Institutional report - Vascular thoracic

Predictive models for thoracic aorta surgery. Is the Euroscore the optimal risk model in the Netherlands?

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Abstract

Prediction models do not optimally perform in the case of aorta surgery. We tried to define models that predict intensive care death for patients who underwent thoracic aorta surgery in the Netherlands. Therefore, we used data of 1290 patients who underwent interventions on the thoracic aorta from 1997 to 2002 which were prospectively collected in seven centers. One outcome was examined: intensive care death. Predicting models were made by multiple logistic regression analysis. The area under the receiver operating characteristics curve was used to study the discriminatory abilities of these models. We compared the models with the Euroscore. Eleven percent of the patients died during operation or on intensive care. Age, creatinine level ≥150 μmol/l, poor left ventricular ejection fraction and urgent indication were most related with intensive care-death. Prolonged extracorporeal circulation and deep hypothermia were also of importance in the peri-operative model. The models performed better than the Euroscore. We conclude that the developed models perform relatively well in discriminating patients with respect to intensive care-death and even better than the Euroscore.

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Keywords: Outcome prediction; Thoracic aorta surgery; Intensive care death

1. Introduction

Outcome prediction is of major importance in cardio-thoracic surgery for individual risk assessment, benchmarking and quality assurance. Several predicting models for cardiac surgery have been published. The models are focused on outcome of coronary artery bypass grafting (CABG) [1–3] or the whole spectrum of cardio-thoracic surgery [4–9]. In those last-mentioned models, thoracic aorta operation seems to be an independent risk factor for in-hospital or early mortality, like in the Euroscore [5].

Nevertheless, it is questionable whether it is fair to include thoracic aorta operations into a predicting model for cardio-thoracic surgery. Firstly, in comparison with CABG and heart-valve operations, techniques used for thoracic aorta operations are more complex, the indication for surgery is often different due to other underlying diseases and frequently serious complications, like spinal cord ischemia and renal failure, that will occur. Secondly, validation with an existing prognostic model in the case of thoracic aorta operations proved to be rather poor [10]. In a recent study, a modification in the Euroscore is presented in the case of thoracic aorta operations, suggesting that the standard Euroscore is not optimal for predicting outcome for thoracic aorta operations [11].

The Dutch committee of heart interventions (Begeleidingscommissie Hartinterventies Nederland, BHN) keeps a nationwide registry on cardio-thoracic operations. Several preoperative, peri-operative and postoperative variables are collected in this registry.

By using this registry, we will try to define preoperative models for predicting outcome in thoracic aorta surgery, and perform validation and calibration of the developed models. The following outcome variable will be used: intensive care death.

2. Material and methods

2.1. BHN-registry

The committee of heart interventions in the Netherlands (Begeleidingscommissie Hartinterventies Nederland, BHN)
is a collaboration of the Dutch Societies for Cardiothoracic Surgery, Cardiology, Pediatric Cardiology and Cardio-anaesthesiology. The BHN keeps a registry of all heart interventions, including cardio-thoracic operations, percutaneous coronary interventions and paediatric catheter interventions performed in the Netherlands since 1995. The department of Medical Informatics of the Academic Medical Center in Amsterdam implements the management and processing of the registry under the auspices of the BHN. Since 1997 also pre-, peri- and postoperative variables are collected in the cardio-thoracic surgery registry.

2.2. Patient population

All consecutive patients entered in the database of the BHN since January 1997 until December 2002, who underwent an operation on the thoracic aorta, were included in this study.

2.3. Determinants

We collected information about the following preoperative variables: age, gender, body mass index (kg/m²), preoperative renal dysfunction (creatinine level \( \geq 150 \mu \text{mol/l} \)), diabetes mellitus (defined as diabetes mellitus with active treatment with insulin or oral antidiabetica), arteriopathy (defined as a history of vascular intervention or planned vascular intervention), neurological disease (defined as a history of transient ischemic attack or cerebrovascular accident), recent myocardial infarction (in the preceding four weeks prior to operation), indication (urgent defined as indication for operation within 24 h), pulmonary hypertension (defined as systolic pulmonary pressure 50 mmHg), type of aorta surgery (ascending, arch, descending or combination) and combined surgery with heart valve operation or coronary artery bypass grafting. The ascending aorta is defined as the part of the aorta from the aortic valve to the anonymous artery, the arch as the part from the anonymous artery to the left subclavian artery and the descending aorta as the part from the left subclavian artery to the diaphragm. We collected information about the following peri-operative variables: aorta clamping time (AOX, in minutes), extracorporeal circulation (ECC, in minutes) and minimal nasopharyngeal temperature (degrees Celsius).

2.4. Outcome variable

We collected information about one outcome: intensive care (IC) death defined as death during operation or stay on intensive care unit.

2.5. Analysis

We developed for each of the four subgroups a prediction model with preoperative variables. We coded qualitative variables with ‘1’ when the characteristic was present and with ‘0’ otherwise. We categorised the following continuous variables: age (for every 10 years over 60, one point), body mass index (<25, 25–29.9 and 30 kg/m² and higher), and AOX as well as ECC (below the 20th percentile, between the 20th and 80th and above the 80th). We replaced missing values in categorical variables with the most prevalent value. We assessed univariate relations between determinants and the two different outcome variables by calculating odds-ratios and 95%-confidence intervals for all individual variables. We used the Pearson chi-squared test to calculate the relationship with the two outcome variables. We used a variable for entry in the logistic regression model, when the \( P \)-value in relation to the outcome was <0.20.

In the logistic model, the remaining variables were entered into a stepwise logistic regression analysis. In the final logistic model, variables with a \( P \)-value <0.05 were entered into the model and variables with a \( P \)-value >0.10 were removed from the model.

2.6. Comparison, validation and calibration

We looked quantitatively to differences between the models. We calculated the predicted risk for each individual patient for the outcome variable by using the developed logistic models. We validated the discriminatory performance of the model internally by area under receiver operating characteristics curve (AUC) analysis of the complete dataset for each of the models. We will compare these performances with existing additive and logistic Euroscore models [5,12].

We compared the observed and predicted event frequencies using the Hosmer–Lemeshow goodness-of-fit statistic.

2.7. Hospitals

The following hospitals participated (in alphabetic order): Amphia Hospital Breda, St. Antonius Hospital Nieuwegein, Catharina Hospital Eindhoven, Medical Center Rijnmond Zuid Rotterdam, Onze Lieve Vrouwe Gasthuis Amsterdam, University Medical Center St. Radboud Nijmegen and Vrije Universiteit Medical Center Amsterdam.

3. Results

The database contained a total of 30,076 cardio-thoracic operations, in 1290 cases (4.3%) the thoracic aorta was involved. Seventeen percent involved an ascending aorta operation, 36% involved an ascending aorta operation with aortic valve operation, 23% involved an aorta arch operation and 26% involved a descending aorta (see Table 1).
Eleven percent of the patients died during the operation or on the intensive care unit.

Table 2 shows the pre- and peri-operative variables present in the study population in relation to the outcome variable. Patients who eventually died on ICU were generally older, had a creatinine \( \geq 150 \, \mu\text{mol}/\text{l} \) and were operated with urgency. When looking to the peri-operative factors, either prolonged aorta clamp time or prolonged extra corporal circulation time were related to death during operation or on ICU.

Table 3 shows the independent predictors for intensive care death divided in pre- and peri-operative models calculated by multiple logistic regression: age, ‘creatinine \( \geq 150 \, \mu\text{mol}/\text{l} \)’, and urgency were present in both models. The type of aortic operation did not influence the model.

Figure 1 shows comparison of the discriminatory power of the different models by using AUCs. The discriminatory power of the preoperative and perioperative models were relatively good: AUC 0.775 (0.734–0.817), respectively 0.752 (0.710–0.794). The models scored better than the Euroscore models, which were only moderate in discriminatory power. The AUC of the Euroscore (additive respectively logistic) were: 0.677 (0.631–0.722), respectively 0.644 (0.596–0.692). The calibration of the models was just satisfactory: goodness-of-fit c-statistic (GOF) was 9.2, degrees of freedom (d.f.) = 4, \( P = 0.057 \) for the preoperative model, but unsatisfactory for the perioperative model: GOF = 25.1, d.f. = 7, \( P = 0.001 \).

4. Discussion

In this study, we developed and validated predictive models for mortality on ICU after thoracic aorta operations in a large cohort of patients from seven institutes in the Netherlands.

The preoperative and perioperative models consist only of a few variables, which make them easily to calculate. All preoperative variables are part of the Euroscore model.

The models performed better than the Euroscore (additive and logistic). Our models were actually easier than the Euroscore models, but different. This implies the weakness of the Euroscore for calculating the risk in thoracic aorta operations. The Euroscore model is made by using a dataset with all kinds of operations, mainly CABG/valve operations and in minority aorta operations, so extrapolation of the Euroscore model to an aorta-model would be quite unnatural. Since the models perform much better than the existing Euroscore model it is quite defendable to make a separate aorta model instead of using the Euroscore.

Table 3 Independent predictors by multivariate analysis for intensive care death for the two models

<table>
<thead>
<tr>
<th></th>
<th>Beta</th>
<th>OR</th>
<th>95% CI</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-operative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>− 3.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.50</td>
<td>1.6</td>
<td>(1.3-2.0)</td>
<td>0.000</td>
</tr>
<tr>
<td>Creatinine ( \geq 150 )</td>
<td>1.11</td>
<td>3.0</td>
<td>(1.8–5.2)</td>
<td>0.000</td>
</tr>
<tr>
<td>Urgent indication</td>
<td>1.47</td>
<td>4.4</td>
<td>(3.0–6.0)</td>
<td>0.000</td>
</tr>
<tr>
<td>Poor LVEF</td>
<td>1.19</td>
<td>3.3</td>
<td>(1.1–9.7)</td>
<td>0.032</td>
</tr>
<tr>
<td><strong>Per-operative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>− 4.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age( ^{a} )</td>
<td>0.53</td>
<td>1.7</td>
<td>(1.4–2.1)</td>
<td>0.000</td>
</tr>
<tr>
<td>Creatinine ( \geq 150 )</td>
<td>1.12</td>
<td>3.1</td>
<td>(1.8–5.3)</td>
<td>0.000</td>
</tr>
<tr>
<td>Urgent indication</td>
<td>1.45</td>
<td>4.3</td>
<td>(3.0–6.2)</td>
<td>0.000</td>
</tr>
<tr>
<td>Prolonged ECC( ^{b} )</td>
<td>0.81</td>
<td>2.2</td>
<td>(1.4–3.5)</td>
<td>0.000</td>
</tr>
<tr>
<td>Deep hypothermia( ^{**} )</td>
<td>0.67</td>
<td>2.0</td>
<td>(1.1–3.6)</td>
<td>0.032</td>
</tr>
</tbody>
</table>

\( ^{a} \) age per 10 years one point from 60; \( ^{b} \) extracorporal circulation 244 min (80th percentile); \( ^{**} \) under 20°C. LVEF = left ventricular function; CABG = coronary artery bypass grafting.
Addition of peri-operative variables like prolonged ECC and AOX, shows that complications, as a cause of prolonged AOX and ECC, could optimise the models, however, the calibration of the model became worse. The finding of these variables is in line with the literature, which has shown that prolonged extracorporeal circulation [13,14] eventually leads to early death. In contrast, deep hypothermia could have a protective effect on spinal cord function [15], which could give a lower rate of postoperative neurological deficit. It would be interesting to study which peri-operative factors led to prolonged AOX and ECC. It would give more insight into the cause of peri- and postoperative mortality.

4.1. Limitations

This study has four limitations. Firstly, we had no information on diagnoses in the registry: only the urgency of the procedure and the segment of the aorta, which was operated upon, were mentioned in the database. Additive information whether a patient had Marfan’s disease, an aneurysm or a dissection could be essential and may change and optimise the developed models. Secondly, we used the outcome variable IC death instead of in-hospital death or 30 days or longer follow-up. But, since a high percentage of patients died on the IC and morbidity and mortality are relatively high compared with, for example, coronary artery bypass grafting or valve operations, we do not think this had a major impact on the developed models. Thirdly, we compared with the Euroscore, nevertheless we did not have all variables of the Euroscore in the database and some cut-off points were different. Chronic pulmonary disease, active endocarditis, critical preoperative state and unstable angina were not present in this database. Active endocarditis could lead to aortic root replacement, so this would lead to some unreliability in the calculating of the Euroscore. Unstable angina is uncommon in aortic disease, chronic pulmonary disease has not a high risk-impact in the model and critical preoperative state, like shock or after resuscitation, is of major importance but uncommon. So we do not think the lack of some Euroscore variables would have a major impact on the calculated models. The cut-off points for pulmonary hypertension, recent myocardial infarction and high creatinine are chosen somewhat different. The database was, however, created before the introduction of the Euroscore, so our definitions do not completely conform with the criteria of the Euroscore. We think, however, that this could have only a slight impact on the eventually calculated models. And finally, we did not validate the models externally. We did not perform this technique, because the group of patients was not large enough.

5. Conclusions

We conclude that the developed models perform relatively well in discriminating patients with respect to IC death and even better than the Euroscore.

References
