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. 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. However, it would be even more efficient if the same predictive accuracy could be obtained without the need for laboratory tests.

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-
surgery). 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 incontinencia 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, gastro-enterostomy, 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
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. 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). 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. 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.

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. 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>
<thead>
<tr>
<th>Table 1. Patient characteristics of derivation and validation set. Values are numbers and percentages between parenthesis.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
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.

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

⁺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.
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): 

\[ 1 \times \text{gender} + 1 \times \text{age} \geq 70 + (1, 2, 4 \text{ or } 5) \times \text{surgical procedure}. \]

Being a woman counts for 1 point, age \( \geq 70 \) 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

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

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

*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.
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 \( \leq 2 \) (or risk of transfusion \( \leq 10\% \)), 104 patients were indeed not transfused, yielding a negative predictive value of 90\%. In the group of patients with score \( \geq 5 \), 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 \( \leq 2 \) 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.

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

\(^\#\) 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 \((\cdot\cdot\cdot -3.701 + 0.629*\text{gender} + 0.546*\text{age} ≥ 70 + 0.524*\text{group2} + 1.291*\text{group3} + 2.287*\text{group4} + 2.386*\text{group5})\))

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.

<table>
<thead>
<tr>
<th>Hb (g dL(^{-1}))¹</th>
<th>&lt; 14.0</th>
<th>≥ 14.0</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfused</td>
<td>44 (90)</td>
<td>5 (10)</td>
<td>49 (100)</td>
</tr>
<tr>
<td>Not Transfused</td>
<td>97 (71)</td>
<td>39 (29)</td>
<td>136 (100)</td>
</tr>
<tr>
<td>N</td>
<td>141 (76)</td>
<td>44 (24)</td>
<td>185 (100)</td>
</tr>
</tbody>
</table>

¹ Preoperative hemoglobin concentration in g dL\(^{-1}\).

N = number of subjects per hemoglobin category.
threshold of $\leq 2$, (or transfusion risk $\leq 10\%$) 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

**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$^{-1}$.

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

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 \(14 \text{ g dL}^{-1}\)) 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 \(\geq 14.0 \text{ g dL}^{-1}\), 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 \(\leq 2\) and subsequently the preopHb level at a threshold of \(\geq 14.0 \text{ g dL}^{-1}\), 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\(^{-1}\).\(^{1,27-35}\) 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. Most studies included at least one laboratory value in their initial prediction model (preoperative hemoglobin concentration or hematocrit). Only one study described a rule without a laboratory parameter, which included similar predictors (e.g. gender) as we found. 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. 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. 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*US$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


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


21 Capraro L. Transfusion practices in primary total joint replacements in Finland. Vox Sang 1998; 75: 1-6
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
33 Weiskopf RB. Do we know when to transfuse red cells to treat acute anemia? Transfusion 1998; 38: 517-21
49 Ransom SB, McNeely SG, Malone JM. A cost-effectiveness evaluation of preoperative type-
