Computerized model for preoperative risk assessment

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Background. In order to improve the consistency of anaesthetic risk scoring, we have developed an automated method for the calculation of ASA (cASA) scores using decision logic programming. We investigated whether ASA scoring by anaesthesia caregivers could be matched or closely approximated by a CASA.

Methods. We used a web-based preoperative assessment system to present a structured questionnaire comprising 22 questions. These were designed to score and identify conditions that are known, from the literature and expert opinion, to be risk factors. The answers from 14 349 cases were processed using decision logic to provide a variety of risk scores including a computed overall anaesthetic risk (cASA), which was then compared with the ASA score estimated by anaesthesia caregivers (eASA).

Results. We found a close agreement between the two measures in almost all cases. In 159 cases (1.1%), there was an underestimation of cASA, in comparison with the eASA, which appeared to be a result predominantly of incorrect or incomplete answers, or an overestimation of the ASA score by the human classifier (43%).

Conclusion. We showed that ASA scores estimated by a heterogeneous group of anaesthesia caregivers could be mimicked by the cASA computed by our preoperative assessment system.

Keywords: decision support; information technology; preoperative assessment; quality of care

Accepted for publication: 26 April 2011

Preoperative assessment by anaesthetists is often not standardized, frequently incomplete, inconsistent, and time-consuming, making preoperative information difficult to interpret. Moreover, communication problems and inadequate information flow are the main causes of medical errors. A report by the Institute of Medicine suggested that electronic systems would support quality improvement by eliminating errors through computerized order entry, automatic reminders, clinical decision support, and financial incentives. It was shown that hospitals which adopted a greater number of information technology applications were significantly more likely to have desirable quality outcomes on seven Inpatient Quality Indicator measures. Therefore, computerized preoperative assessment systems and anaesthesia information management systems (AIMS) have the potential to reduce medical errors and enhance patient safety. Edsall and colleagues demonstrated that AIMS can facilitate and save time spent on record keeping and Gibby showed that pre-hospital assessment programmes might also reduce health-care costs.

There is evidence that the quality of perioperative care (e.g. improved time management and patient safety, better patient satisfaction, more standardized patient information, easier analysis of perioperative data, and optimization of hospital specific perioperative) may be supported and enhanced by a computerized anaesthesia-based preoperative assessment system.

The most important characteristic of such a system is the use of a decision-support tool that is able to distinguish relatively healthy patients from patients who need more intensive assessment. A common tool for patient risk assessment is the ASA physical status classification score. Although the ASA scoring system is known to have its flaws, it is used worldwide as a comprehensible and practical tool for classifying the patient’s clinical preoperative state. Moreover, ASA classification is known to correlate well with postoperative mortality. The purpose of this study was to construct a structured questionnaire and a standardized digital decision-support tool that could efficiently capture the patient’s history and clinical condition in order to assess overall preoperative risk, which will be referred to as the computed ASA (cASA). The correlation between cASA and an ASA score estimated by the anaesthesia caregiver (eASA) was investigated.

Methods

The project was classified as a service evaluation by the Central Committee on Research involving Human Subjects.
(CCRS), meaning that formal ethical approval was unnecessary. Local approval was gained from our institution's audit committee. The study was set in a general teaching hospital, with no cardiac surgery or intracranial surgery.

The questions were presented by a web-based preoperative assessment system (Synopsis IQ, Informatics, Glasgow, Scotland) which had embedded knowledge and decision rules developed using a system which combined conventional univariate and multivariate statistical techniques with genetic programming (Chordiant Strategy Direct 6.1, Cupertino, CA, USA) (Supplementary Appendices 1 and 2). These rules, which were used to provide a range of clinical decision support, were also used to construct a standardized computer-based version of the conventional ASA score (cASA). The cASA was classified using four categories which were defined as follows: cASA 1, a normal healthy patient; cASA 2, a patient with mild systemic disease; cASA 3, a patient with severe systemic disease that limits activity but is not incapacitating; and cASA 4, a patient with severe systemic disease that is a constant threat to life. A total of 137 points could be scored. Cut-off points and ratings used by the decision rules were reviewed and evaluated by clinical experts. The following cut-off values were chosen: cASA 1, 1–3 points; cASA 2, 4–10 points; cASA 3, 11–20 points; and cASA 4, >20 points.

After the questionnaire had been completed and the anaesthesia caregiver had discussed the responses with the patient, a brief physical examination was performed. Important clinical data (e.g. laboratory values, ECG results, and consultations) were retrieved from the general hospital information system (EZIS, Chipsoft®, Amsterdam, The Netherlands) and added to the preoperative assessment system.

eASA was scored by one of the 26 anaesthesia caregivers: 12 anaesthetists, six anaesthesia trainees, and eight physician assistants.

After completion of the preoperative assessment, all data were stored in a Microsoft Structured Query Language (SQL) Server relational database (Microsoft Corporation, Redmond, WA, USA). A subset comprising the required data elements was then exported to a Microsoft Office Excel 2007 spreadsheet (Microsoft Corporation) and analysed retrospectively. Statistical analysis was performed using the R-project statistical package (R Foundation for Statistical Computing, 2010, Vienna, Austria). The Somers2 method of the Hmisc package was used to calculate the area under the curve from the receiver-operating characteristics (ROC).

Results

Preoperative data on 14,349 patients undergoing surgery between April 2008 and May 2009 were used to validate the applicability of cASA.

Table 1 shows the population characteristics during the investigation period. Table 2 shows the type of surgical procedures during the study period. Table 3 shows the correlation between the four defined classifications of cASA and eASA. In 159 cases, 1.1% of the studied population, there was a difference between cASA and eASA scores, which could indicate underscoring of the patient’s clinical status, inadequate risk assessment, or both. One hundred and fifty-nine cases were marked as misclassifications and were further analysed. Table 4 shows the reasons for cASA misclassification. A major factor was incorrect or incomplete answer sets (37%), causing cASA underclassification. In 43% of the misclassifications that were scored cASA 2 by
our preoperative assessment system, the eASA was scored as 3. This discrepancy was associated with chronic obstructive pulmonary disease (COPD) grade 1 or 2 on the Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification, hypertension, pacemaker or treated rhythm disturbances with good left ventricular function, good functional recovery after neurological damage, stable cardiac function after cardiac surgery, malignancy, BMI > 30 kg m\(^{-2}\), and Parkinson’s disease. Physician assistants and anaesthesia trainees had a greater tendency to over-score eASA, compared with trained anaesthetists.

The ASA physical status classification is widely used to triage patients for outpatient surgery or clinical admission for inpatient surgery; therefore, we produced a composite table for division of eASA < 3 and > 2 and an ROC curve which shows the prediction of cASA vs eASA (Table 4 and Fig. 1).

### Discussion

In line with other studies investigating the role of computer-assisted preoperative assessment and AIMS in patient safety, this study shows that cASA generated from our preoperative assessment system which uses a structured questionnaire, standardized answers, and decision logic agrees closely with ASA scores estimated by a heterogeneous group of anaesthetic caregivers in our hospital, provided that the questions are answered correctly and completely. Moreover, this study shows that our system is capable of capturing interindividual variations in risk assessment judgements in a heterogeneous group of anaesthesia caregivers. The eASA score is subject to the anaesthesia caregiver’s subjective estimation, so standardized answers to a questionnaire presented by a computerized preoperative assessment system can produce a more objective and consistent risk assessment which might even prove to be better than that made on the basis of the personal judgement of anaesthetic caregivers. Such a standardized assessment of anaesthetic risk might be of even more importance in countries where preoperative evaluations are done by nurses or physician assistants and where physicians are less involved in the assessment.

An important potential use of cASA is to discriminate ASA I/II patients from ASA III/IV patients. Such a test could be used to screen for patients with a poorer physical condition, for example, the ASA physical status classification is widely used to triage patients for outpatient surgery or clinical admission for inpatient surgery. Of course, the risks related to the specific surgical procedure will also play an important role in the planning. Vice versa, patients at low risk might require less preoperative testing. Even if the results of the cASA are not used to change the standard protocol, it could be very useful as an automated warning. When cASA is used for this purpose, the more serious error occurs when a patient of physical condition ASA III/IV is misclassified as I/II by cASA. In our analysis, 159 misclassification cases were found at the defined cut-off value of 10 for cASA, as is shown in Table 4. This results in a positive predictive value (PPV) of 98.7%, a negative predictive value (NPV) of 57.8%, a sensitivity of 96.3%, and a specificity of 81%, meaning that cASA will accurately predict eASA for division of cASA < 3 and > 2. However, the predictive values are further increased as data are corrected for misclassification, yielding a PPV of 99.8%, a NPV of 58%, a sensitivity of 96.4%, and a specificity of 95.5%. We believe that further improvements in the data capture and re-calibration of the score could increase the PPV even further (Table 5).
A possible limitation of the digital decision-support scoring tool described here is that cut-off values and ratings applied to the decision rules were determined on the basis of expert clinical judgement. In 0.15% of the cases, cASA was underscored (i.e. eASA 3 and cASA 2) by our system. Reasons for this discrepancy were kidney failure, liver failure, and end-organ damage as a consequence of systemic disease. Adaptation of cut-off values or ratings applied to the decision rules within the system could overcome these problems. However, since inter-observer consistency of the ASA physical status score is poor,\(^1\) we think that 0.15% discrepancy is acceptable in the studied population.

Another limitation might relate specifically to our studied population. This study was set in a general teaching hospital, with no cardiac surgery or intracranial surgery; 93.6% of the studied population was scored as ASA I or II with a low rate of co-morbidity. So, in general, this population was relatively healthy. We have to caution against an uncritical extrapolation of our findings to academic or cardiac-surgical centres.

A major factor in misclassification was that the questions were not answered completely, correctly, or both. We believe that patients are able to self-complete the questionnaire. Validation of this hypothesis will be the goal of the future study.

A great advantage of a computerized preoperative assessment system is that evidence-based risk profiles identified from the literature can be incorporated into the decision logic system. On the basis of known risk factors with associated odds ratios and relative risks, such a system is able to generate refined or new preoperative risk assessment scores, which might define the patient’s preoperative condition better than the current eASA (e.g. preoperative cardiac risk,\(^21\) preoperative pulmonary risk,\(^25\) estimation of the intubation difficulty,\(^27\) risk of postoperative nausea and vomiting,\(^30\) postoperative delirium risk, postoperative infection risk, postoperative thrombosis risk, p-POSSUM,\(^35\) and Donati’s score).\(^36\) We hypothesize that incorporating these scores and applying them to management decisions could lead to better preoperative preparation and postoperative care, and a clearer strategy for informing the patient of risks. Of course, this remains to be investigated.

**Table 5** Reasons for misclassification. *COPD GOLD score 1 or 2, hypertension, pacemaker or treated rhythm disturbances with good left ventricle function, good functional recovery after neurological damage, stable cardiac function after cardiac surgery, malignancy, BMI >30 kg m\(^{-2}\), and Parkinson’s disease. \(^1\)Kidney failure, liver failure, end-organ damage as a consequence of systemic disease

<table>
<thead>
<tr>
<th>Reason for misclassification</th>
<th>No. (%)</th>
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<tbody>
<tr>
<td>Impression of patient worse than classified by cASA without clear reason*</td>
<td>68 (43)</td>
</tr>
<tr>
<td>Impression of patient worse than classified by cASA with clear reason†</td>
<td>22 (14)</td>
</tr>
<tr>
<td>Incorrectly filled out list</td>
<td>59 (37)</td>
</tr>
<tr>
<td>Same patient screened for other operation</td>
<td>10 (6)</td>
</tr>
<tr>
<td>Total</td>
<td>159 (100)</td>
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Conflict of interest
None declared.

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