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Mortality and surgical risk assessment among the extreme old undergoing emergency surgery

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Abstract

BACKGROUND: Although longevity is becoming frequent, there are no scores to assess nonagenarians undergoing emergency surgery. The aim of this prospective observational study was to determine 30-day mortality and the individual performance of the Physiological and Operative Severity Score for Enumeration of Mortality and Morbidity (POSSUM) and other scores in predicting their risk for death.

METHODS: A total of 126 patients were included (2006–2011) and followed for 30 days. Patients risk for death was calculated using different scores. The accuracy of each score was assessed with exponential and linear methods and using the area under the receiver operating characteristic curve.

RESULTS: Overall mortality was 34.9%. The POSSUM, with a modification in the age category, had an area under the curve of .71 and ratios of observed to predicted deaths of 1.07 and 1.22, respectively, in the linear and exponential analysis.

CONCLUSIONS: In a population with as high a risk as nonagenarians, the age-modified POSSUM proved accurate to audit surgery and assess mortality risk.

Longevity is becoming less and less exceptional, and accordingly, the number of nonagenarians is increasing, so much so that some authors have started to distinguish between third-age or young old (65–84 years old) and fourth-age or oldest old (>85 years old).[1] This emergent segment of the population poses serious challenges to medical teams, because information about them remains scarce. Furthermore, it is sometimes difficult to decide whether emergency surgery in these patients is a viable option, because there are no validated tools to audit surgical outcomes or to assess their mortality risk.

The Physiological and Operative Severity Score for Enumeration of Mortality and Morbidity (POSSUM) was first developed to audit surgical practice[2] and has recently been suggested as a useful tool to assess risk.[3–5] On the basis of the variables analyzed by the POSSUM (see the Appendix), a number of other scoring systems, some of them specific to certain specialities, have been described. Among them, the Portsmouth POSSUM (P-POSSUM), introduced by Whiteley et al,[6] has been proven to predict deaths better than the POSSUM, especially for patients with low risk.[4,6,7] The Elderly POSSUM (E-POSSUM), in contrast, has succeeded in predicting mortality and morbidity in elderly patients (>65 years old) undergoing colorectal surgery.[8] Furthermore, another age-based system, the Donati score[9] (see the Appendix), is also in use to assess operative risk. It has some advantages over the POSSUM-based scores; namely, it requires fewer variables, and they can all be assessed preoperatively. However, none of these scales has been tested in nonagenarians, a particularly vulnerable population, with many comorbidities and high risk, which becomes even higher when they need emergency surgery.[10]

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The aim of this study was to determine the 30-day mortality rate in nonagenarians undergoing emergency surgery, to assess the individual performance of each of the above-mentioned scores in predicting risk for death.

Methods

Patients

The study was conducted in the general surgical area of our tertiary care university hospital between July 2006 and February 2011. We prospectively recruited all patients aged ≥ 90 years undergoing emergency surgery. Hip fracture repairs and other orthopedic procedures are normally performed in a separate trauma area; therefore, these patients were excluded. For those individuals who were admitted to the hospital more than once during the study period, the analysis includes only information about their first admissions. Most patients who were readmitted to the hospital were readmitted within a short time period and for reasons related to their first admissions. As a result, unless they underwent another surgical procedure (in which case the POSSUM-related scores take it into account), we did not consider the second admission independently.

To calculate the sample size, we used the equation needed to estimate a proportion $(Z_\alpha^2 \times p \times q)/d^2$, where Z_α is the confidence coefficient $(1 - \alpha)$, that is, 1.96 (for a confidence level of 95%); p is the expected proportion, assuming an expected proportion of 30% for the 30-day mortality rate (we estimated this value in other series[11] and our own preliminary descriptive demographic study of this population[12]); q is $1 - p$, .7 in this case; and d is precision, .08 for this study. As a result, 126 patients were necessary for a confidence level of 95% and precision of 8%.

Scores and end points

The postoperative mortality rate (up to 30 days) was the end point. The senior anesthetist on call was in charge of informing the patients and their relatives about the study and obtaining their informed consent. He also recorded the physiologic variables (preoperative) required for the POSSUM-based scores, and those needed for the Donati score, before entering the operating theater. Finally, he asked for a contact telephone number to assess mortality after discharge. The chief investigator was in charge of follow-up, registering the operative variables, and calculating the POSSUM, P-POSSUM, E-POSSUM, and Donati score for each patient. In all cases, the 30-day follow-up call was not considered valid until the patient or a close relative could verify his or her death or survival.

Early on in the analysis, we observed that all scores underpredicted deaths in the lower risk strata. To improve this, we tried introducing the extra age class, validated by Tran Ba Loc et al[8] for the E-POSSUM, to the other scores (see the Appendix). This group adapted the World Health Organization age classification[13] to the POSSUM original coefficients (ie, instead of using 3 coefficients to quantify the risk associated with age, they used 4, the last one including patients aged > 85 years). We used the same weighted age class to calculate the POSSUM and the P-POSSUM. In other words, we recalculated the POSSUM and P-POSSUM for every patient, with a coefficient of 8 in the age category. These are referred to as the modified POSSUM and modified P-POSSUM, respectively.

Statistical analysis

Statistical analysis was performed using SPSS version 17.0 (SPSS, Inc, Chicago, IL). To test the performance of a score in a new cohort, two aspects are important: calibration and discrimination. To assess the calibration of each score (the ability to predict the risk for death for a certain patient or a small group of them), we used the exponential and linear analysis described by Wijesinghe et al.[7] Discrimination is a rank-order statistic for predictions versus actual outcomes.[14] To assess discrimination, we used the area under the receiver operating characteristic (ROC) curve (AUC).

Both exponential and linear analysis aim to obtain a ratio of observed to predicted deaths (O/E). The difference between them lies in the way each method groups patients according to their risk levels, as predicted by each score, to obtain such a ratio. In the exponential method, patients whose predicted risk falls above certain cutoffs are grouped together to calculate the O/E ratio. The linear method, in contrast, which is based on Hosmer and Lemeshow's goodness-of-fit test, stratifies the sample according to the risk level by using deciles, and the O/E ratio is analyzed within each band separately. (In a nutshell, what these calibration methods actually test is whether in a group with a POSSUM of 20%, for example, mortality is also about 20%.) The exponential analysis was first described to assess the calibration of the POSSUM equation; it is not a standard statistical technique, unlike linear analysis, and it has been criticized for its difficulty in attributing a risk score to an individual.[15] Therefore, we used it only to assess the POSSUM-based scores, but not the Donati score.

We also used the findings of the linear analysis to make contingency tables. This way, we were able to calculate sensitivity, specificity, and positive and negative predictive values of the different scores. Unlike in Copeland et al,[2] these values do not consider the sample as a whole; instead, we calculated true-positives, true-negatives, false-positives, and false-negatives stratum by stratum.

Results

Of all the nonagenarians who underwent emergency procedures, 8 were referred to other hospitals immediately after surgery, and 2 could not be followed up. Ultimately, 126

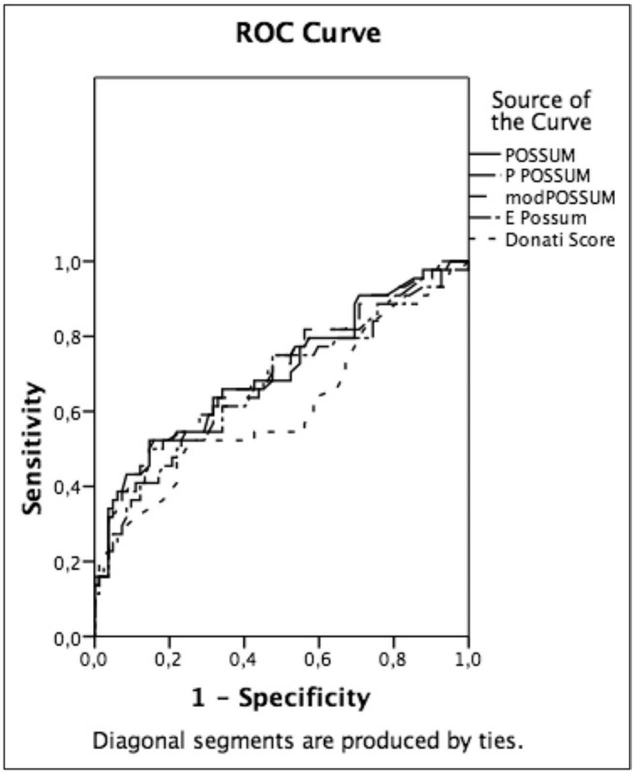

Figure 1 ROC analysis of the scores

patients were included. The in-hospital mortality rate was 29.4% (37 patients), and the 30-day mortality rate was 34.9% (44 patients). Eighteen patients (14.3%) had to be readmitted after discharge during the first postoperative month, and 4 of these died (they were included within the 30-day mortality rate). The mean length of hospital stay was 10 ± 7.14 days (range, 2–26); thus, all in-hospital mortality occurred within 30 days or not at all.

Figure 1 shows the ROC analysis to compare the discriminative ability of the different scores, and Table 1 lists the AUCs.

Linear analysis

Table 2 shows the linear analysis for POSSUM, P-POSSUM, E-POSSUM, modified POSSUM, and Donati score (the modified P-POSSUM proved to be the most inaccurate in all analyses, so results are omitted for this score). Inaccuracies occurred for most scores in the lower strata, which happened to be the deciles with larger number of patients. According to the POSSUM, almost 40% of patients had mortality risk between 0% and 20%, according to the E-POSSUM about 50%, and according to the P-POSSUM about 60%. In all these cases, the O/E ratio was significantly higher than 1. The modified POSSUM, on the contrary, proved accurate for nonagenarians with both low and high mortality risk, with O/E ratios close to 1 in most deciles. The Donati score performed poorly, as it underestimated mortality in all ranges. On the basis of the linear analysis, Table 3 shows the results calculated from the contingency tables.

Exponential analysis

The outcomes of the exponential analysis are summarized in Table 4.

Comments

Nonagenarians are often treated according to the results and experience gained with younger patients.[11] By the same token, the tools used to audit outcomes and assess their surgical risk are the same as those used with the general population. However, the extreme old are at higher risk for morbidity and mortality, especially when they undergo emergency surgery.[12] In this context, the high mortality rate found in our sample might be partly explained by the lack of scores to assess these patients; as the actual risk for surgery in each patient is not clear, many individuals who would not be eligible for surgery with accurate cost-benefit analysis end up undergoing surgery. Furthermore, a sensible risk assessment may prompt a deferral of surgery until the patient's condition is improved or even a reduction in the severity of the procedure.[9] As a result, a validated score enables an objective risk-adjusted comparison of surgical results, as well as an estimation of the risk for death. Regarding the scores discussed in this study, they are all cost-effective tools, as the variables used in them are normally obtained as the basic assessment of the patient in the emergency ward (no extra tests are needed).

The modified POSSUM had an acceptable performance in both the discrimination analysis (AUC = .71) and in the calibration analysis. The most likely explanation for this finding is based on the high risk of this population: the POSSUM equation has proven to be accurate in various studies,[2,16–18] except for patients at low risk and elderly patients with hip fractures,[19] in whom it tended to overestimate mortality. Nonagenarians, however, even healthy ones, are a group of patients with higher risk for death than the rest of the population.[20] As a result, the POSSUM proved accurate, and it was further improved when the extra age category validated by Tran Ba Loc et al[8] included a higher coefficient for nonagenarians (ie, when it was modified to consider fourth-age patients as a separate, more

Table 1 AUCs for the different scores

Score	AUC	95% Confidence Interval
POSSUM	.70	.60–.80
P-POSSUM	.70	.59–.80
Modified POSSUM	.71	.61–.80
Modified P-POSSUM	.64	.56–.77
E-POSSUM	.69	.59–.79
Donati score	.60	.50–.72

Table 2 Linear analysis of mortality predicted by the different scores

Decile Risk	POSSUM n*	POSSUM Deaths†	POSSUM Predicted Mortality‡	POSSUM O/E Ratio	P-POSSUM n*	P-POSSUM Deaths†	P-POSSUM Predicted Mortality‡	P-POSSUM O/E Ratio	E-POSSUM n*	E-POSSUM Deaths†	E-POSSUM Predicted Mortality‡	E-POSSUM O/E Ratio	modPOSSUM n*	modPOSSUM Deaths†	modPOSSUM Predicted Mortality‡	modPOSSUM O/E Ratio	Donati score n*	Donati score Deaths†	Donati score Predicted Mortality‡	Donati score O/E Ratio
0–10	14	2	1	2	50	11	2	5.5	37	8	2	4	7	1	0	—	69	21	3	7
10.1–20	35	10	5	2	28	8	4	2	28	8	4	2	21	4	3	1.33	21	5	3	1.67
20.1–30	19	3	5	.6	14	4	3	1.33	22	6	5	1.2	18	5	5	1	30	12	7	1.71
30.1–40	19	6	7	.86	6	2	2	1	16	6	6	1	20	5	7	.71	0	—	—	—
40.1–50	16	6	7	.86	11	6	5	1.2	8	5	4	1.25	15	5	7	.71	3	3	1	3
50.1–60	8	5	4	1.25	4	3	2	1.5	6	4	3	1.33	17	5	9	.55	2	2	1	2
60.1–70	4	4	3	1.33	5	3	3	1	3	2	2	1	10	5	6	.83	0	0	—	—
70.1–80	5	2	4	.5	3	2	2	1	2	1	1	1	8	7	6	1.16	1	1	1	1
80.1–90	5	5	4	1.25	3	3	3	1	4	4	3	1.33	7	4	6	.66	0	0	—	—
90.1–100	1	1	1	1	2	2	2	1	0	—	—	—	3	3	3	1	0	—	—	—
0–100	126	44	41	1.07	126	44	28	1.57	126	44	30	1.47	126	44	52	.85	126	44	16	2.75

*Number of patients in each decile for each score.

†Actual number of deaths.

‡Number of deaths predicted by each score (in all cases, the figures were rounded to the nearest whole number).

Table 3 Results of the contingency table based on the linear analysis

Score	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
POSSUM	.80	.93	.85	.89
P-POSSUM	.64	1.00	1.00	.84
E-POSSUM	.68	1.00	1.00	.85
Modified POSSUM	.94	.86	.71	.97
Donati score	.36	1.00	1.00	.75

vulnerable group. Accordingly, the P-POSSUM, which was developed to improve the accuracy of the POSSUM with low-risk patients,[21] did not have optimal performance (especially in the calibration tests) with this high-risk population. Regarding the E-POSSUM, its poor predictive power might reflect either the fact that it was also developed for the young old or its specificity for colorectal surgery. At this point, we might suggest that a population-specific score rather than a procedure-specific one seems more reasonable for nonagenarians.

As far as the Donati score is concerned, its poor outcomes can be ascribed to two causes. On one hand, the first of the four variables it is based on, age, was virtually constant in our population (all patients were in their 90s). By contrast, the second and most important variable in this scale, the American Society of Anesthesiologists (ASA) score,[9] which has a large impact in the final result, is fairly subjective. Especially in this population, anesthetists tend to grade patients with higher scores just because they are old and seem fragile.

It is particularly surprising that both POSSUM and modified POSSUM had good outcomes in both calibration tests, the linear and the exponential analyses. Normally, POSSUM shows better outcomes with the exponential method, whereas P-POSSUM does so with the linear method.[15] Furthermore, in our findings, the O/E ratios of POSSUM and modified POSSUM were closer to 1 with the linear analysis (1.07 and .85) than with the exponential analysis (1.69 and 1.22).

The accuracy of these scores, particularly the modified POSSUM, was further confirmed with sensitivity, specificity, and positive and negative predictive values. The advan-

Table 4 Summary of the outcomes obtained in the exponential analysis

Score	O:E ratio
POSSUM	1.69
P-POSSUM	2.20
E-POSSUM	2.09
Modified POSSUM	1.22

tage of the analysis stratum by stratum is that it illustrates how many true-positives, true-negatives, false-positives, and false-negatives there were in each decile of risk predicted by the scores. In this way, it explains the apparent lack of consistency between the discrimination and calibration methods. The ROC analysis yielded similar AUCs for most POSSUM-based scores, but by calculating the number of accurate and false predictions in each stratum, two phenomena become clear: on one hand, most scores underestimate risk in the lower strata, where they allocate most of the patients (in Table 2, all the scores except modified POSSUM have O/E ratios ≥ 2 in the first two deciles), but on the other hand, they compensate for these inaccuracies by overestimating the risk in higher deciles. As a result, the overall inaccuracies are balanced, and the curves seem similar. On the contrary, the modified POSSUM shows both a good AUC in the ROC analysis and good sensitivity, specificity, positive and negative predictive values. Considering that the tool is useful as long as it can be applied in a case-by-case manner, apart from good discrimination, good calibration is crucial. Only the modified POSSUM has proven it in this population.

To illustrate how the different scores function, it is useful to analyze a few cases. We will look at a patient with low risk and another with high risk. The first case was a woman aged 91 years, with an ASA score of 2, operated on an incarcerated hernia who arrived at the operating room in fairly stable condition (slightly hypertensive, 13,800 leukocytes, and blood urea nitrogen of 4.65 mmol/L.) The procedure was uneventful, total blood loss was between 100 and 300 mL, and there was minor peritoneal soiling. This woman had a POSSUM of 6%, a P-POSSUM of 2%, an E-POSSUM of 3%, a modified POSSUM of 8%, and a Donati score of 2%. The patient survived the first postoperative month. This case illustrates how, for these very low risk patients, all scores predicted a mortality rate < 10%. Furthermore, when being informed about the risk, the family can be told that the best-case scenario has a mortality < 10%; nevertheless, this percentage can increase if unexpected findings or complications occur, for example, if the procedure requires a bowel resection because of ischemia or intestinal content is found in the abdomen, the risk could increase considerably: POSSUM would increase to 18%, P-POSSUM to 5%, E-POSSUM to 8%, and modified POSSUM to 30% (the Donati score would remain unchanged).

Our second case highlights the other end of the spectrum: it was also a woman aged 91 years, with an ASA score of 3, who underwent an exploratory laparotomy. In the preoperative examination, she was found to have tachycardia (heart rate, 117 beats/min), normal blood pressure, anemia (hemoglobin, 8 mg/dL), a leukocyte count of 24,200, and a plasma sodium level of of 135 mmol/L. During the procedure, an occlusive abscessed neoplasm was found in the colon, with local peritoneal pus. The surgeon decided to perform a right hemicolectomy with laterolateral anastomosis. Intraoperative bleeding was 700 mL. The scores were calculated as follows: POSSUM of 48%, P-POSSUM of 31%, E-POSSUM of 30%, modified POSSUM of 60%, and Donati score of 26%. The postoperative period was complicated by an anastomotic leak, and the patient died of sepsis 17 days after the procedure. In this situation, if the surgeon had been able to quantify the risk, perhaps he would have chosen a less aggressive procedure.

In any case, the low performance of the Donati score, as stated above, derives mainly from the subjectivity of the ASA classification and the fact that it is purely preoperative. Regarding the other scores, although they do take into account operative severity, they underestimate the age-dependent increase in risk; and this explains why the modified POSSUM was shown to be more accurate. In other words, the advantage of the modified POSSUM over the other scores is the steeper increase in predicted risk, which is probably excessive for a younger population but not for these elderly patients.

Some limitations to this study are worth mentioning. First, the number of patients was limited. Most studies use larger samples,[8,21,22] but nonagenarians are a fast-growing but still small group. As a result, it took our team, at one of the biggest hospitals in Barcelona, 4.5 years to collect a sample with acceptable statistical power. A larger sample would have allowed actual comparisons among the different scores.

Second, the study was not designed or powered to formulate a new score. The modified POSSUM is not a new score but a broader version of an existing and validated one. Furthermore, the addition of an extra coefficient to the age category had been previously described and validated.

Third, the value of this score to predict postoperative mortality before the actual procedure is limited, because it depends on intraoperative variables. Nevertheless, it does provide the medical team with a tool to assess the risk in possible alternative scenarios. This way, patients can be informed of the treatments available, their risk, and the added risk for death when complications occur. Although this is not always possible in the emergency setting, it is important to offer patients and their families the clearest picture, so that they can provide (or withhold) responsible consent. Furthermore, the quantification of risk might help them understand why a procedure should be postponed or why the surgery should be less severe.

Fourth, the ability of the score to predict mortality might seem modest compared with other studies, but it is the first score ever tested for nonagenarians. In this respect, Dalton et al[23] have recently published an interesting index for risk quantification. It is simple, straightforward, and accurate, but it covers the age range between 10 and 90 years (ie, nonagenarians are not considered).

Conclusions

Mortality among nonagenarians undergoing emergency surgery is high, and the POSSUM with a modification in the age category proved to be both an accurate and a cost-effective tool to assess their risk for death. Although the decision whether to operate or not should not be based on it, it could help objectively assess (and inform) the risk for the different possible scenarios arising from such a decision. Furthermore, as an audit tool, it can help compare surgical outcomes for this population within different teams of different hospitals and to plan resources. This is particularly relevant in a fast-growing group so scarcely studied and with such high morbidity and mortality as nonagenarians.

References

1. Christensen K, Doblhammer G, Rau R, et al. Ageing populations: the challenges ahead. Lancet 2009;374:1196–208.
2. Copeland GP, Jones D, Walters M. POSSUM: a scoring system for surgical audit. Br J Surg 1991;78:355–60.
3. Dodds C, Kumar C, Servin F. Anaesthesia for the elderly patient. Oxford, UK: Oxford University Press; 2007.
4. Hobson SA, Sutton CD, Garcea G, et al. Prospective comparison of POSSUM and P-POSSUM with clinical assessment of mortality following emergency surgery. Acta Anaesthesiol Scand 2007;51:94–100.
5. Brooks MJ, Sutton R, Sarin S. Comparison of surgical risk score, POSSUM and P-POSSUM in higher-risk surgical patients. Br J Surg 2005;92:1288–92.
6. Whiteley MS, Prytherch DR, Higgins B, et al. An evaluation of the POSSUM surgical scoring system. Br J Surg 1996;83:812–5.
7. Wijesinghe LD, Mahmood T, Scott DJ, et al. Comparison of POSSUM and the Portsmouth predictor equation for predicting death following vascular surgery. Br J Surg 1998;85:209–12.
8. Tran Ba Loc P, du Montcel ST, Duron JJ, et al. Elderly POSSUM, a dedicated score for prediction of mortality and morbidity after major colorectal surgery in older patients. Br J Surg 2010;97:396–403.
9. Donati A, Ruzzi M, Adrario E, et al. A new and feasible model for predicting operative risk. Br J Anaesth 2004;93:393–9.
10. Severn AM. Time to light the grey touchpaper! The challenge of anaesthesia in the elderly. Br J Anaesth 2001;87:533–6.
11. Ackermann RJ, Vogel RL, Johnson LA, et al. Surgery in nonagenarians: morbidity, mortality, and functional outcome. J Fam Pract 1995; 40:129–35.
12. Pelavski AD, Lacasta A, Rochera MI, et al. Observational study of nonogenarians undergoing emergency, non-trauma surgery. Br J Anaesth 2011;106:189–93.
13. World Health Organization. Ageing and health: technical report. Geneva, Switzerland: World Health Organization; 2001.
14. Pace NL, Stylianou MP. Advances in and limitations of up-and-down methodology: a precis of clinical use, study design, and dose estimation in anesthesia research. Anesthesiology 2007;107:144–52.
15. Neary WD, Heather BP, Earnshaw JJ. The Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (POSSUM). Br J Surg 2003;90:157–65.
16. Copeland GP, Jones D, Wilcox A, et al. Comparative vascular audit using the POSSUM scoring system. Ann R Coll Surg Engl 1993;75: 175–7.
17. Sagar PM, Hartley MN, Mancey-Jones B, et al. Comparative audit of colorectal resection with the POSSUM scoring system. Br J Surg 1994;81:1492–4.
18. Mohamed K, Copeland GP, Boot DA, et al. An assessment of the POSSUM system in orthopaedic surgery. J Bone Joint Surg 2002;84:735–9.
19. Ramanathan TS, Moppett IK, Wenn R, et al. POSSUM scoring for patients with fractured neck of femur. Br J Anaesth 2005;94:430–3.
20. Formiga F, Ferrer A, Chivite D, et al. Predictors of long-term survival in nonagenarians: the NonaSantfeliu study. Age Ageing 2011;40: 111–6.
21. Prytherch DR, Whiteley MS, Higgins B, et al. POSSUM and Portsmouth POSSUM for predicting mortality. Br J Surg 1998;85:1217–20.
22. Al-Homoud S, Purkayastha S, Aziz O, et al. Evaluating operative risk in colorectal cancer surgery: ASA and POSSUM-based predictive models. Surg Oncol 2004;13:83–92.
23. Dalton JE, Kurz A, Turan A, et al. Development and validation of a risk quantification index for 30-day postoperative mortality and morbidity in noncardiac surgical patients. Anesthesiology 2011;114:1336–44.

Appendix

The POSSUM and related systems are all based on two groups of variables: 12 physiologic, which are recorded preoperatively and yield the physiologic score, and 6 operative, recorded during or after surgery, which yield the operative score. The physiologic variables are age, cardiac signs, respiratory history, blood pressure, pulse, Glasgow coma score, hemoglobin, white cell count, urea, sodium, potassium, and electrocardiographic findings. The operative variables are operative severity, multiple procedures, total blood loss, peritoneal soiling, presence of malignancy, and mode of surgery.

Each variable is given a coefficient of 1, 2, 4, or 8 according to the degree of alteration: 1 is the normal weighted class for the variable, and 2, 4, and 8 represent progressive degrees of distortion.

For the POSSUM and the P-POSSUM, the age category can receive only 3 coefficients: 1 ($\leq$60 years), 2 (61–71 years), and 4 ($\geq$71 years). Tran Ba Loc et al[8] added an extra age class to the E-POSSUM. In their system, all patients aged $>$ 85 years were given a coefficient of 8.

With the physiologic and operative scores, the different scales calculate the mortality risk using the following equations:

$$\text{POSSUM} = 1/(1 + e^X),\ \text{where } X = -7.04 + (.13 \times \text{physiologic score}) + (.16 \times \text{operative score});$$

$$\text{POSSUM} = 1/(1 + e^Y),\ \text{where } Y = -9.37 + (.19 \times \text{physiologic score}) + (.15 \times \text{operative score});$$

and

$$\text{E-POSSUM} = 1/(1 + e^Z),\ \text{where } Z = -7.69 + (.14 \times \text{physiologic score}) + (.11 \times \text{operative score}).$$

The Donati score assesses 4 preoperative variables ASA score, age, severity of the procedure, and mode of surgery. ASA score and age are continuous variables, whereas severity and mode of surgery are both categorical, and each is divided into 3 weighted classes. The severity of a procedure can be minimal to moderately invasive (grade I), moderate to significantly invasive (grade II), or highly invasive (grade III). The mode of surgery can be elective, urgent, or emergency.