SCIENCEFORECAST
A digital science library
Research Article
Published: 22 Jan, 2021
Journal of Anesthesia Forecast

Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM) System for Outcome Prediction in Elderly Patients Submitted to Hip Fracture Emergency Surgery

Teles AR[1]*, de Castro JM[2], Teixeira IM[2], Mourão JB[3] and de Azevedo LFR[4]

[1]Department of Anaesthesiology, Hospital São João, Porto, Portugal

[2]Department of Anaesthesiology, University of Oporto, Porto, Portugal

[3]Department of Surgery and Physiology, University of Porto, Porto, Portugal

[4]MEDCIDS- Department of Community Medicine, Information and Health Decision Sciences & CINTESIS-Centre for Health Technology and Services Research, University of Porto, Porto, Portugal

Abstract

Purpose: Evaluate the performance POSSUM system (POSSUM, P-POSSUM and Orthopedic-POSSUM) on predicting 30-day morbimortality in elderly patients undergoing emergent hip fracture surgery.

Methods: A retrospective cohort study was conducted in all elderly patients (≥65 years-old) admitted, at a University Hospital, with hip fracture, that underwent surgery during one year. From 408 patients selected, 328 were excluded for not being submitted to emergency surgery. Data from the remaining 80 patients was retrospectively collected from clinical files. POSSUM system's performance and calibration for predicting morbimortality were assessed. Observed *vs* expected morbidity and mortality were compared using area under Receiver Operating Characteristic (ROC-AUC) curves and Standardized Mortality Ratio (SMR) and the model goodness of fit was assessed using the Hosmer-Lemeshow Test (H-LT).

Results: The overall rate of 30 days mortality and morbidity was 6.3% and 38.8%, respectively. ROC curves of POSSUM system showed good discriminative ability for mortality (AUC=0.879; 95% CI 0.763-0.994) but poor for morbidity (AUC=0.647; 95% CI 0.524-0.771). All models showed good calibration and goodness of fit (H-LT *p*-values for O-POSSUM/POSSUM and P-POSSUM were respectively 0.4627 and 0.2476 for mortality and 0.0932 for O-POSSUM morbidity). SMR indicated significantly fewer than expected deaths for O-POSSUM/POSSUM (0.525; 95% CI 0.065-0.985) but not for P-POSSUM (1.321; 95% CI 0.163-2.479).

Conclusions: POSSUM system is better for predicting mortality than morbidity. All models showed good calibration and goodness of fit. However, SMRs showed mixed results. We showed that POSSUM can be used for predicting 30-day mortality in elderly patients undergoing emergent hip fracture surgery.

Keywords: Anaesthesiology; Aged; Mortality; Morbidity; Risk assessment

Introduction

Hip fractures caused by low-energy trauma are one of the most serious consequences of osteoporosis. According to the World Health Organization (WHO), hip fractures frequently result in chronic pain, loss of mobility, decreased functional capacity and increased mortality. They are one of the most serious consequences of osteoporosis; and often caused by low-energy trauma. All patients with this type of fracture often need prolonged hospitalization, with almost all requiring surgical intervention [1]. It is estimated that, after a year of hip fracture 20 to 30% of these patients die [2], 50-60% have some kind of functional and/or motor loss and only 30-40% of patients obtain functional recovery levels prior to fracture. The majority still requires long-term assistance care, so their medical and socio-economic impact is meaningful and is not limited to the event itself, but rather its consequences [1].

OPEN ACCESS

***Correspondence:**
Ana Rita Teles, Department of Anaesthesiology, Hospital São João, Porto, Portugal.
E-mail: *anarita_teles@hotmail.com*
Received Date: *13 Dec 2020*
Accepted Date: *18 Jan 2021*
Published Date: *22 Jan 2021*
Citation: *Teles AR, de Castro JM, Teixeira IM, Mourão JB, de Azevedo LFR. Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM) System for Outcome Prediction in Elderly Patients Submitted to Hip Fracture Emergency Surgery. J Anesthesia Forecast. 2021; 4(1): 1010.*
Copyright © *2021 Teles AR. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.*

In Portugal, between year 2000 and 2008, 77083 hip fractures were recorded [1] and studies obtained mortality values of 31% in men and 14.1% in women, after 6 months of hip fracture. In the same study, the overall mortality at 12 months was 26.8%, with values of 48.3% in men and 22.2% in women. In general, mortality rates for this cause increases with age and is more frequent in males, where complications also tend to be more serious [2]. All-cause mortality risk in the first 3 months subsequent to hip fracture in older adults increases by 5 to 8-fold. Both women and men face increased annual mortality over time. Excess annual mortality after hip fracture is higher in men than in women at any given age [3].

Copeland et al., [4] developed and validated a score system named POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity) featuring 18 factors divided into two component parts 12 physiological factors (PS) and 6 operative factors (OS). Each factor is scored exponentially increasing from 1 to 8 (1, 2, 4 and 8) dependent upon grading. This system has also been subsequently used for comparing surgeons, resource usage and to compare surgical outcomes in different countries [5].

A new risk model (P-POSSUM) was developed and validated in a large single centre cohort in Portsmouth using alternative risk equations for the same variables [6]. However, due to the original authors' lack of confidence in the reporting of peri-operative complications this model has no morbidity prediction equation [6]. The POSSUM and P-POSSUM systems have proved to be the most reliable and widely applicable scoring methods, with studies showing its effectiveness in predicting mortality and morbidity rates [4,6]. Orthopedic-POSSUM (O-POSSUM) system, a minor adjustment of the POSSUM scoring system, demonstrates that POSSUM can be used as an audit aid to assess the quality of orthopaedic care [7,8].

The aim of this study is to evaluate the performance POSSUM system score (POSSUM, P-POSSUM and O-POSSUM) on predicting 30-day morbimortality of elderly patients undergoing emergent hip fracture surgery.

Methods

Ethics

This study has received ethical approval from São João Health Centre Medical Ethics Committee, Porto, Portugal on 8th November 2016.

Study design

A retrospective cohort study was conducted in all elderly patients (65 or more years-old) admitted, at a University Hospital (São João's Hospital), with hip fracture, that underwent surgery during one year.

Patients

From 408 patients submitted to hip fracture surgery, 328 were excluded for not being submitted to emergency surgery. Data from the remaining 80 was retrospectively collected from the clinical files and included patient age and gender, diagnosis, type of surgery, date of admission, surgery and discharge of the hospital, ASA, comorbidities, physiological and operative parameters, morbidity and mortality.

POSSUM system

The POSSUM score describes 18 factors in two component parts: 12 physiological factors (PS) and 6 operative factors (OS) (Table 1). Each factor is scored exponentially increasing from 1 to 8 (1,2,4 and 8) dependent upon grading [4,6,7]. From these values predicted mortality can be calculated using formulae described. P-POSSUM, using alternative risk equations for the same variables, also calculate the predicted mortality [6]. Almost all the score variables were available for every patient, but when a figure was missing, a score of 1 was allocated.

PS and OS were calculated for each admitted patient and entered onto a database and from these values POSSUM, P-POSSUM and O-POSSUM scores were calculated for each patient. Predictions of mortality and morbidity for individual patients were estimated using the following equations [4,6,7] in which R1 relates to the mortality risk and R2 to the morbidity risk:

Mortality:

POSSUM $Ln[R1/(1-R1)]=-7.04+(0.13xPS)+(0.16xOS)$

P-POSSUM $Ln[R1/(1-R1)]=-9.065+(0.1692xPS)+(0.155xOS)$

O-POSSUM $Ln[R1/(1-R1)] =-7.04+(0.13xPS)+(0.16xOS)$

Morbidity:

O-POSSUM $Ln[R2/(1-R2)] =-5.91+(0.16xPS)+(0.19xOS)$

These are logistic regression models calculated from PS and OS scores. PS and OS scores are calculated as the sum of the score of each of the items.

The outcome was assessed as 30-day morbidity and mortality, which allowed comparability with the system for general surgery. The hospital mortality and long-term mortality (at 30,60 and 90 days) was accessed through the consultation of the Electronic Health Record-SClinic and RNU-Registo Nacional de Utentes (National Registers of Patients). The presence of the following complications was recorded as morbidity: infection, hemorrhage, other wound problems, thromboembolic complications, cardiac, respiratory, renal and unanticipated displacement of an implant. Exact definitions have been described previously [4]. We also recorded other complications as non-fatal cardiac arrest, angina and other cardiac complications, pleural effusion, pneumothorax, bronchospasm, newly required respiratory support, newly required supplemental oxygen and other pulmonary complications, defined by ESA-ESICM joint taskforce on per-ioperative outcome measures [9].

Statistical analysis

Descriptive statistics are presented as numbers and percentages for categorical variables; and as mean and Standard Deviation (SD) for continuous variables, or as median and Inter-Quartile Range (IQR-25th percentile-75th percentile), if the variable empirical distribution function was skewed.

The quality of the POSSUM system score models for mortality and morbidity was assessed. Models goodness-of-fit was assessed by the Hosmer-Lemeshow statistic and test and standardized mortality/morbidity ratios. Discriminative/predictive power of the models was evaluated by ROC curve analysis.

A predictive model like a simple diagnostic test for a particular disease or outcome may classify patients into two groups: those with the outcome as assessed by the test result (test positive) and those without it (test negative). A model or a test are assessed by its ability to diagnose the outcome correctly, whether this is positive or negative [10]. The Receiver Operating Characteristic (ROC) curve is a plot of sensitivity *vs* 1-specificity and it's one of the most common measures of the global test or model discrimination ability. This curve assesses how well a test or a model discriminates individuals into two classes, such as death and alive comparing the test against the actual outcome. The Area Under the Curve (AUC) of the plot (also known as the C-statistic or C-index) assess the discrimination, with 1 being a perfect discriminating test and 0.5 having no discriminative value [10-12]. Discrimination is acceptable for 0.7≤AUC<0.8, excellent for 0.8≤AUC<0.9 and outstanding for AUC≥0.9 [12]. Analysis *via* ROC curves therefore provides not only a useful means to assess the diagnostic accuracy of a given test or predictive model, but also allows for different diagnostic tests or predictive models to be compared [10].

To evaluate model performance it is also important to know whether or not the number of observed events matches the number of predicted events over the range of model predictions. An assessment of calibration or goodness-of-fit of a predictive model may, for example, directly compare the observed and predicted probabilities of the event across subgroups. Because "observed risk" or proportions can only be estimated within groups of individuals, measures of calibration usually form subgroups and compare predicted probabilities and observed proportions within these subgroups [11]. The Hosmer-Lemeshow Test (H-LT) is the most popular measure of goodness-of-fit which forms such subgroups, typically using deciles of estimated risk of events. Within each decile of risk, the estimated observed proportion and the average estimated predicted probability are calculated and compared [11]. The estimated mortality and morbidity rates for each individual and group are obtained through the predictions calculated with each one of the model equations (POSSUM, P-POSSUM or O-POSSUM). The H-LT statistic has a chi-squared distribution with g-2 degrees of freedom, where g is the number of subgroups formed. Although deciles of event risk are most commonly used to form subgroups, other categories, such as those formed on the basis of the predicted probabilities themselves (such as 0 to <5%, 5 to <10%, etc.), may in some cases be more clinically useful [11].

Standardized Mortality Ratio (SMR) is a ratio between the observed number of deaths in a study population and the expected number of deaths, based on the age- and sex-specific rates in a standard population and the age and sex distribution of the study population. If the SMR is significantly greater than 1.0, there is evidence of "excess deaths" in the study population.

The statistical significance level was set at 5% and differences were considered statistical significant when $P<0.05$. Statistical analyses were carried out using SPSS 23 [13].

Results

Over a period of 24 months (from 1st January 2014 to 31st December 2015) there were 408 orthopedic hip operations of which 80 (19.6%) were emergency procedures (36 in 2015 and 44 in 2014). Of these surgeries, 24 (30%) were total hip replacements and 56 (70%) were partial hip replacements. The mean age of individuals studied was 84.1±8.6 SD, with 81% being female. Other baseline demographic and clinical characteristics of the sample are described in Table 2.

The overall rate of 90 days mortality was 13.8% (of which 54.5% occurred during the hospitalization). The overall rate of 30 and 60 days mortality were respectively 6.3% and 7.5%. The overall rate of 30 days morbidity was 38.8%. The detailed list of postoperative complications used to classify the morbidity status is described in Table 3.

The POSSUM system logistic regression equation yields an overall predicted 30 days mortality of 9.41 patients (versus 5 observed) for O-POSSUM/POSSUM and 3.76 patients (*versus* 5 observed) for P-POSSUM. The O-POSSUM equation predicted 30 days morbidity of 39.16 patients (*versus* 31 observed) (Tables 4,5 and 6).

Analysis of area under the Receiver Operating Characteristic (ROC-AUC) curves of POSSUM system showed good discriminative ability for mortality (AUC=0.879; 95% CI 0.763-0.994) but poor for morbidity (AUC=0.647; 95% CI 0.524-0.771) (Figure 1 and 2).

All models showed good calibration as assessed by the ROC curve analysis and adequate goodness of fit as assessed by the Hosmer-Lemeshow Test (H-LT) (H-LT *p*-values for O-POSSUM/POSSUM and P-POSSUM were respectively 0.4627 and 0.2476 for mortality and 0.0932 for O-POSSUM morbidity) (Tables 4,5 and 6).

Standardized Mortality Ratio (SMR) indicated significantly fewer than expected deaths for O-POSSUM/POSSUM (0.525; 95% CI 0.065-0.985) but not for P-POSSUM (1.321; 95% CI 0.163-2.479). Standardized Morbidity Ratio (SMbR) demonstrated that observed and expected morbidity was similar (0.778; 95% CI 0.504-1.052).

Table 1: POSSUM system physiology and operative score variables.

Physiology score	Operative score
Age	Grade of operation
Cardiac Signs	Number of procedures
Respiratory Signs	Total blood loss
Systolic blood pressure	Peritoneal soiling
Pulse rate	Presence of malignancy
Glasgow Coma Score	Timing of operation
Hemoglobin level	
White blood cell count	
Serum sodium	
Serum potassium	
Serum urea	
Eletrocardiogram	

Table 2: Patient demographics, ASA, Charlson and POSSUM baseline data.

Number of patients	n=80
Median age (years) (IQR)	85 (78.25-90.75)
Women (%)	65 (81.3)
Men (%)	15 (18.8)
Median ASA (IQR)	3 (2 -3)
Mean Charlson score (±SD)	2.1 (1.8)
Mean Charlson score age adjusted (±SD)	5.1 (3.3)
Mean hemoglobina (±SD)	12.4 (1.7)
Mean white blood cell count (±SD)	10.7 (3.5)
Mean serum sodium (±SD)	136.6 (4.3)
Mean serum potassium (±SD)	4.1 (0.5)
Mean serum urea (±SD)	56 (28.2)
Abnormal ECG (%)	23.8
Known cardiac co-morbidity (%)	81.3
Known respiratory co-morbidity (%)	3.8
Mean days of post-operative hospitalization (±SD)	12.1 (16.4)

Table 3: The number of patients with post-operative complications.

Complication	n (%)
Cardiovascular	
Non-fatal cardiac arrest	0 (0)
Acute myocardial infarction	4 (5)
Congestive heart failure	1 (1.3)
New cardiac arrhythmia	0 (0)
Angina	0 (0)
Stroke	0 (0)
Other cardiac complications	2 (2.5)
Pulmonary	
Pulmonary embolism	1 (1.3)
Respiratory infection	8 (10)
Respiratory failure	9 (11.3)
Pleural effusion	4 (5)
Atelectasis	2 (2.5)
Pneumothorax	1 (1.3)
Bronchospasm	0 (0)
Aspiration pneumonitis	1 (1.3)
New requirement for respiratory support	1 (1.3)
New requirement for supplemental oxygen	6 (7.5)
Complication	n (%)
Other pulmonary complications	0 (0)
Renal	11 (13.8)
Postoperative hemorrhage	8 (10)
Infection	
Surgical site infection (superficial)	4 (5)
Surgical site infection (deep)	2 (2.5)
Surgical site infection (organ/space)	0 (0)
Urinary	8 (10)
Infection source uncertain	2 (2.5)
Other wound problems	2 (2.5)
Unanticipated displacement of an implant	6 (7.5)

Some patients had multiple complications

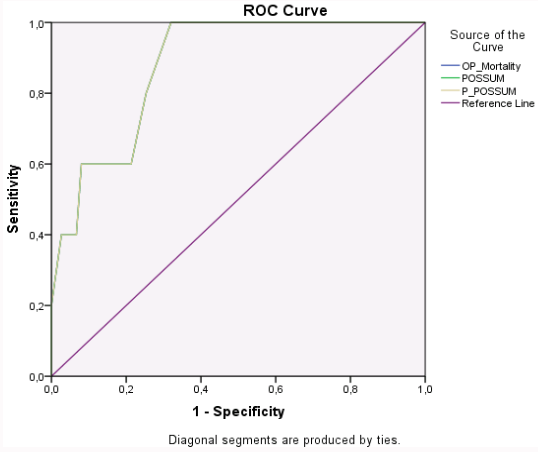

Figure 1: Receiver operating characteristic curve for performance of POSSUM system of 30 days mortality.

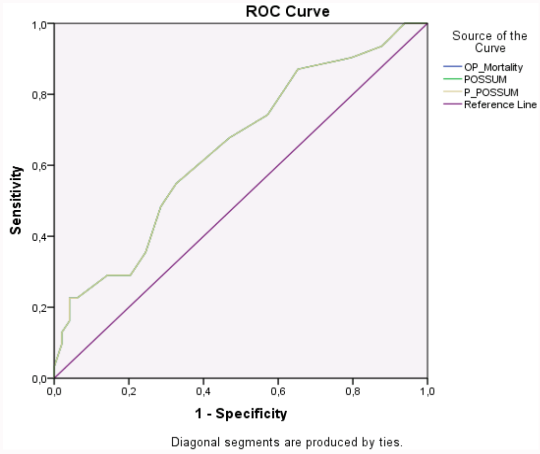

Figure 2: Receiver operating characteristic curve for performance of O-POSSUM score of 30 days morbidity.

Discussion

While some studies have found evidence that POSSUM adequately predicts individual patient morbidity and mortality risk [14-16], others have found this score significantly overestimates mortality [17-19].

P-POSSUM has proven to more accurately predict in-hospital mortality than POSSUM [6,14,18-20] Studies performed in different settings have shown P-POSSUM to both over-predict [17,21] and under-predict mortality [14,22,23].

A study with patients undergoing major digestive surgery showed poor calibration (goodness of fit) and overestimation of O: E ratios, which considerably limits the value of P-POSSUM for outcomes

Table 4: Hosmer-Lemeshow goodness of fit test for O-POSSUM/POSSUM for 30 days mortality.

Groups of risk (deciles)	Number of observed deaths	Number of expected deaths	Mean risk of observed mortality	Mean risk of expected mortality	O:E	HL Statistic
1	2	1.420	0.500	0.355	1.410	0.370
2	1	2.570	0.083	0.214	0.390	1.220
3	0	0.450	0.000	0.149	0.000	0.530
4	2	1.250	0.200	0.125	1.601	0.520
5	0	1.460	0.000	0.098	0.000	1.620
7	0	0.590	0.000	0.084	0.000	0.640
8	0	0.600	0.000	0.074	0.000	0.640
9	0	0.530	0.000	0.066	0.000	0.570
10	0	0.550	0.000	0.055	0.000	0.580

chi-square = 6.68; df = 7; p-value = 0.4627

Table 5: Hosmer-Lemeshow goodness of fit test for P-POSSUM for 30 days mortality.

Groups of risk	Number of observed deaths	Number of expected deaths	Mean risk of observed mortality	Mean risk of expected mortality	O:E	HL Statistic
1	2	0.85	0.5	0.212	2.356	1.98
2	1	1.19	0.083	0.099	0.84	0.03
3	0	0.17	0	0.057	0	0.18
4	2	0.44	0.2	0.044	4.523	5.74
5	0	0.47	0	0.031	0	0.48
7	0	0.18	0	0.025	0	0.18
8	0	0.17	0	0.021	0	0.18
9	0	0.15	0	0.018	0	0.15
10	0	0.14	0	0.014	0	0.14

chi-square = 9.07; df = 7; p-value = 0.2476

Table 6: Hosmer-Lemeshow goodness of fit test for O-POSSUM for 30 days morbidity.

Groups of risk	Number of observed	Number of expected	Mean risk of observed morbidity	Mean risk of expected morbidity	O:E	HL Statistic
1	3	3.49	0.75	0.872	0.861	0.53
2	6	8.78	0.5	0.732	0.683	3.29
3	0	1.89	0	0.629	0	5.1
4	6	5.68	0.6	0.568	1.056	0.04
5	6	7.25	0.4	0.483	0.828	0.42
7	2	3.03	0.286	0.433	0.66	0.62
8	4	3.15	0.5	0.394	1.269	0.38
9	1	2.85	0.125	0.357	0.351	1.87
10	3	3.04	0.3	0.304	0.987	0

chi-square = 12.23; df = 7; *p*-value = 0.0932

prediction for particular patients [24]. In others studies, P-POSSUM had the least overestimation making it the most useful predictor of likely postoperative mortality [25,26]. POSSUM, particularly in lower-risk groups, generally over predicts mortality [14,26] and morbidity [25].

The performance of these models for a variety of surgical specialties, with a systematic review [27] has also been explored, with the P-POSSUM being reported as the most accurate model for predicting postoperative mortality after colorectal cancer surgery and the original POSSUM model as accurate in predicting post-operative complications. However, discrepancy between observed to expected mortality amongst individual studies is large. Similar O: E discrepancies have been reported in other surgical specialties [26,28].

This study shows that POSSUM system score models (POSSUM, P-POSSUM and O-POSSUM) have excellent discriminative ability between survivors and non-survivors, which corroborates previous studies [7,8] but we couldn't demonstrate the same for morbidity. Regarding model calibration, all models showed good calibration and goodness of fit as assessed by the Hosmer-Lemeshow Test (H-LT). Concerning Standardized Mortality Ratios (SMR), only the O-POSSUM/POSSUM indicated significantly fewer than expected deaths.

However, the results and conclusions of the present study ought to be seen in the context of its limitations. First, the retrospective design of our study imposed some limitations, such as missing or incomplete information that is required to calculate some variables. Second, since this study was conducted in a single hospital and only included elderly patients undergoing emergent hip fracture surgery, the sample size is reduced and the number of events is limited. Expanding this study to other centers or performs future prospective studies would improve the findings.

In conclusion, and despite the limitations of the study, we demonstrated that POSSUM system is better for predicting mortality than morbidity; and the POSSUM system can be safely used to predict 30-day mortality in elderly patients undergoing emergent hip fracture surgery, having excellent discriminative ability and good calibration.

References

1. Laires PA, Perelman J, Consciencia JG, Monteiro J, Branco JC. Epidemiology of hip fractures and its social and economic impact. An update for 2014. Acta Reumatol Port. 2015; 40: 223-230.
2. da Costa JA, Ribeiro A, Bogas M, Costa L, Varino C, Lucas R, et al. Mortality and functional impairment after hip fracture - a prospective study in a Portuguese population. Acta Reumatol Port. 2009; 34: 618-266.
3. Haentjens P, Magaziner J, Colon-Emeric CS, Vanderschueren D, Milisen K, Velkeniers B, et al. Meta-analysis: excess mortality after hip fracture among older women and men. Ann Intern Med. 2010; 152: 380-390.
4. Copeland GP, Jones D, Walters M. POSSUM: a scoring system for surgical audit. Br J Surg. 1991; 78: 355-360.
5. Barnett S, Moonesinghe SR. Clinical risk scores to guide perioperative management. Postgrad Med J. 2011; 87: 535-541.
6. Prytherch DR, Whiteley MS, Higgins B, Weaver PC, Prout WG, Powell SJ. POSSUM and Portsmouth POSSUM for predicting mortality. Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity. Br J Surg. 1998; 85: 1217-2120.
7. Mohamed K, Copeland GP, Boot DA, Casserley HC, Shackleford IM, Sherry PG, et al. An assessment of the POSSUM system in orthopaedic surgery. J Bone Joint Surg Br. 2002; 84: 735-739.
8. van Zeeland ML, Genovesi IP, Mulder JW, Strating PR, Glas AS, Engel AF.

POSSUM predicts hospital mortality and long-term survival in patients with hip fractures. J Trauma. 2011; 70: E67-E72.

9. Jammer I, Wickboldt N, Sander M, Smith A, Schultz MJ, Pelosi P, et al. Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European Perioperative Clinical Outcome (EPCO) definitions: a statement from the ESA-ESICM joint taskforce on perioperative outcome measures. Eur J Anaesthesiol. 2015; 32: 88-105.

10. Bewick V, Cheek L, Ball J. Statistics review 13: receiver operating characteristic curves. Crit Care. 2004; 8: 508-512.

11. Cook NR. Statistical evaluation of prognostic versus diagnostic models: beyond the ROC curve. Clin Chem. 2008; 54: 17-23.

12. Hosmer JDW, Lemeshow S. Applied Logistic Regression. John Wiley & Sons Inc. 2000.

13. IBM SPSS Statistics for Windows. IBM Corporation. 2014.

14. 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: 1288-1292.

15. Neary WD, Crow P, Foy C, Prytherch D, Heather BP, Earnshaw JJ. Comparison of POSSUM scoring and the Hardman Index in selection of patients for repair of ruptured abdominal aortic aneurysm. Br J Surg. 2003; 90: 421-425.

16. Campillo-Soto A, Flores-Pastor B, Soria-Aledo V, Candel-Arenas M, Andres-Garcia B, Martin-Lorenzo JG, et al. The POSSUM scoring system: an instrument for measuring quality in surgical patients. Cir Esp. 2006; 80: 395-399.

17. Senagore AJ, Warmuth AJ, Delaney CP, Tekkis PP, Fazio VW. POSSUM, p-POSSUM, and Cr-POSSUM: implementation issues in a United States health care system for prediction of outcome for colon cancer resection. Dis Colon Rectum. 2004; 47: 1435-1441.

18. Ramesh VJ, Rao GS, Guha A, Thennarasu K. Evaluation of POSSUM and P-POSSUM scoring systems for predicting the mortality in elective neurosurgical patients. Br J Neurosurg. 2008; 22: 275-278.

19. Wijesinghe LD, Mahmood T, Scott DJ, Berridge DC, Kent PJ, Kester RC. Comparison of POSSUM and the Portsmouth predictor equation for predicting death following vascular surgery. Br J Surg. 1998; 85: 209-212.

20. Tekkis PP, Kessaris N, Kocher HM, Poloniecki JD, Lyttle J, Windsor AC. Evaluation of POSSUM and P-POSSUM scoring systems in patients undergoing colorectal surgery. Br J Surg. 2003; 90: 340-345.

21. Gocmen E, Koc M, Tez M, Keskek M, Kilic M, Ertan T. Evaluation of P-POSSUM and O-POSSUM scores in patients with gastric cancer undergoing resection. Hepatogastroenterology. 2004; 51: 1864-1866.

22. Tamijmarane A, Bhati CS, Mirza DF, Bramhall SR, Mayer DA, Wigmore SJ, et al. Application of Portsmouth modification of physiological and operative severity scoring system for enumeration of morbidity and mortality (P-POSSUM) in pancreatic surgery. World J Surg Oncol. 2008; 6: 39.

23. Horzic M, Kopljar M, Cupurdija K, Bielen DV, Vergles D, Lackovic Z. Comparison of P-POSSUM and Cr-POSSUM scores in patients undergoing colorectal cancer resection. Arch Surg. 2007; 142: 1043-1048.

24. Merad F, Baron G, Pasquet B, Hennet H, Kohlmann G, Warlin F, et al. Prospective evaluation of in-hospital mortality with the P-POSSUM scoring system in patients undergoing major digestive surgery. World J Surg. 2012; 36: 2320-2327.

25. Chen T, Wang H, Wang H, Song Y, Li X, Wang J. POSSUM and P-POSSUM as predictors of postoperative morbidity and mortality in patients undergoing hepato-biliary-pancreatic surgery: a meta-analysis. Ann Surg Oncol. 2013; 20: 2501-2510.

26. Dutta S, Horgan PG, McMillan DC. POSSUM and its related models as predictors of postoperative mortality and morbidity in patients undergoing surgery for gastro-oesophageal cancer: a systematic review. World J Surg. 2010; 34: 2076-2082.

27. Richards CH, Leitch FE, Horgan PG, McMillan DC. A systematic review of POSSUM and its related models as predictors of post-operative mortality and morbidity in patients undergoing surgery for colorectal cancer. J Gastrointest Surg. 2010; 14: 1511-1520.

28. Patterson BO, Holt PJ, Hinchliffe R, Loftus IM, Thompson MM. Predicting risk in elective abdominal aortic aneurysm repair: a systematic review of current evidence. Eur J Vasc Endovasc Surg. 2008; 36: 637-645.