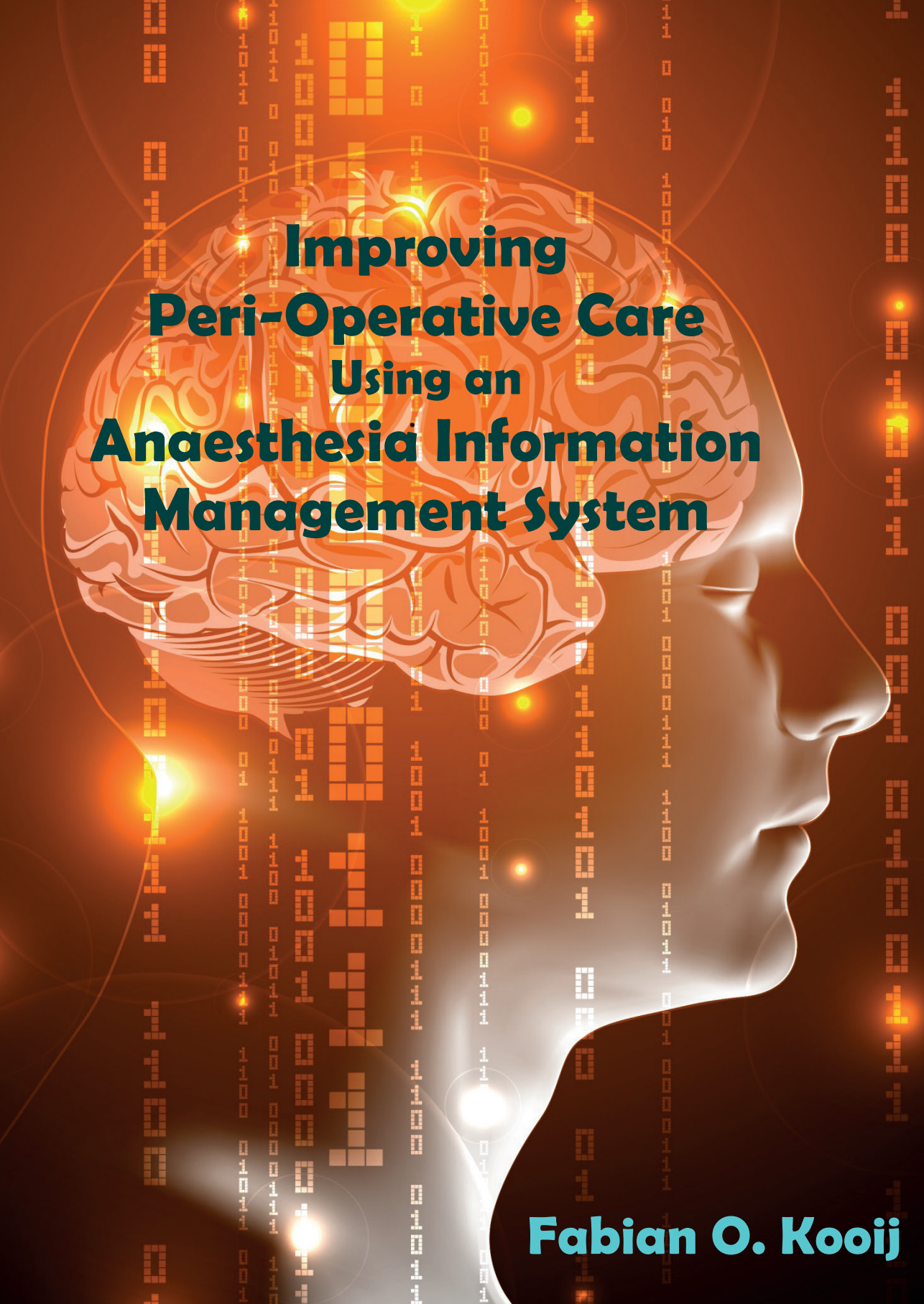
Improving Peri-Operative Care Using an Anaesthesia Information Management System



Fabian O. Kooij

Improving

Peri-operative Care

Using an

Anaesthesia Information

Management System

Fabian Kooij

Colofon

Improving Peri-Operative Care Using an Anaesthesia Information Management System.

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Improving Peri-Operative Care
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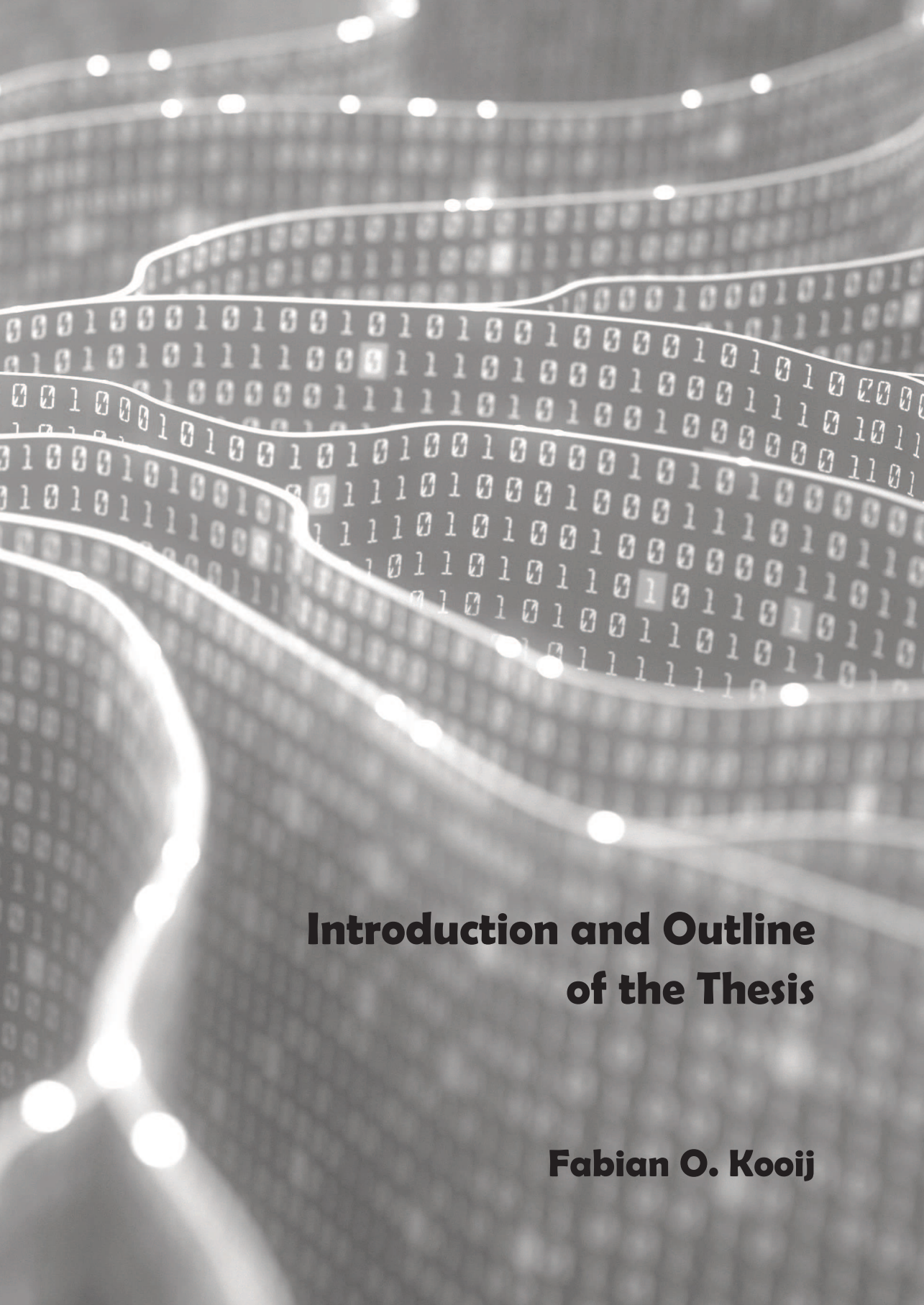


Introduction and Outline of the Thesis

Fabian O. Kooij

Background

Medicine is among the oldest fields of science and has been practiced and researched from as early on as the ancient Egyptian era.[1] Medical knowledge at first was very sparse and often based in theocratic foundations of the societies at the time.[2] Through the progressive expansion of knowledge, the science of medicine has made progress in the ability to increase health and life expectancy and the mortality rates of major diseases have steadily fallen. Much of this is based in interventions identified in scientific research and added to the medical knowledge, such as hygiene measures and antibiotics in infectious diseases, and improved antithrombotic drugs for peri-operative prevention of venous and pulmonary thrombo-embolism.[3-5] Over the last five decades however, the amount of new medical knowledge has expanded so extensively that it is now obviously impossible for any individual human being to have all medical knowledge available by heart.

The scientific methods, statistical methods and reporting have developed in such a way that critical appraisal of evidence has become increasingly challenging.[6] This in turn has led to several interventions that were initially heralded as a big improvement, but were repealed or much more nuanced subsequently. Illustrative of the ever more complex methodology, much of the discussion surrounding such issues is on methodology, statistics, biases and other details of study design and reporting.[7-9]

The expansions of medical knowledge, and increasing complexity of evaluating this knowledge for validity, have made decision making progressively more difficult. The problems with assimilating the ever growing stack of knowledge have translated to under-utilization of proven interventions as well as the application of interventions to patients for whom benefit and the higher risk of unwanted side effects may not be balanced.[10] To assist modern practitioners in this, numerous forms of knowledge aggregation, such as systematic reviews and

practice guidelines have been developed. Having a systematic review or evidence-based practice guideline available does not automatically guarantee an intervention's application in daily practice though.[11-13] This is not necessarily a problem, since practice guidelines rarely apply to 100% of patients, but in many situations adherence is lower than expected based on the patient characteristics.

Barriers for adherence to guidelines

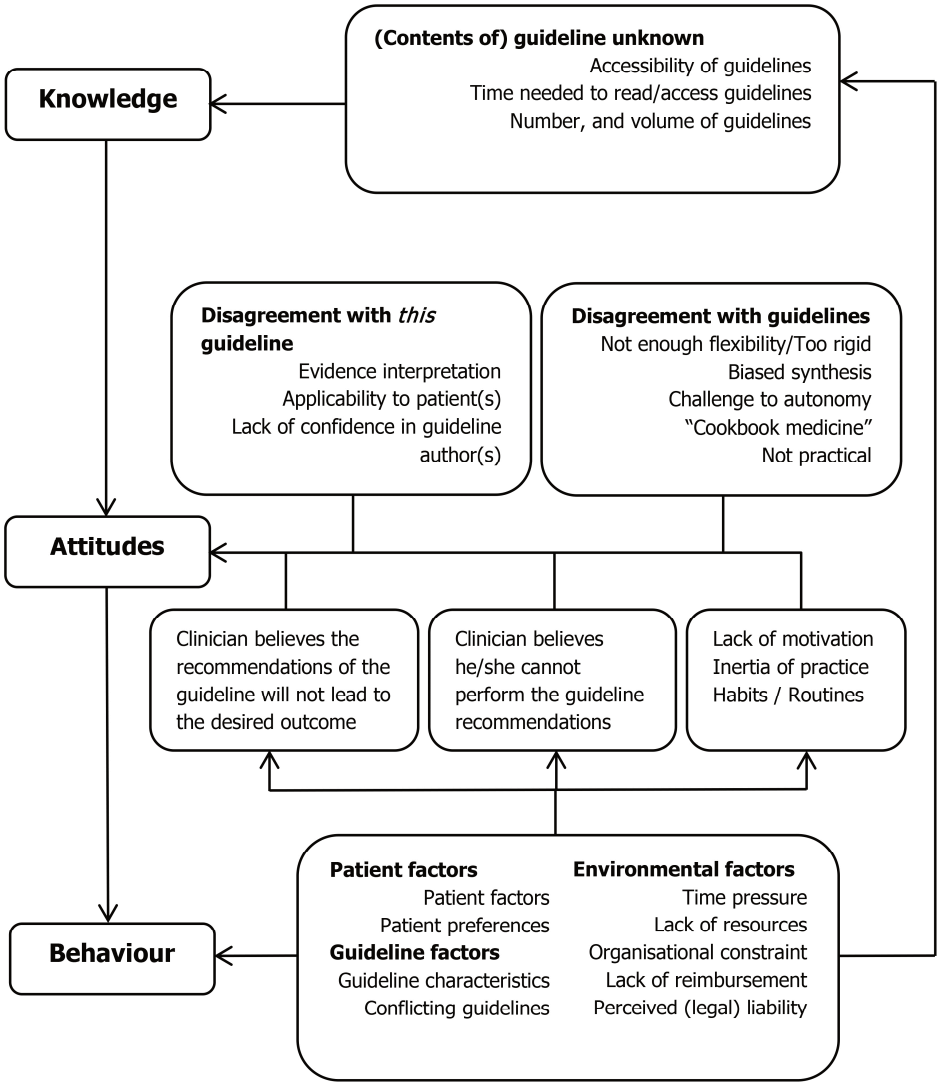
From implementation research, a number of barriers for the implementation of – and the adherence to guidelines have been identified.[11] Barriers can be found in several categories, such as access to knowledge (e.g. familiarity with the existence or contents of the guideline), lack of outcome expectancy (the clinician does not believe that the recommendation will lead to the desired outcome in a certain patient), attitudes (e.g. lack of agreement to the concept of guidelines), and in the system surrounding a practitioner (e.g. financial stimuli or the presence of contradictory guidelines). A summary of the barriers for guideline implementation and adherence is given in figure 1.1.[11]

Typically, during the implementation process, the two barriers that get most attention are knowledge and access to knowledge. The clinicians required to use the guideline get information on its existence and contents. They also receive information on where to find the guideline. It should be no surprise that if none of the other barriers summarized in figure 1.1 are addressed, the chances of a successful implementation are suboptimal.

Some of the barriers due to attitudes and beliefs can be very difficult to overcome. A negative attitude towards guidelines in general ("I am a medical specialist, I do not need a cookbook"), as well as inertia of previous practice ("I've done it my way for years and that has always worked") are two examples of attitude barriers.[11] Although decision support can help in establishing the concept of guidelines and evidence-based decision making, it cannot overcome barriers based in attitudes and beliefs by itself. In other words; decision support systems alone cannot create a positive attitude towards lifelong learning and a willingness to change behavior. Once that willingness is present, clinical decision support systems can actually facilitate to overcome other barriers, such as time pressure or number of guideline and frequency of updates. Barriers due to attitudes, and the underlying beliefs and

concerns, need to be addressed in a broader perspective by other interventions.

Figure 1.1: Why don't physicians follow practice guidelines?



Adapted from Cabana et al, JAMA 1999 282(5)

Forms of electronic decision support

The human brain is very inconsistent in systematic processing of data.[14,15] It is however excellent in association and quickly identifying outliers and rare or unlikely combinations of observations. Computers, on the other hand, are well known for their ability to process large amounts of data in a more reliable and consistent way than the human brain as long as the algorithms by which the data needs to be processed are clear. Several studies have shown that prediction algorithms are more reliable and consistent when compared to a human decision maker.[16-18] However, aversion to algorithms is deeply rooted and people have a strong preference for the natural over the artificial.[19] A common expert opinion is that the expert will outperform algorithms because they have more supplementary information and clinical skill. This may be true in select individual cases, but many top experts have now been defeated at their own field of expertise by a computer. The differences in strengths and weaknesses suggest that both the computer and the human brain could complement each other in making decisions.

Algorithms implemented in technological devices already provide us with many different instances of decision support in everyday life. Reliance on algorithms (in the form of guidelines) in medical practice is less easily endorsed due to the difference in emotional intensity between human error and algorithmic error. It is often perceived that an algorithm would need to be flawless. In reality, the algorithm should merely be better than the human decision makers on the same subject. Although algorithms are increasingly used in medicine, they almost always have an option for a practitioner to override the suggestion by the algorithm with a human judgment instead.

When relating decision support to the barriers for adherence, most of the barriers summarized by Cabana et al. can be addressed and (partially) overcome by decision support.[11] The potency for overcoming any of these barriers depends on the exact specifications of the decision support system. For optimal performance on most barriers mentioned

above, a decision support system would automatically present an actionable, evidence-based recommendation which pertains to the decision being made at that time.[20] In particular, there is a strong association between automatic activation and effect.[20,21] It is therefore not surprising that as soon as medical data was stored in computer databases, the first attempts were made to leverage that data towards decision support.[22]

Decision support has evolved rapidly due to technological developments and wide implementation and use of Electronic Medical Record (EMR) systems. Hence, clinical decision support systems are becoming an inevitable element of modern medicine. A summary of different decision support systems and their properties is given in table 1.1. The electronic forms are discussed below.

Table 1.1: Decision support systems and their properties

	Guidelines	Checklists	Cognitive aids	Smart checklists	Automated reminders
Automated activation	-	-	-	+	++
Patient specific	-/+	-/+	-/+	++	++
Actionable advice	+	-/+	+	-/+	++
Related to decision?	-	-/+	-/+	-/+	++
Over rideable	++	++	++	+	-/+
Integration in workflow	-	-/+	-/+	+	++
Automated feedback	-	-	-	-/+	-/+

Knowledge bases

Medical best practice highly relies on the utilization of large stores of knowledge.[23,24] Knowledge bases are databases that provide aggregated knowledge for specific clinical situations. A knowledge base in in many ways the electronic counterpart of a practice guideline or a textbook. Knowledge bases supply prompt access to information that is supposedly thorough, accurate and relevant. The task of maintaining a knowledge base can be challenging at best however. This means that the information provided may be outdated or not appraised and interpreted entirely correct. Moreover, the information provided applies to a clinical situation, which may or may not apply to the current patient. Finally, the clinician needs to carry out an active search in order to retrieve information from a knowledge base.[25-27] Although not a very powerful decision support system in itself, the information provided by knowledge bases can be leveraged to drive more powerful and invasive decision support systems.

Education and feedback

Education makes clinicians aware of and familiar with guidelines. Feedback provides clinicians with knowledge about their own performance and outcomes of practice. Assuming the will to improve is present, these make for effective strategies. However, in a non-electronic setting, aggregating data and creating feedback reports is very time intensive work and the effort usually outweighs the benefit.

Providing continued feedback in an electronic setting may also have unintended consequences. Frenzel et al. provided feedback and education, using compliance to a guideline for postoperative nausea and vomiting (PONV) prophylaxis, as their metric.[28] They report rather poor guideline compliance on baseline behavior (55% of prophylaxis indicated was given). Although a single didactic session, combined with feedback of personal performance data, led to an improvement of compliance (59 – 65%), the effect is not as big as one might hope for. Moreover, the

authors report on a steep increase in overtreatment of patients (from 13 to 25%).

Smart checklists

Smart (or automated) checklists are an electronic variety of normal checklists and overcome a number of the disadvantages of paper checklists. A smart checklist is able to check the patient's file for documentation suggesting that an item on the list was indeed completed. For example, when a certain lab value is required pre-operatively, a smart checklist can automatically find the actual result and show that next to the checklist item.

Smart checklists can be implemented in several situations, such as computer-assisted diagnostic approaches[29,30] and peri-operative care.[31] Smart checklist can also request a reason for not completing one of the items on the list, which has been identified as a positive influence on clinical practice and guideline adherence.[20] By adding logical rules to a smart checklist, the items on the checklist and their content (for example the type of antibiotic indicated for the situation) could also be modified based on data in the EMR.[32]

The added functionality and automated activation of smart checklists address several of the barriers that paper checklists cannot. Smart checklist have the ability to be case-specific, can be used to drive workflow instead, and can actively request for a clinician to complete the checklists items or provide a reason for not doing so.

Automated reminders

Automated reminders are both the most invasive type as well as the most potent type of decision support tools available. They are believed to be most compatible with strained workload and high time-pressure environments when it comes to augmenting decision making. Using a pre-programmed set of rules this system integrates all information available from an EMR, as well as from a predefined knowledge base in near real time. Based on these rules, the system checks whether a specific guideline is applicable and whether the recommendations from

the guideline were applied. If necessary, the system shows a reminder message. Automated reminder systems can provide instant patient and situation specific feedback to the user. The major advantage of this type of decision support is that clinicians do not need to perform any particular action and are actively reminded of knowledge and data that they did not think about during the decision process.

To realize automated reminders in clinical practice, a system is required that consists of three components: as much discrete and granular patient information as possible, a model that analyses this data, and an interface for collecting data as well as display automated recommendations in clinician workflow.[33] In a peri-operative setting, Anesthesia Information Management Systems (AIMS) measure, store, query and recall peri-operative vital signs, medication administration and events, creating a pool of real-time patient parameters that can be analyzed by a pre-programmed set of rules.[34] An AIMS linked to- or integrated in a broader EMR also has access to more general patient information (such as allergies, medical history, co-morbidities and previous events). This augments the versatility and reliability of the system by enhancing the amount of data available and forms a potent platform for automated reminders.

Effectiveness of reminders has been studied on several aspects with mixed results. One study reports on a rather poor baseline compliance (12%) with the prophylactic antibiotic re-dosing for prolonged surgery guideline.[35] Using a basic 'time-triggered' reminder (always remind users at 3 hours) and a reminder based on actual case data. Although both reminders improved guideline adherence, the effect of data based reminder was larger than that of the time triggered reminder (84 vs 63% adequate re-dosing).

In another study, the authors demonstrated an increase in correct execution of preventive therapies (such as pneumococcal vaccination and prophylactic aspirin) due to integrated automated reminders in a computerized physician order entry system.[36] Reminders to order a

specific drug were generated if, based upon medical record, a patient matched the guideline criteria and the drug was not already ordered. Moreover, preventive medication could be ordered in the same display by executing a prewritten order, requiring no further action, which is also believed to be a property increasing effect.[20]

Besides careful design, thoughtful implementation of automated reminder systems is crucial for maximum effect. During implementation, alert fatigue is an evident cause of reminder ignorance that needs to be addressed. However, as with any set of rules or diagnostic test, preventing false positive messages is associated with more false negatives which for a reminder system would translate to not generating a reminder message when it actually should have been generated.

The timing of the reminder is also an important determinant of effectiveness. As the intended purpose and the importance of reminder messages can vary, their timing should vary. For example, a reminder message for something that does not necessarily need to happen instantaneous can be programmed to track the activities of the user and provide reminders at the least intrusive time. Conversely, a reminder signaling a potential crisis event should appear immediately and unrelated to activities. Reminders occurring at fixed times (e.g. logging in to the EMR or opening a patient file) are easiest to program but also most prone to result in false positive messages. Triggering reminders from documented actions and adding a so called "grace period" (a delay), decreases the amount of reminders for actions that users would also have performed without the reminder message.[37]

Goal and outline of this thesis

This thesis investigates a reminder system and intends to form a proof of the concept that decision support, using patient and situation specific automated reminders, can actually improve patient outcome. The research in this thesis was planned and executed within the scope of a guideline implementation process. Due to the broad applicability and relevance, we decided on the departmental guideline for postoperative nausea and vomiting (PONV) for our research.

We started with an extensive implementation process which included educational sessions, discussions on the underlying evidence and a Delphi process in which all clinicians were expected to contribute and consent was eventually reached. This resulted in an evidence based, generally accepted PONV guideline that formed the basis of our studies. According to this guideline, risk assessment is done using four risk factors: female sex, non-smoking status, previous PONV or motion sickness and expected postoperative opioid use. A patient would be arbitrarily labeled "high risk" when three or four positive risk factors were present and would then be eligible for prophylaxis using dexamethasone 4 mg iv upon induction and 1 mg of granisetron before emergence. We developed automated reminder to support every decision step of this evidence-based guideline (prescribing, administering upon induction and administering upon emergence) and measured the effect on clinician behavior and patient outcome.

The studies were all planned to investigate one aspect of our guideline. There were three decision points in the guideline; the first was the identification of high-risk patients and ordering of PONV prophylaxis in the pre-operative screening clinic. The second decision was to administer dexamethasone during or just after induction of anesthesia and the third decision to administer granisetron upon emergence. Chapter 2 and chapter 3 report on two studies that evaluated clinician performance at these decisions with and without automated reminders.

As mentioned in the introduction, not all reasons for adherence are amenable through automated reminders. Both the reminders for ordering PONV prophylaxis as well as the reminders for the administration of PONV prophylaxis were extended with a second reminder requesting a reason for not following the recommendation (if applicable). This study is reported in chapter 4.

All aspects of the guideline had now been investigated and we expected to have found a significant improvement in clinician behavior with regard to this guideline. The next step would be the final step; does the improved clinician behavior eventually lead to less PONV for our patients? In chapter 5, we report a prospective cohort study that included independent PONV assessment up to 24 – 48 hour post-surgery.

Finally, chapter 6 reports on a study that employs a negative reminder; a reminder that discourages an action. Many reminder systems are set up to promote certain actions. This study was set up to investigate whether discouraging an action would actually work in a similar manner. The automated reminders in this study discouraged diclofenac prescription for patients with one or more contra-indications.

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CHAPTER 2

Decision Support Increases Guideline Adherence for Prescribing PONV Prophylaxis

Fabian O. Kooij, Toni Klok,
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Anesthesia & Analgesia
2008; 106 (3): 893 – 898

Abstract

Background

Guidelines for PONV prevention are implemented widely but their effectiveness may be limited by poor adherence. We hypothesize that the use of an electronic decision support system will significantly improve guideline adherence.

Methods

Medical information of all patients undergoing elective surgery in our regional teaching hospital is routinely entered in an Anesthesia Information Management System (AIMS) at the preoperative screening clinic. Our departmental PONV prevention guideline identifies patients as "high-risk" and thus eligible for PONV prophylaxis based on the presence of at least three of the following risk factors: female gender, previous history of PONV or motion sickness, non-smoker status, and anticipated use of postoperative opioids. Using automated reminders, we studied the effect of decision support on guideline adherence using an off-on-off design. In these three study periods, we queried for all consecutive patients visiting the preoperative screening clinic that were eligible for PONV prophylaxis and studied how often it was prescribed correctly.

Results

Between November 2005 and June 2006, 1340, 2715 and 1035 patients were included in the control, decision support (DS) and post-DS periods, respectively. As a result of mandatory data entry of risk factors, the percentage of high-risk PONV patients increased from 28% in the control period to 32% and 31% in the DS and post-DS periods, respectively. During the control period, 38% of all high-risk patients were prescribed PONV prophylaxis. This increased to 73% during the DS period and decreased to 37% in the post-DS period.

Conclusion

Electronic decision support increases guideline adherence for the prescription of PONV prophylaxis in high-risk PONV patients.

Introduction

In recent years, several studies have identified risk factors and developed risk models to predict which patients are at risk for post-operative nausea and vomiting (PONV).[1-6] Guidelines have been suggested for the prevention and treatment of PONV acknowledging the importance of the problem.[7]

However, the effectiveness of a clinical guideline may be limited severely by poor adherence.[8,9] There may be guideline-related, physician-related and/or external reasons for poor guideline adherence.[8] Reasons for poor guideline adherence might include lack of attention by the attending physician responsible for the preoperative assessment of the patient. This may be overcome with the use of a decision support system that reminds the physician of the action suggested by the guideline at the time and place of care.[10]

Recent advances in peri-operative care include the introduction of Anesthesia Information Management Systems (AIMS) that may prompt users to take action according to guidelines based on real time patient data, i.e. decision support systems. Relatively few studies focusing on decision support in anesthesiology and critical care have been conducted.[11,12] We hypothesize that a decision support system can significantly improve guideline adherence for the prescription of PONV prophylaxis in a preoperative screening clinic.

Methods

For identification of patients at high risk for PONV, we used the simplified risk score based on the risk stratification by Apfel and co-workers.[1,13] This risk score uses four risk factors: female gender, history of PONV or motion sickness, non-smoking status, and post-operative opioid use. According to this model 56 – 61% of the patients are expected to experience PONV in the presence of at least three positive risk factors.[1,14] Since it is not clear how to predict postoperative opioid use preoperatively, we have linked this risk factor to the type of admission, assuming that scheduled day care patients were expected not to receive opioids in contrast to clinical patients that were expected to receive opioids. Our departmental guideline dictated that in the presence of three or four positive risk factors, it was indicated to prescribe PONV prophylaxis, which consisted of dexamethasone 8 mg IV upon induction of general anesthesia and granisetron 1 mg IV shortly before awakening. This guideline was discussed with – and accorded by all anesthesiologists. To implement the guideline, meetings with the whole staff (nurses, nurse practitioners and anesthesiologists) screening patients pre-operatively were held. These meetings contained information about the guideline, the evidence supporting it and the expected change in patient care resulting from this guideline. All meetings were held at least two weeks before the first study period began.

This study was conducted in the pre-operative screening clinic of a regional teaching hospital in Amsterdam, The Netherlands. In this outpatient clinic, an anesthesiologist screens all patients scheduled for elective surgery preoperatively before the admission for surgery. During this visit, the anesthesiologist plans the anesthetic technique, prescribes the premedication for the day of surgery and decides on the indication for any prophylactic medication, such as PONV prophylaxis. This information is entered in an AIMS (Metavision®; iMDSoft, Tel Aviv, Israel). No patient data is stored primarily on paper. In the pre-

operative screening department, a workstation is available in all screening offices and in the 12-room OR complex, all anesthesia machines are equipped with an AIMS workstation.

The decision support system consisted of an automated reminder based on Apfel's simplified risk score.[1] To reliably calculate a simplified risk score for every patient being screened, recording data for all risk factors (gender, smoking status, history of PONV or motion sickness, post-operative opioid use) was made mandatory within the computer program. We programmed the system to remind the anesthesiologist of the indication for PONV prophylaxis if three or four risk factors were positive, general anesthesia was scheduled, and only in case PONV prophylaxis had not been prescribed yet. Thus, if all of the conditions mentioned above had been met, the system created a message stating: "*This patient has at least three positive risk factors for PONV and is eligible for PONV prophylaxis, but is not prescribed prophylaxis yet. Do you want to prescribe PONV prophylaxis?*" This message appeared instantaneously after selecting 'general anesthesia' as the preferred anesthesia technique. The system prompted the user for a response to the message (either negative or affirmative). Consequently, the anesthesiologist was never forced to adhere to the guideline; he or she was only reminded of it in eligible patients.

All consecutive patients visiting the pre-operative screening department, with the exception of patients scheduled for cardiac surgery were included.

The study was divided into three study periods, each lasting for 8 or 16 weeks and was set-up according to an off-on-off design. By using this design, both learning effects and bias from conducting a study (as opposed to common practice) can be separated from the effects of a decision support system. During the first eight-week study period (control period), PONV prophylaxis was managed according to the paper version of the guideline. No reminders were used, as our goal was to interfere with normal practice as little as possible. During the 16-week

decision support period, the automated reminders as described above were activated. After de-activating the automated reminders, the post decision support period was managed with only the paper guideline again, for another eight weeks.

After completion of all study periods, the relevant data fields were extracted from the database by pre-written scripts. The primary endpoint of our study was guideline adherence. All patients eligible for prophylaxis based on three or more positive risk factors were identified and the percentage of those that had prophylaxis scheduled was calculated for all three periods. Confidence intervals were calculated and, where appropriate, chi square tests were used to identify differences between the three time periods.

As secondary endpoint, we used the percentage of patients that was identified to be at high risk to develop PONV.

To identify learning effects within the three study periods, we stratified the study population into one-week time periods. We repeated the analysis for those subgroups.

Results

Between November 2005 and June 2006, 5090 consecutive patients were included in the study: 1340 patients in the control period and 2715 and 1035 patients in the decision support and post decision support periods, respectively.

Basic demographics and incidence of risk factors for the three study periods are shown in table 2.1. Patient characteristics were distributed equally across the periods.

The percentage of patients with three or four positive risk factors increased from 28% (95% CI: 25 – 30%) in the control period to 32% (95% CI: 30 – 34%) during decision support and remained at 31% (95% CI: 28 – 34%) in the post decision support period.

Off all patients eligible for PONV prophylaxis, the percentage of patients who were prescribed prophylaxis increased from 38% (95% CI: 33 – 42%) in the control period to 73% (95% CI: 70 – 76%) in the decision support period. After the decision support had been de-activated, this percentage decreased to 37% (95% CI: 32 – 42%).

The prescription of PONV prophylaxis not according to the guideline, i.e. to patients with two or less positive risk factors, remained unchanged for all study periods (table 2.2).

We studied the presence of a possible learning effect within the three study periods by analyzing the one-week subgroups. As shown in figure 2.1, guideline adherence (prescription behavior) was similar within each study period. The increase in guideline adherence was immediate and complete after introduction of the automated reminders in week 9. After discontinuation in week 24, guideline adherence returned to control levels immediately.

Table 2.1: Demographics and risk factors for PONV

		Pre-control	Decision support	Post-control	Significance
Number of patients (N)		1340	2715	1035	
Age, mean (SD)		52 (15)	52 (15)	53 (15)	NS
Female gender (%)		57	57	56	NS
Smoking (%)		29	33	31	NS
History of PONV or MS (%)		23	23	20	NS
Expected opioid use (%)		55	53	58	NS
High-risk (≥ 3 RF) patients (%)		28	32	31	P = 0.022
ASA class N (%)	**I**	737 (55)	1448 (53)	536 (52)	
	II	526 (40)	1095 (40)	411 (40)	
	III	74 (5)	160 (6)	80 (8)	
	IV	3 (0)	11 (0)	8 (1)	
	V	0 (0)	1 (0)	0 (0)	NS

ASA: American Society of Anesthesiologists

PONV: Post-Operative Nausea and Vomiting, MS: Motion Sickness,

NS: Not Significant, RF: Risk Factor

Table 2.2 Scheduling PONV prophylaxis

	Pre-Control	Decision support	Post-Control	Significance
Prophylaxis indicated	373 (100)	871 (100)	321 (100)	
Prophylaxis prescribed?				
Yes	**140 (38)**	**632 (73)**	**119 (37)**	P < 0.001
No	233 (62)	239 (27)	202 (63)	
Total number of patients	1340	2715	1035	
Total prescribed	216 (16)	819 (30)	195 (19)	
Correctly	140 (10)	632 (23)	119 (12)	
Without indication	**76 (6)**	**187 (7)**	**76 (7)**	NS

Data are presented as N (%)

DS: Decision Support; NS: Not Significant

To study the effect of decision support on prescription behavior of the anesthesiologists, we analyzed the percentage of high-risk patients with prophylaxis prescribed for each anesthesiologist for the three study periods. The number of patients screened by each anesthesiologist was comparable per period. The percentages are shown in figure 2.2, which shows that all anesthesiologist except one follow a similar pattern of guideline adherence. In general, guideline adherence increases after introduction of decision support and decreases back to control levels after cessation of decision support.

Figure 2.1: Week by week analysis of all high-risk patients. The bars show the percentage of high-risk patients getting PONV prophylaxis prescribed.

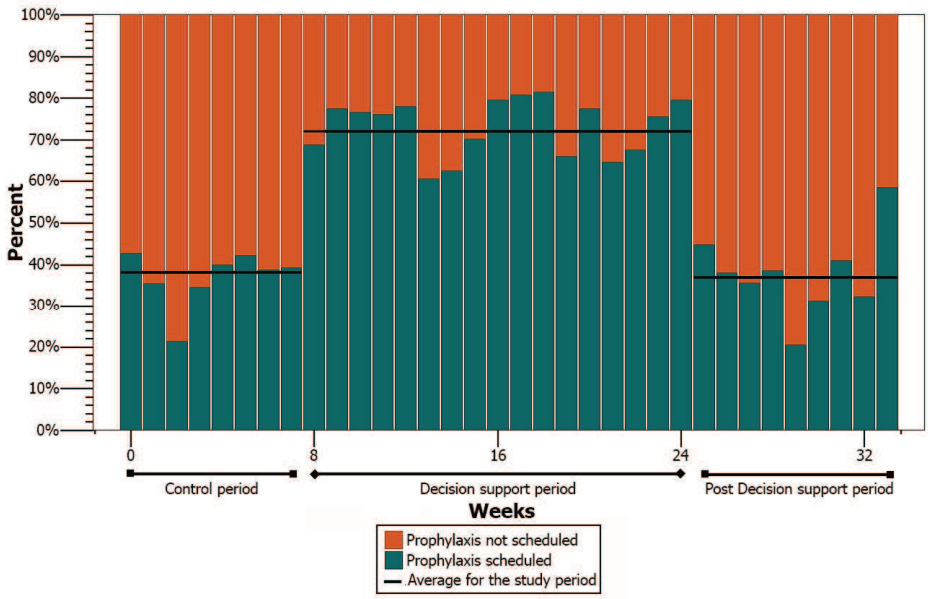
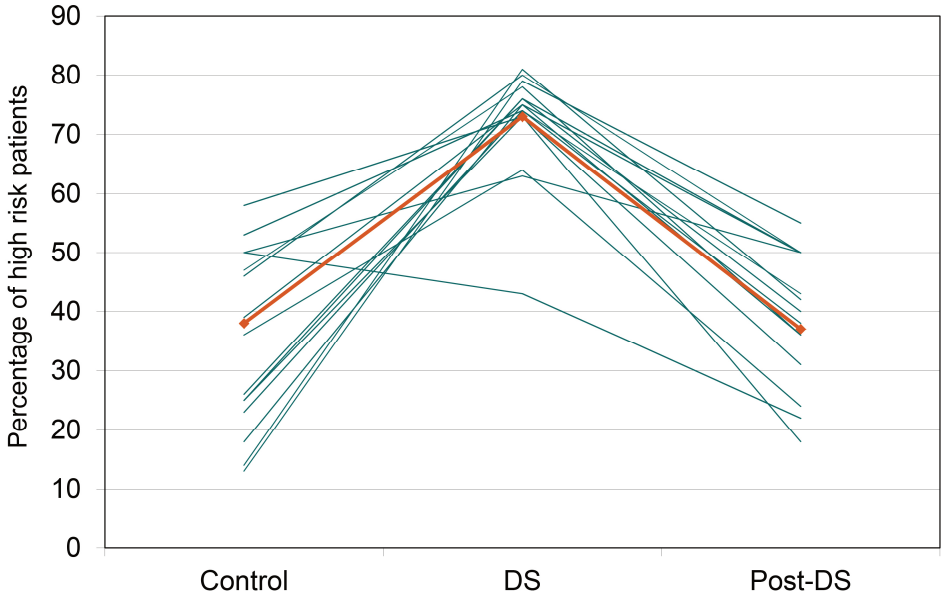


Figure 2.2 Guideline adherence per anesthesiologist. Shown is the percentage of high-risk patients that was prescribed PONV prophylaxis by each individual anesthesiologist. The orange line (marked ◆) is the overall average (DS: decision support)



Discussion

We demonstrated that an electronic decision support system significantly improved guideline adherence for the prescription of PONV prophylaxis in the preoperative screening clinic. However, after withdrawal of the decision support system guideline adherence decreased to control levels again. In addition, we demonstrated that identification of patients at high risk for PONV could be increased significantly by making the risk factor data mandatory.

For the current study, we used Apfel´s simplified risk score for PONV, because this score combines adequate discriminative power with ease of use.[1,13,14] The incidence of the four risk factors used in this risk score (female gender, non-smoking status, previous history of PONV or motion sickness and post-operative opioid use) has varied considerably between the studies published previously. In the present study, the percentage of identified high-risk PONV patients (three or four positive risk factors) was 31%. This appears to be slightly less than the ± 40% incidence of high-risk patients found in the original study by Apfel and coworkers.[1,14] The lower percentage of non-smoking patients and the relatively low incidence of a positive history for PONV or motion sickness in our study presumably accounted for this difference.

The present study is in agreement with earlier reports showing that decision support at the time and place of care may constitute an effective option for helping physicians adhere to a certain guideline.[8,11,15] The increasing use of electronic file systems for medical information, like an AIMS, greatly increases our opportunities to use decision support for quality improvement in clinical care. However, for maximum effect, a decision support system must "present the right information, in the right format, at the right time, without requiring special effort".[16] Our patient specific decision support system is unique within the field of anesthesia to actively select patients that are at high risk for a certain complication (i.e. PONV), verify the scheduled anesthesia technique (i.e. general anesthesia), and only interfere with normal workflow if a guideline

violation is impending (i.e. no PONV prophylaxis scheduled in high risk PONV patients scheduled for general anesthesia). This is in contrast to a system reminding the physician of a guideline in every single case, which may be inappropriate. As an alternative, we could have included the reminder for PONV prophylaxis in a checklist in analogy to a recently published study by O'Reilly and coworkers. They reported an increase in the timely administration of prophylactic antibiotics as a result of a reminder in a checklist.[12] Although the guideline-reminder studied by O'Reilly could very well be suited for inclusion in a checklist since it was applicable to the majority of patients, such a checklist may not be the most suitable method for decision support on PONV prophylaxis since only 30% of all patients are eligible for PONV prophylaxis. In fact, a guideline reminder for every single case may cause an abundance of unnecessary reminders, which may undermine the confidence of the user in the decision support system and may give rise to unnecessary annoyance. Therefore, the optimal method of decision support may depend on the guideline and on the percentage of eligible patients involved.

Even in the presence of decision support, a number of high-risk patients remained in which no PONV prophylaxis was prescribed. The reasons for this residual non-adherence are not known and were beyond the scope of the present study. One might suggest that lack of computer skills or hidden disagreement with the guideline may have played a role in the residual non-adherence. However, the percentage of patients that qualified for PONV prophylaxis but did not receive a correct prescription was comparable for all anesthesiologists except one, suggesting that these factors did not play a major role (figure 2.2).

Another explanation for non-adherence may be related to the incidence of the intervention that is dictated by a guideline. For example, billing needs to be done on every single patient and antibiotic prophylaxis has to be administered in almost every patient.[12,17] Therefore, these actions may become part of the routine for every

patient. In contrast, PONV prophylaxis is indicated only in about one third of patients and therefore may not become part of this routine. We speculate that the difference in incidence may have an effect on the maximum level of guideline adherence that can be achieved.

The importance of the multifactorial reasons for non-adherence is illustrated by the fact that the increase in guideline adherence following the implementation of decision support has varied considerably between studies reported earlier. In a general population of hospitalized patients, Dexter and coworkers showed that with the use of automated reminders, the prescription of subcutaneous heparin for prevention of thrombotic complications increased from 19 to 33%.[15] Even though this is a significant improvement, it implies that the majority of patients (67%) eligible for preventive subcutaneous heparin did not receive the medication. In the study by O'Reilly et al mentioned before, correct prophylactic administration of antibiotics within 1 hour from incision increased from 62% to 92% over a one year period.[12] Residual non-adherence was still 8%.

The above illustrates that the reasons for non-adherence may be more interesting than its mere presence, and stresses the importance for future studies on the effect of decision support not to focus on guideline adherence only, but also on possible reasons for non-adherence. This may further enhance our understanding of the prerequisites for optimal decision support that may help us further improve quality of care.

One might argue that we did not include incidence of PONV as a measure of outcome. However, there were multiple reasons not to study the occurrence of PONV as an outcome measure. First, the effectiveness of PONV prophylaxis as we describe it has been proven repeatedly.[18] Secondly, the application of the simplified risk score to guide prescription and administration of PONV prophylaxis has been shown to be effective in reducing the incidence of PONV.[13] Finally, the incidence of PONV on the day of surgery is influenced by a series of factors other

than the correct scheduling of PONV prophylaxis in the preoperative screening clinic. In contrast, the present study was designed to study the effect of decision support on the prescription behavior (i.e. guideline adherence) of the anesthesiologist in the preoperative screening clinic. However, it seems logical to belief that improved guideline adherence must finally result in better outcome, since otherwise the validity of the guideline itself may be questioned.

Conclusion

An electronic decision support system using patient-specific automated reminders significantly improved the guideline adherence for the prescription of PONV prophylaxis. Moreover, the mandatory data entry of risk factors for PONV improved identification of patients at high risk for PONV. After deactivating the decision support system, the effect on guideline adherence disappeared completely.

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CHAPTER 3

Automated Reminders increase Adherence to Guidelines for Administration of Prophylaxis for Postoperative Nausea and Vomiting

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Abstract

Background

Correct identification of patients at high-risk for postoperative nausea and vomiting (PONV), prescription of PONV prophylaxis and correct administration of medication are all important for effective PONV prophylaxis. This has been acknowledged by development of guidelines throughout the world. We studied the effect of introducing patient specific automated reminders on timely administration of PONV prophylaxis medication during general anesthesia.

Methods

During the visit to the preoperative screening clinic, patients at high-risk for PONV were identified and PONV prophylaxis was prescribed.

To study the effect of patient specific decision support (a pop-up window reminding the (nurse-) anesthetist that PONV prophylaxis had been prescribed in this particular patient) on the timely administration of PONV medication, we queried our database to extract data on all patients for three consecutive periods: 6 weeks before decision support (control), 12 weeks during decision support (DS) and 6 weeks after discontinuation of decision support (Post-DS) and studied how often PONV prophylaxis was administered correctly.

Results

Between November 2005 and May 2006, 1727, 2594 and 1331 patients presented for elective surgery in the control, DS and post-DS periods, respectively. In the control period, 236 patients receiving general anesthesia were scheduled to receive PONV prophylaxis. Of these, 93 (39%) received both dexamethasone and granisetron in a correct timeframe. This increased to 464 (79%) of 591 patients in the DS period and decreased back to 99 (41%) of 243 patients in the post-DS period ($p<0.001$).

Conclusion

Decision support is effective in improving administration and timing of PONV prophylaxis medication. After withdrawal of decision support, adherence decreased to pre-decision support levels.

Introduction

Post-operative nausea and vomiting (PONV) is a relatively common side effect of general anesthesia. It occurs in approximately one third of untreated patients in a general surgical population.[1-3] In recent years, risk factors as well as prophylactic and therapeutic options for PONV have been identified and guidelines have been proposed.[3-7] Some studies have shown that risk score based strategies to prevent and treat PONV may potentially be effective and efficacious.[8-10]

In a previous study we demonstrated that decision support was effective in improving both identification and correct PONV prophylaxis prescription in the preoperative screening clinic.[11] However, that study was neither designed to test the execution of the decision to prescribe PONV prophylaxis, nor was it set in the OR. The current study investigates whether the prescription of PONV prophylaxis is correctly executed in the OR. Further, a set of automated reminders is tested for its ability to improve the execution of a previously prescribed PONV prophylaxis order. Since timing may be important in achieving the optimal effect of PONV prophylaxis, we also investigated the effect of a patient specific reminder (decision support) on the timing of the PONV prophylaxis medication.[12]

Methods

This study was conducted in the OR complex of our regional teaching hospital in Amsterdam, The Netherlands. Patients at high risk for PONV should receive PONV prophylaxis, consisting of dexamethasone 8 mg IV upon induction and granisetron 1 mg IV shortly before awakening. For a more comprehensive description of the hospital setting and the departmental guideline on PONV in our hospital, we refer to a previous study on decision support in our center.[11]

To study the effect of decision support on the actual administration rate of prescribed PONV prophylaxis, we developed a patient specific decision support system (DSS). This system consisted of two different reminders that suggested administering PONV prophylaxis in case non-adherence to the departmental guideline was impending. The reminders were active both in the OR (OR reminder) and on the recovery (recovery reminder). For a more comprehensive explanation on such reminders, we refer to a previous study on decision support in our center.[11]

Included in our study were all consecutive adult patients presenting for non-cardiac surgery that had been evaluated in the pre-operative screening clinic. The study was divided in three study periods, each lasting for 6 to 12 weeks and was set-up according to an off-on-off design. During the first 6 week study period (control period) PONV prophylaxis was managed according to the paper version of the protocol as it had been in place before this study. In the second period, which lasted for 12 weeks (decision support period) the automated reminders as described above were activated. After de-activating the automated reminders, PONV prophylaxis in the post decision support period was managed as it was in the control period.

After all study periods were completed, the relevant data were extracted from the database by pre-written scripts.

Our primary outcome was guideline adherence. We selected all patients that were prescribed PONV prophylaxis at the preoperative

screening clinic and calculated the percentage that actually received either dexamethasone, granisetron or both medications during anesthesia in each study period. In addition, we evaluated the effect of decision support on the behavior of each individual anesthesiologist. Therefore, we determined the anesthesiologist that had been responsible for each general anesthesia administered to a high risk patient and calculated the percentage of high-risk patients that actually received the prophylactic medication in the three study periods per anesthesiologist.

As a secondary outcome, we analyzed timing of the prophylactic medication. For this analysis, we categorized the time at which dexamethasone and granisetron had been administered. Four categories were made for each parameter: before the first reminder, after the first and before the second reminder, after the second reminder and before the third reminder, and after the third reminder. The change in timing of the prophylactic medication was analyzed per study period. Further, we dichotomized the medication timing in correct and incorrect. We arbitrarily considered timing of a dexamethasone dose correct if it had been given in the OR (before arrival at the recovery room) and within 30 minutes from induction of general anesthesia. Timing of granisetron was arbitrarily considered correct when granisetron was given either before or within 15 minutes after arrival at the recovery room. The latter is mainly intended to distinguish granisetron as PONV prophylaxis from granisetron used as a PONV therapeutic.

For all percentages, confidence intervals were calculated and significance of the differences between the periods was established with a chi-square test.

Results

Between November 2005 and June 2006, 5652 consecutive patients were included in the study: 1727, 2594 and 1331 patients in the control period, decision support and post decision support periods, respectively.

Demographics and incidence of risk factors for the patients included in the three study periods are shown in table 3.1. Generally, demographics were equally distributed across the study groups. However, compared to the control period, PONV prophylaxis was prescribed more often in the decision support and the post-DS period.

In table 3.2, prophylaxis administration is presented for patients that did have PONV prophylaxis prescribed and received general anesthesia. Dexamethasone was given in 46% of these patients in the control period. In the decision support period this increased significantly to 95% and after de-activating the automated reminders, it decreased to 47% in the post decision support period ($p<0.001$). For granisetron these percentages were 53%, 81% and 51%, respectively ($p < 0.001$).

In the control period, only 39% of patients eligible for PONV prophylaxis received both medications within the time frame we considered acceptable; dexamethasone in the OR within 30 minutes after induction and granisetron before – or within 15 minutes after arrival in the recovery. This increased to 79% in the decision support group and decreased again to 41% in the post-decision support group ($p < 0.001$).

When analyzing the data for each individual anesthesiologist, we find a similar pattern for all users. As shown in figure 3.1a, all anesthesiologists are more compliant in administering dexamethasone during the decision support period and less compliant in the control – and post-DS period. As shown in figure 3.1b, this pattern is the same for granisetron. The single anesthesiologist scoring 0% adherence in the post decision support period only attended to a single case of general

Table 3.1, Basic demographics and co-morbidities

	Control	Decision Support	Post DS
N	1727 (100%)	2594 (100%)	1331 (100%)
Age (years), mean (SD)	49.3 (16.0)	49.2 (16.2)	49.7 (16.4)
Female	942 (55%)	1489 (57%)	745 (56%)
Smoking status			
Smoking	536 (31%)	853 (33%)	420 (32%)
Non smoking	785 (45%)	1586 (61%)	831 (62%)
Not entered	406 (24%)	155 (6%)	80 (6%)
History of PONV or motion sickness	376 (22%)	614 (24%)	271 (20%)
Anticipated opioid use	857 (50%)	1264 (49%)	674 (51%)
PONV prophylaxis scheduled?	280 (16%)	739 (29%)	296 (22%)
ASA Class			
I	1012 (59%)	1520 (59%)	758 (57%)
II	641 (37%)	968 (37%)	494 (37%)
III	70 (4%)	102 (4%)	71 (5%)
IV	2 (0.1%)	3 (0.1%)	5 (0.3%)
Co-morbidity			
Hypertension	302 (18%)	472 (18%)	248 (19%)
History of AMI	41 (2%)	54 (2%)	37 (3%)
History of PVD	20 (1%)	27 (1%)	17 (1%)
Diabetes Mellitus	96 (6%)	174 (7%)	79 (6%)
Asthma/COPD	92 (5%)	126 (5%)	61 (5%)

Data are presented as N(%) unless otherwise indicated.

AMI: Acute Myocardial Infarction

PVD: Peripheral Vascular Disease

Table 3.2, Guideline adherence per study period

	Control	Decision Support	Post DS	Signif.
N	1727 (100)	2594 (100)	1331 (100)	
PONV prophylaxis scheduled	280 (16%)	739 (29%)	296 (22%)	
General anesthesia	1383 (80%)	2078 (80%)	1054 (79%)	
PONV prophylaxis scheduled & General Anaesthesia	236 (100%)	591 (100%)	243 (100%)	
Dexamethasone given				
Yes	**108 (46%)**	**563 (95%)**	**115 (47%)**	
Yes, but wrong timing	21 (9%)	16 (3%)	19 (8%)	
No	107 (45%)	12 (2%)	109 (45%)	P < 0.001
Time since induction, minutes, median (min/max)	*8 (-1/152)*	*7 (-7/101)*	*5 (-3/185)*	
Granisetron given				
Yes	**124 (53%)**	**479 (81%)**	**125 (51%)**	
Yes, but wrong timing	12 (5%)	63 (11%)	17 (7%)	
No	100 (42%)	49 (8%)	101 (42%)	P < 0.001
Time since recovery arrival Minutes, median (min/max)	*-16 (-108/138)*	*-14 (-100/119)*	*-17 (-91/194)*	
Both given?				
Yes, both correctly timed	**93 (39%)**	**464 (79%)**	**99 (41%)**	
Yes, one wrongly timed	22 (9%)	66 (11%)	18 (7%)	
Yes, both wrongly timed	1 (0%)	5 (1%)	5 (2%)	
No, only one given	33 (14%)	51 (9%)	32 (13%)	
No, none given	87 (37%)	5 (1%)	89 (37%)	P < 0.001

Data are presented as N (%) unless otherwise indicated

anesthesia during that period, therefore we consider this line an artefact.

Figure 3.2a demonstrates that besides an increase in dexamethasone administration, the timing changes as well. Significantly more dexamethasone is given within the first 30 minutes after induction. A similar pattern is shown in figure 3.2b for granisetron; a significant increase in administration before – and within 15 minutes after arrival on the recovery.

As demonstrated in table 3.3, prophylactic medication was in some cases given to patients that had no prescription for PONV prophylaxis. This occurred in only 1 – 2% of patients. This rate remained constant throughout the study periods. Moreover, 39% of patients receiving prophylaxis without prescription were actually at high risk for PONV and should have had a prescription.

Table 3.3; PONV Prophylaxis given when patients were not scheduled

	Control (n=1727)	**Decision Support (n=2594)**	**Post DS (n=1331)**
PONV Prophylaxis given without scheduling	33 (2%)	37 (1%)	26 (2%)
		96 (100%)	
Number of positive risk factors			
0		*3 (3%)*	
1		*15 (16%)*	
2		*40 (42%)*	
3		**28 (29%)**	
4		**10 (10%)**	
Which risk factor was positive			
Gender		81 (84%)	
History		49 (51%)	
Opioids		48 (50%)	
Smoking		41 (43%)	

Data are presented as N (%) unless otherwise indicated

Figure 3.1a Percentage of patients that received *dexamethasone*. Each line represents one attending anesthesiologist. The orange line represents the average of all anesthesiologists.

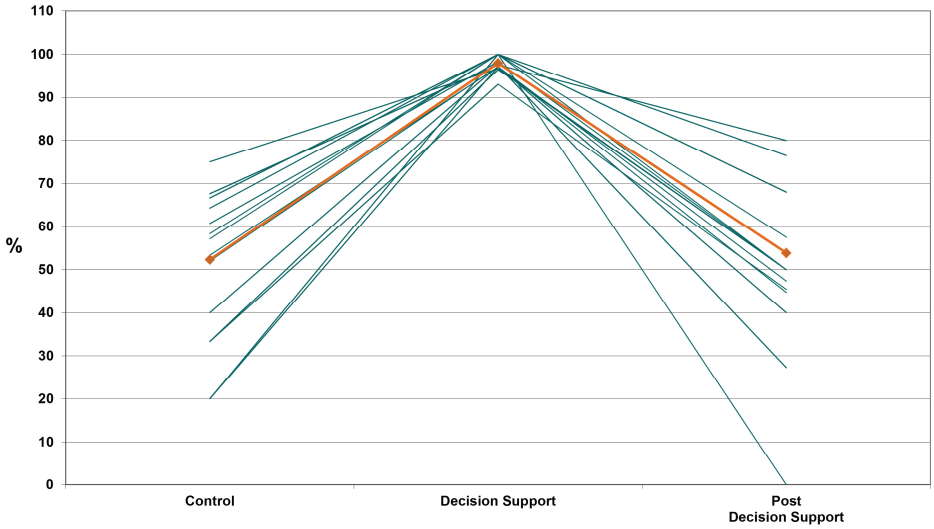


Figure 3.1b Percentage of patients that received *granisetron*. Each line represents one attending anesthesiologist. The orange line represents the average of all anesthesiologists.

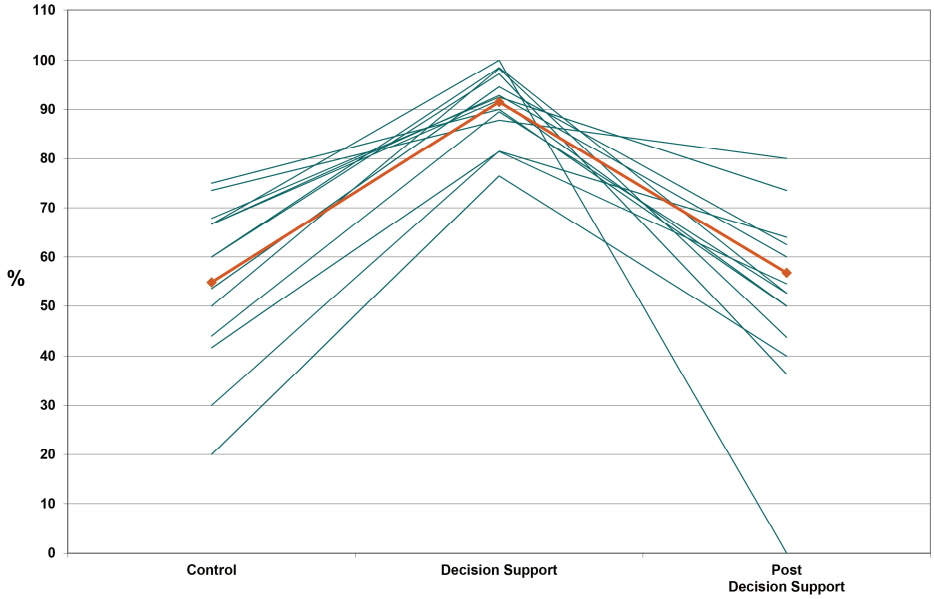


Figure 3.2a *Dexamethasone* timing by study period. * denotes a significant difference ($p < 0.001$) based on a χ^2 test.

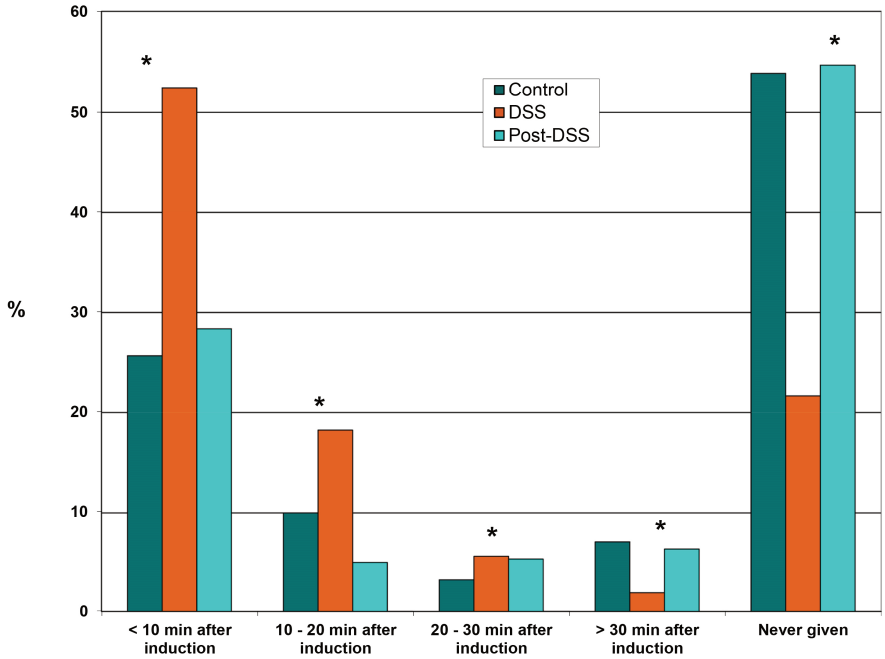
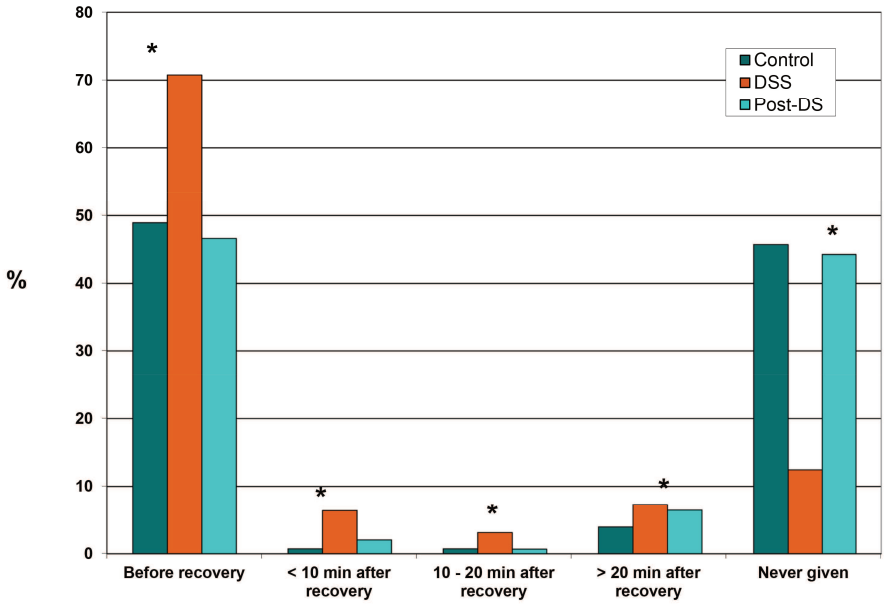


Figure 3.2b *Granisetron* timing by study period. * denotes a significant difference ($p < 0.001$) based on a χ^2 test.



Discussion

The present study showed that guideline adherence in administering PONV prophylaxis in our hospital was very poor and that automated decision support was able to improve guideline adherence significantly. Moreover, we demonstrated a significant improvement in timing of the PONV prophylaxis administration: both dexamethasone and granisetron were more frequently given within a timeframe considered acceptable and even before the first reminder.

Previous studies on decision support have focused on either the prescription, or the execution of an intervention.[11,13,14] In the current study, we focused on the execution of a previously prescribed order by co-workers. The results showed that compliance regarding the actual administration of previously prescribed medication was poor. This suggests that the use of decision support only on the prescription of an intervention, such as the one we studied in a previous report may not be an effective strategy since even if prescription is good, the execution lags behind.[11] Instead, decision support designed to improve the actual administration of PONV prophylaxis seems more effective than using decision support only to improve correct prescription of PONV prophylaxis.

As in our previous study, we found that after discontinuation of the decision support guideline adherence returned to control levels. The absence of any form of learning from the system is not only in accordance with our previous study, but also with the only other study that reported on a control group after the intervention; both describe a marked decrease in adherence after discontinuing decision support.[11,15]

Future research could include a study on the optimal (combination of) reminders, so as to attain maximum effect with a minimum number of reminders. Applied to PONV prophylaxis, it may be most effective to use decision support for the identification of high-risk patients in the OR instead of at the pre-operative screening clinic and support the actual

administration of PONV prophylaxis medication at the same time. A reminder at the pre-operative screening clinic could then be omitted, saving a potentially redundant pop-up message.

The importance of timing and form of decision support may be illustrated by the residual non-adherence regarding granisetron. On average, 95% of the patients that were eligible for dexamethasone received it within an acceptable timeframe during the decision support period. For granisetron, the adherence was lower; approximately 81% of eligible patients received it within the accepted timeframe. Although this is a marked improvement over the control period, guideline adherence of approximately 80% is clearly suboptimal. This may be related to the timing of the reminder. Upon arrival on the recovery room, many different tasks have to be performed simultaneously. This may not be the optimal time to remind users of yet another action. The importance of timing was also demonstrated in a different setting by Vigoda and coworkers.[16] These authors showed that an electronic mail reminder the night before elective, non-cardiac surgery had no effect on anesthesiologist behavior, as guideline adherence regarding peri-operative beta blockade in eligible patients remained unchanged. Both studies demonstrate that for decision support to work, the user needs to be able to process the information presented to him. Therefore, this information needs to be presented to the user as close as feasible to the time a decision is made.

One might argue that we did not include PONV itself as an outcome measure. However, our study was neither powered, nor designed to provide evidence for or against the hypothesis that PONV prophylaxis works. Instead, our study was designed to study the effect of decision support on the execution of previously prescribed orders. Moreover, the effectiveness of PONV prophylaxis medication used in this study has already been demonstrated by several excellent studies.[1,2,17]

In conclusion, decision support significantly improved administration of PONV prophylaxis medication and a complete disappearance of this effect after discontinuing the reminders. In addition, timeliness of administration was also significantly improved by decision support. The effect on adherence was stronger regarding dexamethasone stressing the importance of timing of decision support.

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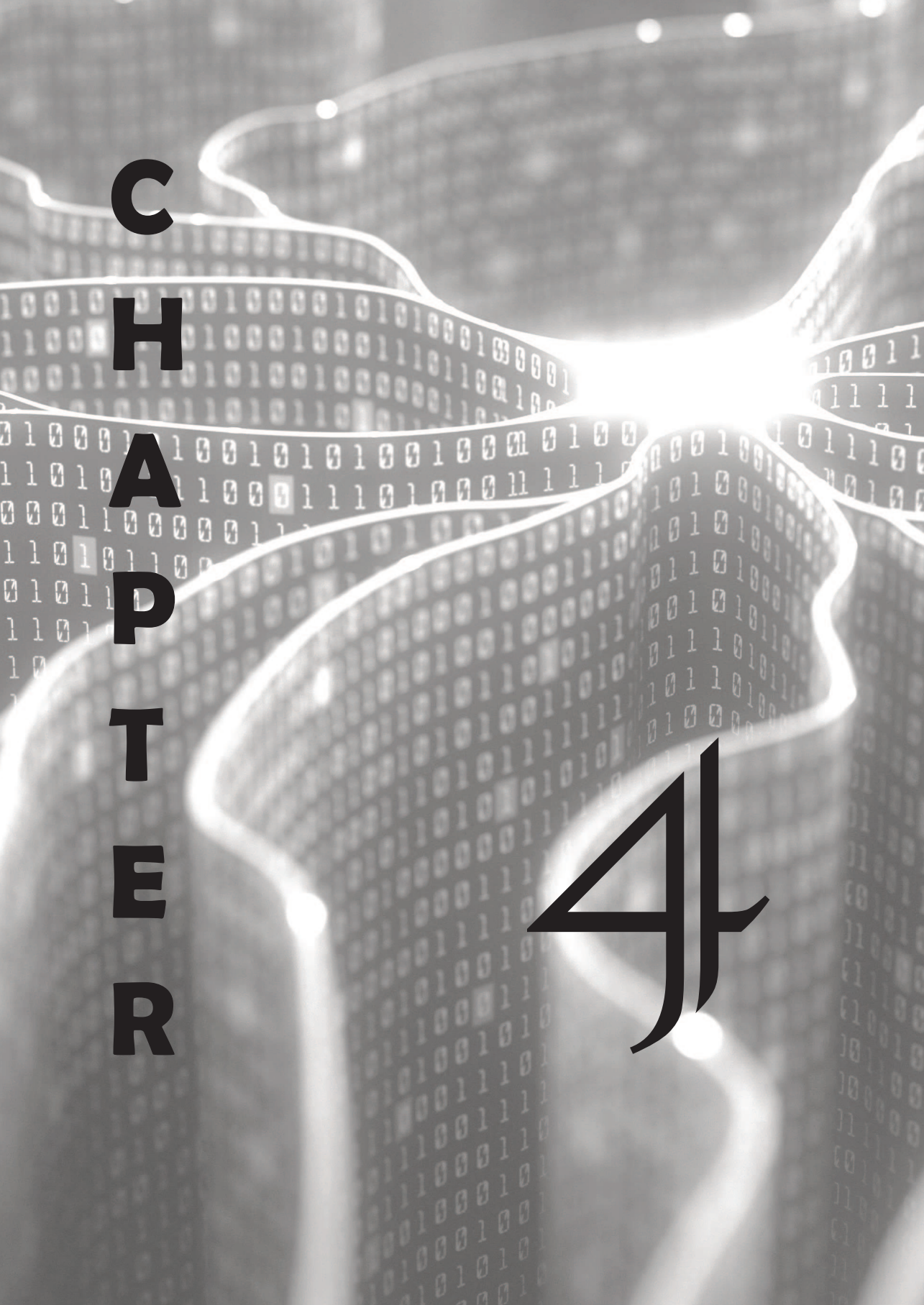

CHAPTER 4

The Effect of Requesting a Reason for Non-Adherence to a Guideline in a Long Running Automated Reminder System for PONV Prophylaxis

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Abstract

Background

Automated reminders are employed frequently to improve guideline adherence, but limitations of automated reminders are becoming more apparent. We studied the reasons for non-adherence in the setting of automated reminders to test the hypothesis that a separate request for a reason in itself may further improve guideline adherence.

Methods

In a previously implemented automated reminder system on prophylaxis for postoperative nausea and vomiting (PONV), we included additional automated reminders requesting a reason for non-adherence. We recorded these reasons in the pre-operative screening clinic, the OR and the PACU. We compared adherence to our PONV guideline in two study groups with a historical control group.

Results

Guideline adherence on prescribing and administering PONV prophylaxis (dexamethasone and granisetron) all improved compared to the historical control group (89 vs. 82% ($p< 0.0001$), 96 vs 95% (not significant) and 90 vs 82% ($p<0.0001$)) while decreasing unwarranted prescription for PONV prophylaxis (10 vs. 13%). In the pre-operative screening clinic, the main reason for not prescribing PONV prophylaxis was disagreement with the risk estimate by the decision support system. In the OR/PACU, the main reasons for not administering PONV prophylaxis were: 'unintended non-adherence' and 'failure to document'.

Conclusions

In this study requesting a reason for non-adherence is associated with improved guideline adherence. The effect seems to depend on the underlying reason for non-adherence. It also illustrates the importance of human factors principles in the design of decision support. Some reasons for non-adherence may not be influenced by automated reminders.

Background and significance

In recent years, automated reminders and electronic decision support have been used to improve behavior of medical personnel, improve guideline adherence, documentation, billing and patient outcome.[1-5] Recently the effects of "alert fatigue" and unintended effects of decision support have also gained attention.[6-8]

The expected effect of a decision support system depends on a multitude of factors, including the underlying guideline itself, as well as the design of the system, and the situation in which the decision support system is activated. From previous studies, automated reminders offering a recommendation instead of observation and requesting a reason from the user for not following recommendations offered by decision support systems, have all been suggested as features that may increase the effect of decision support systems.[9] From studies on human factors, the type, the design, the message and the timing of automated reminders also have been shown to influence their effect.[10-12] From a user acceptance point of view, it is also known that the system should be designed so that at least 80% of the reminders offer a correct observation and/or advice for optimal effectiveness.[13]

In previous studies that evaluated the effects of decision support for prescribing and administering prophylactic medication for postoperative nausea and vomiting (PONV), we demonstrated that, although significantly improving guideline adherence, there was still residual non-adherence between 5 and 27%.[14,15] Although 100% adherence is not realistic or even opportune for most guidelines, the particular guideline that was the basis for this decision support system had been written with the involvement and consent of all anesthesiologists and is to be applied to every single patient receiving anesthesia care in our hospital. Given the properties described above, it is clear to us that at 27% non-adherence the system was not working optimally and needed further improvement.[14] We reviewed the literature to identify potential improvements in the design of our decision support.[9-12] We modified our

existing decision support system to include documentation of a reason for non-adherence when applicable.

Objectives

Since requesting a reason has previously been shown to improve guideline adherence, we hypothesized that this modification improves adherence to the local PONV prophylaxis guideline.[9] Moreover, on a more operational level, we intended to determine the underlying reasons for non-adherence in order to identify potential sources for improvement of our decision support systems.

Methods

This study was conducted in a 550-bed teaching hospital. An anesthesia information management system (AIMS) workstation is present in all pre-operative screening offices, all 12 ORs and adjacent to all 15 PACU beds. Within the AIMS, a comprehensive decision support system on prescription and administration of PONV prophylaxis is implemented. PONV prophylaxis was to be prescribed to every patient with at least three risk factors on an Apfel's simplified risk score and consisted of dexamethasone 4 mg iv. after induction of, and granisetron 1 mg iv. before emergence from anesthesia.[14,16]

In the pre-operative screening department, our decision support system consisted of an automated reminder based on Apfel's simplified risk score.[14,16] The system calculated the risk score for every patient and reminded the anesthesiologist of the indication for PONV prophylaxis. A reminder message would be triggered if: (1) three or four risk factors were positive; (2) general anesthesia was scheduled; and (3) no PONV prophylaxis had been prescribed. This message appeared immediately after selecting 'general anesthesia' as the preferred anesthesia technique. The system prompted the user for a response to the message (agree or disagree with the recommendation) and automatically prescribed PONV prophylaxis if the user agreed. Since our AIMS is not a Computerized Physician Order Entry (CPOE) system, there were no specific medications prescribed at that point in time, just an order for "PONV prophylaxis according to protocol". For the purpose of this study, a second reminder appeared immediately if a negative response to the first reminder was entered. This reminder requested the reason for not prescribing PONV prophylaxis.

There were two different reminders in the OR/PACU suggesting administering of PONV prophylaxis to the clinicians.[15] The first reminder was programmed to appear 10 minutes after induction of anesthesia (OR reminder). The second reminder was programmed to occur upon arrival in the PACU (PACU reminder). The OR reminder showed a

message if: (1) PONV prophylaxis had been prescribed; (2) general anesthesia had been recorded; and (3) dexamethasone (or other steroids) had not been recorded as 'administered'. If dexamethasone (or other steroids) had not been administered another 10 minutes later, a second reminder appeared requesting a reason for non-adherence. This reminder kept re-appearing every 10 minutes until either a reason was documented or steroids were administered.

The PACU reminder checked patient data upon arrival in the PACU and was triggered if: (1) PONV prophylaxis had been prescribed; (2) general anesthesia had been given; and (3) no granisetron had been recorded as 'administered' yet. Again, a second reminder requesting a reason appeared 10 minutes later if granisetron had still not been administered.

For all of the reminders, a response was required to continue working with the AIMS. However, the response required was one mouse-click or keystroke, validating only that the user had seen the message. The users (anesthesiologists, anesthesia residents and anesthesia nurses) were never forced to adhere to the protocol; they were only repeatedly reminded of it.

As described, the second tier of reminders requested a reason for non-adherence. Based on known reasons for non-adherence, as well as personal experience and conversations with colleagues, we predefined several choices which we expected to cover most of the reasons for non-adherence to the departmental protocol.[17] The predefined reasons were: mistake/forgotten, disagree with guideline, disagree with risk estimate, contraindication, and documentation error (OR/PACU only). To facilitate any other possible reason, an option "other" and a free text field were also available.

In this observational study we report three different patient sets: a first study group in the pre-operative screening department, a second study group in the OR/PACU, and a historical control group. In both study groups, the second tier of reminders requesting a reason for non-

adherence was employed. The division between pre-operative screening and OR/PACU within the study groups was made because the date of pre-operative screening can be up to 6 months prior to surgery, a different anesthesiologist may be involved, and the two visits (pre-operative and OR) should be considered unrelated within the scope of this study. For example, one patient may have been pre-operatively screened before the study period and may have received anaesthesia within the study period. The study groups included all consecutive adult patients for elective, non-cardiac surgery in our hospital. The need for informed consent as well as full IRB approval was waived by the institutional IRB (Medisch Ethische Commissie, OLVG hospital). Data collection was done automatically within the AIMS database and data were extracted from the AIMS database after study completion. For this observational study, we arbitrarily decided to set the sampling time frame to 9 months (or approximately 10000 non-cardiac patients) for the OR/PACU group and 2 years (or approximately 20000 patients) for the pre-operative screening group. For the historical control group, we used a set of patients from a previous study, which was treated similarly using the same automated reminders with the exception of the request for a reason for non-adherence in the second tier of reminders.[15]

For comparison of the different study groups, proportions were calculated. Statistical significance of differences was assessed by Chi square statistic using SPSS (version 19).

Results

In the pre-operative screening department, 27332 patients were screened while the additional reminders requesting the reason for non-adherence were active (between Jan 1st 2009 – Dec 31st 2010). In the OR, there were 11270 patients who received anaesthesia while the additional reminders were active in the OR/PACU (between Jan 1st 2009 – Oct 11th 2009). In the historical control group (Jan 18th 2006- April 30th 2006), 2594 patients were screened and/or received anaesthesia. Demographic properties of the populations are shown in table 4.1.

Table 4.1: This table shows basic demographics for all three study periods. No statistical comparison between the groups was done.

	Control	Study population	
	N (%)	Pre-Operative N (%)	OR/PACU N (%)
Total number of patients	*2594*	*27332*	*11270*
ASA class			
I	1520 (59)	15053 (55)	6300 (56)
II	968 (37)	8594 (31)	3517 (32)
III	102 (4)	2463 (9)	965 (9)
IV	3 (0,1)	396 (2)	153 (1)
V	0 (0)	37 (0,1)	18 (0,2)
Planned general anaesthesia	1729 (67)	16052 (59)	6898 (61)
Executed general anaesthesia	1768 (68)	Unknown	7472 (66)
PONV risk factors			
Female gender	1489 (57)	15771 (58)	6454 (57)
Non smoker	1586 (61)	15197 (55)	6501 (57)
Previous PONV or motion sickness	614 (24)	5249 (19)	2138 (19)
Expected opioid use	1264 (49)	11662 (42)	5041 (45)
High-risk patients (3 or more risk factors)	781 (30)	6881 (25)	2934 (26)

Table 4.2 demonstrates that guideline adherence was better in the study groups when compared to the historical control group. Prophylaxis was prescribed to high-risk patients more often in the study group (89% vs 82%, p < 0.0001), while simultaneously prescription to 'low risk' patients decreased compared to the control group (10% vs 13%, p < 0.0001).

Table 4.2: Changes in guideline adherence between the control period and the intervention period. A statistically significant increase in prescription and administration of PONV prophylaxis to high-risk patients was observed. Prescription and administration to low-risk patients remained the same or decreased.

	Control N (%)	Study N (%)	
Pre-operative: PONV prophylaxis prescription			
High-risk patients with scheduled G.A.	523 (100)	4522 (100)	
PONV prophylaxis prescribed	426 (82)	4026 (89)	p < 0.001
Low-risk patients with scheduled G.A.	1206 (100)	11530 (100)	
PONV prophylaxis prescribed	161 (13)	1115 (10)	p < 0.001
OR/PACU: PONV prophylaxis administration			
High-risk patients with received G.A.	541 (100)	1958 (100)	
Prophylaxis prescribed	433 (80)	1642 (84)	p = 0,03
Dexamethasone administered*	411 (76/95)	1576 (80/96)	n.s.
Granisetron administered*	356 (66/82)	1480 (76/90)	p < 0.001
Low-risk patients with received G.A.	1227 (100)	5514 (100)	
Prophylaxis prescribed	158 (13)	457 (8)	p < 0.001
Dexamethasone administered	181 (15)	871 (16)	n.s.
Granisetron administered	176 (14)	805 (15)	n.s.

G.A. general anaesthesia

n.s. not significant

*** N (% of high-risk patients with G.A. / % of high-risk patients with G.A. and prescription)**

In the OR, administration of dexamethasone remained the same (95 vs 96%, not significant) while administration of granisetron further improved (82 vs 90%, $p < 0.0001$). Administration of both dexamethasone and granisetron to low risk patient remained the same.

Although the guideline adherence improved, in the study group still 496 patients (11% of high risk patients with scheduled general anaesthesia) were not prescribed PONV prophylaxis initially. In 97 of these patients, a reason for non-adherence was documented. Subjective disagreement with the risk estimate by the decision support system was the main reason for not prescribing PONV prophylaxis (44 times). In a small proportion of patients (31 out of 496 patients, 6%), the reason request caused a change in policy, resulting in either prescribing PONV prophylaxis after all (21 patients), or changing the planned anaesthesia technique to regional instead of general anaesthesia (10 patients).

In the OR/PACU, the main reasons for not administering dexamethasone and granisetron were: unintended non-adherence (33% for dexamethasone and 42% for granisetron, respectively), and failure to document the administration of medication (26% and 44%, respectively). A change of policy was more frequent than in the pre-operative screening clinic. An additional 65 out of 131 patients (50%) received dexamethasone after the reason request, and 290 out of 452 patients (64%) received granisetron after the second reminder with the reason request.

These reasons for non-adherence are summarized in table 4.3

Table 4.3 Reasons for non-adherence in the high-risk study population. For the prescription of prophylaxis, disagreement with the risk estimate was the most frequently entered reason. In the OR and PACU, unintended non-adherence (forgotten/mistake or failure to document) was the reason most frequently documented.

	Prescribing N (%)	Administration	
		Dexamethasone N (%)	Granisetron N (%)
PONV prophylaxis NOT prescr./admin.	496 (100)	131 (100)	452 (100)
Reason documented	97 (20)	131 (100)	452 (100)
Prescr./admin. after reason request	21 (4)	65 (50)	290 (64)
Change of technique to regional	10 (2)	NA	NA
Total reasons documented	97 (100)	131 (100)	452 (100)
Unintended (forgotten / by mistake)	19 (20)	43 (33)	188 (42)
Administered but not registered	NA	34 (26)	198 (44)
Guideline overestimates risk	44 (45)	25 (20)	46 (10)
Contraindication	16 (17)	2 (2)	3 (1)
ICU patient/other steroid given*	5 (5)	7 (5)	NA
Other	13 (13)	20 (15)	17 (4)

NA: Not applicable

*** This reason was entered using the free text option by the users and categorized by the authors afterwards.**

Discussion

This observational study demonstrated that requesting a reason for non-adherence to the local PONV prophylaxis guideline was associated with an increase in PONV prophylaxis prescription and administration without causing an increase in inappropriate PONV prophylaxis prescription and administration to low risk patients. In addition, we gained interesting insights in some of the reasons for residual non-adherence in a long running clinical decision support system.

Although not scientifically reported, it is a known phenomenon that users will in some situations discard a reminder by routinely clicking the upper or lowermost option available in a reminder or just press enter to select the default option (if available). Although we had no formal process of eliminating that this happened, we do not feel this played a big role. First of all, no default reason was pre-selected so just pressing enter would not select any reason. Secondly, there was a marked difference between the pre-operative screening department and the OR/PACU in the most frequently selected reasons for non-adherence. The most frequent reason for non-adherence at the pre-operative screening department was disagreement with the guideline (the third option from the top). In the OR, failure to document (second option from the top), and unintended non-adherence (first option from the top) were the two most frequent explanations for not following the suggestion by the decision support system. Since the predefined reasons were sorted in the same order in the pre-operative screening clinic as in the OR/PACU, this would make "routine selection" less likely.

Moreover, there was a marked difference in the effect on adherence of the reason request; in the pre-op screening clinic, only 4% of reminders triggered a prescription. In the OR and PACU, 50 – 64% of reason requests triggered additional administration of medication.

Looking at the medical evidence supporting our PONV guideline and decision support system, the risk scoring was based on publications by

Apfel et al., while the choice of drugs (dexamethasone and a 5-HT-3 receptor antagonist) was made on the basis of the available Cochrane review on drugs for PONV prevention and therapy.[16,18,19] Reviewing this evidence, we concluded that the decision support rules implemented were evidence based and that our guideline most likely did not overestimate PONV risk. In contrast, our guideline and decision support system may have slightly underestimated the risk in medium-risk patients (1 or 2 positive risk factors).[20]

Since the design of a decision support system is crucial to its efficacy, we evaluated the design of our automated reminders.[9,12] The review by Kawamoto et al. suggests a number of properties that may predict the effectiveness of decision support systems.[9] Our decision support system possesses all independent predictors for effectiveness as defined by this review: automated activation within workflow, specific actionable advice, requesting a reason, and being computer based. Another review by Phansalkar et al. evaluated human factors principles and their application to automated reminders.[12] Again, most of these principles were incorporated in our decision support system.

Another human factor principle that may be important is workload. It is well known that performance can decrease as a result of distractions by increased workload. This factor may have influenced the present study. The time frame in which granisetron is administered and documented, between the end of surgery and the arrival in the PACU, is a high workload situation and therefore particularly susceptible to distractions resulting in decreased performance and documentation failure. This may explain the relatively large effect of automated reminders on adherence in this situation. In the design of our decision support system, we have chosen not to interfere with busy clinical care during emergence from anaesthesia and transport to the PACU, but to remind the user of the omission upon arrival in the PACU.[15] This illustrates the importance of timing of automated reminders.

The request for a reason itself also seems to have an effect on residual non-adherence. More specifically, the second reminder (requesting a reason) has led to the administration of the PONV medication in 50 – 64% of times it was shown (an extra 3 – 17% of all high-risk patients receiving general anaesthesia).

Besides the possible beneficial effect of the reason request on residual non-adherence, another finding is that residual non-adherence may have decreased considerably over time. The difference is most clear-cut in the outpatient clinic for prescription of PONV prophylaxis. In the study described in our original report, the non-adherence for prescribing PONV prophylaxis decreased from 63% to 27% using reminders.[14] This decreased even further to 18% in the intervention group of our second study.[15] During the current study period, three years later, this was only 11%. This finding is in contradiction with some studies done in CPOE systems, where reminders are actually overridden more frequently over time.[8] The difference between the CPOE literature and our study may be in the relative frequency of overrides. In the report by Topaz, override frequencies of up to 89% are reported.[8] This is quite high in comparison to the overrides in our system (between 4% and 18%, depending on the specific reminder). So, placing our results in context of this report, although we demonstrated absence of a short term learning effect (weeks) in our original report, we now think there may be a long term "learning" effect (years).[14] This may be due to a combination of factors, including but not limited to continuous education and feedback on guideline adherence by the reminders, increased confidence in the suggestions made by the decision support system, and a change in perceived importance of PONV prophylaxis over time.

Limitations

The most important limitation of this study is that only associative conclusions can be drawn. Due to the case-control type design, there is no possibility to conclude on causation. Moreover, due to the longer period of time between the control group and the intervention group, it is possible that the perception regarding the guideline by providers had changed in between the two study periods. Also, the sample size of the control group is rather small in comparison to the intervention groups. Nevertheless, we feel the study gives an interesting insight in both the potential effects of requesting a reason for non-adherence to an automated reminder as well as the actual reasons for non-adherence. Finally, for a complete evaluation of the system, we could have sought user feedback and try to gain insight in the experience, for example by using a survey.

Conclusion

In conclusion, the request for a reason for non-adherence was in itself associated with an increase in guideline adherence in a long running automated reminder system for PONV prophylaxis. Moreover, we have identified different reasons for non-adherence in the setting of automated decision support. The present study illustrates that human factors are important to account for when designing decision support systems. In addition, not all reasons for non-adherence may be amenable by decision support.

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CHAPTER 5

Automated Reminders Decrease Postoperative Nausea and Vomiting Incidence in a General Surgical Population

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Abstract

Introduction

Guidelines to minimize the incidence of PONV have been implemented in many hospitals. In previous studies, we have demonstrated that guideline adherence is suboptimal and can be improved using decision support.[1,2] In this study, we investigate whether decision support improves patient outcome through improving physician behavior.

Methods

Medical information of surgical patients is routinely entered in our anaesthesia information management system (AIMS), which includes automated reminders for PONV management based on the simplified risk score by Apfel.[3] This study included consecutive adult patients undergoing general anaesthesia for elective non-cardiac surgery which were treated according to normal clinical routine. The presence of PONV was recorded in the AIMS both during the recovery period and at 24 hours. Two periods were studied: one without the use of decision support (control period) and one with the use of decision support (support period). Decision support consisted of reminders on PONV both in the pre-operative screening clinic and at the time of anaesthesia.

Results

In the control period 981 patients, of which 378 (29%) were high risk patients, received general anaesthesia. Overall 264 (27%) patients experienced PONV within 24 hours. In the support period 1681 patients, of whom 525 (32%) had a high risk for PONV, received general anaesthesia. In this period, only 378 (23%) patients experienced PONV within 24 hours postoperatively. This difference is statistically significant ($p = 0.01$).

Conclusion

Automated reminders can improve patient outcome by improving guideline adherence.

Introduction

Postoperative nausea and vomiting (PONV) is a well-known problem affecting approximately one third of all patients receiving general anaesthesia. In selected high-risk populations, the incidence may be as high as 80%.[3,4] PONV is the second cause (after pain) for unplanned admission after day-care surgery and can also be a contributing factor to several complications, such as suture dehiscence and aspiration.[5,6] From a patient perspective, vomiting is the most undesirable outcome and nausea is the fourth most undesirable outcome after surgery.[7]

An extensive body of research exists on the causes, prediction, prevention and treatment of PONV, which has resulted in the development of risk scores, guidelines and treatment protocols.[8-11]

Adherence to PONV prophylaxis guidelines is low. In previous studies we found prescription of PONV prophylaxis to be as low as 37%.[2] Low adherence to guidelines is a well-known problem in the medical field. Reasons for low adherence and potential solutions have been studied extensively.[12-18] Automated reminders have been proven to be very effective modifiers of physician and nurse behaviour.[1,2,14,15,19] In previous research, we demonstrated a doubling of guideline adherence both for correct prescription and for actual administration of PONV prophylaxis using automated reminders.[1,2] We hypothesize that, using a set of automated reminders, we can adequately select high risk patients and have them receive prophylaxis without over-exposing low-risk patients to prophylactic anti-emetics they hardly benefit from and thereby reduce the overall 24-hour incidence of PONV. In the present study we tested the above hypothesis in a general surgical population.

Methods

The study was performed between June 29th and December 20th 2009 in a 555 bed, 12 OR regional teaching hospital in Amsterdam, the Netherlands. An Anaesthesia Information Management System (AIMS) is available in all anaesthetic care locations and all patient data is stored primarily in the AIMS.

Based on the results of our previous studies, applying the same set of reminders, the IRB decided that this study was a natural extension of the previous studies and that no IRB review or informed consent was necessary.[1,2]

In this study, all adult patients (age >18 year) scheduled for elective non-cardiac surgery under general anaesthesia were included. Exclusion criteria were pregnancy, known allergies to anti-emetic drugs, anti-emetic therapy before surgery and inability to communicate with the patient.

According to departmental guidelines, PONV risk was estimated at the preoperative clinic using Apfel's simplified risk score.[3] Patients with three or more positive risk factors were considered at high risk to develop PONV.

Once identified as a high-risk patient, PONV prophylaxis was scheduled, consisting of dexamethasone after induction of general anaesthesia and granisetron upon awakening.

A decision support system (DSS) using patient specific automated reminders was implemented, supporting the physicians in their decision to prescribe PONV prophylaxis in the preoperative screening clinic, and reminding the anaesthesia team to administer PONV prophylaxis in the OR. For a more extensive description of the decision support system we refer to our previous studies.[1,2]

This prospective study was set up as an on-off study to compare the 24 hour incidence of PONV in a cohort of patients treated with decision

support for PONV prophylaxis (DS period, June 29th – October 8th) to a cohort of patients treated without the use of the decision support system (control period, October 9th – December 20th).

Based on the analysis of our previous data, we expected that we would find an increase in administration from 50 to 95% for dexamethasone, from 50 to 80% for granisetron.[1] Based on a study by Apfel et al we assumed a maximal relative risk reduction of 26% for both drugs.[9] Combined with the expected PONV incidence based on the risk profile and of our population, we expected an overall reduction in PONV incidence from 30% to 25%.[2] Power analysis using these figures ($\alpha = 0.05$, $\beta = 0.2$) suggested a sample size of 1250 patients per study period.

PONV outcome was recorded with a 24 hours follow-up. In the PACU, the nurses were prompted by another reminder included in the AIMS to specifically ask for PONV every two hours, as well as before discharge from the recovery room. 24 hour after surgery, dedicated study personnel interviewed patients in a standard way. Either at the clinical ward or by phone for day case surgery patients. All patients were asked whether they had experienced PONV and if so, at which time they did. Although the study personnel were not formally blinded, they were neither involved in nor informed about prophylactic or therapeutic anti-emetic medication given in the OR and the PACU. The use of anti-emetic medication in the OR, on the PACU was extracted from the AIMS. The study personnel recorded the anti-emetic use after PACU discharge. The primary outcome of this study was the incidence of PONV within the first 24 hours after surgery. Secondary, incidence of early and late PONV was calculated. Early PONV was defined as PONV up to discharge from the recovery room and late PONV as any PONV thereafter up to 24 hours. Anti-emetic drug usage was also analyzed to identify an increase or decrease between the control and DS periods.

Statistical analysis

The primary comparisons were done between the intervention and control groups using a chi square test for proportions and either a Student T test or a Mann-Whitney U test, depending on distribution. We accepted a difference as statistically significant when the p-value of the statistical test was smaller than 0.05.

Results

Overall, 2662 patients (1681 in the intervention period and 981 in the control period) were included in this prospective study. Patient characteristics are summarized in table 5.1.

Table 5.1 Patient characteristics

	Intervention period (with reminders) N (%)	Control period (without reminders) N (%)	
	1681 (100)	981 (100)	
Patient demographics			
Age (years, mean, SD)	50 (16)	49 (16)	*ns*
BMI (kg*m-2, median, IQR)	25 (22/28)	25 (23/28)	*ns*
ASA class			
I	891 (53)	545 (56)	*ns*
II	636 (38)	360 (37)	*ns*
III	144 (9)	73 (7)	*ns*
IV	9 (0.5)	3 (0.3)	*ns*
PONV risk factors			
Female sex	933 (56)	532 (54)	*ns*
Non smoking status	1117 (68)	651 (68)	*ns*
History of PONV or motion sickness	408 (24)	247 (25)	*ns*
Expected opioid use	863 (52)	393 (40)	$p < 0.001$
Anaesthesia duration (minutes, median, IQR)	67 (43/110)	61 (41/97)	*ns*
Apfel's risk score			$p = 0.02$
0 factor positive	126 (8)	91 (10)	
1 factor positive	411 (25)	279 (29)	
2 factors positive	577 (35)	305 (32)	
3 factors positive	389 (24)	218 (23)	
4 factors positive	136 (8)	60 (6)	

Comparing the presence of risks factors in both groups, in the control period less patients were expected to receive postoperative opioids (40%), in comparison with the intervention period (52%).

During the intervention period, the overall incidence of early or late PONV was 23% compared to 27% in the control period (p = 0.01, table 5.2). The incidence of early nausea (4 vs. 5%), early vomiting (1 and 1%) and late vomiting (8 vs. 9%) were not significantly lower in the intervention period. In contrast, late nausea was significantly lower in the intervention period (21 vs. 24%, p = 0.03). The reduction in overall PONV incidence was exclusively in the high-risk patient group, where PONV incidence was reduced from 47 to 30% (p < 0.001).

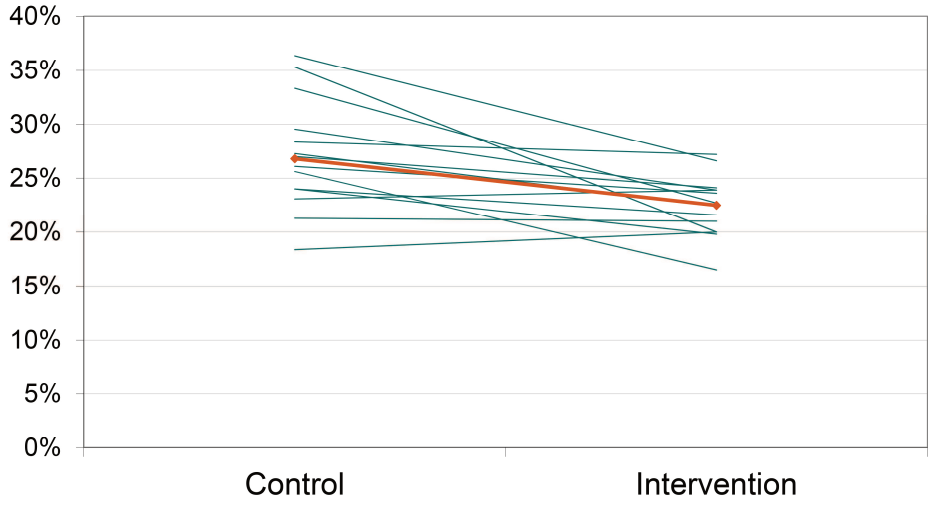
Table 5.2 Effect of reminders on incidence of postoperative nausea and vomiting

	With reminders N (%)	Without reminders N (%)	
Early (before PACU discharge)	1681 (100)	981 (100)	
Nausea	72 (4)	50 (5)	*ns*
Vomiting	16 (1)	10 (1)	*ns*
Late (after PACU discharge)	1672 (100)	959 (100)	
Nausea	349 (21)	234 (24)	*p* = 0.03
Vomiting	140 (8)	83 (9)	*ns*
Overall Nausea and Vomiting	378 (23)	264 (27)	*p* = 0.01
In high risk patients (≥3 RF)	162 (31)	133 (47)	*p* < 0.001
In low risk patients (< 3 RF)	216 (19)	131 (19)	*ns*

RF: Risk Factor

Figure 5.1 shows the incidence of PONV per responsible anaesthesiologist. The incidence decreases for every anaesthesiologist, although there is one anaesthesiologist with a slightly increasing incidence of PONV (from 23 to 24%). Moreover, the range of incidences decreases with the incidence of PONV ranging between 18 – 36% in the control period and between 17 – 27% in the intervention period.

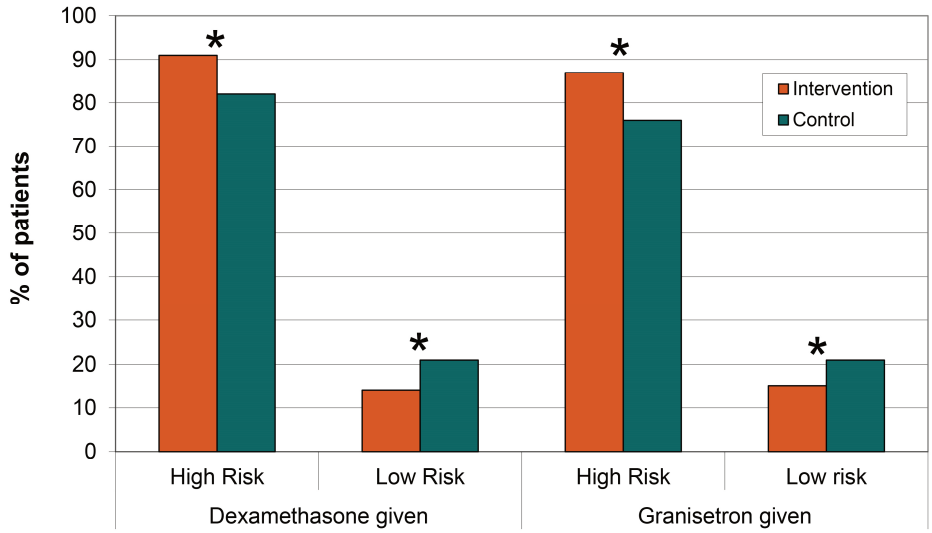
Figure 5.1 PONV Incidence per responsible anaesthesiologist. The orange line indicated the average of all anaesthesiologists



The overall use of dexamethasone, granisetron and metoclopramide did not differ between the intervention and control period. A reduction in the use of droperidol was observed in the control period when compared to the intervention period (2 vs. 1%, table 5.3).

The administration of PONV prophylaxis to high risk and low risk patients is also shown in table 5.3 and figure 5.2. The administration of prophylactic medication to high-risk patients significantly increased with the help of decision support, from 82 to 91% for dexamethasone ($p < 0.001$) and from 76 to 87% for granisetron ($p < 0.001$). In contrast, low risk patients received less PONV prophylaxis during the intervention period. Dexamethasone was given to 21% of low risk patients in the control period vs. 14 % in the intervention period ($p < 0.001$). For granisetron, these percentages are 21 vs. 15%, respectively ($p = 0.002$).

Figure 5.2 Administration of prophylactic medication



*** Denotes statistically significant difference**

Table 5.3 Anti-emetic use and PONV prophylaxis in high- and low-risk patients

	With reminders N (%)	Without reminders N (%)	
	1681 (100)	981 (100)	
Overall anti-emetic use			
Dexamethasone	635 (38)	379 (38)	*ns*
Droperidol	9 (1)	22 (2)	$p < 0.001$
Granisetron	627 (37)	362 (37)	*ns*
Metoclopramide	2 (0)	2 (0)	*ns*
PONV Prophylaxis			
High-risk patients	525 (100)	278 (100)	
Dexamethasone given	479 (91)	227 (82)	$p < 0.001$
Granisetron given	457 (87)	212 (76)	$p < 0.001$
Low-risk patients	1114 (100)	675 (100)	
Dexamethason given	150 (14)	139 (21)	$p < 0.001$
Granisetron given	161 (15)	136 (21)	$p = 0.002$

Discussion

The most important finding of this study is that in routine daily practice, an automated patient specific decision support system is able to improve patient outcome, a decreased incidence of PONV, through improving guideline adherence.

The potential limitation of any guideline is the adherence to it by clinicians. Adherence to any guideline, such as hand hygiene or antibiotic prophylaxis, has been repeatedly proven to be difficult using conventional measures.[20,21] Several studies have demonstrated that patient specific decision support may be an effective modifier of physician behavior and may therefore improve guideline adherence.[1,2,12,13,22-24]

Patient specific decision support is a much more effective method to improve behavior than traditional tools, such as education and feedback. In a recent study, despite vastly improving adherence, even the most intensive strategy the authors employed (education plus a quarterly personalized review of performance) was not able to attain a genuinely satisfactory adherence level (65% overall adherence)[19]. In contrast, patient specific decision support, without any structural educational or feedback effort by personnel, instantaneously improved guideline adherence from 46 to 95% for the administration of dexamethasone.[1] The difference in effect between these two studies demonstrates the very high effectivity of automated reminders in influencing physician behavior.

The difficulty in applying guidelines to selected groups of patients is also reflected by the practice to give 'universal' PONV prophylaxis, where every individual patient receives one or more prophylactic drugs, regardless of the PONV risk. There is no evidence available to support such practice, nor is there any literature on PONV incidence in populations receiving universal PONV-prophylaxis. It can however be calculated that, in a population with a 10% baseline risk (i.e. no positive

risk factors), assuming a relative risk reduction of 26% per prophylactic medicine given, 90% of patients will not experience PONV regardless of whether they receive PONV prophylaxis and 7.4% will still experience PONV regardless of the medication. Only 2.6% of patients do not experience PONV because of the prophylactic medication. In contrast, all patients are exposed to the potential (usually mild) side effects.

The optimum between a risk score based approach and a universal prophylaxis approach remains to be defined. This was also illustrated in a recent pro-con discussion.[25-27]

In the present study, we have shown that AIMS and decision support systems can make a difference. In addition to the demonstrated increase in PONV prophylaxis administration to high risk patients, decision support decreased the inappropriate administration of PONV prophylaxis to low risk patients. This suggests that automated reminders not only are effective in promoting correct actions, but may prevent unnecessary prescription to other patients.

There were also several limitations to our study, the most important of which is that the calculated sample size of the control group was not achieved. Unfortunately, due to a change in hospital logistics, we were not able to continue gathering data for our study. Further, compared to other studies, PONV incidence in the control group was relatively low: 27%. This is probably due to a relatively high guideline adherence in the control group in the present study: even without decision support 83% and 77% of high-risk patients correctly received dexamethasone and granisetron, respectively. This may suggest a long term (years) learning effect in our hospital. In a previous study, we have demonstrated the absence of such a learning effect over a shorter period of time (months).[1,2] Performing several studies on PONV over the last few years may thus have increased the awareness among the anaesthesia care-givers that has not been demonstrated in a single study. This high adherence in the control group may have mitigated the effect of decision support in the present study. It may also demonstrate that

continued attention for PONV prevention is essential and in itself may eventually increase guideline adherence.

In addition, the greater proportion of high-risk patients in the intervention period, compared to the control period, may have reduced the measured effect of decision support in the present study. Thus, the real effect of decision support on the incidence of PONV may even be more pronounced than the estimate in our study.

In conclusion, we showed that implementation of decision support for the selection of high risk PONV patients, combined with automated reminders for the administration of PONV prophylaxis significantly decreases the incidence of PONV in routine daily practice.

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CHAPTER 6

Preventing diclofenac prescription, a simple reminder with unintended consequences

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Manuscript in preparation

Introduction

Clinical decision support systems have been identified as powerful modulators of clinical behaviour; they exist as a simple paper checklist or as sophisticated automated reminder systems integrated in an electronic medical record system.[2,9,21,22] In previous studies, we demonstrated that automated reminders can improve prescription and administration of medication and can improve patient outcome.[5,15,23] It is also known that decision support systems can cause unintended effects by a number of different mechanisms.[24] These unintended effects are difficult to predict and careful testing of decision support before implementation, as well as evaluation after implementation should be performed.

Non-steroid anti-inflammatory drugs (NSAIDs) are potent analgesic drugs used worldwide in peri-operative medicine.[25-27] NSAIDs also have serious side effects, such as gastric ulceration/perforation or acute kidney failure, and prescription should include careful consideration of risks and benefits.[28,29] NSAIDs are prescribed frequently at the pre-anaesthetic screening visit. During this visit, the anaesthesiologist considers a number of different guidelines, indications and contra-indications for different aspects of the anaesthetic plan. One of those aspects is prescription of an NSAID as pre-medication before surgery. The NSAID of choice for analgesic premedication in our departmental guideline is diclofenac, which - according to our guideline - should always be supplemented with a proton pump inhibitor (esomeprazole) for gastric protection. Therefore, the prescription of NSAIDs in the pre-operative screening clinic is susceptible to errors. In our hospital, we felt that the awareness for NSAID contra-indications was suboptimal leading to NSAIDs prescription regardless of contra-indications. To improve correct prescription of NSAIDs, we decided to employ a decision support system.

This study focussed on the co-prescription of esomeprazole with diclofenac to pre-surgical patients in the context of a decision support system discouraging diclofenac prescription to patients with at least one contra-indication for NSAIDs. In other words: our study studied the unintended consequences from decision support. We hypothesized that the decision support system would affect appropriate co-prescription of esomeprazole, while correctly reducing diclofenac prescription to patients with one or more contra-indications for NSAIDs.

Methods

This study was conducted at the pre-operative outpatient clinic of the Academic Medical Centre (AMC) Amsterdam, The Netherlands. In this department, all nurse and physician offices are equipped with anaesthesia information management system (AIMS) workstation and all anaesthesia-related patient data regarding pre-anaesthetic evaluation is primarily stored in the AIMS database. Annually, approximately 24000 patients undergo surgery at the AMC and approximately 75% of these patients are screened at the pre-anaesthetic outpatient clinic. This study included all consecutive patients evaluated at the pre-anaesthetic outpatient clinic from march 1st to august 31st, 2010. Since the study was strictly observational, free of any intervention to the patient and the decision support system only provided information that was otherwise available as well, informed consent process for this study was waived by the local IRB.

Although the effects of decision support were measured in patients, the actual subject of our study was physician behaviour. The focus group in that respect was formed by department's physicians; 47 anaesthesiologists and 35 residents. The effect of the decision support system on actual prescription of diclofenac was evaluated using data from the AIMS.

The study was conducted over two study periods: the first four months were used as control period followed by a two month intervention in which the decision support system in the AIMS was activated.

Our decision support system consisted of a single pop-up window, programmed into our AIMS. The reminder appeared only when the anaesthesiologist prescribed diclofenac in the presence of a documented contra-indication in the AIMS. Contra-indications that were used to trigger the reminder were previous gastric ulcer, pyrosis, gastro-oesophageal reflux disease, renal function impairment, creatinine value

> 120 μmol/l. Although this list is not complete regarding all contra-indications for diclofenac, these contra-indications were the most frequently occurring ones in our AIMS at that time. A contra-indication could have been either mentioned by the patient in the pre-operative patient questionnaire, or in the patient's history entered in our AIMS by the anaesthesiologist during the visit. The reminder stated "*Based on the data entered in the patient questionnaire and history, a relative contra-indication to NSAIDs is present.*" In order to continue, the anaesthesiologist had to validate the reminder and could then choose whether or not to prescribe diclofenac despite the contra-indication(s).

Patient characteristics, data regarding contra-indications, as well as diclofenac and esomeprazole prescription were extracted from the AIMS database by pre-written queries.

Primary outcome was the incidence of diclofenac prescription to patients with at least one contra-indication for NSAIDs. Secondary outcomes were the percentage of patients that received gastric protection as indicated (i.e. esomeprazole) and the percentage of patients without a contra-indication that received a diclofenac prescription.

Survey

User experience was evaluated by a survey. The survey was sent to all anaesthesiologists and residents at the end of the intervention period, followed by reminders to return the survey after one and two weeks. We measured user friendliness by asking questions regarding computer skills, annoyance caused by the system and trust. The survey data was entered in a dedicated database and analysed separately.

Statistics

For comparisons between the control- and intervention group regarding proportions, a χ^2 test was used to compare control and intervention period data, and to test for statistical significance of

differences. For continuous variables, a Students *t*-test was employed. $P < 0.05$ was considered statistically significant.

Sample size analysis

Based on retrospective data analysis, diclofenac was prescribed to approximately 25% of our patients. About 35% of these patients had at least one contraindication for diclofenac. We assumed a decrease of approximately 70% in prescription of diclofenac in patients with a contra-indication, which would translate to a total decrease of 6% (from 25 to 19%) in the overall patient population. Based on the estimate that 50% of patients receive esomeprazole with their diclofenac, our primary outcome measure (correct esomeprazole prescription) would occur in 12,5% in the control group and 9,5% in the intervention group.

Based on these data and using $\alpha = 0.05$ and $\beta = 0.80$, the suggested sample size was 1704 patients per group. This corresponds to just under a two-month period, based on production of the pre-operative screening clinic. To confirm the assumption of our power calculation, we decided to use a 4-month period for inclusion of the control group.

Results

During the study period, 5082 patients were screened at the pre-operative screening clinic by a total of 82 individual physicians. Esomeprazole and diclofenac prescriptions were ordered by 43 physicians during this study period. Besides an increased incidence of reflux in the intervention period, there were no differences in characteristics of patients included during the control and the intervention period with regard to prevalence of NSAID contraindications (table 6.1).

Table 6.1 Patient demographics

	Control N (%)	Intervention N (%)	Significance
Total number of patients	3351	1731	
Age (mean(SD), year)	44,5 (24,3)	46,3 (20,4)	NS
Length (mean(SD), cm)	162 (29)	170 (21)	NS
Weight (mean(SD), kg)	67,1 (27,1)	71,8 (23,2)	NS
Any contraindication			
Pyrosis	440 (13%)	232 (13%)	NS
Reflux	71 (2%)	90 (5%)	$p < 0.0001$
Ulcer	111 (3%)	43 (2%)	NS
Renal disease	174 (5%)	89 (5%)	NS

NS Not significant

The prescription of esomeprazole in the presence of an NSAID prescription decreased from 54% of diclofenac prescriptions in the control period to 41% of diclofenac prescriptions during the intervention period ($p < 0.0001$, table 6.2). In patients without a contra-indication for diclofenac, the decrease of esomeprazole prescriptions was more marked (55 vs 32%, $p<0.0001$) than in patients with a contra-indication for diclofenac (43 vs 35%, not significant).

Prescription of diclofenac to patients with a contra-indication decreased, as expected, from 18% during the control period to 11% in the intervention period (p = 0.003). The number of prescriptions of diclofenac to patients without a contra-indication remained similar in both periods (29 vs 27%, respectively, not significant, table 6.2).

Table 6.2 Prescription of NSAIDs and Diclofenac

	Control N (%)	Intervention N (%)	Significance
Total number of patients	3351	1732	
NSAID prescribed	910 (25)	423 (21)	p = 0,04
Gastric protection prescribed	490 (54% of 910)	140 (41% of 423)	p < 0.0001
Without contraindications	2697 (80)	1386 (80)	
Diclofenac prescribed	794 (29)	386 (28)	NS
Gastric protection prescribed	440 (55% of 794)	127 (32% of 386)	p < 0.0001
With contraindications	654	346	
Diclofenac prescribed	116 (18)	37 (11)	p = 0.003
Gastric protection prescribed	50 (43% of 116)	13 (35% of 37)	NS

Table 6.3 displays results from the survey. Despite two additional reminders, only 26 out of 82 (32%) anaesthesiologists and residents returned the survey. Of these, 16 out of 43 (37%) had worked at the outpatient clinic during the study period. Due to the low response rate we could not quantitatively analyse the results about the decision support system. All respondents rated their own computer skills as "moderately proficient" or better.

Thirteen out of 16 physicians wanted to receive more often similar reminders, and nine physicians reported that they would like to receive periodical feedback about their performance. However, only six out of 16 physicians replied they "trusted" the system to make the right decision for them. Two of the physicians responded they were "annoyed by the system" and six physicians reported they found the system had some drawbacks.

Table 6.3 Survey results

	Years experience	Computerskills[1]	# Reminders recieved	Reminders unexpected[2]
Median response	13.5	3	1.5	3.5
Minimum	0	3	0	1
Maximum	29	4	8	5

[1]Skills defined as: 1 = not proficient, 5 = very proficient;

[2] Level of unexpectancy: 1 = No, 3 = sometimes, 5 = Yes

Discussion

The main finding of the present study was that the introduction of the decision support system led to an unwanted and unintended effect on the co-prescription of esomeprazole, while effectively reducing improper diclofenac prescription. During the intervention period, co-prescription of esomeprazole with any diclofenac prescription decreased from 42 to 35% (relative risk increase 19%). Prescription of diclofenac to patients with a contra-indication decreased by 7% (relative risk reduction 48%). In the patients without a contra-indication for diclofenac, the decrease of esomeprazole prescription was even more marked.

Frenzel et al. have previously reported unintended adverse effects of decision support systems.[24] The authors investigated individualized feedback as well as education to improve adherence to a PONV prophylaxis protocol. Although this study reported a moderate increase in compliance by the reminders, the authors also showed that the number of patients being overmedicated doubled. In the accompanying editorial, Epstein stressed the importance of adequate investigation and possibly even regulation of CDSS due to the risks of serious adverse events that might be caused by system errors and unintended consequences.[7] Our results underline the importance of rigorous evaluation of any automated decision support system and illustrate that even a single reminder can have unintended consequences. Based on our results we decided to modify the reminder to include a recommendation for co-prescription of esomeprazole.

The decrease in prescription of esomeprazole may be an unintended effect of the reminders. This may have been the result of the distraction caused by the respective reminder, a phenomenon known as task interruption. After being distracted (receiving a reminder), the task originally planned next is omitted and forgotten.[30] As a result, the positive effect of the reminder is partly counteracted by its unwanted consequences. Therefore, potential benefits (improved guideline

adherence) should be weighed against the risks (e.g. task interruption) when designing a decision support system.

Although there is a significant reduction of inappropriate diclofenac prescriptions, some patients with at least one contra-indication still received the drug despite the reminder. We speculate that physicians prescribed diclofenac in spite of known relative contra-indications because they weighed the relatively strong analgesic and anti-inflammatory effects against the relative contra-indications and decided to prescribe after that.

As with every set of rules or tests, there is always a balance between the amount of false positives and false negatives. Although false positives are probably more harmful for user trust in a system, false negatives may have such an effect too. Our system was designed to not generate any false positives. Due to technical limitations in the design of the system, there were a number of situations in which a reminder should have triggered but did not. Although our system did not generate any unjustified reminders, only 31% of responders to the survey stated they would trust such a system to make correct decisions. Two physicians rated the system as "annoying"; one of them received a reminder on only one occasion and the other received two reminders. All of the physicians stated that they would like to see more decision support systems implemented in the future.

Limitations

We performed an observational before-after study, which makes the conclusions mainly associative, not causative. We found an unexplained difference in the study groups; the incidence of reflux was significantly higher in the intervention group. There was no change in the way this was documented during the study period, nor was there any intended change in the surgical populations in our hospital that could explain this increase. However, the clinical actions taken for an individual patient

upon the presence of a symptom (such as reflux) do not change if the incidence in a patient population is higher.

Not all contra-indications known were included in this decision support system. Although the system included a number of contra-indications (previous gastric ulcer, pyrosis, gastro-oesophageal reflux disease, renal function impairment/creatinine value > 120 μmol/l), there were several others that were not included (M. Crohn, Colitis ulcerosa, congestive heart failure, bone marrow depression). These contra-indications are off course not less relevant, although in our patient population they were more rare. The reason why they were not included is that we had no discrete parameter indicating their presence; these co-morbidities would typically be stored in a free text field within our AIMS. This meant that the system was unable to trigger a reminder message for every contra-indication, just for the ones discretely documented in the AIMS. Also, if a contra-indication was not documented (and not reported by the patient), the system would not trigger a reminder.

Due to the low response rate of the survey it is not possible to draw any solid conclusions from this part of our study.

Conclusion

Unintended consequences are a real pitfall in designing and implementing decision support systems. Although our automated reminder system reduced unwanted diclofenac prescription, the concurrent and unintended decrease in indicated esomeprazole prescription might have negated part of the positive effects. Our study once again emphasizes that careful testing and evaluating is always warranted when implementing decision support systems.

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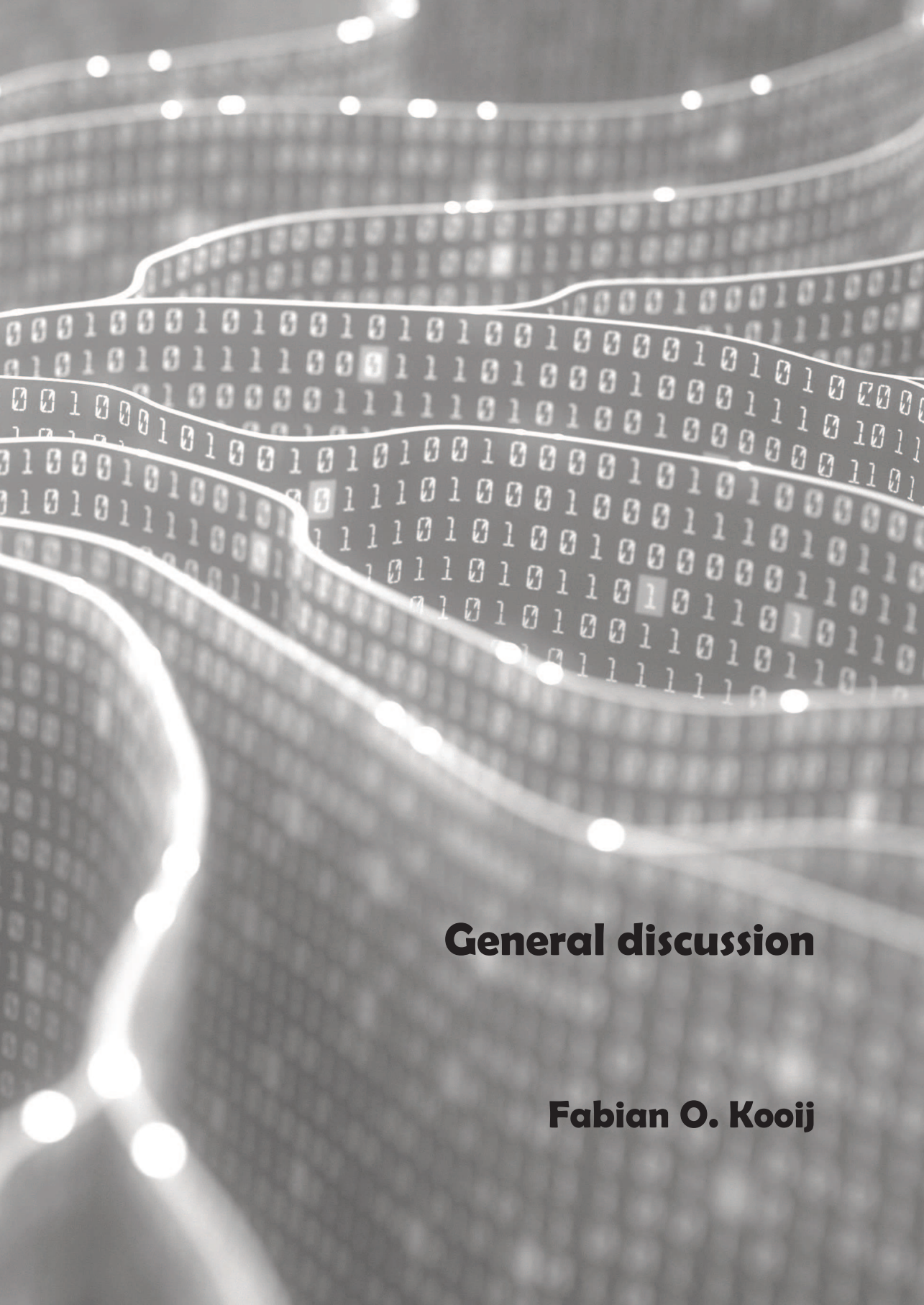
CHAPTER 7



General discussion

Fabian O. Kooij

This thesis demonstrated that an automated reminder system, clinically relevant and statistically significant, improves patient outcome by modifying clinician behavior to improve guideline adherence. By using a set of four different automated reminders, we effectively doubled guideline adherence and thereby reduced postoperative nausea and vomiting in high-risk patients from 47 to 31% without increasing the amount of anti-emetics used.

Although this sounds almost self-explanatory, the number of studies showing limited or no effect of decision support, an unintended effect or a very high override of alerts or reminders are multiple.[1-5] The effectiveness and safety of decision support is by no means "out of the box" functionality. The exact trigger, the timing of the message, the design of the message, the exact recommendation displayed as well as the options given to execute the recommendation offered are all of major importance for efficacy and safety of a decision support system.

The trigger to activate a decision support system is essentially a set of rules that selects and combines data elements to decide when a reminder message should appear. Equally important: this set of rules also defines the situations in which a decision support system should not activate a reminder message. Optimal selection could be defined as a message that appears every single time it is applicable and never appears when it is not applicable (either because the action had already been performed or because the patient did not fit the criteria). When not applied correctly, this leads to alert fatigue and eventually to ignored reminders.[6] As demonstrated in this thesis, it is achievable to create an adequate set of rules using binary risk factors and/or ordinal scores. Future research could be directed towards stratifying more complex (combinations of) risk factors to drive decision support and develop smarter algorithms to recognize clinical situations from the automated data flowing into an electronic patient data management system.

The timing of the message does also matter. Decision support is most effective when it is delivered automatically whenever and wherever a

decision is made. Predicting when a decision is made in a clinical workflow is possible (chapter 2, chapter 3), but there is a real chance that a message will not be followed if the user is already busy with a number of other tasks or does not agree with the advice given (chapter 4). Moreover, there is a real chance of task interruption (chapter 6), which can lead to other aspects of clinical care being forgotten or omitted. Further refining of the algorithm deciding when to show a message in relation to user activity could further boost the effectivity of decision support.

A third important factor is the content of a reminder. To achieve maximum effectiveness, the information should be as patient specific as reasonably achievable and should contain an actionable advice. Providing information that is too generic may lead to an undesirable deterioration of care due to clinicians following the recommendation where it is not applicable.[5] On the other hand, clinicians tend to ignore messages they perceive as incorrect or irrelevant. Whenever a system shows too many incorrect or irrelevant messages, reminders are routinely overridden, as occured in some medication order entry systems.[3]

Decision support systems should offer actionable advice.[7] However, the ease of use in effectuating that advice is also relevant for its efficacy. A decision support system cannot change the amount of actual clinical work involved (such as drawing up and administering drugs, drawing labs or setting the ventilator). However, it can offer easy options for documenting these actions within the electronic health record. This actually requires some further development from the patient data management system vendors, as currently it usually requires a rather large number of clicks and keystrokes to document the clinical actions based on the advice from the reminder.

Besides careful design, every decision support system should be evaluated for effect upon implementation. Special attention should be given to potential unintended effects as demonstrated in chapter 6. The

reminder in that study probably caused a task interruption that led to a decrease in co-prescription of gastric protection with an NSAID (table 6.2). This unintended consequence potentially negated an important part of the beneficiary effect of the reminder.

There are several studies in the literature that show either ineffective decision support systems or systems with unintended side effects.[1-5] In implementing systems that interfere with behavior of clinicians, it remains essential to continuously evaluate for effect as well as side effects.

As mentioned in the introduction of this thesis, decision support systems cannot ameliorate all reasons for non-adherence. Especially disagreement with the guideline and a negative attitude towards guidelines in general are difficult to overcome with decision support alone. Therefore, decision support systems can never be an alternative to education and implementation, which may not be a guarantee to overcome reasons for non-adherence based in attitudes and beliefs.[8] This is also demonstrated in chapter 4. Despite having completed an extensive implementation process, there were still some clinicians that disagreed with the risk estimation by the guideline and did explicitly chose not to adhere to it because they did not agree with the guideline or it's risk estimation (table 4.3). This demonstrates an important limitation of decision support and mandates a proper implementation process for any major changes in clinical practice, but even if that can apparently not guarantee complete agreement.

In conclusion, decision support using automated reminders can be an effective tool for supporting guideline implementation, modifying physician behavior and improving patient outcome.

To achieve this the data processing should be designed in a way that there is a minimum of false-positive reminders and as little as possible false-negative situations, where a reminder does not appear when indicated. In addition, the timing, content and the means of effectuating the advice given should be optimally designed. However, even with

optimal designs, automated reminders cannot overcome every reason for non-adherence and employing decision support does not replace an implementation and education process.

To prevent unintended deterioration of care, any decision support system employed should be evaluated for its effect.

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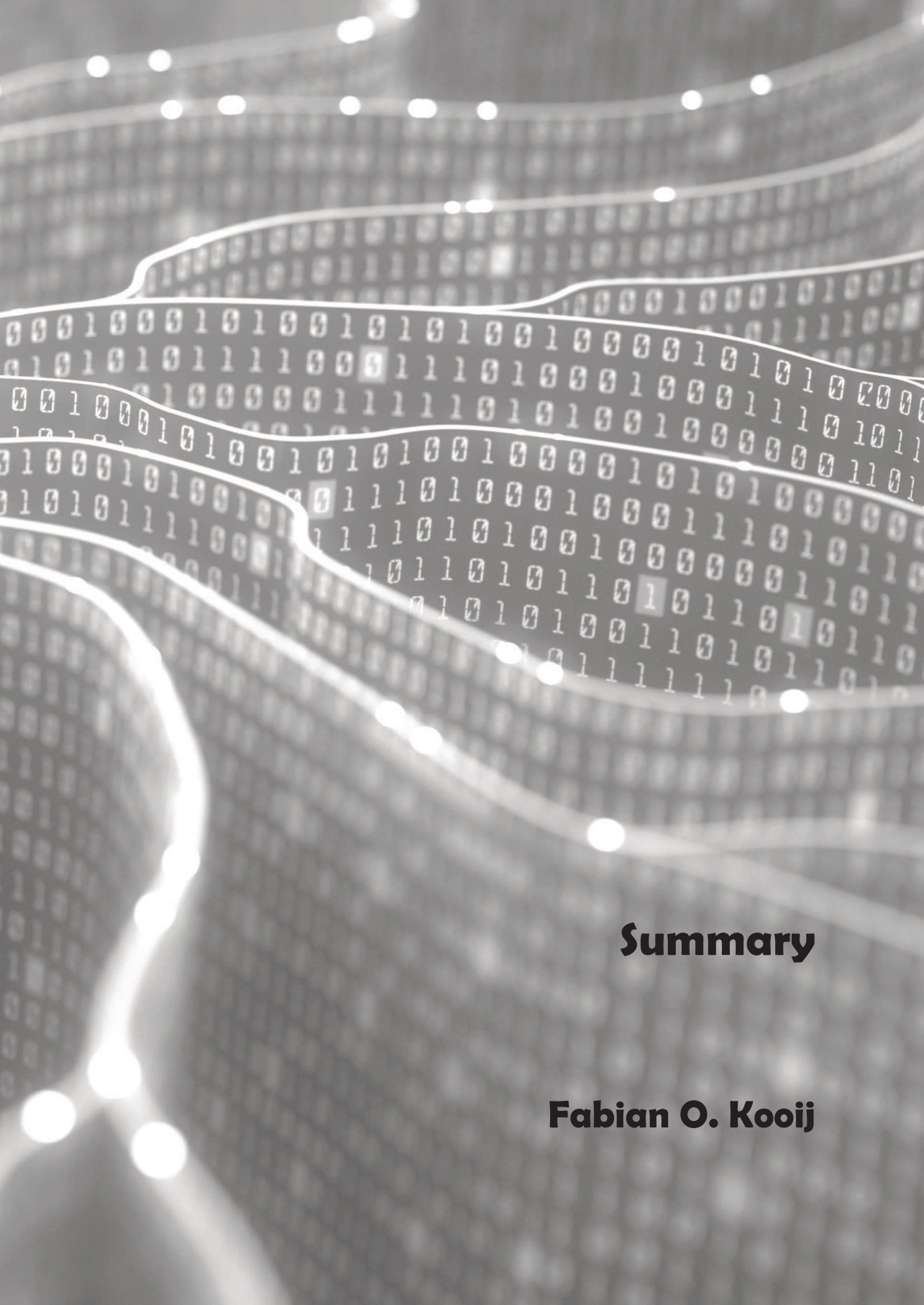
CHAPTER 8



Summary

Fabian O. Kooij

This thesis reports on four studies on guideline adherence to a departmental PONV guideline and a study on preventing NSAID prescription to patients with a contra-indication.

In **chapter 2**, we measured the effect of decision support on identifying high-risk patients and ordering PONV prophylaxis. Using a combination of mandatory fields, we facilitated the case providers to adequately document risk factors, so that a risk estimate could be made more reliably. Once general anesthesia was scheduled for a high-risk patient, but no PONV prophylaxis had been scheduled, a reminder suggested that this patient was eligible for PONV prophylaxis. Using this fairly simple intervention we improved ordering of PONV prophylaxis from 38 to 73% in high-risk patients without increasing ordering of prophylaxis for low-risk patients (table 2.2). Interestingly, there was no learning effect at all; upon activating the reminders, adherence went to 73% within days (figure 2.1). However, after de-activating the reminders, guideline adherence fell back to the control level (37%) instantaneously (figure 2.1).

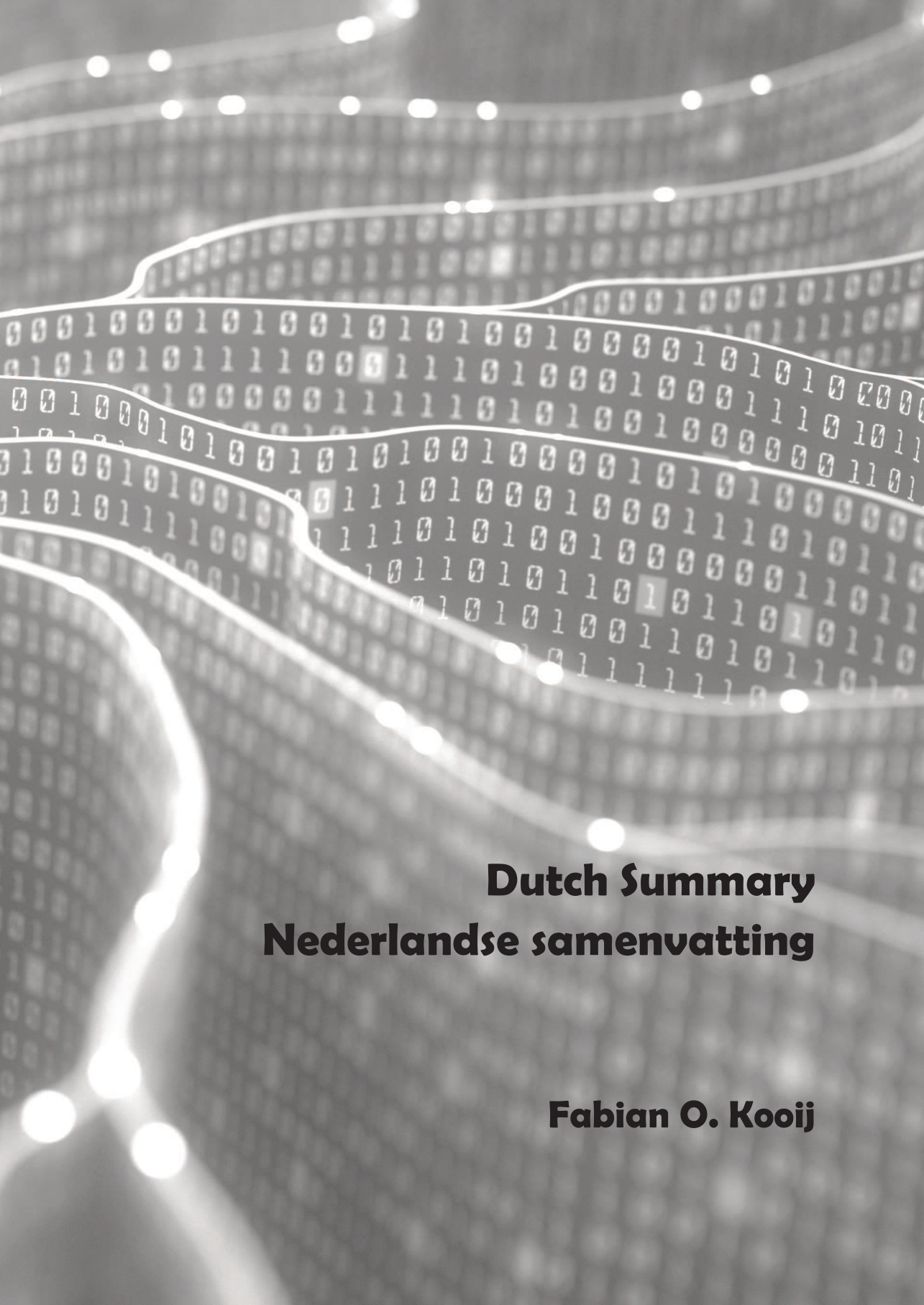
In **chapter 3** we investigated the next step in decision making; the actual administration of prophylactic medications. We identified the high-risk patients receiving general anaesthesia and monitored the medications that were documented as being administered. Reminders suggesting the need for prophylactic medication appeared 10 minutes after induction (for dexamethasone) and upon arrival at the recovery room (for granisetron). Again, during the intervention period there was a clear improvement of prophylactic medication administration. Dexamethasone was administered to 95% of eligible patients instead of 46% of patients, and granisetron in 89% instead of 53%. Moreover, not just the administration of dexamethasone and granisetron improved significantly: the timeliness of the administration improved significantly as well (figure 3.2). Similar to the previous study, no learning effect was seen at all. Again, immediately after de-activating of the reminders adherence fell back to the control levels.

Chapter 4 describes why clinicians did not follow the recommendation provided by the reminders. Requesting a reason for not following a prompted recommendation improved adherence more effectively than reminders without requesting a reason. However, it also showed a marked difference between different settings; in the outpatient clinic the main reason for non-adherence was disagreement with the risk assessment for PONV suggested by the guideline. Consequently, the reminder with reason request led to a change in only 31 out of 496 patients (6%). In the operating room and PACU, unintended non-adherence was the main reason for not following the guideline. For granisetron administration, 290 out of 452 patients (64%) received prophylaxis following our intervention to request a reason. The difference in reason for non-adherence and effect of the reason request demonstrates that not all barriers for adherence can be amended by decision support.

In **chapter 5**, we investigated the effect of decision support on actual patient outcome. All surgical patients received a follow up visit between 24 and 48 hours after surgery. By means of these follow up visits, we found that the use of our decision support system reduces PONV incidence in a general surgical population. PONV incidence decreased overall from 27 to 23%. For high-risk patients, the decrease was even more profound; from 47 to 30%. Interestingly, the overall amount of anti-emetics (dexamethasone, granisetron, droperidol, metoclopramide) used in the OR and on the PACU did not change. This suggests that the decision support succeeded in modifying clinician´s behavior to a point where the anti-emetic was redistributed to those patients that benefitted the most of them. Interestingly, PONV prophylaxis in the control group of this study was much better than the original control groups from chapter 2 and 3, suggesting that some form of learning process took place through the continued focus on PONV prophylaxis.

Chapter 6 reports on a study that discourages unwanted prescriptions. The decision support system in this study, using a single automated reminder, tells clinicians not to prescribe diclofenac as anesthetic premedication to patients with a contra-indication for diclofenac. The most interesting conclusion of this study is that even a single reminder can have unwanted and unintended consequences. Besides prescribing less diclofenac in the intervention period (relative risk reduction 48%), the clinicians also co-prescribe less gastric protection (esomeprazole, relative risk increase 19%). Part of the beneficial effects (less diclofenac and thereby less side effects) is therefore negated by the unintended effects (less esomeprazole). Evaluation of all effects of a decision support system should be part of any implementation of a decision support system.

CHAPTER 9



Dutch Summary
Nederlandse samenvatting

Fabian O. Kooij

Het is algemeen bekend dat richtlijnen niet altijd gevolgd worden. Dit is meestal het gevolg van een matige implementatie, maar zelfs bij goede implementatie wordt zeer frequent afgeweken van sommige richtlijnen. Soms wordt de richtlijn slechts gevolgd bij 40 - 50% van alle patiënten waarbij géén klinische reden is om deze richtlijn niet te volgen. Aangezien richtlijnen in essentie een samenvatting van het wetenschappelijk bewijs zijn met als doel de zorg voor patiënten te verbeteren, is ongewenst afwijken in potentie verantwoordelijk voor een slechtere patiëntenzorg en mogelijk zelfs uitkomst.
Beslissingsondersteuning bestaat in vele vormen, zoals checklists en automatische herinneringen binnen een elektronisch patiënten dossier. In potentie is beslissingsondersteuning in staat het volgen van richtlijnen door clinici te bevorderen.

Dit proefschrift bespreekt verschillende aspecten van een beslissingsondersteuningssysteem met automatische, op de patiënt en situatie aangepaste, herinneringen. Het onderzoek dat in dit proefschrift besproken wordt is gepland als onderdeel van een implementatie proces van een richtlijn. Op basis van brede toepasbaarheid en relevantie binnen de anesthesie is gekozen voor de afdelingsrichtlijn preventie en behandeling van postoperatieve nausea en vomitus (PONV) te gebruiken voor ons onderzoek. Voor de eerste studie zijn we gestart met een uitgebreid richtlijn ontwikkelings- en implementatie proces waarbij onder anderen gebruik gemaakt werd van onderlinge discussies, informatieve en educatieve sessies en een Delphi proces waarbij van alle anesthesiologen inbreng verwacht werd. Alle PONV studies in dit proefschrift (hoofdstuk 2, 3, 4 en 5) maken gebruik van deze richtlijn als basis.

Volgens deze richtlijn wordt voor de operatie een risico inschatting gemaakt aan de hand van vier risicofactoren: vrouwelijk geslacht, niet-roken, eerdere PONV of bewegingsziekte en verwachte postoperatieve opiaatbehoefte. Een patiënt wordt als hoog risico bestempeld wanneer 3 of meer risicofactoren aanwezig zijn. Hoog risico patiënten hebben volgens het protocol recht op profylaxe met dexamethason 4 mg iv bij inductie en 1 mg granisetron tijdens de uitleiding van de anesthesie.

Het meten van onze uitvoering van de richtlijn en het zo nodig inrichten en invoeren van beslissingsondersteuning waren geplande onderdelen van het implementatieproces. Uiteindelijk hebben we geautomatiseerde herinneringsmeldingen ontwikkeld voor iedere stap van het richtlijnproces (voorschrijven, toediening tijdens inductie, toediening tijdens uitleiding). Het effect van deze meldingen op het gedrag van de zorgverleners (anesthesiologen en anesthesiemedewerkers) en op misselijkheid en braken van patiënten hebben wij onderzocht. De uitkomsten daarvan beschrijven wij in hoofdstukken 2, 3, 4 en 5.

In **hoofdstuk 1** is een samenvatting van de kennis welke een rol gespeeld heeft tijdens het ontwerp en implementatie van de richtlijn en de herinneringsmeldingen. Achtereenvolgens bespreken wij een aantal mechanismen die een rol spelen in het maken van beslissingen, een aantal redenen om richtlijnen niet te volgen en bespreken wij de verschillende beschikbare vormen van beslissingsondersteuning en hun eigenschappen.

Hoofdstuk 2 beschrijft een studie naar het effect van beslissingsondersteuning in het correct identificeren van patiënten met een hoog risico op PONV. Hiervoor is een combinatie van verplicht in te vullen velden en een herinneringsbericht gebruikt. De verplichte velden zijn bedoeld om de vier risicofactoren zeker te documenteren, zodat bij iedere patiënt een adequate risico schatting gemaakt kan worden. Op moment dat een patiënt als hoog-risico geclassificeerd was (3 of meer aanwezige risicofactoren) en algehele narcose, maar geen PONV profylaxe werd afgesproken werd de herinnering getoond die aangaf dat deze patiënt volgens de richtlijn PONV profylaxe zou moeten krijgen. Met behulp van deze relatief eenvoudige maatregelen werd het correct voorschrijven van PONV profylaxe bijna verdubbeld van 38% naar 73% zonder dat onterecht voorschrijven van PONV profylaxe aan laag-risico patiënten toenam (tabel 2.2). Binnen enkele dagen na inschakelen van de meldingen was het effect volledig, maar na deactiveren van de meldingen was het effect ook vrijwel instantaan verdwenen (figuur 2.1). Er leek geen leercurve te identificeren.

In **hoofdstuk 3** beschrijven we het onderzoek naar de volgende stap; het toedienen van de profylactische medicatie op OK. Van alle patiënten op OK zijn de patiënten met een verhoogd risico op PONV geïdentificeerd en vervolgens is bekeken hoe vaak de profylactische medicatie (correct) werd toegediend. De herinneringsmeldingen in deze studie werden 10 minuten na de inleiding (voor dexamethason) en bij aankomst op de verkoeverkamer (voor granisetron) getoond. Tijdens de interventieperiode was opnieuw een duidelijke verbetering van uitvoering van de richtlijn te zien. Aan 95% (in plaats van 46%) van de patiënten die dexamethason zouden moeten krijgen werd het ook daadwerkelijk gegeven. Voor granisetron kreeg 89% (in plaats van 53%) de medicatie toegediend. Interessant is ook dat het op tijd toedienen van medicatie toeneemt; zowel dexamethason als granisetron worden tijdens de interventieperiode vaker "op tijd" gegeven (figuur 3.2). Ook in deze studie werd geen leercurve gevonden; direct na de-activatie van de meldingen verslechterde de uitvoering van de richtlijn weer tot het niveau waarop hij was voordat de meldingen geactiveerd werden.

Hoofstuk 4 beschrijft een studie naar redenen die zorgverleners hebben om de aanbevelingen van de meldingen alsnog niet te volgen. Het toevoegen van een tweede melding waarin gevraagd wordt naar een reden blijkt de uitvoering van de richtlijn nog verder te verbeteren dan de meldingen die niet naar een reden vragen. Uit deze studie wordt ook duidelijk dat de redenen het advies van een melding niet te volgen kunnen verschillen afhankelijk van de omgeving. Op de pre-assessment poli was de meest genoemde reden om af te wijken dat de zorgverleners het niet eens waren met de risico schatting van het systeem. De extra herinnering leidde dan ook niet tot veel veranderingen; bij 31 van de 496 patiënten (6%) waar een melding getoond werd, werd het beleid ook gewijzigd. Dit was anders op de OK, waar het per ongeluk niet volgend van de richtlijn het meest genoemd werd. Van de 452 patiënten waarbij de melding voor granisetron getoond werd, kregen er 290 (64%) alsnog granisetron. Het verschil in effect van de tweede melding maakt duidelijk dat

beslissingsondersteuning niet bij iedere reden om van een richtlijn af te wijken effect heeft.

In **hoofdstuk 5** wordt een onderzoek naar het effect van de eerder onderzochte interventies op de uitkomst van patiënten, het vóórkomen van PONV, beschreven. Tijdens deze studie werd bij alle patiënten die algehele anesthesie gehad hadden een controle gedaan tussen 24 en 48 uur postoperatief. Door in dit bezoek te vragen naar misselijkheid en braken konden wij aantonen dat het gebruik van ons beslissingsondersteuningssysteem de incidentie van PONV verlaagt. In de interventieperiode daalde de incidentie van 27 naar 23% van alle geopereerde patiënten. In de groep met een verhoogd risico was het verschil nog duidelijker; de incidentie daalde van 47% in de controleperiode naar 30% in de interventieperiode. Hoewel de incidentie van misselijkheid en braken aanzienlijk daalde bleef de totale hoeveelheid toegediende anti-emetica (dexamethason, granisetron, droperidol en metoclopramide) gelijk. Dit suggereert dat de beslissingsondersteuning zorgde voor een betere verdeling van de anti-emetica; in de interventieperiode werden de anti-emetica vaker profylactisch toegediend aan die patiënten die er het meeste voordeel van hadden. Een nevenbevinding was dat de profylactische toediening in de controlegroep van deze studie duidelijk beter was dan in de controlegroepen van de studies die in hoofdstuk 2 en 3 beschreven worden. Hoewel het mechanisme onduidelijk blijft, lijkt het alsof over de voortdurende aandacht voor PONV profylaxe toch leidt tot een geleidelijk leerproces.

Hoofdstuk 6 beschrijft een studie waarin ongewenst voorschrijven geremd wordt met behulp van beslissingsondersteuning. Het beslissingsondersteuningssysteem in deze studie helpt clinici met behulp van één enkele herinnering minder diclofenac premedicatie voor te schrijven aan patiënten met een contra-indicatie voor diclofenac. De belangrijkste bevinding van deze studie is dat een eenvoudige herinnering onbedoelde gevolgen kan hebben. Hoewel er inderdaad minder diclofenac voorgeschreven wordt (48% relatieve risicoreductie), wordt er ook minder esomeprazol mee voorgeschreven met diclofenac

(19% relatieve risicotoename). Een deel van het positieve en gewenste effect (minder diclofenac, dus minder bijwerkingen) wordt dus weer teniet gedaan door het ongewenste effect (minder esomeprazol). Bij iedere invoering van een beslissingsondersteuningssysteem is het essentieel dat nauwkeurig naar álle effecten van dat systeem gekeken wordt.

APPENDICES

Dankwoord

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Hooggeleerde Preckel, beste Benedikt, de manier waarop jij eigenlijk altijd in staat bent om in de grote drukte snel naar een stuk te kijken en bovendien in staat bent een gezonde werk-prive balans te behouden dwingt bij mij respect af. Jouw betrokkenheid bij dit traject is pas in de tweede helft intensiever geworden, maar daarom niet minder belangrijk. Dank voor je begeleiding en ondersteuning die zelfs tot op Madagascar reikte.

Weledelzeergeleerde Kal, beste Jasper, de basis van deze promotie ligt bij jou. Een eerste poging waagde je al toen ik, nog als co-assistent, voor een opleidingsplaats kwam solliciteren en jij als gepromoveerde arts-assistent in de sollicitatiecommissie zat. Zo'n 2 jaar later, toen inmiddels in het OLVG, bediscussieerden wij de mogelijkheden van het electronische verslagleggingssysteem. Op onnavolgbare wijze heb je mij alsnog weten te motiveren en is de basis gelegd voor deze promotie. Ik denk nog met veel genoegen terug aan onze trip naar San Diego, waar we door alle Amerikanen werden uitgelachen omdat wij met ons idee de

kwaliteit wilden verbeteren in plaats van de "billing". Jouw wijze, soms bijna paternalistische adviezen en jouw bijzondere aandacht voor precisie hebben de stukken en daarmee dit boek mede gemaakt tot wat zij zijn. Daarnaast ben je er meester in om op precies het juiste moment dat duwtje te geven wat nodig is om de volgende stap te zetten. Dank voor jouw begeleiding.

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Hoogeleerde Schlack, Beste Wolfgang, toen jij mij eind 2008 vroeg of ik geen interesse had in een stafplek op het AMC heb ik daar maar heel kort over na hoeven denken. Behalve dat ik alles wat ik wilde (en meer) kon doen is, op een hele andere manier, wat hierboven bij Markus staat ook op jou van toepassing. Jouw gedrevenheid om de anesthesiologie veiliger te maken en de visie over hoe dat dan zou moeten, gecombineerd met jouw respect voor een goed beargumenteerde standpunt (ook als dat initieel niet het jouwe was) maken dat ik mij geen beter afdelingshoofd kan wensen. Ik heb de afgelopen 8 jaar met veel plezier meegebouwd aan de ontwikkeling van onze afdeling en

hoop daar nog lang mee door te mogen gaan. Dank dat je in mijn commissie zitting wil nemen.

Hooggeleerde Goslings, Beste Carel, Hooggeleerde Kerkhoffs, Beste Gino, op een ander vlak dan waar dit boek over gaat komen wij elkaar het meest tegen, namelijk op de OK en/of de traumakamer. Daar waar nog steeds het meest mijn hart ligt: in de (acute) patientenzorg. Nu dit werk klaar is hoop ik Gino's patienten weer wat vaker te mogen voorzien van anesthesie met, zo zullen jullie nu begrijpen, voldoende maar niet te veel anti-emetica. Voor Carel zal ik dat helaas niet meer mogen doen, maar in het OLVG zijn de reminders uit dit proefschrift nog immer actief. Hartelijk dank voor jullie bereidheid zitting te nemen in de commissie.

Hooggeleerde van Hulst, Beste Rob, ook hyperbare- en duikgeneeskunde is een iets ander vlak van de anesthesiologie dan automatische beslissingsondersteuning. Het zal ook nog wel even duren voordat we ín de tank gebruik kunnen maken van dit soort automatische herinneringen. Daarbuiten, achter het paneel, doen de technici dat al jaren (hoewel niet automatisch) in de vorm van de tabellen. Dank dat je dit boek hebt willen lezen en in mijn commissie zitting wil nemen. Tot bij de volgende (acute) patient in de tank.

Hooggeleerde Vroom, Beste Margreeth, de intensive care en per-operatieve anesthesiologie zijn in mijn optiek elkaars complementaire verlengstukken. Ook in het onderzoek naar electronische verslaglegging en beslissingsondersteunings lijken deze twee specialismen meer op elkaar dan op welke andere zorgsetting ook. Ik ben zeer benieuwd naar jouw gedachten en kijk er naar uit met je van gedachten te wisselen. Mijn hartelijke dank dat je in mijn commissie wil plaatsnemen.

Weledelgeleerde Klok, Beste Toni, ik ken weinig dokters die zo enthousiast over computers, elektronische verslaglegging en databases kunnen praten als jij. Vanaf het eerste begin ben jij betrokken geweest bij de ideeën, maar ook het programmeren van bijna alle reminders en queries ten behoeve van de studies in dit boek. Op mijn mening dat dokters niet moeten programmeren omdat ze daar hooguit middelmatig

in worden en te duur zijn ken ik tenminste één uitzondering en dat ben jij. Toen we hier aan begonnen hebben we ons voorgenomen dat we er allebei op zouden promoveren. Als jij dit leest is het mij gelukt. Het is mij een groot genoegen dat je op deze dag naast mij wil staan, maar toch daag ik je uit om dat oude voornemen alsnog waar te maken en op een dag achter het katheder te staan in plaats van ernaast te zitten.

Roelant, mijn andere paranimf en broer. In alle drukte en hectiek van de afgelopen jaren (niet alleen aan mijn kant overigens) heb ik je veel minder vaak gesproken dan ik had gewild. Daar zijn altijd redenen voor, maar des te trotser ben ik dat je vandaag naast mij wil staan als paranimf. Laten wij ons voornemen om vaker even koffie te drinken. Helemaal nu je op "spitting distance" van mijn huis werkt.

Gedurende een promotietraject van meer dan 10 jaar in twee verschillende ziekenhuizen is het bijna onvermijdelijk iemand te vergeten. Ik ga dan ook niet proberen uitputtend te zijn, maar toch zijn er een aantal mensen die ik nog wil noemen.

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Nicky Vos en Pieter Siebenga. Wat voor jullie begon als een wetenschappelijke stage eindigde met bijna 6 maanden lang iedere individuele patient 24 uur later opsporen. Het klinkt simpel, 24 uur na de operatie even een kort gesprekje hebben met de patiënt om te zien of hij/zij misselijk geweest is. De praktijk van een ziekenhuis met dagbehandeling en een beddentekort maakte dat jullie meerdere

serieuze speurtochten hebben ondernomen. Uiteindelijk hebben jullie (bijna) iedereen gevonden. Dank voor jullie inspanningen. Hoofdstuk 5 zou er niet geweest zijn zonder jullie.

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Dit werk is af, nu is het tijd voor jouw grote sprong: je eigen edelsmederij en het opbouwen van een eigen collectie.

List of Publications

Reanimatie na trauma: Betere overlevingskansen door doelgerichte behandeling
Lena Koers, Hans L. van Schuppen, Victor A. Viersen, ***Fabian O. Kooij***, Carel Goslings en Markus W. Hollmann
Ned Tijdschr Geneeskd. 2017;161:D1174

Out of hospital thoracotomy for cardiac arrest after penetrating thoracic injury.
Mark G. van Vledder, Oscar J.F. van Waes, ***Fabian O. Kooij***, Joost H. Peters, Esther M.M. van Lieshout, Michael H.J. Verhofstad
Injury 2017 in press

The effect of requesting a reason for non-adherence to a guideline in a long running automated reminder system for PONV prophylaxis.
Fabian O. Kooij, Toni Klok, Benedikt Preckel, Markus W. Hollmann, Jasper E. Kal
Appl Clin Inform. 2017 Mar 29;8(1):313-321

Postoperatieve Nausea en Vomitus (PONV)
Fabian O. Kooij and Teus H. Kappen (2016)
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Fabian O. Kooij, Anouk P. van Alem, Rudolph W. Koster, Rien de Vos.
Resuscitation 2004 Oct; 63(1): 33-41

About the Author

About the author

Fabian Kooij was born on august 2nd, 1978 in Hilversum. During highschool he followed first aid and CPR courses and graduated from high school in 1996. He was able to continue with his medicine study without delay.

He studied medicine at the university of Amsterdam (1996-2003). A scientific project on training of police officers as AED first-responders within the ARREST group confirmed a passion for emergency critical care. During senior internships in intensive care medicine and surgery at Onze Lieve Vouwe Gasthuis in Amsterdam Fabian secured a residency position and immediately continued as an anaesthesia resident.

Back at Onze Lieve Vrouwe Gasthuis as an anaesthesia resident the first work on this thesis was done while continuing clinical training.

After finishing formal training as an anaesthesiologist in 2009, he started work as a consultant anaesthesiologist and, besides clinical care and continuing work on this thesis, he has filled positions as the medical coordinator of the PACU, in the management team of the department of anaesthesia, the lead clinician in the implementation of a new anaesthesia information management system (as part of a hospital wide electronic medical record, Epic) and most recently as the lead clinician for emergency & acute care anesthesia.

Besides residency and working on the research in this thesis, Fabian worked as physician repatriating patients back to their home country, as well as doing intensive care transfers an intensive care physician with the Amsterdam Mobile Intensive Care Unit (MICU).

In 2012, Fabian was able to fulfill a long term ambition of caring for critically sick or injured patients prehospital as a physician on a medical emergency helicopter, Lifeliner 1, based at the Free University Medical Center (VUmc) in Amsterdam.

In private live, Fabian is happily married to Linda and enjoys their time together either riding on horseback in the beautiful surroundings of the Veluwe (or anywhere else in the world), traveling and cooking. Especially with a glass of good wine or whiskey.