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ASA classification and perioperative variables as predictors of postoperative outcome

U. WOLTERS, T. WOLF, H. STÜTZER AND T. SCHRÖDER

Summary

In a prospective study of 6301 surgical patients in a university hospital, we examined the strength of association between ASA physical status classification and perioperative risk factors, and postoperative outcome, using both univariate analysis and calculation of the odds ratio of the risk of developing a postoperative complication by means of a logistic regression model. Univariate analysis showed a significant correlation ($P < 0.05$) between ASA class and perioperative variables (intraoperative blood loss, duration of postoperative ventilation and duration of intensive care stay), postoperative complications and mortality rate. Univariate analysis of individual preoperative risk factors demonstrated their importance in the development of postoperative complications in the related organ systems. Estimating the increased risk odds ratio for single variables, we found that the risk of complication was influenced mainly by ASA class IV (risk odds ratio = 4.2) and ASA class III (risk odds ratio = 2.2). We conclude that ASA physical status classification was a predictor of postoperative outcome. (*Br. J. Anaesth*. 1996; **77**; 217–222).

Key words

Complications, ASA classification. Assessment, ASA classification. Complications, postoperative. Recovery, postoperative. Organisations, American Society of Anesthesiologists.

The American Society of Anesthesiologists' (ASA) classification of physical status was introduced in 1941 by Saklad [1] in an attempt to provide a basis for comparison of statistical data in anaesthesia. The classification was revised in 1963 [2] with the number of classes being reduced from seven to five. Several retrospective studies have demonstrated a correlation between ASA classification and perioperative mortality [3–8], and have suggested its usefulness as a predictor of patient outcome. Prospective studies correlating ASA classification with both perioperative mortality and morbidity have suffered either from small patient numbers [4] or from focusing only on anaesthetic complications [9, 10].

The aim of this prospective study was to evaluate the prognostic value of ASA classification with regard to perioperative variables such as blood loss, duration of intensive care stay, postoperative complications and mortality. In addition, we investigated the relationship between the presence of specific preoperative disease states (arterial hypertension, previous myocardial infarction, smoking and severe bronchopulmonary disease) and the development of major postoperative complications (cardiac and pulmonary), and the need for postoperative ventilation. Further, we used logistic regression analysis to provide an estimate of the risk odds ratio implied by specific perioperative variables, together with an estimate of the risk odds ratio when more than one perioperative variable was considered.

Patients and methods

All patients operated on in the Department of General and Vascular Surgery, University of Cologne, between May 1, 1989 and April 30, 1993, were included prospectively in the study. All patients were assessed before operation by an anaesthetist, wherever possible. Assignation of the 1963 ASA classification (table 1) was performed by two anaesthetists, of which at least one was a consultant. The standard anaesthetic record was used. Specific data retrieved from the anaesthetic record were: ASA classification; emergency or elective operation; the presence of specific preoperative disease states (anaemia, defined as haemoglobin concentration < 100 g litre^{-1} or arterial hypertension systolic pressure > 160 mm Hg); previous myocardial infarction; previous stroke; smoking (positive if > 20 cigarettes per week); severe bronchopulmonary disease (vital capacity or forced expiratory volume in 1 s < 40 % of predicted); diabetes mellitus (all types requiring medication); acute or chronic renal failure (serum creatinine > 1.5 mg dl^{-1}); and major gastrointestinal diseases (e.g. ulcerative colitis, gastric or duodenal ulcer). Type of anaesthesia, operation performed, operating time (time from skin incision to wound closure) and intraoperative blood loss, as estimated by the anaesthetist, were also recorded.

Operations were classified according to the Hoehn system [11], as used frequently in Germany, into

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Table 1 American Society of Anesthesiologists' (ASA) physical status classification

Class	Description
I	Healthy patient
II	Mild systemic disease—no functional limitation
III	Severe systemic disease—definite functional limitation
IV	Severe systemic disease that is a constant threat to life
V	Moribund patient unlikely to survive 24 h with or without operation

minor (e.g. repair of soft tissue wounds, perineal surgery), moderate (colostomy formation, cholecystectomy, herniotomy) or major (bowel resection, thoracic surgery, abdominal and peripheral vascular interventions). Preoperative investigations in all patients undergoing moderate and major operations included serum electrolyte (Na^+, K^+, Cl^-), creatinine and glucose concentrations, blood count (haemoglobin, packed cell volume, platelet count, leucocyte count), coagulation screen (prothrombin time, partial thromboplastin time), chest x-ray and an ECG. Also, all patients received cephazolin (Elzogram 2 g) i.v. and single-dose low molecular weight heparin (Dalteparin sodium 7500 i.v.) s.c. after induction.

Postoperative data were obtained by surgical interns and final year medical students. Attention was focused on pulmonary complications such as bronchopulmonary infection, as diagnosed by positive sputum culture or positive chest x-ray, or both, atelectasis or pleural effusion, as seen on the chest x-ray. Significant arrhythmias such as new atrial fibrillation or acute myocardial infarction confirmed by ECG changes and increases in CPK-MB enzymes were recorded as cardiac complications. Wound inflammation or a purulent wound discharge was recorded as a wound infection, and clinically apparent anastomotic leakage was also noted. Culture-positive urinary tract infections were also recorded.

The data were summarized into two groups. First, to allow comparison between ASA classification and perioperative variables, we recorded duration of operation, intraoperative blood loss, duration of postoperative ventilation, stay in intensive care, postoperative hospital stay, and rates of pulmonary complications, cardiac complications, wound infection, anastomotic leakage, urinary tract infection and in-hospital mortality (expressed as means). The second grouping allowed a univariate analysis of the relationship between the most prevalent preoperative disease states and the incident of major postoperative events. Finally, logistic regression was applied to the data to estimate the risk odds ratio of single and combined perioperative variables.

STATISTICAL METHODS

The Student's t test was used to quantify the difference in the means of independent perioperative variables between ASA classifications. Differences in the rates of complications between ASA classifications were assessed by Fisher's exact test. The significance of the impact of preoperative disease states on the development of a specific postoperative complication was also assessed by Fisher's exact test. The logistic regression model is explained in the appendix.

Results

A total of 6301 patients were operated on in the sample period and patient data are summarized in table 2. More than 75 % of patients were classified as ASA II or III (table 3). As only 15 patients (0.2 %) were classified as ASA V and as 14 of these patients died in hospital, they were excluded from statistical analysis on morbidity.

There were a total of 9136 pre-existing disease states in 6301 patients (table 4). The major preoperative disease states identified were arterial hypertension, smoking, severe bronchopulmonary disease and major gastrointestinal disease, each with an incidence of more than 20 %. The type of operation according to Hoehn system was 1004 (16 %) minor, 1695 (27 %) moderate and 3602 (57 %) major. All ASA V patients underwent major operations. The specific sites of operation are summarized in table 5. As an indication of the type of operation performed, the 1077 operations listed as "colon and rectum" included mainly partial and total colectomy, and the 1495 operations listed as "vascular" included aortic procedures and carotid surgery.

Table 2 Patient data (mean (SD) [range] or number (%))

Total number of patients	6301
Males	3699 (59 %)
Females	2602 (41 %)
Emergency operations	1279 (20 %)
Malignant disease identified	1631 (26 %)
Age (yr)	52 [0–98]
Type of anaesthesia	
General	97.5 %
Regional	1.4 %
Combined	1.1 %
Operating time (min)	107 (48.2) [5–830]
Postoperative stay (days)	12 (2.8) [1–132]
Hospital stay (days)	16.5 (3.4) [1–179]

Table 3 ASA classification of all patients

	n	%
ASA I	1133	18
ASA II	2685	42.6
ASA III	2181	34.6
ASA IV	290	4.6
ASA V	15	0.2

Table 4 Incidence of specific preoperative disease status

	n	%
Anaemia	501	8
Arterial hypertension	1817	28
Previous myocardial infarction	272	4
Previous stroke	460	7
Positive smoking history	1823	28
Severe bronchopulmonary disease	1353	21
Diabetes mellitus	685	11
Acute or chronic renal failure	685	11
Major gastrointestinal disease	1540	24

Table 5 Sites of surgery for the 6301 patients

Site of surgery	*n*	%
Thyroid and parathyroid	421	6.7
Oesophagus	283	4.5
Gastric	232	3.7
Small bowel	172	2.7
Colon rectum	1077	16.9
Biliary tract	358	5.7
Liver	137	2.2
Pancreas	66	1
Spleen	74	1.7
Adrenal gland, kidney	69	1
Hernia	600	9.4
Kidney transplant	235	3.7
Other abdominal surgery	314	5
Breast surgery	23	0.4
Extra-abdominal lymph nodes	106	1.7
Other neck surgery	32	0.5
Soft tissue tumours	210	3.3
Vascular	1495	23.6
Thoracic	397	6.3

For perioperative variables in relation to ASA (table 6), we found an increase in duration of operation between ASA I and ASA II–IV combined ($P < 0.05$) and between ASA II and III ($P < 0.05$). Intraoperative blood loss was 5–20-fold greater in ASA IV than in ASA I–III groups ($P < 0.05$). We found a 2–6-fold increase in the duration of postoperative ventilation between individual groups ($P < 0.05$). Postoperative intensive care and total hospital stay of ASA II–IV patients were 1–5 and 7–11 days longer, respectively, than in ASA I ($P < 0.05$). We found a 2–3-fold incidence of postoperative bronchopulmonary complications in a stepwise manner through each ASA class ($P < 0.05$). A threefold increase in cardiac complications was found between individual classes I–IV ($P < 0.05$). The incidence of postoperative wound and urinary tract infections was 2–3 times greater in ASA classes II–IV than in ASA class I (I *vs* II–IV, $P < 0.05$). Postoperative anastomotic leakages were independent of ASA class. We found a significant 5–7-fold stepwise increase in hospital mortality per ASA class.

The relationship between specific preoperative disease states and individual postoperative complications is shown in table 7. Arterial hypertension and previous myocardial infarction implied a 50 % increase in the rate of developing a cardiac complication, and previous myocardial infarction implied longer postoperative ventilation. Severe bronchopulmonary disease implied a significant increase in the chance of developing a cardiac or pulmonary complication and increased duration of postoperative ventilation. We did not find that smoking was a significant factor in the development of the four major postoperative complications.

The logistic regression analysis data are summarized in table 8. The highest risk odds ratios for developing a postoperative complication were associated with worsening ASA classification and a "major" *vs* a "moderate" or "minor" operation, as per the Hoehn classification. Particularly, assignation of ASA IV implied a risk odds ratio of 4.26, that is a 4.26 times higher risk of developing a postoperative complication than for ASA I. As-

Table 6 Preoperative variables in relation to ASA. *Chi-square analysis by Fisher's exact test; † Student's *t* test

	ASA I	ASA II	ASA III	ASA IV	*P*
Operation duration (min)	75	108	124	116	< 0.05†
Intraoperative blood loss (ml)	78	105	293	1548	< 0.05†
Postoperative ventilation (h)	1.1	4.2	7.7	46.5	< 0.05†
Intensive care stay (days)	0.2	0.8	1.9	5.4	< 0.05†
Postoperative stay (days)	9.3	16.4	20.8	17.6	< 0.05†
Bronchopulmonary infection (%)	0.5	2.2	5.2	12.1	< 0.05*
Other pulmonary complications (%)	0.6	2.1	4.3	9.9	< 0.05*
Cardiac complications (%)	0.1	1.5	5.5	18	< 0.05*
Wound infection (%)	1.8	3.8	6.3	10.6	< 0.05*
Anastomotic leakage (%)	0.6	1.3	1.5	1.6	0.14456*
Urinary infection (%)	2.1	4.6	6.1	5	< 0.05*
Mortality (%)	0.1	0.7	3.5	18.3	< 0.05*

Table 7 Univariate analysis of preoperative disease status in relation to postoperative complications. *$P < 0.05$

	Postoperative ventilation (h) (mean (SD))	Cardiac complications (%)	Pulmonary complications (%)	Pneumonia (%)	Mortality (%)
Arterial hypertension (%)					
Yes	7.4 (37.3)	4.8	3.4	4.0	2.9
No	6.5 (29.8)	2.7*	2.8	3.0	1.5
Previous myocardial infarction (%)					
Yes	13.7 (52.2)	7.2	4.5	4.2	4.2
No	6.4 (34.3)*	3.1*	2.9	3.2	1.8
Severe bronchopulmonary disease (%)					
Yes	10.6 (45.5)	5.9	5.5	5.8	3.8
No	2.7 (32.0)*	2.6*	2.3*	2.6*	1.4*
Smoker (%)					
Yes	6.3 (30.8)	3.3	3.3	4.9	1.9
No	6.9 (37.0)	3.3	2.8	2.6*	1.9

Table 8 Risk factors for postoperative complications. [a] β, estimated regression coefficient, [b] standard error of β, [c] P value for Wald's test, [d] odds ratio related to reference class adjusted for all other independent variables in the model, [e] 95 % confidence intervals for the odds ratio, [f] reference class is set to ASA I: ASA (1) = indicator for class ASA II; ASA (2) = indicator for class ASA III; ASA (3) = indicator for class ASA IV, [g] "Major" operations compared with "moderate" or "minor" operations, as per the Höhn classification

Independent variables (poorer class or "yes" coded 1)	Logistic regression variables and statistics				
	β[(a)]	SE[(b)]	P[(c)]	Risk ratio[(d)]	95 % CI[(e)]
ASA[(f)]			< 0.00005		
ASA (1)	0.45	0.1319	0.0007	1.5668	1.21; 2.03
ASA (2)	0.81	0.1400	< 0.00005	2.2457	1.71; 2.96
ASA (3)	1.45	0.1855	< 0.00005	4.2600	2.96; 6.13
Class of operation[(f,g)]	0.63	0.0783	< 0.00005	1.8604	1.61; 2.19
Emergency	0.21	0.0440	< 0.00005	1.2366	1.13; 1.34
Renal insufficiency	0.33	0.1010	0.0008	1.3976	1.14; 1.70
Anaemia	0.21	0.0921	0.0259	1.2279	1.03; 1.48
Bronchopulm. disease	0.26	0.0763	0.0009	1.2911	1.12; 1.51
History of smoking	0.15	0.0718	0.0346	1.1638	1.01; 1.34
Age (yr)	0.01	0.0022	< 0.00005	1.0105	1.0006; 1.014
Op. duration (min)	< 0.0001	< 0.0001	< 0.00005	1.0001	1.0001; 1.000
Constant	−3.5622	0.1475	< 0.00005		

signation of ASA II and III implied risk odds ratios of 1.57 and 2.25, respectively. A moderate increase in the risk odds ratio was also seen in patients with renal disease, anaemia, bronchopulmonary disease and in those undergoing emergency operations.

Discussion

The ASA classification has established itself as the most widely used patient risk assessment scheme in anaesthesia, despite being developed in 1941 by Saklad [1] for the purpose of statistical data management. The 1963 revision eliminated the emergency classes of the original version and an emergency operation is noted by placing an "E" after the remaining five classes. No other preoperative risk assessment scheme developed has achieved the same widespread use. Other internationally known patient scoring systems outside the field of anaesthesia include APACHE II [12], used widely in intensive care, but the need for a 24-h sampling period of 12 routine physiological measurements, age and previous health status underlies the unsuitability of this system for anaesthesia. The Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity (POSSUM) was presented by Copeland, Jones and Walters in 1991 [13] and is based on a point score derived from 12 physiological and six operative severity score factors. The authors' intention was to develop a score to aid surgical audit and thus their method does not give the full score and the numerical estimate of the risk of mortality and morbidity until the outcome is known. In contrast, the ASA classification represents a simple estimation of physiological status without the need for clinical resources and can be applied to every patient before operation.

A major drawback of the ASA system is assessment of a patient's "correct" ASA classification by different anaesthetists and this was shown clearly by Owens, Felt and Spitznagel [14]. In their study, 304 anaesthetists were requested to classify 10 hypothetical patients and the mean numbers of patients rated identically by the authors and the responders was 5.9 (mode 6). To minimize this variability in our study, assignation of ASA class was performed by two experienced anaesthetists adhering strictly to the 1963 criteria (table 1). It is important to remember that these criteria do not take into account age and the complexity of operation, and there is no differentiation between a systemic disease that leads to operation and one that is an incidental chronic finding.

Few studies have examined the relationship between ASA physical status and perioperative morbidity. Cohen, Duncan and Tate [15] studied anaesthetic complications in the intraoperative period and in the recovery room (e.g. cardiac arrest, hypotension, aspiration). Tiret and Hatton [10] reported similar major complications during or within 24 h of anaesthesia. Both studies found significant correlations between these anaesthetic complications and patient ASA classification.

Our data identified several specific intra- and postoperative variables correlated significantly with ASA classification. Intraoperative blood loss, duration of postoperative ventilation, duration of intensive care stay, rates of pulmonary and cardiac complications, and in-hospital mortality showed significant increases as patient ASA defined status advanced from I to IV, with a 20–180-fold difference between ASA I and IV, and an average 2.8- and 3.7-fold difference in these variables between ASA II and III, and ASA III and IV, respectively. The high incidence of perioperative morbidity in ASA classes III and IV, especially pulmonary and cardiac complications (4–18 %), supports the concept of directing therapy, particularly ventilatory support and other intensive care resources, towards these patients.

The correlation between ASA classification and postoperative mortality has been shown in several previous studies [3, 5–8] and was confirmed by our data. The published absolute mortality rates of the individual classes showed considerable variation, with 0–0.3 % for ASA I, 0.3–1.4 % for ASA II, 1.8–5–4 % for ASA III, 7.8–25.9 % for ASA IV and 9.4–57.8 % for ASA V. This variation may be explained by differences in assessment of the patient's ASA physical status, patient population, sample size, operations performed and duration of postoperative monitoring. The latter is particularly important, as some of the older studies included only deaths occurring within the first 48 h [6] or within the first 7 days [5] after operation, while none covered the whole hospital stay. Thus these studies missed almost 50 % of postoperative in-hospital deaths occurring after the seventh postoperative day [3]. Often these limits are placed to assess the possible role of anaesthesia in postoperative mortality. In contrast, our data, with mortality rates of 0.1 % for ASA I, 0.7 % for ASA II, 3.5 % for ASA III, 18.3 % for ASA IV and 93.3 % for ASA V, were based on all deaths in hospital after surgical intervention, as we wished to quantify the total in-hospital risk.

Univariate analysis of four major preoperative disease states against individual postoperative complications (table 7) demonstrated their role in the development of complications in the related organ systems. This information is of little impact as patients usually have more have one significant pre-existing disease and it cannot be used to quantify the relative risk. Therefore, our study attempted to quantify the importance of specific risk factors in the evaluation of surgical outcome using multiple risk analysis as the appropriate statistical method. This was done as a means of eliminating the interference of these variables, as in previous studies [9, 12, 13]. The risk odds ratio (ROR), reflecting the relative increase in the complication risk of a single variable, was calculated by multivariate analysis and stepwise regression. The highest risk odds ratio of 4.26 was calculated for ASA IV, followed by ASA III (ROR 2.25), class of operation (ROR 1.86), ASA II (ROR 1.57) and emergency operation (ROR 1.24).

All other variables were of minor significance. Again, this highlights the value of the ASA classification system for the prediction of postoperative complications. A similar conclusion was reached by Pedersen and colleagues [4] who evaluated the possible relationship of 35 preoperative variables to only one event: the need for postoperative mechanical ventilation in a 3-month screening study. The best predictor of all variables was an ASA classification of greater than III. To assess the role of the complexity of an operation as an independent risk factor, previous studies divided the interventions into two groups (minor/major) [9], or into four groups (minor/moderate/major/major+) [13]. Applying the Hoehn classification [11], we differentiated three classes and found no significant difference between minor and moderate interventions, whereas major operations implied an almost doubled risk of complications.

The relative risk of 1.24 for patients undergoing emergency operations developing a postoperative complication was lower than risk odds ratios reported previously. Tiret and Hatton reported an ROR of 2.0 for intraoperative complications [10], Pedersen and colleagues 2.1 for the risk of postoperative ventilation [4] and Cohen, Duncan and Tate 4.4 for the risk of dying within 7 days [15] after an emergency operation.

Forrest and colleagues [16] showed that ASA classes III and IV were major predictors for severe cardiorespiratory outcome in a study which included only patients for elective surgery.

To extend the use of the multivariate risk analysis concept, the impact of more than one variable can be assessed using the formulae in the appendix, together with estimated regression coefficients derived from the logistic regression analysis of our data. This attempted quantification of "total" relative risk is of great value as it could lead to improvement in patient therapy.

Appendix

The goal of logistic regression analysis is to describe the relationship between a prospectively observed dichotomous outcome (the occurrence of a postoperative complication or not—the dependent variable) and a set of independent indicator variables (perioperative variables in our model) by modelling the probability "P" of the outcome by an expression of the form:

$$P = \frac{1}{1 + e^{-g(X)}} \qquad (1)$$

where $g(X) = \beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n$, β_0 = model constant, $\beta_{1 \ldots n}$ = regression coefficients (estimated by maximum likelihood methods) and $X_{1 \ldots n}$ = independent predictor variables coding perioperative clinical risk factors.

In our model there are three types of predictor variables: (i) those coding the dichotomous state yes/no (i.e. presence or not) of known clinical variables before operation, such as bronchopulmonary disease or an emergency operation; these are usually coded "1" if a clinically poorer status is present and otherwise "0"; (ii) those variables coding values of continuous variables such as duration of operation; (iii) those categorical or ordinal items, such as ASA classification, where "dummy" using $k-1$ indicator variables for k categories of the item is set up. To simplify our model, the reference category for ASA status was set to ASA 1 and indicator variables for ASA II, III and IV termed ASA (1), ASA (2) and ASA (3), respectively (table A1).

To calculate the risk odds ratio (ROR) for an outcome we use:

$$\frac{P}{1-P} = e^{g(X=x)} \qquad (2)$$

which by substitution becomes ROR =

$$e^{\beta} \text{ or } e^{c \times \beta} \text{ respectively} \qquad (3)$$

and may be estimated for each risk pattern.

An estimator for the multiplicative change in the ROR when switching an indicator variable to poorer status, leaving the values of all other independent variables fixed, is given by the expression:

$$e^{\beta} \qquad (4)$$

An estimator for 100 $(1-\alpha)$ % confidence interval for the ROR is given by:

$$e^{\beta \pm 1.96 \text{SE}(\beta)} \qquad (5)$$

where $\text{SE}(\beta)$ = standard error of the regression coefficient β belonging to the variable studied for the change in ROR.

To obtain an estimate of the ROR of multiple variables we used equation (4). For example, using table 8, the ROR for a population with the risk pattern (a):

Table A1 Indicator variables for ASA categories

ASA status	Indicator variables		
	ASA (1)	ASA (2)	ASA (3)
I	0	0	0
II	1	0	0
III	0	1	0
IV	0	0	1

(a) ASA = II

Emergency operation = yes
Bronchopulmonary disease = yes
Smoker = yes

relative to a population with risk pattern (b):

(b) ASA = I

Emergency operation = no
Bronchopulmonary disease = no
Smoker = no

and with equal values for all other risk variables, is estimated through:

$$e^{(0.45+0.21+0.26+0.15)} = 2.9 \approx 3 \qquad (6)$$

In terms of relative risk this indicates that a postoperative complication may occur approximately three times as often among patients with risk pattern (a) than among patients with risk pattern (b), assuming all other clinical risk factors are identical.

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