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Original Article

Surgery Section

Calibration and Discrimination of POSSUM and P-POSSUM Scores in Elective General Surgery: A Prospective Observational Study

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ABSTRACT

Introduction: Risk stratification is central to perioperative decision-making and audit. The Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (POSSUM) and its Portsmouth Modification (P-POSSUM) are widely used. Yet performance can vary by population and patient-procedure profile.

Aim: To evaluate the calibration and discrimination of POSSUM and P-POSSUM in elective general surgery at a tertiary Indian centre.

Materials and Methods: The present prospective observational study was conducted in the Department of General Surgery at Dr. D. Y. Patil Medical College, Hospital and Research Centre, Pune, Maharashtra, India, between January 2023 and March 2025. A total of 200 consecutive adults undergoing elective, non-cardiac general surgery were included. Primary endpoints were postoperative morbidity and 30-day all-cause mortality. Performance was assessed using Observed versus Expected (O:E) rates, Hosmer-Lemeshow goodness-of-fit, and Area Under the Receiver Operating Characteristic curve (AUROC). Diagnostic metrics {sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV)} were calculated.

Results: The mean age of the cohort was 52.4±14.8 years, with a predominance of males (male-to-female ratio 1.67:1). Observed morbidity was 52/200 (26.0%; 95% Confidence Interval (CI) 20.0-32.7) and 30-day mortality 8/200 (4.0%; 95% CI 1.8-7.8). POSSUM-predicted morbidity was 67/200 (33.5%; 95% CI 27.0-40.3) and mortality 12/200 (6%; 95% CI 3.1-10.0), giving O:E values of 0.78 (morbidity) and 0.68 (mortality). P-POSSUM predicted mortality 8/200 (4%; 95% CI 1.7-7.3) with an O:E of 0.96. Calibration by Hosmer-Lemeshow was acceptable for all models with p>0.85. P-POSSUM demonstrated superior discrimination for mortality compared with POSSUM (AUC 0.893, 95% CI 0.812-0.974 vs 0.841, 95% CI 0.732-0.950; p=0.042). For morbidity, the original POSSUM morbidity model showed moderate performance (AUC 0.772, 95% CI 0.689-0.855).

Conclusion: In elective general surgery, POSSUM remains adequate for morbidity estimation but overpredicts mortality. P-POSSUM shows near-unity calibration and better discrimination for mortality and should be preferred for perioperative risk stratification and audit in similar populations.

Keywords: Healthcare, Logistic models, Perioperative period, Prognostic models, Quality assurance, Risk adjustment

INTRODUCTION

Surgical risk prediction is a cornerstone of modern perioperative care, enabling clinicians to anticipate adverse outcomes, optimise resource allocation, and provide more informed patient counseling. The science of risk prediction has evolved from subjective clinical judgment to structured, evidence-based models that quantify perioperative risk. Early methods, such as the American Society of Anesthesiologists (ASA) grading, provided broad risk stratification; however, advances in surgical audit demanded more detailed tools that incorporated both physiological status and operative severity [1]. The development of quantitative systems, such as POSSUM and its derivatives, marked a significant step in surgical audit, offering objective and reproducible frameworks that link preoperative and intraoperative variables to outcomes [2]. More recently, Bedford JP et al., have stressed that perioperative risk scores remain vital for surgical audit but often generalise poorly unless locally validated, reinforcing their role as benchmarking tools in real-world settings [3].

Prospective Indian data have shown that both POSSUM and P POSSUM provide reasonably accurate predictions of postoperative morbidity and mortality in general surgical patients, particularly in higher risk groups, and can therefore be used to benchmark outcomes in this population [4]. Recent work on surgical risk prediction has shown that miscalibrated models can lead to both overestimation and underestimation of perioperative risk, promoting unnecessary interventions in some patients and insufficient escalation of care in others. Large contemporary evaluations of POSSUM type scores further demonstrate that systematic overprediction of mortality, particularly in low risk general surgical cohorts, can obscure true performance differences between units and misinform clinical decision making [5,6]. Thus, precision in surgical risk modelling is not merely academic but has real-world implications for patient safety and system efficiency. The POSSUM scoring system, introduced by Copeland GP et al., integrated 12 physiological and six operative variables into a logistic regression model to predict morbidity and mortality [2,7].

Its strength lies in the dual assessment of patient general status and operative insult, offering a comprehensive perioperative profile. However, subsequent validation revealed that its logistic regression model disproportionately inflates mortality estimates for straightforward elective procedures and fails to adjust for advances in perioperative care adequately. Moreover, the equal weighting of variables may not reflect their true clinical contribution, and the model's performance varies significantly between high-risk emergency and low-risk elective surgeries. Kim SY et al., in a Korean cohort of 400 gastrectomy patients, found that POSSUM predicted nearly double the actual mortality rate, leading to concerns about its applicability in low-risk elective gastrointestinal surgery [8]. In response, the Portsmouth modification (P-POSSUM) was developed, applying a revised regression equation while retaining the same variables, thereby refining the predictive capacity for mortality, especially in low-risk settings; calibration improved in several cohorts [9], though some limitations persisted in adjusting for contemporary perioperative improvements and case-mix variability [10,11]. Comparative evaluations of POSSUM and P-POSSUM have yielded mixed results across populations. Recent evaluations of POSSUM type scores in East Asian and hepatobiliary pancreatic cohorts have shown that P POSSUM generally provides better calibrated mortality estimates than the original POSSUM model, whereas both systems display only moderate accuracy and some miscalibration for predicting postoperative morbidity [12]. These findings underscore that while P-POSSUM refines mortality prediction, the two models remain complementary, and their relative performance may vary with demographic, institutional, and procedural characteristics.

In the Indian context, there is a conspicuous lack of prospective validation of these scoring systems. Most existing reports are retrospective, single-center analyses with small sample sizes, limiting their generalisability. Given the heterogeneity of Indian surgical practice, resource disparities, and diverse patient demographics, robust prospective evaluation is imperative. The present study was therefore designed to compare the predictive accuracy of POSSUM and P-POSSUM in elective general surgery patients across multiple centers, with endpoints including observed versus predicted mortality and morbidity, calibration (e.g., Hosmer Lemeshow), discrimination (e.g., AUROC), and potential clinical utility in perioperative planning.

MATERIALS AND METHODS

The present prospective observational study was conducted in the Department of General Surgery at Dr. D. Y. Patil Medical College, Hospital and Research Centre, Pune, Maharashtra, India, from January 2023 to March 2025, after approval from the Institutional Ethics Committee (IESC/PGS/2023/90). A total of 200 adult patients undergoing elective general surgical procedures were enrolled after obtaining informed consent from each participant.

Sample size calculation: A consecutive sampling approach was used. The sample size was determined using Cochran's formula [13] for proportions, a standard method for estimating the required number of participants when the parameter of interest is a single proportion.

$$n_0=\frac{z^2\times p\times(1-p)}{d^2}$$

Where:

- n_0=minimum sample size
- Z=standard normal deviate for 95% confidence (1.96)
- P=anticipated prevalence (expected complication rate) - Recent Indian cohorts report postoperative morbidity close to 25%, with 28% after elective surgery as demonstrated by Agarwal V et al., and 24.5% in geriatric vascular cohort by Dsouza RJ et al., [14,15]. We therefore set the value of p at 0.25, a conservative central estimate that balances these bounds and helps prevent overpowering or underpowering.
- d=absolute precision (margin of error tolerated) - Set at 6% (0.06)

$$n_0=\frac{1.96^2\times 0.25\times(1-0.25)}{0.06^2}$$

$$n_0=\frac{3.8416\times 0.1875}{0.0036}$$

$$n_0=200.08$$

$$n_0\approx 200$$

Inclusion criteria: Adults (≥18 years) undergoing elective, non-cardiac general surgical procedures, including gastrointestinal, hepatobiliary, abdominal wall, breast, thyroid, and soft-tissue operations. Elective surgery was defined according to the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) classification as procedures planned and scheduled in advance, without the need for immediate intervention due to acute physiological deterioration [16]. Only patients with complete preoperative physiological and intraoperative data sufficient to calculate POSSUM and P-POSSUM scores were included. Eligible participants were limited to those classified as ASA physical status I-III, ensuring that outcomes reflected model performance in routine elective practice. Patients were enrolled only if reliable 30-day follow-up could be obtained through clinic visits, telephone review, or electronic medical records.

Exclusion criteria: Emergency, urgent, or expedited surgeries (e.g., perforated viscus, active haemorrhage, bowel obstruction) were excluded, as were pregnant patients and cases from other surgical specialties-such as cardiothoracic, neurosurgery, transplant, or obstetrics-for which dedicated risk models exist. Patients undergoing minor procedures not requiring an operative severity score (e.g., day-case local excisions, diagnostic endoscopy) were excluded, since key POSSUM variables could not be derived. Those with missing mandatory data despite reasonable retrieval efforts, or with preoperative sepsis or septic shock as defined by Sepsis-3 criteria, were excluded because their acute physiology would disproportionately influence scoring. Finally, patients with severe end-organ failure necessitating life support preoperatively, or with profound chronic immunosuppression where attribution of complications was unreliable, were not considered for inclusion.

Study Procedure

For each enrolled patient, the 12 physiological and six operative parameters required to compute the POSSUM score [1] were meticulously recorded during the preoperative and intraoperative periods, as shown in [Table/Fig-1,2]. The P-POSSUM mortality score [6] was calculated using the standard modified logistic regression formula [Table/Fig-3,4]. All surgeries were performed by the same experienced team of general surgeons following standardised protocols.

The primary endpoints were postoperative morbidity and 30-day all-cause mortality. Morbidity was defined as the occurrence

Variables	Score=1	Score=2	Score=4	Score=8
Age (years)	≤60	61-70	≥71	
Cardiac signs	No failure	Diuretic, digoxin, antianginal or hypertensive therapy	Peripheral oedema; warfarin therapy; Borderline cardiomegaly	Raised jugular venous pressure; Cardiomegaly
Respiratory history	No dyspnoea	Dyspnoea on exertion	Limiting dyspnoea (one flight); Moderate COAD	Dyspnoea at rest (rate ≥30/min); Fibrosis or consolidation
Systolic blood pressure (mmHg)	110-130	131-170 or 100-109	≥171 or 90-99	≤89
Pulse (beats/min)	50-80	81-100 or 40-49	101-120	≥121 or ≤39
Glasgow coma score	15	12-14	9-11	≤8
Haemoglobin (g/100 mL)	13-16	11.5-12.9 or 16.1-17.0	10.0-11.4 or 17.1-18.0	≤9.9 or ≥18.1
White cell count (×10^{12}/L)	4-10	10.1-20.0 or 3.1-3.9	≥20.1 or ≤3.0	
Urea (mmol/L)	≤7.5	7.6-10.0	10.1-15.0	≥15.1
Sodium (mmol/L)	≥136	131-135	126-130	≤125

Potassium (mmol/L)	3.5-5.0	3.2-3.4 or 5.1-5.3	2.9-3.1 or 5.4-5.9	≤2.8 or ≥6.0
Electrocardiogram	Normal	Atrial fibrillation (rate 60-90)	>5 ectopics/min; Q waves	Any other abnormal rhythm; ST/T wave changes

[Table/Fig-1]: POSSUM and P-POSSUM Physiological score variables with scoring ranges - 1, 2, 4, 8 [1].
COAD: Chronic obstructive airway disease

Variables	Score=1	Score=2	Score=4	Score=8
Operative severity	Minor	Moderate	Major	Major+
Multiple procedures	1	2		>2
Total blood loss (mL)	≤100	101-500	501-999	≥1000
Peritoneal soiling	None	Minor (serous fluid)	Local pus	Free bowel content, pus or blood
Presence of malignancy	None	Primary only	Nodal metastases	Distant metastases
Mode of surgery	Elective	Emergency resuscitation >2 h possible/Operation <24 h after admission		Emergency (immediate surgery <2 h needed)

[Table/Fig-2]: POSSUM and P-POSSUM Operative score variables with scoring ranges - 1, 2, 4, 8 [1].

POSSUM morbidity and mortality prediction equation
Logit (Morbidity)=-5.91+(0.16×Physiology Score)+(0.19×Operative Severity Score)
Logit (Mortality)=-7.04+(0.13×Physiology Score)+(0.16×Operative Severity Score)

[Table/Fig-3]: POSSUM morbidity and mortality prediction equation [1].

P-POSSUM Mortality prediction equation
Logit (Mortality)=-9.065+(0.1692×Physiology Score)+(0.1550×Operative Severity Score)

[Table/Fig-4]: P-POSSUM Mortality prediction equation-morbidity estimation is performed using the same formula as used in the POSSUM scoring system [6].

of at least one Clavien-Dindo grade II or higher complication within 30 days or during the index admission, encompassing infectious, cardiopulmonary, thromboembolic, gastrointestinal, and wound-related events. Thirty-day mortality was defined as any death within 30 days of surgery, in line with NCEPOD [16] and American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) standards [17]. Secondary endpoints included model performance, assessed through calibration (observed-to-expected ratios, calibration curves) and discrimination (ROC-AUC).

STATISTICAL ANALYSIS

The analyses were performed using Statistical Package for the Social Sciences (SPSS) software (version 25.0; IBM Corp., Armonk, NY, USA). Predicted risks were calculated using published POSSUM and P-POSSUM equations. Discrimination was assessed by ROC-AUC with 95% CIs and compared using DeLong's test. Calibration was examined by observed-to-expected ratios and calibration plots; overall accuracy was quantified using Brier scores. All analyses were two-sided at α=0.05, with Holm-Bonferroni correction applied to secondary comparisons. A p-value<0.05 was considered statistically significant.

RESULTS

A total of 200 adult patients undergoing elective general surgical procedures were included in this study. The mean age of the cohort was 52.4±14.8 years, with a predominance of males (male-to-female ratio of 1.67:1). The majority of the patients (n=124; 62.0%) underwent procedures classified as moderate in complexity, followed by major surgeries (n=52; 26.0%). Minor procedures accounted for 11.0% (n=22) of the cases, while only 1.0% (n=2) of patients were categorised under major plus procedures [Table/Fig-5].

Parameters	Value
Age (years, Mean±SD)	52.4±14.8
Gender	
- Male	125 (62.5%)
- Female	75 (37.5%)
BMI (kg/m², Mean±SD)	24.7±3.6
Co-morbidities	
- Hypertension	41 (20.5%)
- Diabetes mellitus	38 (19.0%)
- Chronic Obstructive Pulmonary Disease (COPD)	12 (6.0%)
- Ischemic heart disease	9 (4.5%)
- Chronic kidney disease	6 (3.0%)
Surgical procedures	
- Gastrointestinal surgeries	84 (42.0%)
- Hernia repairs	41 (20.5%)
- Hepatobiliary surgeries	35 (17.5%)
- Others (breast, urological, soft tissue)	40 (20.0%)

[Table/Fig-5]: Baseline characteristics of patients undergoing elective general surgical procedures.
SD: Standard deviation

In this cohort of 200 patients undergoing elective general surgical procedures, the observed postoperative morbidity was 26.0% (n=52), while the 30-day postoperative mortality was 4.0% (n=8). Using the POSSUM scoring system, the expected morbidity was 33.5% (n=67) and the expected mortality was 6% (n=12). In comparison, the P-POSSUM model predicted a mortality rate of 4% (n=8), which closely aligned with the observed figure. The observed-to-expected (O:E) ratios for POSSUM were 0.78 for morbidity and 0.68 for mortality, both indicating systematic overestimation by the original model. By contrast, the P-POSSUM O:E ratio for mortality was 0.96, reflecting near-perfect calibration to actual outcomes in this elective surgical cohort. Both scoring systems demonstrated excellent calibration across morbidity and mortality, with non-significant Hosmer-Lemeshow χ^2 values (all p>0.85), indicating close agreement between predicted and observed outcomes. For morbidity prediction, POSSUM achieved a sensitivity of 92.0% and a specificity of 48.0%. For mortality prediction, POSSUM had a sensitivity of 75.0% and a specificity of 62.0%. In contrast, P-POSSUM demonstrated superior discrimination, with a sensitivity of 93.0% and a specificity of 71.0% [Table/Fig-6].

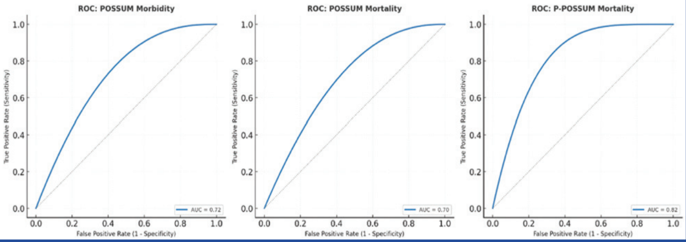
The AUCs were as follows: POSSUM (morbidity), 0.72 (95% CI: 0.689-0.855); POSSUM (30-day mortality), 0.70 (95% CI: 0.732-0.950); and P-POSSUM (30-day mortality), 0.82 (95% CI: 0.812-0.974) [Table/Fig-7].

DISCUSSION

Risk-adjusted surgical audit has emerged as essential for high-volume general surgery programmes, as it converts diverse case data into clear, metric-based parameters that guide governance, benchmarking, and the allocation of perioperative resources. Torlot F et al., externally validated Surgical Outcome Risk Tool (SORT), New Zealand Risk of Death Score (NZRISK), POSSUM, and P-POSSUM in a single-centre cohort and reported strong discrimination but suboptimal calibration for 30-day mortality, arguing for local validation and periodic recalibration before using any model for

Model	Outcome	HL χ^2	p-value	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV % (95% CI)	NPV % (95% CI)	AUC
POSSUM	Morbidity	2.34	0.96	92.0 (81.2-97.8)	48.0 (38.2-57.9)	69.0 (58.0-78.7)	83.0 (72.3-90.7)	0.72
POSSUM	Mortality	3.67	0.88	75.0 (34.9-96.8)	62.0 (54.7-69.0)	55.0 (25.0-82.0)	77.0 (69.8-83.4)	0.70
P-POSSUM	Morbidity	2.34	0.96	92.0 (81.2-97.8)	48.0 (38.2-57.9)	69.0 (58.0-78.7)	83.0 (72.3-90.7)	0.72
P-POSSUM	Mortality	1.45	0.99	93.0 (66.1-99.8)	71.0 (63.9-77.3)	72.0 (46.5-89.7)	89.0 (81.9-94.0)	0.82

[Table/Fig-6]: Calibration and discrimination metrics of POSSUM and P-POSSUM for morbidity and 30-day mortality {Hosmer-Lemeshow (HL) χ^2 statistics and p-values demonstrate calibration of observed versus expected (O:E) outcomes}.



[Table/Fig-7]: Receiver operating characteristic (ROC) curves for POSSUM and P-POSSUM (Note: P-POSSUM has no separate morbidity equation; morbidity prediction uses the original POSSUM model).

quality benchmarking [18]. Nally DM et al., demonstrated that a structured quality-improvement programme increased the routine use of perioperative risk scoring and improved the consistency of senior review and escalation to higher levels of care, showing that embedding risk tools within pathways can change behaviour and support better outcomes in real services [19].

perioperative pathways that can lower observed event rates, all of which can make legacy equations overpredict or underpredict when applied in new settings. Differences in age structure and operative approach further account for the convergence of findings across studies. Feng S et al., derived and externally validated a mortality model tailored to older emergency surgical patients, showing that geriatric physiology and treatment patterns alter risk relationships [25]. This implies that tools built in younger or mixed cohorts can misclassify risk in elderly populations. The Emergency Laparotomy Enhanced Recovery After Surgery (ERAS) consensus, led by Peden CJ et al., reported improvements in complication rates and care processes with structured pathways, which lower baseline event rates and widen the gap between predicted and observed outcomes when historical models are used without updating [26]. Teixeira IM et al., found that P-POSSUM performed best for 30-day mortality [27]. At the same time, morbidity prediction was inadequate across systems, supporting our observation that models emphasising

Study	Population	Endpoint	Metric	POSSUM	P-POSSUM	Key note
Present study	General surgical cohort	Mortality	AUC	0.841 (CI NR)	0.893 (CI NR)	P-POSSUM>POSSUM (mortality)
		Morbidity	AUC	0.772 (CI NR)	0.734 (CI NR)	POSSUM>P-POSSUM (morbidity)
		Mortality	O:E	0.68	0.96	POSSUM overpredicts; P-POSSUM≈observed
Shekar N et al., [20]	Emergency abd surgery (n=150)	Mortality	AUC	0.818 (CI NR)	0.836 (CI NR)	Both moderately discriminative
		Mortality	O:E	0.91	0.84	Overprediction in both models
		Morbidity	O:E	0.79	0.84	Overprediction; closer with P-POSSUM
Alabbasy MM et al., [21]	Emergency laparotomy (n=670)	Mortality (30-d)	AUC (95% CI)	-	0.763 (0.719-0.806)	Underestimation overall (model drift)
		Mortality (90-d)	AUC (95% CI)	-	0.782 (0.737-0.828)	-
Bullagan A et al., [22]	Emergency GI surgery (n=45)	Mortality	AUC (95% CI)	-	0.944 (0.879-1.000)	Small sample; excellent AUC
		Morbidity	AUC (95% CI)	0.945 (0.886-1.000)	-	High discrimination; small n
Bürtin F et al., [23]	Colorectal cancer surgery	Mortality	O:E (range)	≈0.11 overall	0.24 overall (1.01-1.19 at high-risk deciles)	Systematic overprediction across models

[Table/Fig-8]: Head-to-head performance of POSSUM and P-POSSUM in recent studies and in the present cohort [20-23].

In our cohort, POSSUM overpredicted both outcomes (O:E morbidity ratio, 0.78; O:E mortality ratio, 0.68), Whereas P-POSSUM showed near-unity calibration for mortality (O:E mortality ratio, 0.96). This pattern mirrors recent Indian and international data. In a 150-patient Indian emergency abdominal cohort, Shekar N et al., reported POSSUM O:E morbidity and mortality ratios of 0.79 and 0.91, respectively, with a P-POSSUM O:E mortality ratio of 0.84, demonstrating relative overprediction but closer agreement than POSSUM [Table/Fig-8] [20-23].

Shared patterns across our cohort and contemporary series are most plausibly explained by transportability and calibration drift. External validation of the updated National Emergency Laparotomy Audit (NELA) model by Hansted AK et al., showed strong discrimination for 30-day mortality, with an area under the curve of approximately 0.85 [24]. Yet calibration analysis demonstrated systematic underestimation at the population level, underscoring that models travel poorly without local recalibration. Bedford JP et al., synthesised the broader perioperative literature [3]. They attributed such miscalibration to changes in baseline risk, variation in case mix and comorbidity load, coding and data-quality differences, and shifts in

physiological factors can track mortality risk well but struggle with the heterogeneous mechanisms that generate postoperative complications.

Limitation(s)

The present single-centre design and modest sample size limit precision around subgroup estimates and preclude robust recalibration. Important covariates (e.g., anaesthesia strategy, timing of sepsis source control, and organ support) were not explicitly adjusted for in the models, leaving residual confounding.

CONCLUSION(S)

The present study reinforces the utility of both POSSUM and P-POSSUM scoring systems as valuable tools in perioperative risk stratification, with P-POSSUM demonstrating superior accuracy in mortality prediction and POSSUM showing marginally better sensitivity for morbidity. When used in tandem, these models offer a pragmatic, evidence-based framework for surgical audit and patient counselling. Their integration into routine clinical practice, particularly in resource-constrained settings in India, has the potential to enhance surgical outcomes, optimise resource allocation, and uphold the principles of accountable, patient-centred care.

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