	Dutch Association of Cardiologists (Hartstichting, 2012) *Nederlandse Vereniging van Cardiologen*
	Dutch Association of Cardiovascular Nurses (Hartstichting, 2012) *Nederlandse Vereniging Hart- en Vaatverpleegkundigen*
	Heart foundation (Hartstichting, 2012) *Hartstichting*
	Healthcare Insurance companies
	Health Inspection *Inspectie gezondheidszorg (IGZ)*
	Department of Health *Ministerie voor volksgezondheid*

Table 26 – Indirect Stakeholders of the CP of UA at the CHE

APPENDIX E – KEY PERFORMANCE INDICATORS FOR UA

Domain	Process phase	Performance indicator	Description
Clinical	***Initial evaluation***	Patients admitted to the CCU or EHH[2]	Percentage of UA patients that are admitted to the CCU or EHH
Clinical	***Initial evaluation***	Troponin measuring (%)[4]	Percentage of UA patients, where Troponin is measured
Clinical	***Diagnosis validation and risk assessment***	Use of aspirin[2,4,7]	Percentage UA patients where aspirin is prescribed during hospitalization
Clinical	***Diagnosis validation and risk assessment***	Use of tricagrelor or clopidogrel[2,4,7]	Percentage UA patients where tricagrelor or clopidogrel is prescribed during hospitalization
Clinical	***Diagnosis validation and risk assessment***	Use of fondaparinux or enoxaparin [2,4,7]	Percentage UA patients where fondaparinux or enoxaparin is prescribed during hospitalization
Clinical	***Diagnosis validation and risk assessment***	Use of enoxaparin in patient with kidney failure?[7]	Percentage of UA patients with kidney failure where enoxaparin is prescribed Percentage of UA patients with kidney failure where Fondaparinux is prescribed
Clinical	***Invasive strategy***	Use of early invasive procedures by intermediate- to high-risk patients[2]	Percentage UA patients with a GRACE > 108 and/or one or more risk factors that get an CAD within 120 minutes
Clinical	***Revascularisation modules***	Complications (%)[5]	*numerator: Number of patients in which a re-operation within the same hospitalization is necessary because of a bleeding, with or without a tamponade, graft occlusion or other cardiac cause.* *denominator: Number of patients undergoing a CABG surgery for the first time.*
Clinical	***Revascularisation modules***	Percentage of deep sternal wound infections[5]	*numerator: Number of patients who develop a deep sternal wound infection related to muscle, bone and/or mediastinum within 30 days after the operation* *denominator: Number of patients undergoing a CABG surgery for the first time.*
Clinical	***Revascularisation modules***	Percentage CVA with permanent injury[5]	*numerator: Number of patients who develop a postoperative stroke.* *denominator: Number of patients undergoing a CABG surgery for the first time.*
Clinical	***Revascularisation modules***	Glycoprotein IIb/IIIa inhibitor given for PCI?[3]	
Clinical	***Revascularisation modules***	Angiographic success (successful PCI <20% stenosis) (%)[5]	numerator: PCI patients with <20% rest stenosis in all lesions where PCI is attempted denominator: Total number of PCI procedures in this hospital.
Clinical	***Revascularisation modules***	Emergency CABG-operation (%)[5]	Numerator: PCI-patients that underwent an emergency CABG operation after a PCI, during the hospitalization of this PCI procedure. Denominator: Total number of PCI procedures in this hospital.
Clinical	***Discharge***	Advice on quitting smoking[2,3]	Percentage of patients that is given advice to stop smoking
Clinical	***Discharge***	Golden five medicine prescribed at discharge[1,3,6,7] Should be ≥90% according to (VMS Veiligheidsprogramma, 2010)	Percentage UA patients where the five medicine ASA, thienopyridine, statin, beta blocker and ACE inhibitor (or ATII) are prescribed at discharge

Clinical	***Discharge***	Beta-blocker at discharge by patients with LV dysfunction[2]	Percentage UA patients with LV dysfunction where the beta blocker is prescribed at discharge
Clinical	***Discharge***	Use of Statins[2]	Percentage UA patients where statins is prescribed at discharge
Clinical	***Discharge***	Use of ACE-inhibitor of ARB[2]	Percentage UA patients where Ace-inhibitor or ARB is prescribed at discharge
Clinical	***Discharge***	Antacid prescribed for patient with gastric disorder[7]	
Clinical	***Discharge***	Sign up for Heart rehabilitation [1,2,7]	Percentage UA patients that is signed up for heart rehabilitation at discharge
Clinical	***Discharge***	Sign up for X-ergometry[1,7]	Percentage UA patients that is signed up for an X-ergometry at discharge
Clinical	***Remainder***	Major bleeds[2]	Percentage UA patients that have major bleedings during hospitalization
Service	***Remainder***	Patient satisfaction about pathway	
Team	***Invasive strategy***	Trained HCK team	
Team	***Invasive strategy***	Equal contribution from HCK team members	
Team	***Remainder***	Effectiveness of team[8]	The effectiveness of a multidisciplinary team based on Fry's theory of focusing on shared goals, clear role definitions, clear procedures and, finally good team relationships, also noted as the Leuven Team effectiveness Scale.
Process	***Initial evaluation***	ECG done within 10 minutes (%)[2,4]	Percentage of UA patients, where an ECG is done within 10 minutes after arrival at the hospital or in the Ambulance to the hospital
Process	***Diagnosis validation and risk assessment***	GRACE-score documented in EPR (%)[1,2,7]	Percentage UA patients where the GRACE-score is documented in the EPR
Process	***Diagnosis validation and risk assessment***	Diagnosis and Risk assessment on basis of clinical history, physical examination, ECG and biomarkers? (%)[2, 3,7]	
Process	***Invasive strategy***	Treatment decision on basis of risk assessment (i.e. GRACE-score)[3,6] Should be ≥90% according to (VMS Veiligheidsprogramma, 2010)	
Process	***Invasive strategy***	CAG scheduled within time frame of treatment decision[7]	
Process	***Revascularisation modules***	Door-to-needle time	Time between arrival of the patient at the hospital and the moment the PCI is conducted. Only for patients that are treated with emergency!
Process	***Discharge***	Discharge from 7 West	Percentage of patient that is discharge from 7 West and hasn't had a CABG Percentage of patient that is discharge from CCU and hasn't had a CABG
Process	***Remainder***	Throughput times	
Process	***Remainder***	Cardiologist seen on day 1 (%)[3]	Percentage of patients that see a cardiologist on the First day of their hospitalization
Financial	***Discharge***	DOT properly checked	

Table 27 – Performance indicators for the CP of Unstable Angina (UA), with the following sources: [1]CZE protocol ACS (see Appendix I), [2]ESC guidelines (Hamm, et al., 2011), [3] (Grech & Ramsdale, 2003), [4] (Grimm & Maisch, 2006), [5]Meetbaar Beter Boek (van Veghel, van den Bosch, Dekker, & Tonino, 2012), [6] (VMS Veiligheidsprogramma, 2010), [7] (Peeters, 2013) and [8] (Vanhaecht & Sermeus, 2003)

APPENDIX F – PERSPECTIVES

Perspectives / Diagrams	EHH nurse	CCU / 7west nurse	Cardiologist	HCK team	6west nurse	Nurse Practitioner / physician / CTC surgeon in training	CTC Surgeon	Anaesthetist
0. CP UA @ CHE (Top Level)	x	x	x	x	x	X	x	x
1.1 Initial evaluation	x		x					
1.1.1 Give nitrates	x							
1.2 Diagnosis validation and risk assessment			x					
1.2 Diagnosis validation and risk assessment [EHH]	x							
1.2 Diagnosis validation and risk assessment [CCU/7west]		x						
1.2.1 Take ECG	x	x						
1.2.2 Give medicine (ACS-NSTEMI)	x	x	x					
1.2.3 CK/CKmb measuring		x	x					
1.3 Invasive strategy	x	x	x	x				
1.3.1 Perform CAG				x				
1.4 Revascularization modalities		x	x	x	x	x	x	x
1.4.1 Prepare and conduct PCI		x		x				
1.4.2 Prepare, await and hold Heartteam meeting		x	x				x	
1.4.3. Await and conduct screening + intake CABG [Cardio]		x	x					
1.4.3. Await and conduct screening + intake CABG [CTC]					x	x	x	x
1.4.3.1 Screening + intake						x	x	
1.4.4 Await CABG					x	x	x	x
1.4.3.1 Give medicine (ACS-NSTEMI-CABG)					x	x	x	x
1.4.5 Prepare acute CABG		x					x	x
1.4.6 Perform CABG							x	x
1.5 Hospital discharge		x	x		x	x	x	x
1.5.1 Nurse and mobilize patient (at Cardio)		x	x					
1.5.2 Discharge patient (at Cardio)		x	x					
1.5.3 Provide post operative care								x
1.5.3.1 Give medicine (ACS-NSTEMI-postCABG)								x
1.5.3.2 Take ECG @ IC								x
1.5.4 Nurse and mobilize patient (at CTC)					x	x	x	
1.5.5 Discharge patient (at CTC)					x	x	x	

Table 28 – Overview of all diagrams of the model and the involved perspectives. Note that the diagrams of the sub processes are only stated once (at the moment they are called up first)

APPENDIX G – BPMN 2.0 ELEMENTS AND MEANING

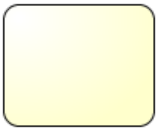
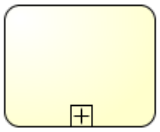
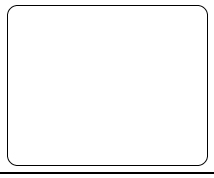
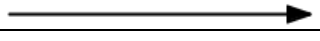
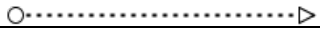
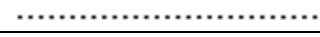
Events			
	Start event		End event
	The process will be started when a message is received.		The process ends after a message has been send.
	The process is started with the escalation of it to another role in the organization.		This event activates the escalation of the process to another role within the organization, after which the process proceeds.
	The process waits until a message is received and progress afterwards.		A message will be send, after which the process proceeds.
	The process waits until a certain time has passed or until a certain moment in time before it continuous.		The process waits until a certain condition is met before proceeding.
	This symbol is always attached to the boundary of a *collapsed sub process* and 'catches' the error that has been 'thrown' within the sub process after which the process continuous with the flow connected to the error-symbol.		The process ends in an error-state, as a result from a 'thrown' error.
	The process waits until a certain signal is received before it proceeds.		A signal will be send, after which the process will proceed.
	Off-page catching event, whereby two corresponding events form a sequence flow.		Off-page throwing event, whereby two corresponding events form a sequence flow.
Activities		**Gateways**	
	A task is a unit of work.		An AND split or join, whereby all outgoing flows will be activated, or the process will wait until all incoming flows have arrived.
	Is a 'collapsed sub process' (an activity that can be split) of which the activities are visual in the diagram of the sub process.		A XOR split or join, whereby one of the outgoing flows will be activated based on their condition. Or whereby the process continuous after one of the incoming flows has been activated.
	Is a 'expanded sub process' wherein the sub process is directly visual.		An INCLUSIVE join, whereby the process waits until all activated incoming flows have been completed.
Associations			An EVENT-BASED split, whereby the process proceeds with the flow belonging to the first arriving message/signal.
	Sequence flow		
	Message flow		
	association		

Table 29 – BPMN 2.0 elements and meaning

APPENDIX H – CHECKLISTS

Number	Owner	Question
IE1	Cardiologist	Patient attached to the monitor?
IE2	Cardiologist	Is the ECG made?
IE3	Cardiologist	Has the patient ST-segment evaluation, new LBTB and/or rear infarction? *If yes, the patient needs to switch to the STEMI protocol.*
IE4	Cardiologist	Is a blood test ordered?
IE5	Cardiologist	Clinical status evaluated (anamnesis, physical examination and patients' history)? Important here is also to check on the present of different comorbidities, like heart failure, renal failure, DM and COPD.
IE6	Cardiologist	Is the working diagnosis NSTEMI/UA? *If not, withdraw patient from pathway.*
IE7	Cardiologist	GRACE score calculated?
IE8	Cardiologist	ECG deviation different than for STEMI and typical ACS? *If not, continue to **DV01**. If yes, continue to **RA1**.*

Table 30 – Checklist belonging to the Initial Evaluation phase

Number	Owner	Questions
DV01	Cardiologist	Is the hsTnT-level ≥30ng/L? *If yes, then continue to **DV02**, otherwise to **DV31**.*
DV02	Cardiologist	Patient has typical ACS? *If yes, continue to **RA1**, otherwise to **DV31**.*
DV31	Cardiologist	Is the ECG made at T=3hrs?
DV32	Cardiologist	Has the patient ST-segment evaluation, new LBTB and/or rear infarction? *If yes, the patient needs to switch to the STEMI protocol.*
DV33	Cardiologist	Is a blood test ordered at T=3hrs?
DV34	Cardiologist	Is $\Delta_{T=0hr,T=3hrs}$hsTnT ≥8ng/L? *If not, continue with question **DV37**.*
DV35	Cardiologist	Was the hsTnT-level at T=0hrs ≥30ng/L? *If yes, continue with **RA1**.*
DV36	Cardiologist	Is the hsTnT-level at T=3hrs > 30ng/L? *If yes continue with **RA1**. If not, continue with **DV61**.*
DV37	Cardiologist	Is an echocardiogram considered? *If not, the patient is withdrawn from pathways.*
DV38	Cardiologist	Is the exercise ECG positive for NSTEMI–UA? *If yes, continue with **RA1**. In no, the patient is withdrawn from the pathway.*
DV61	Cardiologist	Is the ECG made at T=6hrs?
DV62	Cardiologist	Has the patient ST-segment evaluation, new LBTB and/or rear infarction? *If yes, the patient needs to switch to the STEMI protocol.*
DV63	Cardiologist	Is a blood test ordered at T=6hrs?
DV64	Cardiologist	Is the hsTnT-level at T=3hrs > 30ng/L? *If yes continue with **RA1**.*
DV65	Cardiologist	Is an echocardiogram considered? *If not, the patient is withdrawn from pathways.*
DV66	Cardiologist	Is the exercise ECG positive for NSTEMI–UA? *If yes, continue with **RA1**. In no, the patient is withdrawn from the pathway.*
RA1	Cardiologist	Are the medication prescribed and given?
RA2	Cardiologist	In case the patient has renal failure, is enoxaparine prescribed instead of fondaparinux? [Only show if renal failure has been indicated as a comorbidity or if ClCr < 30mL.min]
RA3	Cardiologist	In case the patient is allergic to ticagrelor, has clopidogrel been prescribed instead?
RA4	Cardiologist	In case the CKmb/CK levels are not decreasing yet, is it noted that this needs to be measured again after 8hrs?
RA5	Cardiologist	Has the patient Refractory symptoms, hemodynamically instable, associate heart failure and/or ventricular tachyarrhythmia? *If not, continue with **RA7**.*
RA6	Cardiologist	Has patient been assigned to an urgent invasive treatment? (i.e. CAG needs to be performed within 120minutes) *If yes, continue with **IS1**. If not, patient will be withdrawn from the pathway.*
RA7	Cardiologist	Are any primary risk factors identified? (increased troponin, dynamical ECG changes) *If yes, continue with **RA10**.*
RA8	Cardiologist	Are any secondary risk factors identified? (DM, GFR<60, LVEF<40%, post-infarct AP, prior CABG or PCI, intermediate GRACE score) *If yes, continue with **RA13**.*
RA9	Cardiologist	GRACE score > 140? *If not, continue with **RA11**.*
RA10	Cardiologist	Has patient been assigned to an early invasive treatment? (i.e. CAG needs to be performed within 24hrs) *If yes, continue with **IS1**. If not, patient will be withdrawn from the pathway.*
RA11	Cardiologist	GRACE score >108? *If yes, continue with **RA13**.*
RA12	Cardiologist	Has patient been assigned to a conservative treatment? (i.e. patient will be treated with medicines) *If yes, continue with **HD1**.*
RA13	Cardiologist	Has patient been assigned to an invasive treatment? (i.e. CAG needs to be performed within 72hrs) *If yes, continue with **IS1**. If not, patient will be withdrawn from the pathway.*

Table 31 – Checklists belonging to the Diagnosis validation and risk assessment phase

Number	Owner	Questions
IS1	HCK	Is the CAG scheduled within the correct timeframe?
IS2	CCU /7west Nurse	Has the "contract nefropathie protocol" been initiated? [only for patients with GFR>60ml/min and assigned to an (early) invasive treatment]
IS3	CCU /7west Nurse or HCK	Has the patient been changed into theater clothing?
IS4	HCK	Is 5000units of UFH been given?
IS5	HCK	Has the groins been sterilize and anaesthetize?
IS6	HCK	Are the results of the CAG documented? *In case a PCI is conducted directly afterwards continue with* ***PCI1****.*
IS7	HCK	Is the further treatment plan documented? [only in case no PCI is conducted directly afterwards] *continue with either* ***HT1*** *or* ***HDC1****.*

Table 32 – Checklists belonging to the Invasive strategy phase

Number	Owner	Questions
PCI1	CCU /7west Nurse	Has the patient been changed into theater clothing? [only in case of a prior Heart team meeting]
PCI2	HCK	Is 5000units of UFH been given? [only in case of a prior Heart team meeting]
PCI3	HCK	Has the groins been sterilize and anaesthetize? [only in case of a prior Heart team meeting]
PCI4	HCK	Are the results of the PCI documented?
PCI5	HCK	Is the further treatment plan documented? *Continue with either* ***HDC1*** *or* ***HT1.***

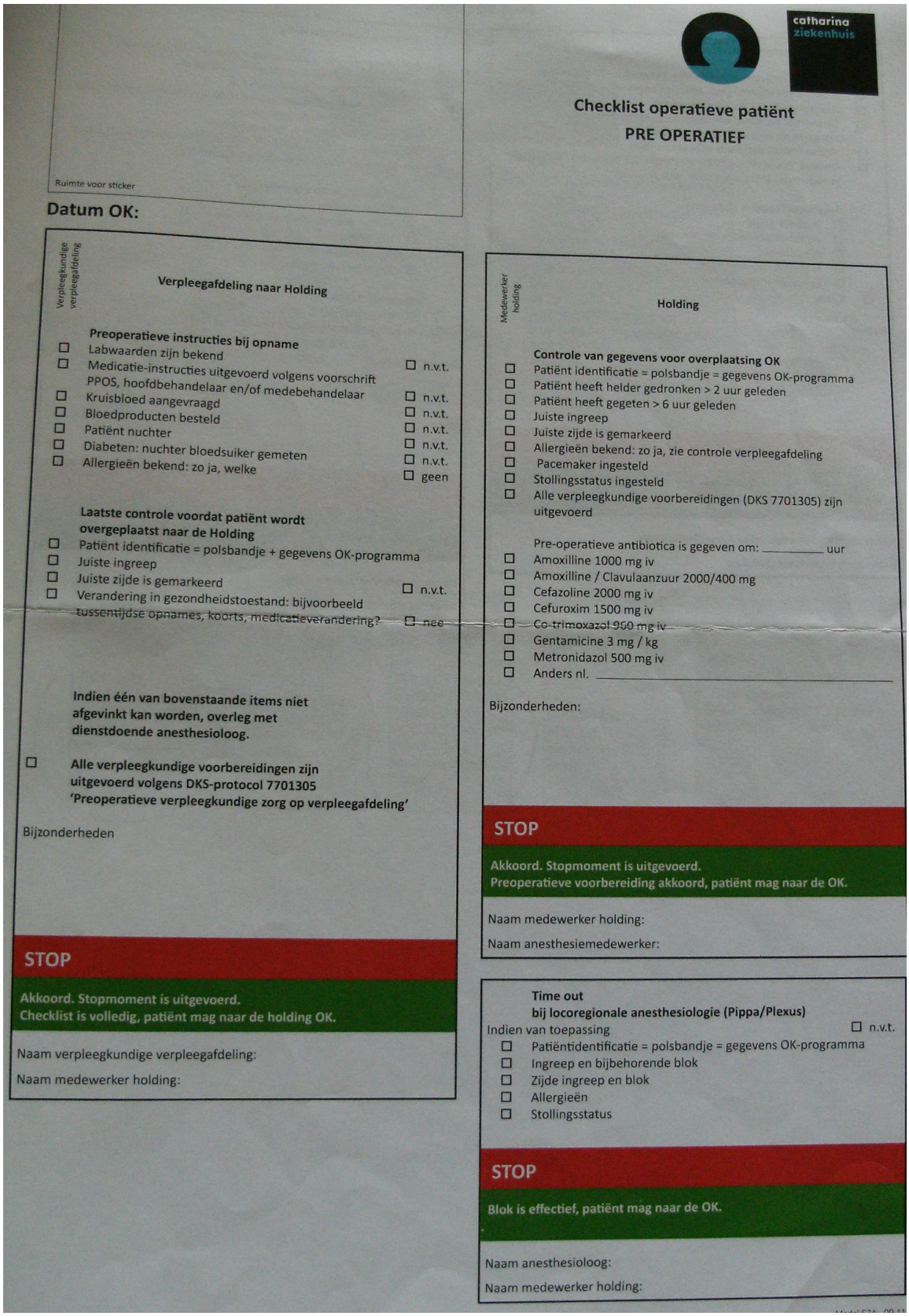
Table 33 – Checklist belonging to the PCI path of the Revascularization modalities phase

Number	Owner	Questions
HT1	CCU /7west Nurse and CTC secretariat	Is an echocardiogram present?
HT2	CCU /7west Nurse and CTC secretariat	Are the results of the ICC Jaw back? [only in case of an additional operation on the valves]
HT3	CCU /7west Nurse and CTC secretariat	Are the results of the ICC ENT back? [only in case of an additional operation on the valves]
HT4	CCU /7west Nurse and CTC secretariat	Are the results of the CT-scan back? [only in case of an additional operation on the aorta]
HT5	CTC secretariat	Has the patient been signed up for the heart team meeting?
HT6	Heart team	Is the report of the meeting been recorded?
HT7	Heart team	Has the EuroSCORE been filled in?
HT8	Heart team	Is the further treatment plan documented?
HT9	Heart team	Has the CTC secretariat been informed to put the patient on the 'klinische wachtlijst'? [only in case of an elective or urgent CABG operation]
HT10	Heart team	Has the CTC and CCU departments been informed to start the preparation of an emergency CABG right away? [only in case of an emergency CABG operation]
HT11	Heart team	Has the HCK been informed to schedule a PCU after all? [only in case of an PCI]

Table 34 – Checklist belonging to the Heart team meeting path of the Revascularization modalities phase

Number	Owner	Questions
CABG1	Intervention cardiologist / NP	P2Y12 inhibitors discontinued? *Note that it is possible to continue the checklist if the answer here is no.*
CABG2	NP	MRSA treatment started/continued? [only in case MRSA is present]
CABG3	Nurse and NP	ECG made?
CABG4	Nurse and NP	Blood test conducted?
CABG5	NP	Clinical status evaluated (anamnesis, physical examination and patients' history)? Important here is to note comorbidities and the present of a pacemaker.
CABG6	NP	Has the GIK schema been initiated? [only in case of present DM]
CABG7	NP	Are the results of the ICC Internist back? [only in case of present DM]
CABG8	NP	Are the results of the ICC Pulmonologist back? [only in case of present COPD≥3]
CABG9	NP	Gathered information recorded in EZIS?
CABG10	NP	EuroSCORE updated?
CABG11	NP	Proceed according to pathway? [only in case EuroSCORE ≥ 10] *if not, withdrawal patient from pathway.*
CABG12	Nurse	Information DVD showed and guided tour given?
CABG13	surgeon in training / CTC physician	Information about operation provided and risks discussed?
CABG14	surgeon in training / CTC physician	Informed consent for operation?
CABG15	surgeon in training / CTC physician	CPR policy recorded?
CABG16	surgeon in training / CTC physician	Any medical objections for the operation? *If yes, continue with **CABG16**, otherwise with **CABG17**.*
CABG17	surgeon in training / CTC physician	Proceed according to pathway?
CABG18	Anaesthetist	Information about operation provided?
CABG19	Anaesthetist	Indication given for PACU or HC post operative treatment?
CABG20	Anaesthetist	Pre medication prescribed?
CABG21	Anaesthetist	Any medical objection? *In case of prolonged objection withdraw patient.*
CABG22	Secretary	IS NEC procedure completed?
CABG23	Secretary	Are the X-ray results back?
CABG24	NP	Looked at X-ray results?
CABG25	NP	EuroSCORE updated?
CABG26	NP	Proceed according to pathway? [only in case EuroSCORE ≥ 10] *If not, withdrawal patient from pathway. If yes, continue with **CABG30**.*
CABG27	NP	Any medical objections for the operation? *If not continue with **CABG30**.*
CABG28	NP	Proceed according to pathway? *If not, withdrawal patient from pathway. If yes, continue with **CABG30**.*
CABG29	NP	Hibiscrub and mupirocine prescribed?
CABG30	CTC surgeon	Introduced to patient? *If yes, continue with "checklist operatieve patient"* (see Appendix H – Figure 18)

Table 35 – Checklist belonging to the CABG path of the Revascularization modalities phase



catharina ziekenhuis

Checklist operatieve patiënt
PRE OPERATIEF

Ruimte voor sticker

Datum OK:

Verpleegkundige verpleegafdeling

Verpleegafdeling naar Holding

Preoperatieve instructies bij opname
- ☐ Labwaarden zijn bekend
- ☐ Medicatie-instructies uitgevoerd volgens voorschrift PPOS, hoofdbehandelaar en/of medebehandelaar ☐ n.v.t.
- ☐ Kruisbloed aangevraagd ☐ n.v.t.
- ☐ Bloedproducten besteld ☐ n.v.t.
- ☐ Patiënt nuchter ☐ n.v.t.
- ☐ Diabeten: nuchter bloedsuiker gemeten ☐ n.v.t.
- ☐ Allergieën bekend: zo ja, welke ☐ n.v.t.
  ☐ geen

Laatste controle voordat patiënt wordt overgeplaatst naar de Holding
- ☐ Patiënt identificatie = polsbandje + gegevens OK-programma
- ☐ Juiste ingreep
- ☐ Juiste zijde is gemarkeerd ☐ n.v.t.
- ☐ Verandering in gezondheidstoestand: bijvoorbeeld tussentijdse opnames, koorts, medicatieverandering? ☐ nee

Indien één van bovenstaande items niet afgevinkt kan worden, overleg met dienstdoende anesthesioloog.

☐ **Alle verpleegkundige voorbereidingen zijn uitgevoerd volgens DKS-protocol 7701305 'Preoperatieve verpleegkundige zorg op verpleegafdeling'**

Bijzonderheden

STOP

Akkoord. Stopmoment is uitgevoerd.
Checklist is volledig, patiënt mag naar de holding OK.

Naam verpleegkundige verpleegafdeling:

Naam medewerker holding:

Medewerker holding

Holding

Controle van gegevens voor overplaatsing OK
- ☐ Patiënt identificatie = polsbandje = gegevens OK-programma
- ☐ Patiënt heeft helder gedronken > 2 uur geleden
- ☐ Patiënt heeft gegeten > 6 uur geleden
- ☐ Juiste ingreep
- ☐ Juiste zijde is gemarkeerd
- ☐ Allergieën bekend: zo ja, zie controle verpleegafdeling
- ☐ Pacemaker ingesteld
- ☐ Stollingsstatus ingesteld
- ☐ Alle verpleegkundige voorbereidingen (DKS 7701305) zijn uitgevoerd

Pre-operatieve antibiotica is gegeven om: _____ uur
- ☐ Amoxilline 1000 mg iv
- ☐ Amoxilline / Clavulaanzuur 2000/400 mg
- ☐ Cefazoline 2000 mg iv
- ☐ Cefuroxim 1500 mg iv
- ☐ Co-trimoxazol 960 mg iv
- ☐ Gentamicine 3 mg / kg
- ☐ Metronidazol 500 mg iv
- ☐ Anders nl. _____

Bijzonderheden:

STOP

Akkoord. Stopmoment is uitgevoerd.
Preoperatieve voorbereiding akkoord, patiënt mag naar de OK.

Naam medewerker holding:

Naam anesthesiemedewerker:

Time out
bij locoregionale anesthesiologie (Pippa/Plexus)

Indien van toepassing ☐ n.v.t.
- ☐ Patiëntidentificatie = polsbandje = gegevens OK-programma
- ☐ Ingreep en bijbehorende blok
- ☐ Zijde ingreep en blok
- ☐ Allergieën
- ☐ Stollingsstatus

STOP

Blok is effectief, patiënt mag naar de OK.

Naam anesthesioloog:

Naam medewerker holding:

Figure 18 – Checklist operatieve patient - PRE OPERATIEF of the Catharina Hospital Eindhoven

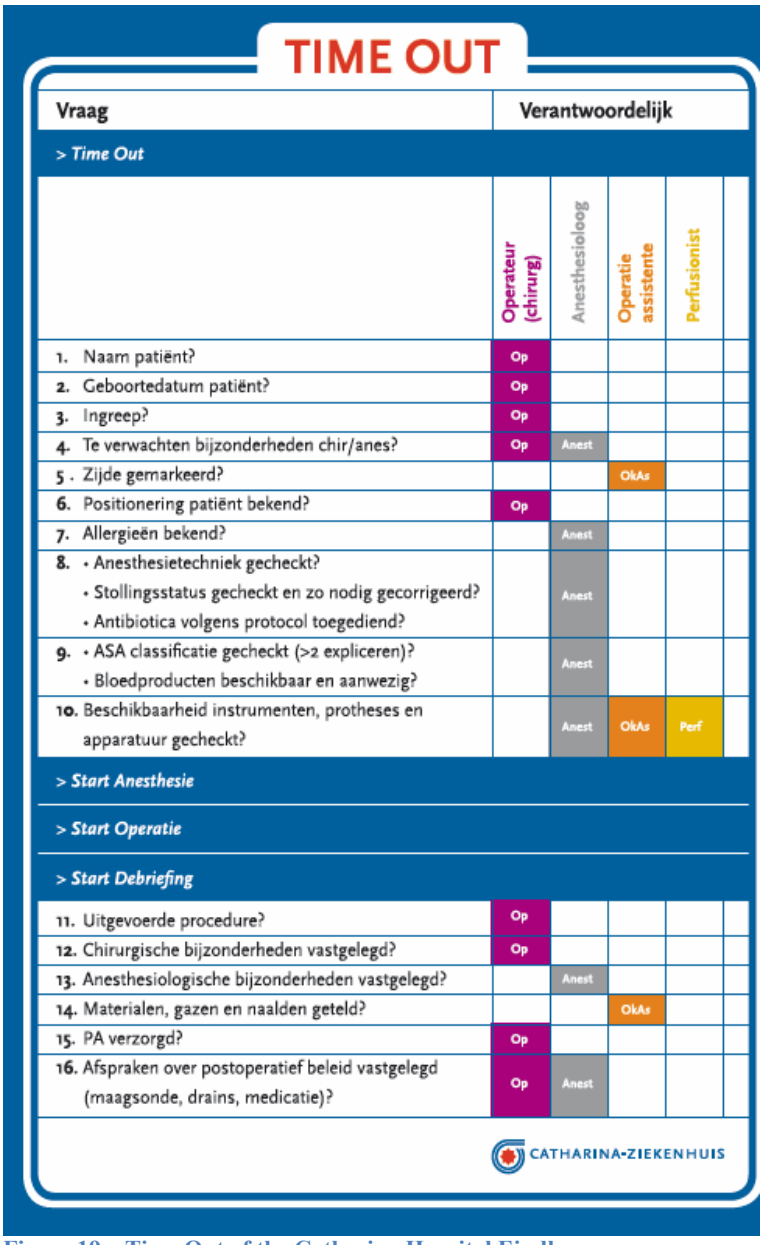
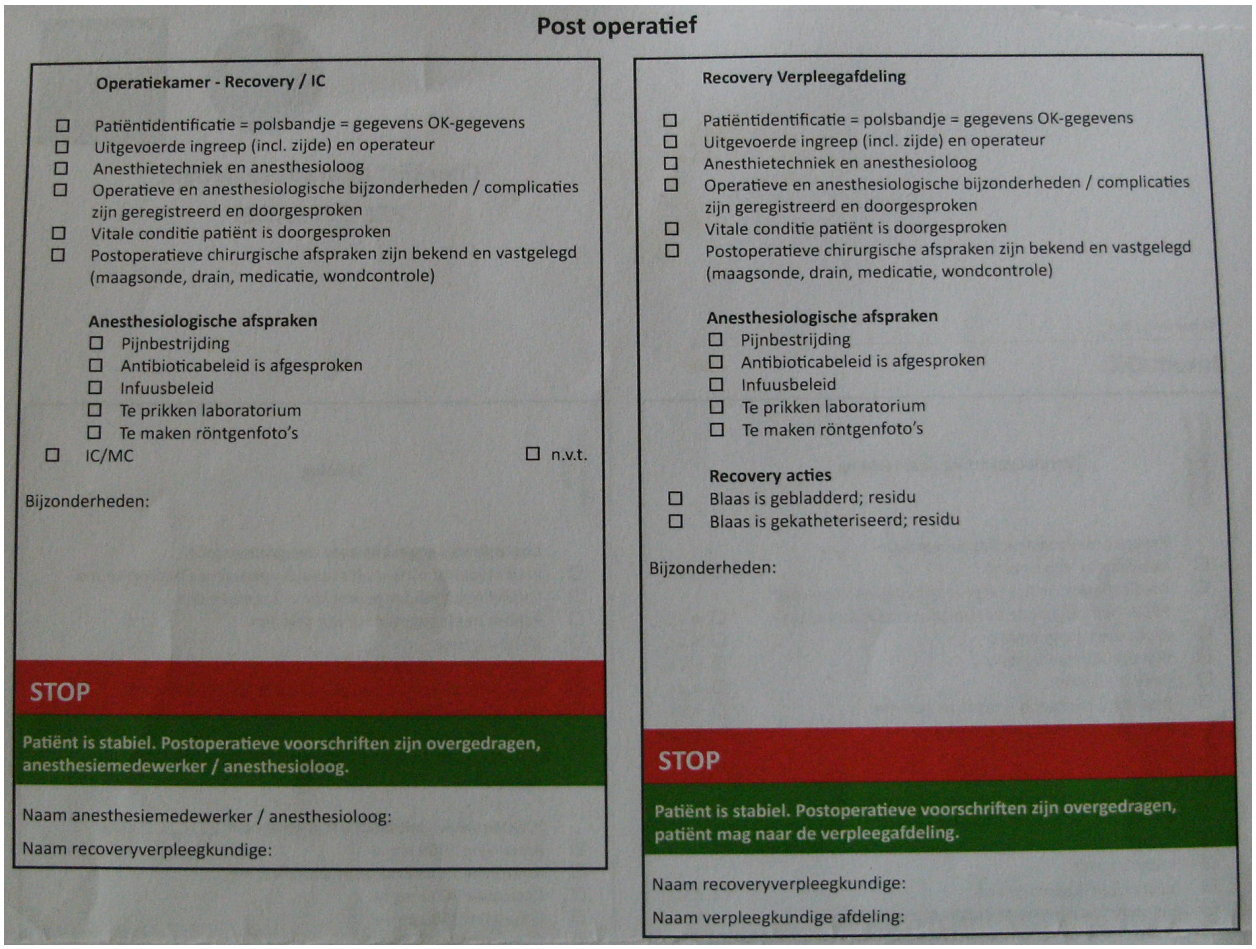


Figure 19 – Time Out of the Catharina Hospital Eindhoven



Post operatief

Operatiekamer - Recovery / IC

- ☐ Patiëntidentificatie = polsbandje = gegevens OK-gegevens
- ☐ Uitgevoerde ingreep (incl. zijde) en operateur
- ☐ Anesthietechniek en anesthesioloog
- ☐ Operatieve en anesthesiologische bijzonderheden / complicaties zijn geregistreerd en doorgesproken
- ☐ Vitale conditie patiënt is doorgesproken
- ☐ Postoperatieve chirurgische afspraken zijn bekend en vastgelegd (maagsonde, drain, medicatie, wondcontrole)

Anesthesiologische afspraken

- ☐ Pijnbestrijding
- ☐ Antibioticabeleid is afgesproken
- ☐ Infuusbeleid
- ☐ Te prikken laboratorium
- ☐ Te maken röntgenfoto's

☐ IC/MC ☐ n.v.t.

Bijzonderheden:

STOP

Patiënt is stabiel. Postoperatieve voorschriften zijn overgedragen, anesthesiemedewerker / anesthesioloog.

Naam anesthesiemedewerker / anesthesioloog:

Naam recoveryverpleegkundige:

Recovery Verpleegafdeling

- ☐ Patiëntidentificatie = polsbandje = gegevens OK-gegevens
- ☐ Uitgevoerde ingreep (incl. zijde) en operateur
- ☐ Anesthietechniek en anesthesioloog
- ☐ Operatieve en anesthesiologische bijzonderheden / complicaties zijn geregistreerd en doorgesproken
- ☐ Vitale conditie patiënt is doorgesproken
- ☐ Postoperatieve chirurgische afspraken zijn bekend en vastgelegd (maagsonde, drain, medicatie, wondcontrole)

Anesthesiologische afspraken

- ☐ Pijnbestrijding
- ☐ Antibioticabeleid is afgesproken
- ☐ Infuusbeleid
- ☐ Te prikken laboratorium
- ☐ Te maken röntgenfoto's

Recovery acties

- ☐ Blaas is gebladderd; residu
- ☐ Blaas is gekatheteriseerd; residu

Bijzonderheden:

STOP

Patiënt is stabiel. Postoperatieve voorschriften zijn overgedragen, patiënt mag naar de verpleegafdeling.

Naam recoveryverpleegkundige:

Naam verpleegkundige afdeling:

Figure 20 – Checklist operatieve patient – POST OPERATIEF of the Catharina Hospital Eindhoven

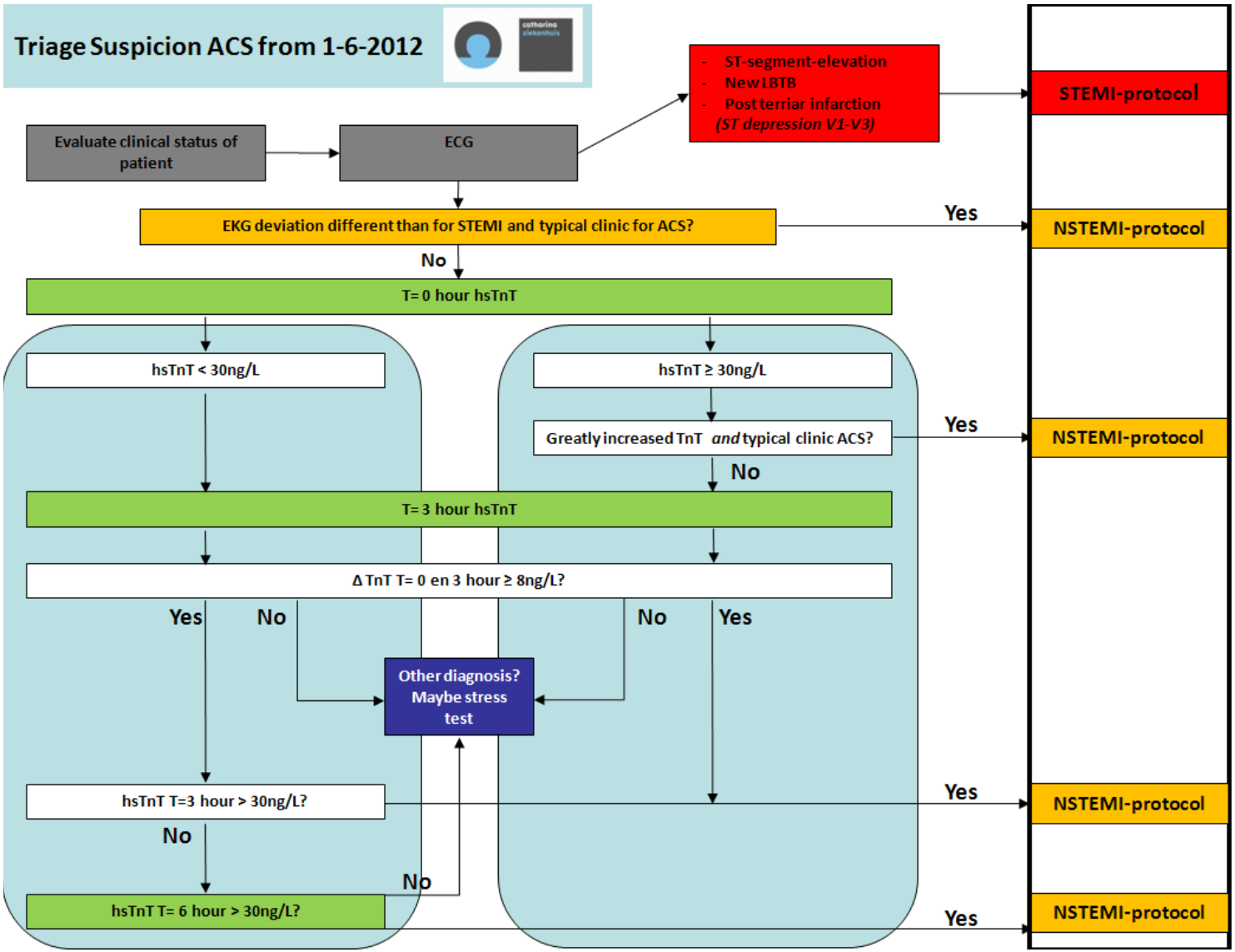
Number	Owner	Questions
HDC1	Nurse	Pre-discharge ECG made?
HDC2	Nurse	Life style advice given to the patient?
HDC3	Cardiologist	Patient signed up for rehabilitation program and the according X-ergometry?
HDC4	Cardiologist	Update letter for GP (and/or Cardiologist) made?
HDC5	Cardiologist	Control appointment made by cardiologist?
HDC6	Cardiologist	Golden 5 medicines prescribed?
HDC7	Cardiologist	Clopidogrel prescribed in case patient is allergic to ticagrelor?
HDC8	Cardiologist	Are one of the following criteria are applicable on the patient? above ≥65year, stomach bleeding or uclus of H. Pylori in vg, steroid and/or combined anticoagulantia. *If yes, continue with **HDC9** otherwise with **HDC10**.*
HDC9	Cardiologist	Is a proton pump inhibitor prescribed?
HDC10	Cardiologist	Is the GRACE score checked?
HDC11	Cardiologist	Is the DOT checked?

Table 36 – Checklist belonging to the discharge patient (at cardio) sub phase of the Hospital discharge phase

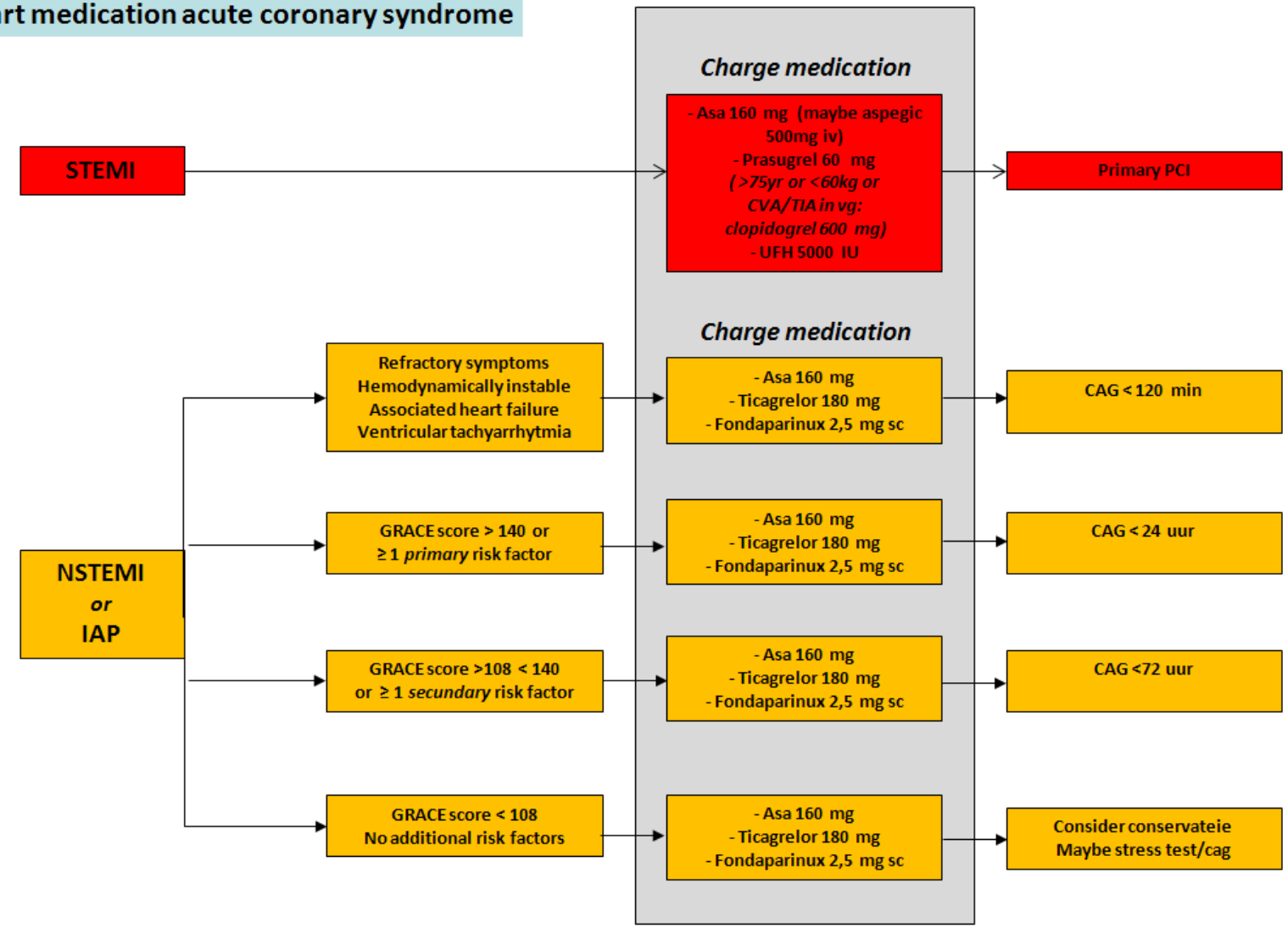
Number	Owner	Questions
HDCT1	NP / Physician	Pre-discharge ECG made and findings alright?
HDCT2	NP / Physician	Blood test "ontslag CABG blok" taken and findings alright?
HDCT3	NP / Physician	Update letter for GP (and/or Cardiologist) made?
HDCT4	NP / Physician	Quickview report recorded?
HDCT5	NP / Physician	OR report recorded?
HDCT6	NP / Physician	Survey hand over?
HDCT7	NP / Physician	Patient signed up for rehabilitation program and the according X-ergometry?
HDCT8	NP / Physician	Control appointment made by cardiologist?
HDCT9	NP / Physician	Control appointment made by cardiothoracic surgeon?
HDCT10	NP / Physician	Patient referred to intensive care for thrombotic patients? [only for patients that are prescribed an anticoagulation, like vitamin K antagonists]
HDCT11	NP / Physician	Echo cor + Doppler scheduled? [only for patients that had an operation on one of the valves]
HDCT12	NP / Physician	CT thorax scheduled? [only for patients that had an operation on the aorta]
HDCT13	NP / Physician	Echo Doppler scheduled? [only for patients that had an operation on the aorta]
HDCT14	NP / Physician	Golden 5 medicines prescribed?
HDCT15	NP / Physician	Clopidogrel prescribed in case patient is allergic to ticagrelor?
HDCT16	NP / Physician	Are one of the following criteria are applicable on the patient? above ≥65year, stomach bleeding or uclus of H. Pylori in vg, steroid and/or combined anticoagulantia. *If yes, continue with **HDCT17** otherwise with **HDCT18**.*
HDCT17	NP / Physician	Is a proton pump inhibitor prescribed?
HDCT18	NP / Physician	Is the DOT checked?
HDCT19	NP / Physician	Discharge letter made and hand over?

Table 37 – Checklist belonging to the discharge patient (at CTC) sub phase of the Hospital discharge phase

APPENDIX I – ACS PROTOCOL CATHARINA HOSPITAL EINDHOVEN



Start medication acute coronary syndrome



Important items acute coronary syndrome

- Deviation from these protocols is allowed, if motivated
- The GRACE score must be filled into the EPR for all NSTEMI/UA patients!
- Primary risk factors for ACS: Increased troponin/ dynamic ecg changes
- Secundary risk factors for ACS: DM/ GFR<60/ LVEF<40%/ post-infarct AP/ status after CABG or PCI/ interm. GRACE score.

- When using fondaparinux, keep kidney failure in mind: look at pharmacotherapeutic compass (alternative: enoxaparine)
- When discharging, think of:
    - ASA 1dd80mg, thienopyridine 12 months, statine, beta blocker, ACE inhibitor (of ATII).
    - Antacid (if ≥65jr, stomache bleeding or ulcus of H. pylori in vg, steroids, combined anticoagulantia)
    - Sign up heart rehab, pre rehab x-ergometry.
    - Outpatient echo cor (unless clinically necessary).
    - DOT

APPENDIX J – ORGANIZATION VIEW

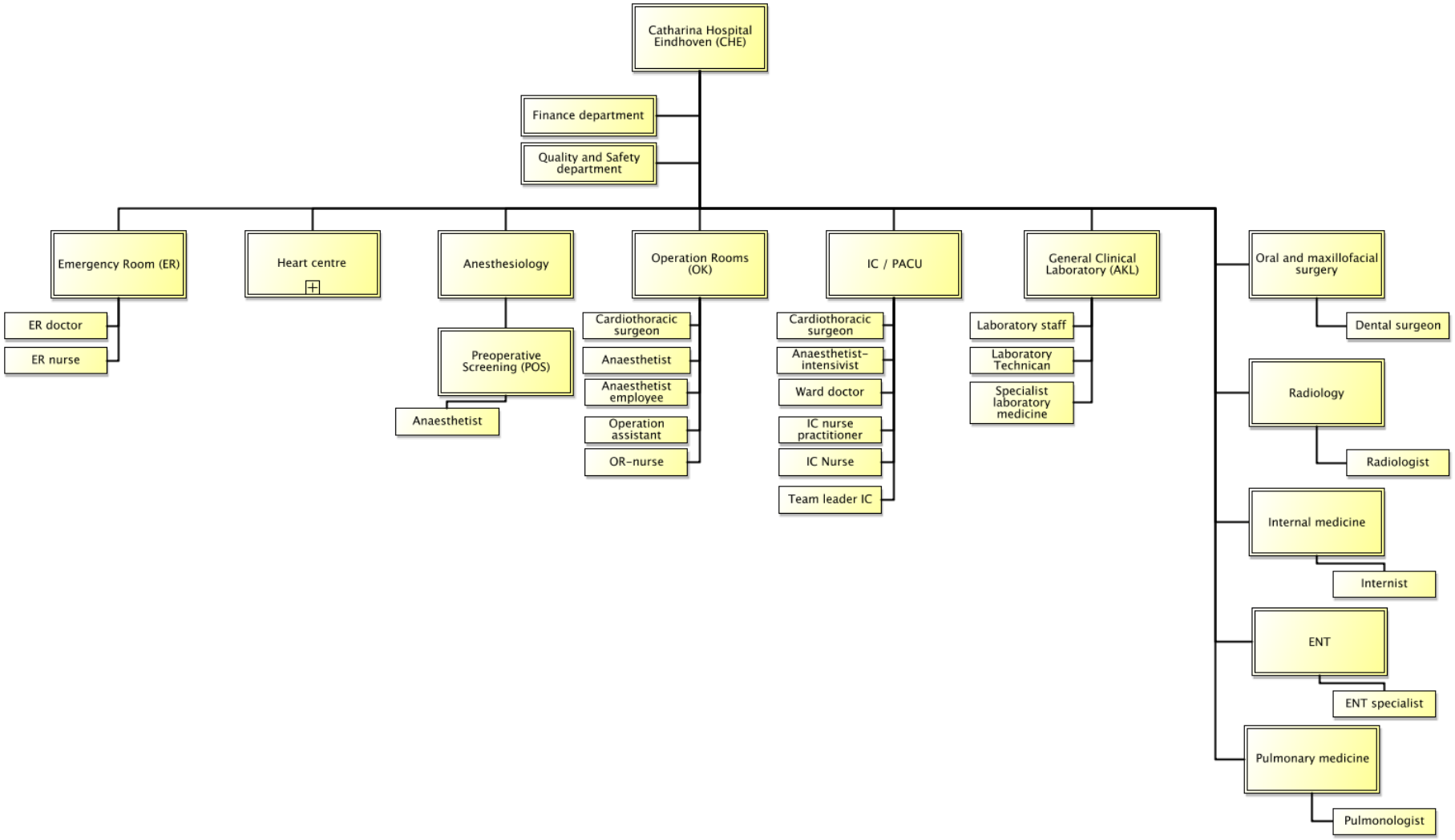


Figure 21 – Organization view of the Catharina Hospital Eindhoven (CHE)

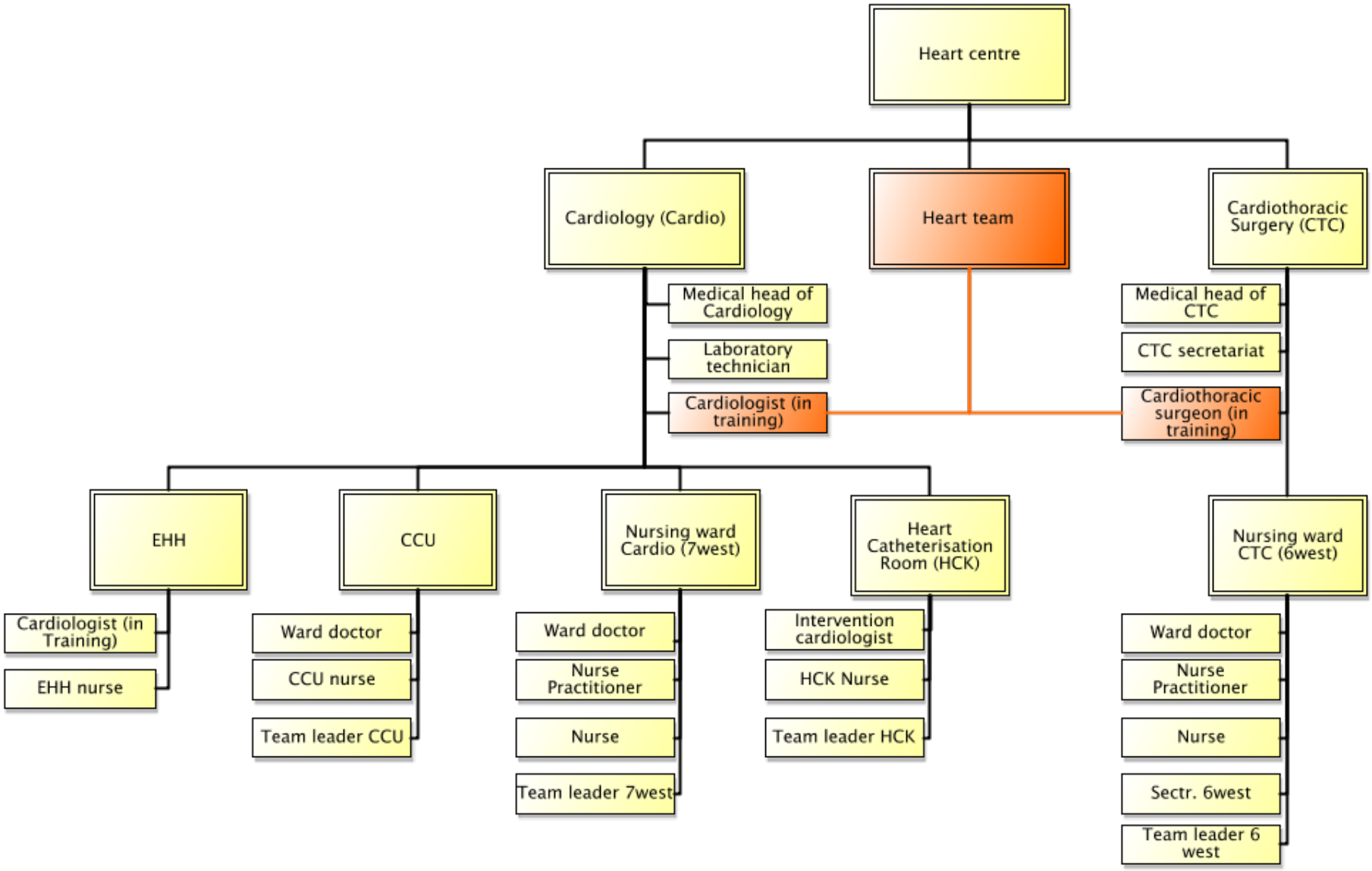


Figure 22 – Organization view of the Heart Centre of the Catharina Hospital Eindhoven (CHE)

APPENDIX K – BUSINESS VIEW

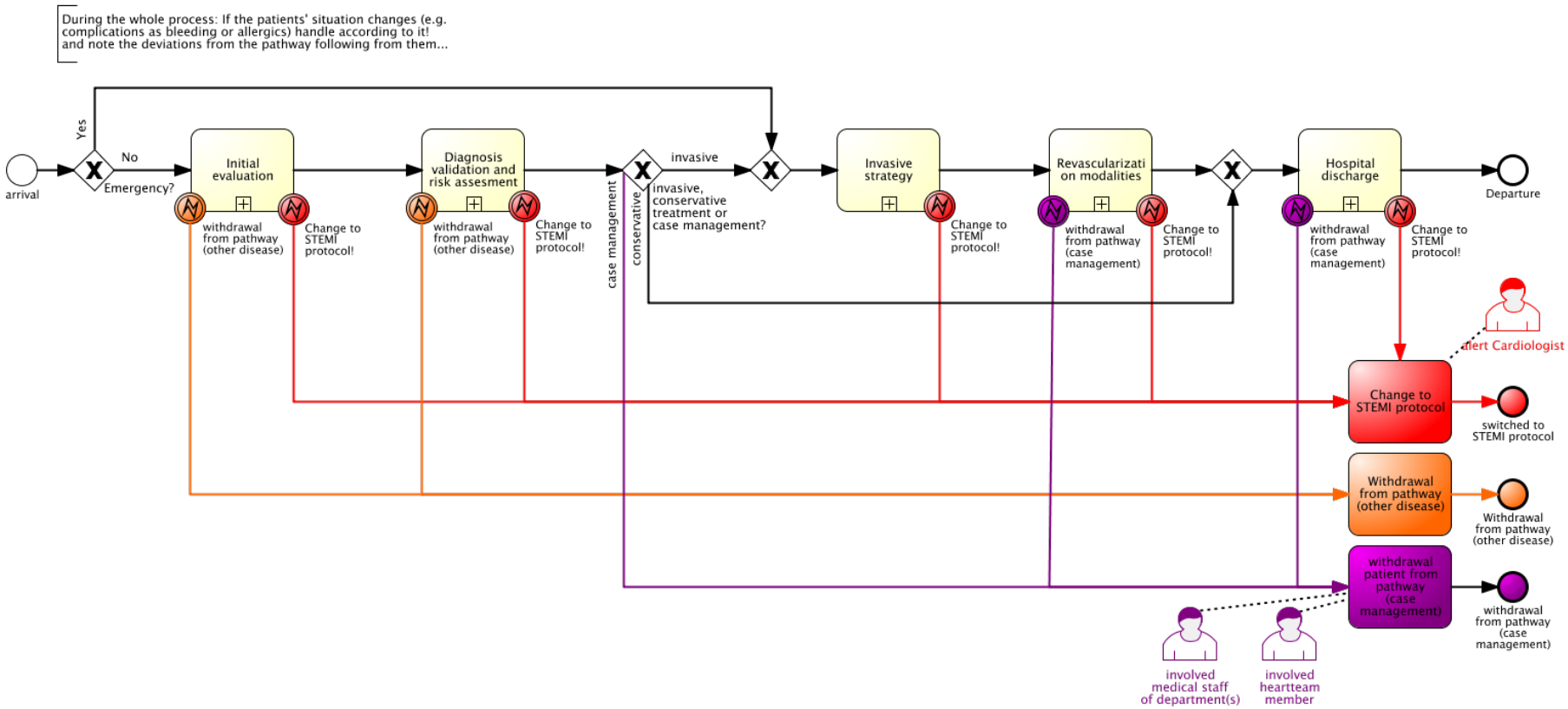


Figure 23 – Business view of the Top–Level CP UA @ CHE

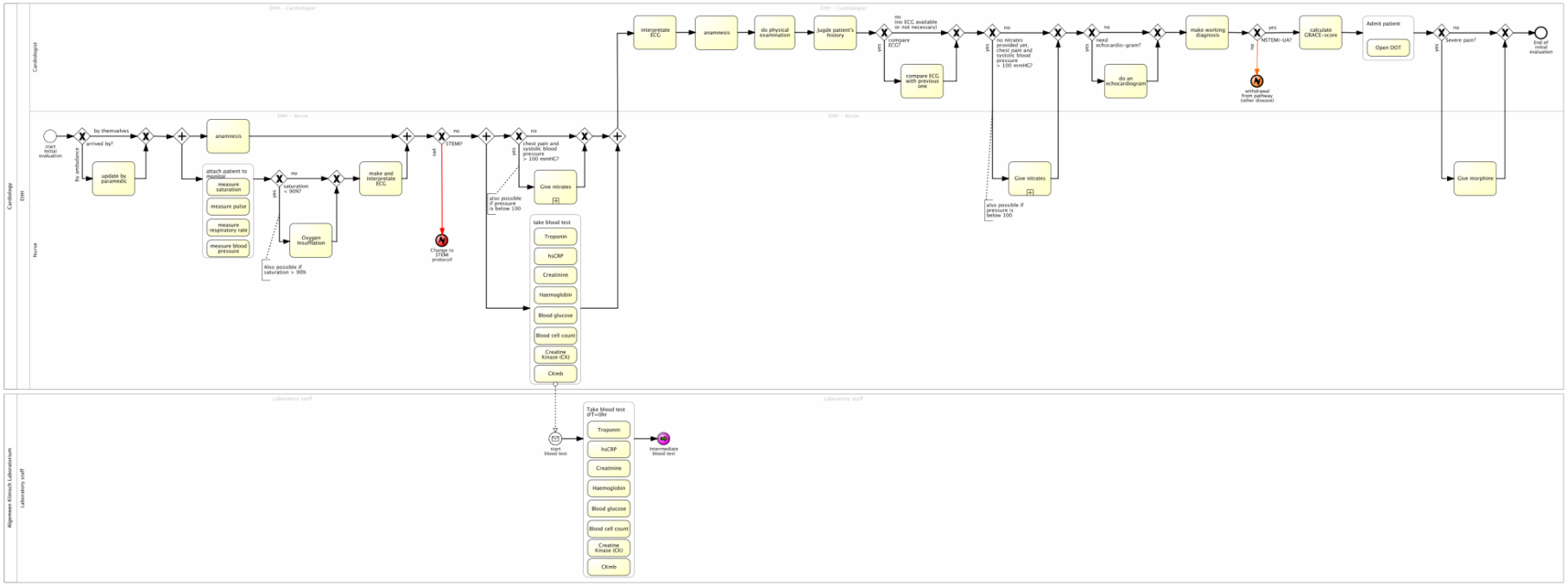


Figure 24 – Business view of the phase Initial Evaluation

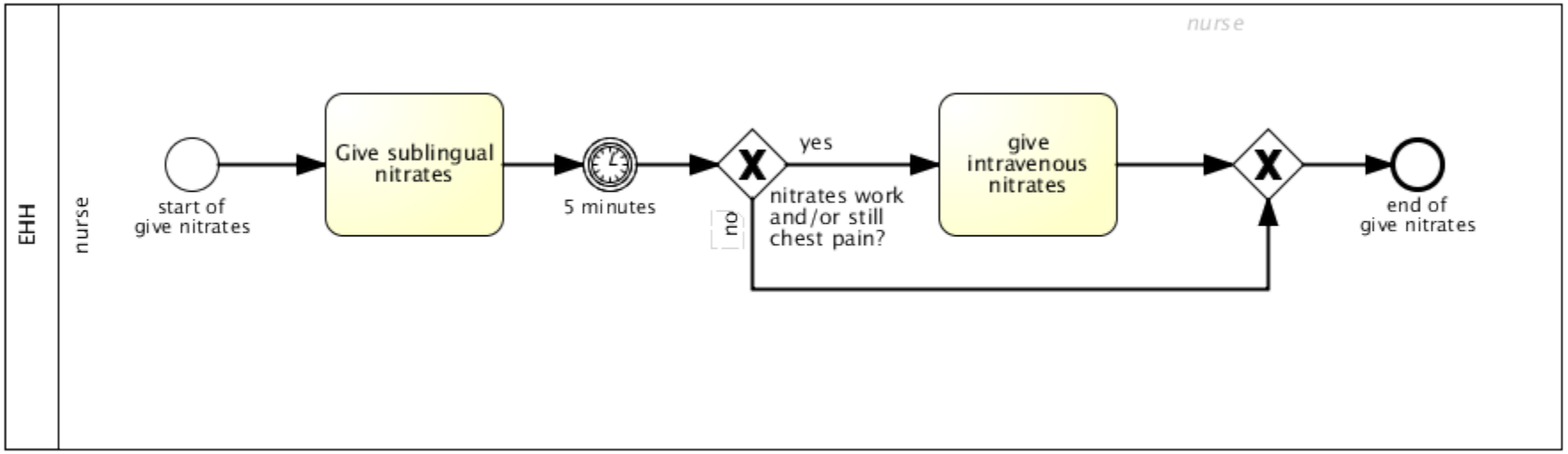


Figure 25 – Business view of the sub process Give Nitrates

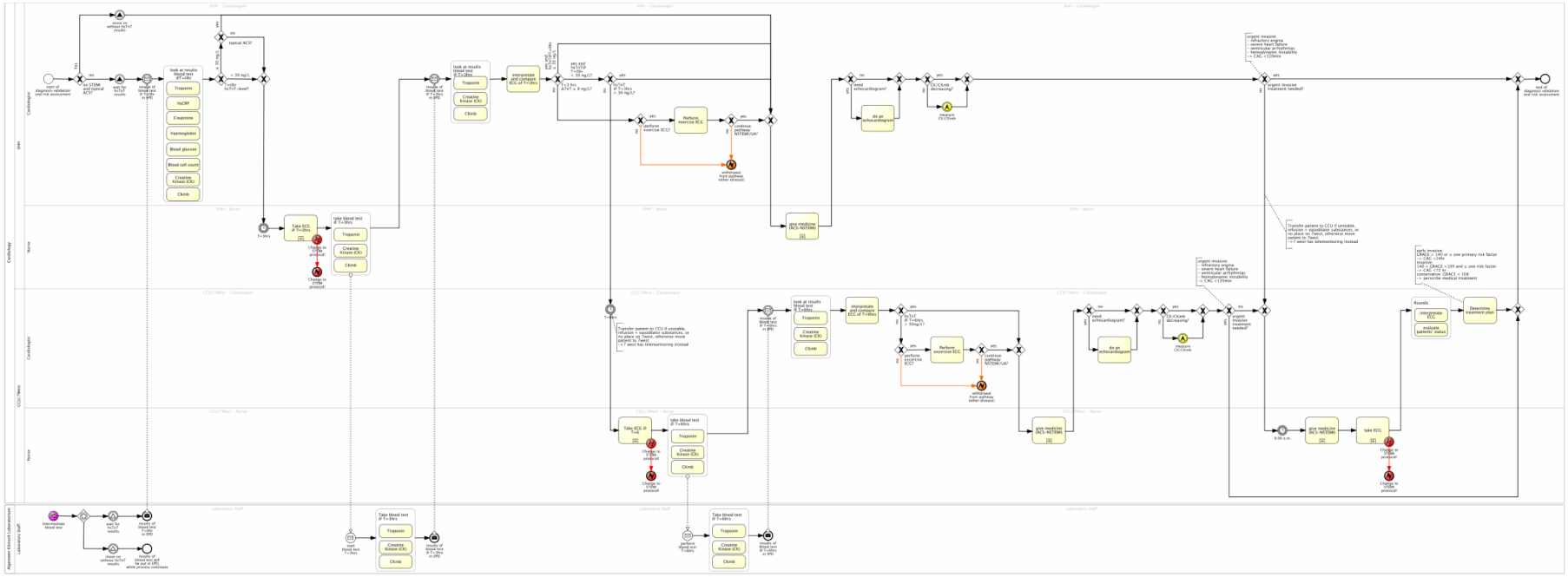


Figure 26 – Business view of the phase Diagnosis validation and risk assessment

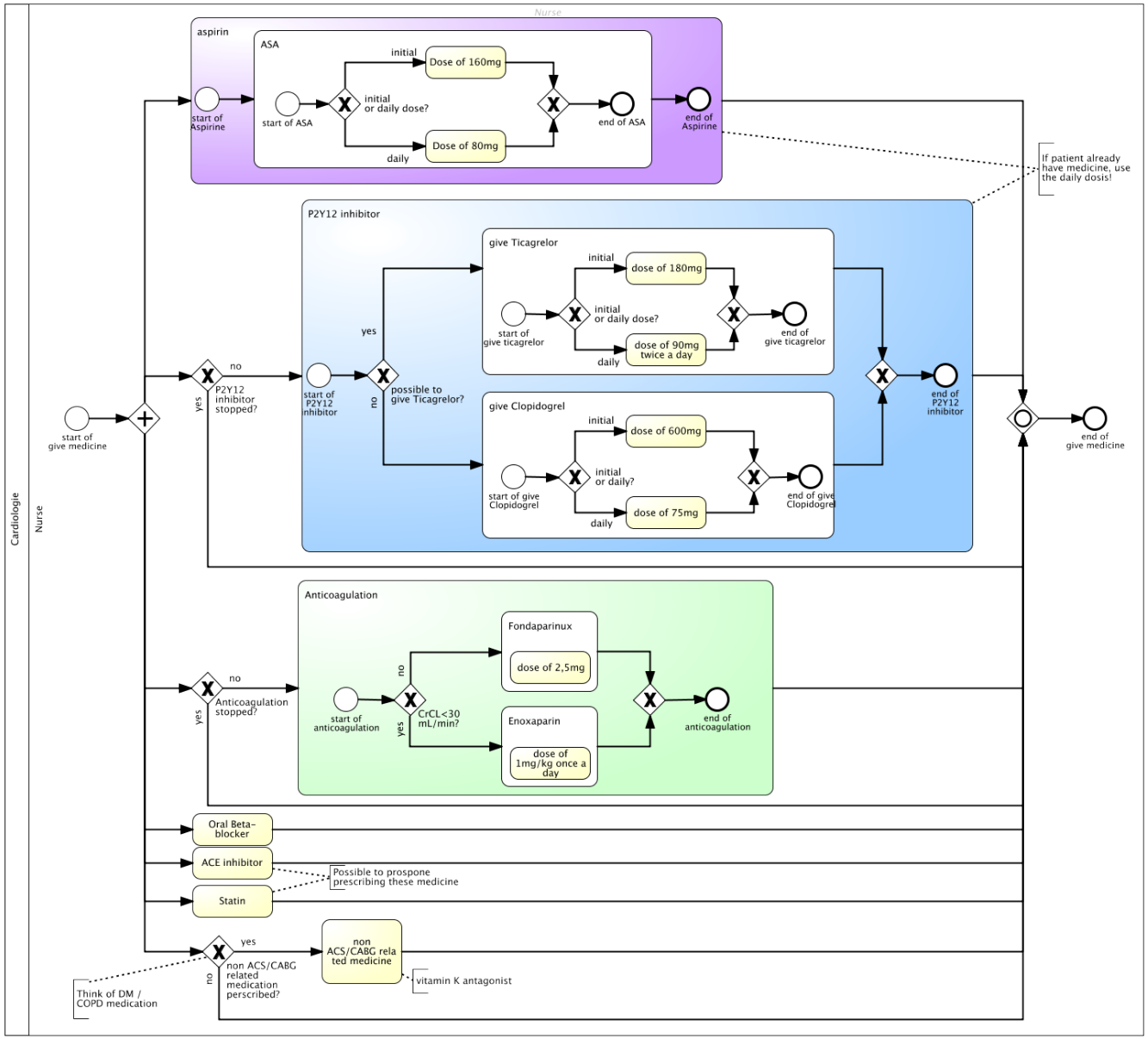


Figure 27 – Business view of the sub process Give medicine (ACS-NSTEMI)

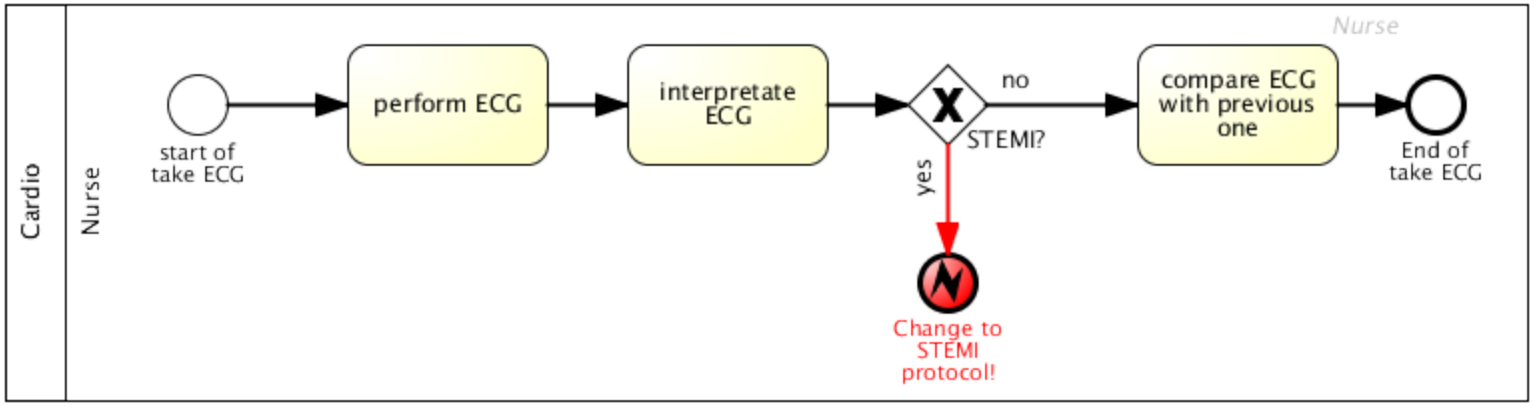


Figure 28 – Business view of the sub process Take ECG

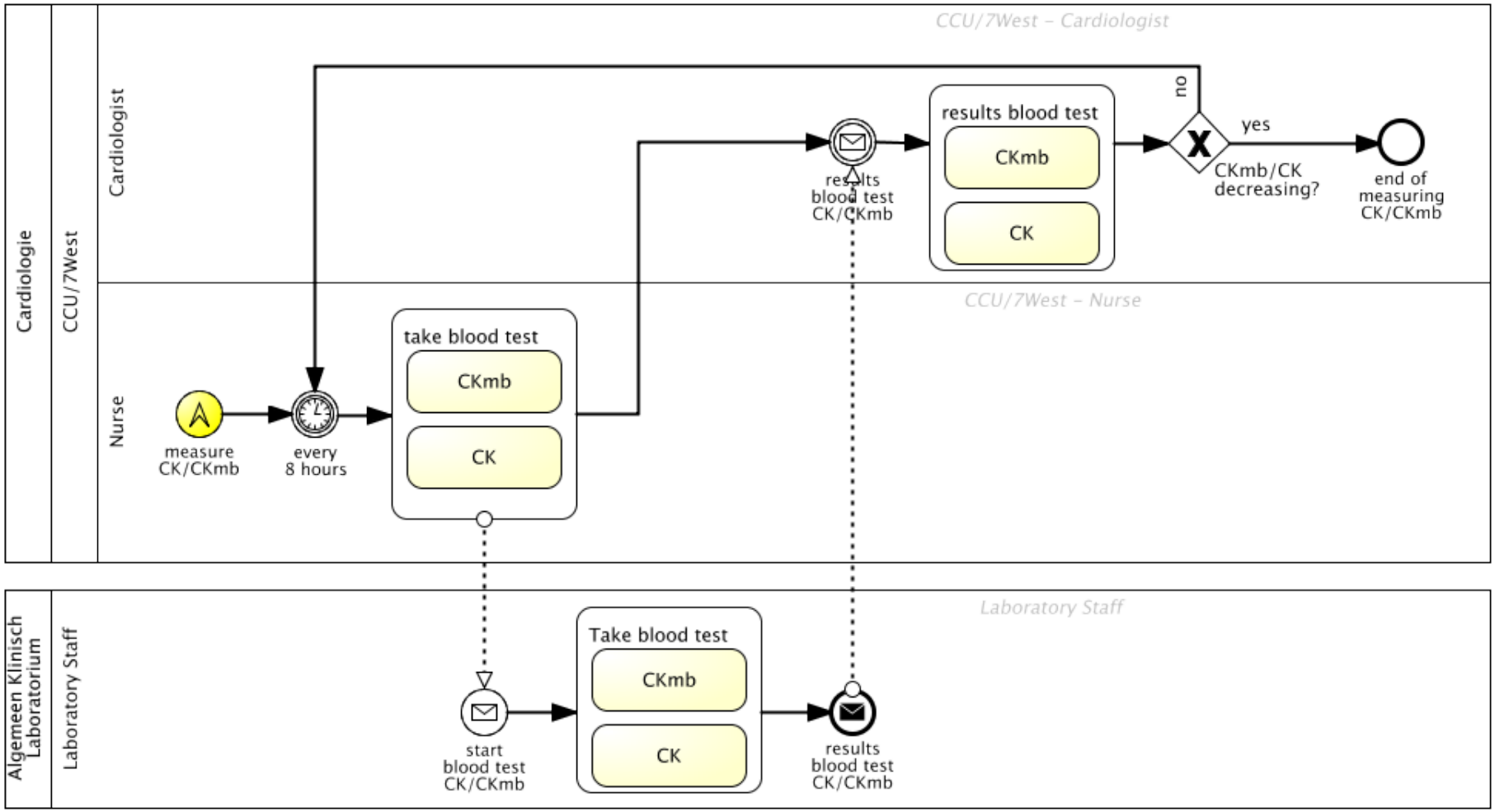


Figure 29 – Business view of the CK/CKmb measuring diagram

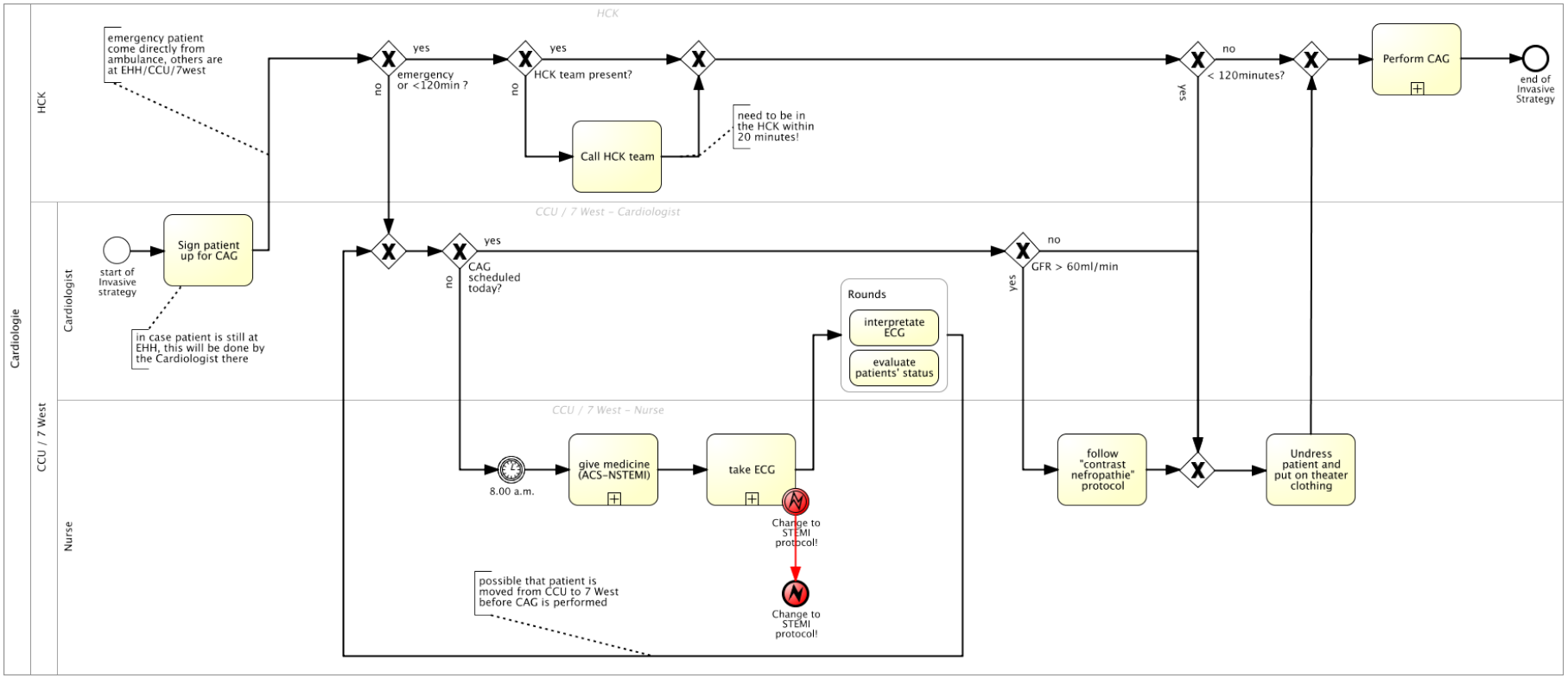


Figure 30 – Business view of the phase Invasive Strategy

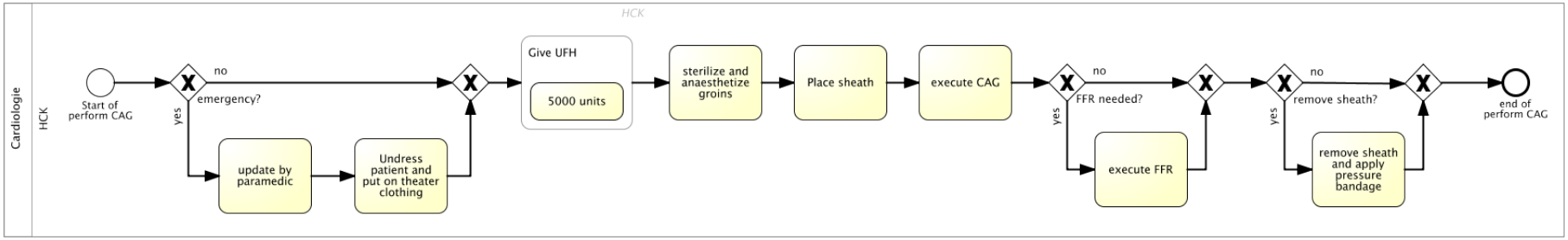


Figure 31 – Business view of the sub process Perform CAG

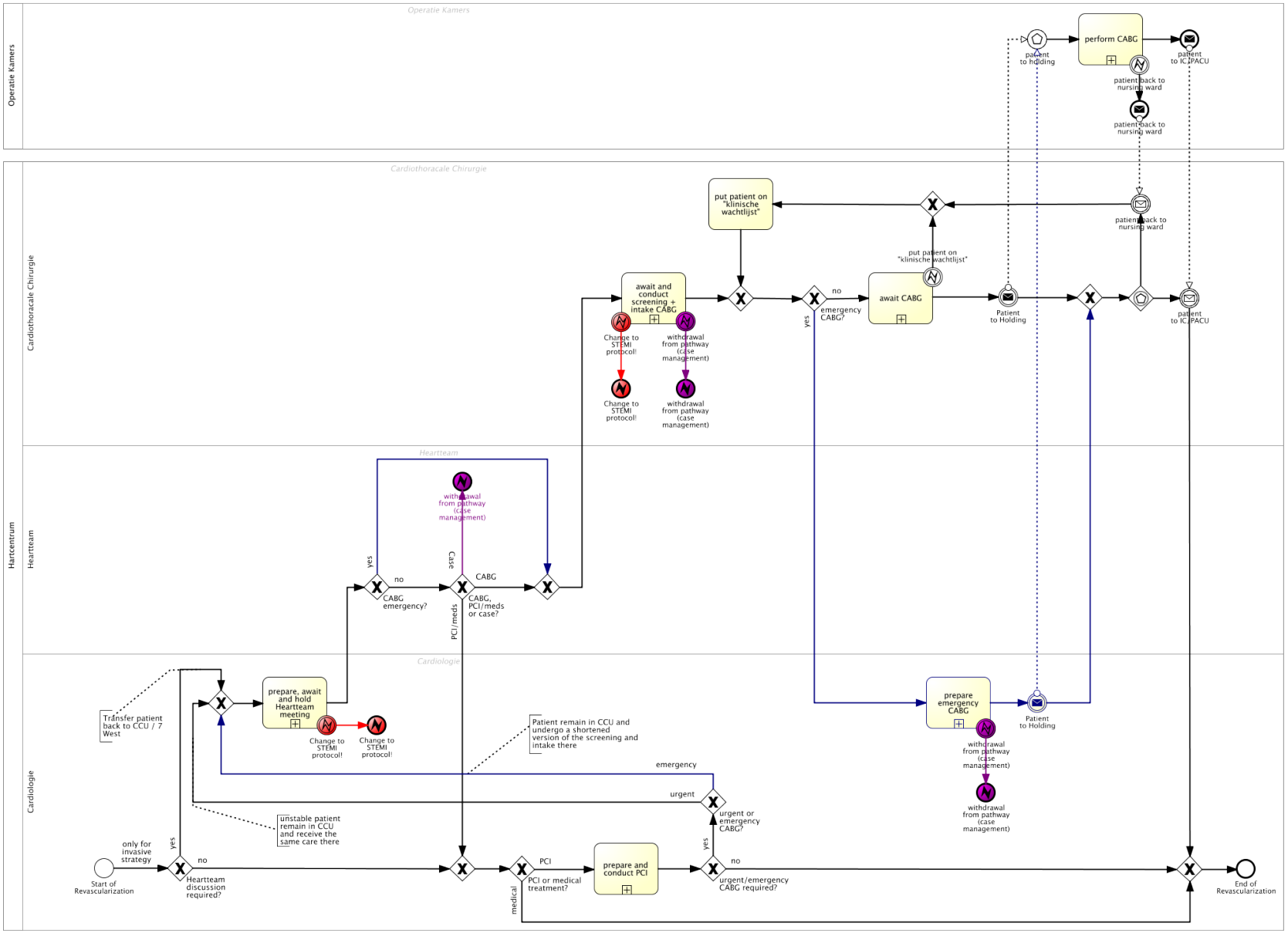


Figure 32 – Business view of the phase Revascularization modalities

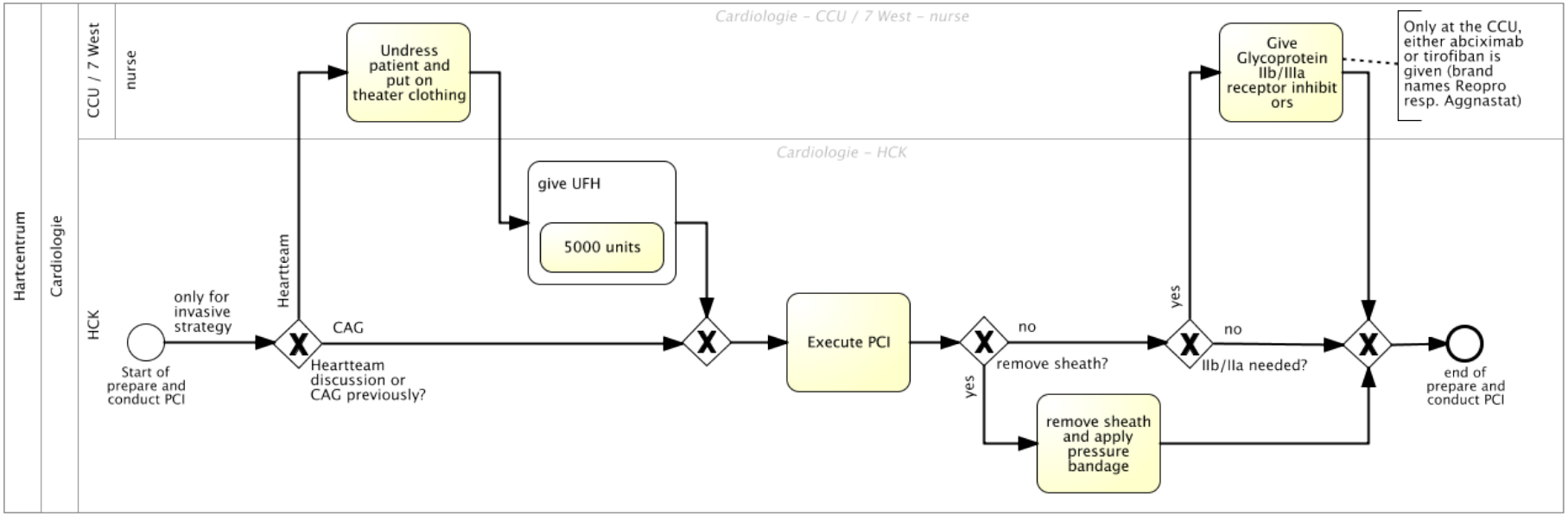


Figure 33 – Business view of the sub phase Prepare and conduct PCI

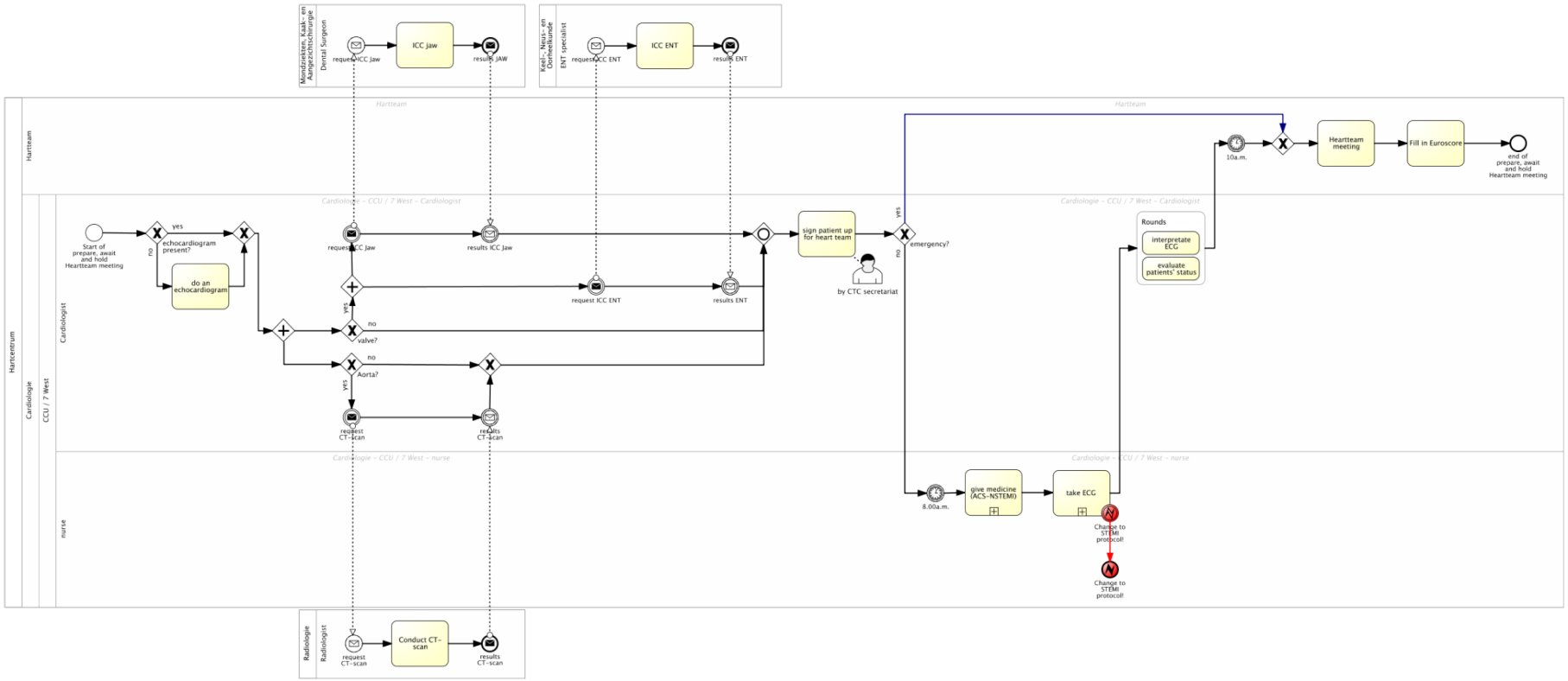


Figure 34 – Business view of the sub phase Prepare, await and conduct Heartteam meeting

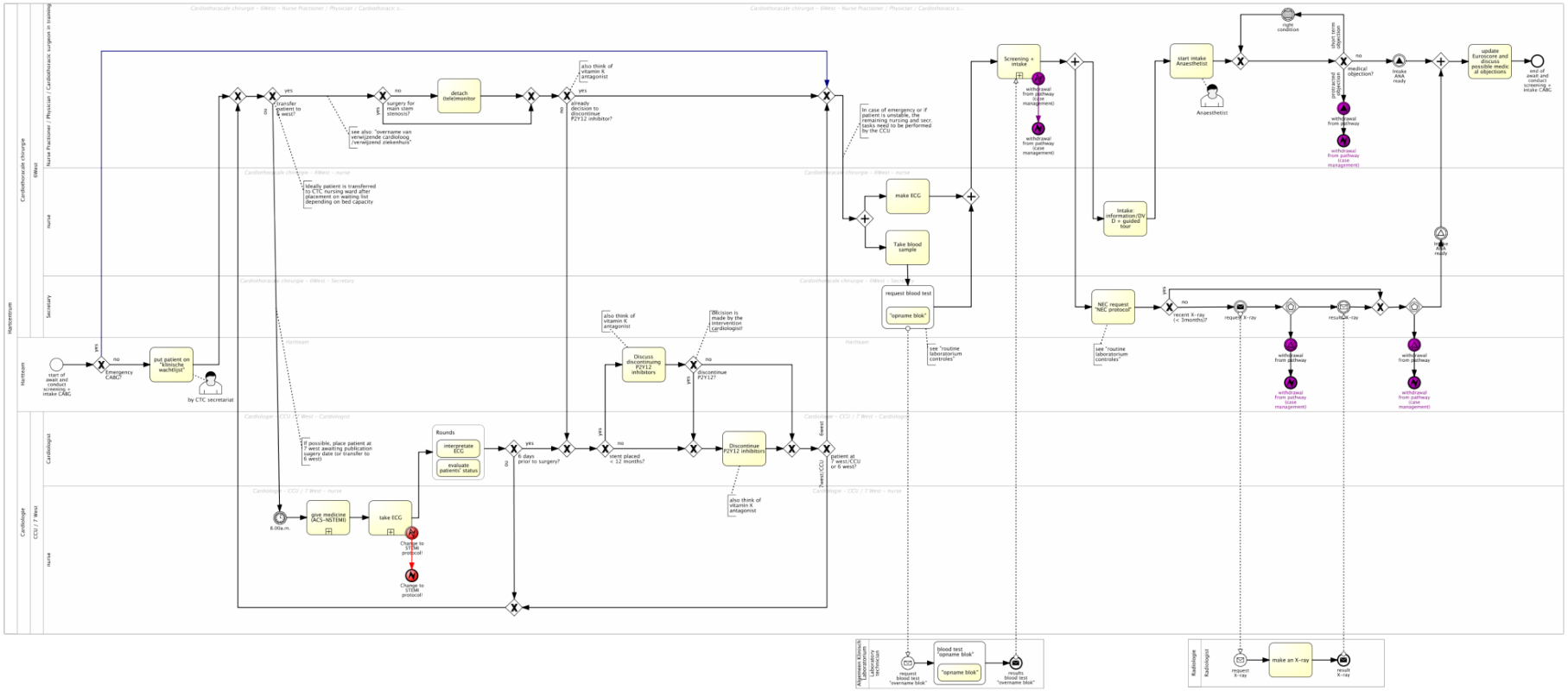


Figure 35 – Business view of the sub phase Await and conduct screening + intake CABG

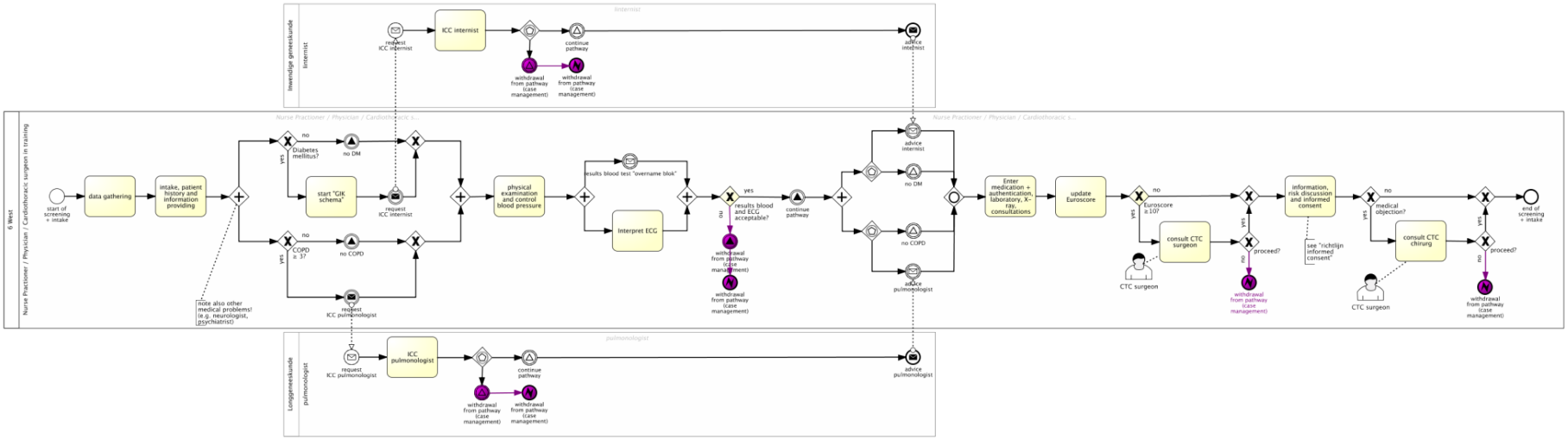


Figure 36 – Business view of the sub process Screening + intake

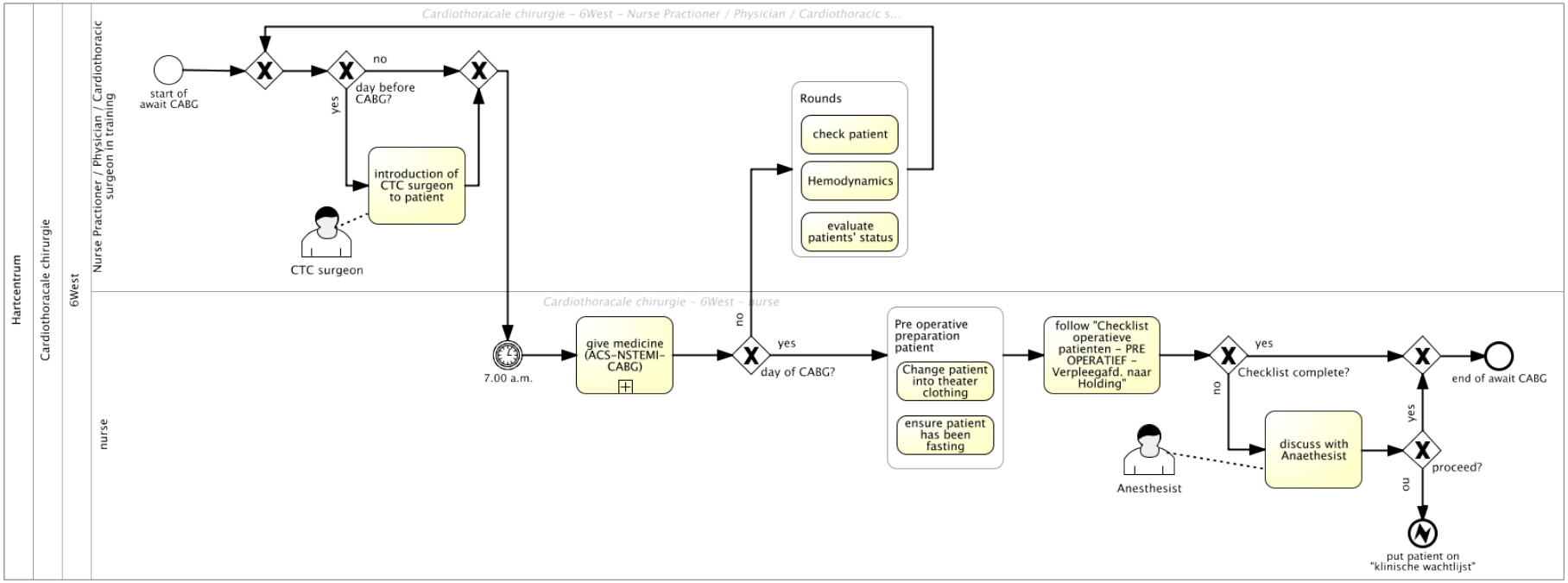


Figure 37 – Business view of the sub phase Await CABG

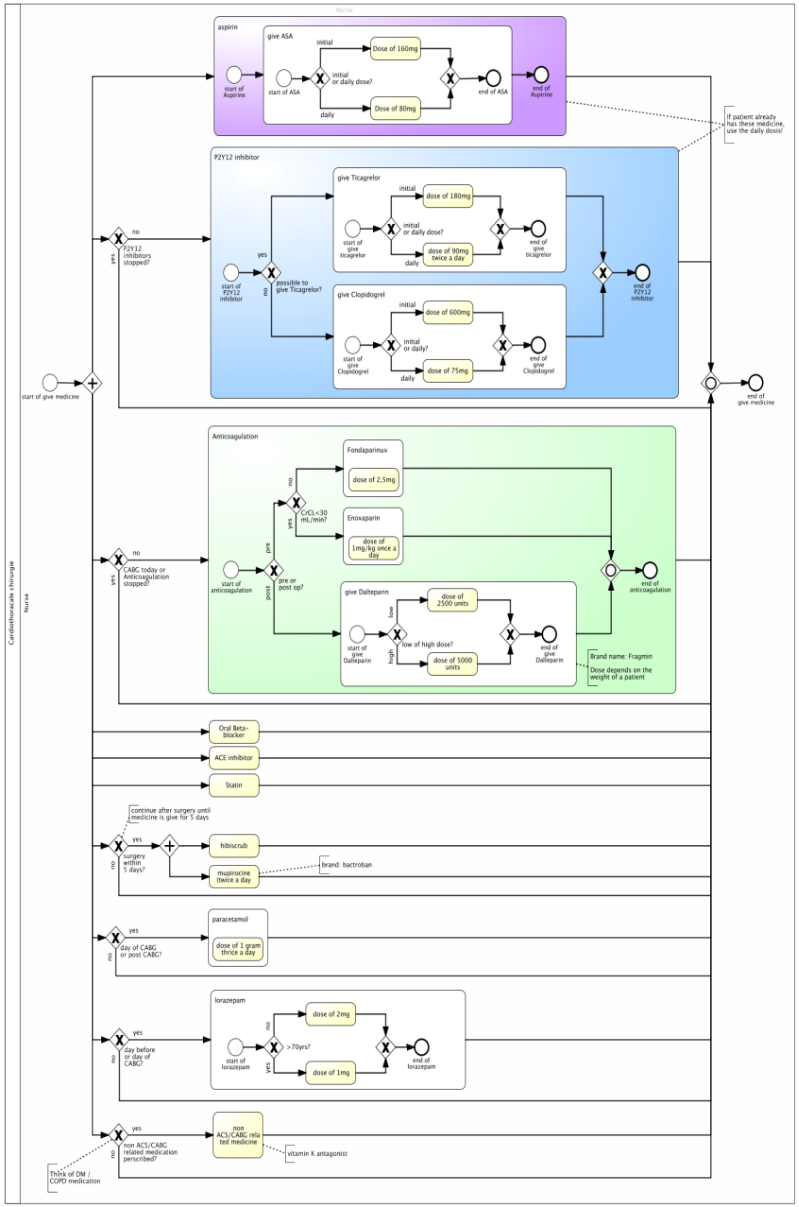


Figure 38 – Business view of the sub process Give medicine (ACS-NSTEMI-CABG)

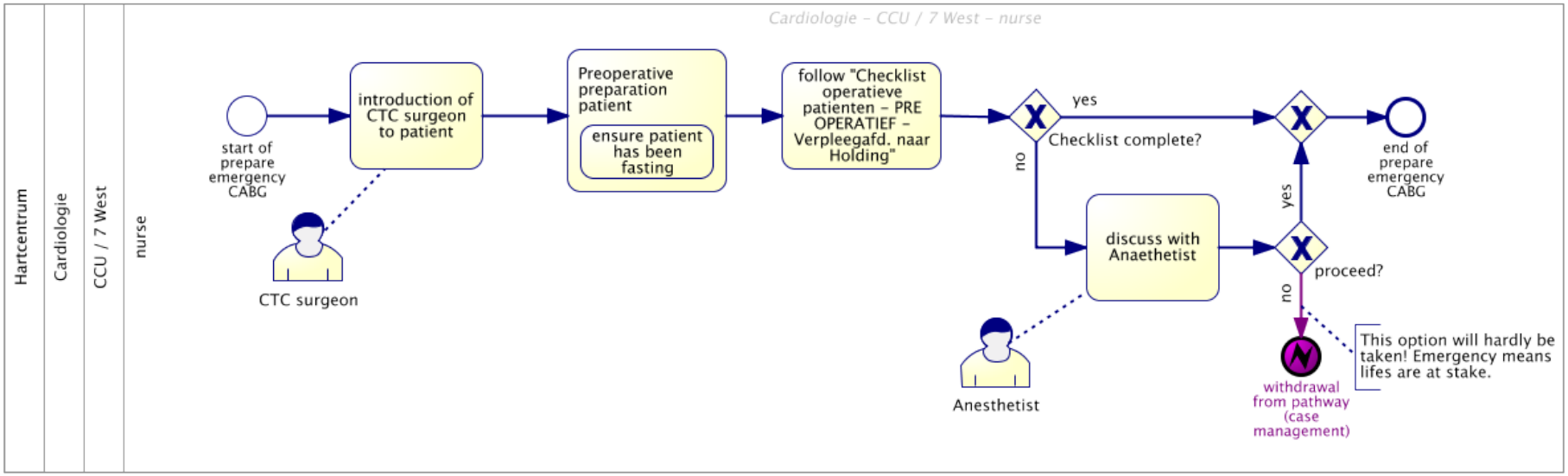


Figure 39 – Business view of the sub phase Prepare emergency CABG

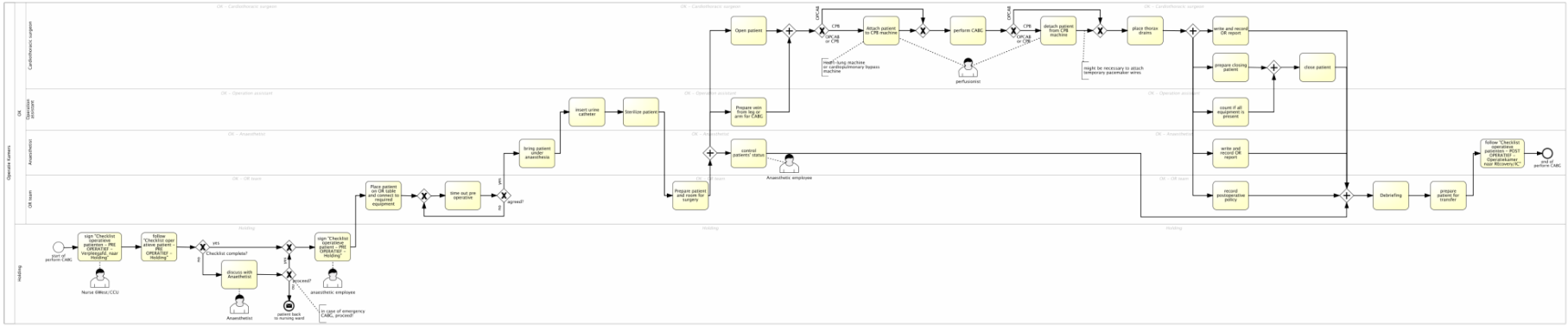


Figure 40 – Business view of the sub phase Perform CABG

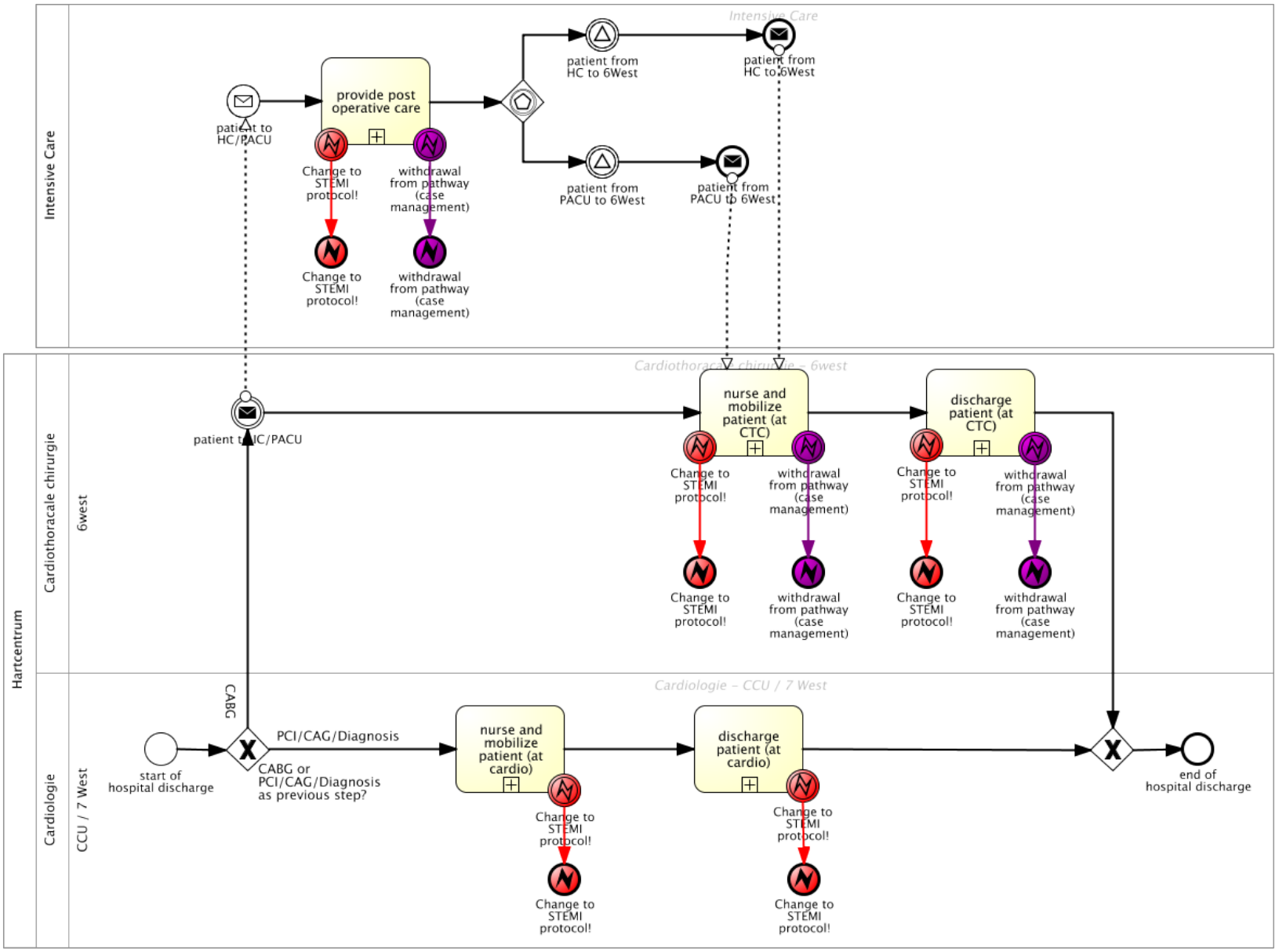


Figure 41 – Business view of the phase Hospital discharge

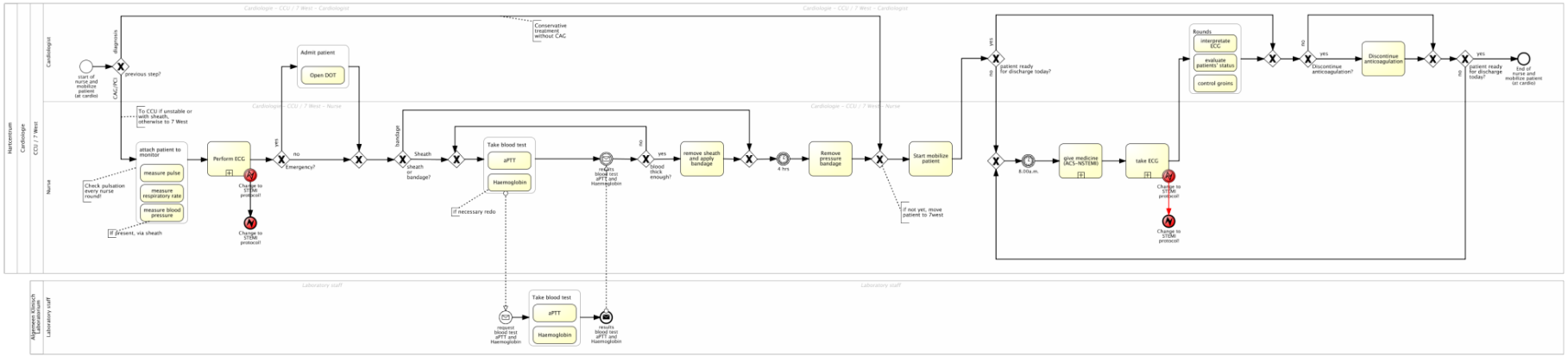


Figure 42 – Business view of the sub phase Nurse and mobilize patient (at cardio)

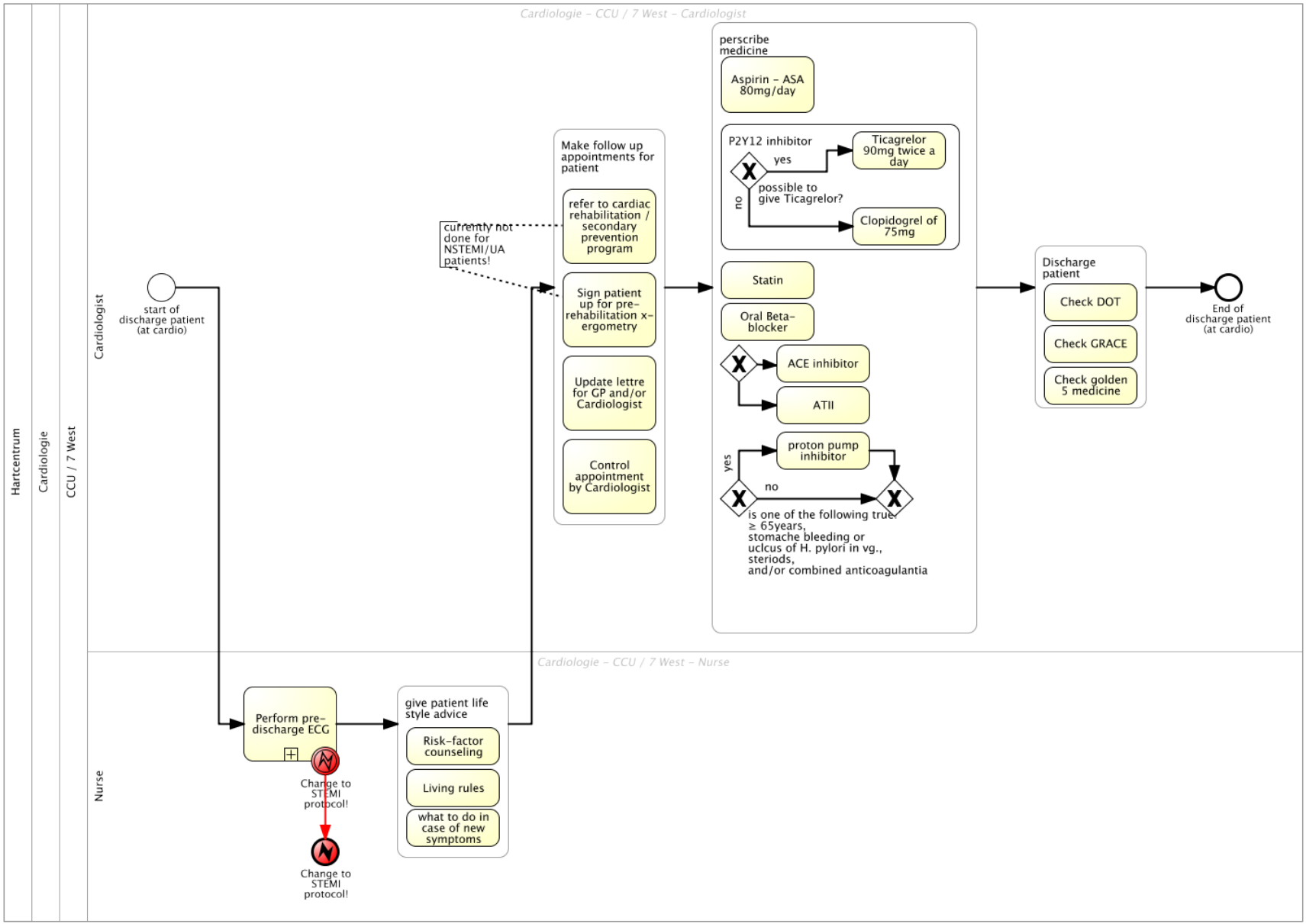


Figure 43 – Business view of the sub phase Discharge patient (at cardio)

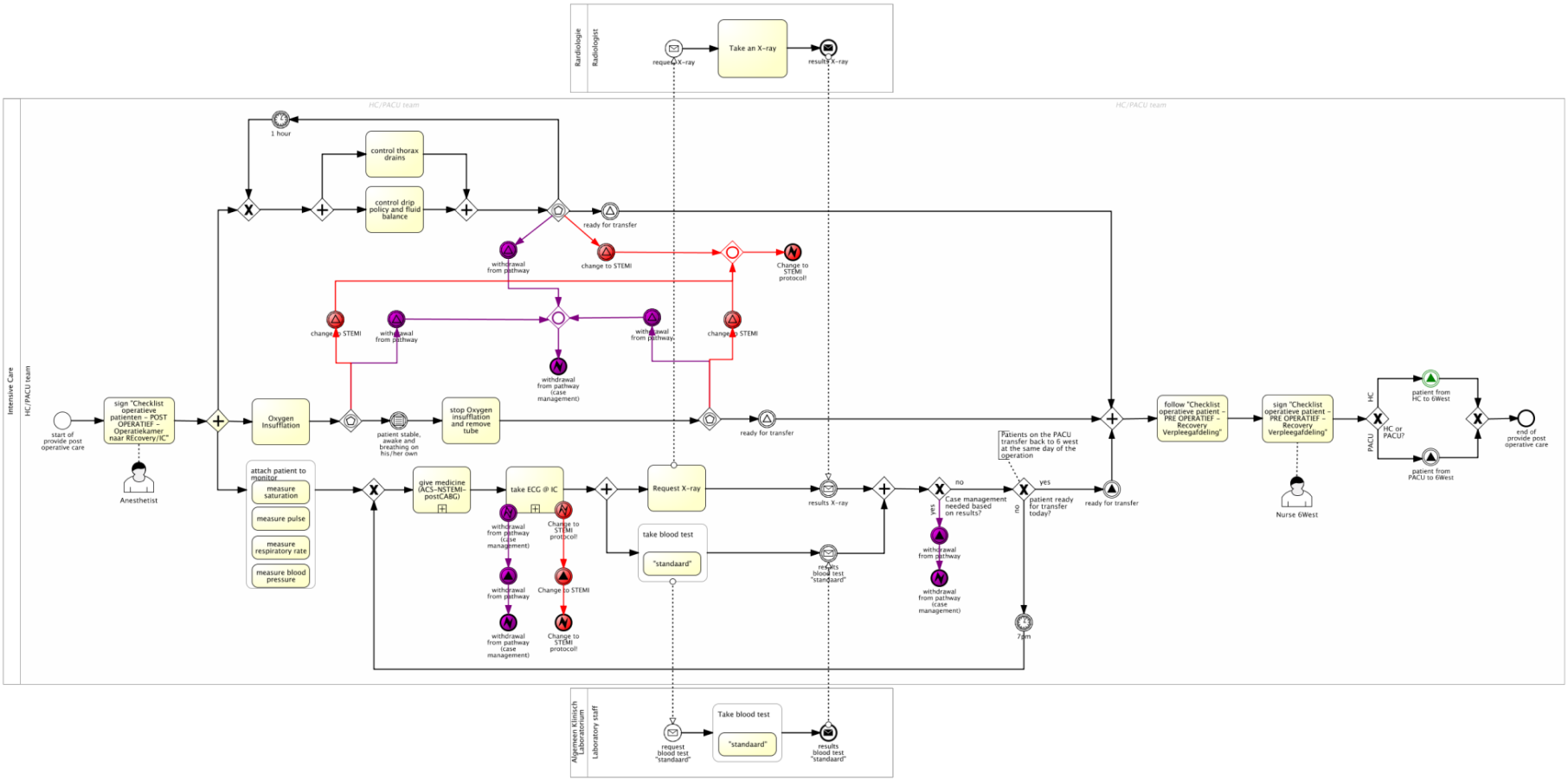


Figure 44 – Business view of the sub phase Provide post operative care

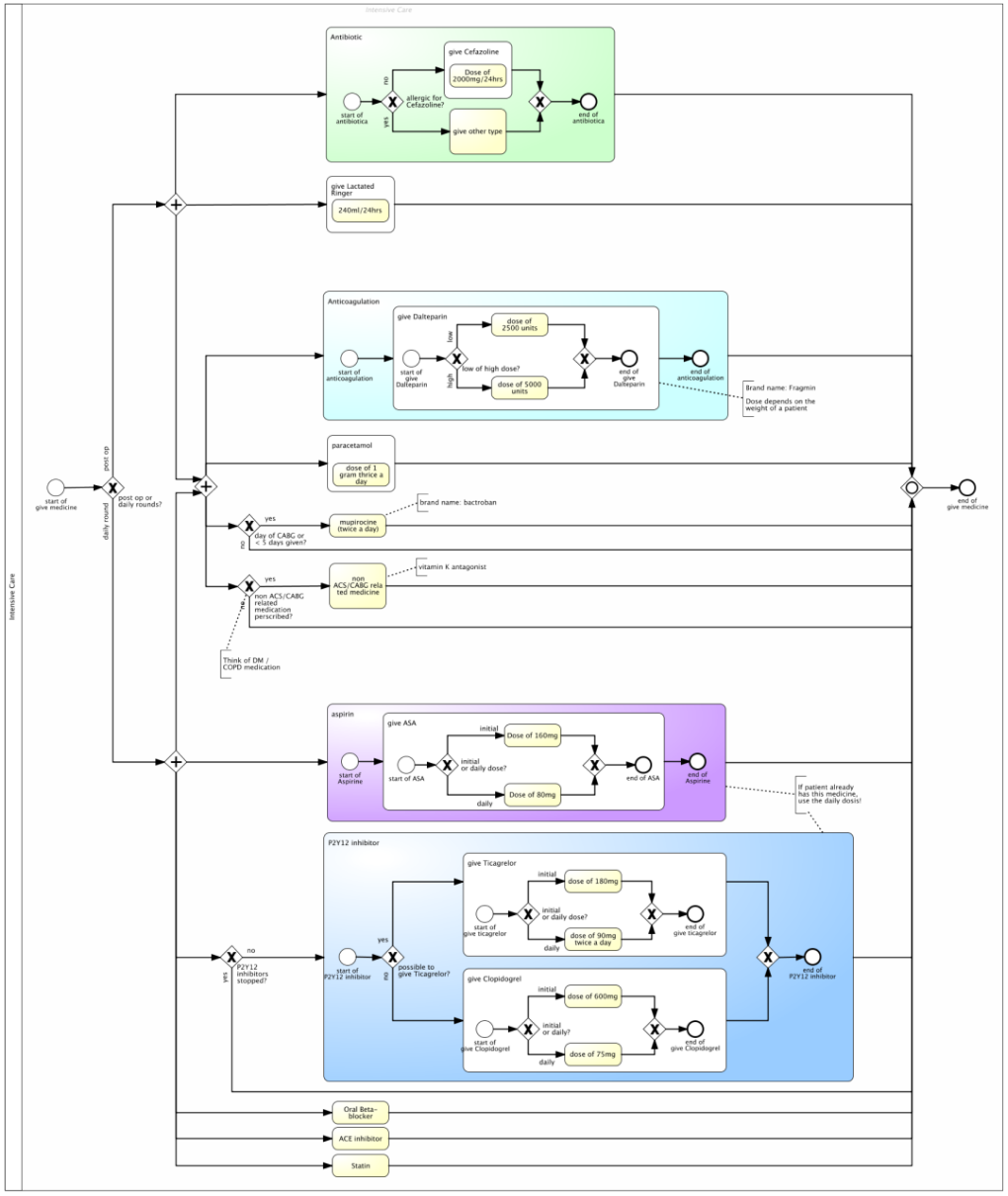


Figure 45 – Business view of the sub process Give medicine (ACS-NSTEMI-postCABG)

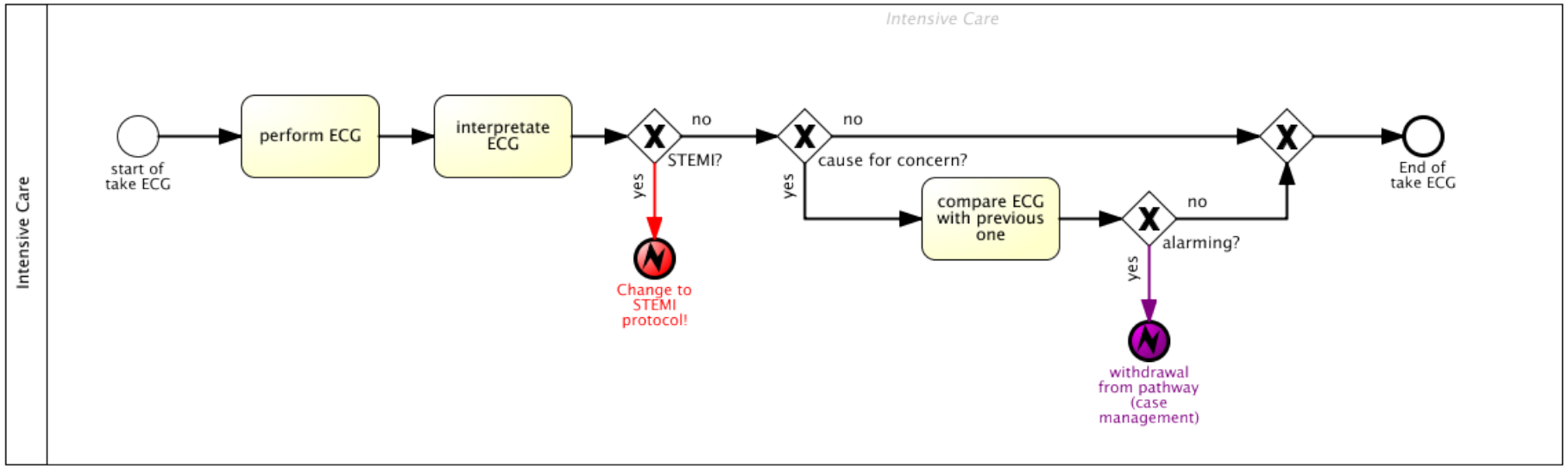


Figure 46 – Business view of the sub process Take ECG @ IC

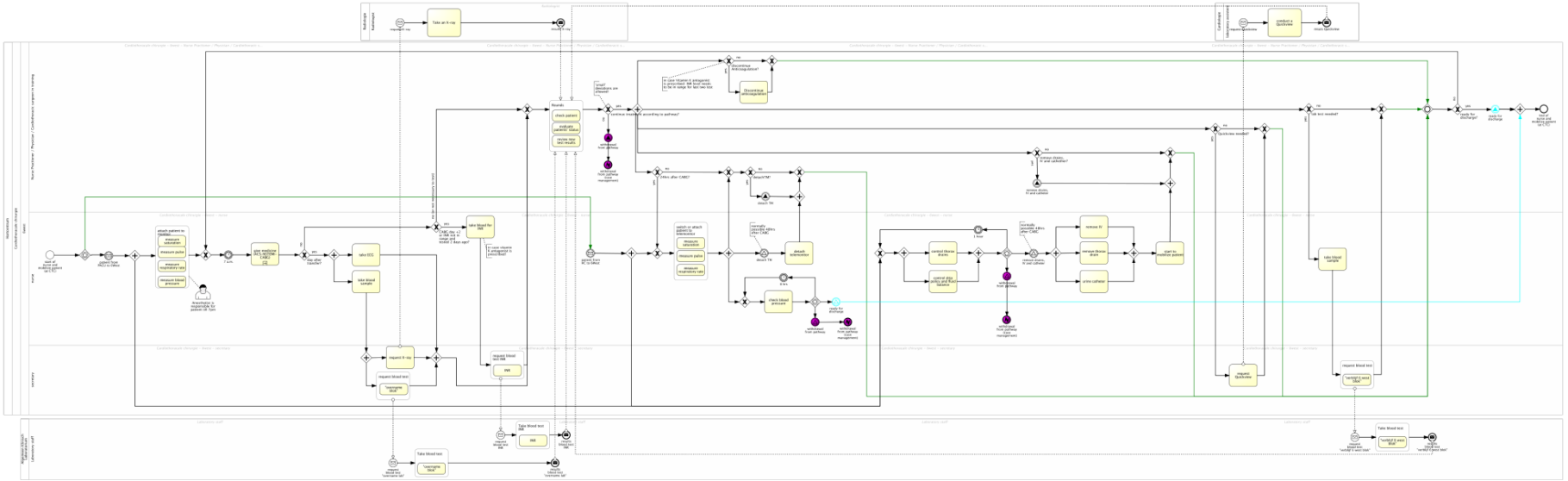


Figure 47 – Business view of the sub phase Nurse and mobilize patient (at CTC)

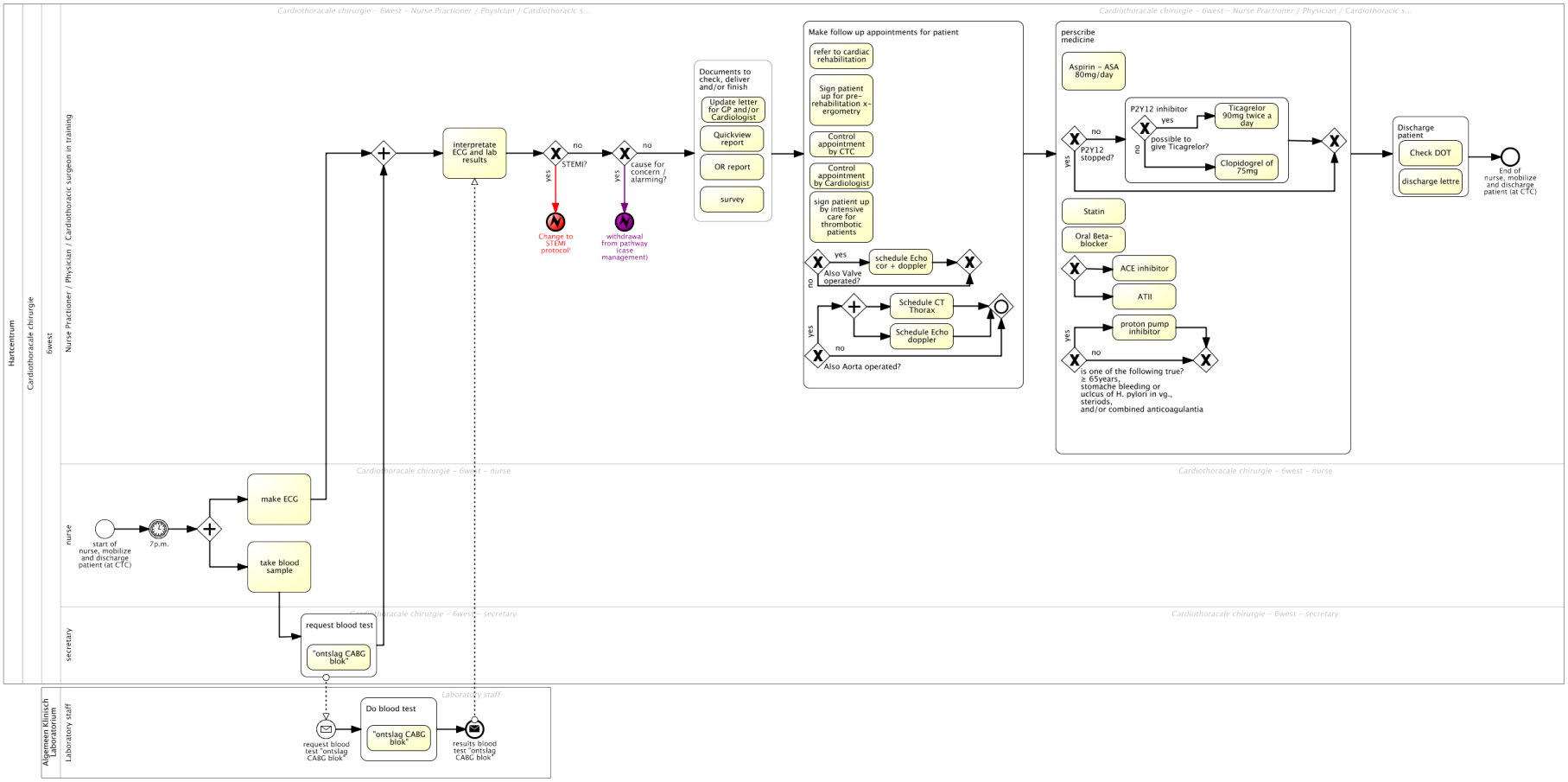


Figure 48 – Business view of the sub phase Discharge patient (at CTC)

APPENDIX L – PATTERNS

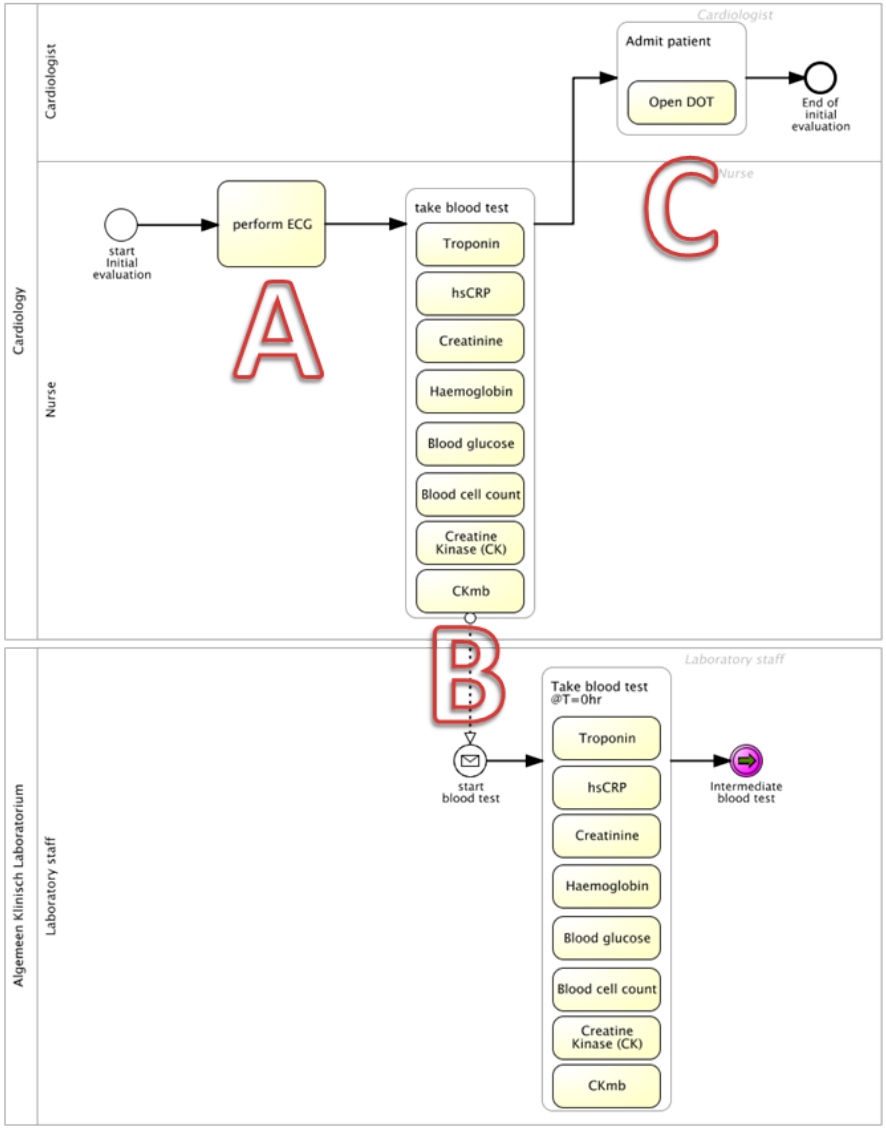


Figure 49 – Pattern of the Initial evaluation phase

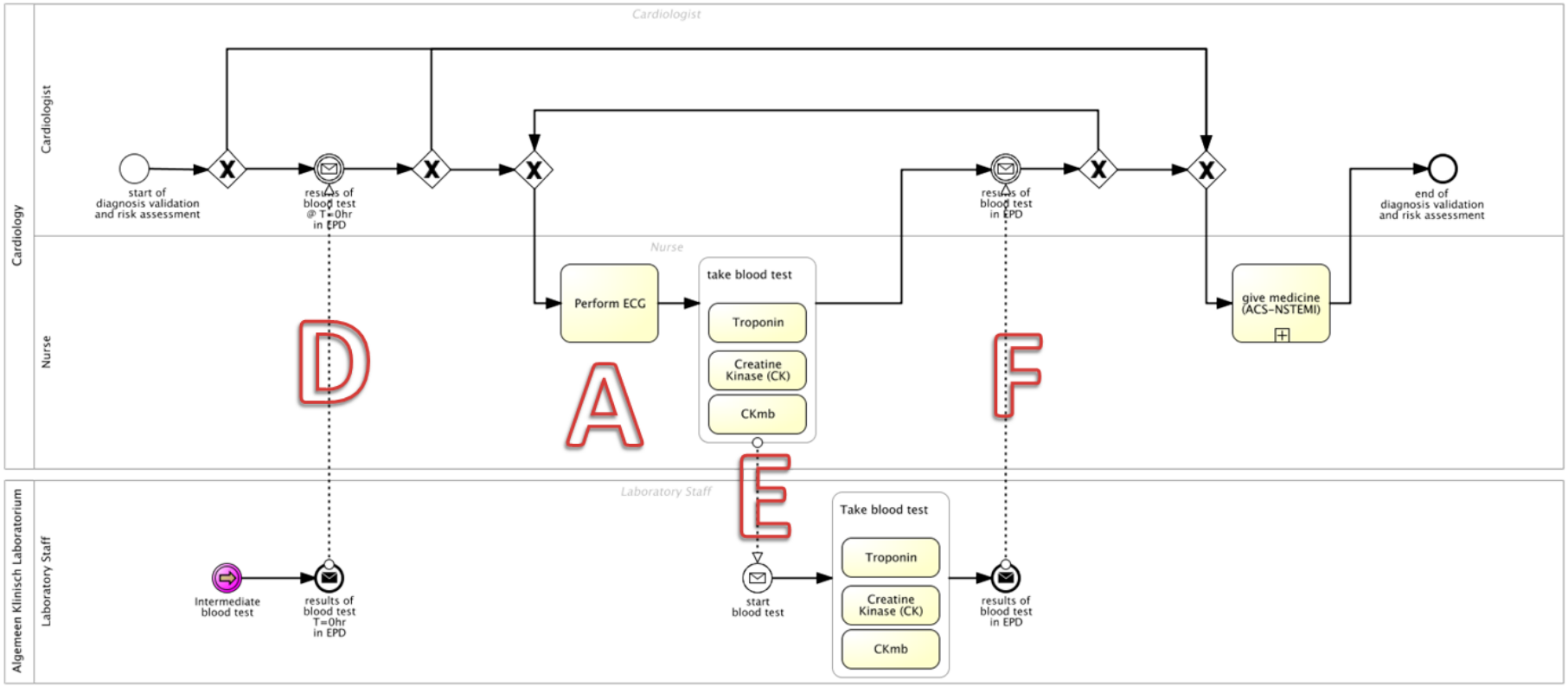


Figure 50 – Pattern of the Diagnosis validation and risk assessment phase

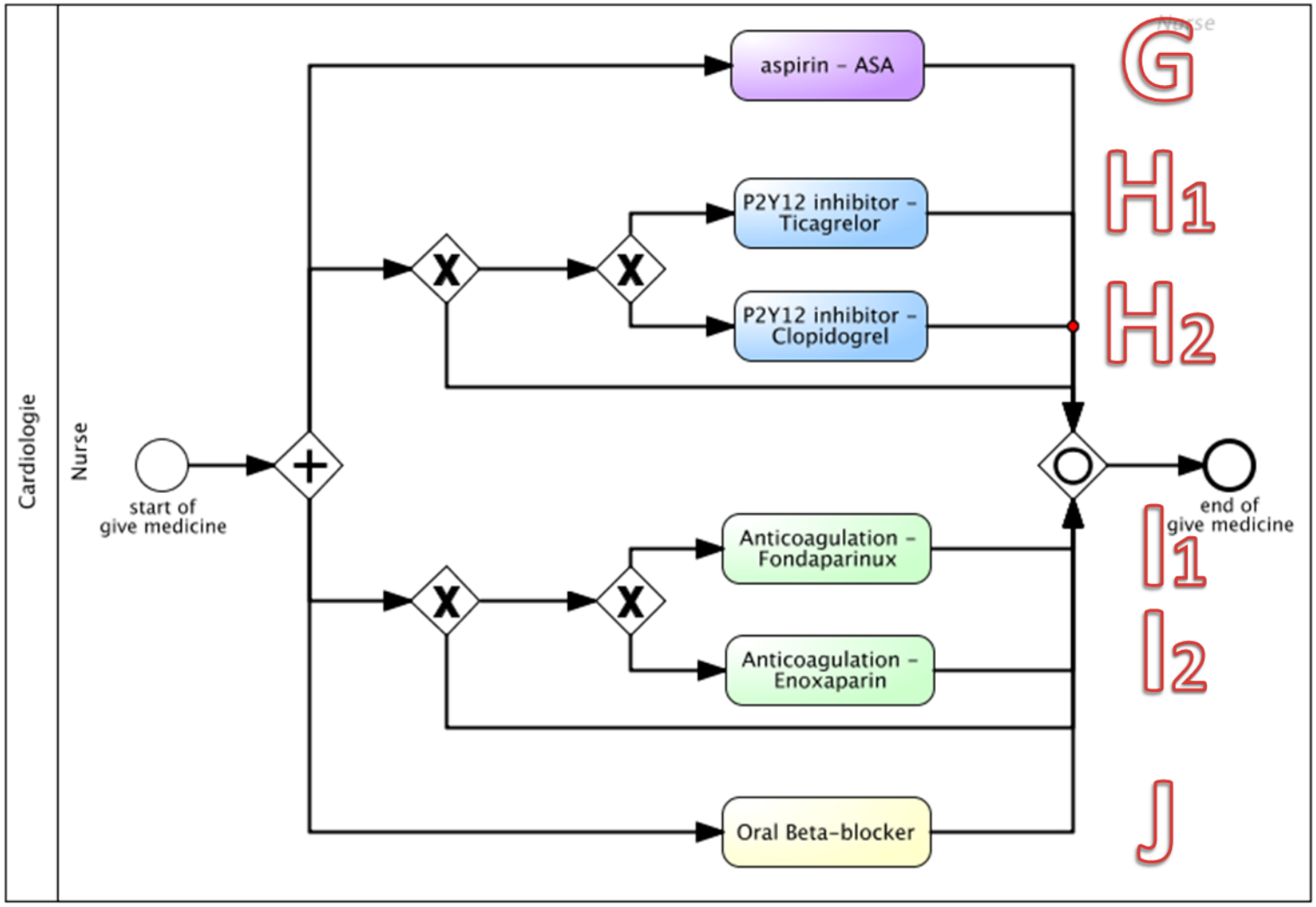


Figure 51 – Pattern of the sub process give medicine (ACS-NSTEMI)

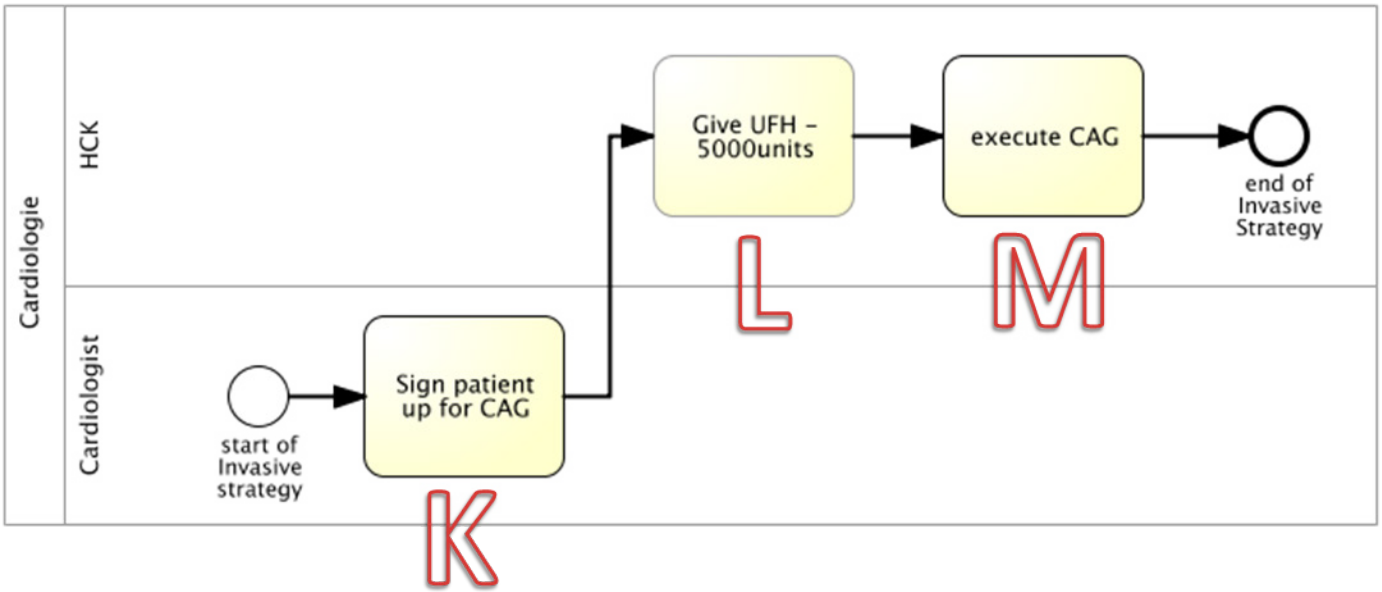


Figure 52 – Pattern of the Invasive strategy phase

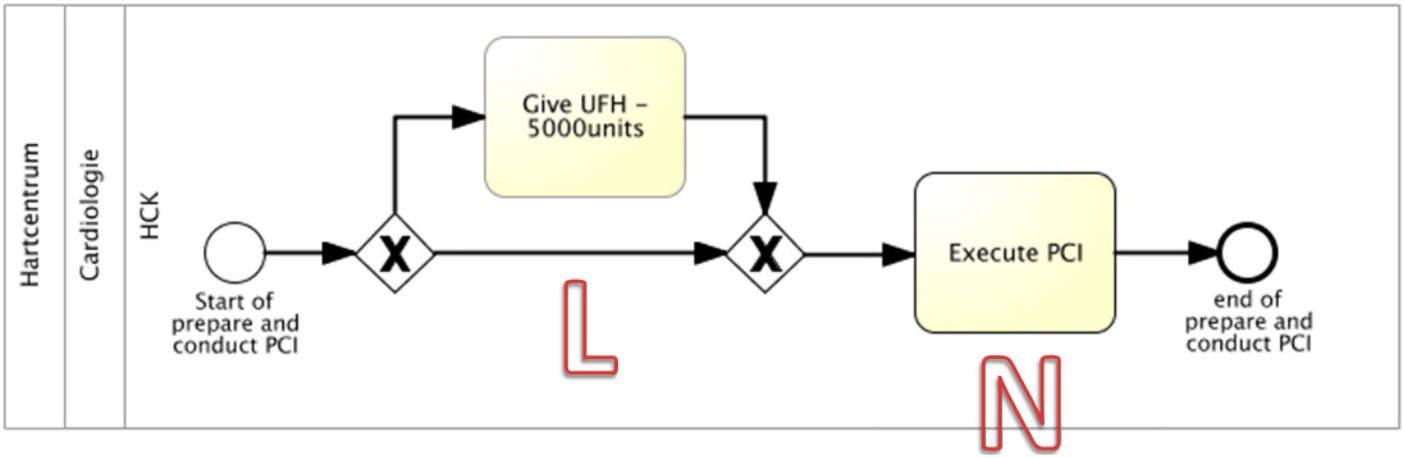


Figure 53 – Pattern of the prepare and conduct PCI sub phase

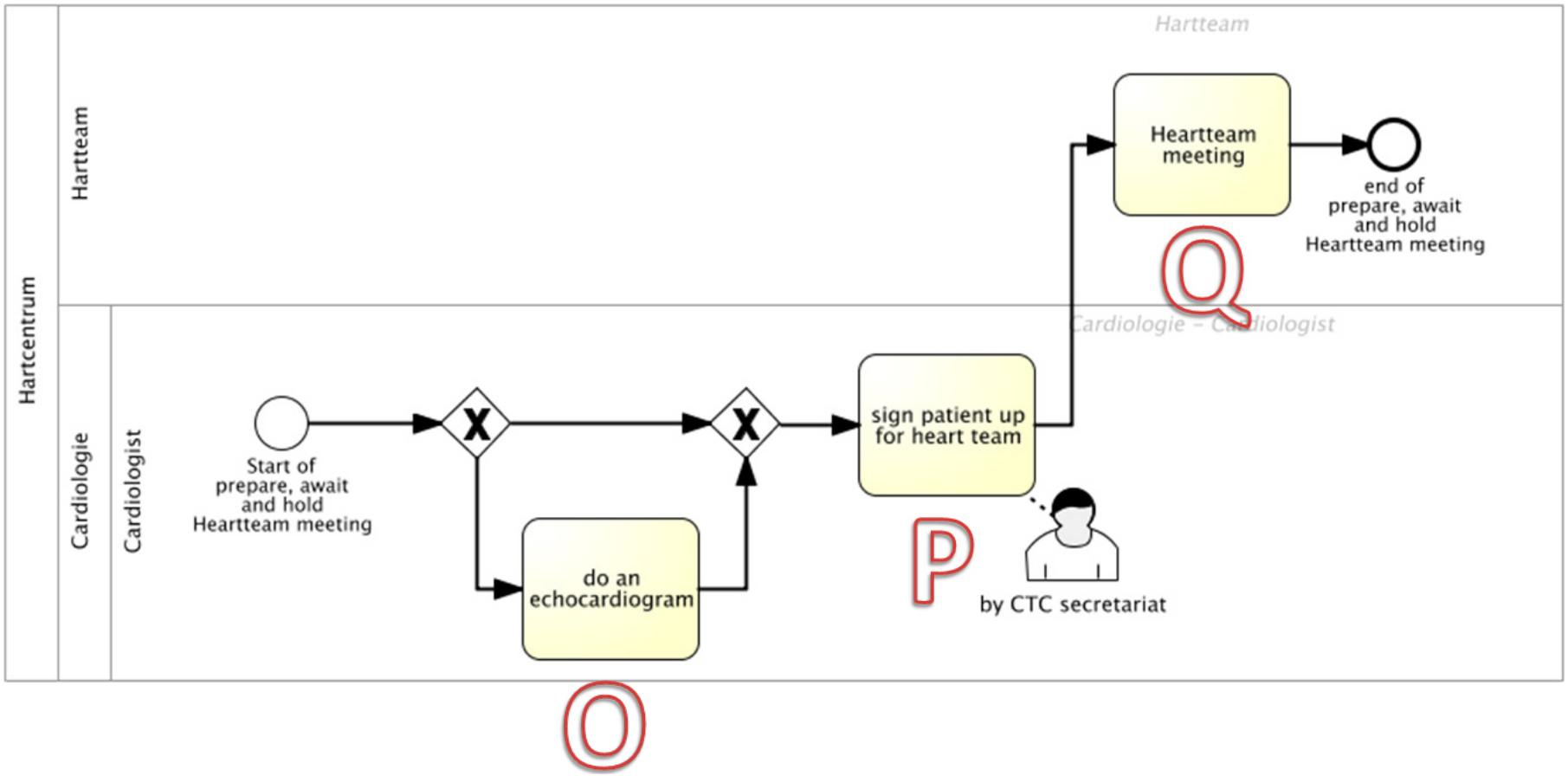


Figure 54 – Pattern of the prepare, await and hold Heartteam meeting sub phase

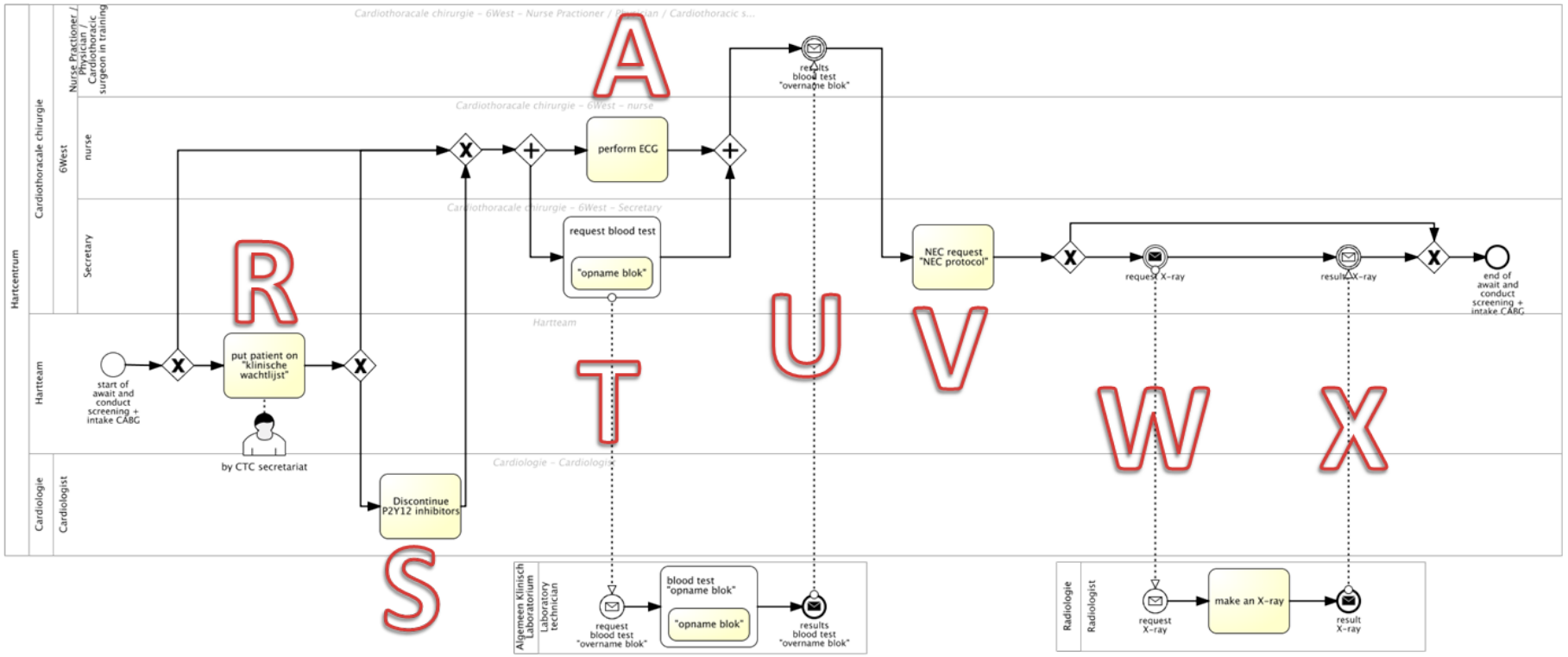


Figure 55 – Pattern of the await and conduct screening + intake CABG sub phase

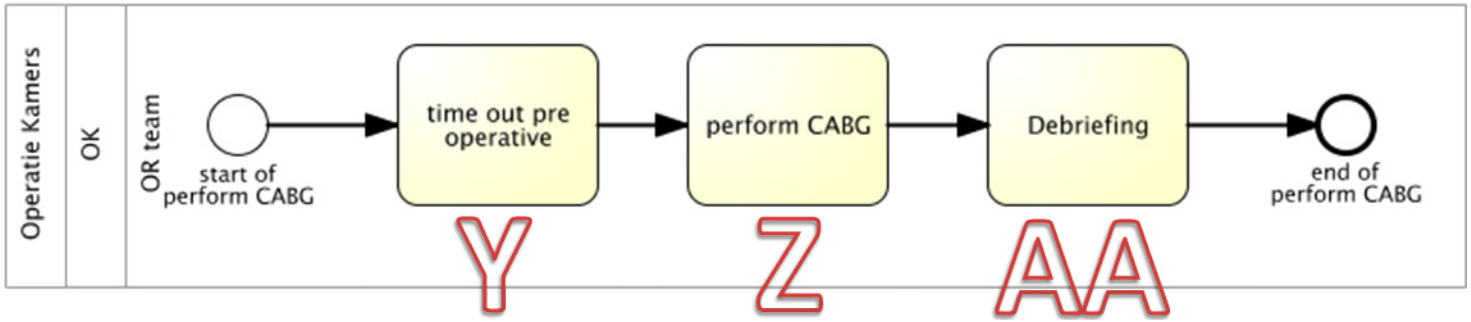


Figure 56 – Pattern of the perform CABG sub phase

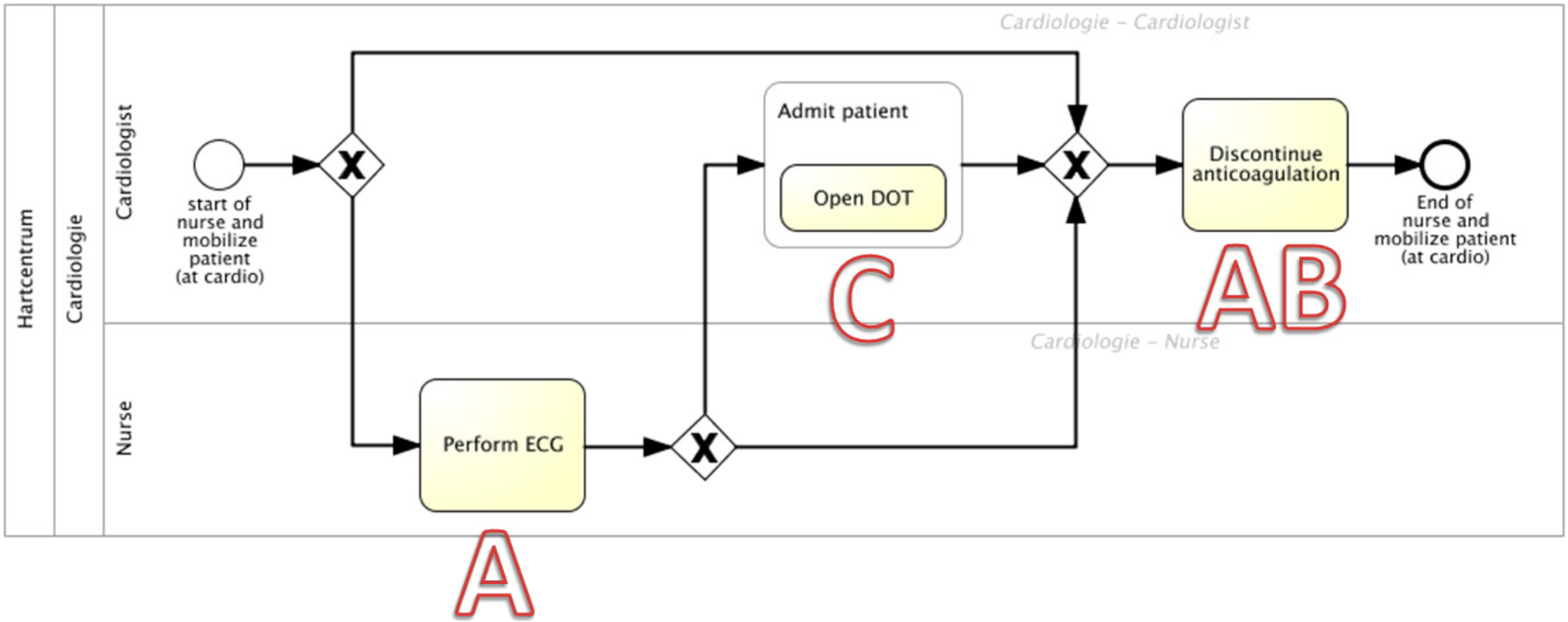


Figure 57 – Pattern of the nurse and mobilize patient (at cardio) sub phase

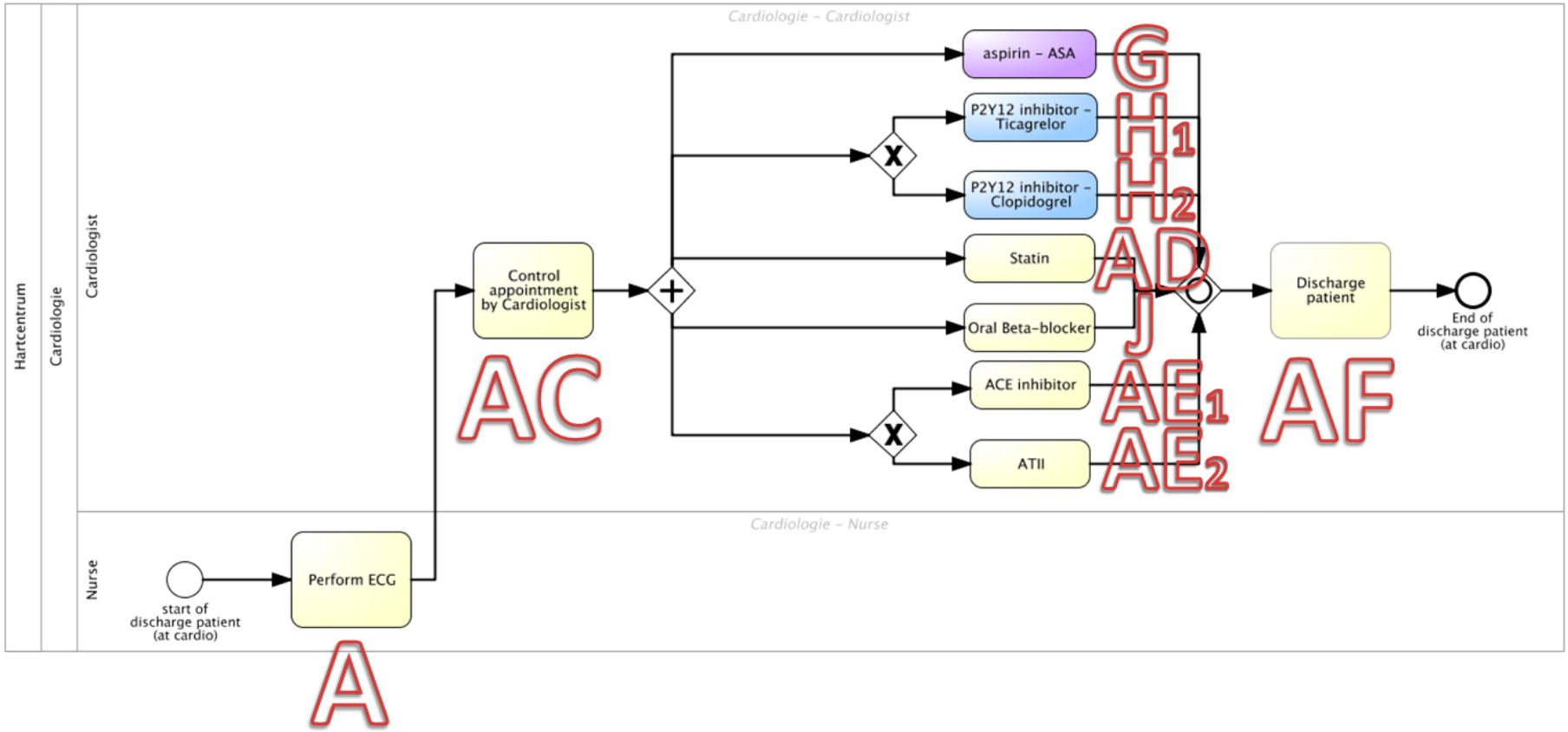


Figure 58 – Pattern of the discharge patient (at cardio) sub phase

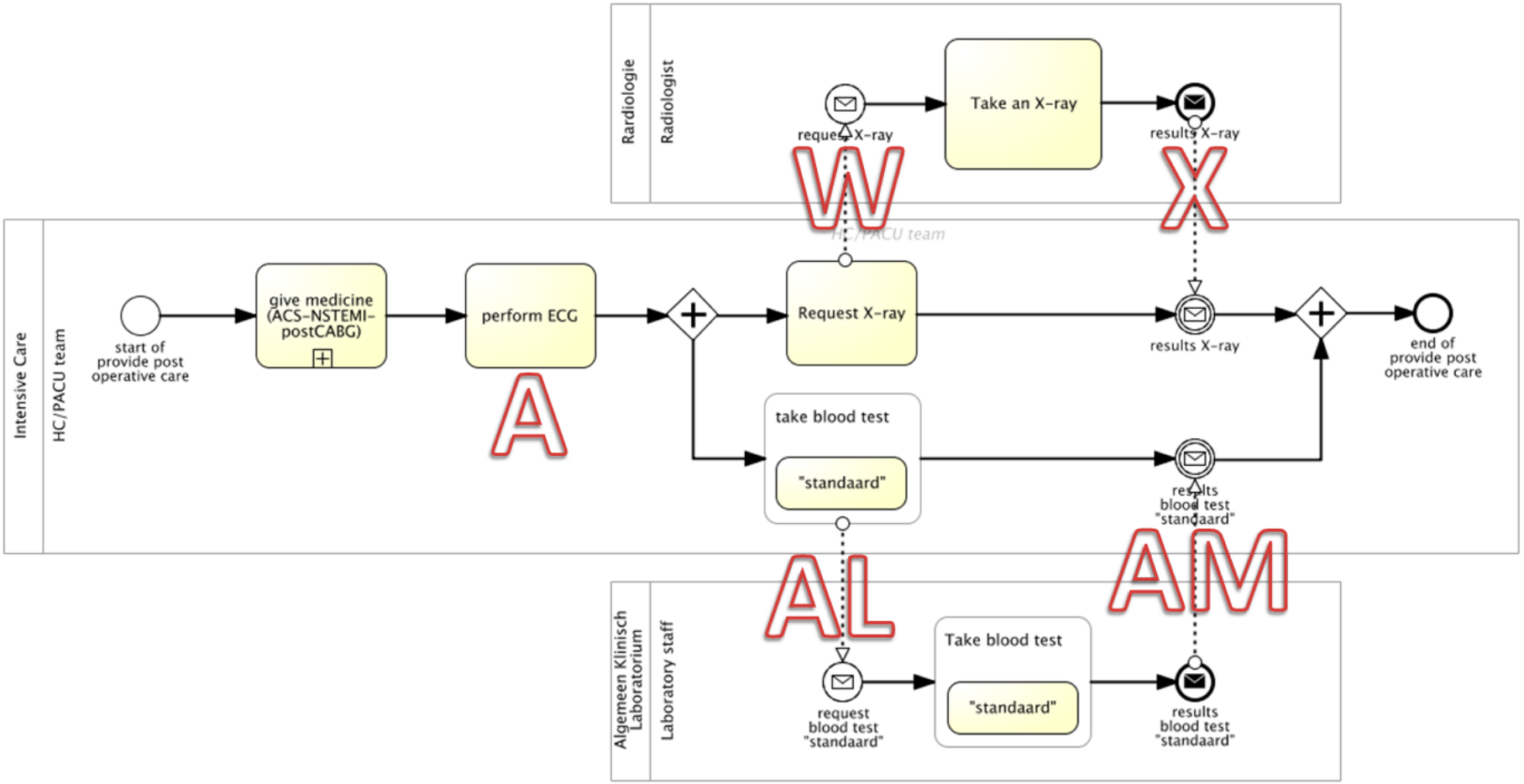


Figure 59 – Pattern of the provide post operative care sub phase

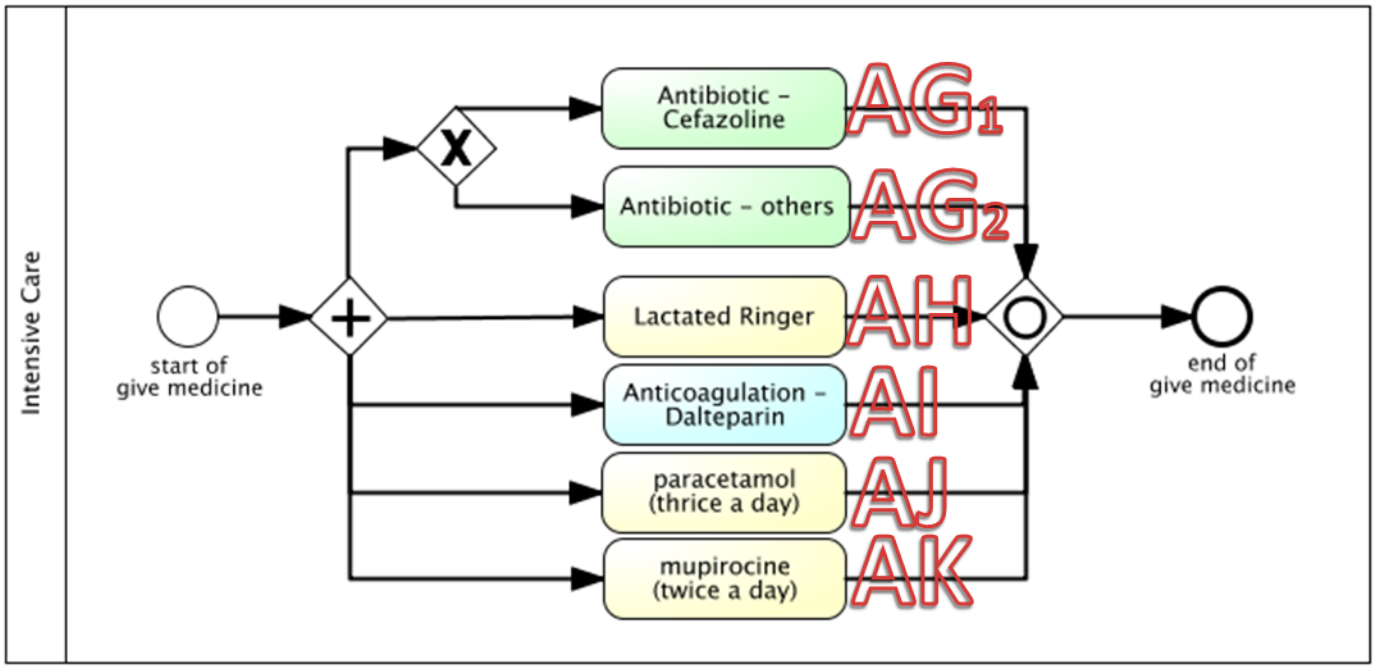


Figure 60 – Pattern of the sub process give medicine (ACS-NSTEMI-postCABG)

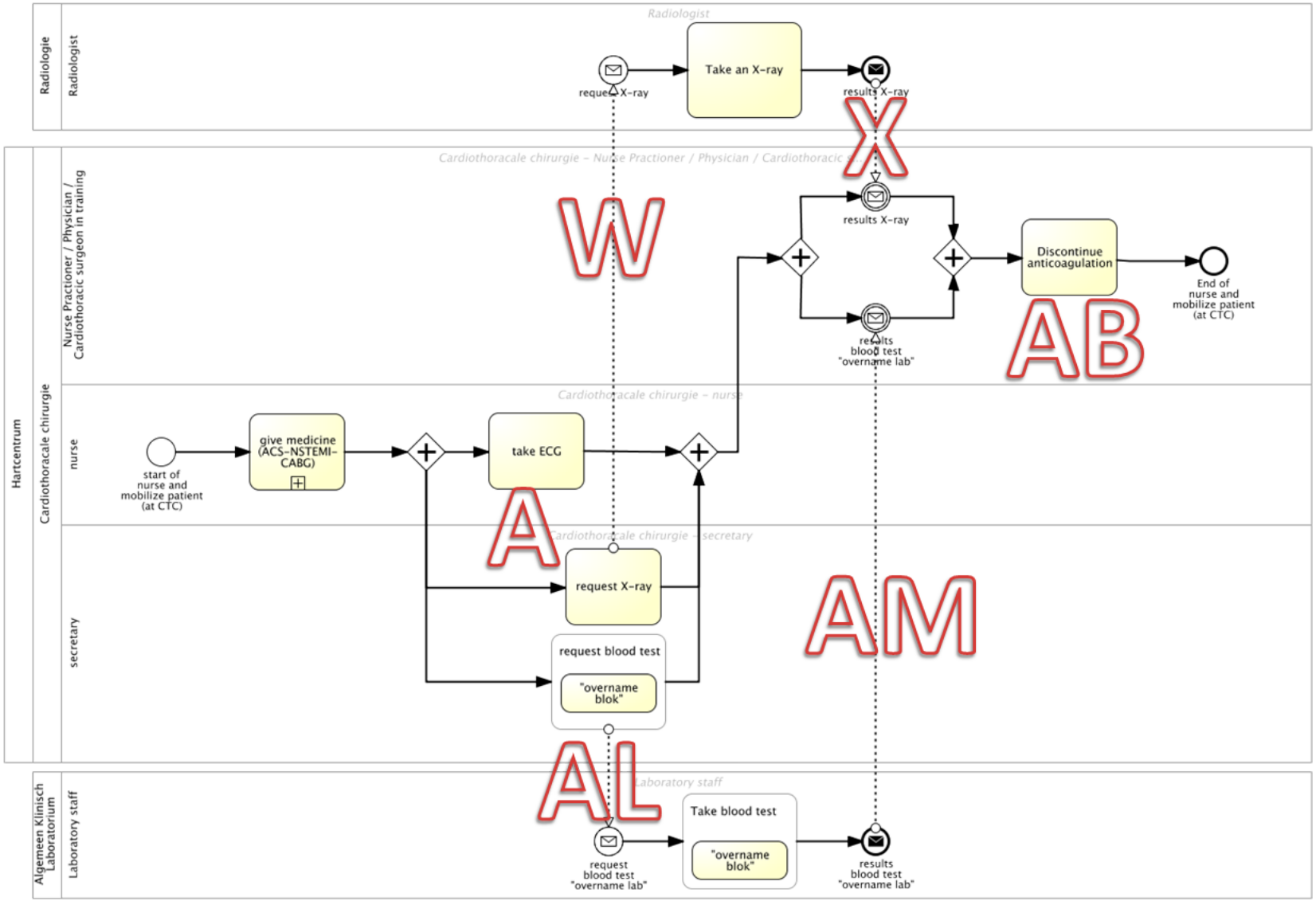


Figure 61 – Pattern of the nurse and mobilize patient (at CTC) sub phase

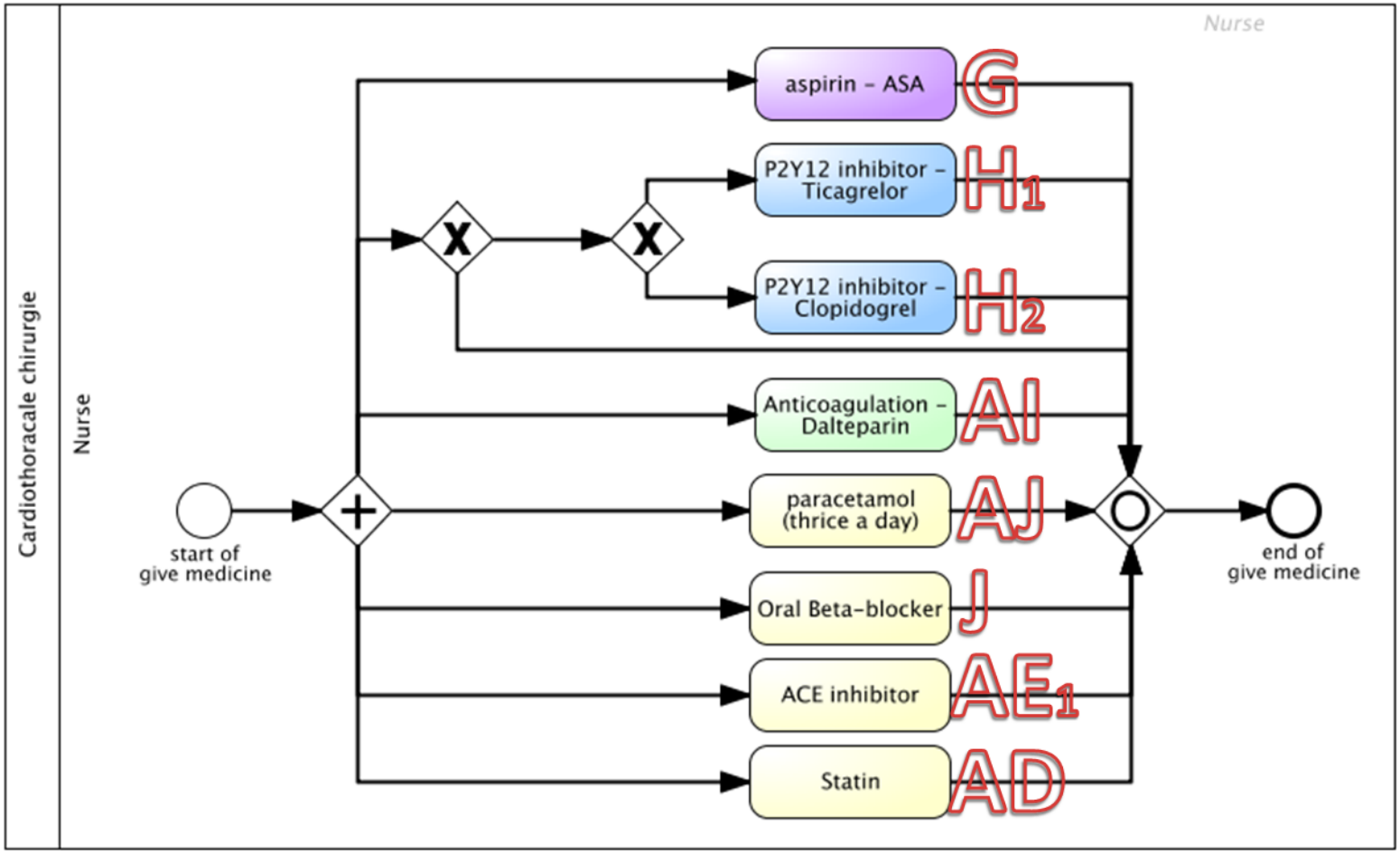


Figure 62 – Pattern of the sub process give medicine (ACS-NSTEMI-CABG)

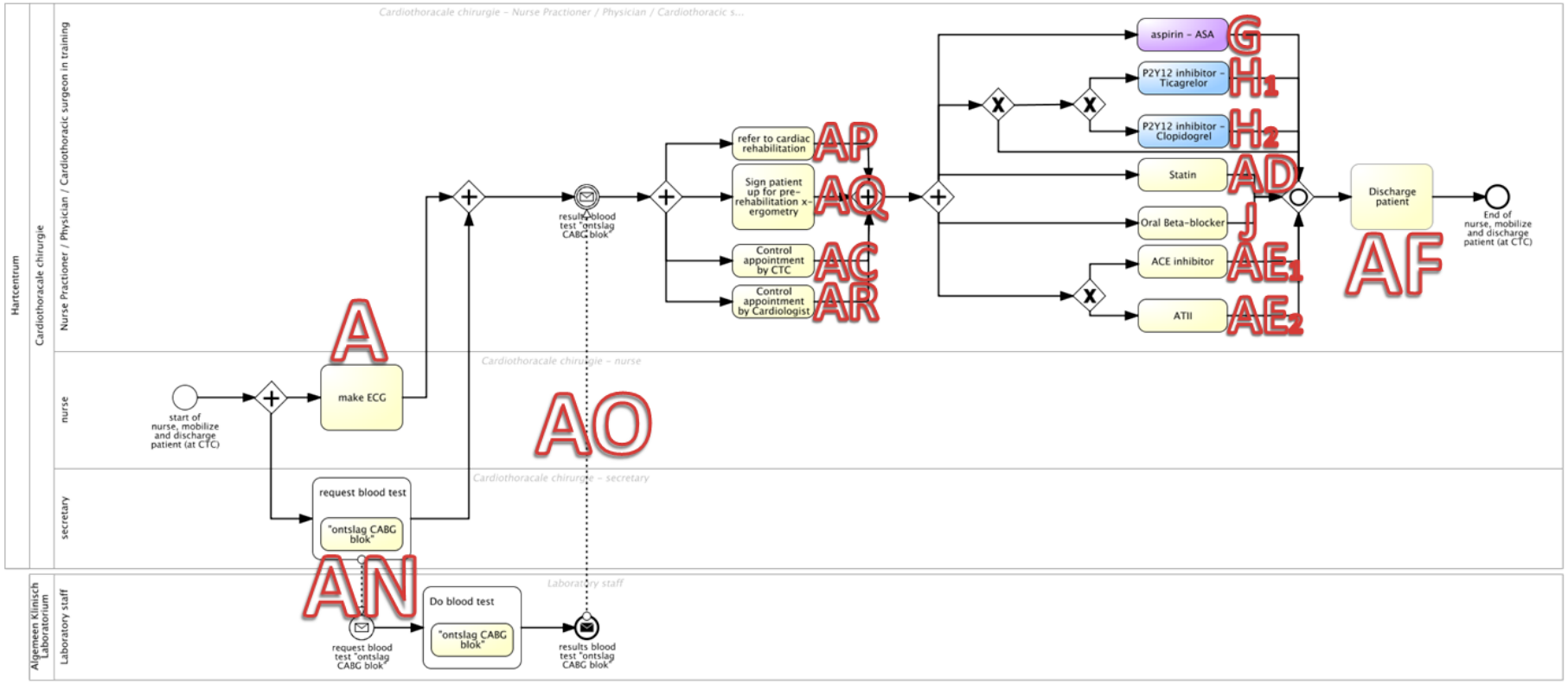


Figure 63 – Pattern of the discharge patient (at CTC) sub phase

APPENDIX M – MEASURES FOR TAM

		(Davis, 1989)	(Moody, 2003)
Perceived Usefulness	PU1	Using CHART-MASTER in my job would enable me to accomplish tasks more quickly.	I believe that this method would reduce the effort required to document large data models (Q2)
	PU2	Using CHART-MASTER would improve my job performance.	
	PU3	Using CHART-MASTER in my job would increase my productivity.	
	PU4	Using CHART-MASTER would enhance my effectiveness on the job.	Large data models represented using this method would be more difficult for users to understand (Q3) This method would make it easier for users to verify whether data models are correct (Q5) Overall, I found the method to be useful (Q7) Overall, I think this method is an improvement to the standard Entity Relationship Model (Q15)
	PU5	Using CHART-MASTER would make it easier to do my job.	Using this method would make it more difficult to maintain large data models (Q8) Using this method would make it easier to communicate large data models to end users (Q13)
	PU6	I would find CHART-MASTER useful in my job.	Overall, I think this method does not provide an effective solution to the problem of representing large data models (Q12)
Perceived Ease of Use	PEOU1	Learning to operate CHART-MASTER would be easy for me.	I found the procedure for applying the method complex and difficult to follow (Q1)
	PEOU2	**I** would find it easy to get CHART-MASTER to do what **I** want it to do.	Overall, I found the method difficult to use (Q4)
	PEOU3	My interaction with CHART-MASTER would be clear and understandable.	I found the method easy to learn (Q3) I found it difficult to apply the method to the example data model (Q9)
	PEOU4	I would find CHART-MASTER to be flexible to interact with.	
	PEOU5	It would be easy for me to become skilful at using CHART-MASTER.	I found the rules of the method clear and easy to understand (Q11)
	PEOU6	**I** would find CHART-MASTER easy to use.	I am not confident that I am now competent to apply this method in practice (Q14)
Intention to Use	ITU1 ITU2	Assuming CHART-MASTER would be available on my job, I predict that I will use it on regular basis in the future	I would definitely not use this method to document large Entity Relationship models (Q10) I intend to use this method in preference to the standard Entity Relationship Model if I have to work with large data models in the future (Q16)

Table 38 – Measures for Perceived Usefulness, Perceived Ease of Use and Intention to Use, adopted from (Davis, 1989; Moody, 2003)