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# Transforming Clinical Practice Guideline Usage Through the Use of a Clinical Decision Support System: An Explorative Study at the University Medical Centre Utrecht

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## Transforming Clinical Practice Guideline Usage Through the Use of a Clinical Decision Support System: An Explorative Study at the University Medical Centre Utrecht

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MATTHIJS BERKHOUT & PASCAL RAVESTEYN

**Abstract** Medical treatments require a lot of knowledge and skills. To safeguard the quality of healthcare in general, Clinical Practice Guidelines (CPG) are written. Different studies show that the quality of healthcare improves by using CPGs. Based on the advancements in IT, a CPG could best be supported through the use of a Clinical Decision Support System (CDSS). In this paper, we seek to transform the use of several CPGs with regards to anti-clotting medicine and treatments through the utilization of a CDSS at the University Medical Centre Utrecht (UMCU) in the Netherlands. Data analysis shows that many of the included CPGs overlap and that the utilization of a CDSS for the determination of anti-clotting medicine and treatments could result in more effective and efficient decision making. Additionally, during the validation of the CDSS, we derived the attitude of the stakeholders towards the use of a CPG in a pilot study comprising a CDSS and identified several success factors that should be taken into account when designing, validating, and implementing CPGs into CDSS.

**Keywords:** • Clinical Practice Guideline • Clinical Decision Support System • Medical Treatment • Healthcare •

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## 1 Introduction

Medical protocols are used by physicians as guidelines to perform a diagnosis and subsequently a treatment that fits that diagnosis. These protocols, also referred to as Clinical Practice Guidelines (CPGs), are defined and maintained by medical organizations such as hospitals, but also by national or international governing medical institutions. A CPG may offer specific instructions on which diagnostic or screening tests to use, how to provide medical or surgical services, the duration that patients should stay in a hospital, or regarding other details of clinical practice. These CPGs may contain overlapping content between different medical specialties. To help to determine the right decision for an accurate diagnosis, despite the redundancy (Alonso-Coello et al., 2010), it is possible to implement the different protocols into one Clinical Decision Support System (CDSS).

A CDSS can be described as the provision of the knowledge of clinical experts in combination with patient-related information in an information system (Chang et al., 2011). Medical knowledge and patient-related information combined are filtered and presented at the times necessary. These actions are performed to improve patient care by providing an accurate decision on what medicine and corresponding treatment to adhere to (Chang et al., 2011; Minutolo, Esposito, & De Pietro, 2012). Essentially, CPGs are an accumulation of rules with regards to diagnostics, medication and treatments, thus these rules can be programmed in a CDSS. This research paper will explore how the existing anti-clotting CPGs at the University Medical Centre Utrecht (UMCU) can be embedded into a knowledge model to be implemented in a CDSS to support decision making.

A similar study by Ozel, Bilge, Zayim, & Cengiz (2013) focused on the development and evaluation of a web-based CDSS that supports Intensive Care Unit providers in making decisions more efficient and effective. This particular study states that “The aim of the study was to develop a supportive web-based system which was constructed in line with the needs and preferences of intensive care physicians and evaluate its efficiency, effectiveness and usability” (Ozel, Bilge, Zayim, & Cengiz, 2013). In contrast to this study, the challenge addressed in this paper is the development of a CDSS containing eight CPGs, each from different specialties at the UMCU. Currently, when the diagnostic, medicine and treatment variables have to be determined for a patient, all involved specialties have to discuss the best course of action, based on their specific CPG.

To ensure that medical professionals with different specialties and backgrounds follow decision-making processes in a consistent manner, it is important that the different CPGs are combined (Alonso-Coello et al., 2010). A successful implementation of CPGs into a CDSS will provide stakeholders in medical processes with the ability to systematically make decisions in an effective manner, without the need to discuss medicine and treatment variables with each specialism. Furthermore, the utilization of a CDSS for decision making could result in a reduced error margin as the decisions supported can be

evaluated appropriately (Ozel et al., 2013). The evaluation of the output is important as it enables the CDSS to ‘learn’ to provide more accurate decision-support (Jiménez-Serrano, Tortajada, & García-Gómez, 2015). To ground our goal to develop a CDSS for the determination of anti-clotting medicine and treatment, the following research question is formulated;

RQ: “How can the available anti-clotting CPGs of the UMCU be combined into a CDSS with the aim to support decision making and increase adoption of the CDSS?”

The remainder of this paper is organized as follows: in section two the background and related work with regards to CPGs and CDSSs will be explored. Next, the research method is presented in section three. This is followed by section four in which the data collection and analysis are described. Finally, in section five the results of our study are presented and in section six we draw conclusions from our results followed by a discussion with regards to the research study conducted, after which we provide directions for future research.

## **2 Background and Related Work**

In literature, several definitions for a CPG exist. In our study, the following extensively cited definition from Field & Lohr (1990) will be used: “systematically developed statements to assist practitioner decisions about appropriate healthcare for specific clinical circumstances.” Since CPGs are developed and implemented in the clinical practice, it has shown a lot of potential for the improvement of the quality of the healthcare (Grol, 2001; Lugtenberg, Burgers, & Westert, 2009). The combination of scientific literature and evidence with insights from clinical experts form the basis for a CPG, usually published by national medical governing bodies, for example, the Dutch College of General Practitioners (NHG) or the American Institute of Medicine and are further specialized and instantiated per hospital. Based on this, recommendations are developed on specific clinical subjects. For example, a clinical subject (i.e. coronary heart disease) is given a score based on the insights from the clinical experts, the height of the total score determines what treatment is supposed to be given. The recommendation according to the score is always backed by scientific literature. These recommendations provide professionals working in healthcare guidance, whom in some cases don’t have the expertise required to effectively and/or efficiently determine medicine and treatment for a patient (Davis & Taylor-Vaisey, 1997). A couple of proven benefits that CPGs realize in the clinical domain are: 1) decision making on appropriate care for patients, 2) promote education and improvement of care processes, 3) reduce unwanted variation in the delivery of health care, and 4) help contain costs. Most of these positive attributes are similar with the benefits from CDSSs (Grol, 2001; Lugtenberg et al., 2009; Woolf, Grol, Hutchinson, Eccles, 1999). However, the utilization of CPGs also poses stakeholders with challenges like how to maintain CPGs so that state-of-the-art knowledge is guaranteed (Shekelle et al., 2001) and how to ensure the validity of its contents (Browman, 2000).

## 2.1 Implementation of CPGs

For a CPG to be effectively utilized, it needs a successful implementation. Multiple studies show that in some cases, after the dissemination of the CPGs, there is a lack of usage in the clinical practice (Cabana et al., 1999; Grol, 2001). A part of the problem is the lack of behavior change by the physicians, this is mostly caused by a lack of agreement with CPGs itself (Gravel, Légaré, & Graham, 2006; Members et al., 2017). The lack of agreement can be based on specific factors, for example, a lack of confidence in the author, or it can be based on the lack of agreement in general (Cabana et al., 1999). Other identified reasons for a failing implementation of CPGs can be the wrong distribution of the CPGs (Grol, 2001). Although these are serious concerns for the adoption and utilization of CPGs, two studies show that, in the Netherlands, a high acceptance and feasibility level is achieved for the development and implementation of CPGs (Grol, 2001; Lugtenberg et al., 2009).

Although CPGs help stakeholders in the diagnosis and treatment of diseases, another challenge exists. Most CPGs are printed on paper, which limits practical clinical use (Davis & Taylor-Vaisey, 1997). This is one of the reasons that Clinical Decision Support Systems (CDSSs) are developed (Lamy et al., 2010). The combination of the knowledge of clinical experts with patient-related information is filtered and presented by a CDSS when it is required. There are different sorts of CDSS archetypes. According to Power (2008) those are 1) Model-driven, 2) Data-driven, 3) Communication-driven, 4) Document-driven and 5) Knowledge-based CDSSs.

## 2.2 Clinical Decision Support Systems

Knowledge-based systems are used most and proved most efficient in the CDSSs setting (Sanchez et al., 2013). Knowledge-based systems hold knowledge about a (clinical) domain. In the (clinical) domain, this knowledge is the understanding of the problems and skills for solving these problems (Kalogeropoulos, Carson, & Collinson, 2003; Sanchez et al., 2013). Knowledge-based systems mostly use ontologies for structuring the knowledge. In this paper, we use ontologies that refer to an engineering artifact, as formulated by the popular work of (Guarino, 1998): “These are constituted by a specific vocabulary used to describe a certain reality, plus a set of explicit assumptions regarding the intended meaning of the vocabulary words. This set of assumptions has usually the form of a first-order logical theory, where vocabulary words appear as unary or binary predicate names, respectively called concepts and relations.”

Some of the benefits that CDSSs provide are: 1) Providing knowledge to medical professionals at appropriate time and manner, 2) Facilitating an efficient and effective decision making, 3) Reducing preventable medical errors, 4) Improving the overall quality of healthcare for patients and 5) Serving as a didactic tool for critical learning for medical students (Chang et al., 2011; Sanchez et al., 2013). Several studies have proven

that CDSSs improve the clinical practice and practitioner performance by respectively 64% and 68% (Garg et al., 2005; Kawamoto, Houlihan, Balas, & Lobach, 2005). A recent implementation of a web-based CDSS in an intensive care unit in Turkey shows that the CDSS significantly (positively) contributed in the accuracy of the decision-making by the physicians (Ozel et al., 2013). Although the time for making decisions wasn't reduced, this study did show that user satisfaction and usability were high. In two test scenarios, 150 questions were posed. In the first scenario, the participants needed to answer these questions without the support of a CDSS, in the second scenario, the CDSS supported the decision-making by the participants. Without the support of a CDSS, 24% of the answers were correct, with the support of a CDSS the number of correct answers increased significantly to 83.2%. Finally, the study states that there is a great need for research and development of CDSSs, especially in the Intensive Care Unit (ICU), since the ICU produces large volumes of data (Ozel et al., 2013).

Since the clinical environment is always developing and changing, the knowledge in CDSSs requires a high level of modifiability and maintainability. However, when changes are made in CPGs, it is hard to implement these in the CDSS. This is because it requires both the expertise of the clinical domain as well as the informatics domain (Lamy et al., 2010; Minutolo et al., 2012; Ozel et al., 2013). A possible solution for the problem is simplifying the manner in which knowledge can be modified within CDSSs. This particular functionality is referred to as knowledge editing. If this functionality is simplified in a way that requires less expertise in the informatics domain, adoption of the change process by clinical experts increases as it becomes more easy to modify the CDSS knowledge based on changes in CPGs. For example, this can be achieved with the visualization of the knowledge in schematic plans such as an event-based decision tree (Minutolo et al., 2012).

### 3 Study Design

To construct a CDSS and assess the value of the knowledge in the CDSS, a three-phase research design has been implemented. The first phase comprised the analysis of eight anti-clotting CPGs, followed by the construction of the actual knowledge in the CDSS. The second phase consisted of the validation of the content of the knowledge in the CDSS by a group of medical stakeholders at the UMCU. The third phase comprised the refinement based on the feedback that was received from the medical stakeholders, which was followed by another round of validation, but in an individual setting with the additional goal to evaluate the utilization of CPGs through a DSS.

An important factor in determining the appropriate research method to validate the CDSS is the maturity of the research field. In literature we identified several developments and trends regarding the use of DSS in a medical context, however, the research field of CPG usage through a DSS in the Dutch context, to the knowledge of the authors, is still nascent. According to Edmondson & Mcmanus (2007), the focus of research in nascent research

fields should be on identifying new constructs and establishing relationships between identified constructs. Therefore the construction of the consolidated anti-clotting CPG will be performed using a round of secondary data collection and analysis, consisting of documents regarding the eight anti-clotting CPGs available at the UMCU.

As our goal is to validate the CDSS and to explore the challenges related to the adoption of a CDSS at the UMCU, a wide range of possible ideas or solutions should be explored from different stakeholders. An adequate research method needs to be used to explore a broad range of possible ideas and/or solutions from a complex issue and combine them into one view when a lack of empirical evidence exists. In this light group-based research techniques are adequate (Delbecq & Van de Ven, 1971; Okoli & Pawlowski, 2004; Ono & Wedemeyer, 1994). Examples of group based techniques are Focus Groups, Delphi Studies, Brainstorming and the Nominal Group Technique. The main characteristic that differentiates these types of group-based research techniques from each other is the use of face-to-face versus non-face-to-face approaches. Both approaches have advantages and disadvantages, for example, in face-to-face meetings, provision of immediate feedback is possible. However, face-to-face meetings have restrictions with regard to the number of participants and the possible existence of group or peer pressure. To ground our research results and to eliminate the disadvantages, we combined the face-to-face and non-face-to-face technique by means of applying a focus group as well as individual semi-structured interviews.

#### **4 Data Collection & Analysis**

Data for this study is collected over a period of two months, between November 2016 and December 2016, through 1) secondary data analysis, 2) one round of validation utilizing a focus group session, and 3) one round of validation utilizing individual semi-structured interviews, see also Figure 1. All three methods of data collection and analysis are further discussed in the remainder of this section.

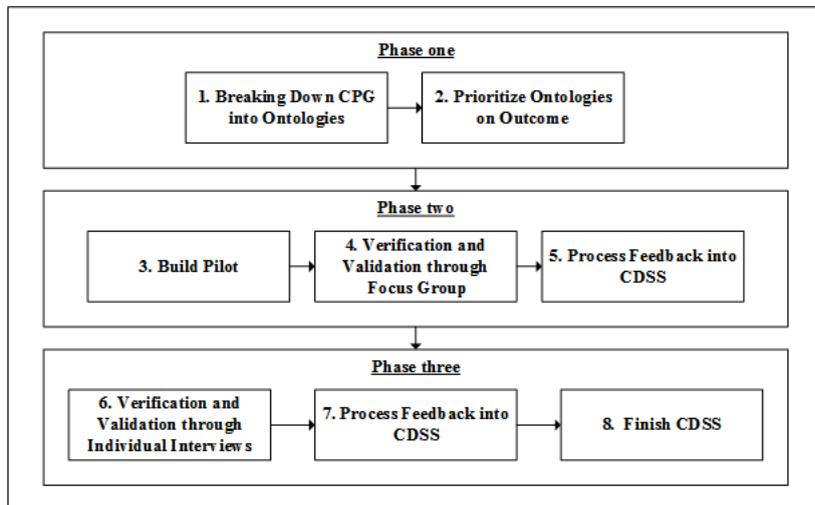


Figure 1: Development process overview

#### 4.1 Modeling of UMCU CPGs

In the first phase, the eight CPGs of UMCU had to be collected and transformed into ontologies to understand the process of a medical examination and to be able to model them in the CDSS pilot at the UMCU. One challenge was that the team of researchers, consisting out of three researchers with experience in knowledge modeling and three researchers with experience in the field of CDSSs, quickly came to the conclusion that the CPGs are predominantly textual documents that rarely visualize the process. The CPGs included in this study were: 1) Bridging Vitamin K Antagonists, 2) Direct Oral Anticoagulants, 3) Heparin-Induced Thrombocytopenia, 4) Unfractionated Herapine Use, 5) start Vitamine K Antagonists, 6) Profylaxe Venous Thromboembolism, 7) Venous Thromboembolism, and 8) Nerve and Neuraxial Blockade with Anticoagulant. The process of transformation of the CPGs into ontologies was conducted as a cyclic approach. First, the researchers with experience in knowledge modeling analyzed the secondary data and modeled the ontologies to be implemented. These ontologies were then submitted for review by the CDSS researchers. This process was repeated five times before the final CDSS pilot for validation in the focus group was established.

In order create the CDSS, eight CPGs were developed into a model. This model links ontologies collected from the CPGs in the pilot of the CDSS. To make sure that the modeling of the CPGs was performed adequately, the researchers started with the analysis and modeling of only one ontology, which was then validated by the CDSS researchers. When the first CPG was modeled and found valid, the knowledge modeling researchers started with the development of all CPGs involved and repeated the internal validation

process with the CDSS researchers. Based on the developed ontologies, the researchers had to analyze which of the ontologies was characterized by the highest uniqueness as the analysis resulted in overlapping rules and content in the included CPGs. Based on the analysis of the created ontologies, the hemorrhage risk ontology was found most unique and therefore the largest contributor to the determination of anti-clotting medicine and treatment. For this reason, we selected the hemorrhage risk ontology to serve as a basis for the creation of the ‘bridging’ ontology, which contained all decision knowledge from all ontologies to determine anti-clotting medicine and treatment at the UMCU. The ontologies were built using the Decision Support System of BeInformed, a supplier of (C)DSS. The output of the modeling phase was used to prepare and structure the validation of the ontology by means of the focus group session.

#### **4.2 Focus Group Validation**

Subsequently, to the modeling of the knowledge into the CDSS, the focus group session was prepared and conducted in December 2016; the session had a duration of one and a half hour in total. Before a focus group is conducted, first, a number of key design concepts need to be considered (Morgan, 1996): 1) the goal of the focus group, 2) the selection of participants, 3) the number of participants, 4) the selection of the facilitator, 5) the information recording facilities and 6) the protocol of the focus group.

The goal of the focus group was to validate the anti-clotting CDSS. Based on this, we selected eight participants. The selection was done in collaboration with the UMCU. The selection consisted of five specialized physicians, from which each one was responsible for one or more of the CPGs included. Furthermore, two pharmacists and one laboratory expert were involved. The focus group was chaired by an experienced facilitator, one of the CDSS research team members. Additionally, one knowledge modeling research member was present to take notes. As the contents of the ‘bridging’ ontology are confidential, the focus group meeting could not be captured via audio or video. Lastly, the protocol of the focus group was based on the CPGs modeled, which were presented one-by-one during the focus group session. This protocol provided each participant the opportunity to provide feedback per CPG.

The results from the focus groups were also utilized to get an impression of the attitude of stakeholders and challenges for stakeholders with regards to the use of a CDSS and develop a list of topics to address in the individual interviews. These particular questions were not posed during the focus group as it would allow for peer pressure amongst the participants, thus would be more appropriate during the semi-structured validation interviews.

### 4.3 Semi-Structured Interview Validation

After the focus group session was finished the researchers continued to refine the CDSS, for example, by changing the sequence of questions posed by the CDSS and the formulation of the questions. After this, the third phase of this study was conducted, comprising the semi-structured interviews with the same five physicians that participated in the focus group session in phase two. The main goal of the interviews was to validate the refined CDSS based on the feedback provided in the focus group validation session. Furthermore, based on the input of the participants in the focus group session, we managed to develop the following set of four topics that were discussed with each interviewee:

- Experiences with regards to the (personal) current use of CPGs
- Improvements with regards to the (personal) current use of CPGs
- Problems that are anticipated with regards to the use of a CDSS
- Significant features that should be included into the CDSS to promote adoption

As stated in subsection 4.2, each of the interviewed physicians was responsible for one or multiple CPGs. Furthermore, none of the participants had knowledge on what their co-workers had answered. The individual interviews were audiotaped and transcribed within 48 hours. The interview data was analyzed by linking and categorizing answers from the physicians. If several responses matched they were labeled by the researcher on perceived advantages and disadvantages with regards to working with a CDSS. This was then cross-checked by other researchers from the research team to ensure coding accuracy. This approach resulted in patterns with regards to the four topics that were addressed in the interviews.

## 5 Results

In this section, the results of the three phases executed in this study are reported. First, we present the results of the modeling phase, where we collected, analyzed and transformed the CPGs into ontologies to be implemented into the CDSS. This is followed by the results of the validation focus group session in which we validated the first version of the CDSS and used to prepare the semi-structured interviews. Lastly, the results of the interviews are presented that comprise the validation of the refined CDSS as well as an exploration of the experiences, problems, improvements and significant functionalities with regards to CPGs and CDSSs.

### 5.1 Modeling phase

The first and most complex CPG was transformed in an understandable way to model in the CDSS. The first step was to extract different ontologies from the CPG. Building rules

on top of those ontologies is a proven method to model medical knowledge (Minutolo et al., 2012). The hemorrhage risk showed to be the most important factor in determining which treatment should be started and therefore, the first ontology the research team started with. When the hemorrhage risk is known, a treatment could be prescribed. The ontologies modeled that comprised the vitamin K antagonist bridging CPG were as follows: 1) Specialism type, 2) Treatment type, 3) Action at anti-clotting treatment, 4) Indications, 5) Anti-clotting treatment Periopera, 6) Thromboembolic complication risk factor, 7) Hemorrhage risk and 8) CHA2DS2-VASc risk factor, see for an example Figure 2.

As stated above, the determination is mostly depended on the level of hemorrhage risk, i.e. whenever a type of surgical intervention depicts a certain risk level, which triggers a certain treatment, none of the other questions about other indications are posed.

In the final model, the surgical interventions were categorized in the different kinds of medical specialism. This resulted in a better overview in the first version of the CDSS. First, the medical specialism was posed, before showing the surgical interventions. As soon as the model behind the first version could make a decision based on the different ontologies included, the CDSS would stop posing questions with regards to possible indications and provides a treatment as a suggestion.

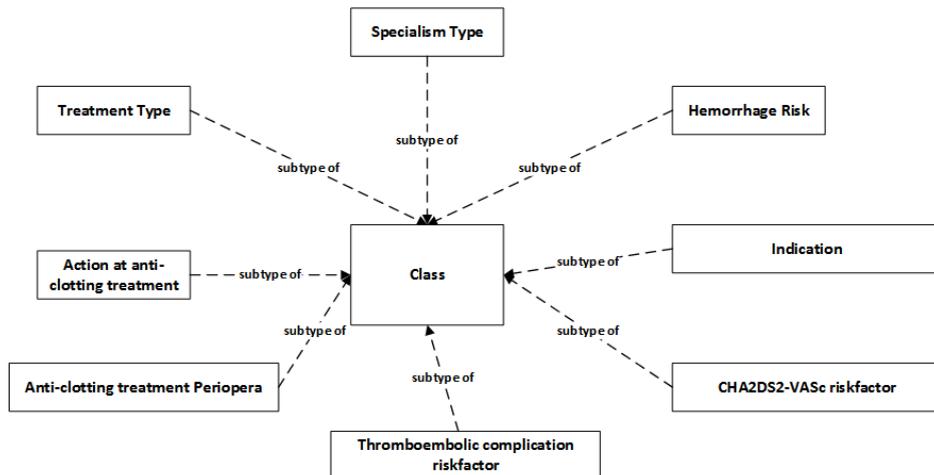


Figure 2: Example high-level excerpt from the vitamin K antagonist bridging CPG

## 5.2 Focus Group

The first version of the CDSS was presented to the hemorrhage risk commission, consisting of the hemorrhage-related CPG owners, of the UMCU. At this presentation, the bridging CPG was shown in the CDSS. The participants expressed mixed feelings about the first version, although it was predominantly positive feedback. Most of the positive feedback concerned the model-driven method of the CDSS. The participants acknowledged that this was a “powerful” method to overcome the complexity of the CPG. A large amount of feedback with regards to the CDSS was provided by the participants and noted by one of the researchers. This feedback comprised errors in the contents of the model. The feedback was used to refine the CDSS after the focus group session.

Another topic that was addressed during the focus group meeting was the possibility to store decisions made by physicians. It became clear that the focus group saw this as an opportunity to improve the CPGs. Whenever a physician would execute the CDSS and document his or her decision, statistics could provide or suggest which CPG needs alternation.

After the presentation of the first version of the ‘bridging’ CPG, the focus group had some input for the actual functionality of the CDSS. A clear majority of the focus group participants (five or more) addressed the need for an integration with the Personal Health Records (EPD) or at least an import of patient data from EPD, which also should eliminate the overlap between different CPGs.

One participant proclaimed that the CDSS would result in ‘cookbook’ medical care. This argument is in conformance with the results of a study about physicians barriers for utilizing CPGs. Cookbook medical care was labeled as a bad attitude against the CPG, showing a lack of agreement with guidelines in general (Cabana et al., 1999).

## 5.3 Semi-Structured Interviews

After the CDSS was refined by the research team based on the feedback acquired in the focus group session in phase two, the semi-structured interviews were conducted. With regards to the first goal, the final design of the CDSS was presented per interviewee. All interviewees provided feedback as part of the validation of the CDSS, which was processed after the third phase of data collection and analysis. The average duration of the interviews was one hour, consisting of 40 minutes for the second round of validation of the CDSS and 20 minutes for the additional topics on experiences, problems, improvements and essential functionality of the CDSS.

With regards to the second goal, four topics provided insights into the experiences and preferences of the physicians in using CPGs in a CDSS. In this subsection, we report on

our finding that was brought up or confirmed by the majority (three out of five) of the interviewees.

With regards to the first topic, the attitude of the current use of the CPGs, the majority claimed that the use of CPGs in the daily practice is an improvement of medical care. This amplifies the conclusion that CPGs are found to be successful in the Dutch clinical setting (Lugtenberg et al., 2009). The majority thought the CPGs, although improving medical care, are indistinct. They claimed this is a consequence of CPGs with a large amount of text. Also, the majority confirmed that the current CPGs are not always state-of-the-art when applied in practice.

Some improvements the participants addressed in using CPGs are discoverability, the amount of text and coverage. The majority would like to see that the discoverability of the CPGs is improved. The CPGs should be listed on the intranet, but should also be state-of-the-art when listed. Furthermore, the majority stated that large amounts of text should be prevented in CPGs, which aligns with the attitude of the use of CPGs. The majority also mentioned the need for improvement with regards to the existing amount of overlap between CPGs. Overlap in CPGs is a factor that increases the difficulty in maintaining the CPGs, because if one CPG changes, other CPGs get outdated instantly.

Next, we asked what challenges the participants would find in using a CDSS. The majority fear that the implementation of a CDSS will create a large dependency on IT. The interviewees stated that physicians do not want to be dependent on IT too much. Whether this is because of earlier failures of DSS or other IT-related influences remains unknown. Furthermore, the majority doubt the CDSS will be a user-friendly system.

Lastly, one particular property of a CDSS was deemed indispensable by the majority of the interviewees; linking to the CPGs that are available on the intranet. Such a construction will not replace how the CPG is used but merely simplify its use. We believe that this preference is caused by the low amount of trust that the interviewees have in a CDSS, specifically with regards to their requirement of state-of-the-art CPGs in the CDSS, which is not always safeguarded, even in the current paper practices at the UMCU.

## 6 Discussion & Conclusion

In this paper, we aimed to find an answer to the following question: “How can the available anti-clotting CPGs of the UMCU be combined into a CDSS with the aim to support decision making and increase adoption of the CDSS?” In this question, two subjects are of relevance; 1) How to combine different anti-clotting CPGs in a CDSS and 2) What do the physicians need to increase the likelihood that they will adopt the CDSS.

The data shown in section five shows that a majority of the physicians have uncertainties in the overlap of the various CPGs and the correctness when modifying versions. More

than half of the physicians indicated that large amounts of text should be avoided in CPGs. In addition, most of the physicians indicated the need for the CPGs to be available on the intranet, next to the CDSS. To merge the different anti-clotting CPGs in a CDSS, the current overlap must be eliminated and the physicians need a guarantee that the state-of-the-art versions will always be applied in the CDSS. Besides this, the CDSS needs to be available in the alignment of the current CPGs. This way, the CDSS will simplify the use of the CPGs but not replace them. From the collected and analyzed data gathered from the various CPG owners, we can conclude that the reactions towards the use of a CDSS are mostly positive. This enthusiasm shows that, despite the physician's doubts with regards to ease of use, they are open for the use of a CDSS and will be likely to adopt it, given the fact that most if not all challenges identified are overcome.

Taking a look at our study, several limitations could be identified. One limitation is the available time that was planned for the focus group and the individual interviews. With more time we probably could have delved deeper into the experiences, problems, improvements and essential functionality of a CDSS as perceived by our interviewees in more focus groups. However, this was hard to negate as the physicians stated to have meager time to participate in this kind of research projects and are needed in the UMCU most of their time. We aimed to negate this partly by interviewing the individual participants as this allowed for further data collection and validation without utilizing focus groups which allow multiple stakeholders to be available on the same time and place. Furthermore, our sample composition and sample size are limited to eight stakeholders. While we believe this is appropriate at this stage of design of a CDSS in the context of the UMCU, future research should focus on the utilization of more quantitative research methods such as surveys, using larger sample sizes to increase the generalizability of the results. Also, future stages of development should medical informatics specialists, which excel in extensive testing on the subject-matter as well as the decision making process by a CDSS. In this study, we included a sample of eight stakeholders, which is, according to the guidelines of Dworkin (2012), a valid amount of participants for a qualitative study. Therefore, an important note with regards to future research is that quantitative research methods are dependent on the actual implementation and (partly) adoption of the CDSS in practice. Hence, we encourage the UMCU to invest in further research projects to establish whether a CDSS contributes to the quality (in terms of efficiency and effectiveness) of healthcare.

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