Preoperative evaluation

Risk management and implementation aspects

Wilton A van Klei

Preoperative evaluation

Risk management and implementation aspects

Preoperatief onderzoek

Risico management en implementatie aspecten

(met een samenvatting in het Nederlands)

Proefschrift ter verkrijging van de graad van doctor
aan de Universiteit Utrecht
op gezag van de Rector Magnificus, Prof. dr. W.H. Gispen,
ingevolge het besluit van het College voor Promoties
in het openbaar te verdedigen op

dinsdag 16 april 2002 om 12:45 uur

door

Wilhelmus Antonie van Klei

geboren op 29 november 1970 te Gorinchem

Promotoren : Prof.dr. JTA Knape, Universitair Medisch Centrum Utrecht
Prof.dr. DE Grobbee, Universitair Medisch Centrum Utrecht

Copromotoren : dr. KGM Moons, Universitair Medisch Centrum Utrecht
dr. CLG Rutten, Isala klinieken Zwolle

ISBN: 90-393-2993-1

Design and Lay-out: MTM, grafische studio, UMC Utrecht
Printed by: Krips bv, Meppel
Cover: View from the Chimney Tops, Great Smoky Mountains National Park, Tennessee, USA, October 2001

This thesis is also available at http://www.library.uu.nl

Financial support by Zorgonderzoek Nederland (Den Haag), the department Julius Center and the department Perioperative care, Anesthesia and Pain management of the UMC Utrecht, and Ortho-Biotech (Tilburg), for the publication of this thesis is gratefully acknowledged

Ach wie flüchtig, ach wie nichtig
Ist der Menschen Leben!
Wie ein Nebel bald entstehet
Und auch wieder bald vergehet
So ist unser Leben, sehet!

So schnell ein rauschend Wasser schießt
So eilen unsers Lebens Tage
Die Zeit vergeht, die Stunden eilen
Wie sich die Tropfen plötzlich teilen
Wenn alles in den Abgrund schießt

Die Freude wird zur Traurigkeit
Die Schönheit fällt als eine Blume
Die größte Stärke wird geschwächt
Es ändert sich das Glücke mit der Zeit
Bald ist es aus mit Ehr und Ruhme
Die Wissenschaft und was ein Mensche dichtet
Wird endlich durch das Grab vernichtet.

An irdische Schätze das Herze zu hängen
Ist eine Verführung der törichten Welt
Wie leichtlich entstehen verzehrende Gluten
Wie rauschen und reißen die wallenden Fluten
Bis alles zerschmettert in Trümmern zerfällt

Die höchste Herrlichkeit und Pracht
Umhüllt zuletzt des Todes Nacht
Wer gleichsam als ein Gott gesessen
Entgeht dem Staub und Asche nicht
Und wenn die letzte Stunde schläget
Daß man ihn zu der Erde träget
Und seiner Hoheit Grund zerbricht
Wird seiner ganz vergessen

Ach wie flüchtig, ach wie nichtig
Sind der Menschen Sachen!
Alles, alles, was wir sehen
Das muß fallen und vergehen
Wer Gott fürcht', bleibt ewig stehen

Anonymous author (JS Bach. Dominica 24 post trinitatis. BWV 26)

Table of contents

1

General introduction

Before undergoing surgery, each patient is evaluated by an anesthesiologist. The aims of this preoperative evaluation are fourfold: the probability of perioperative morbidity and mortality due to the scheduled surgical procedure is estimated, the required anesthetic policy is determined, the patient is informed about anesthesia and informed consent is obtained.[1-3] To the first aim, the general health status of each patient is assessed with an emphasis on the vital functions. Currently, this health status assessment primarily consists of a medical history and a physical examination. If necessary, additional laboratory tests or consultation of other medical specialists (e.g. a cardiologist) are obtained.[2;3] When indicated, the patients' physical condition will be improved by specific interventions, such as blood pressure regulation in case of hypertension or optimization of pulmonary function. Based on the results of these health and risk assessments, the required anesthetic policy during the scheduled surgical procedure is determined and explained to the patient.[1-3]
For a decade, a large number of additional tests, such as ECG or laboratory investigations, were routinely performed in every patient before surgery, as a surrogate for preoperative evaluation. It has been demonstrated extensively that additional tests should be ordered as indicated by the findings of the patients' history and physical examination. Routinely performed preoperative testing is not only unnecessary, but it may even harm patients.[1-14] Currently, however, it remains unclear how elaborate the patient history and physical examination before surgery should be and to what extent the results of this assessment predict patient outcome.

The aim of this thesis was to explore to what extent simple patient characteristics (particularly obtained from preoperative patient history and physical examination) could contribute to the probability estimates of perioperative morbidity and mortality. In other words, which information is necessary to assess the patient's health status properly and which information may be redundant (diagnostic value) and is this information useful to predict outcome (prognostic value)?
To this aim, the literature on preoperative patient history and physical examination was reviewed (chapter 2). In chapter 3 (second part) the value of the Dutch Health Council guidelines on the contents of preoperative evaluation was evaluated. Chapter 4 describes the value of preoperative auscultation for detecting the presence of valvular heart disease as an example of diagnostic

research in perioperative care. To determine whether and in which patients a preoperative 'type and screen' and hemoglobin level measurement are necessary, a prediction rule for the need of perioperative red blood cell transfusion was derived (chapter 5.1) and validated (chapter 5.2). To determine which patients will benefit from preoperative blood conservation strategies, another prediction model was derived and validated (chapter 6). Chapter 5 and 6 are both examples of prognostic prediction research in perioperative patient care.

Traditionally, patients are visited on the ward by the anesthesiologist for preoperative evaluation the day before surgery. Mainly as a result of the increasing number of patients operated in outpatient surgery or after same day admission in the past decade, the timing of preoperative evaluation has shifted from the day before surgery to *outpatient* preoperative evaluation (some weeks before surgery). It has been reported that outpatient preoperative evaluation increases quality of care and cost-effectiveness.[3;15-20] In particular, it allows for comprehensive assessment, additional evaluation and optimization of the patient's condition without delaying surgery. Hence, outpatient preoperative evaluation enhances implementation of outpatient surgery and same-day admissions and has the potential to reduce the number of late operating room cancellations due to newly discovered co-morbidity.[1;3;15-19;21;22] As a result of these developments, in 1997 the Dutch Health Council suggested to implement outpatient preoperative evaluation clinics in each hospital and issued guidelines on the contents of preoperative evaluation.[1]
As it has been recommended to perform the health status assessment some weeks before surgery, we also quantified the implementation process of OPE clinics in the Netherlands as well as the effects of introducing OPE in a particular university teaching hospital. A quantification of the implementation of OPE clinics in the Netherlands as proposed by the Dutch Health Council is given in chapter 3 (first part). To examine the logistical effects of outpatient preoperative evaluation, we compared the rate of cancellation of surgery and length of hospital stay before and after the introduction of an outpatient clinic (chapter 7).

Finally, chapter 8 discusses research methods that are applicable in preoperative evaluation, including suggestions for further research.

References

1 Health Council of the Netherlands, Committee on preoperative evaluation. Preoperative evaluation. 1997/2. [Dutch, English summary]

2 Adriaensen, Baele, Camu, et al. Recommendations on pre-anesthetic evaluation of patients put forward jointly with the BSAR and the BPASAR. The Belgian Society of Anesthesia and Reanimation and the Belgian Professional Association of Specialists in Anesthesia and Reanimation. Acta Anaesthesiol Belg 1998; 49: 47-50

3 Roizen MF. Preoperative evaluation. In: Miller RD, ed. Anaesthesia. New York: Churchill Livingstone, 2000; 824-83

4 Macario A, Roizen MF, Thisted RA, et al. Reassessment of preoperative laboratory testing has changed the test-ordering patterns of physicians. Surg Gynecol Obstet 1992; 175: 539-47

5 McCallion J, Krenis LJ. Preoperative cardiac evaluation. Am Fam Physician 1992; 45: 1723-32

6 Narr BJ, Hansen TR, Warner MA. Preoperative laboratory screening in healthy mayo patients: Cost-effective elimination of tests and unchanged outcomes. Mayo Clin Proc 1991; 66: 155-9

7 Narr BJ, Warner ME, Schroeder DR, et al. Outcomes of patients with no laboratory assessment before anesthesia and a surgical procedure. Mayo Clin Proc 1997; 72: 505-9

8 Perez A. Value of routine preoperative tests: a multicentre study in four general hospitals. Br J Anaesth 1995; 74: 250-6

9 Tait AR, Parr HG, Tremper KK. Evaluation of the efficacy of routine preoperative electrocardiograms. J Cardiothorac Vasc Anesth 1997; 11: 752-5

10 Brorsson B, Arvidsson S. The effect of dissemination of recommendations on use. Preoperative routines in Sweden, 1989-91. Int J Technol Assess Health Care 1997; 13: 547-52

11 Haug RH, Reifeis RL. A prospective evaluation of the value of preoperative laboratory testing for office anesthesia and sedation. J Oral Maxillofac Surg 1999; 57: 16-20

12 Goldberger AL, O'Konski M. Utility of the routine electrocardiogram before surgery and on general hospital admission: Critical review and new guidelines. Ann Intern Med 1986; 105: 552-7

13 Munro J, Booth A, Nicholl J. Routine preoperative testing: a systematic review of the evidence. Health Technol Assess 1997; 1: 1-63

14 Schein OD, Katz J. The value of routine preoperative testing before cataract surgery. N Engl J Med 2000; 342: 168-75

15 Fischer SP. Development and effectiveness of an anesthesia preoperative evaluation clinic in a teaching hospital. Anesthesiology 1996; 85: 196-206

16 Rutten CLG, Post D, Smelt WLH. Outpatient preoperative examination by the anesthesiologist I. Fewer items of service and preoperative hospital days. Ned Tijdschr Geneeskd 1995; 139: 1028-32 [Dutch, English summary]

17 Pollard JB, Zboray AL, Mazze RI. Economic benefits attributed to opening a preoperative evaluation clinic for outpatients. Anesth Analg 1996; 83: 407-10

18 Pollard JB, Garnerin P. Use of outpatient preoperative evaluation to decrease length of stay for vascular surgery. Anesth Analg 1997; 85: 1307-11

19 van Klei WA, Moons KGM, Rutten CLG, et al. Effect of outpatient preoperative evaluation on cancellation of surgery and length of hospital stay. Anesth Analg; in press

20 Frost EA. Outpatient evaluation: A new role for the anesthesiologist. Anesth Analg 1976; 55: 307-10

21 Pollard JB, Olson L. Early outpatient preoperative anesthesia assessment: does it help to reduce operating room cancellations? Anesth Analg 1999; 89: 502-5

22 Cassidy J, Marley RA. Preoperative assessment of the ambulatory patient. J Perianesth Nurs 1996; 11: 334-43

2

The role of history and physical examination in preoperative evaluation: much 'opinion' and little 'evidence'

Wilton A van Klei, Diederick E Grobbee, Charles LG Rutten, Pim J Hennis, Johannes TA Knape, Cornelis J Kalkman, Karel GM Moons

Submitted

Before undergoing surgery, each patient is evaluated by an anesthesiologist. The primary aim of this preoperative evaluation is to estimate and to decrease the probability of perioperative morbidity and mortality due to the scheduled anesthetic and surgical procedure.[1-3] To this aim, the general health status of each patient is assessed with an emphasis on the vital functions. If necessary, the patients' health condition will be improved by specific interventions. Based on the results of the health and risk assessments the required anesthetic policy is determined and the patient is informed about the anesthetic techniques. Finally, informed consent is obtained.[1-3]

This preoperative evaluation of surgical patients has been changed in the past decade. Traditionally, patients were hospitalized at least one day before the day of surgery and visited by the anesthesiologist for preoperative evaluation. Since it has been reported that outpatient preoperative evaluation (OPE) increases quality of care and cost-effectiveness, nowadays an increasing number of patients is evaluated on an outpatient basis.[3-8] In particular, OPE allows for comprehensive assessment of the patient at a time that additional investigations and measures to optimize the patient's health are still possible. Hence, it reduces the number of late operating room cancellations and facilitates outpatient surgery and same-day admissions.[1;3;5-11]

Widespread implementation of OPE will require an increase in the number of anesthesiologists. This might increase the costs of anesthetic care and the shortage of anesthesiologists that exists in some West European countries. Therefore, it would be attractive if patients who are 'healthy and ready for surgery without further evaluation' could be easily distinguished from those who 'require more extensive evaluation'. Such a distinction could improve the cost-effectiveness of OPE. In this context the role of nurse practitioners at the OPE clinic has been discussed.[5;12] The use of an initial screening questionnaire including 7 questions on exercise tolerance, current treatment by a physician and use of drugs has also been suggested.[1] However, it has been doubted whether such short questionnaire serves the aim of early discrimination properly.[13]

The aim of this overview is to examine whether the published literature provides evidence to determine how elaborate preoperative patient history and

physical examination must be to assess the health status of surgical patients. Additionally, we briefly discuss the need for additional tests such as ECG and laboratory tests.

Methods

A Medline search was conducted over the years 1991 to 2000 (May), using the following keywords: 'anesthesia AND preoperative evaluation OR assessment', 'anesthesia AND preoperative history', 'anesthesia AND preoperative physical examination', and on additional tests such as: 'preoperative AND chest X-ray', 'preoperative AND laboratory' and 'preoperative AND ECG'. Off all retrieved studies only those that really dealt with the following terms were selected: 'preoperative patient history', 'preoperative physical examination' and 'preoperative additional tests' (ECG, X-ray and laboratory tests). Since we wanted to focus on the role of preoperative history and physical examination, we decided to select only review- and meta-analytical studies on the value of additional tests.

Results

With respect to preoperative history and physical examination two hundred-six articles were found, of which twenty-nine were selected. Seven articles were found and selected on additional tests and in total thirty-two cross-references were selected. Furthermore, we included two papers that currently have been submitted. Thus, seventy articles were used for the present review.

Patient history A thorough patient history is considered mandatory by all authors.[2;3;10;14-30] All tracts should be evaluated with predefined questions, but the focus is on the cardiovascular and respiratory tracts.[3] Additional information on previous anesthesia, hospital admissions, familiar disorders, medications and allergies should be obtained.[3] It is possible to obtain a patient history either through interview by a physician or using an automated questionnaire; both seem to provide appropriate health status assessments.[10;29;30]
It may be questioned to what extent this extensive information is relevant for

anesthesia and long-term prognosis.[13] After all, the majority of patients undergoing elective surgery is in good health; on average about 85% of the patients is classified as ASA class 1 and 2, and may not need to be assessed extensively anyway.[5;23-26;31;32] On the other hand, a short questionnaire emphasizing exercise tolerance, treatment by a physician and use of drugs only, was considered to be insufficient for proper assessment of the patients' preoperative condition: essential information to conduct a safe anesthesia might be missed (e.g. information on muscle diseases or allergies).[1;33;34] This rises the issue to what extent an extensive history determines ASA physical status assessment. One approach to assess physical status may be to use only the anesthesiologists' impression (or 'clinical view') of the patient combined with a short history or questionnaire. This is common practice in many hospitals.[34]

Physical examination Since most preventable causes of death and major morbidity after surgery results from cardiovascular events, it seems logical to focus the preoperative physical examination on the cardiovascular system. At a minimum this should include measurement of blood pressure, auscultation for significant murmurs of heart and carotid arteries and inspection of the legs for signs of oedema.[3;14;16;18;35;36] Potential difficulties with tracheal intubation can be detected by careful examination of head and neck.[37-39] Some authors recommend to assess the risks of pulmonary complications by auscultation of the lungs in all surgical patients, others restrict auscultation to patients undergoing abdominal or thoracic surgery only.[10;36] A major textbook state that it is unnecessary to perform lung auscultation in every patient, since all abnormal sounds suggestive for lung or hart diseases will be detected well by history.[3] A few authors have proposed multifactorial risk scores such as the 'Goldman Cardiac Risk Index' for perioperative cardiac risk in non-cardiac surgery.[21;40-43]

Aortic valvular stenosis seems to be the only cardiovascular risk that requires further examination for its detection. However, for several reasons routine cardiac auscultation can be questioned. First, the ability of anesthesiologists to detect and interpret heart murmurs has not been studied, but it is reported that the diagnostic skills of internists (junior and senior house staff) in interpreting heart murmurs are low: about 50%.[44] Moreover, even an experienced cardiologist detects only 80% of all heart murmurs in asymptomatic subjects under research conditions with only 70% of the patients having valvular heart

disease diagnosed correctly.[45] Second, the true prevalence of aortic valve stenosis in otherwise healthy surgical patients is unknown. Weidenbener et al estimated the prevalence of bicuspid aortic valves (but not of aortic stenosis) at 0.3%, in a population of 2997 athletes.[46] Others found a prevalence of aortic valve stenosis of 2% in a population of elderly patients (aged 65 years or over).[47] Third, it has been suggested, that the majority of patients with significant aortic valvular stenosis (N=48, mean age 73) who have good exercise tolerance, will tolerate anaesthesia.[48] Alternatively, valvular heart disease (e.g. aortic stenosis) may be detected using transthoracic echocardiography. The diagnostic accuracy of this method in patients with suspected valvular heart disease is very high (almost 100%).[49;50] However, the accuracy of echocardiography as a preoperative screening tool for aortic stenosis is unknown. In conclusion, it seems unreasonable to diagnose valvular heart disease based on auscultation only. We think that at least each patient having a murmur detected by auscultation should be evaluated by echocardiography.

The reason to perform preoperative examination of head and neck is to anticipate potential difficulties during tracheal intubation.[3;37-39;51] A difficult laryngoscopy, grade III or IV laryngeal view as described by Cormack and Lehane, is associated with a difficult intubation.[51] The prevalence of such a laryngeal view is about 5% (table).[52] However, a 'difficult laryngoscopy' does not necessarily mean a difficult intubation. It was tried to predict difficult intubation with a single classification (Mallampati; a categorical scale that rates view of the pharyngeal arches) or multiple (Wilson risk score) predictors.[37-39;52-56] Resulting from various factors contributing to a difficult intubation and the low prevalence, tests predicting this difficulty with an acceptable number of 'false alarms' need a high specificity and positive predictive value. Thus, the likelihood ratio of a positive test result (LR+) needs to be high. The LR+ is the ratio of the probability of finding a test result when difficult laryngoscopy is present (sensitivity) and the probability of the same finding when it is absent (1-specificity). It can range from 1 (useless test) to infinity (perfect test). The tests described have a LR+ between 1 and 50 (table).[37-39;52-56] Remarkably, these two extremes are reported for the same test (Mallampati's), which suggests a high inter-observer variability.[57] Although the Mallampati test as described in the original paper seems the best test, others were not able to reproduce its results.[39] A reasonable test to predict difficult intubation is indi-

Table. Tests to predict a difficult intubation (a difficult laryngoscopy, grade III or IV). [51]

Test	N	Difficult laryngoscopy* (%)	PPV (%)	NPV (%)	LR+
Mallampati 1985 [39]					
Mallampati 2 or 3	210	13	51	100	7
Mallampati 3			93	93	50
Wilson 1988 [38]					
Wilson's score	778	2	10	99	6
Oates 1991 [53]					
Mallampati 3	675	2	4	99	3
Wilson's score			9	99	5
Frerk 1991 [54]					
Mallampati 3-m **	244	5	6 #	99	4
Thyromental distance < 7			7#	100	4
Combined method			21#	100	15
Tse 1995 [55]					
Mallampati 3	471	13	22	93	2
Thyromental distance < 7			20	89	2
Combined method			28	88	3
Combined + head extension $<80^0$			38	87	5
el Ganzouri 1996 [37]					
Mallampati 3-m **	10,507	6	21	96	4
Airway risk index > 3			32	96	10
Yamamoto 1997 [56]					
Mallampati 3-m **	3,680	2	2	99	1
Wilson's score	(3,608)	2	6	99	3
Indirect laryngoscopy	(2,504)	1	31	98	19
Rose 1994 [52]					
Score	17,903	5	27	96	6
Prevalence of difficult laryngoscopy	34,468	5			

* Prevalence of a difficult laryngoscopy (grade III or IV) [50]
** Modified Mallampati score
# Recalculated to allow comparison with other tests (as done by Bellhouse also) [70]
PPV = positive predictive value, NPV = negative predictive value,
LR+ = Likelihood ratio of a positive test result (sensitivity / (1-specificity))

rect laryngoscopy as performed by ENT specialists to view the upper airway (table).[56] It has a positive predictive value of 31, which means that 31 out of 100 patients predicted to be difficult to intubate truly have a grade III or IV laryngeal view with direct laryngoscopy. The corresponding LR+ of 19 means that indirect laryngoscopy in this study increases the patients' probability of having a difficult direct laryngoscopy from 1% (prevalence in that study) to 18%.[56] However, a substantial part of the patients (30%) can not be evaluated by indirect laryngoscopy due to, for example, excessive gag reflexes, which reduces its applicability.[56] Other 'tests' to predict difficult intubation are the airway risk index and the combined method of Tse et al. The first is a summary score test that consists of 7 different variables and therefore has limited value for bedside use, whereas the latter has a low LR+ (table).[37]
In summary, it is currently unclear whether it is necessary to predict a possible difficult intubation, and which method should be used. We think that the 'clinical view' of the anesthesiologist possibly predicts as good as prediction tests do.

Additional investigations It has been recommended to refrain from any routine preoperative laboratory- or function tests, such as ECG or chest radiography, when an extensive history and physical examination do not show abnormalities, suggesting the patient is healthy.[1-3;15;17;19;58-63] A large systematic review on routine preoperative testing showed that only 0.5% (range 0-2.1%) of routine preoperative chest X-rays and ECG's lead to a change in clinical management.[64] This percentage was even lower (0.2% or less) for hemoglobin level, blood count and coagulation tests.[64] Recently, a large randomized controlled trial indeed demonstrated that patients do not benefit from any preoperative additional test: the complication rate in patients who had or had not undergone additional testing after history and physical examination before cataract surgery was identical.[28] The benefits from routine preoperative testing for all surgical patients are extremely limited and should therefore not be advocated in healthy patients under 60 years of age.[1-3;64] Moreover, because all tests will have false positive results, further testing may actually harm healthy patients.[1;3]

Preoperative physical condition (ASA) and risk assessment The preoperative physical condition and the occurrence of perioperative complications are closely related.[27;31;32] Patient history and physical examination are the primary

sources to assess this physical condition. Usually, it is scored in the ASA classification.[65;66] It should be noted that in many studies patients were allocated into an ASA class based on extensive medical history, physical examination and additional tests (such as ECG).[21-27] Different prospective studies showed that ASA classification correlates with perioperative morbidity and mortality, although the classification was initially made to describe the physical status only.[21;23-27] Although consistency of ASA class rating between anesthesiologists is poor, there is no other accurate grading system to describe the preoperative physical status or to predict patient outcome.[67-69] Lee et al proposed a model to predict unanticipated intra-operative events (such as hyper- or hypotension and tachy- or bradycardia), which includes type of surgery, level of preoperative preparation, type and duration of anesthesia and ASA class.[22] This model predicted intra-operative events much better than ASA class alone: the area under the receiver operating characteristic curve was 0.72 versus 0.57 for the ASA class only.[22] However, only 'simple' intra-operative events but not postoperative outcomes were evaluated.

Conclusion

In summary, the level of detail of history and physical examination necessary to obtain a reasonable estimate of perioperative risk (and the required anesthetic policy) remains unclear. Further studies may well show that a routine physical examination in all surgical patients is unnecessary. We believe that it is reasonable to assess the ASA class and surgical risk of these patients based on history and physical examination. Additional preoperative tests, such as ECG or laboratory investigations, should be ordered as indicated by the findings of history and physical examination. Routinely performed preoperative testing is not only unnecessary, but may actually harm patients.

References

1 Health Council of the Netherlands, Committee on preoperative evaluation. Preoperative evaluation. 1997/2. [Dutch, English summary]

2 Adriaensen, Baele, Camu, et al. Recommendations on pre-anesthetic evaluation of patients put forward jointly with the BSAR and the BPASAR. The Belgian Society of Anesthesia and Reanimation and the Belgian Professional Association of Specialists in Anesthesia and Reanimation. Acta Anaesthesiol Belg 1998; 49: 47-50

3 Roizen MF. Preoperative evaluation. In: Miller RD, ed. Anaesthesia. New York: Churchill Livingstone, 2000; 824-83

4 Frost EA. Outpatient evaluation: A new role for the anesthesiologist. Anesth Analg 1976; 55: 307-10

5 Fischer SP. Development and effectiveness of an anesthesia preoperative evaluation clinic in a teaching hospital. Anesthesiology 1996; 85: 196-206

6 Pollard JB, Zboray AL, Mazze RI. Economic benefits attributed to opening a preoperative evaluation clinic for outpatients. Anesth Analg 1996; 83: 407-10

7 Pollard JB, Garnerin P. Use of outpatient preoperative evaluation to decrease length of stay for vascular surgery. Anesth Analg 1997; 85: 1307-11

8 van Klei WA, Moons KGM, Rutten CLG, et al. The effect of outpatient preoperative evaluation on cancellation of surgery and length of hospital stay. Anesth Analg; in press

9 Pollard JB, Olson L. Early outpatient preoperative anesthesia assessment: does it help to reduce operating room cancellations? Anesth Analg 1999; 89: 502-5

10 Cassidy J, Marley RA. Preoperative assessment of the ambulatory patient. J Perianesth Nurs 1996; 11: 334-43

11 Rutten CLG, Post D, Smelt WLH. Outpatient preoperative examination by the anesthesiologist I. Fewer items of service and preoperative hospital days. Ned Tijdschr Geneeskd 1995; 139: 1028-32 [Dutch, English summary]

12 Vaghadia H, Fowler C. Can nurses screen all outpatients? Performance of a nurse based model. Can J Anaesth 1999; 46: 1117-21

13 van Klei WA, Moons KGM, Rutten CLG, et al. Preoperative outpatient investigation by the anesthesiologist in young adults: the case history and physical examination suffice, the short questionnaire of the Netherlands Health Council does not. Ned Tijdschr Geneeskd 2000; 144: 1389-93 [Dutch, English summary]

14 Almany SL, Mileto L, Kahn JK. Preoperative cardiac evaluation. Assessing risk before noncardiac surgery. Postgrad Med 1995; 98: 171-2

15 Brorsson B, Arvidsson S. The effect of dissemination of recommendations on use. Preoperative routines in Sweden, 1989-91. Int J Technol Assess Health Care 1997; 13: 547-52

16 Van Aken H, Rolf N. Preoperative evaluation and preparation. The view of the anesthetist. Anaesthesist 1997; 46 Suppl 2: S80-S84 [German, English summary]

17 McCallion J, Krenis LJ. Preoperative cardiac evaluation. Am Fam Physician 1992; 45: 1723-32

18 Mangano DT. Perioperative cardiac morbidity. Anesthesiology 1990; 72: 153-84

19 Narr BJ, Warner ME, Schroeder DR, et al. Outcomes of patients with no laboratory assessment before anesthesia and a surgical procedure. Mayo Clin Proc 1997; 72: 505-9

20 Coriat P, Kieffer E. Preoperative risk stratification in vascular surgical patients. Acta Anaesthesiol Scand Suppl 1996; 109: 127-30

21 Prause G, Ratzenhofer-Comenda B, Pierer G, et al. Can ASA grade or Goldmans' cardiac risk index predict peri-operative mortality? Anaesthesia 1997; 52: 203-6

22 Lee A, Lum ME, Perry M, et al. Risk of unanticipated intraoperative events in patients assessed at a preanaesthetic clinic. Can J Anaesth 1997; 44: 946-54

23 Wolters U. ASA classification and perioperative variables as predictors of postoperative outcome. Br J Anaest 1996; 77: 217-22

24 Arvidsson S. The Gothenburg study of perioperative risk. I. Preoperative findings, postoperative complications. Acta Anaesthesiol Scand 1994; 38: 679-90

25 Arvidsson S. Predicting postoperative adverse events. Clinical efficiency of four general classification systems. Acta Anaestesiol Scand 1996; 40: 783-91

26 Menke H. Präoperative Risikoeinschätzung mit der ASA-Klassification. Eine prospectieve Untersuchung zu Morbidität und Letalität in verschiedenen ASA-Klassen bei 2937 Patienten mit allgemeinchirurgischen Operationen. Chirurg 1992; 63: 1029-34 [German, English summary]

27 Arbous, MS. Anesthesia-related risk factors for perioperative severe morbidity and mortality. Thesis, Utrecht University, The Netherlands. 1998.

28 Schein OD, Katz J. The value of routine preoperative testing before cataract surgery. N Engl J Med 2000; 342: 168-75

29 Roizen MF, Coalson D, Hayward RS, et al. Can patients use an automated questionnaire to define their current health status? Med Care 1992; 30: MS74-MS84

30 Lutner RE, Roizen MF, Stocking CB, et al. The automated interview versus the personal interview. Do patient responses to preoperative health questions differ? Anesthesiology 1991; 75: 394-400

31 Vacanti CJ, Vanhouten RJ, Hill RC. A statistical analysis of the relationship of physical status to postoperative mortality in 68388 cases. Anesth Analg 1970; 49: 564-6
32 Fowkes FGR, Lunn JN, Farrow SC. Epidemiology in anaesthesia III: mortality risk in patients with coexisting physical disease. Br J Anaesth 1982; 54: 819-25
33 Escolano F. Drug allergy in a population of surgical patients. Rev Esp Anestesiol Reanim 1998; 45: 425-30 [Spanish, English summary]
34 van Klei WA, Moons KGM, Lo B, et al. Evaluation of Dutch Health Council guidelines on preoperative evaluation. Submitted
35 Griffith KE. Preoperative assessment and preparation. Int Anesthesiol Clin 1994; 32: 17-36
36 Mohr DN, Lavender RC. Preoperative pulmonary evaluation. Identifying patients at increased risk for complications. Postgrad Med 1996; 100: 241-8
37 el Ganzouri AR, McCarthy RJ, Tuman KJ, et al. Preoperative airway assessment: predictive value of a multivariate risk index. Anesth Analg 1996; 82: 1197-204
38 Wilson ME, Spiegelhalter D, Robertson JA, et al. Predicting difficult intubation. Br J Anaesth 1988; 61: 211-6
39 Mallampati SR, Gatt SP, Gugino LD. A clinical sign to predict difficult tracheal intubation: a prospective study. Can J Anaesth 1985; 32: 429-34
40 Goldman L. Cardiac risk in noncardiac surgery. Ann Intern Med 1983; 98: 504-13
41 Goldman L. Cardiac risk in noncardiac surgery: an update. Anesth Analg 1995; 80: 810-20
42 Larsen SF, Olesen KH, Jacobsen E. Prediction of cardiac risk in non-cardiac surgery. Eur Heart J 1987; 8: 179-85
43 Detsky AS, Abrams HB, McLaughlin JR. Predicting cardiac complications in patients undergoing noncardiac surgery. J Gen Intern Med 1986; 1: 211-9
44 St.Clair EW, Oddone EZ, Waugh RA, et al. Assessing house staff diagnostic skill using a cardiology patient simulator. Ann Intern Med 1992; 117: 751-6
45 Roldan CA, Shively BK, Crawford MH. Value of the cardiovascular physical examination for detecting valvular heart disease in asymptomatic subjects. Am J Cardiol 1996; 77: 1327-31
46 Weidenbener CJ, Kraus MD, Waller BF, et al. Incorporation of screening echocardiography in the preparticipation exam. Clin J Sports Med 1995; 5: 86-9
47 Otto CM, Bonnie KL, Kitzman DW, et al. Association of aortic-valve sclerosis with cardiovascular mortality and morbidity in the elderly. N Engl J Med 1999; 341: 142-7
48 O'Keefe JH, Shub C, Rettke SR. Risk of non-cardiac surgical procedures in patients with aortic stenosis. Mayo Clin Proc 1989; 64: 400-5
49 Jaffe WM, Roche AHG, Coverdale HA, et al. Clinical evaluation versus Doppler echocardiography in the quantitative assessment of valvular heart disease. Circulation 1988; 78: 267-75

50 Hoffmann A, Burckhardt D. Evaluation of systolic murmurs by Doppler ultrasonography. Br Heart J 1983; 50: 337-40

51 Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. Anaesthesia 1984; 39: 1105-11

52 Rose DK, Cohen MM. The airway: problems and predictions in 18,500 patients. Can J Anaesth 1994; 41: 372-83

53 Oates JD, Macleod AD, Oates PD, et al. Comparison of two methods for predicting difficult intubation. Br J Anaesth 1991; 66: 305-9

54 Frerk CM. Predicting difficult intubation. Anaesthesia 1991; 46: 1005-8

55 Tse JC, Rimm EB, Hussain A. Predicting difficult endotracheal intubation in surgical patients scheduled for general anesthesia: a prospective blind study. Anesth Analg 1995; 81: 254-8

56 Yamamoto K, Tsubokawa T, Shibata K, et al. Predicting difficult intubation with indirect laryngoscopy. Anesthesiology 1997; 86: 316-21

57 Karkouti K, Rose DK, Ferris LE, et al. Inter-observer reliability of ten tests used for predicting difficult tracheal intubation. Can J Anaesth 1996; 43: 554-9

58 Macario A, Roizen MF, Thisted RA, et al. Reassessment of preoperative laboratory testing has changed the test-ordering patterns of physicians. Surg Gynecol Obstet 1992; 175: 539-47

59 Narr BJ, Hansen TR, Warner MH. Preoperative laboratory screening in healthy mayo patients: Cost-effective elimination of tests and unchanged outcomes. Mayo Clin Proc 1991; 66: 155-9

60 Perez A. Value of routine preoperative tests: a multicentre study in four general hospitals. Br J Anaesth 1995; 74: 250-6

61 Tait AR, Parr HG, Tremper KK. Evaluation of the efficacy of routine preoperative electrocardiograms. J Cardiothorac Vasc Anesth 1997; 11: 752-

62 Haug RH, Reifeis RL. A prospective evaluation of the value of preoperative laboratory testing for office anesthesia and sedation. J Oral Maxillofac Surg 1999; 57: 16-20

63 Goldberger AL, O'Konski M. Utility of the routine electrocardiogram before surgery and on general hospital admission: Critical review and new guidelines. Ann Intern Med 1986; 105: 552-7

64 Munro J, Booth A, Nicholl J. Routine preoperative testing: a systematic review of the evidence. Health Technol Assess 1997; 1: 1-63

65 Saklad M. Grading of patients for surgical procedures. Anesthesiology 1941; 2: 281-4

66 American Society of Anesthesiologists. New classification of physical status. Anesthesiology 1963; 24: 111

67 Owens WD, Felts JA, Spitznagel EL. ASA physical status classifications: a study of consistency for rating. Anesthesiology 1978; 49: 239-43

68 Wilson ME, Williams NB, Baskett PJF. Assessment of fitness for surgical procedures and the variability of anaesthetists' judgement. Br Med J 1980; 280: 509

69 Haynes SR, Lawler PGP. An assessment of the consistency of ASA physical status classification allocation. Anaesthesia 1995; 50: 195-9

70 Bellhouse CP. Predicting difficult intubation. Anaesthesia 1992; 47: 440-1

3

Evaluation of Dutch Health Council guidelines on preoperative evaluation

WA van Klei, KGM Moons, B Lo, JTA Knape, DE Grobbee, CLG Rutten

Submitted

Published previously in Dutch in Nederlands Tijdschrift voor Geneeskunde 2001; 145: 25-29 and 2001; 145: 2174-8

Outpatient preoperative evaluation (OPE) importantly increases quality of care and cost-effectiveness.[1-6] OPE allows for comprehensive patient assessment, thereby reducing the number of late operating room cancellations, and it facilitates outpatient surgery and same-day admissions.[1-5;7-9] Therefore in 1997, the Health Council of the Netherlands recommended to create OPE clinics.[10] At these clinics, surgical patients should be evaluated by the anesthesiologist. Furthermore, it was recommended to apply a short structured questionnaire (table 1) as an initial screening tool to rapidly assess the health status of patients.[10] If a patient answers all questions in the first column he can be considered as healthy (ASA-1); no physical examination or additional (laboratory) tests would be necessary. Patients giving one or more answers in the second column of table 1 require extensive history and physical examination. In all cases, additional tests should be done if indicated only. At present, it is yet unclear whether the proposed short questionnaire is informative enough for a safe and balanced anesthesia.[11] Moreover, publishing guidelines ascertains not their implementation.[12;13]

The aim of the present study was first to determine the number of OPE clinics in the Netherlands three years after the publication of the Health Council guidelines. A second objective was to determine the ability of anesthesiologists to assess health status and to propose an anesthesia care plan using the short questionnaire (table 1) only, compared to 'conventional' extensive health assessment.

Table 1. Short questionnaire as preoperative assessment, as recommended by the Dutch Health Council. All answers in column I: the patient is healthy and ASA-1. One or more answers in column II: additional history and physical examination necessary.[10]

	I	II
Are you younger than 40 years?	yes	no
Are you sporting?	yes	no
Are you able to do heavy exercise without complaints?	yes	no
Have you recently been ill?	no	yes
Have you recently had an accident?	no	yes
Are you using drugs?	no	yes
Does a physician currently (or recently) treat you?	no	yes

Methods

First objective: Implementation of guidelines on OPE

Hospitals. To determine the number of OPE clinics all 127 Dutch anesthesiologic partnerships in February 2000 received a structured questionnaire on local hospital characteristics (e.g. number of anesthesiologists) and on the organization of preoperative evaluation. For the latter question, three answers were possible: all surgical patients are assessed by OPE (complete OPE clinic), part of these patients (partial OPE clinic) or none (no OPE clinic). Furthermore, questions were asked about the contents of preoperative health assessment (e.g. whether they used the short questionnaire and performed a physical examination in each patient). After one month, non-responders (30%) were asked again to participate.

Analysis. All returned questionnaires were handled anonymously. The responders were categorized into three groups: hospitals with a complete OPE clinic, with a partial or without OPE clinic. Answers across these three types of hospitals were compared with the Chi-square test and odds ratios (OR) with a 95% confidence interval (95% CI) were calculated.

Second objective: Utility of the short questionnaire

Patients. To determine the ability of anesthesiologists to assess the health status of patients using the short questionnaire, 2090 surgical patients aged 16-40 years were asked to fill in the short questionnaire of table 1. These patients visited the OPE clinic of the University Medical Center Utrecht, a 1080 bed Dutch hospital, between June 1999 and June 2000. Subsequently, in each patient the usual extensive health assessment was performed, including a questionnaire of 38 questions and a physical examination of 7 items (in total 45 items). This extensive health assessment was based on current international guidelines as given, for example, by Roizen.[1;14]

Hundred patients were selected from the 379 (18%) who filled in the short questionnaire (table 1) with all answers in column I (which means: 'healthy patient'). Fifty patients scored 'abnormal' at the usual extensive health assessment and 50 were randomly selected from those who scored 'normal'. 'Abnormal' was defined as ≥ 10% (≥ 5/45 items) deviancies in the extensive health assessment and 'normal' was defined as < 10% (< 5/45 items) devian-

cies. This selection was made because the prevalence of conditions that influence anesthesia care in patients aged 16-40 is very low. A simple random sample from the total population might have resulted in a study population with only uncomplicated patients.

Panel of anesthesiologists. A panel of 10 anesthesiologists, employed in different types of hospitals, received on paper the age, gender and proposed surgical procedures of the selected 100 patients, together with the information that each patient answered the questions of table 1 in column I. Each anesthesiologist was asked to answer the following structured questions:

1. To which ASA class belongs this patient?
2. Do you have sufficient information to propose an anesthesia care plan?
3. When you have sufficient information, did you use all information given, or was some information redundant? If so, which information?
4. When you have insufficient information, which information was lacking? When you would have had this lacking information, would you then be able to propose an anesthesia care plan?

A few months later, each anesthesiologist received the results of the extensive health assessment of the same patients and was asked to answer the same four questions.

Outcomes. The main outcome was the frequency at which the anesthesiologists judged to have insufficient information to classify this patient to an ASA class and the frequency at which an anesthesia care plan could be proposed for both sources of information. Furthermore, the items of health assessment that were judged by the anesthesiologists as 'redundant' and 'necessary' were described. This provided information about the desired extensiveness of preoperative health assessment in patients aged 16-40 years.

Analysis. Initially, 1000 responses were analyzed (10 anesthesiologists * 100 patients). Data on five of these 1000 were lost, so 995 patients remained. The difference (with 95% Confidence Interval) between the two frequencies in the main outcome was estimated and tested using the McNemar test. Second, to estimate diversity in judgment between anesthesiologists, the data were aggregated over the 10 anesthesiologists to obtain averaged answers per anesthesiologist. Finally, frequencies of items scored as 'redundant' or 'necessary' were obtained.

Results

Implementation of guidelines on OPE. Of the 127 anesthesiologist partnerships that were asked to participate, 101 (80%) responded, of which 1 refused to fill in the questionnaire. There was no difference in hospital type (size, teaching or not) between responders and non-responders.
On January 1, 2000, 21 (21%) hospitals had a complete and 33 (33%) a partial OPE clinic. Of the latter, in 11 (33%) only elective inpatients were evaluated, in 9 (27%) only day-surgery patients and in 8 (24%) clinics patients were

Table 2. Hospital characteristics, organization of preoperative evaluation and contents of preoperative evaluation according to complete OPE (all patients were evaluated by OPE), partial OPE (some patients were evaluated by OPE) and no OPE (no patients were evaluated by OPE). Values are shown as percentages.

OPE clinic:	complete (N=21)	partial (N=33)	none (N=46)
Hospitals with > 500 beds	38	38	26
Anesthesiologic partnerships in employment	48	30	22 *
Mean number of anesthesiologists / partnership (SD)	8 (7.7)	9 (9.6)	5 (2.5)§
Preoperative evaluation by or under supervision of:			
anesthesiologist	100	100	81
surgical specialist	0	0	19
Contact between patient and anesthesiologist at least 1 hour before start of surgery	52	30	16 #
Use of short questionnaire of Dutch Health Council	24	15	17
Physical examination in all patients preoperatively	76	36	41 ¶
Additional laboratory- or function tests by protocol	76	88	85
Standing agreements with consultative specialists about treatment of common co-morbidity	67	61	62

* Odds ratio complete versus partial or no OPE clinic: 2.5 (95% CI: 1.0-10).
§ Difference in mean number of anesthesiologists in hospitals with complete and partial OPE clinics versus hospitals without an OPE clinic: 3.3 (95% CI: 0.6-6.0).
# Odds ratio complete versus partial or no OPE clinic: 3.2 (95% CI: 1.2-8.8); p = 0.008 (Chi-square trend-test).
¶ Odds ratio complete versus partial or no OPE clinic: 5.0 (95% CI: 1.6-15).
OPE = outpatient preoperative evaluation; SD = standard deviation.

evaluated on their own demand, after consultation by telephone or after review of a health questionnaire. In the remainder 16% the type of patients was not specified. Of all 54 (complete and partial) outpatient clinics, 21 (39%) existed already before the publication of the Health Council guidelines in 1997. The most frequently reported problem in implementation of an OPE clinic concerned financing this clinic (66% of all hospitals).
Table 2 shows the differences in hospital characteristics and the contents of preoperative evaluation across the three types of hospitals. In hospitals with a complete OPE clinic, anesthesiologists more frequently had a fixed salary (they worked in employment), anesthesiologists more often saw the patient at least one hour before initiation of surgery, and a physical examination was performed more frequently. The short questionnaire was used in on average 18% of all hospitals.

Utility of the short questionnaire. The mean age of the 100 patients was 29 years (60% women). Their distribution over the different specialties was in tune with the age category.
Table 3 shows the ASA classification of patients based on both sources of information. The ability of the panel to classify patients according to the ASA classification based on the short questionnaire was significantly less (difference 41%; 95% CI: 38-44%; $p < 0.0001$). Using the extensive information, in 44% of patients scheduled for large Dental- or Orthopedic surgery (Le Fort reconstruction, Isala frame, etc.) the panel judged to have insufficient information for classification. This judgment was given to 20% of all other patients, scheduled to undergo relatively 'simple' procedures (OR 3.1; 95% CI: 1.9-

Table 3. ASA classification of the patients by the panel of anesthesiologists.

	Short questionnaire	Extensive assessment
ASA-1	36%	60%
ASA-2	1%	18%
Unable to classify[#]	63% [¶]	22% [¶]

[#]The members of the panel had insufficient information to classify the patient
[¶] Difference: 41% (95% CI: 38-44%; $p < 0.0001$)

4.9). The mean frequency in which patients were judged as 'unable to classify' differed between the panel members: the range was 0-100% and 4-57% based on the short questionnaire and the extensive evaluation, respectively.

Based on the short questionnaire, for none of the cases an anesthesia care plan was proposed. Table 4 shows items that were judged necessary in addition to the information of the short questionnaire in > 30% of the cases. When this

Table 4. Information with respect to the preoperative general physical condition judged to be at least necessary in addition to the information given by the short questionnaire as proposed by the Dutch Health Council (table 1).

	% missed (95% BI)
History:	
Allergies	97% (96-98%)
Previous perioperative complications	95% (93-96%)
Previous surgeries	83% (81-86%)
Excessive (postoperative) hemorrhage	70% (67-73%)
Neck complaints / impaired retroflexion	59% (56-62%)
Perioperative complications in family	59% (56-63%)
Pulmonary diseases	57% (54-60%)
Smoking behavior and alcohol abuse	55% (52-58%)
Dental status	53% (50-56%)
Drug abuse	44% (41-47%)
Pyrosis and regurgitation	41% (38-45%)
Excessive hemorrhage in family members	38% (35-41%)
Cardiac diseases in history	38% (35-41%)
Current cardiac disease	37% (34-40%)
Back complaints or hernia	34% (31-37%)
(Family) muscle diseases	32% (29-35%)
Physical examination:	
Ability to intubate	92% (90-93%)
Weight	86% (83-88%)
Blood pressure	66% (63-68%)
Length	66% (63-68%)
Cardiac and pulmonary auscultation	65% (62-68%)

information would have been available the panel members thought to have sufficient information to initiate anesthesia in almost all cases. Based on the extensive information, in 65% (95% CI: 62-68%, range 29-93%) of the cases an anesthesia care plan was proposed. In the remaining 35% more information about the indication for surgery, history and physical examination was judged as necessary. In 4% additional (laboratory) tests were judged necessary. No information that was given in the extensive evaluation was judged as 'redundant'.

Discussion

Three years after the publication of the Dutch Health Council guidelines on preoperative evaluation, we quantified the current status of preoperative evaluation in the Netherlands and the implementation of OPE clinics. The guidelines on the organization of preoperative evaluation had limited effects: only 20% of the hospitals had implemented an OPE clinic. Second, we evaluated the value of a short questionnaire (table 1) to assess the health status of surgical patients. Anesthesiologists are unable to assess the patients' health status (ASA classification) using a short questionnaire in the majority of cases.
Some comments are necessary. First, in both parts of this study we used structured questionnaires to enhance data management. However, this may have led to oversimplification of daily practice. For example, in quantifying the number of OPE clinics hospitals having an organizational structure that is not exactly given in our questionnaire are nevertheless allocated to one of the three possibilities. Second, we evaluated the value of the short questionnaire by imitating daily practice with 100 real cases instead of comparing the opinion of anesthesiologists with the opinion of the Dutch Health Council. However, the anesthesiologists were unable to see the patients.

Implementation of guidelines on OPE Although there is an increasing number of (partial) OPE clinics in the Netherlands since 1997, 80% of all hospitals did not organize preoperative evaluation as recommended, which was mainly due to financing problems.[10] There was large diversity between hospitals in organization and contents of preoperative evaluation (table 2). In 70% of the hospitals the anesthesiologist did not evaluate every patient before entering the

operating room (most likely these were day-surgery patients), although both patient history and physical examination are widely considered mandatory in preoperative patient care.[1;7;14] It has been reported that practice guidelines are not always implemented, even though clinicians acknowledged their utility.[12;13] An oversimplification of daily practice and a challenge of professional autonomy were argued against implementation.[13] Furthermore, the attitude of physicians regarding guidelines is related to the physicians' affiliation with the organization that issued them and to the payment method of physicians (those who were paid a fixed salary had a more favorable attitude).[12]

Utility of the short questionnaire A rapid health assessment using the short questionnaire is insufficient compared to a 'conventional' assessment. Only 18% of the 2090 patients answered the short questionnaire with all answers in column I of table 1, indicating that the remainder would still have been evaluated extensively. Furthermore, an anesthetic plan could not be proposed in that 18%, although in about one-third an ASA classification was given. However, based on the extensive assessment patients were more frequently allocated to an ASA class. The latter was associated with the type of surgical procedure and showed large variability between anesthesiologists, as has been reported before.[15-17] Additional (laboratory) tests were rarely (4%) judged necessary, which is in agreement with international recommendations on preoperative additional testing.[1;18] A preoperative health assessment should at least contain the items shown in table 4, in addition to the information that is obtained by the short questionnaire of table 1.

In conclusion, large diversity in preoperative patient care in the Netherlands exists. The Dutch Health Council guidelines regarding preoperative evaluation, i.e. implementation of outpatient preoperative evaluation clinics, had only limited effects. Furthermore, a short questionnaire to rapidly assess the health status of patients is not useful in practice.

References

1 Roizen MF. Preoperative evaluation. In: Miller RD, ed. Anaesthesia. New York: Churchill Livingstone, 2000;824-83

2 Fischer SP. Development and effectiveness of an anesthesia preoperative evaluation clinic in a teaching hospital. Anesthesiology 1996;85:196-206

3 Pollard JB, Zboray AL, Mazze RI. Economic benefits attributed to opening a preoperative evaluation clinic for outpatients. Anesth Analg 1996; 83: 407-10

4 Pollard JB, Garnerin P. Use of outpatient preoperative evaluation to decrease length of stay for vascular surgery. Anesth Analg 1997; 85: 1307-11

5 Rutten CLG, Post D, Smelt WLH. Outpatient preoperative examination by the anesthesiologist I. Fewer items of service and preoperative hospital days. Ned Tijdschr Geneeskd 1995; 139: 1028-32 [Dutch, English summary]

6 Rutten CLG, Gubbels JW, Smelt WLH, et al. Outpatient preoperative examination by the anesthesiologist II. Patients' satisfaction. Ned Tijdschr Geneeskd 1995; 139: 1032-6 [Dutch, English summary]

7 Cassidy J, Marley RA. Preoperative assessment of the ambulatory patient. J Perianesth Nurs 1996; 11: 334-43

8 Pollard JB, Olson L. Early outpatient preoperative anesthesia assessment: does it help to reduce operating room cancellations? Anesth Analg 1999; 89: 502-5

9 van Klei WA, Moons KGM, Rutten CLG, et al. Effect of outpatient preoperative evaluation on cancellation of surgery and length of hospital stay. Anesth Analg; in press

10 Health Council of the Netherlands, Committee on preoperative evaluation. Preoperative evaluation. 1997/2 [Dutch, English summary]

11 van Klei WA, Moons KGM, Rutten CLG, et al. Preoperative outpatient investigation by the anesthesiologist in young adults: the case history and physical examination suffice, the short questionnaire of the Netherlands Health Council does not. Ned Tijdschr Geneeskd 2000; 144: 1389-93 [Dutch, English summary]

12 Tunis SR, Hayward RSA, Wilson MC, et al. Internists' attitudes about clinical practice guidelines. Ann Intern Med 1994; 120: 956-63

13 James PA, Cowan TM, Graham RP, et al. Family physicians' attitudes about and use of clinical practice guidelines. J Fam Pract 1997; 45: 341-7

14 Adriaensen, Baele, Camu, et al. Recommendations on pre-anesthetic evaluation of patients put forward jointly with the BSAR and the BPASAR. The Belgian Society of Anesthesia and Reanimation and the Belgian Professional Association of Specialists in Anesthesia and Reanimation. Acta Anaesthesiol Belg 1998; 49: 47-50

15 Owens WD, Felts JA, Spitznagel EL. ASA physical status classifications: a study of consistency for rating. Anesthesiology 1978; 49: 239-43

16 Wilson ME, Williams NB, Baskett PJF. Assessment of fitness for surgical procedures and the variability of anaesthetists' judgement. Br Med J 1980; 280: 509

17 Haynes SR, Lawler PGP. An assessment of the consistency of ASA physical status classification allocation. Anaesthesia 1995; 50: 195-9

18 Schein OD, Katz J. The value of routine preoperative testing before cataract surgery. N Engl J Med 2000; 342: 168-75

4

Preoperative auscultation and detection of valvular heart disease

Wilton A van Klei, Charles LG Rutten, Karel GM Moons, Wilco E van Genderen, Johannes TA Knape, Diederick E Grobbee, Cornelis J Kalkman

Submitted

Most preventable causes of death and major morbidity during and after surgery result from cardiovascular events such as myocardial infarction and cerebrovascular accidents.[1-3] Patient history and physical examination to detect cardiovascular morbidity are therefore considered mandatory before surgery.[3] Inspection and basal physical examination can detect obesity, leg edema, arrhythmia and hypertension. To detect valvular heart disease (VHD) in particular aortic valve stenosis, cardiac auscultation is recommended.[3;4] However, a routine auscultation by the anesthesiologist before surgery is not always performed and the prevalence of VHD in the surgical population is unknown.[5-8] Furthermore, the ability of physicians to detect and interpret heart murmurs by auscultation is low and the value of routine cardiac auscultation as a screening tool for detection of VHD is unknown.[9;10]

We first aimed to estimate the prevalence of heart murmurs as detected by auscultation in a population of surgical patients. In addition, echocardiography was used to determine to what extent these murmurs reflected the presence of VHD. This allowed an estimation of the prevalence of VHD in a general surgical population. Second, the prevalence of hypertension and obesity as important risk factors for VHD was estimated in the same patient population.

Methods

Patients. The study population comprised all 9396 consecutive adult surgical patients from three Dutch general hospitals between October 1, 2000 and March 31, 2001. These patients visited the outpatient preoperative evaluation clinic on average three weeks before the scheduled surgery date and were evaluated by the anesthesiologist who obtained a medical history. Subsequently, in hospital 1 heart and lung auscultation and head and neck evaluation were routinely performed in all patients. In hospital 2 and 3 physical examination was performed only if considered necessary by the anesthesiologist, typically based on history or general physical impression. In each hospital, a medical receptionist routinely measured weight and height, blood pressure and heart rate (using an automated non-invasive blood pressure device).

Data collection. All data were collected prospectively. For each patient visiting the outpatient preoperative evaluation clinic of the participating hospitals during the study period, the medical receptionist documented the patients' demographics, weight, height, heart rate and blood pressure. Subsequently, the anesthesiologist documented his general physical impression of the patient on a four-point scale (healthy, not entirely healthy, poor and very ill).
In hospital 1, each patient underwent auscultation of the heart and lungs and head and neck evaluation by the anesthesiologist. In case of abnormal findings it was documented whether they were new and whether they resulted in additional evaluations (e.g. echocardiography). Finally, each patient was assigned an ASA physical status. All patients in whom a heart murmur was discovered during auscultation were referred for echocardiography (reference standard for VHD). When aortic valve stenosis was diagnosed the peak gradient was determined. Echocardiography was not performed in elderly patients who were scheduled for cataract surgery under local anesthesia or patients scheduled for minor invasive surgical procedures under loco-regional anesthesia (e.g. lipoma excision). These anesthetic techniques have no important hemodynamic consequences and prophylactic antibiotics are not necessary in case of VHD. This procedure reflected daily practice in hospital 1.
In hospital 2 and 3 it was documented whether or not auscultation or head and neck evaluation had been performed and the reason why it was omitted. When auscultation was performed, abnormal findings (e.g. heart murmurs) were documented as well as the results of subsequent additional evaluations resulting from these abnormal findings.

Outcomes. VHD was defined as any valvular abnormality (e.g. mitral valve insufficiency, aortic stenosis, etc.) detected by echocardiography. Hypertension was defined as a diastolic blood pressure (DBP) $\geq$ 100 mm Hg and / or a systolic blood pressure (SBP) $\geq$ 180 mm Hg.[3] A DBP $\geq$ 110 mm Hg an / or a SBP $\geq$ 200 mm Hg was defined as severe hypertension.[4] These definitions included patients with an elevated blood pressure who were already on antihypertensive treatment. Overweight was defined as a body mass index (BMI) $\geq$ 28 kg/m^2, whether a BMI $\geq$ 31 kg/m^2 was defined as obesity.[3]

Analysis. We first described various patient characteristics (e.g. mean age and mean blood pressure) per hospital. Second, the data from hospital 1 (in which

each patient underwent auscultation) were used to estimate the prevalence of heart murmurs and VHD as well as the prevalence of abnormal lung sounds. Subsequently, from the same data prevalence rates for gender specific age strata (in decades) were estimated. These prevalence rates were extrapolated to similar strata of hospital 2 and 3 to obtain an estimate of the expected number of heart murmurs and VHD in these two hospitals. Using the data from all hospitals, the prevalence of hypertension and obesity was determined.

Results

Table 1 shows the patient characteristics over the three hospitals. Compared to hospital 3, in hospital 1 and 2 the mean age was 5 and 3 years higher, respectively. This difference in age was reflected in the differences in hospital mean blood pressure, heart rate and general physical impression (in hospital 1 more patients were considered not to be healthy).
In hospital 1, auscultation and head and neck evaluation was indeed performed in nearly all patients (97%), whereas in hospital 2 and 3 this was done in 24% and 54%, respectively. Furthermore, in hospital 2 and 3 in many of these patients only head and neck evaluation was performed (therefore, the number of patients in which auscultation was performed is unknown). In hospital 2 and 3 the decision not to perform auscultation was in general (93%) based on the presence of a normal history and general physical impression. In the remaining 7% no reason was given.
Table 2 shows that on average 27% of all patients had overweight and 12% had hypertension. The prevalence of detected heart murmurs in hospital 1 was 4%. As in hospital 2 and 3 auscultation was not performed routinely in every patient, this frequency was much lower (0.7 and 0.2%, respectively).

Table 3 shows the echocardiographic diagnosis of the 106 patients from hospital 1 in which a heart murmur was detected by auscultation. Of the 35 patients in whom echocardiography was considered as not indicated, 19 (54%) were scheduled for cataract surgery under local anesthesia. The remainder were scheduled for simple procedures under loco-regional anesthesia (e.g. lipoma excision).

Patients with a murmur were older (mean age 69 years) than those without a detected murmur (difference 16 years, 95% CI: 12-19 years) and 34% were men. Their mean SBP (166 mm Hg) was also significantly higher (difference 15 mm Hg, 95% CI: 10-20 mm Hg). Of the 17 patients (0.6%) with aortic valve stenosis, two (12%) had a hemodynamically important stenosis (peak

Table 1. Characteristics of patients visiting the outpatient preoperative evaluation clinic in three general hospitals. Values are mean and Standard Deviation between parenthesis or absolute numbers and percentages between parenthesis.

	Hospital (N=2618)	Hospital 2 (N=5014)	Hospital 3 (N=1764)	Total (N=9396)
Gender: men (%)	1040 (40)	2075 (41)	698 (40)	3813 (41)
Age in years (SD)	54 (19)	52 (18)	49 (18)	52 (19)*
Body Mass Index in kg/m^2 (SD)	27 (5)	26 (4)	27 (6)	26 (5)
Systolic Blood Pressure in mm Hg (SD)	152 (26)	141 (22)	139 (22)	144 (24)*
Diastolic Blood Pressure in mm Hg (SD)	85 (11)	79 (14)	82 (12)	81 (13)*
Heart rate in Bpm (SD)	80 (15)	78 (14)	76 (21)	78 (16)*
General Physical Impression (%)				
Healthy / vital	1764 (67)	3959 (79)	1350 (77)	7073 (75)
Not entirely healthy	619 (24)	626 (13)	286 (16)	1531 (16)
Poor	164 (6)	85 (2)	48 (3)	247 (3)
Very ill	2 (0.1)	12 (0.2)	12 (1)	26 (0.3)
Unknown	69 (3)	332 (7)	68 (4)	469 (5)
Physical examination¶ (%)	2530 (97)	1225 (24)	954 (54)	#
ASA physical status (%)				
ASA 1	952 (36)	#	#	#
ASA 2	1162 (44)	#	#	#
ASA 3	416 (16)	#	#	#
ASA 4	15 (1)	#	#	#
Unknown	73 (3)	#	#	#

*The values differed significantly across the three clinics.
#As these would not reflect the truth, no values are given, since only a selection of the patients underwent physical examination
¶Auscultation of heart and lungs and / or head and neck evaluation
SD = Standard Deviation; Bpm = Beats per minute; n.a. = not applicable

gradient ≥ 50 mm Hg) and two (12%) had a gradient between 30 and 50 mm Hg.[4] For three of these four patients the diagnosis was already available from the chart. Sixteen of the 17 patients (94%) with aortic valve stenosis were 65 years or older, resulting in a prevalence of aortic stenosis in this subgroup of patients of 1.7%. In hospital 2, all patients in whom a new heart murmur was detected (N=8) were evaluated by echocardiography. Two of them had hemodynamically significant aortic valve stenosis (peak gradient ≥ 50 mmHg)[4], one had mitral valve insufficiency and five showed no valvular abnormalities. In the remaining three patients, prior echocardiographic diagnosis was available from the medical record; two patients had severe aortic valve stenosis and one had no abnormality. In hospital 3, an echocardiography was performed in 2 out of the 12 patients with a detected heart murmur. Both had a moderately severe mitral valve insufficiency.

Table 2. Prevalence of disorders detected after physical examination in patients visiting the outpatient preoperative evaluation clinic in three general hospitals. Values are absolute numbers (percentages of total number of patients between parenthesis).

	Hospital 1 (N=2618)	Hospital 2 (N=5014)	Hospital 3 (N=1764)	Total (N=9396)
Routine physical examination				
Overweight (BMI ≥ 28 kg/m^2)	899 (34)	1054 (21)	584 (33)	2536 (27)
Obesity (BMI ≥ 31 kg/m^2)	452 (17)	465 (9)	284 (16)	1199 (13)
Hypertension#	466 (18)	509 (10)	192 (11)	1167 (12)
Severe hypertension##	167 (6)	108 (2)	42 (2)	317 (3)
Results of auscultation				
Heart murmurs*	106 (4)	11 (0.2)	12 (0.7)	n.a.
Abnormal lung sounds*	144 (6)	9 (0.2)	21 (1)	n.a.

#Hypertension was defined as a Systolic Blood Pressure ≥ 180 and/or a Diastolic Blood Pressure ≥ 100 mm Hg

##Severe hypertension was defined as a Systolic Blood Pressure ≥ 200 and/or a Diastolic Blood Pressure ≥ 110 mm Hg

*Note that in hospital 2 and 3 heart and lung auscultation and / or head and neck evaluation was performed in 24% and 54%, respectively, reflecting the lower frequency of murmurs and abnormal lung sounds.

BMI = Body Mass Index; n.a. = not applicable

Table 3. Diagnosis by echocardiography of patients with heart murmurs in hospital 1 (N=106).

Diagnosis	Number (%)[#]	95% CI (%)	Newly detected (%)†
Not evaluated by echocardiography *	35 (1.3)	n.a	35 (100)
Available for echocardiography	71 (2.7)	n.a.	35 (49)
Echocardiography results:			
Mitral valve insufficiency	28 (1.1)	0.7-1.5	11 (39)
Aortic valve stenosis	17 (0.6)	0.3-1.0	12 (71)
Combined valvular insufficiencies	12 (0.5)	0.2-0.7	3 (25)
Pulmonary valve stenosis, VSD, TF	4 (0.2)	0.0-0.3	0 (0)
No valvular abnormality	10 (0.4)	0.1-0.6	9 (90)

[#]In parenthesis is indicated the frequency of the echocardiographic diagnosis as a percentage of all 2618 patients who visited the preoperative evaluation clinic of hospital 3.
*19 (54%) of these patients were scheduled for Cataract surgery under local anesthesia, the remainder were simple surgical cases (e.g. lipoma excision) operated under regional anesthesia
†Newly detected means that in these patients no echocardiograpic diagnosis was available already from the medical record: the diagnosis VHD was 'new'
VSD = Ventricular Septum Defect; TF = Fallots' tetralogy

Extrapolating gender and age specific prevalence rates of heart murmurs from hospital 1 to hospital 2 and 3 yielded an expected number of murmurs of 179 (observed: 11) and 56 (observed: 12), in hospital 2 and 3, respectively. Therefore, the expected frequencies were 3.1% and 3.6%, respectively. Similarly, the prevalence of aortic valve stenosis in hospital 2 and 3 was estimated. For example, the expected number of aortic valve stenosis in hospital 2 was 20 (12/106 * 179), whereas the observed number was 2.

Discussion

We estimated the prevalence of heart murmurs reflecting VHD, hypertension and obesity in surgical patients. As far as we know this is the first study that attempts to estimate the prevalence of heart murmurs and, more specifically, the prevalence of VHD in a general surgical population. Detection of heart

murmurs by auscultation yielded a prevalence of 4%. Subsequent verification by echocardiography showed that 17% of these patients had aortic valve stenosis (overall prevalence: 0.6%). The prevalence of hypertension and overweight in our study was 12% and 27%, respectively.

This study has some limitations. First, it should be noted that the estimated prevalence of VHD is likely an underestimation, as patients were referred to echocardiography only when a heart murmur was detected by auscultation. Assuming that not all murmurs (valvular abnormalities) were detected by auscultation, this implies that the true prevalence of VHD may be higher than estimated. To get an estimate of this true prevalence, the frequency of murmurs that are missed by auscultation ('false negatives') should be known. As a result of the study design, no inference can be drawn about these 'false negative auscultations' (this would require a study in which all patients undergo echocardiography). It has been reported that even cardiologists detect only 80% of all heart murmurs, which implies that the true prevalence of heart murmurs in our study population is at least 5% (4/0.8).[9] Using cardiac auscultation, 26% (9/35, table 3) of all newly detected murmurs were 'false positives', i.e. 'echocardiography evaluation of a detected murmur did not reveal VHD'. Second, the estimation of the prevalence of murmurs was based on data from one particular hospital population. Although this is a general hospital, its particular patient population may have influenced the frequency (the expected frequencies of heart murmurs after extrapolation were lower in hospital 2 and 3, but still over 3%). It should be noted that this extrapolation assumed that the patient population in the three hospitals was comparable after adjustment for age and gender. Third, in our study the diagnosis 'hypertension' was based on a single measurement and it is not uncommon to find an elevated blood pressure in patients visiting a hospital (the so called 'white coat hypertension'). However, it has been shown that the subset of patients with an elevated blood pressure during the preoperative visit likely will also show an exaggerated blood pressure before induction of anesthesia or during endotracheal intubation.[11] They are therefore more at risk for perioperative myocardial ischemia. Furthermore, the cut-off points for diagnosing hypertension in our study were chosen at 100 and 180 mm Hg (diastolic and systolic, respectively). These thresholds are higher than those used in general practice (WHO criteria: on average 90 and 140 mm Hg, respectively, after repeated measure-

ments).[12] Finally, we did not document which patients were already on antihypertensive treatment. However, patients treated for hypertension who show high blood pressure at the preoperative clinic are likely to react similar to untreated patients during the perioperative period.

We found an overall prevalence of aortic valve stenosis of 0.6% and a prevalence of 1.7% in adults over 65 years of age. This latter percentage is comparable to that found previously in patients from the same age category (2%).[13]
Only a few studies have reported the prevalence of preoperative hypertension, but unfortunately different definitions were used (for example, blood pressure levels > 140/90 mm Hg), making it difficult to compare these studies with our results.[11] A blood pressure level of > 140/90 mm Hg is used for the indication of long-term treatment, but seems of less clinical importance in the treatment of preoperative hypertension.[12] One study used a definition of hypertension that closely resembled ours (blood pressure > 170/95 mm Hg) and reported a prevalence of 13% (present study: 12%).[14]
The prevalence of overweight (BMI ≥ 28) in the general population in the United States and West European countries ranges between 20 and 50%.[3] We found a comparable prevalence of 27%. Apparently, in this respect the surgical population appears to reflect the general population in Western countries.

Although it has been reported that the ability of physicians to interpret heart murmurs is low, cardiac auscultation by the anesthesiologist seems a reasonable screening tool to detect clinically relevant VHD, with 26% 'false positives' (echocardiography evaluation of a detected murmur did not reveal VHD) in the present study (positive predictive value: 74%).[9;10] The results of our study suggest that each patient, and especially the elderly patient of 65 years or older, should be referred for echocardiography after detection of a murmur by auscultation. The diagnostic accuracy of echocardiography in patients with suspected VHD is very high (close to 100%).[15;16] When history or general physical impression are used as a screening tool to select patients for auscultation (hospital 2 and 3), only 6 to 20% of the expected murmurs were detected. This implies that many patients with VHD may have been missed. Even in the absence of significant hemodynamic abnormalities, this may be important because it is recommended to administer prophylactic antibiotics preoperatively for mitral valve insufficiency and aortic valve stenosis. Furthermore, it is rec-

ommended to pay particular attention to maintenance of adequate coronary perfusion, to prevent tachy- and bradycardia and to maintain blood pressure and normovolemia in hemodynamically important aortic valve stenosis.[4;17]

In conclusion, preoperative cardiac auscultation by the anesthesiologist seems a reasonable screening tool to select patients who are at high risk for VHD. Subsequent echocardiography in these selected patients (only about 4% of the patients) is necessary to establish or exclude a definite diagnosis of VHD, in order to plan perioperative care. As routine auscultation before surgery takes little time and echocardiography has a high diagnostic accuracy, echocardiography in all patients with a heart murmur seems effective.

Hospitals participating in patient recruitment

Gemini hospital, Den Helder, The Netherlands;
Medical Center Alkmaar, Alkmaar, The Netherlands;
Isala clinics (Weezenlanden), Zwolle, The Netherlands.

References

1. Mangano DT. Perioperative cardiac morbidity. Anesthesiology 1990; 72: 153-84
2. Goldman L. Cardiac risk in noncardiac surgery: an update. Anesth Analg 1995; 80: 810-20
3. Roizen MF. Preoperative evaluation. In: Miller RD, ed. Anaesthesia. New York: Churchill Livingstone, 2000; pp 824-83
4. Stoelting RK, Dierdorf SF. Anesthesia and Co-Existing Disease. New York: Churchill Livingstone, 1993; pp 21-35 and 79-86
5. Fischer SP. Development and effectiveness of an anesthesia preoperative evaluation clinic in a teaching hospital. Anesthesiology 1996; 85: 196-206
6. Pollard JB, Olson L. Early outpatient preoperative anesthesia assessment: does it help to reduce operating room cancellations? Anesth Analg 1999; 89: 502-5
7. Vaghadia H, Fowler C. Can nurses screen all outpatients? Performance of a nurse based model. Can J Anaesth 1999; 46: 1117-21
8. van Klei WA, Moons KGM, Lo B, et al. Evaluation of Dutch Health Council guidelines on preoperative evaluation. Submitted
9. St.Clair EW, Oddone EZ, Waugh RA, et al. Assessing house staff diagnostic skill using a cardiology patient simulator. Ann Intern Med 1992; 117: 751-6
10. Roldan CA, Shively BK, Crawford MH. Value of the cardiovascular physical examination for detecting valvular heart disease in asymptomatic subjects. Am J Cardiol 1996; 77: 1327-31
11. Bedford RF, Feinstein B. Hospital admission blood pressure: A predictor for hypertension following endotracheal intubation. Anesth Analg 1980; 59: 367-70
12. WHO. Hypertension. 1999 http://www.who.int/ncd/cvd/ht_guide.html
13. Otto CM, Bonnie KL, Kitzman DW, et al. Association of aortic-valve sclerosis with cardiovascular mortality and morbidity in the elderly. N Engl J Med 1999; 341: 142-7
14. Asidao CB, Donegan JH, Whitesell RC. Factors associated with perioperative complications during carotid endarterectomy. Anesth Analg 1982; 61: 631
15. Jaffe WM, Roche AHG, Coverdale HA, et al. Clinical evaluation versus Doppler echocardiography in the quantitative assessment of valvular heart disease. Circulation 1988; 78: 267-75
16. Hoffmann A, Burckhardt D. Evaluation of systolic murmurs by Doppler ultrasonography. Br Heart J 1983; 50: 337-40
17. Torscher LC, Shub C, Rettke SR, Brown DL. Risk of patients with severe aortic stenosis undergoing noncardiac surgery. Am J Cardiol 1998; 81: 448-52

5.1

A reduction in Type and Screen: preoperative prediction of RBC transfusions in surgical procedures with intermediate transfusion risks

Wilton A van Klei, Karel GM Moons, Aart T van Rheineck Leyssius, Johannes TA Knape, Charles LG Rutten, Diederick E Grobbee

British Journal of Anaesthesia 2001; 87: 250-7

Transfusion of blood (Red Blood Cells or RBC's) is sometimes necessary in patients having surgery. A 'type and screen' is done preoperatively to prevent complications due to blood group incompatibility between donor and recipient or the existence of irregular antibodies. This procedure is much cheaper than full cross matching, and gives the same immuno-hematological safety.[1-4] Generally, physicians preoperatively type and screen patients who might need a perioperative transfusion (commonly based on past experience with the surgical procedure as single predictor). However, most patients who are typed and screened before surgery will not require a transfusion, which means unnecessary patient burden and costs. It would be efficient to further classify patients according to their risk of transfusion using objective and easy obtainable information. Various prediction rules have been developed (especially in orthopedic surgery), but a laboratory parameter (preoperative hemoglobin concentration or hematocrit) was always included.[5] However, it would be even more efficient if the same predictive accuracy could be obtained without the need for laboratory tests.[6-9]

We developed and validated a rule based on patient and surgery characteristics, to predict surgical blood transfusion in patients undergoing surgery with intermediate transfusion risk (1% to 30%). Subsequently, we evaluated how knowing the preoperative hemoglobin concentration could increase the predictive accuracy of this prediction rule.

Methods

Patients. We studied 1482 patients (aged 18-98 years) with intermediate transfusion risk ('type and screen patients'), undergoing surgery in the Twenteborg hospital in The Netherlands, in 1998. This hospital is a 638-bed non-university hospital in which neurosurgery and cardiac surgery are not performed. The classification of type and screen patients was based on the current transfusion guide. This divides patients into three surgical groups according to expert opinion. Group A patients have low expected risk for transfusion (0 - 1%; e.g. arthroscopy or ear surgery), group B patients have intermediate risk for transfusion (1% to approximately 30%; e.g. cholecystectomy or hysterectomy) and group C are high risk patients (more than 30%; e.g. aortic sur-

gery). In group A patients, type and screen is never done (78% of all patients). Patients belonging to group B are always typed and screened, but blood is not stored (16%). Group C patients are always typed and screened and blood is stored (6%). Of all patients in group A, nearly 2% received transfusions. In group B and C the transfusion incidence was 19% and 43%, respectively. This study evaluates only group B patients ('type and screen patients'). None of the 1482 patients donated autologous blood preoperatively.

Outcome. The outcome was defined as any allogeneic RBC transfusion (defined as transfusion of one or more units packed cells) at the day of surgery or the first postoperative day. The transfusion decision was made by individual clinicians (anesthesiologists and surgeons). A rigid protocol was not in use, but in general blood was given when the hemoglobin level was below 10 g dL^{-1} (6 mmol $litre^{-1}$).

Potential predictor variables. Age, gender, surgical procedures, whether it was an emergency operation (yes/no), the anesthetic technique and the preoperative hemoglobin level were evaluated as potential predictors. As 39 different surgical procedures were used, they were allocated into 5 categories based on actual risk (occurrence) of transfusion: Group 1 contained only laparoscopic cholecystectomy (transfusion incidence < 5%); Group 2 mastectomy and transurethral resection of tumor (TURT) or prostate (TURP) (transfusion incidence 5-9%); Group 3 open cholecystectomy, vaginal hysterectomy, Cesarean section, urine incontinentia surgery and vaginal prolaps surgery (10-19%); Group 4 non-cardiac thoracic surgery (e.g. lobectomy), vascular (arterial) surgery (e.g. femoro-popliteal bypass), prostate enucleation and endometrial cancer surgery (20-29%); Group 5 abdominal and supravaginal hysterectomy, hip fracture surgery, revision knee prosthesis, leg amputation, gastroenterostomy, colon-resection and radical abdominal hysterectomy (30% or more). Anesthetic technique was defined as a dichotomous variable: a single form of anesthesia (general, regional or local) compared with combination anesthesia (general anesthesia combined with epidural analgesia). Although in principle a potential predictor, we decided not to include the identity of the surgeon and anesthesiologist in the model, as they are hard to extrapolate to other hospitals and the aim was to derive an easy and widely applicable prediction rule.

Data collection. The hospital ethics committee approved the study. All data were collected retrospectively from the hospital information system. There were no missing data on any of the predictor or outcome variables, except for the hemoglobin concentration. In 152 patients (10%) it was not measured preoperatively.

Analysis. In the present study, two data sets were randomly selected from all 1482 patients: a derivation set of approximately 75% (1151 patients) and a validation set of approximately 25% (331 patients). SPSS release 9.0 for Windows was used in the analysis (Windows NT 4.0, DELL computer). In the derivation set the association between each predictor and transfusion outcome was quantified using univariable logistic regression modeling. This type of analysis is alternative to using chi-square tests and gives similar results. In the analysis, surgery was included as four indicator variables (group 2 to 5) with group 1 as the reference. As the incidence of transfusion in patients aged 18 to 69 was between 10% and 20% in each decade, whereas in patients aged over 70 the incidence increased more rapidly, age was included in the model after dichotomization at 70. After univariate analyses, multivariable logistic regression modeling was applied in order to obtain a prediction model including the independent predictors of transfusion outcome only. This was done by a two-step approach. As age, gender, type of surgery (again included as 4 indicators), elective surgery and anesthetic procedure are much easier to obtain, we first evaluated whether these had independent value in the prediction of perioperative transfusion. In this, the interaction between type of surgery and anesthetic technique was evaluated as well, since both are closely related (regional anesthesia may reduce blood loss). Subsequently, the added predictive value of the preoperative hemoglobin concentration was evaluated. The full model was reduced by manually (i.e. not automatically) deleting non-significant variables. Predictors with odds ratios that differed significantly from one, defined as odds ratio with p-value < 0.10 using log likelihood ratio testing, were considered as independent predictors and retained in the final model. This is commonly done in prognostic research.[10]

To obtain an easy applicable prediction or scoring rule, the regression coefficients (=ln(OR)) of the predictors in the final model were divided by the

smallest coefficient and rounded to the nearest integer. For each subject a score was estimated by assigning points for each variable present and adding the results. The reliability of our prediction rule (goodness of fit) was quantified by using the Hosmer & Lemeshow test. This test is used to compare observed probabilities with predicted probabilities. A high p-value of this test (> 0.20) indicates that there is no difference between both probabilities, which means good fit of a model.[11] The ability of the model to discriminate between patients with and without transfusion was quantified by using the area under the Receiver Operating Characteristic curve (ROC area).[10-12] The ROC area can range from 0.5 (useless model, like a coin flip) to 1.0 (perfect discrimination). A value over 0.7 can be interpreted as reasonable or fair, and over 0.8 as good.[13] Differences in ROC area were used to quantify the difference in discriminative ability between full and reduced models taking into account the correlation between the models as they were based on the same cases.[14]

The performance of the rule was tested in the validation set and the resulting ROC area was compared with the derivation set. A ROC area reflects the overall added value of a model and does not directly indicate its clinical value.[15;16] Therefore, in the validation set, we estimated the absolute number of correctly predicted transfused and not transfused patients across various risk scores of the rule.

Results

Table 1 shows the comparison of patient characteristics of the derivation and validation set. There were no major differences between the two sets. The transfusion rates for the derivation and validation set were 18.1% (N=208) and 20.8% (N=69), respectively.

In the univariate analysis (table 2) all variables were significantly associated with transfusion. The odds ratios of the 4 indicators for surgery (group 2 to 5) indicate the relative risk of transfusion for that group, compared to the reference group 1 (e.g. group 3 procedures have a 4.1 times higher risk of transfusion than those of group 1).
After entering age, gender, surgical procedure and emergency surgery into a

multivariate logistic model, all were independently associated with transfusion (table 3), except emergency surgery (OR 1.26; 95% CI: 0.84-1.88). The ROC area of this first model was 0.75 (95% CI: 0.71-0.79). As further exclusion of variables from this model significantly reduced the ROC area, the model with dichotomized age, gender and surgical procedure was defined as the final prediction model. Addition of anesthetic technique (including the

Table 1. Patient characteristics of derivation and validation set. Values are numbers and percentages between parenthesis.

	Derivation set (N=1151)	Validation set (N=331)
Mean age (years)		
transfused patients	62 (21.3)#	62 (20.3)
non-transfused patients	56 (18.3)	58 (18.8)
Age (%)		
18-69 years	790 (69)	218 (66)
≥ 70 years	361 (31)	113 (34)
Gender (%)		
male	404 (35)	119 (36)
female	747 (65)	212 (64)
Anesthetic technique (%)		
mono-anesthesia	1052 (91)	307 (93)
combined-anesthesia	99 (9)	24 (7)
Surgical procedures*(%)		
group 1	121 (11)	23 (7)
group 2	295 (26)	94 (28)
group 3	356 (31)	93 (28)
group 4	94 (8)	24 (7)
group 5	285 (25)	97 (29)
Type of surgery (%)		
elective	787 (68)	226 (68)
emergency	364 (32)	105 (32)
Transfusion (%)	208 (18)	69 (21)

#Values are mean and standard deviation between parenthesis.
*Procedures are listed in the text.

interaction terms with surgical procedure) to this model showed no added value in the prediction of transfusion: the ROC area remained 0.75. (For the estimation of the added value of the preoperative hemoglobin concentration see below.) Its ROC area in the validation set was 0.71 (95% CI: 0.64-0.78). The model's estimated risks of transfusion were comparable to the observed risks, which indicated a good model fit (the p-value of the Hosmer and

Table 2. Association of each variable with the incidence of transfusion.

Determinant	Transfused	Not transfused	OR (95% CI)	p-value (LLR)
Age (%)				
18-69 years	110 (14)	680 (86)	#	
≥ 70 years	98 (27)	263 (73)	2.3 (1.7-3.1)	< 0.001
Gender (%)				
male	49 (12)	355 (88)	#	
female	159 (21)	588 (79)	2.0 (1.4-2.8)	< 0.001
Anesthetic technique (%)				
mono-anesthesia	167 (16)	885 (84)	#	
combined-anesthesia	39 (39)	60 (61)	3.4 (2.2-5.3)	< 0.001
Surgical procedures* (%)				
group 1	5 (4)	116 (96)	#	
group 2	18 (6)	277 (94)	1.5 (0.5-4.2)	0.425
group 3	53 (15)	303 (85)	4.1 (1.6-10.4)	0.002
group 4	25 (27)	69 (73)	8.4 (3.1-23.0)	< 0.001
group 5	107 (38)	178 (62)	13.9 (5.5-35.2)	< 0.001
Type of surgery (%)				
elective	112 (14)	675 (86)	#	
emergency	96 (26)	268 (74)	2.2 (1.6-2.9)	< 0.001
Preoperative hemoglobin (g dL^{-1})	13.4¶	11.5¶	0.4 (0.3-0.5)†	< 0.001

#Reference category.
*Surgical procedures were included as 4 indicator variables with group 1 as the reference category.
¶mean
†OR per g dL^{-1} increase in hemoglobin concentration
OR = Odds Ratio; 95% CI = 95% Confidence Interval; LLR = Log likelihood ratio test.

Table 3. Association of each variable with the incidence of transfusion in the multivariable logistic model.

Determinant	Regression coefficient (95% CI)	OR (95% CI)	P-value	Score#
Gender (woman)	0.629 (0.20; 1.06)	1.9 (1.2; 2.9)	0.004	1
Age ≥ 70	0.546 (0.18; 0.90)	1.7 (1.2; 2.5)	0.003	1
Surgical procedure*				
- group 2	0.524 (-0.52; 1.06)	1.7 (0.6; 4.8)	0.324	1
- group 3	1.291 (0.35; 2.23)	3.6 (1.4; 9.3)	0.007	2
- group 4	2.287 (1.26; 3.32)	9.8 (3.5; 27.8)	< 0.001	4
- group 5	2.386 (1.45; 3.33)	10.9 (4.2; 27.9)	< 0.001	5
Intercept (constant)	-3.701 (-4.67;-2.73)		< 0.001	

*Procedures per group are listed in the text; group 1 is the reference group.
#The score of each predictor was obtained by dividing the corresponding regression coefficient by the smallest coefficient (0.524) and rounded to the nearest integer.
95% CI = 95% Confidence Interval; OR = Odds Ratio.

Lemeshow test was 0.98). This final model was transformed into an easy used scoring rule by dividing each regression coefficient by the smallest coefficient (0.524) and rounded to the nearest integer (last column of table 3): *1*gender + 1*age ≥ 70 + (1, 2, 4 or 5)*surgical procedure*. Being a woman counts for 1 point, age ≥ 70 for 1 point, and surgical procedure for 1, 2, 4 or 5 points (for group 2, 3, 4 and 5, respectively). Such a scoring rule can be considered as one overall predictor test, including several predictor variables.
The score can be considered as its (test) result and can be estimated for each patient by assigning the points for each predictor present and adding these points. For instance, a 72 years old man who will undergo a colon-resection, receives a score of 6 (0 + 1 + 5). In both datasets the score ranged from 0 to 7. The ROC area of the transformed prediction rule was 0.75 (95% CI: 0.71-0.78) and 0.70 (95% CI: 0.63-0.77) in the derivation and validation set, respectively (figure 1).

This prediction rule can be used preoperatively to distinguish patients who will and will not be transfused and therefore should and should not be typed and

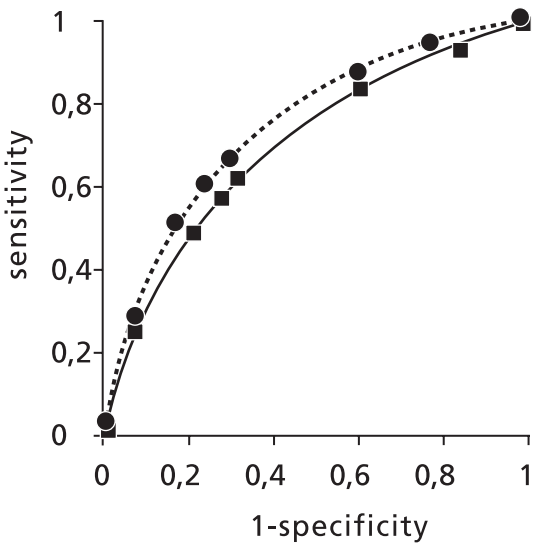

Figure 1. ROC curves of the transformed prediction rule (table 3).
Black line: validation set; dashed line: derivation set.
Each bullet indicates a score threshold from 0 (upper-right) to 7 (bottom-left). For example, a threshold >2 gives a sensitivity of 0.84 and a specificity of 0.40 (validation set)

screened. Table 4 shows the actual number of transfused and not transfused patients across score categories (and across corresponding risk of transfusion as estimated by the untransformed model, i.e. second column of table 3), after the rule was applied to the validation set. From table 4 one can directly obtain the predictive value for transfusion per score category (reading the table vertically). For example, of all 115 patients with score ≤ 2 (or risk of transfusion ≤ 10%), 104 patients were indeed not transfused, yielding a negative predictive value of 90%. In the group of patients with score ≥ 5, 39 of the 111 were indeed transfused; a positive predictive value of 35%. Table 4 also enables to estimate the sensitivity and specificity at different score thresholds (reading the table horizontally). For example, introducing a threshold at 2, a score ≤ 2 will be considered as test negative and a score > 2 will be considered as test positive. This means that, according to the rule, a test negative patient will not be transfused and does not need to be typed and screened, whether a test positive patient will be transfused and needs to be typed and screened. Using this

Table 4. Distribution of transfused and not transfused patients in the validation set, according to the score of the rule (and to the corresponding risk of transfusion. Values are presented as absolute numbers and as percentages of the 'Total' column between parenthesis.

Score by the rule[#]	≤ 2	3 and 4	≥ 5	
Risk of transfusion[*] (%)	≤ 10	11-20	≥ 21	Total
Transfused	11 (16)	19 (26)	39 (58)	69 (100)
Not Transfused	104 (40)	86 (32)	72 (28)	262 (100)
N	115 (35)	105 (31)	111 (34)	331 (100)

[#]Categories of the score as estimated from the (transformed) scoring rule (table 3).
[*]Risk or probability of transfusion as estimated by the untransformed prediction model (table 3) that correspond to the score from the first row: Risk = 1/(1 + exp -(-3.701 + 0.629*gender + 0.546*age≥ 70 + 0.524*group2 + 1.291*group3 + 2.287*group4 + 2.386*group5))
N = number of subjects per score (risk) category.

Table 5. Distribution of transfused and not transfused patients according to the preoperative hemoglobin concentration in the patients from table 4 with score > 2. Values are presented as absolute numbers and as percentages of the 'Total' column between parenthesis.

Hb (g dL^{-1})[*]	< 14.0	≥ 14.0	Total
Transfused	44 (90)	5 (10)	49 (100)
Not Transfused	97 (71)	39 (29)	136 (100)
N	141 (76)	44 (24)	185 (100)

[*]Preoperative hemoglobin concentration in g dL^{-1}.
N = number of subjects per hemoglobin category.

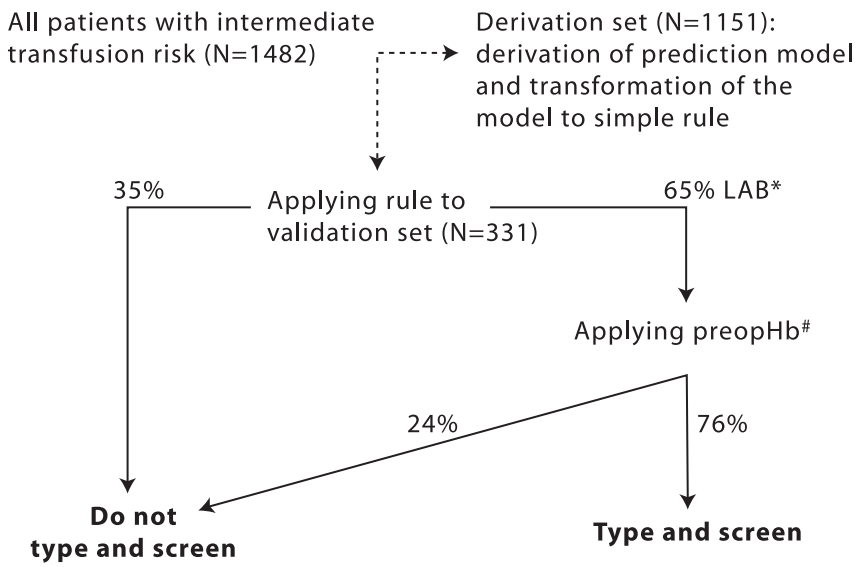

Figure 2. Flow chart of the results of this study after using the scoring rule at a threshold of score > 2 and a preoperative hemoglobin concentration of 14.0 g dL^{-1}.
#Preoperative hemoglobin concentration.
*LAB: patients have to go to the laboratory, and 2 blood samples have to be taken: 1 to measure the preoperative Hb and 1 to investigate the blood group eventually.

threshold of ≤ 2, (or transfusion risk ≤ 10%) the specificity was 40% (104 / 262) with 60% unnecessary type and screen procedures, whereas the sensitivity was 84% (19+39 / 69) with 11 (16%) missed transfused patients.
This 16% of patients who needed transfusion and who would not have been tested, was only 2% less than using a model with type of surgery as a single predictor. Because age and gender are easy obtainable predictors, we decided to leave them in the model. The sensitivity and specificity of all possible score thresholds can be obtained from the ROC curve in figure 1.
We wished to reduce the number of unnecessary type and screen procedures (i.e. to obtain a high specificity). We tested whether the preoperative hemoglobin concentration (preopHb), when added to the former prediction model

(table 3), contributed useful information. Adding preopHb to the previous model of table 3, the ROC area increased from 0.71 to 0.80 (95% CI: 0.74-0.86) in the validation set. In absolute numbers the percentage of missed transfused patients decreased from 16% to 12%. We reasoned that it would therefore be inefficient to include preopHb in the initial prediction model, as it led to only a small decrease (4%) in missed transfusions at the expense of a hemoglobin measurement in all patients. Nevertheless, using the preopHb additionally *after* the application of the rule, i.e. only measuring the preoperative hemoglobin level among those patients with score > 2, a further reduction in the number of unnecessary type and screen procedures *was* achievable. Of the 216 patients with score > 2 (table 4), 31 were excluded due to missing values on preopHb, leaving 185. Although we evaluated preopHb as a contin-

Table 6. Surgery and transfusion characteristics of missed transfused patients (N=55) after application of the scoring rule and the preoperative hemoglobin concentration (derivation and validation set combined).

Surgical procedure	Patients (N)	Patients (N) with > 2 units transfused (no. of units RBC)¶
After application of the scoring rule:		
TUR Prostate / Tumor#	17	5 (3; 3; 4; 4; 6)
cholecystectomy (laparoscopically / open)	10	2 (8; 10)
mastectomy with lymph node dissection	8	0
After additional application of preopHb*:		
abdominal hysterectomy	6	0
hip fracture surgery	4	0
lobectomy (lung)	3	1 (5)
peripheral artery surgery	3	1 (4)
colon resection	1	0
prostate adenoma enucleation	2	1 (5)
revision knee prosthesis	1	0

Between parenthesis the individual number of units RBC of the patients who required > 2 units.
#TUR = Transurethral resection of prostate or tumor
*PreopHb = preoperative hemoglobin concentration.

uous as well as a dichotomous predictor variable, we decided to use the dichotomized form (at 14 g dL^{-1}) to enhance applicability, as there was no difference in predictive accuracy. Table 5 shows the results and can be read in the same way as table 4. Withholding type and screen procedures in all patients with a preopHb level ≥ 14.0 g dL^{-1}, a *further* reduction in type and screen investigations of 24% could be achieved at the expense of another 5 missed transfused patients. Other hemoglobin thresholds yielded worse results.

Figure 2 summarizes the results. Using the scoring rule with a threshold of ≤ 2 and subsequently the preopHb level at a threshold of ≥ 14.0 g dL^{-1}, type and screen would be withheld in about 50% of all patients undergoing surgical procedures with intermediate transfusion risk (35% plus 24% of 65%), with 16 (23%) missed transfusions. We investigated the characteristics of the missed transfused patients in the total population of 1482 patients (derivation and validation set together). The prediction rule and subsequent use of the preoperative hemoglobin concentration would miss 55 (20%) transfused patients (table 6). On average, they required 2.5 units RBC per subject (95% CI: 2.1-2.9) and 82% of them (45 subjects) required no more than 2 units. Two patients required 8 and 10 units. They were emergency patients who were re-operated due to postoperative hemorrhage.

Discussion

To reduce the number of unnecessary preoperative type and screen procedures, we defined an easy applicable scoring rule containing three simple variables (gender, age, and surgical procedure) to predict transfusion in patients undergoing surgical procedures with intermediate transfusion risk.

Some comments are necessary. First, the prediction rules were based on data from one particular hospital. It is commonly known, that there are large differences in blood use between hospitals.[17-23] Although we have tried to show the robustness of the rule by testing it in a second dataset of our hospital, further research has to be done to validate the rule in other hospitals. Second, the transfusion trigger was a hemoglobin level of 10 g dL^{-1} as was recommended formerly.[24-26] Currently, fewer patients are transfused as RBC transfusion is

now based on the patient's risk for developing inadequate tissue oxygenation, which in fact decreases the transfusion trigger to a hemoglobin level between 6 and 10 g dL^{-1}.[27-35] This means that when the proposed prediction rule (including the subsequent preoperative hemoglobin measurement) will be applied in current practice, the yearly number of (missed) transfusions will be lower. Rehm et al, for example, found a 26% decline in the number of RBC transfusions when the modern recommendations for transfusions were used.[4]
This can be inferred from table 6: the large majority of patients received only 2 units packed cells or less, and would likely not now be transfused. However, although the number of wrongly predicted transfusions when using our rule in current practice will likely be much lower, the question about the acceptability of the remaining missed transfusions still exists. As can be seen in table 6, an emergency transfusion seemed in general not probable (except for 2 patients who were re-operated). If a patient is not typed and screened and massive hemorrhage occurs, colloids must be administered and the patient typed and screened. If, however, the patients' blood group is not available on time 0-blood can always be administered even though the presence or absence of irregular erythrocyte antibodies is not yet known.[36]
Furthermore, the risk of adverse reactions would be low anyway, given the low prevalence of these antibodies in the general population (2.5%).[37-40] We estimated that in only 0.1% of all transfusions among surgical procedures with intermediate transfusion risk irregular antibodies can be a problem. (The 10 patients in table 6 who required more than 2 units packed cells count for 3.6% of all transfusions; 2.5%*3.6% = 0.1%). Finally, ASA-classification and BMI are predictors of transfusion.[5-7;9;41] Unfortunately, as a result of the study design, these variables were not available for most of our patients. This limits the results of the study although body mass index alone is an objective parameter, but the ASA-classification is proven to be subjective.[42;43]

The results of this study support previous work. All predictors for transfusion in surgery found in this study (gender, age over 70, surgical procedure and preoperative hemoglobin concentration) were also found by others.[5-9;20;41;44-46] However, direct comparison of our rule with other prediction models is difficult as most studies evaluated a particular type of surgery. One study of different types of surgery showed that complexity of surgical procedure, age and preoperative hemoglobin concentration significantly determine the need for

perioperative RBC transfusion.[6] Most studies included at least one laboratory value in their initial prediction model (preoperative hemoglobin concentration or hematocrit).[5-9;41] Only one study described a rule without a laboratory parameter, which included similar predictors (e.g. gender) as we found.[47] This study only assessed total hip replacement and the outcome was blood loss rather than transfusion. We are the first to construct a prediction rule for surgical transfusion in procedures with intermediate transfusion risk without a laboratory value.

We suggest using our prediction rule at a threshold score of ≤ 2 or an estimated risk ≤ 10%, as was done by Weber in his model for preoperative prediction of transfusion in cancer surgery.[48] Sensitivity and specificity corresponding to this threshold (84% and 40%, respectively) are obtained in a prognostic setting and should not be confused with (usually much higher) estimates obtained in a diagnostic setting. Subsequently, we used the preoperative hemoglobin level at a threshold of ≥ 14.0 g dL^{-1}. These threshold choices are arbitrary. One could use other thresholds in the scoring rule of table 4 and the hemoglobin level, though leading to other percentages of misclassifications (figure 1).

We assumed that the average direct costs of type and screen are about US$ 80.[48-50] Using the prediction rule, 35% of all type and screen investigations in intermediate risk surgical procedures can be avoided, which will lead to a reduction in costs of 3 million dollar per 100,000 of these procedures (35,000*$80). When the preoperative hemoglobin concentration is used additionally, a further reduction in costs seems achievable, although the measurement costs of the hemoglobin concentration have to be taken into account. Further cost-effectiveness analyses, including the 'costs' of the missed transfusions, should be done and is topic for further research.

In conclusion, we believe that prediction of blood transfusion in patients having surgery with intermediate transfusion risks is feasible using the rule we have developed together with the preoperative hemoglobin concentration. Using these predictors, the number of preoperative type and screen investigations will be reduced by about 50% leading to a considerable reduction in costs.

References

1 Atrah HI, Galea G, Urbaniak SJ. The sustained impact of a group and screen and maximum surgical blood ordering schedule policy on the transfusion practice in gynaecology and obstetrics. Clin Lab Haem 1995; 17: 177-81

2 Riedler GF. 'Type and screen': die immunhamatologische Sicherheit ist gewahrleistet und die Kosten werden gesenkt. Schweiz Med Wochenschr 1996; 126: 1946-51 [German, English summary]

3 Ng SP. Blood transfusion requirements for abdominal hysterectomy: 3-year experience in a district hospital (1993-1995). Aust N Z J Obstet Gynaecol 1997; 37: 452-7

4 Rehm JP, Otto PS, West WW, et al. Hospital-wide educational program decreases red blood cell transfusions. J Surg Res 1998; 75: 183-6

5 Nuttall GA, Santrach PJ, Oliver WC, et al. The predictors of red cell transfusions in total hip arthroplasties. Transfusion 1996; 36: 144-9

6 Ong AH, Sim KM, Boey SK. Preoperative prediction of intra and postoperative red blood cell transfusion in surgical patients. Ann Acad Med Singapore 1997; 26: 430-4

7 Keating EM, Meding JB, Faris PM, et al. Predictors of transfusion risk in elective knee surgery. Clin Orthop 1998; 357; 50-9

8 Larocque BJ, Gilbert K, Brien WF. Prospective validation of a point score system for predicting blood transfusion following hip or knee replacement. Transfusion 1998; 38: 932-7

9 Bierbaum BE, Callaghan JJ, Galante JO, et al. An analysis of blood management in patients having a total hip or knee arthroplasty. J Bone Joint Surg Am 1999; 81: 2-10

10 Harrel FE, Lee KL, Mark DB. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med 1996; 15: 361-87

11 Hosmer DW, Lemeshow S. Applied Logistic Regression. New York: J Wiley and sons, 1989; 140-5

12 Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic curve. Radiology 1982; 143: 29-36

13 Weinstein MC, Fineberg HV. Clinical decision Analysis. Philadelphia: WB Saunders, 1980

14 Hanley JA, McNeil BJ. A method of comparing the areas under receiver operating characteristic curves derived from the same cases. Radiology 1983; 148: 839-43

15 Moons KGM, Stijnen T, Michel BC, et al. Application of treatment thresholds to Diagnostic-test Evaluation: An alternative to the comparison of areas under the Receiver Operating Characteristic Curves. Med Decis Making 1997; 17: 447-54

16 Moons KGM, van Es G, Michel BC, et al. Redundancy of Single Diagnostic Test Evaluation. Epidemiology 1999; 10: 276-81
17 Carson JL, Spence RK, Poses RM, et al. Severity of anaemia and operative mortality and morbidity. Lancet 1988; 340: 727-9
18 The Sanguis study group. Use of blood products for elective surgery in 43 European hospitals. Trans Med 1994; 4: 251-68
19 Carson JL, Duff A, Poses RM, et al. Effect of anaemia and cardiovascular disease on surgical mortality and morbidity. Lancet 1996; 348: 1055-60
20 Baele P, Beguin C, Waterloos H, et al. The Belgium BIOMED Study about transfusion for surgery. Acta Anaesthesiol Belg 1998; 49: 243-303
21 Capraro L. Transfusion practices in primary total joint replacements in Finland. Vox Sang 1998; 75: 1-6
22 Surgenor DM, Churchill WH, Wallace EL, et al. The specific hospital significantly affects red cell and component transfusion practice in coronary artery bypass graft surgery: a study of five hospitals. Transfusion 1998; 38: 122-33
23 Carson JL, Duff A., Berlin JA, et al. Perioperative blood transfusion and postoperative mortality. JAMA 1998; 279: 199-205
24 Adams RC, Lundy JS. Anesthesia in cases of poor surgical risk. Some suggestions for decreasing the risk. Surg Gynecol Obstet 1942; 74: 1011-9
25 Kowalyshyn TJ, Prager D, Young J. A review of the present status of preoperative hemoglobin requirements. Anesth Analg 1972; 51: 75
26 Finch CA, Lenfant C. Oxygen transport in man. N Engl J Med 1972; 286: 407-15
27 National Institute of Health. (Bernstein M.) Perioperative Red Blood Cell transfusion. JAMA 1988; 250: 2700-3
28 Stehling L, Simon TL. The red blood cell transfusion trigger. Arch Pathol Lab Med 1994; 118: 429-34
29 Task force on blood component therapy. Practice guidelines for blood component therapy. A report by the American Society of Anesthesiologists task force on blood component therapy. Anesthesiology 1996; 84: 732-47
30 Spence RK. Emerging trends in surgical blood transfusion. Semin Hematol 1997; 34: 48-53
31 Loo S, Low TC. Perioperative transfusion strategies: a national survey among anaesthetists. Ann Acad Med Singapore 1997; 26: 193-9
32 Spence RK. Anemia in the patient undergoing surgery and the transfusion decision. A review. Clin Orthop 1998;19-29.
33 Weiskopf RB. Do we know when to transfuse red cells to treat acute anemia? Transfusion 1998; 38: 517-21

34 Carson JL, Terrin ML, Barton FB, et al. A pilot randomized trial comparing symptomatic vs. hemoglobin-level-driven red blood cell transfusions following hip fracture. Transfusion 1998; 38: 522-9

35 McFarland JG. Perioperative blood transfusions: indications and options. Chest 1999; 115: 113S-21S

36 Fiebig E. Safety of blood supply. Clin Orthop Research 1998; 357: 6-18

37 Wittkopf D, Grundmann A, Sibrowski W, et al. Analyse irregularer Antikorper in der Abteilung fur Transfusionsmedizin am Universitats-Krankenhaus Hamburg-Eppendorf von 1984-1988. Infusionstherapie 1990; 17: 280-2 [German, English summary]

38 Burin-des RN, Nasr O. Recherche des anticorps irreguliers erythrocytaires par la methode du gel-test. Analyse de 35,882 echantillons. Rev Fr Transfus Hemobiol 1993; 36: 391-9 [French, English summary]

39 Trophilme C, Becker AM, Jaffard HP, et al. Recherche d'anticorps irreguliers. Etude comparative sur 2 series de 20,000 sujets, l'une avec identification en technique tube, l'autre en gel-test. Transfus Clin Biol 1995; 2: 189-99 [French, English summary]

40 Heddle NM, Soutar RL, O'Hoski PL, et al. A prospective study to determine the frequency and clinical significance of alloimmunization post-transfusion. Br J Haematol 1995; 91: 1000-5

41 Magovern JA, Sakert T, Benckart DH, et al. A model for predicting transfusion after coronary artery bypass grafting. Ann Thorac Surg 1996; 61: 27-32

42 Owens WD, Felts JA, Spitznagel EL. ASA Physical status classifications: a study of consistency for rating. Anesthesiology 1978; 49: 239-43

43 Wilson ME, Williams NB, Baskett PJF, et al. Assessment of fittness for surgical procedures and the variability of anaesthesists' judgement. Br Med J 1980; 280: 509

44 Fawcus S, McIntyre J, Jewkes RK, et al. Management of incomplete abortions at South African public hospitals. National Incomplete Abortion Study Reference Group. S Afr Med J 1997; 87: 438-42

45 Warner DO, Warner MA, Schroeder DR, et al. Changing transfusion practices in hip and knee arthroplasty. Transfusion 1998; 38: 738-44

46 Sculco TP, Gallina J. Blood management experience: relationship between autologous blood donation and transfusion in orthopedic surgery. Orthopedics 1999; 22: s129-s134

47 Grosflam JM, Wright EA, Cleary PD, et al. Predictors of blood loss during total hip replacement surgery. Arthritis Care Res 1995; 8: 167-73

48 Weber RS. A model for predicting transfusion requirements in head and neck surgery. Laryngoscope 1995; 105: 1-17

49 Ransom SB, McNeeley SG, Malone JM. A cost-effectiveness evaluation of preoperative type-and-screen testing for vaginal hysterectomy. Am J Obstet Gynecol 1996; 175 : 1201-3

50 Diagnostisch kompas 1999/2000 Ziekenfondsraad, The Netherlands, 1999. [Dutch]

5.2

Validation of a clinical prediction rule to reduce preoperative Type and Screen procedures

Wilton A van Klei, Karel GM Moons, Aart T Rheineck-Leyssius, Cornelis J Kalkman, Charles LG Rutten, Johannes TA Knape, Diederick E Grobbee.

British Journal of Anaesthesia, in press

Each surgical patient is evaluated by an anesthesiologist before surgery. This preoperative evaluation consists of a medical history, physical examination and, if necessary, additional preoperative testing such as laboratory tests.[1] However, vast amounts of financial resources seem to be wasted on inappropriate additional preoperative testing.[1-7] For example, most patients who are typed and screened preoperatively do not require a transfusion after all.
Previously, we have developed a clinical prediction rule based on simple patient characteristics to predict blood transfusion in patients undergoing surgery with intermediate transfusion risk (1% to 30%).[8] It was found that with this rule the number of preoperative type and screen procedures could be reduced by about 50%, with an acceptable number of missed transfused patients.

We set on to determine whether the rule could be adopted by other clinics. In this validation study we aimed to evaluate the robustness of our prediction rule in new patients from another hospital, which is a proper methodological standard before implementing a prediction rule in clinical practice.[9-11]

Methods

Prediction rule. In a previous study at (chapter 5.1) a non-university hospital (further referred to as derivation study) we included 1482 patients who underwent surgery with intermediate transfusion risk (1-30%).[8] We developed a prediction rule for the occurrence of perioperative red blood cell (RBC) transfusion. The rule aimed to reduce the number of unnecessary preoperative type and screen procedures. Table 1 shows the contents of the rule, i.e. *1*gender + 1*age 70 + (1, 2, 4 or 5)*surgical procedure*. For each patient a score can be estimated in which female sex and age ≥ 70 count for 1 point and scheduled surgical procedure for 1, 2, 4 or 5 points, depending on the procedure. The surgical procedures were allocated into 5 categories (Group 1: laparoscopic cholecystectomy; Group 2: mastectomy and transurethral resection of tumor (TURT) or prostate (TURP); Group 3: open cholecystectomy, vaginal hysterectomy, Cesarean section, urine incontinentia surgery and vaginal prolaps surgery; Group 4: non-cardiac thoracic surgery (e.g. lobectomy), vascular (arterial) surgery (e.g. femoro-popliteal bypass), prostate enucleation and endometrial cancer surgery; Group 5: abdominal and supravaginal hysterecto-

my, hip fracture surgery, revision knee prosthesis, leg amputation, gastroenterostomy, colon-resection and radical abdominal hysterectomy).[8] A threshold value of 2 was introduced, in which ≤ 2 indicated 'transfusion will not occur; a preoperative type and screen procedure can be withheld.' Using this threshold, in 35% of the patients a type and screen could be omitted, with 16% missed transfused patients. Subsequently, in the subgroup of patients with score > 2 the preoperative hemoglobin concentration (preopHb) at a threshold of 14 g dL^{-1} was used to further reduce the number of type and screen procedures. A preopHb ≥ 14 g dL^{-1} indicated 'transfusion will not occur; do not type and screen' and < 14 g dL^{-1} indicated 'type and screen'. Doing so, the number of type and screen procedures could be reduced by about 50%, with in total 20% missed transfused patients. For further details of the derivation and validation of the prediction rule we refer to the previous publication (chapter 5.1).[8]

Table 1. Components of the rule with corresponding scores and original regression coefficients (β).[8]

Variable	Score[#]	β (95% CI)
Gender (woman)	1	0.63 (0.20; 1.06)
Age ≥ 70	1	0.55 (0.18; 0.90)
Surgical procedure[*]		
- group 2	1	0.52 (-0.52; 1.06)
- group 3	2	1.30 (0.35; 2.23)
- group 4	4	2.29 (1.26; 3.32)
- group 5	5	2.39 (1.45; 3.33)

The intercept (constant) was -3.70 (95% CI: -4.67;-2.73)
[#]The score of each predictor was obtained by dividing the corresponding regression coefficient by the smallest coefficient (0.52) and rounded to the nearest integer.
[*]Procedures are listed in the text
β = regression coefficient of the logistic model, 95% CI = 95% Confidence Interval

Patients. To determine the robustness of these numbers, the rule was retrospectively applied to 1282 consecutive patients (aged 18-103). These patients underwent the surgical procedures the rule applies to, and were operated in 1998 at the University Medical Center Utrecht, a 1080-bed teaching hospital in The Netherlands (further referred to as 'validation set'). All patients were typed and screened before surgery, conform routine practice.

Outcome. The outcome in the present study was defined as in the derivation study: the need for any allogeneic RBC transfusion, defined as transfusion of one or more units packed cells, at the day of surgery or the first postoperative day. The transfusion decision was made by individual clinicians (anesthesiologists and surgeons), who were unaware of the prediction rule value, as the rule was validated retrospectively. In general blood was given when the hemoglobin level was below 8 g dL^{-1}.

Data collection. After approval of the hospital ethics committee, all necessary data were collected from the hospital information system. There were no missing data on any of the predictor or outcome variables, except for the hemoglobin concentration: in 245 patients (19%) it was not determined preoperatively. Comparable to the derivation study, the surgical procedures were allocated to five subgroups.

Analysis. SPSS release 10.1 for Windows was used in the analysis. The discriminative value of the prediction rule (table 1) was assessed using the area under the Receiver Operating Characteristic curve (ROC area) and compared with the ROC area of the rule in the derivation study.[8;12] Subsequently, the same threshold value as used in the derivation study ($\leq$ 2 points) was used to compare the number of correctly predicted transfused and not transfused patients with those in the derivation study. Finally, the preoperative hemoglobin concentration was used at the same threshold of 14 g dL^{-1} in all patients with score > 2, and the number of correctly predicted and missed transfusions was compared.

Results

There were no major differences in the patient characteristics of the derivation and validation study, except for the transfusion incidence. In the derivation study it was 18%, and in the validation set 8% (table 2). In the validation set the ROC area of the prediction rule was 0.78 (95% CI: 0.73-0.82) (figure 1). This area was within the 95% confidence interval of the ROC area found in the derivation study (0.75; 95% CI: 0.72-0.79).
Table 3 shows the number of transfused and not transfused patients across score categories of the rule. Applying the score threshold of > 2, type and screen would be omitted in 23% of the patients, with 8% missed transfused patients (derivation study: 35% and 16%, respectively). Consequently, using the threshold of > 2 the specificity was 24% (283 / 1182) and the sensitivity

Table 2. Patient characteristics of derivation[8] and validation set. Values are numbers and column percentages between parenthesis.

	Derivation set[8] (N=1151)	Validation set (N = 1282)
Mean age (years)		
transfused patients	62 (21)[#]	62 (23)[#]
non-transfused patients	56 (18)[#]	49 (19)[#]
Age		
18-69 years	790 (69)	1016 (79)
≥ 70 years	361 (31)	266 (21)
Gender		
male	404 (35)	368 (29)
female	747 (65)	914 (71)
Surgical procedures[*]		
group 1	121 (11)	81 (6)
group 2	295 (26)	205 (16)
group 3	356 (31)	539 (42)
group 4	94 (8)	121 (9)
group 5	285 (25)	336 (26)

[#]Values are mean and standard deviation between parenthesis.
[*]The surgical procedures are listed in the text.

Table 3. Distribution of transfused and not transfused patients according to the score of the rule (and corresponding risk of transfusion). Values are presented as absolute numbers and as percentages of the 'Total' column between parenthesis.

Score by the rule[#]	≤ 2	3 and 4	≥ 5	
Risk of transfusion[*] (%)	≤ 10	11-20	≥ 21	Total
Transfused	8 (8)	60 (60)	32 (32)	100 (100)
Not Transfused	283 (24)	828 (70)	71 (6)	1182 (100)
N	291 (23)	888 (69)	103 (8)	1282 (100)

[#]Categories of the score as estimated from the clinical scoring rule.
[*]Risk or probability of transfusion as estimated by the untransformed prediction rule as given in the third column of table 1: Risk = 1/(1 + exp -(-3.701 + 0.629*gender + 0.546*age≥ 70 + 0.524*group2 + 1.291*group3 + 2.287*group4 + 2.386*group5))
N = number of subjects per score (risk) category.

92% (60+32 / 100), compared to 40% and 84%, respectively, in the derivation study. Reading the table horizontally, one can estimate the sensitivity and specificity of the rule for various thresholds.

Table 4. Distribution of transfused and not transfused patients according to the preoperative hemoglobin concentration in the patients from table 2 with score > 2. Values are presented as absolute numbers and as percentages of the 'Total' column between parenthesis.

Hb (g dl^{-1})[*]	< 14.0	≥ 14.0	Total
Transfused	63 (93)	5 (7)	68 (100)
Not Transfused	613 (84)	117 (16)	730 (100)
N	676 (85)	122 (15)	798 (100)

*Preoperative hemoglobin concentration in g dl^{-1}.
N = number of subjects per hemoglobin category.

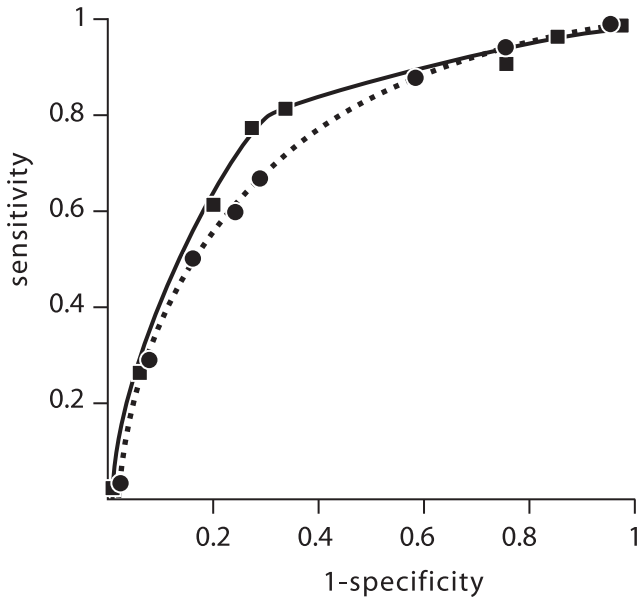

Figure 1. ROC curves of the transformed prediction rule (table 1) in the derivation set (dashed line) and the present validation set (black line). Each bullet indicates a score threshold from 0 (upper-right) to 7 (bottom-left).

The sensitivity and specificity of all possible score thresholds is obtainable from the ROC curve (figure 1). Table 3 vertically provides the predictive values per score. Of all 291 patients with score ≤ 2, 283 patients were indeed not transfused, yielding a negative predictive value of 97% (derivation study: 90%). In the group of patients with score > 2, 92 of the 991 patients were indeed transfused, a positive predictive value of 9% (derivation study: 27%).

Table 4 shows the distribution of the patients with score > 2 across the two categories of preoperative hemoglobin concentration. Of the 991 patients with score > 2, 193 had missing values on preopHb. These missing data were equally distributed among patients with (10%) and without (7%) transfusion ($p = 0.13$, likelihood ratio test). Therefore, they were excluded from the analysis. A further reduction in type and screen investigations of 15% (derivation study: 24%) could be achieved by withholding type and screen in all patients

Table 5. Surgery and transfusion characteristics of transfused patients (N=13) with a score > 2 and a preoperative hemoglobin concentration ≥ 14 g dL^{-1} ('Missed transfused patients').

Surgical procedure	Patients (N)	Units transfused¶
TUR Prostate / Tumor	3	2; 2; 5
cholecystectomy (laparoscopically / open)	3	3; 4; 4
mastectomy with lymph node dissection	2	2; 2
abdominal hysterectomy	2	1; 3
hip fracture surgery	1	2
colon resection	1	2
leg amputation	1	3

¶The number of units red blood cells per patient.
TUR = Transurethral resection of prostate or tumor. N = number of patients.

with a preopHb level ≥ 14 g dL^{-1}, at the expense of another 5 missed transfusions.

In total, after applying the rule and the preopHb to the validation set, 35% of the type and screen procedures could be omitted (derivation study: 50%), with 13 (13%) missed transfused patients (derivation study: 20%). On average, these patients required 2.7 units RBC per subject (95% CI: 2.0-3.4), 6 patients required more than 2 units (table 5).

Discussion

In the present study, the robustness of our rule to predict perioperative RBC transfusions in order to reduce the amount of type and screen procedures was evaluated in new patients undergoing identical surgery from another hospital. In total 35% of the preoperative type and screen procedures could be omitted, at the expense of 13% missed transfused patients. These results are comparable to the numbers found in the derivation study.[8]

To appreciate these findings, it should first be noted that the rule applies only to patients scheduled for the surgical procedures included in the rule. Second, in this validation study the incidence of transfusion (8%) was substantially lower than in the derivation study (18%). This is probably caused by the transfusion trigger of 8 g dL^{-1} used in the present study, compared to a trigger of 10 dL^{-1} in the derivation study. The value of a prediction rule may be affected by differences in incidence.[13-15] We estimated the performance of the rule after adjusting for the difference in transfusion incidence, i.e. after adjusting the intercept of the original logistic regression model from which the scoring rule was derived (table 1).[8] However, this adjustment showed no effect on the ROC area and did not improve the predictive accuracy in terms of absolute numbers proportions (probabilities) as shown in table 3 and 4. We therefore believe that adjustment for differences is not necessary in the scoring rule. Third, 19% of the data on the preoperative hemoglobin concentration were missing. We evaluated these missing data and found that they were randomly distributed over the outcome. Hence, we think their exclusion has not biased the results of table 4. Fourth, the acceptability of the 13% missed transfusions (table 5) must be discussed. Possibly, patients who received 2 units or less could be typed and screened during the surgery itself and colloids could be administered in the meanwhile. In the 6 patients who required more than 2 units the same could have been done and O- blood could have been administered in case of emergency. In our previous paper we extensively discussed administering 0- blood, given the low prevalence of irregular antibodies in the general population (2.5%).[8] Although one can argue against administering 0- blood in non-emergency operations, we estimated that in only 0.1% of all transfusions among surgical procedures with intermediate transfusion risk irregular antibodies can be a problem.[8] Finally, the rule was derived and validated in a general hospital and in the present study validated in a university hospital. Since it performed well in both hospital types, we conclude that the prediction rule is robust and likely to work in both types of clinics.

Several prediction rules for perioperative blood transfusion have been developed already, mainly in orthopedic surgery.[16-20] As far as we know, only one study validated a score system for predicting blood transfusion like we did.[21] In this study, the accuracy of a scoring rule for predicting blood transfusion

following hip or knee replacement (containing surgical procedure, preoperative hemoglobin concentration and weight) was prospectively evaluated at to different clinics and judged as reasonable with ROC areas of 0.78 and 0.79. These results are comparable to those found in our study, but our rule applies to a wider range of surgical procedures. Most prediction models for surgical blood transfusion described in the literature are covering a small range of surgical procedures.[16] Our study includes a much wider range. However, it would be desirable to derive and validate a prediction model that covers all types of surgery (procedures with low, intermediate and high risk for transfusion) and to evaluate whether additional predictors play a role. This is topic for further research.

In conclusion, the previously derived rule to predict the need for blood transfusion in surgical procedures with intermediate transfusion risk can be applied in other clinics as well. As our rule aimed to reduce preoperative type and screen procedures, the use of the rule could reduce the costs of perioperative patient care. Assuming that the average direct costs of type and screen are about US$ 80, the application of our rule will lead to a reduction in costs of 3 million dollar per 100,000 surgical procedures with intermediate transfusion risk (35%*100,000*$80).[8] When the measurement costs of the hemoglobin concentration are taken into account, this reduction in costs will be somewhat lower.

References

1 Roizen MF. Preoperative evaluation. In: Miller RD, ed. Anaesthesia New York: Churchill Livingstone, 2000; 824-83

2 Schein OD, Katz J. The value of routine preoperative testing before cataract surgery. N Engl J Med 2000; 342: 168-75

3 Haug RH, Reifeis RL. A prospective evaluation of the value of preoperative laboratory testing for office anesthesia and sedation. J Oral Maxillofac Surg 1999; 57: 16-20

4 Narr BJ, Warner ME, Schroeder DR, et al. Outcomes of patients with no laboratory assessment before anesthesia and a surgical procedure. Mayo Clin Proc 1997; 72: 505-9

5 Pollard JB, Zboray AL, Mazze RI. Economic benefits attributed to opening a preoperative evaluation clinic for outpatients. Anesth Analg 1996; 83: 407-10

6 Perez A. Value of routine preoperative tests: a multicentre study in four general hospitals. Br J Anaesth 1995; 74: 250-6

7 Narr BJ, Hansen T, Warner ME. Preoperative laboratory screening in healthy mayo patients: Cost-effective elimination of tests and unchanged outcomes. Mayo Clin Proc 1991; 66: 155-9

8 van Klei WA, Moons KGM, Rheineck Leyssius AT, et al. A reduction in Type and Screen: preoperative prediction of RBC transfusions in surgical procedures with intermediate transfusion risks. Br J Anaesth 2001; 87: 250-7

9 Wasson JH, Sox HC, Neff RK, Goldman L. Clinical prediction rules. Applications and methodological standards. N Engl J Med 1985; 313: 793-9

10 Laupacis A, Sekar N, Stiell IG. Clinical prediction rules. A review and suggested methods of methodological standards. JAMA 1997; 277: 488-94

11 Justice AC, Covinsky KE, Berlin JA. Assessing the generalizability of prognostic information. Ann Intern Med 1999; 130: 515-24

12 Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic curve. Radiology 1982; 143: 29-36

13 Wigton RS, Connor JL, Centor RM. Transportability of a decision rule for the diagnosis of streptococcal pharyngitis. Arch Intern Med 1986; 146: 81-3

14 Poses RM, Cebul RD, Collins LM, et al. The importance of disease prevalence in transporting clinical prediction rules. Ann Intern Med 1986; 105: 586-91

15 Moons KGM, van Es G, Michel BC, et al. Redundancy of Single Diagnostic Test Evaluation. Epidemiology 1999; 10: 276-81

16 Grosflam JM, Wright EA, Cleary PD, et al. Predictors of blood loss during total hip replacement surgery. Arthritis Care Res 1995; 8: 167-73

17 Keating EM, Meding JB, Faris PM, et al. Predictors of transfusion risk in elective knee surgery. Clin Orthop 1998; 357: 50-9

18 Larocque BJ, Gilbert K, Brien WF. A point score system for predicting the likelihood of blood transfusion after hip or knee arthroplasty. Transfusion 1997; 37: 463-7

19 Magovern JA, Sakert T, Benckart DH, et al. A model for predicting transfusion after coronary artery bypass grafting. Ann Thorac Surg 1996; 61: 27-32

20 Nuttall GA, Santrach PJ, Oliver WC, et al. The predictors of red cell transfusions in total hip arthroplasties. Transfusion 1996; 36: 144-9

21 Larocque BJ, Gilbert K, Brien WF. Prospective validation of a point score system for predicting blood transfusion following hip or knee replacement. Transfusion 1998; 38: 932-7

6

Identifying patients for blood conservation strategies

Wilton A van Klei, Aart T Rheineck Leyssius, Diederick E Grobbee,
Karel GM Moons

British Journal of Surgery, accepted for publication

Blood transfusion during surgery can be life saving. Hospital procedures, e.g. a 'type and screen' procedure and storage of patient-specific red-cell units, are aimed at the prompt availability of blood or at the prevention of homologous blood transfusion.[1] The latter is done mainly by preoperative erythropoietin administration or by conservation. For example, autologous blood is donated preoperatively and re-transfused during or after surgery in case of blood losses.[2-6] These procedures are time-consuming, expensive and some may potentially harm the patient.[7-9] Meanwhile, only a minority of the patients will receive a transfusion.
In most hospitals only the type of surgical procedure is used to regulate the indications for a type and screen procedure or blood conservation. Other predictors for the occurrence of perioperative blood transfusion such as gender, preoperative hemoglobin concentration, age and emergency surgery are generally not taken into account.[3;10-13] More accurate estimates of the transfusion risk in individual patients could help to restrict erythropoietin administration or conservation procedures to patients with a high-risk profile only.

We quantified to what extent the estimation of the need for perioperative homologous blood transfusion improves if simple patient characteristics such as age, gender and hemoglobin concentration are taken into account in addition to type of surgery. A second aim was to label candidates for erythropoietin administration or blood conservation strategies. To these aims, prediction models were derived and validated and their generalizability was tested in patients from another hospital.

Methods

Patients. The first part of the study was performed in a 638-bed non-university hospital in the Netherlands, in which neurosurgery and cardiac surgery are not performed. Data on all 9033 adult patients (≥ 18 years) undergoing surgery under general or regional anesthesia in 1998, were entered in the so-called derivation database. This database was used to develop a model to predict the need for perioperative transfusion. Data on 6494 patients undergoing surgery between 1-1-1999 and 1-10-1999 were used to validate the applicability of this prediction model (internal validation set). To evaluate the generaliz-

ability of the model it was subsequently applied to 8982 similar patients operated in 1998 in a 1080 bed Dutch university hospital (external validation set).

Predictors. Type of surgical procedure, age, gender, emergency surgery, preoperative autologous blood donation and preoperative hemoglobin concentration were evaluated as potential predictors for transfusion outcome. Surgical procedures were categorized into fourteen categories with increasing transfusion incidence: Non-invasive surgery; mild invasive surgery; Cesarean section and medium gynecologic surgery; pulmonary surgery; laparotomy and small bowel resection; major vascular surgery; major bone surgery; colon surgery; major obstetric, gynecologic and urologic surgery; resection of the rectum; hip prosthesis replacement; abdominal aortic prosthesis (elective); abdominal aortic prosthesis (ruptured); esophageal surgery.

Outcome. The outcome was the incidence of red-cell blood transfusion at the day of surgery or during the first postoperative day. Transfusion of plasma or platelets was not included. The decision to transfuse was made by individual clinicians and a protocol stating specific transfusion triggers was not in use. In general, in transfused patients, the last hemoglobin concentration measured before transfusion was between 9 and 10 g dL^{-1} in the general and below 8 g dL^{-1} in the university hospital.

Data collection. After approval of the hospital ethics committee, data were retrieved from three independent databases: operation theatre, laboratory and blood bank. The unique hospital identification code assigned to each patient was used to merge these data. In case of a re-operation at the same day or the first postoperative day only the first procedure was counted. There were no missing data, except for the hemoglobin concentration. It was not determined in 310 (3.4%), 83 (1.3%) and 2433 (27%) patients in the derivation, internal- and external validation set, respectively. In the university hospital the preoperative hemoglobin concentration was determined only if considered reasonable with respect to the expected transfusion risk.

Analysis. SPSS for Windows (release 10.1) was used for statistical analysis. In the derivation set, the incidence of transfusion was estimated for each surgical category and a logistic regression model to predict transfusion occurrence was

fitted, using type of surgical procedure as the only predictor (univariable prediction model). In this, surgery was included as thirteen indicator variables with mild-invasive surgery as the reference category. The area under the Receiver Operating Characteristic curve (ROC area) was estimated to evaluate the ability of the model to discriminate between patients with and without transfusion.[14-16]

Subsequently, the added value of all five other potential predictors was quantified using multivariable logistic regression modeling (full model). Age and hemoglobin concentration were initially analyzed as continuous variables, but these two variables were also included as categorized variables. Age was coded in four categories (18-29, 30-49, 50-69, ≥ 70 years) and hemoglobin in eight categories (< 8, 8-9.9, 10-10.9, 11-12.9, 13-14.4, 14.5-15.9, ≥ 16 g dL^{-1} and missing hemoglobin level), in which the lowest age category and the highest hemoglobin concentration category were used as reference categories.

Finally, to enhance applicability, a simplified multivariable model was tested, including surgery and hemoglobin level only. In this, 'Non-invasive surgery' (67% of all patients) was included as in the full model, 'Moderately invasive surgery' (19%) was the reference category and included surgical categories with a transfusion incidence up to 20% (mild invasive surgery, Cesarean section and medium gynecologic). 'Major invasive surgery' (14%) included the remainder categories. Preoperative hemoglobin concentration was included as unavailable or 'normal' (> 13 g dL^{-1}; reference category), as 'mild anemia' (10-13 g dL^{-1}) or as 'severe anemia' (< 10 g dL^{-1}). It was quantified whether this model was as predictive as the full model.

Differences in ROC area were used to quantify the difference in discriminative ability between the univariable and the two multivariable models, taking into account the correlation between the models as they were based on the same cases.[15; 16] The reliability (goodness of fit) of all three models was quantified using the Hosmer & Lemeshow test.[17] This test is used to compare observed probabilities with predicted probabilities and a high p-value (> 0.20) indicates that there is no difference between both probabilities, i.e. good model fit.

It is a proper methodological standard to validate the applicability of a prediction model and to evaluate its generalizability in new but plausibly related patients from another hospital before implementing such a model in clinical practice.[14;18] Therefore, the performance of both multivariable models was

tested in the internal and external validation set by comparing the ROC area to that found in the derivation set. As a ROC area reflects the overall added value of a model and does not directly indicate its clinical value, in both validation sets the absolute number of transfused patients across various patient subgroups defined by the predictors in the simplified model was estimated.[19;20]

Results

Table 1 gives general characteristics of the patients included in the study. Important differences between the derivation- and the internal validation set were not observed. The number of patients that received a transfusion was 651

Table 1. Data of patients, surgery and red blood cell transfusion.

	Derivation set	Validation set	
		Internal	External
	(N=9033)	(N=6494)	(N=8982)
Age in years (mean)	52	51	50
Age > 70 years (%)	23	21	17
Gender: males (%)	42	42	46
Emergency surgery (%)	18	19	20
Surgery type (%)			
Non-invasive	67	67	53
Moderately invasive	19	19	25
Major invasive	14	14	22
PreopHb* in g dL^{-1} (mean)	13.8	13.9	13.4
PreopHb (%)			
< 10 g dL^{-1}	3	2	3
10-13 g dL^{-1}	22	19	24
> 13 g dL^{-1}	72	78	46
not performed	3	1	27†
Transfused patients (%)	7	7	6
Units transfused per patient (mean)	3.4	3.5	4.2

*PreopHb = preoperative hemoglobin concentration
†In the university hospital the hemoglobin concentration was determined only if considered reasonable with respect to the expected transfusion risk.

Table 2. Risk of transfusion per surgical category (derivation set).

Surgical category	Number of patients		Risk (%)*
	All	Transfused	
Non-invasive surgery	6053	11	0.2
Mild invasive surgery	1424	98	7
Cesarean section / gynecology (medium)	331	62	19
Pulmonary surgery	59	16	27
Major vascular surgery	64	20	31
Major bone surgery	544	173	32
Laparotomy / small bowel resection	107	41	38
Colon surgery	104	39	38
Resection of the rectum	43	20	47
Obstetrics, gynecology, urology (major)	201	95	47
Hip prosthesis replacement	32	20	63
Abdominal aortic prosthesis (elective)	37	24	65
Abdominal aortic prosthesis (ruptured)	20	18	90
Esophageal surgery	14	14	100

*Risk of transfusion (transfused patients / total number of patients)

(7.2%) and 486 (7.4%), respectively. The external validation set was comparable to the other two data sets, with an overall transfusion risk of 5.7%, but including more patients having moderately and major invasive surgery (risk of transfusion 2-20% and > 20%, respectively).

Table 2 shows the risk of transfusion per surgical category in the derivation set. This transfusion risk ranged from 0.2% (non-invasive surgery) to 100% (esophageal surgery). The prediction model including these surgical categories only yielded a ROC area of 0.92 (95% CI: 0.91-0.93).

Adding the five other predictors to this model significantly increased the ROC area to 0.95 (95% CI: 0.94-0.96). Including age and hemoglobin as categorical variables yielded a similar ROC area. In this model, each predictor was independently associated ($p < 0.05$) with the outcome, except for the age categories < 70 years and the hemoglobin categories $\geq$ 14.5 g dL^{-1} (data are not shown). Hence, age was further categorized as < 70 and $\geq$ 70 years and the hemoglobin categories > 13 g dL^{-1} as one category. The ROC area of this full model remained 0.95 and the regression coefficients of each variable included

Table 3. The reduced prediction model including surgery type and preoperative hemoglobin concentration only.

Predictor	Regression coefficient	Odds ratio (95% CI)
Surgery		
Non-invasive	3.56	0.03 (0.02-0.05)
Moderately invasive	reference	reference
Major invasive	1.80	6.6 (5.3-8.2)
Hemoglobin concentration		
< 10 g dL^{-1}	2.89	18 (13-35)
10-13 g dL^{-1}	1.22	3.4 (2.7-4.2)
> 13 g dL^{-1}	reference	reference
Intercept (constant)	- 3.13	

Non-invasive surgery = risk of transfusion < 2%; Moderately invasive surgery = risk of transfusion 2-20%; Major invasive surgery = risk of transfusion > 20%; 95% CI = 95% confidence interval

are given in the appendix. Mild invasive surgery, age < 70 and hemoglobin concentration > 13 g dL^{-1} were used as reference categories.

The regression coefficients and odds ratios of the variables included in the simplified model are shown in table 3. The ROC area this model was 0.94 (95% CI: 0.93-0.95).

The estimated risks for transfusion of all three models were comparable to the observed risks, which indicated good fit of the models (Hosmer and Lemeshow test). As the multivariable models were significantly better than the univariable model, both were applied to the two validation sets. The ROC area of the full model was 0.89 (95% CI: 0.88-0.91) and 0.76 (0.74-0.78) in the internal and external validation set, respectively. The ROC area of the simplified model was 0.89 (0.88-0.91) and 0.85 (0.83-0.86), respectively. Patients in which the hemoglobin concentration was not determined preoperatively (in the external validation set) were counted as having a hemoglobin level of > 13 g dL^{-1}. Most of them had undergone non-invasive surgery.

Table 4 shows the absolute risks of transfusion for the nine possible categories

Table 4. The actual observed number (%) transfused patients across the 9 categories of the simplified prediction model after it is applied to both validation sets.

		Hemoglobin concentration		
		< 10 g dL^{-1}	10-13 g dL^{-1}	> 13 g dL^{-1}
		(N=135)	(N=1409)	(N=4950)
Internal validation set				
Non-invasive	(N=4325)	13 (27)	16 (2)	12 (0.3)
Moderately invasive	(N=1243)	10 (56)	45 (12)	37 (4)
Major invasive	(N= 926)	53 (77)	160 (50)	140 (26)
		(N=284)	(N=2181)	(N=6517)
External validation set				
Non-invasive	(N=4776)	6 (6)	7 (1)	10 (0.3)
Moderately invasive	(N=2272)	9 (8)	46 (6)	73 (5)
Major invasive	(N=1934)	44 (43)	140 (24)	176 (14)

Non-invasive surgery = risk of transfusion < 2%; Moderately invasive surgery = risk of transfusion 2-20%; Major invasive surgery = risk of transfusion > 20%;

of the simplified model. Patients undergoing moderately invasive surgery having a preoperative hemoglobin concentration of < 10 g dL^{-1} and patients undergoing major invasive surgery having a hemoglobin concentration < 13 g dL^{-1} had the highest risks for transfusion.

Discussion

Our results indicate that prediction of the need for perioperative homologous blood transfusion improves if easy obtainable parameters, such as age, gender and preoperative hemoglobin concentration are taken into account in addition to the surgical procedure. Using the full model (appendix) would enhance the use of blood conservation strategies before surgery for individual patients. To predict this transfusion risk a computer calculation is necessary. Although this

can easily be done using a spreadsheet algorithm during planning the operation schedule, it may limit the clinical applicability. Therefore, a simplified easy applicable model was derived yielding similar predictive performance.

Some comments are necessary. First, no specific transfusion trigger was used in the outcome definition, because this study was pragmatic and we aimed to reflect daily practice as much as possible. Therefore, transfusion at the day of surgery and the first postoperative day was chosen as outcome parameter to observe the care process of both the anesthesiologist (day of surgery) and the surgeon (first postoperative day). Second, a postoperative hemoglobin concentration of less than 8 g dL^{-1} is commonly considered as safe and sufficient.[21-23] The last measured hemoglobin concentration prior to transfusion in the general hospital was 9-10 g dL^{-1}, which suggests that excessive transfusion occurred in a number of patients. This can be inferred from table 1 and 4 as well: in the university hospital more invasive procedures were done with a slightly lower incidence of transfusion. This did not affect the generalizability of the simplified prediction model, as the predictive performance of this model in the external validation set was comparable to the derivation set. Third, the ROC area of the full model in the external validation set was much lower compared to the internal validation set, indicating some 'overfitting' of the full model. However, a ROC area of 0.76 can be considered as reasonable. This 'overfitting' played no role in the simplified model, which suggested that this model should be used.

Previous studies suggested that the predictors found in our study could be used to improve prediction of transfusion in orthopedic, rectal or cardiac surgery.[3;12;24] We demonstrated that these predictors are suitable to use over a wide range of surgical procedures.
For a decade, blood saving strategies e.g. preoperative autologous blood donation, were offered to patients to reduce the risk for HIV infection or hepatitis. Currently, these risks are very low, but allogeneic transfusion has been reported to be associated with postoperative infectious complications and tumor recurrence after cancer surgery.[24;25] Therefore, potential benefits of blood saving strategies should be weighed against disadvantages such as unnecessary donation, reduced preoperative hematocrit with increased risk for ischemia and costs. It was stated that preoperative autologous blood donation should only

be performed if the risk of transfusion is more than 50%.[26] In the internal validation set (general hospital) patients undergoing moderately invasive surgery with a hemoglobin concentration < 10 g dL^{-1} or major invasive surgery with a hemoglobin concentration < 13 g dL^{-1} are at high risk (≥ 50%) for transfusion and would therefore be potential candidates for blood conservation (table 4). Very likely as a result of the more restrictive transfusion policy in the university hospital (external validation set), none of the 9 categories of the reduced model (table 4) showed transfusion incidences of > 50%. Using this reduced model in a hospital with modern transfusion triggers, none of the 9 patient categories from table 4 seem to benefit by preoperative autologous blood conservation.

It has been reported that preoperative administration of high-dose erythropoietin and iron increases the hemoglobin concentration about 2 g dL^{-1} and reduces the risk of transfusion.[27] Our simplified model can be used to estimate the benefits of treating patients with erythropoietin. For example, a patient undergoing abdominal hysterectomy (major invasive surgery, table 4) having a preoperative hemoglobin concentration of 9 g dL^{-1} (category < 10 g dL^{-1}, table 4) who is treated with erythropoietin will shift to the hemoglobin level category > 10 g dL^{-1}. The reduction in transfusion risk will be 19% (43%-24%, table 4, external validation set), which means that 5.3 patients should be treated to prevent homologous transfusion in one patient (1 / 0.43-0.24). Similarly, patients undergoing major surgery who shift from hemoglobin level category 10-13 g dL^{-1} to the highest category seem to benefit from erythropoietin treatment, but 10 patients should be treated then to prevent one transfusion (1 / 0.24-0.14).

In conclusion, an algorithm to be used in a spreadsheet computer program or 'at bedside' in a simplified form is effective to identify patients at high risk for homologous red-cell blood transfusion over a wide range of surgical procedures. It may improve the accuracy of labeling eligible candidates for preoperative autologous blood donation or erythropoietin administration.

References

1 Mackinnon S, Newland L. A blood bank audit of elective gynecological surgery: a case for group and antibody screen. Clin Lab Haem 1986; 8: 221-5

2 Goodnough LT, Monk TG, Brecher ME. Autologous blood procurement in the surgical setting: lessons learned in the last 10 years. Vox Sang 1996; 71: 133-41

3 de Andrade JR, Jove M, Landon G, et al. Baseline hemoglobin as a predictor of risk of transfusion and response to Epoetin alfa in orthopedic surgery patients. Am J Orthop 1996; 25: 533-42

4 Brecher ME, Rosenfeld M. Mathematical and computer modeling of acute normovolemic hemodilution. Transfusion 1994; 34: 176-9

5 Monk TG, Goodnough LT, Brecher ME. Acute normovolemic hemodilution can replace preoperative autologous blood donation as a standard of care for autologous blood procurement in radical prostatectomy. Anesth Analg 1997; 85: 953-8

6 Napier JA, Bruce M, Chapman J. Guidelines for autologous transfusion II. Perioperative haemodilution and cell salvage. British Committee for Standards in Haematology Blood Transfusion Task Force. Autologous Transfusion Working Party. Br J Anaesth 1997; 78: 768-71

7 Cohen JA, Brecher ME. Preoperative autologous blood donation: benefit or detriment? A mathematical analysis. Transfusion 1995; 35: 640-4

8 Kanter MH, van Maanen D, Anders KH, et al. Preoperative autologous blood donations before elective hysterectomy. JAMA 1996; 276: 798-801

9 Renner SW, Howanitz PJ, Bachner P. Preoperative autologous blood donation in 612 hospitals. A College of American Pathologists' Q-Probes study of quality issues in transfusion practice. Arch Pathol Lab Med 1992; 116: 613-9

10 Larocque BJ, Gilbert K, Brien WF. A point score system for predicting the likelihood of blood transfusion after hip or knee arthroplasty. Transfusion 1997; 37: 463-7

11 Larocque BJ, Gilbert K, Brien WF. Prospective validation of a point score system for predicting blood transfusion following hip or knee replacement. Transfusion 1998; 38: 932-7

12 Magovern JA, Sakert T, Benckart DH, et al. A model for predicting transfusion after coronary artery bypass grafting. Ann Thorac Surg 1996; 61: 27-32

13 Bierbaum BE, Callaghan JJ, Galante JO, et al. An analysis of blood management in patients having a total hip or knee arthroplasty. J Bone Joint Surg Am 1999; 81: 2-10

14 Harrel FE, Lee KL, Mark DB. Multivariable prognostic models:issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med 1996; 15: 361-87

15 Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic curve. Radiology 1982; 143: 29-36

16 Hanley JA, McNeil BJ. A method of comparing the areas under receiver operating characteristic curves derived from the same cases. Radiology 1983; 148: 839-43

17 Hosmer DW, Lemeshow S. Applied Logistic Regression. New York: J Wiley and sons, 1989; 140-5

18 Laupacis A, Sekar N, Stiell IG. Clinical prediction rules. A review and suggested methods of methodological standards. JAMA 1997; 277: 488-94

19 Moons KGM, Stijnen T, Michel BC, et al. Application of treatment thresholds to Diagnostic-test Evaluation: An alternative to the comparison of areas under the Receiver Operating Characteristic Curves. Med Decis Making 1997; 17: 447-54

20 Moons KGM, van Es G, Michel BC, et al. Redundancy of Single Diagnostic Test Evaluation. Epidemiology 1999; 10: 276-81

21 Task force on blood component therapy. Practice guidelines for blood component therapy. A report by the American Society of Anesthesiologists task force on blood component therapy. Anesthesiology 1996; 84: 732-47

22 National Institute of Health. (Bernstein M.) Perioperative Red Blood Cell transfusion. JAMA 1988; 250: 2700-3

23 Centraal Begeleidingsorgaan Intercollegiale Toetsing. Tweede herziening consensus bloedtransfusiebeleid. (ISBN 90-6910-194-7) 1997. [Dutch]

24 Benoist S, Panis Y, Pannegeon V, et al. Predictive factors for perioperative blood transfusions in rectal resection for cancer: A multivariate analysis of a group of 212 patients. Surgery 2001; 129: 433-9

25 Regan FA, Hewitt P, Barbara JA, et al. Prospective investigation of transfusion transmitted infection in recipients of over 20 000 units of blood. Br Med J 2000; 320: 403-6

26 Thomas MJ, Gillon J, Desmond MJ. Consensus conference on autologous transfusion. Preoperative autologous donation. 1996.

27 Feagan BG, Wong CJ, Kirkley A, et al. Erythropoietin with iron supplementation to prevent allogeneic blood transfusion in total hip joint arthroplasty. Ann Intern Med 2000; 133: 845-54

Appendix

Full logistic regression model to predict transfusion in surgical patients (PreopHb = preoperative hemoglobin concentration):

Probability (risk) of transfusion =

1 / (1 + exp - (-3.85 + (-3.28*non-invasive surgery) + (0.82*Caesarean section and medium gynecologic surgery) + (1.25*pulmonary surgery) + (1.51*small bowel resection and laparotomy) + (1.60*colon surgery) + (1.69*major bone surgery) + (1.73*major vascular surgery) + (2.42* major obstetrics, gynecologic and urologic surgery) + (2.69*rectum resection) + (3.65*hip prosthesis replacement) + 3.04* abdominal aortic prosthesis, elective) + (5.09*abdominal aortic prosthesis, ruptured) + (infinite*oesophageal surgery) + (0.95* PreopHb 11.5-13g dL^{-1}) + (1.58* PreopHb 10-11.5g dL^{-1}) + (2.87* PreopHb 8-10 g dL^{-1}) + (5.10* PreopHb < 8 g dL^{-1}) + (0.25*PreopHb unknown) + (0.34*age (70 years) + (0.45* being female) + (0.18*emergency surgery) + (-1.80*preoperative autologous blood donation))).

7

The effect of outpatient preoperative evaluation of hospital inpatients on cancellation of surgery and length of hospital stay

Wilton A van Klei, Karel GM Moons, Charles LG Rutten, Anke Schuurhuis, Johannes TA Knape, Cornelis J Kalkman, Diederick E Grobbee

Anesthesia & Analgesia, March 2002 (in press)

Traditionally, all surgical patients were hospitalized at least one day before their operation and then visited by the anesthesiologist for preoperative evaluation. The aim of preoperative evaluation is to estimate the risk of perioperative morbidity and mortality and to optimize the patients' condition.[1] It has been reported that outpatient preoperative evaluation (OPE) saves costs to hospitals and society and improves quality of care.[1-8] OPE allows for comprehensive assessment of the patient when additional investigations and optimization of the patient's health status is still possible. Hence, OPE could reduce perioperative morbidity and prevent late operating room cancellations. Moreover, OPE is a prerequisite for outpatient surgery and same-day admissions.
Various studies have shown that the number of cancelled operations decreases and the number of same-day admissions increases after OPE implementation.[3-6;8;9] However, varying rates of reduction in surgery cancellations were reported with different definitions of cancellations.[1;10] Moreover, most studies included a relatively small number of patients, studied specific surgical populations only (e.g. ambulatory patients), or evaluated single effects of the introduction of OPE (such as admission length).[6-10]

We examined a range of effects of OPE in a large series of surgical inpatients. In particular, the effect OPE can have on the rate of operating room cancellations, length of hospital stay and same day admissions was determined.

Methods

Patients. The study population comprised of 21,553 elective adult surgical inpatients in which 24,685 elective, non-cardiac operating room visits were scheduled. Inpatients are patients admitted postoperatively after same day admit surgery and patients already admitted preoperatively. All patients were admitted between 1 January 1997 and 31 December 1999 to the University Medical Center of Utrecht, a 1080-bed teaching hospital in The Netherlands. Obstetric and pediatric cases were not included, because most of these operating room visits were in the adjacent children's hospital. Because they were already submitted to OPE since the mid-eighties, patients operated in same-day surgery, who were discharged within eight hours after surgery, were also excluded.
OPE was gradually introduced in June 1997 with orthopedic surgery, plastic

surgery and urology. It was then introduced in the years after to other various specialties such as gynecology and vascular surgery in October 1998, ear-nose-throat and dental surgery in May 1999, neurosurgery in June 1999 and general and eye surgery in October 1999. Across all surgical specialties, the occurrence of several outcomes before and after the implementation of an OPE clinic was compared.

Preoperative evaluation. Before the introduction of OPE, the anesthesiologist visited the patient on the ward the day before surgery. The medical history and physical examination were obtained and the patient was informed about anesthesia. After OPE was introduced, patients visited the OPE clinic on average three weeks before the surgery date. At this clinic, each patient was evaluated by the anesthesiologist through an extensive questionnaire, additional medical history, and a physical examination. Subsequently, a specially trained nurse informed the patient about the perioperative care.

Outcomes. The primary outcome of this study was the rate of surgical cases cancelled for medical reasons. A case was considered cancelled if scheduled at 1 PM on the day before surgery, but not performed on the planned date.
The secondary outcome was measured by the rate of same day admissions, the average number of (preoperative) admission days, the rate of patients that made a preoperative visit to an internist, cardiologist or pulmonologist ('consultative specialists'), the rate of postoperative Intensive Care Unit (ICU) admissions, and the rate of additional preoperative testing, such as laboratory tests. A same day admission was defined as a patient admitted and operated on the same day, for non-emergency reasons. Preoperative admission days were the number of days between the admission day and the day of surgery. Although some patients were operated on more than once within one admission, for this outcome, the first operating room visit was always taken. Postoperative ICU-admission was defined as admission into the ICU on the day of surgery or until the seventh postoperative day.

Data collection. Beginning January 1, 1997, six months before the first OPE clinic was started, we documented every surgical procedure whether it was before or after the introduction of OPE and whether it was performed as scheduled or cancelled. For each cancelled procedure the surgical specialty, the

reason for cancellation, and sex and age of the patient were documented. For cases not canceled the same data were obtained as well as data about the (preoperative) length of admission, preoperative visits by these patients to consultative specialists, the additional tests and postoperative ICU admission. A time window of 100 days before the day of surgery was chosen for visits to consultative specialists and additional testing. For patients who visited a consultative specialist more than once within these 100 days, only the most recent visit was counted. The same was done for each additional test.

Analysis. The odds ratio (OR) and a 95% confidence interval (95% CI) were used to estimate the difference in rate of operation room cancellation before and after the introduction of OPE. To adjust for age, sex and date of introducing OPE, multivariable logistic regression analysis was used. The variable 'date of introduction' was categorized into five 'period-groups' (i.e. June 1997, October 1998, May 1999, June 1999 and October 1999) and was included as four indicator variables with the first period as the reference group. This adjustment for the date of introduction was made because the distribution of specialties in the period before the introduction of OPE differed from the distribution in the period after OPE introduction. This could have influenced the studied associations. This same analytical approach was used to compare the rate of same day admissions, the rate of preoperative visits by patients to consultative specialists, the rate of preoperative chest radiographs and Electrocardiograms (ECG's) and the rate of postoperative ICU-admissions.
To determine whether admission times (estimated in days using midnight census) and the number of preoperative laboratory tests significantly changed after OPE introduction, the differences in means before and after OPE were estimated. Multivariable linear regression analysis was used to adjust these differences again for age, sex and 'introduction date'. After log transformation, the two variances (before and after OPE) of the log admission time were equal. Therefore, to quantify whether the admission time before and after OPE introduction was significantly changed, we could use the Student's T-test based on the log admission time.[11]

Results

Before the introduction of OPE, 14,148 patients were scheduled for surgery and 7,405 were scheduled after OPE introduction (Table 1). In these 21,553 adult patients, 24,685 operating room visits were scheduled (16,219 before and 8,466 after OPE introduction; some patients were scheduled more than once). The number of patients operated on for the first time was 13,162 before and 7,024 after OPE introduction.

In 96% of all cancellations the reason for cancellation was documented (Table 2). After adjustment, the OR for all cancellations together was 0.88 (95% CI: 0.76-1.02). The rate of cancellations for medical reasons only, which were

Table 1. Characteristics of elective admitted adult patients scheduled for surgery, before and after OPE introduction.[1]

	Before OPE		After OPE	
	Patients (N=14148)	Procedures[2] (N= 16219)	Patients (N=7405)	Procedures[2] (N=8466)
Mean age (SD)	53 (18)[3]		51 (18)[3]	
Sex (% men)	47		48	
Date of OPE[1,4]				
June 1997	961 (7)	1150 (7)	4408 (59)	5052 (59)
October 1998	1890 (13)	2277 (14)	948 (13)	1165 (14)
May 1999	3116 (22)	3287 (21)	959 (13)	1025 (12)
June 1999	1533 (11)	1828 (11)	368 (5)	421 (5)
October 1999	6648 (47)	7677 (47)	722 (10)	803 (10)

[1]The specialties were combined by their entry date at the OPE clinic: June 1997: orthopedic surgery, plastic surgery and urology; October 1998: gynecology (obstetric procedures were not included) and vascular surgery; May 1999: Ear-Nose-Throat- and dental surgery; June 1999: neurosurgery; October 1999: general- and eye surgery.
[2]The sum of surgical procedures exceeds the sum of patients, because some patients had undergone more than 1 procedure.
[3]Mean age differed before and after OPE; mean difference 2.2 years (95% CI: 1.8-2.7).
[4]Numbers reflect absolute numbers and column % between parenthesis.
OPE = Outpatient Preoperative Evaluation; SD = standard deviation

Table 2. Number of operating room cancellations for different reasons before and after the introduction of OPE (% between parenthesis) and corresponding Odds Ratios.

	Before OPE (N=16219)	After OPE (N=8466)	Crude OR (95% CI)	Adjusted OR (95% CI)¶
Medical reasons				
Cancelled by anesthesiologist				
Untreated hypertension	30 (0.2)	6 (0.1)	0.4 (0.2-0.9)	
Cardiac / pulmonary instability	65 (0.4)	12 (0.1)	0.3 (0.2-0.6)	
Continued use of anticoagulants / other drugs with increased risk	10 (0.1)	5 (0.1)	0.9 (0.3-2.8)	
Laboratory test abnormalities	20 (0.1)	9 (0.1)	0.8 (0.4-1.9)	
No fasting by patient	6 (0.0)	2 (0.0)	0.6 (0.1-3.1)	
Illness / fever in patient	74 (0.5)	21 (0.3)	0.5 (0.3-0.9)	
Cancelled by surgeon				
Insufficient (diagnostic) work-up	111 (0.7)	24 (0.3)	0.4 (0.3-0.6)	
Total medical reasons	**316 (2.0)**	**79 (0.9)**	**0.5 (0.4-0.6)**	**0.7 (0.5-0.9)**
Other reasons				
Logistic*	506 (3.1)	225 (2.7)	0.8 (0.7-1.0)	
No hospital- or ICU bed / ICU contaminated with MRSA	32 (0.2)	11 (0.1)	0.6 (0.3-1.3)	
Illness of surgeon	15 (0.1)	8 (0.1)	1.0 (0.4-2.4)	
Cancelled by patient	60 (0.4)	34 (0.4)	1.1 (0.7-1.6)	
Patient already operated#	25 (0.2)	5 (0.1)	0.8 (0.4-1.6)	
Surgery no longer indicated	29 (0.2)	13 (0.2)	0.9 (0.5-1.7)	
Total other reasons	**667 (4.1)**	**296 (3.5)**	**0.8 (0.7-1.0)**	**0.9 (0.8-1.1)**
Unknown reasons	44 (0.3)	18 (0.2)	0.8 (0.4-1.3)	
Total	**1027 (6.3)**	**393 (4.6)**	**0.7 (0.6-0.8)**	**0.9 (0.8-1.0)**

¶Adjusted for age, sex and date of entry at the OPE clinic (specialties combined as in Table 1).
*Another (emergency) patient in place, patient scheduled as 'PM', too many patients scheduled, implants not available, etc.
#Patient already operated (due to emergency reasons) in the weekend or night before (e.g. Cesarean deliveries).
OPE = Outpatient Preoperative evaluation; ICU = Intensive Care Unit; MRSA = Methicillin resistant Staphylococcus Aureus

Table 3. Mean and median admission time, geometric mean and estimated ratio's of admission time before OPE versus after OPE.

Admission time:			Preoperative	Total
Before OPE	Mean (SD)		1.7 (3.5)	8.8 (12.0)
	Median (25th; 75th)		1 (1;1)	5 (3;9)
	Geometric mean†		1.30	1.85
After OPE	Mean (SD)		1.5 (4.6)	8.1 (11.5)
	Median (25th; 75th)		1 (1;1)	5 (3;9)
	Geometric mean†		1.15	1.78
Estimated ratio# (95% CI):		unadjusted	0.89 (0.88-0.91)	0.92 (0.90-0.94)
		adjusted	0.88 (0.86-0.90)	0.92 (0.90-0.94)

†Geometric mean = Exp (mean log admission time)
#The ratio is the ratio of the geometric mean before versus after OPE. The adjusted ratio was adjusted for age, sex and introduction date of OPE (specialties combined as in Table 1) using linear regression analysis.
OPE = Outpatient Preoperative evaluation; 95% CI = 95% Confidence Interval; SD = standard deviation; 25th = 25th percentile

expected to be influenced mostly by OPE, decreased from 1.95% to 0.93%, yielding an OR of 0.5 (0.4-0.6) and a difference of 1.02% (95% CI: 0.07-1.31%). After adjustment the OR was 0.7 (95% CI: 0.5-0.9).

The admission time was skewly distributed; the overall mean was 8.6 days (SD 11.8) and the median 5 days. The preoperative and total admission time were significantly decreased after OPE introduction ($p < 0.001$). The preoperative admission time after OPE was 0.89 (95% CI: 0.88-0.91) times the value found before OPE, a relative decrease of 11%. For total admission time, this relative decrease was 8% (Table 3). After adjustment similar ratios were found.

The rate of same day admissions increased from 5.26% (692 / 13,162) before to 7.72% (542 / 7,024) after OPE introduction. This difference of 2.46% (95% CI: 1.73-3.17%) yielded an OR of 1.19 (95% CI: 1.01-1.39) after adjustment. Figure 1 shows the total rate of same day admissions in our clinic

Table 4. Number of postoperative ICU admissions, preoperative visits by patients to consultative specialists, ECG's and chest radiographs before and after OPE (% between parenthesis) and odds ratio's.

	Before OPE (N = 13162)	After OPE (N = 7024)	Odds Ratio (95% CI) Crude	Adjusted*
Postop ICU admission	670 (5.0)	255 (3.6)	0.7 (0.6-0.8)	1.0 (0.9-1.2)
Preoperative visit by patient to				
pulmonologist	176 (1.3)	102 (1.5)	1.1 (0.9-1.4)	1.2 (0.9-1.6)
internist	1254 (9.5)	646 (9.3)	1.0 (0.9-1.1)	1.0 (0.9-1.2)
cardiologist	327 (2.5)	185 (2.6)	1.1 (0.9-1.3)	0.9 (0.7-1.1)
Preoperative				
ECG	7347(55.8)	3307(47.1)	0.7 (0.7-0.8)	0.7 (0.7-0.8)
chest X-ray	264 (2.0)	11 (0.2)	0.1 (0.0-0.1)	0.1 (0.0-0.1)

*Adjusted for age, sex and OPE introduction date (specialties combined as in table 1)
OPE = Outpatient Preoperative evaluation; 95% CI = 95% Confidence Interval; ICU = Intensive Care Unit; ECG = Electrocardiogram

per semester since 1997. At the end of 2000, the absolute rate of same day admissions was 20%.

After adjustment for age, sex and introduction date, the number of postoperative ICU admissions and visits to consultative specialists did not differ before and after OPE, but the number of preoperative ECG's performed and chest radiographs decreased significantly (Table 4). Also, the mean number of preoperative laboratory tests performed per patient decreased from 2.4 before to 1.5 tests after OPE introduction (difference 0.84; 95% CI: 0.81-0.88). After adjustment this difference was 0.70 (95% CI: 0.66-0.74). The rate of patients in which no laboratory test was performed increased from 17% (2,278 / 13,162) before to 37% (2,295 / 7,024) after OPE introduction (difference after adjustment 15%; 95% CI: 14-17%), yielding an OR of 3.1 (95% CI: 2.8-3.4) after adjustment.

Figure 1. Percentage of same day admissions of total number of admissions per semester since 1997, with upper and lower bound 95% CI.

Discussion

We evaluated the possible effects of introduction of an OPE clinic for surgical inpatients. The number of operating room cancellations for medical reasons (such as untreated hypertension) decreased by 30%. In addition, the length of hospital stay and the number of preoperative additional tests (e.g. ECG's, chest radiographs and laboratory tests) were significantly reduced.

To appreciate these results, it should be noted that this study was nonrandomized; it compared the situation before and after the introduction of OPE. Although we made adjustments for several confounders (age, sex and 'introduction date'), it may well be that there were unmeasured differences between both groups, that were responsible for the observed effects. Second, only the data on surgery cancellations were collected prospectively. Data on other out-

comes were obtained from the hospital information system. Although these data appeared to be reliable, we have no information on error rates. However, errors in such data are likely to be non-differential before and after OPE introduction.

Previous studies reported effects of OPE comparable to those observed here, including a reduction in cancelled cases and in additional preoperative tests.[3-9] The relative reduction in surgical cancellations ranged from 20% to 88%, but most studies included a relatively small number of patients. In one study from a university hospital in the USA, Fisher reported a decrease from 1.96% to 0.21% (relative reduction: 88%) in cancellations for medical reasons in adult out- and inpatients and in the number of additional tests ordered.[5]
In our study the observed effect was smaller, which is likely the result of differences in patient population (we included inpatients only). Several studies have also shown a reduction in preoperative length of admission.[2;3;6;8] In most instances this reduction resulted from an increased number of same-day admissions (up to more than 50%) or to an increase in patients that were operated on in ambulatory surgery. In our study the increase in same day admissions (from 5% to 20% one year after complete OPE introduction, Figure 1) was much smaller. The observed decrease in postoperative admission length after introduction of OPE in our clinic, has been less.[8]

The effects of the introduction of OPE in our hospital were smaller than anticipated. Despite the fact that OPE allowed same day admissions, a number of specialists admitted patients to the ward one day before surgery for reasons of teaching medical students or routine additional tests. Obviously, to change these existing practice patterns, the incentives for all those concerned must be clear. It will take time to change habits, to define new clinical pathways to reduce variability between specialists and to receive the full benefits from OPE. In this context it should be noted that OPE was introduced gradually. We found that it took at least one year after entering patients in the OPE process before a change in practice pattern was evident in a particular surgical specialty. Because the present data suggest that our hospital has not yet extracted the maximal benefit from the OPE clinic, our institutional policy should possibly be changed; i.e. surgical departments should be urged to increase their number of same day admissions.

The effects of OPE observed in our study most likely resulted from a better timing of the preoperative evaluation of surgical inpatients; OPE allows ample time for comprehensive assessment of the patient and treatment of co-morbidity before the scheduled date of surgery. This reduces the number of late cancellations (within 24 hours before surgery) because of newly discovered conditions (Table 2). Most preventable perioperative events are cardiopulmonary in origin.[1;12-17] Since preoperative evaluation focuses on these organ systems, the observed reduction in cancellations for newly discovered cardiopulmonary disease was expected. The reduction in postoperative admission time was possibly the result of a reduction in morbidity, this is the result of a better preoperative optimization of the patients' condition and the information given by nurses at our OPE clinic.[18-20] Furthermore, by making OPE an integral component of perioperative care, the number of unnecessary preoperative tests will decrease considerably.

In conclusion, OPE of hospital inpatients leads to an increase in quality of perioperative care, as a result of a reduction of cancelled surgery, hospital admission time and preoperative testing.

Acknowledgement

The authors gratefully acknowledge Monique Pluer, operating room coordinator at the University Medical Center Utrecht, who collected and documented the data about the cancelled surgical cases from 1997 to 1999.

References

1 Roizen MF. Preoperative evaluation. In: Miller RD, ed. Anaesthesia. New York: Churchill Livingstone, 2000; 824-83

2 Frost EA. Outpatient evaluation: A new role for the anesthesiologist. Anesth Analg 1976; 55: 307-10

3 Rutten CLG, Post D, Smelt WLH. Outpatient preoperative examination by the anesthesiologist I. Fewer items of service and preoperative hospital days. Ned Tijdschr Geneeskd 1995; 139: 1028-32 [Dutch, English summary]

4 Boothe P. Changing the admission process for elective surgery: An economic analysis. Can J Anaesth 1995; 42: 391

5 Fischer SP. Development and effectiveness of an anesthesia preoperative evaluation clinic in a teaching hospital. Anesthesiology 1996; 85: 196-206

6 Pollard JB, Zboray AL, Mazze RI. Economic benefits attributed to opening a preoperative evaluation clinic for outpatients. Anesth Analg 1996; 83: 407-10

7 Starsnic MA, Guarnieri DM, Norris MC. Efficacy and financial benefit of an anesthesiologist-directed university preadmission evaluation center. J Clin Anesth 1997; 9: 299-305

8 Pollard JB, Garnerin P. Use of outpatient preoperative evaluation to decrease length of stay for vascular surgery. Anesth Analg 1997; 85: 1307-11

9 Conway JB, Goldberg J, Chung F. Preadmission anaesthesia consultation clinic. Can J Anaesth 1992; 39: 1051-7

10 Pollard JB, Olson L. Early outpatient preoperative anesthesia assessment: does it help to reduce operating room cancellations? Anesth Analg 1999; 89: 502-5

11 Zhou XH, Gao S, Hui SL. Methods for comparing the means of two independent log-normal samples. Biometrics 1997; 53: 1129-35

12 Cassidy J, Marley RA. Preoperative assessment of the ambulatory patient. J Perianesth Nurs 1996; 11: 334-43

13 Mohr DN, Lavender RC. Preoperative pulmonary evaluation. Identifying patients at increased risk for complications. Postgrad Med 1996; 100: 241-8

14 Mangano DT. Perioperative cardiac morbidity. Anesthesiology 1990; 72: 153-84

15 Van Aken H, Rolf N. Preoperative evaluation and preparation. The view of the anesthetist. Anaesthesist 1997; 46 Suppl 2: S80-S84 [German, English summary].

16 Wolters U. ASA classification and perioperative variables as predictors of postoperative outcome. Br J Anaest 1996; 77: 217-22

17 Schein OD, Katz J. The value of routine preoperative testing before cataract surgery. N Engl J Med 2000; 342: 168-75

18 Klafta J, Roizen MF. Current understyanding of patients' attitudes toward and preparation for anesthesia: A review. Anesth Analg 1996; 83: 1314-21

19 Gammon J, Mulholland CW. Effect of preparatory information prior to elective total hip replacement on post-operative physical coping outcomes. Int J Nurs Stud 1996; 33: 589-604

20 Shuldham C. A review of the impact of pre-operative education on recovery from surgery. Int J Nurs Stud 1999; 36: 171-6

8

General discussion

An important goal in anesthesiology is to estimate the probability of morbidity and mortality in a particular patient in view of planning a surgical procedure. Preoperative risk management includes the detection of significant co-morbidity and probability estimation of perioperative complications. Subsequently, knowledge about the effects of interventions on the complication rate is used to determine the required anesthetic strategy in order to minimize the risk of morbidity and mortality. To aid risk management, it would be very useful if evidence-based risk estimates of perioperative complications including long-term negative outcomes, were available to the anesthesiologist. In other words, in preoperative risk management diagnostic information is used to estimate the probability of outcomes and to decide on the anesthetic strategy in a particular patient.

The studies in this thesis explored to what extent easy accessible patient characteristics, particularly those that can be obtained from preoperative patient history and physical examination, could contribute to preoperative risk management. Furthermore, as it is recommended to perform the preoperative evaluation some weeks before the scheduled surgery date, the implementation of outpatient preoperative evaluation (OPE) clinics in the Netherlands as well as the effects of OPE in a particular hospital were examined.[1-11]

Preoperative risk management

Diagnostic strategies to detect significant co-morbidity

Diagnostic research. Most patients undergoing elective surgery are in good health (about 85% of surgical patients are classified as ASA class 1 and 2) and have only a minor risk of complications during surgery and anesthesia.[5;12-18] During the preoperative health assessment these 'healthy' patients need to be distinguished from those who are 'not healthy'; i.e. patients suffering from additional conditions that might increase the risk of morbidity and mortality. Preferably, the 'healthy' patients are easily distinguished from the remainder using a minimal but optimal set of diagnostic tests. Until now the literature offers no evidence on the optimal content of the preoperative health assessment (chapter 2). To serve the aim of easy health assessment, in 1997 the Dutch Health Council proposed the use of a short questionnaire including 7

questions only as a diagnostic test to distinguish 'healthy' patients from those who are 'not healthy'.[3] We found that the rapid health assessment using the short questionnaire was insufficient compared to the 'conventional' extensive assessment. Substantial diagnostic information considered necessary by a panel of 10 anesthesiologists was missing (chapter 3). However, the use of an expert panel as a reference standard to determine the necessary extent of diagnostic information is not optimal.[19;20] To determine the optimal set of diagnostic tests to appropriately detect existing co-morbidity would require an empirical diagnostic study. In such a study the contribution of each diagnostic test obtained from patient history, physical examination and additional testing is related to the diagnostic outcome, i.e. 'presence or absence of significant co-morbidity as independently determined by an objective reference test in each patient'.[21-23] In such a study, each piece of information, including a single answer to a simple question from patient history, can be considered as a different diagnostic test result.[24;25] Diagnostic tests that are unrelated to the diagnostic outcome are redundant. While diagnostic research may decrease redundant information, it requires the a priori definition of what constitutes significant co-morbidity. Therefore, the quality circle can only be closed when perioperative and long-term complications are registered.

Cardiac auscultation. To demonstrate how diagnostic research might be used in the clinical setting of an OPE clinic, we studied the diagnostic value of cardiac auscultation to detect valvular heart disease (VHD) (chapter 4). In particular, undetected severe aortic valve stenosis is associated with significant hemodynamic complications and even sudden death during anesthesia.[26;27] Preoperative detection of aortic valve stenosis is therefore a valid goal of preoperative evaluation.

To quantify the diagnostic value of cardiac auscultation by the anesthesiologist to diagnose the absence or presence of VHD, we estimated the prevalence of heart murmurs by auscultation before surgery. Subsequently, patients with a heart murmur were referred for echocardiography (reference test or 'gold standard'). We found that 74% of the heart murmurs detected by cardiac auscultation reflected VHD, yielding an overall prevalence of VHD of 3%. The prevalence of aortic valve stenosis was 1.7% in patients aged over 65 years. Using cardiac auscultation, 26% of all detected murmurs appeared to be 'false positives', i.e. 'echocardiography evaluation did not reveal VHD'.

However, for reasons of efficiency our study did not follow an optimal diagnostic design (not all patients underwent the reference test, but only those in which a heart murmur was detected). Hence, we were not able to draw inferences about the number of false negative auscultation results, i.e. patients who do have VHD, but where auscultation did not reveal a heart murmur. In a proper diagnostic study all patients would undergo cardiac auscultation and subsequent echocardiography. Such a study, although very costly, will show the true prevalence of VHD among surgical patients evaluated at the OPE clinic and will also quantify the extent to which detection of a heart murmur can discriminate between the true presence or absence of VHD. Such a study might possibly show that the ability of anesthesiologists to detect all relevant heart murmurs is low and that screening for VHD should use transthoracic echocardiography in all patients (above a certain age).

Probability estimation of patient outcome

Prognosis. To serve the aim of preoperative risk management, the anesthesiologist should also have knowledge about the probability of perioperative complications and to what extent the anesthetic strategy may alter the complication rate. This prognostic knowledge includes the probability of a particular outcome in a particular patient, for example a patient who has an increased risk of perioperative myocardial ischemia. Other outcomes of potential interest are postoperative pain, nausea and vomiting and thrombo-embolism. An important long-term outcome for patients may be the duration until total recovery (e.g. the time he or she starts to work again). Prognostic knowledge is particularly used to decide on whether a patient should be treated or not. In practice, these treatment decisions are frequently based on past experience with comparable patients under comparable circumstances. However, it would be preferable to have more evidence-based risk estimates of patient outcomes.

Prognostic prediction research. Prognostic prediction studies aim to estimate the probability of future occurrence of a particular outcome in a particular patient, for example the need for transfusion of homologous red blood cells (chapter 5 and 6). Commonly, (logistic) regression analysis is used to relate multiple predictors (e.g. patient characteristics such as age and sex or type of surgery) to the outcome. In a multivariable regression analysis the prognostic contribution of each predictor to the outcome is estimated independent of the

prognostic contribution of all other predictors in the prediction model. Usually, the prognostic contribution of a predictor estimated in a multivariable analysis is smaller than estimated in a univariable analysis, because various other predictors are also correlated to the outcome and provide to some extent identical information.[21;28;29] Hence, multivariable risk estimates are more accurate than univariable risk estimates.

Risk modification. Prediction models are also suitable to estimate to what extent the individual risk of a patient can be modified, for example by preoperative treatment. For instance, patients who can be shifted to a higher preoperative hemoglobin level by preoperative erythropoietin administration will have a lower risk of perioperative homologous transfusion (chapter 6). Similarly, other pre-emptive strategies can be developed based on the results of prediction research. For example, pre-emptive strategies to decrease the incidence of postoperative nausea and vomiting by administering effective anti-emetics before the patient is awakening, strategies to reduce postoperative pain or perioperative β-adrenergic receptor blockade to reduce the risk of myocardial ischemia and infarction.[30]

Implementation of prognostic prediction models. Before a prediction model can be implemented in practice, its generalizability should be determined. Prediction models are frequently only validated in another subset of the source population from which the model was derived, which gives an impression of the 'internal validity' of a prognostic model: the prognostic value in similar patients as analyzed in the dataset (e.g. from the same hospital).[29;31-34] Internal validity, however, is no guarantee for generalizability and thus no substitute for 'external validation'. Therefore, the ultimate test of the robustness of a prognostic model is its application to patients from a different but related population ('external validation').[31-33;35] To obtain an estimate of the 'external validity' or generalizability, we applied both the prediction model to reduce type and screen procedures (chapter 5.2) and the model to label patients for blood conservation strategies (chapter 6) to a patient population from another hospital. Both models stayed robust and we concluded that they can be implemented in practice.

The role of information technology. It would be very useful if evidence-based individual risk estimates were available to the anesthesiologist during preoperative evaluation. In this context, there will be an important role for information technology. Patient data of the entire process of perioperative care (from the first visit of a patient to the surgical specialist to the last postoperative visit), including the occurrence of complications and outcomes, may be collected and stored using an electronic patient record system. Currently, however, perioperative and long-term complications and outcomes are not registered routinely. It is a challenge for anesthesiology in the next decade to create a well performing complication registration system in close collaboration with our surgical colleagues. Such a system could provide the necessary data for continuous prognostic prediction research, which in turn will provide prediction models or risk stratification systems for (long-term) morbidity and mortality to the anesthesiologist. These prediction models or stratification systems can be built-in in the electronic patient record software used at the OPE clinic. This will provide direct individual estimates of several outcomes to the anesthesiologist after completing the preoperative health evaluation, resulting in an increase in the quality of perioperative care.

Implementation and effects of outpatient preoperative evaluation

The benefits of outpatient preoperative evaluation (OPE). Traditionally, patients were visited on the ward by the anesthesiologist for preoperative evaluation in the afternoon before surgery. Mainly as a result of the increasing number of patients operated in outpatient surgery or after same day admission during the past decade, preoperative evaluation has been shifted from the day before surgery to OPE some weeks before surgery. There are several potential benefits of OPE. For example, it has been reported that OPE allows for comprehensive assessment, additional evaluation and optimization of the patient's health status without delaying surgery. Hence, OPE facilitates the use of outpatient surgery and same-day admissions (even in patients suffering from significant additional conditions) and may reduce the number of late operating room cancellations due to newly discovered co-morbidity.[1-7;9;11;36;37] For these reasons the Dutch Health Council recommended implementation of OPE clin-

ics in 1997 and stated that preoperative evaluation should be performed under the responsibility of both the anesthesiologist and the surgical specialist.[3]

Implementation of OPE in the Netherlands. Although an increasing number of OPE clinics has been implemented in Dutch hospitals since 1997, we found that 80% of all hospitals did not organize preoperative evaluation in the way it was recommended. This was mainly due to financing problems and the current shortage of anesthesiologists (chapter 3). Furthermore, in 70% of the Dutch hospitals the anesthesiologist did not evaluate every patient before entering the operating room. This suggests that the health status of many patients (most likely day-surgery patients) is only evaluated by taking a short medical history during positioning of the patient in the operating room, or is not evaluated at all. Depending on the co-morbidity of a patient, this substandard care might lead to an increase in perioperative morbidity and mortality.

Effects of OPE implementation. In the University Medical Center of Utrecht, OPE was implemented between 1997 and 1999. Introduction of OPE resulted in a decrease in late operating room cancellations for medical reasons (30%), indicating that the health status of patients is much better evaluated using OPE. Furthermore, we found an increase in the rate of same day admissions one year after complete implementation of the OPE clinic (from about 7% in 1997 to more than 20% at the end of 2000) (chapter 7). However, the effects were smaller than anticipated. Despite the fact that OPE allowed same day admissions, patients were still admitted to the surgical ward one day before surgery for reasons of teaching medical students or to perform 'routine' additional tests. Obviously, in order to change existing practice patterns, the incentives for all those concerned in preoperative patient care, such as anesthesiologists and surgical specialists, must be clear. It is well known that practice guidelines are not always implemented, even though clinicians have publicly acknowledged their utility.[38;39] In general, an oversimplification of daily practice and a threat to professional autonomy were among the forces acting against implementation of guidelines.[38] Furthermore, a reluctant attitude of physicians regarding guidelines may be related to the physicians' affiliation with the organization that issued them.[39] This dilemma could be overcome when professional organizations of both anesthesiologists and surgical disciplines would recommend and facilitate OPE implementation.

As our hospital did not yet extract the maximal benefit from the OPE clinic, our institutional policy should be changed; i.e. surgical departments should be coerced by the hospital board to increase their number of same day admissions to increase cost savings.

Preoperative evaluation by anesthetic nurses. Ideally, all patients are evaluated by the anesthesiologist at the OPE clinic (an 'anesthesiologist-led OPE clinic'). However, widespread implementation of OPE will require an increase in the number of anesthesiologists, which in turn might increase the costs of anesthetic care. The shortage of anesthesiologists forces a choice between provision of adequate OPE or maintaning the capacity to provide clinical operating room anesthesia. Although we found that the short questionnaire was not sufficient to serve the aim of rapid health assessment, the suggestion of the Netherlands Health Council to use minimal resources, i.e. to label patients as 'healthy' or as 'requiring extensive evaluation' early in the OPE process, is very attractive. Such a distinction could improve the cost-effectiveness of OPE and allow the allocation of scarce resources to those patients who are most likely to benefit from OPE.

The question then arises whether a specially trained anesthesia nurse can screen these 'healthy' patients adequately. Only one study discussed the impact of the partial substitution of the anesthesiologist by a specially trained nurse in the OPE process, but the cost-effectiveness of this strategy has never been quantified.[40] In primary care settings, a comparison of nurse practitioners and physicians has been described more often. Various studies showed no differences in cost-effectiveness between general practitioners and nurse practitioners; there was no difference in health status outcome, prescriptions or referrals, but the patients visiting the nurse practitioner were more satisfied and reported to be better informed.[41-43] Furthermore, these studies demonstrated that the health service costs of consultation by nurses were 12.5% lower than those of general practitioners.[41;42] The mean consultation time of a nurse practitioner was significantly longer than that of the general practitioner (12 versus 8 minutes).[41;43] However, it should be noted that this comparison between physicians and nurse practitioners was performed in primary care settings and not in the setting of an OPE clinic in a secondary or tertiary level hospital. Further research is necessary to quantify the ability of specially trained nurses to evaluate the health status of patients preoperatively.

There could be several benefits of partial OPE by nurses. First, if in a majority of elective surgical patients the distinction between patients who are 'healthy and ready for surgery' and those 'requiring assessment by the anesthesiologist' can be done by a well-trained anesthetic nurse, the benefit / cost ratio of OPE would be further improved. In particular, the quality of care for patients who need extensive evaluation will increase, as the anesthesiologist has more time for these patients and the costs for patients who are judged as 'ready for surgery' will decrease. Second, if a partial substitution of anesthesiologists by nurses appears cost-effective, it will decrease the practical problem of the current and increasing shortage of anesthesiologists. Finally, because OPE by nurses requires predefined and well-structured protocols, it will provide a framework for more standardized methods of OPE in the future. In conclusion, this 'mixed-provider model OPE clinic' might increase the quality and cost-effectiveness of OPE.

Final conclusion

Preoperative risk management can be improved by implementing strategies derived from diagnostic and prognostic research. To provide the necessary research data, a fully functional complication registration system should be developed in close collaboration with surgical disciplines. The research results of well-validated prediction models can in turn be used as components of the electronic patient record software to provide a tool for standardized methods of risk stratification and management. Such computerized standardization will enhance the effectiveness of the 'mixed-provider model OPE clinic', where anesthesiologists collaborate closely with nurses to optimally prepare patients for surgery, including optimization of the patient with significant co-morbidity.

References

1 Roizen MF. Preoperative evaluation. In: Miller RD, ed. Anaesthesia. New York: Churchill Livingstone, 2000; 824-83

2 Pollard JB, Olson L. Early outpatient preoperative anesthesia assessment: does it help to reduce operating room cancellations? Anesth Analg 1999; 89: 502-5

3 Health Council of the Netherlands, Committee on preoperative evaluation. Preoperative evaluation. 1997/2. [Dutch, English summary]

4 Starsnic MA, Guarnieri DM, Norris MC. Efficacy and financial benefit of an anesthesiologist-directed university preadmission evaluation center. J Clin Anesth 1997; 9: 299-305

5 Fischer SP. Development and effectiveness of an anesthesia preoperative evaluation clinic in a teaching hospital. Anesthesiology 1996; 85: 196-206

6 Pollard JB, Zboray AL, Mazze RI. Economic benefits attributed to opening a preoperative evaluation clinic for outpatients. Anesth Analg 1996; 83: 407-10

7 Pollard JB, Garnerin P. Use of outpatient preoperative evaluation to decrease length of stay for vascular surgery. Anesth Analg 1997; 85: 1307-11

8 Boothe P. Changing the admission process for elective surgery: An economic analysis. Can J Anaesth 1995; 42: 391

9 Rutten CLG, Post D, Smelt WLH. Outpatient preoperative examination by the anesthesiologist I. Fewer items of service and preoperative hospital days. Ned Tijdschr Geneeskd 1995; 139: 1028-32 [Dutch, English summary]

10 Conway JB, Goldberg J, Chung F. Preadmission anaesthesia consultation clinic. Can J Anaesth 1992; 39: 1051-7

11 Frost EA. Outpatient evaluation: A new role for the anesthesiologist. Anesth Analg 1976; 55: 307-10

12 Arbous, MS. Anesthesia-related risk factors for perioperative severe morbidity and mortality. Thesis, Utrecht university, The Netherlands. 1998.

13 Wolters U. ASA classification and perioperative variables as predictors of postoperative outcome. Br J Anaest 1996; 77: 217-22

14 Arvidsson S. The Gothenburg study of perioperative risk. I. Preoperative findings, postoperative complications. Acta Anaesthesiol Scand 1994; 38: 679-90

15 Arvidsson S. Predicting postoperative adverse events. Clinical efficiency of four general classification systems. Acta Anaestesiol Scand 1996; 40: 783-91

16 Menke H. Präoperative Risikoeinschätzung mit der ASA-Klassification. Eine prospectieve Untersuchung zu Morbidität und Letalität in verschiedenen ASA-Klassen bei 2937 Patienten mit allgemeinchirurgischen Operationen. Chirurg 1992; 63: 1029-34 [German, English summary]

17 Vacanti CJ, Vanhouten RJ, Hill RC. A statistical analysis of the relationship of physical status to postoperative mortality in 68388 cases. Anesth Analg 1970; 49: 564-6

18 Fowkes FGR, Lunn JN, Farrow SC. Epidemiology in anaesthesia III: mortality risk in patients with coexisting physical disease. Br J Anaesth 1982; 54: 819-825.

19 Swets J. Measuring the accuracy of diagnostic systems. Science 1988; 240: 1285-93

20. Begg C, McNeill B. Assessment of radiologic tests; control of bias and other design considerations. Radiology 1988; 167: 565-9

21 Moons KGM, van Es G, Michel BC, et al. Redundancy of Single Diagnostic Test Evaluation. Epidemiology 1999; 10: 276-81

22 Jaeschke R, Guyatt G, Sackett D. Users' guides to the medical literature. III. How to use an article about a diagnostic test. A. Are the results of the study valid? JAMA 1994; 271: 389-91

23 Jaeschke R, Guyatt G, Sackett D. Users' guides to the medical literature. III. How to use an article about a diagnostic test. B. What are the results and will thay help me in caring for my patients? JAMA 1994; 271: 703-7

24 Feinstein A. Clinical epidemiology: the architecture of clinical research. Philadelphia: WB Saunders Company, 1985

25 Sackett D, Haynes R, Tugwell P. Clinical epidimiology; a basic science for clinical medicine. Boston: Little, Brown & Co, 1985

26 Stoelting RK, Dierdorf SF. Anesthesia and Co-Existing Disease. New York: Churchill Livingstone, 1993

27 Torscher LC, Shub C, Rettke SR, et al. Risk of patients with severe aortic stenosis undergoing noncardiac surgery. Am J Cardiol 1998; 81: 448-52

28 Harrel FE, Lee KL, Mark DB. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med 1996; 15: 361-87

29 Wasson JH, Sox HX, Neff RK, et al. Clinical prediction rules. Applications and methodological standards. N Engl J Med 1985; 313: 793-9

30 Poldermans D, Boersma E, Bax JJ, et al. The effect of bisoprolol on perioperative mortality and myocardial infarction in high-risk patients undergoing vascular surgery. N Engl J Med 1999; 1789-94

31 Laupacis A, Sekar N, Stiell IG. Clinical prediction rules. A review and suggested methods of methodological standards. JAMA 1997; 277: 488-94

32 McGinn TG, Guyatt GH, Wyer PC, et al. Users' guides to the medical literature: XXII: how to use articles about clinical decision rules. JAMA 2000; 284: 79-84

33 Justice AC, Covinsky KE, Berlin JA. Assessing the generalizability of prognostic information. Ann Intern Med 1999; 130: 515-24

34 Harrell FE, Lee KL, Mark DB. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med 1996; 15: 361-87

35 Knottnerus JA. Prediction rules: statistical reproducibility and clinical similarity. Med Decis Making 1992; 12: 286-7

36 van Klei WA, Moons KGM, Rutten CLG, et al. Effect of outpatient preoperative evaluation on cancellation of surgery and length of hospital stay. Anesth Analg; in press

37 Cassidy J, Marley RA. Preoperative assessment of the ambulatory patient. J Perianesth Nurs 1996; 11: 334-43

38 James PA, Cowan TM, Graham RP, et al. Family physicians' attitudes about and use of clinical practice guidelines. J Fam Pract 1997; 45: 341-7

39 Tunis SR, Hayward RSA, Wilson MC, et al. Internists' attitudes about clinical practice guidelines. Ann Intern Med 1994; 120: 956-63

40 Vaghadia H, Fowler C. Can nurses screen all outpatients? Performance of a nurse based model. Can J Anaesth 1999; 46: 1117-21

41 Venning P, Durie A, Roland M, et al. Randomised controlled trial comparing cost effectiveness of general practitioners and nurse practitioners in primary care. Br Med J 2000; 320: 1048-53

42 Mundinger MO, Kane RL, Lenz ER, et al. Primary care outcomes in patients treated by nurse practitioners or physicians. JAMA 2000; 283: 59-68

43 Kinnersley P, Anderson E, Parry K, et al. Randomised controlled trial of nurse practitioner versus general practitioner care for patients requesting "same day" consultations in primary care. Br Med J 2000; 320: 1043-8

Summary

An important task of the anesthesiologist during preoperative evaluation is to estimate the probability of perioperative morbidity and mortality. Knowledge about the effects of interventions on the complication rate is used to determine the required anesthetic strategy in order to minimize the risk of morbidity and mortality (chapter 1).
The aim of this thesis was to explore to what extent simple patient characteristics obtained from preoperative patient history and physical examination could contribute to the probability estimates of perioperative morbidity and mortality. We also quantified the aspects of implementation of outpatient preoperative evaluation (OPE) clinics.

Chapter 2 describes an overview of the current knowledge on the necessary contents of preoperative patient history, physical examination and additional testing.
The level of detail of preoperative patient history and the value of physical examination to obtain a reasonable estimate of perioperative risk remains unclear. Both for history and physical examination it seems logical to focus on the cardiovascular system, as most preventable causes of perioperative death and major morbidity result from cardiovascular events. Concerning patient history, it is questionable to what extent an extensive history is relevant for anesthesia and long-term prognosis. With respect to physical examination (weight and height, blood pressure, cardiac and pulmonary auscultation and head and neck evaluation), the diagnostic accuracy of cardiac auscultation by anesthesiologists is unknown. Therefore, it seems unreasonable to diagnose valvular heart disease based on cardiac auscultation only. It is also unclear which method should be used to predict tracheal intubation difficulties. The benefits of routine additional testing for all surgical patients, such as laboratory tests, are extremely limited and should therefore not be advocated.

Since it has been reported that OPE increases quality of care and cost-effectiveness, in 1997 the Dutch Health Council issued guidelines on preoperative evaluation. The Dutch Health Council proposed to implement outpatient evaluation clinics and to use a short questionnaire (consisting of only 7 questions) to rapidly assess the patients' health status. In chapter 3 we first aimed to determine the number of OPE clinics in the Netherlands three years after the publication of the Health Council guidelines. A second objective was to deter-

mine the ability of anesthesiologists to assess health status and to propose an anesthesia care plan using the short questionnaire only, compared to 'conventional' extensive health assessment.
We first performed a survey among all 127 Dutch anesthesiologic partnerships, which received a structured questionnaire about preoperative evaluation. It was found that a complete outpatient clinic existed in only 21% of the hospitals. The most frequently reported problem in implementation concerned financing a clinic. In 70% of the Dutch hospitals the anesthesiologist did not evaluate every patient before entering the operating room.
To the second aim, a panel of 10 anesthesiologists evaluated 100 patients, using the short questionnaire and the conventional extensive health evaluation. The ability of the panel to classify patients according to an ASA class based on the short questionnaire was significantly less compared to a classification based on the extensive evaluation. Using the short questionnaire, for none of the cases an anesthesia care plan was proposed.
We concluded that the Dutch Health Council guidelines regarding preoperative evaluation had only limited effects and a short questionnaire to rapidly assess the health status of patients is not useful in practice.

As most preventable causes of death and major morbidity during and after surgery result from cardiovascular events (chapter 2), the physical examination before surgery should focus on this organ system. To detect valvular heart disease (VHD), cardiac auscultation has been recommended. In chapter 4 we aimed to estimate the prevalence of VHD, hypertension and overweight in surgical patients.
Data on 9396 patients visiting the preoperative evaluation clinic of three general hospitals were collected prospectively. In hospital 1 cardiac auscultation was performed routinely and patients in whom a heart murmur was detected were referred to echocardiography. In hospital 2 and 3 auscultation was performed only if considered necessary. The data from hospital 1 were used to estimate the prevalence of heart murmurs and VHD. These numbers were extrapolated to obtain an estimate of the expected number of heart murmurs and VHD in hospital 2 and 3 (adjusted for age and sex). Using the data from all hospitals, the prevalence of hypertension and obesity was determined. In hospital 1, the prevalence of heart murmurs was 4% (N=106). Of the 17 patients (0.6%) with aortic valvular stenosis, 4 had a hemodynamically impor-

tant stenosis. In 26% of the patients with a murmur echocardiography did not reveal VHD. Extrapolating gender and age specific prevalence rates of heart murmurs from hospital 1 to hospital 2 and 3 yielded an expected number of murmurs of 179 (observed: 11) and 56 (observed: 12), respectively. Overall, 27% of all patients had overweight and 12% had hypertension.
We concluded that cardiac auscultation before surgery seems a reasonable screening tool to select patients who are at high risk for VHD. Subsequent echocardiography in these selected patients is necessary to establish or exclude a definite diagnosis of VHD.

In chapter 2 we described that the benefits from routine additional testing for all surgical patients are extremely limited. For example, many patients in whom a 'type and screen' procedure is performed before surgery are not transfused after all. The question raised whether we could predict which patients will and which will not be transfused, to reduce the number of unnecessary type and screen investigations.
To this aim, we investigated 1482 consecutive patients undergoing surgery with intermediate risk for transfusion (chapter 5.1). Multivariable logistic regression modeling and the area under the Receiver Operating Characteristic curve (ROC area) were used to quantify how well age, gender, applied surgery, emergency or elective surgery and anesthetic technique predicted the occurrence of perioperative transfusion and whether the preoperative hemoglobin concentration had added value to this. We found that gender, age $\geq$ 70, and type of surgery were independent predictors of transfusion, with a ROC area of 0.75 (95% CI: 0.72-0.79). Validating this model in the form of an easy applicable prediction rule in a second patient population from the same hospital yielded a ROC area of 0.70 (95% CI: 0.63-0.77). In absolute numbers, with this rule type and screen could correctly be withheld in 35% of these patients. In the remaining 65% of the patients, a further reduction in unnecessary type and screen investigations of 15% could be achieved using the preoperative hemoglobin concentration.
To evaluate the robustness or generalizability of this prediction rule, it was retrospectively applied to 1282 consecutive patients from another hospital ('external validation set') who underwent identical surgical procedures (chapter 5.2). The ROC area of the prediction rule in this new patient population was 0.78 (95% CI: 0.73-0.82), which was quite similar to the ROC area found in

the derivation study (0.75; 95% CI: 0.72-0.79, chapter 5.1). In this new population in total 35% of the type and screen procedures could be omitted (derivation study: 50%), with 13% missed transfused patients (derivation study: 20%). After comparing the results of this validation study with that of the derivation study, the prediction rule was defined as robust and may work in other clinics as well.

In most hospitals only the type of surgical procedure is used to regulate the indications for preoperative erythropoietin administration and blood conservation strategies (in order to reduce the rate of homologous blood transfusion). Other predictors for the occurrence of perioperative blood transfusion such as age and gender, emergency surgery and hemoglobin concentration are generally not taken into account. More accurate estimates of the transfusion risk in individual patients could help to restrict erythropoietin administration or conservation procedures to patients with a high-risk profile only. In order to label candidates for erythropoietin administration or blood conservation, we quantified over a wide range of surgical procedures to what extent the estimation improves if simple patient characteristics are taken into account additionally to type of surgery. (chapter 6).
Retrospective data on 24509 consecutive adult surgical patients were used to derive and validate three models to predict perioperative homologous transfusion. The first model was a univariable model with type of surgery as the only predictor. The second and third were a full multivariable logistic regression model (including age, gender, emergency, 13 groups of type of surgery, 5 classes of preoperative hemoglobin concentration and autologous blood donation before surgery) and a simplified model (including 3 groups of type of surgery and 3 classes of hemoglobin concentration). After deriving the models from the derivation set, the performance of the models was tested in two validation sets, i.e. in similar patients operated in the same general hospital (internal validation) and in those operated in a university hospital (external validation). The areas under the ROC curve were compared to that found in the derivation set. The ROC area of the model including surgery only was 0.92 and of the full and simplified multivariable model 0.95 and 0.94, respectively. In the external validation set the ROC area of the simplified model was 0.85. Patients having a preoperative hemoglobin level of < 13 g dL^{-1} undergoing major invasive surgery had the highest risk of transfusion.

It was concluded that a simple algorithm using type of surgery and hemoglobin level is effective to identify patients at high risk for perioperative homologous blood transfusion and may improve the accuracy of labeling eligible candidates for erythropoietin administration or blood conservation.

Since it has been reported that OPE increases quality of care and cost-effectiveness, we evaluated the effects of OPE in a university hospital (chapter 7).
To this aim, we conducted an observational study in which various outcomes before and after the introduction of an OPE clinic were compared. The study population comprised all elective adult inpatients operated between 1 January 1997 and 31 December 1999 (N=21553). The main outcome measures were the rate of surgical cases canceled for medical reasons (which were expected to decrease), the rate of same day admissions (which were expected to increase) and length of hospital stay (which was also expected to decrease). After introduction of OPE, the rate of cancellations for medical reasons decreased from 2.0% to 0.9% (adjusted OR 0.7, 95% CI: 0.5-0.9). The rate of same day admissions increased from 5.3% before to 7.7% after OPE introduction (adjusted OR 1.2, 95% CI: 1.01-1.39). One year after completion of the implementation process the rate of same day admissions was 20%. The total hospital length of stay (in days) significantly decreased by a factor of 0.92 (0.90-0.94), which was partly the result of a reduction in preoperative admission time.
We concluded that the use of OPE for potential inpatients leads to a significant reduction of canceled cases and of length of admission, although the effects were smaller than anticipated. Further increase of these benefits from OPE requires changes in institutional policy, such as forcing surgical departments to increase their number of same day admissions.

In preoperative risk management diagnostic information is used to estimate the probability of outcomes and to decide on the anesthetic strategy in a particular patient (chapter 8). The aim of this thesis was explore to what extent simple patient characteristics, particularly obtained from preoperative patient history and physical examination, could contribute to preoperative risk management. Furthermore, the implementation of OPE clinics in the Netherlands as well as the effects of OPE in a particular hospital were quantified.
Preferably, during OPE, 'healthy' patients are easily distinguished from the

remainder using a minimal but optimal set of diagnostic tests. To determine the optimal set of diagnostic tests to appropriately detect existing co-morbidity would require a diagnostic study. In such a study the contribution of each diagnostic test obtained from patient history, physical examination and additional testing is related to the diagnostic outcome, i.e. 'presence or absence of significant co-morbidity'. To demonstrate how diagnostic research might be used in the clinical setting of an OPE clinic, we studied the diagnostic value of cardiac auscultation to detect VHD (chapter 4). Diagnostic research will decrease redundant information, but requires the a priori definition of what constitutes significant co-morbidity. Therefore, the quality circle can only be closed when perioperative and long-term complications are registered.

The anesthesiologist should also have evidence-based knowledge about the probability of perioperative complications and to what extent the anesthetic strategy may alter the complication rate. Prognostic prediction studies aim to estimate the probability of future occurrence of a particular outcome in a particular patient and are also suitable to estimate to what extent the individual risk of a patient can be modified using pre-emptive strategies, such as administering erythropoietin before surgery (chapter 6 and 8). Before a prediction model can be implemented in practice, its generalizability (the application to patients from a different but related population) should be estimated. To obtain an estimate of the generalizability, we applied both the prediction model to reduce type and screen procedures (chapter 5.2) and the model to label patients for blood conservation strategies (chapter 6) to a patient population from another hospital. Both models stayed robust and we concluded that they can be implemented in practice.

In this context, there will be an important role for information technology: a complication registration system could provide the necessary data for continuous prognostic prediction research, which in turn will provide risk stratification systems for (long-term) morbidity and mortality to be built-in in electronic patient record software used at the OPE clinic.

There are several potential benefits of OPE. For example, OPE allows for comprehensive assessment and optimization of the patient's health condition without delaying surgery. However, to extract the maximal benefits from OPE the incentives for all those concerned in preoperative patient care, such as anesthesiologists and surgical specialists, must be clear to change existing practice patterns, such as routine admission of patients to the ward the day before sur-

gery (chapter 3 and 7). Because widespread implementation of OPE will require an increase in the number of anesthesiologists, the questions arises whether a specially trained anesthetic nurse can screen patients adequately. The partial substitution of the anesthesiologist by a specially trained nurse in a 'mixed-provider model OPE clinic' could have several benefits and might increase the quality and cost-effectiveness of OPE (chapter 8).

Samenvatting

Tijdens het preoperatief onderzoek van patiënten die zullen worden geopereerd, schat de anesthesioloog de kans in op complicaties rondom de operatie. Complicaties kunnen leiden tot ziekte en sterfte, ofwel tot morbiditeit en mortaliteit. De anesthesioloog stelt met behulp van zijn/haar kennis van de effecten van een eventuele behandeling een anesthesieplan voor de operatie op. Met dit anesthesieplan wordt beoogd de kans op morbiditeit en mortaliteit rond de operatie te minimaliseren (hoofdstuk 1).
Het doel van dit proefschrift was vast te stellen in welke mate eenvoudige patiëntgegevens die kunnen worden verkregen uit de anamnese en het lichamelijk onderzoek (zoals leeftijd en soort operatie), kunnen bijdragen aan de kansschattingen van morbiditeit en mortaliteit. Tevens kwantificeerden wij de implementatieaspecten van een polikliniek voor preoperatief onderzoek (PREOP polikliniek).

In hoofdstuk 2 wordt een overzicht gegeven van de huidige kennis ten aanzien van de inhoud van de preoperatieve anamnese, het lichamelijk onderzoek en het aanvullend onderzoek (zoals een ECG).
De gedetailleerdheid van de preoperatieve anamnese en de waarde van het lichamelijk onderzoek voor een redelijke schatting van het risico op complicaties blijft onduidelijk. Anamnese en lichamelijk onderzoek dienen gericht te zijn op de conditie van hart en bloedvaten, aangezien de meeste oorzaken van morbiditeit en mortaliteit rondom de operatie cardiovasculair van aard zijn. Het is de vraag in hoeverre een uitvoerige anamnese relevant is voor de anesthesie en voor de uitkomst op lange termijn. Betreffende het lichamelijk onderzoek (gewicht en lengte, bloeddruk, auscultatie van hart en longen en evaluatie van het hoofd-hals gebied) kan worden opgemerkt dat de diagnostische waarde van auscultatie door anesthesiologen onbekend is. Het lijkt niet redelijk om hartklepafwijkingen alleen te diagnosticeren met behulp van auscultatie. Tevens is het onduidelijk welke methode bruikbaar is om problemen bij endotracheale intubatie te voorzien. De voordelen van routinematig aanvullend onderzoek (bijvoorbeeld laboratoriumonderzoek) bij alle patiënten die zullen worden geopereerd, zijn zeer gering. Dit routinematig aanvullend onderzoek dient dan ook te worden afgeraden.

De Nederlandse gezondheidsraad bracht in 1997 een rapport uit met richtlijnen aangaande het preoperatief onderzoek. Verschillende onderzoekers rappor-

teerden namelijk dat een poliklinisch uitgevoerd preoperatief onderzoek enkele weken voor de geplande operatie de kwaliteit van zorg en de kosteneffectiviteit zou verhogen. De gezondheidsraad stelde daarom voor PREOP poliklinieken te implementeren. Daarnaast werd een korte vragenlijst (van 7 vragen) voorgesteld waarmee de gezondheid van patiënten snel kan worden beoordeeld. In hoofdstuk 3 beoogden wij in de eerste plaats het aantal PREOP poliklinieken in Nederland vast te stellen dat drie jaar na het verschijnen van de gezondheidsraadrichtlijnen was geïmplementeerd. Een tweede doel was vast te stellen in hoeverre anesthesiologen in staat zijn de gezondheid van patiënten te beoordelen en een anesthesieplan op te stellen als zij alleen gebruik maken van de voorgestelde korte vragenlijst, vergeleken met de gebruikelijke uitgebreide gezondheidsbeoordeling.
Allereerst ontvingen de 127 vakgroepen anesthesiologie in Nederland een gestructureerde vragenlijst over het preoperatief onderzoek. Een PREOP polikliniek waar alle operatiepatiënten preoperatief worden beoordeeld, bestond in slechts 21% van de ziekenhuizen. Het meest genoemde probleem bij de implementatie betrof de financiering. In 70% van de Nederlandse ziekenhuizen wordt niet iedere patiënt door de anesthesioloog beoordeeld voordat de patiënt in de operatiekamer aankomt.
In de tweede plaats beoordeelde een panel van 10 anesthesiologen 100 te opereren patiënten. Zij gebruikten eerst de gegevens die de korte vragenlijst opleverde en enkele maanden daarna de gegevens van de gebruikelijke uitgebreide gezondheidsbeoordeling. Het panel was significant minder vaak in staat de patiënten in te delen in een ASA klasse als de gegevens van de korte vragenlijst werden gebruikt. In geen enkel geval kon met behulp van deze gegevens een anesthesieplan worden opgesteld.
Wij concludeerden dat de richtlijnen van de gezondheidsraad betreffende het poliklinisch preoperatief onderzoek slechts geringe effecten hebben en dat de korte vragenlijst voor een snelle gezondheidsbeoordeling in de praktijk niet bruikbaar is.

De meeste te voorkomen oorzaken van mortaliteit en ernstige morbiditeit tijdens en na de operatie zijn cardiovasculair van aard (hoofdstuk 2). Daarom dient het preoperatief lichamelijk onderzoek zich te richten op de conditie van hart en bloedvaten. Het wordt aanbevolen aandoeningen aan de hartkleppen ('kleplijden') te diagnosticeren door middel van auscultatie. In hoofdstuk 4

beoogden wij de prevalentie van kleplijden, hypertensie en overgewicht bij operatiepatiënten te schatten.
De gegevens van 9396 patiënten die de PREOP polikliniek van drie algemene ziekenhuizen bezochten werden prospectief verzameld. In ziekenhuis 1 werd routinematig bij alle patiënten het hart geausculteerd. Patiënten bij wie een hartgeruis werd gehoord werden verwezen voor een echocardiogram. In ziekenhuis 2 en 3 werd alleen bij patiënten bij wie dit noodzakelijk werd geacht het hart geausculteerd. De gegevens van ziekenhuis 1 werden gebruikt om de prevalentie van hartgeruisen en kleplijden te schatten. Vervolgens werden deze prevalenties geëxtrapoleerd om een schatting te verkrijgen van het verwachte aantal hartgeruisen en hartklepafwijkingen in de ziekenhuizen 2 en 3 (deze schattingen werden gecorrigeerd voor leeftijd en geslacht). De gegevens van alle drie de ziekenhuizen werden gebruikt om de prevalentie van hypertensie en overgewicht vast te stellen. In ziekenhuis 1 was de prevalentie van hartgeruisen 4% (N=106). Van de 17 patiënten (0.6%) met een aortaklepstenose, hadden vier patiënten een stenose met hemodynamische consequenties. Bij 26% van de patiënten met een hartgeruis kon met echocardiografie geen kleplijden worden vastgesteld. Na extrapolatie van de geslacht- en leeftijdspecifieke prevalenties van hartgeruisen uit ziekenhuis 1, bedroeg het verwachte aantal hartgeruisen in ziekenhuis 2 en 3 respectievelijk 179 (gediagnosticeerd: 11) en 56 (gediagnosticeerd: 12). De prevalentie van hypertensie en overgewicht in de drie ziekenhuizen samen was respectievelijk 12% en 27%.
Wij concludeerden dat preoperatieve auscultatie van het hart een redelijke methode is om patiënten te selecteren die een hoog risico hebben op hartkleplijden. Aanvullend echocardiografisch onderzoek in de patiënten die op deze wijze zijn geselecteerd is noodzakelijk om kleplijden definitief te diagnosticeren dan wel uit te sluiten.

In hoofdstuk 2 rapporteerden wij dat de voordelen van routinematig aanvullend onderzoek bij alle operatiepatiënten zeer gering zijn. Veel patiënten bij wie voor de operatie de bloedgroep wordt bepaald door middel van 'type and screen', blijken bijvoorbeeld uiteindelijk geen bloedtransfusie te behoeven. De vraag was dan ook of het mogelijk is om te voorspellen welke patiënten wel en welke geen homologe bloedtransfusie zullen behoeven, teneinde het aantal type and screen bepalingen te reduceren.

Om deze vraag te beantwoorden onderzochten wij 1482 opeenvolgende patiënten die ingrepen ondergingen met een intermediair risico op transfusie (hoofdstuk 5.1). Multivariabele logistische regressie analyse en de oppervlakte onder de ROC (Receiver Operating Characteristic) curve werden gebruikt om vast te stellen in hoeverre de leeftijd, het geslacht, het type operatie, een spoedoperatie en de anesthesietechniek het optreden van transfusie tijdens of na de operatie voorspelden. Vervolgens werd geëvalueerd of de preoperatieve hemoglobine concentratie toegevoegde waarde had in deze voorspelling. Wij vonden dat het geslacht, een leeftijd van 70 jaar of ouder en het type operatie onafhankelijke voorspellers waren van transfusie, met een oppervlakte onder de ROC curve van 0,75 (95% BI: 0,72-0,79). Het model met deze variabelen is vervolgens gevalideerd in de vorm van een eenvoudig toe te passen 'voorspelregel' in een tweede patiëntengroep uit hetzelfde ziekenhuis ('interne validatie'). De oppervlakte onder de ROC curve in deze populatie bedroeg 0,70 (95% BI: 0,63-0,77). In absolute getallen uitgedrukt kon in 35% van de patiënten een type and screen bepaling achterwege blijven. In de overige 65% van de patiënten kon een verdere reductie van het aantal type and screen bepalingen met 15% worden bereikt, indien de preoperatieve hemoglobine concentratie als additionele voorspeller werd gebruikt.
Om de generaliseerbaarheid van de voorspelregel te evalueren, werd zij retrospectief toegepast op 1282 patiënten uit een ander ziekenhuis ('externe validatie'). Deze patiënten hadden dezelfde typen operaties ondergaan (hoofdstuk 5.2). De oppervlakte onder de ROC curve van de voorspelregel in deze nieuwe patiëntengroep was 0,78 (95% BI: 0,73-0,82) en was daarmee vergelijkbaar met de oppervlakte onder de curve in de oorspronkelijke populatie (hoofdstuk 5.1 de 'derivatie set': 0,75; 95% BI: 0,72-0,79). In deze nieuwe patiëntenpopulatie kon in totaal 35% van het aantal type and screen bepalingen worden voorkomen (derivatieset: 50%), waarbij 13% van de patiënten die een transfusie kregen werd gemist (derivatie set: 20%). Wij concludeerden dat de voorspelregel toepasbaar is in andere klinieken.

In de meeste ziekenhuizen wordt alleen het type operatie gebruikt om de indicatie te stellen voor het preoperatief toedienen van erythropoietine of het doneren van autoloog bloed (teneinde het aantal homologe bloedtransfusies te beperken). Met andere factoren die de noodzaak van een perioperatieve bloedtransfusie mede bepalen, zoals leeftijd, geslacht, de urgentie van de operatie en

de preoperatieve hemoglobine concentratie, wordt in het algemeen geen rekening gehouden. Een betere schatting van het individuele risico op een homologe bloedtransfusie zou kunnen bijdragen tot een restrictiever gebruik van erythropoietine of autologe donatie; alleen patiënten met een hoog risico zouden dan kunnen worden behandeld. Wij evalueerden voor alle typen operaties in hoeverre de schatting van het risico op een transfusie verbeterde indien naast het type operatie eveneens eenvoudige patiëntgegevens worden gebruikt om het risico op transfusie te voorspellen (hoofdstuk 6). Hierdoor konden patiënten die potentieel voordeel zouden hebben bij het toedienen van erythropoietine of autologe bloeddonatie worden geïdentificeerd.
Er werden met behulp van retrospectieve gegevens van 24509 volwassen patiënten drie modellen ontwikkeld om homologe bloeddonatie te voorspellen. Deze modellen werden vervolgens gevalideerd. Het eerste model was een univariabel model met alleen het type operatie als voorspeller. Het tweede model was een compleet multivariabel logistisch regressiemodel, met de leeftijd, het geslacht, de urgentie, het type operatie in 13 groepen, de preoperatieve hemoglobine concentratie in 5 groepen en de preoperatieve autologe bloeddonatie als voorspellers. Het derde model tenslotte was een vereenvoudigd multivariabel logistisch regressiemodel, met 3 groepen voor het type operatie en 3 groepen voor de hemoglobine concentratie. Nadat de modellen waren ontwikkeld in de derivatieset is de toepasbaarheid getest bij vergelijkbare operatiepatiënten uit hetzelfde ziekenhuis (interne validatie) en uit een ander ziekenhuis (externe validatie). De oppervlaktes onder de ROC curve van de interne validatieset werden vergeleken met die van de derivatieset. De oppervlakte onder de ROC curve van het eerste model (alleen het type chirurgie) was 0,92. Die van het complete en het vereenvoudigde multivariabele model bedroeg respectievelijk 0,95 en 0,94. In de externe validateset was de oppervlakte onder de ROC curve van het vereenvoudigde multivariabele model 0,85. Patiënten met een preoperatieve hemoglobineconcentratie van < 8 mmol / L die grote chirurgische ingrepen ondergaan, hebben het hoogste risico op transfusie.
Een eenvoudig algoritme dat gebruik maakt van het type operatie en de preoperatieve hemoglobineconcentratie is dus effectief om patiënten te selecteren die een hoog risico lopen om rond de operatie een homologe bloedtransfusie te ondergaan. Hiermee zouden patiënten die potentieel voordeel hebben bij het toedienen van erythropoietine of autologe bloeddonatie kunnen worden geïdentificeerd.

In hoofdstuk 7 evalueerden wij de implementatieaspecten van een polikliniek voor preoperatief onderzoek (PREOP polikliniek), aangezien een poliklinisch uitgevoerd preoperatief onderzoek de kwaliteit van zorg en de kosteneffectiviteit zou verbeteren.
Voor dit doel werd een observationeel onderzoek uitgevoerd, waarin verschillende uitkomstmaten voor en na de implementatie van een PREOP polikliniek werden vergeleken. De onderzoekspopulatie bestond uit alle volwassen operatiepatiënten (N=21553) die klinisch een geplande ingreep ondergingen tussen 1 januari 1997 en 31 december 1999. De belangrijkste uitkomstmaten waren het percentage op het laatste moment om medische redenen uitgestelde operaties (waarvan werd verwacht dat dit percentage zou dalen), het aantal operaties na een nuchtere opname (waarvan werd verwacht dat dit aantal zou stijgen) en de opnameduur (waarvan werd verwacht dat deze zou dalen). Na de implementatie van de PREOP polikliniek daalde het percentage op het laatste moment om medische redenen uitgestelde operaties van 2,0% naar 0,9% (gecorrigeerde OR 0,7; 95% BI: 0,5-0,9). Het percentage nuchtere opnames nam toe van 5,3% voor, tot 7,7% na de implementatie van de PREOP polikliniek (gecorrigeerde OR 1,2; 95% BI: 1,01-1,39). Een jaar na de implementatie bedroeg het percentage nuchtere opnames ruim 20%. De totale opnameduur daalde significant met een factor 0,92 (0,90-0,94). Dit laatste was deels het gevolg van een daling in de preoperatieve opnameduur.
Wij concludeerden dat een PREOP polikliniek voor patiënten die klinisch een operatie zullen ondergaan leidt tot een significante daling in het aantal op het laatste moment om medische redenen uitgestelde operaties. Tevens daalt de opnameduur. De effecten waren echter kleiner dan verwacht. Een maximale benutting van de voordelen van een PREOP polikliniek vereist beleidsveranderingen. Chirurgische afdelingen zouden bijvoorbeeld kunnen worden gedwongen om meer patiënten nuchter op te nemen op de dag van de operatie.

Tijdens het preoperatief onderzoek van patiënten die zullen worden geopereerd, schat de anesthesioloog de kans in op complicaties rondom de operatie en wordt op basis daarvan het anesthesiebeleid bepaald. Bij dit preoperatief risico management wordt gebruik gemaakt van diagnostische informatie (hoofdstuk 8). Het doel van dit proefschrift was vast te stellen in hoeverre eenvoudige patiëntgegevens, in het bijzonder de gegevens die worden verkregen uit de anamnese en het lichamelijk onderzoek, een bijdrage zouden kunnen

leveren aan het preoperatief risicomanagement. Tevens werd de implementatie van PREOP poliklinieken in Nederland gekwantificeerd, alsmede de effecten van een dergelijke polikliniek in een academisch ziekenhuis.
Tijdens het preoperatief onderzoek worden 'gezonde' patiënten bij voorkeur op eenvoudige wijze (dat wil zeggen met een minimaal aantal diagnostische tests) onderscheiden van de overige patiënten. Om het optimale aantal en soort diagnostische tests te bepalen die relevante nevenaandoeningen accuraat vast stellen, is een empirisch diagnostisch onderzoek noodzakelijk. In een dergelijk onderzoek wordt de bijdrage van iedere afzonderlijke diagnostische test (verkregen uit anamnese, lichamelijk onderzoek of aanvullend onderzoek) gerelateerd aan de diagnostische uitkomst, dat wil zeggen: aan- of afwezigheid van een relevante nevenaandoening. Wij onderzochten bijvoorbeeld de diagnostische waarde van het ausculteren van harttonen voor het diagnosticeren van hartklepafwijkingen, om te demonstreren hoe diagnostisch onderzoek in de setting van een PREOP polikliniek kan worden gebruikt (hoofdstuk 4). Diagnostisch onderzoek zal de hoeveelheid overbodige informatie verkleinen, maar vereist wel de a-priori definitie van voor het anesthesiebeleid relevante nevenaandoeningen. De kwaliteitscirkel kan daarom alleen worden gesloten wanneer (lange termijn) complicaties worden geregistreerd.
De anesthesioloog dient eveneens te beschikken over evidence-based kennis over de kans op complicaties en in hoeverre het anesthesiebeleid deze kans op complicaties kan veranderen. Prognostische predictie onderzoeken hebben als doel een kansschatting te maken van het optreden van complicaties bij een individuele patiënt. Dergelijke onderzoeken zijn tevens geschikt om te schatten in hoeverre het individuele risico van een patiënt kan worden verkleind door het nemen van preventieve maatregelen, zoals het gebruik van erythropoietine bij patiënten met een hoog risico op een bloedtransfusie (hoofdstuk 6 en 8). Voordat een voorspellend model echter in de praktijk kan worden geïmplementeerd, dient eerst de generaliseerbaarheid van het model te worden bepaald (het toepassen van het model in een andere, maar vergelijkbare populatie). Teneinde een schatting te verkrijgen van de generaliseerbaarheid van de predictiemodellen om het aantal type and screen bepalingen te verlagen (hoofdstuk 5.1) en om patiënten voor het toedienen van erythropoietine te selecteren (hoofdstuk 6), zijn beide modellen toegepast op een patiëntenpopulatie uit een ander ziekenhuis (hoofdstuk 5.2 en 6). Wij concludeerden dat beide modellen generaliseerbaar zijn en in de praktijk kunnen worden geïmplementeerd.

Binnen deze context zal een belangrijke rol zijn weggelegd voor de informatietechnologie: een complicatie registratiesysteem zou de noodzakelijke gegevens kunnen opleveren voor prognostisch predictie onderzoek. Dit onderzoek zal op haar beurt voorzien in risicostratificatie systemen voor (lange termijn) morbiditeit en mortaliteit, die kunnen worden gebruikt in de software van het elektronisch patiënten dossier op een PREOP polikliniek.
Er zijn verschillende voordelen verbonden aan een poliklinisch preoperatief onderzoek, zoals de mogelijkheid van een uitgebreide preoperatieve gezondheidsbeoordeling en het optimaliseren van de conditie van de patiënt, zonder dat de operatie behoeft te worden uitgesteld. Echter, om de voordelen van een PREOP polikliniek maximaal te benutten, zullen deze voordelen voor alle betrokkenen (zoals anesthesiologen en snijdend specialisten) duidelijk moeten zijn. Alleen dan kunnen bestaande gewoonten, zoals het routinematig opnemen van patiënten een dag voor de operatie, veranderen (hoofdstuk 3 en 7). Grootschalige implementatie van PREOP poliklinieken zal een toename in het aantal anesthesiologen vereisen. Dit doet de vraag rijzen of een goed getrainde anesthesie verpleegkundige eveneens in staat is de gezondheid van patiënten adequaat te beoordelen. Deze gedeeltelijke vervanging van de anesthesioloog door een verpleegkundige in een 'mixed-provider model PREOP polikliniek' kan verschillende voordelen hebben en zou de kwaliteit en kosteneffectiviteit van een PREOP polikliniek kunnen verhogen.

Dankwoord

Bijna drie jaar geleden begon ik aan het werk dat zou leiden tot dit 'boekje'. Ik had niet verwacht dat dit proefschrift nu al zou zijn afgerond. Dat was niet gelukt zonder een aantal mensen om mij heen, die ik graag wil bedanken.

Professor Hans Knape, ik herinner me nog dat je eind 1998 belde om te zeggen dat ik was aangenomen als AGIKO. Je motivatie dat ik 'geschikt' was, was in mijn ogen verbluffend simpel: ik was jong getrouwd en kon dus verantwoordelijkheid dragen; ik had in deeltijd de co-schappen gevolgd in verband met de zorg voor ons oudste kind en kon dus een oplossing vinden voor lastige problemen. Ik had altijd gedacht dat mijn 'afwijkend gedrag' in mijn nadeel zou werken en was dan ook erg verheugd dat mijn aanstaande opleider hier anders tegen aankeek. Het leek mij dat ik bij zo'n promotor binnen zekere grenzen mijn eigen weg kon gaan. Dat is juist gebleken en daar wil ik je dan ook hartelijk voor bedanken: dit 'boekje' is inderdaad *mijn* boekje. Daarnaast wil ik je bedanken voor de waarderende wijze waarop je naar mijn wetenschappelijke producten keek en er zo nodig kritiek op leverde. Ik heb dat als zeer stimulerend ervaren.
Professor Rick Grobbee, ik heb bewondering voor de snelheid (minuten) waarmee je een vaag onderzoeksidee kunt omzetten in het raamwerk van een uitvoerbaar onderzoek. Zonder deze denkkracht waren een aantal hoofdstukken waarschijnlijk nooit geschreven, omdat ze het stadium van idee niet te boven zouden zijn gekomen. Ik heb er van geleerd het vooral simpel te houden, 'dan is het al moeilijk genoeg'. Alle manuscripten die ik je stuurde voorzag je van een algemene kritiek: 'probeer je data te ontstijgen' en 'vraag je af welke boodschap je wilt brengen'. Deze stimulans om voortdurend rekening te houden met de potentiële lezer heeft mij geholpen bij het schrijven en ik hoop daar nog lang profijt van te hebben.
Mijn dagelijkse begeleiding gedurende het onderzoek kreeg ik van doctor Carl Moons. Carl, je bent een enthousiasteling die in staat is leven te blazen in gortdroge stof, waardoor ik heb ontdekt dat epidemiologie ook interessant kan zijn. Je bent erg goed in het gebruik van de rode pen: ik verbaas me iedere keer weer hoeveel tijd je stopt in het gedetailleerd lezen van een manuscript. Toch had je de meeste stukken snel gelezen en van goede opmerkingen voorzien, wat er toe heeft bijgedragen dat ik dit proefschrift zo spoedig heb kunnen afronden.

In Zwolle ben ik bij mijn bezoeken aan doctor Charles Rutten overstelpt met ideeën over preoperatief onderzoek en hoe het misschien nog beter zou kunnen. Charles, je bent een inspirerende persoon en je was altijd bereikbaar voor overleg. Na een 'dagje Zwolle' had ik weer voldoende ideeën voor nóg een proefschrift. Je bent zeer geïnteresseerd in de persoon achter de onderzoeker: dat waardeer ik bijzonder. Ik hoop dat onze samenwerking met betrekking tot het preoperatief onderzoek niet eindigt bij het tot stand komen van dit proefschrift.

I am very proud that doctor Michael Roizen from Chicago (USA) participated in the assessment of the scientific quality of this thesis. You are one of the most cited authors in the field of research in preoperative evaluation.
Professor Cor Kalkman, hoewel je pas in een later stadium bij mijn onderzoek bent betrokken, heb ik bij het schrijven veel aan je gehad. Op het wetenschappelijk vlak ligt jouw lat hoog: je bent zeer kritisch en het is niet snel 'goed'. Mede daardoor heb je veel energie gestopt in het meeschrijven aan een aantal hoofdstukken, waar ik veel van heb geleerd. Je had steeds weer de rust en het geduld om er samen voor te gaan zitten. Daar heb ik bewondering voor.
Zonder de 'hapklare' data van doctor Aart van Rheineck Leyssius was het tweede deel van dit proefschrift (hoofdstuk 5 en 6) nooit tot stand gekomen. Aart, ik wil je hartelijk bedanken voor het belangeloos beschikbaar stellen van de prachtige database met de peri-operatieve transfusiegegevens van het Twenteborg ziekenhuis. Er zijn drie mooie publicaties uit voortgekomen.
Doctor Pim Hennis wil ik bedanken voor zijn grote enthousiasme en hartelijke belangstelling. Ik heb bewondering voor de manier waarop je in het leven staat en in staat bent anderen te enthousiasmeren en te coachen. Ik heb daar veel van geleerd en hoop nog veel van je te leren.
Anke Schuurhuis heeft een groot aandeel gehad in het opzetten van de polikliniek voor PreOperatieve Screening (POS poli) in het UMCU. Zonder deze polikliniek was een deel van dit onderzoek niet mogelijk geweest, sterker nog: er zou waarschijnlijk in het geheel geen onderzoeksproject zijn geweest, waardoor dit proefschrift niet zou zijn geschreven. Anke, bedankt.
Ik wil de medewerkers van de POS poli bedanken voor hun inzet bij het onderzoek zoals dat beschreven staat in hoofdstuk 3 en voor hun belangstelling voor al mijn activiteiten op het vlak van preoperatief onderzoek. Albert, Anneke, Annelize, Chantal, Eelkje, Edwin, Hester, Jeroen, Lia, Monique,

Netty, Rianne en Rob, ik hoop dat ons nieuwe onderzoek (de OPEN study) gaat brengen wat een ieder er van verwacht, maar in ieder geval de voldoening van het gezamenlijk uitvoeren van een onderzoek.
Marianne, Nella en Willie wil ik bedanken voor het afstemmen van de agenda van de hooggeleerden als ik weer eens langs wilde komen en voor alle andere 'kleine' dingen waarmee ik jullie kon lastigvallen.

Olaf, we hebben een groot deel van onze onderzoekstijd tegenover elkaar doorgebracht: achter het bureau, in de trein naar Rotterdam of in De Brink, maar ook wel figuurlijk: 'waarom pak je dit zús aan en niet zó?' Ik wil je bij voorbaat bedanken voor de morele ondersteuning bij de verdediging van dit boekwerk: sta je ook eens áchter me.

Gedurende het laatste half jaar dat ik fulltime aan onderzoek heb besteed, bracht ik mijn dagen door in eenzame opsluiting: ik had geen kamergenoten meer omdat na Cecile en Henk ook Michiel vertrok. Ik wil jullie hartelijk bedanken voor jullie gezelligheid, belangstelling en behulpzaamheid. Jullie zullen het ongetwijfeld ook naar je zin hebben op je nieuwe werkplek.
Gelukkig waren er dat laatste half jaar nog wel enkele ganggenoten aanwezig. Ad, Ben, Ed, Luuk, Marjan en Peter wil ik bedanken voor hun gezelligheid en hun hulpvaardigheid bij diverse probleempjes. Ben, ik zal je directe verslaglegging van zoekgeraakte en gelukkig ook weer teruggevonden miljoenen wel missen.

Er zijn diverse anesthesiologen en maatschappen anesthesiologie wiens inzet ik speciaal wil noemen. De collegae Bouman, Dijkhuis, Doesburg, Gerritsen, Kerkkamp, van der Poel, Siepert, Smelt, Visser, en Wille wil ik bedanken voor hun werk als panellid (hoofdstuk 3). De maatschappen anesthesiologie van de Isala klinieken (locatie Weezenlanden) in Zwolle, het Medisch Centrum Alkmaar en het Gemini ziekenhuis in Den Helder wil ik bedanken voor het documenteren van de gegevens van het preoperatief lichamelijk onderzoek (hoofdstuk 4).

Mijn ouders wil ik bedanken voor wat zij mij hebben meegeven: ik ben er mee geworden wie ik ben (een eigenzinnige einzelgänger: 'als-ie iets in z'n kop heeft, krijg je het er niet meer uit'). Mijn moeder kan het verschijnen van dit

boekje helaas niet meer meemaken. Ze zou trots geweest zijn.
Herman en Joke van Kleffens verdienen speciale aandacht: jullie onvoorwaardelijke steun (op verschillende manieren) en jullie oprechte belangstelling heb ik al eerder verwoord, maar wil ik op deze plaats toch nog eens benadrukken.

Céline, we zijn al meer dan 10 jaar vriendjes en (studie)maatjes en ik heb in die tijd onder andere van je geleerd om met een zekere zelfspot naar het dagelijkse leven te kijken. Daar heb ik veel aan. Om te voorkomen dat ik in trivialiteiten verval, ga ik je nergens voor bedanken; ik hou van je.

Houten, februari 2002

Publications and Abstracts

Wilton A van Klei, Charles LG Rutten, Karel GM Moons, Wilco E van Genderen, Johannes TA Knape, Diederick E Grobbee, Cornelis J Kalkman. Preoperative auscultation and detection of valvular heart disease.
submitted

WA van Klei, KGM Moons, CLG Rutten, PJ Hennis, JTA Knape, CJ Kalkman, DE Grobbee. The role of history and physical examination in preoperative evaluation: Much 'opinion' and little 'evidence'.
submitted

WA van Klei, AT Rheineck Leyssius, DE Grobbee, KGM Moons. Identifying patients for blood conservation strategies.
Br J Surg; accepted for publication

WA van Klei, KGM Moons, B Lo, JTA Knape, DE Grobbee, CLG Rutten. Evaluation of Dutch Health Council guidelines on preoperative evaluation.
submitted

WA van Klei, KGM Moons, AT Rheineck Leyssius, CJ Kalkman, JTA Knape, CLG Rutten, DE Grobbee. Validation of a clinical prediction rule to reduce preoperative Type and Screen procedures.
Br J Anaesth; in press

Wilton A van Klei, Karel GM Moons, Charles LG Rutten, Anke Schuurhuis, Johannes TA Knape, Cornelis J Kalkman, Diederick E Grobbee. Effect of outpatient preoperative evaluation on cancellation of surgery and length of hospital stay.
Anesth Analg; March 2002 (in press)

WA van Klei, KGM Moons, JTA Knape, DE Grobbee, CLG Rutten. Het kort preoperatief onderzoek zoals aanbevolen door de Gezondheidsraad is in de praktijk niet bruikbaar.
Ned Tijdschr Geneeskd 2001; 145: 2174-8

WA van Klei, KGM Moons, AT Rheineck Leyssius, JTA Knape, CLG Rutten, DE Grobbee. A reduction in Type and Screen: preoperative prediction of RBC transfusions in surgery procedures with intermediate transfusion risks.
Br J Anaesth 2001; 87: 250-7

WA van Klei, CLG Rutten, KGM Moons, B Lo, JTA Knape, DE Grobbee. Gering effect van Gezondheidsraad richtlijn over preoperatieve poliklinieken in Nederland; Een inventariserend onderzoek.
Ned Tijdschr Geneeskd 2001; 145: 25-9

WA van Klei, KGM Moons, CLG Rutten, JTA Knape, DE Grobbee. Poliklinisch preoperatief onderzoek door de anesthesioloog bij jonge volwassenen: anamnese en lichamelijk onderzoek volstaan, de korte vragenlijst van de Gezondheidsraad niet.
Ned Tijdschr Geneeskd 2000; 144: 1389-93

WA van Klei, JM Havenaar, FAM Klijn, A van Dijk. Ethanol ter behandeling van delieren bij alcoholafhankelijke patiënten op Nederlandse intensive-care afdelingen: effectiviteit niet aangetoond.
Ned Tijdschr Geneeskd 2000; 144: 710-3

Wilton van Klei.
Mijn eerste slecht nieuws gesprek.
Med Cont 1997; 52: 1053-4.

Abstracts

Wilton A van Klei, Karel GM Moons, Charles LG Rutten, Anke Schuurhuis, Johannes TA Knape. Effects of outpatient preoperative evaluation on hospital inpatients.
Anesthesiology 2001; 95: A1136 (www.asa-abstracts.com)

Wilton A van Klei, Karel GM Moons, Aart T van Rheineck Leyssius, Cornelis J Kalkman, Charles LG Rutten. Validation of a preoperative prediction rule to predict RBC transfusions.
Anesthesiology 2001; 95: A1083 (www.asa-abstracts.com)

Wilton A van Klei, Karel GM Moons, Aart T van Rheineck Leyssius, Johannes ThA Knape, Charles LG Rutten. Preoperative Prediction of RBC Transfusions: a Reduction in Type and Screen Investigations.
Anesthesiology 2000; 94: A1243 (www.asa-abstracts.com)

WA van Klei, CLG Rutten, KGM Moons, B Lo, JTA Knape, DE Grobbee. Organisatie en inhoud van het anesthesiologisch preoperatief onderzoek in Nederland: een inventarisatie.
Ned Tijdschr Anesth; 2000; 13 suppl: 6

WA van Klei, KGM Moons, AT van Rheineck Leyssius, JTA Knape, CLG Rutten, DE Grobbee. Preoperatieve bloedgroepbepaling: ook bij chirurgische ingrepen met een zeker risico op transfusie niet altijd noodzakelijk.
Ned Tijdschr Anesth; 2000; 13 suppl: 19
Ned Tijdschr Geneeskd 2001; 145: 447-8

Curriculum Vitae

Wilton van Klei was born on November 29, 1970 in Gorinchem, The Netherlands.
After graduating high school at the 'Oude Hoven' in Gorinchem in 1990, he began medical studies at the University of Utrecht and passed the final examination in February 1999. Subsequently, he started the work described in this thesis at the Department Perioperative care, Anesthesia and Pain therapy and the Julius Center for General Practice and Patient Oriented Research at the University Medical Center Utrecht (promotors: Prof.dr. JTA Knape and Prof.dr. DE Grobbee). Simultaneously, he started specialist training at the department Perioperative care, Anesthesia and Pain therapy at the University Medical Center Utrecht (supervisor: Prof.dr. JTA Knape). In June 2001 he obtained the Master of Science degree in Clinical Epidemiology at the Netherlands Institute for Health Sciences in Rotterdam.
Wilton is married with Céline van Kleffens. They have two children: Mias (1995) and Janoah (1999).