SPECIAL ARTICLE

The POSSUM System of Surgical Audit

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Surgical audit is not a new phenomenon. As early as 1750 BC, King Hammurabi of Babylon issued decrees for the punishment of negligent physicians, particularly surgeons. In such a decree discovered at Susa in Iran and inscribed on a 2-m-high black diorite stone, Hammurabi states that:

> If a doctor inflicts a serious wound with his operation knife on a free man's slave and kills him, the doctor must replace the slave with another. If a doctor has treated a free man but caused a serious injury from which the man dies, or if he has opened an abscess and the man goes blind, the man is to cut off his hands.

Not surprisingly, internal medicine rather than surgery was popular at that time. Indeed, to many surgeons today, this edict still seems to be exacted in a sublimated way.

The outcome of surgical intervention, whether death or uncomplicated survival, complications, or long-term morbidity, is not solely dependent on the abilities of the surgeon in isolation. The patient's physiological status, the disease that requires surgical correction, the nature of the operation, and the preoperative and postoperative support services have a major effect on the ultimate outcome. It is evident to surgeons worldwide that raw mortality and morbidity rates do little to expound these differences, and that the use of such statistics is at best inaccurate and at worst dangerous. When taken to an extreme, mortality rates can achieve what appears to be a self-fulfilling prophecy. The unit that selects only low-risk cases achieves a low mortality rate and therefore attracts more patients, perhaps undeservedly, whereas the unit that cannot select only low-risk cases is left with a worsening case mix, and their performance as judged by mortality rate will appear to deteriorate still further over time.

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With this in mind, during the 1980s a system was developed to allow for the first time an assessment of surgical quality that was risk adjusted for the patient's acute and chronic physiological status and for the nature of the operation. By using a process of multivariate discriminant analysis, a scoring system was developed that could accurately predict 30-day mortality and morbidity rates. The POSSUM audit system (Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity)[1] was designed to be easy and rapid to use and to have wide application across the general surgical spectrum, both in the elective and emergency settings, and to be applicable in most health care systems.[2-6]

The POSSUM system is a 2-part scoring system that includes a physiological assessment and a measure of operative severity. The physiological part of the score includes 12 variables, each divided into 4 grades with an exponentially increasing score (1, 2, 4, and 8) (**Figure 1**). The physiological variables are those apparent at the time of surgery and include clinical symptoms and signs, results of simple biochemical and hematological investigations, and electrocardiographic changes. If a particular variable is not available, a score of 1 is allocated. Some variables may be assessed by means of clinical symptoms or signs or by means of changes on chest radiographic findings. The minimum score, therefore, is 12, with a maximum score of 88.

The operative severity part of the score includes 6 variables, each divided

Physiological

Score	1	2	4	8
Age, y	≤60	61-70	≥71	…
Cardiac Signs	Normal	Cardiac drugs or steroids	Edema; warfarin	JVP
CXR	Normal	…	Borderline cardiomegaly	Cardiomegaly
Respiratory signs	Normal	SOB exertion	SOB stairs	SOB rest
CXR	Normal	Mild COAD	Mod COAD	Any other change
Systolic BP, mm Hg	110-130	131-170 100-109	≥171 90-99	≤89
Pulse, beats/min	50-80	81-100 40-49	101-120	≥121 ≤39
Coma score	15	12-14	9-11	≤8
Urea nitrogen, mmol/L	<7.5	7.6-10	10.1-15	≥15.1
Na, mEq/L	>136	131-135	126-130	≤125
K, mEq/L	3.5-5	3.2-3.4 5.1-5.3	2.9-3.1 5.4-5.9	≤2.8 ≥6
Hb, g/dL	13-16	11.5-12.9 16.1-17	10-11.4 17.1-18	≤9.9 ≥18.1
WCC $x10^{12}/L$	4-10	10.1-20 3.1-3.9	≥20.1 ≤3	…
ECG	Normal	…	AF (60-90)	Any other change

General Surgery POSSUM

Operative Severity

Score	1	2	4	8
Operative magnitude	Minor	Intermediate	Major	Major+
No. of operations within 30 d	1		2	>2
Blood loss per operation, mL	<100	101-500	501-999	>1000
Peritoneal contamination	No	Serious	Local pus	Free Bowel content, pus or blood
Presence of malignancy	No	Primary cancer only	Node metastases	Distant metastases
Timing of operation	Elective		Emergency resuscitation possible, operation <24 h	Emergency immediate, operation <2 h

Operation classification, see Table 1
If not documented, pick appropriate operation group

Patient name:

Unit number:

DOB:

Consultant:

Operating surgeon: ______

Anesthetist: ______

Operation date: ______

Date admitted: ______

Date discharged: ______

Complications

Hemorrhage
- ☐ Wound deep

Infection
- ☐ Chest
- ☐ Wound
- ☐ UTI
- ☐ Deep
- ☐ Septicemia
- ☐ PUO
- ☐ Wound dehiscence
- ☐ Prosthesis loose/displaced

Thrombosis
- ☐ DVT
- ☐ PE
- ☐ CVA
- ☐ MI
- ☐ Renal failure
- ☐ Respiratory failure
- ☐ Cardiac failure
- ☐ Hypotension
- ☐ Any other

If death, circle

No complications ☐

Figure 1. Physiological and operative severity assessment for the POSSUM system (Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity). In some variables, signs may be assessed clinically and/or by changes in results on chest x-ray film (CXR). Ellipses indicate not applicable; JVP, jugular venous pressure; UTI, urinary tract infection; SOB, shortness of breath; PUO, pyrexia of unknown origin; COAD, chronic obstructive airway disease; Mod, moderate; BP, blood pressure; DVT, deep venous thrombosis; PE, pulmonary embolism; CVA, cerebrovascular accident; MI, myocardial infarction; Na, sodium; DOB, date of birth; K, potassium; Hb, hemoglobin; WCC, white blood cell count; ECG, electrocardiogram; and AF, atrial fibrillation.

into 4 grades with an exponentially increasing score (1, 2, 4, and 8) (Figure 1). The number of operations indicates the chronology of the procedure(s) within 30 days. Examples of surgical magnitude for general surgery are shown in **Table 1**.

Once these scores are known, it is possible to estimate the predicted risk for mortality and morbidity using the following equations (where R1 indicates mortality and R2, morbidity):

$$\text{Log}_e R1/(1-R1) = -7.04 + (0.13 \times \text{Physiological Score}) + (0.16 \times \text{Operative Severity Score})$$

and

$$\text{Log}_e R2/(1-R2) = -5.91 + (0.16 \times \text{Physiological Score}) + (0.19 \times \text{Operative Severity Score})$$

Although at first sight complex, a patient score can be obtained with practice in 90 seconds, and commercially available computer packages can be used to estimate risk instantly (even manual estimation takes only 60 seconds). We have recently validated an orthopedic POSSUM system that uses the same physiological assessment and predictive equations but has a modified operative severity score (**Figure 2**). Examples of operative magnitude for orthopedic surgery are shown in **Table 2**.

Individualized patient predictions allow assessment of a patient's risk for death or complication. They also allow a retrospective assessment as to whether a procedure was reasonable to attempt. However, as the operative severity score is not available until the operation has been undertaken, the POSSUM score cannot be used to prevent a patient from undergoing a potentially curative procedure. Although the POSSUM system was designed specifically not to be used as a "futility index," it is possible to select a combination of scores for which a more senior opinion must be sought before surgical intervention. As the POSSUM system uses a logistic model, predictions of less than 0% and greater than 100% are impossible. This model more closely approximates the clinical situation, in which we can never be certain that a patient will survive or die after surgery. Predictions beyond these extremes (<0% and >100%), however, are possible if linear models are used, and this is a major danger of the Portsmouth POSSUM adaptation.[7] However, within the normal range, both a linear and a logistic model will yield similar results if the appropriate mathematical methods are used.[8]

Surgical procedures for patients with predictions of mortality exceeding 95% rarely result in a successful outcome. Whatever the findings of the audit of "surgical success," the patient with a high prediction of death or complication but for whom no such adverse outcome occurs often has more to teach us than our failures. In my own

Table 1. Examples of Magnitude for General Surgery*

- Minor
  - Hernia
  - Varicose vein
  - Minor perianal surgery
  - Scrotal surgery
  - Minor TURT
  - Excision of large subcutaneous lesion
- Intermediate
  - Open cholecystectomy
  - Laparoscopic cholecystectomy
  - Appendectomy
  - Excision of lesion requiring grafting or minor excision
  - Minor amputation
  - Thyroid lobectomy
- Major
  - Laparotomy and small-bowel resection
  - Colonic resection or anterior resection
  - Major amputation
  - Nonaortic vascular surgery
  - Cholecystectomy and exploration of bile duct
  - Total thyroidectomy
- Major +
  - Abdominoperineal excision of rectum
  - Aortic surgery
  - Whipple resection
  - Radical total gastrectomy

*TURT indicates transurethral resection of tumor.

unit, such a success audit has identified groups of patients, in particular the high-risk patient with a perforated viscus, in whom more rapid resuscitation and surgery can produce better outcomes.[9] This group of patients certainly does not benefit from prolonged attempts at resuscitation without rapid surgical intervention.

By using the predictions from individual patients, it is possible to extrapolate from groups of patients the likely number of adverse outcomes and thus obtain a risk-adjusted quality measure. This measure, the ratio of observed number of adverse outcomes to predicted number of adverse outcomes (O/E ratio), can be used to assess differences between surgeons and to observe changes over time. A ratio of 1.00 indicates average performance; greater than 1.00, performance worse than expected; and less than 1.00, performance better than expected.[5] These definitions remain the mainstay of application of the O/E ratio in general surgery, although models have been designed recently that use the POSSUM system to assess risk-adjusted length of hospital stay for comparative purposes.[10]

Using the O/E ratio, we can assess overall surgeon performance across the whole range of general and orthopedic surgery. Examples of variability in mortality and morbidity rates, with their attendant O/E ratios, are shown for one unit in **Table 3**. This clearly demonstrates the danger of using raw mortality and morbidity rates for comparative audit. Not surprisingly, vascular surgeons have

Physiological

Score	1	2	4	8
Age, y	≤60	61-70	≥71	…
Cardiac signs	Normal	Cardiac drugs or steroids	Edema; warfarin	JVP
CXR	Normal	…	Borderline cardiomegaly	Cardiomegaly
Respiratory signs	Normal	SOB exertion	SOB stairs	SOB rest
CXR	Normal	Mild COAD	Mod COAD	Any other change
Systolic BP, mm Hg	110-130	131-170 100-109	≥171 90-99	≤89
Pulse, beats/min	50-80	81-100 40-49	101-120	≥121 ≤39
Coma score	15	12-14	9-11	≤8
Urea nitrogen, mmol/L	<7.5	7.6-10	10.1-15	≥15.1
Na, mEq/L	>136	131-135	126-130	≤125
K, mEq/L	3.5-5	3.2-3.4 5.1-5.3	2.9-3.1 5.4-5.9	≤2.8 ≥6
Hb, g/dL	13-16	11.5-12.9 16.1-17	10-11.4 17.1-18	≤9.9 ≥18.1
WCC $x10^{12}$/L	4-10	10.1-20 3.1-3.9	≥20.1 ≤3	…
ECG	Normal	…	AF (60-90)	Any other change

Orthopedic POSSUM

Operative Severity

Score	1	2	4	8
Operative magnitude	Minor	Intermediate	Major	Major +
No. of operations within 30 d	1		2	>2
Blood loss per operation, mL	<100	101-500	501-999	>1000
Contamination	No	Incised wound ie, stab	Minor contamination or necrotic tissue	Gross contamination or necrotic tissue
Presence of malignancy	No	Primary cancer only	Node metastases	Distant metastases
Timing of operation	Elective		Emergency resuscitation possible <48 h	Emergency immediate, <6 h

Operation classification, see Table 1
If not documented, pick appropriate operation group

Patient name:

Unit number:

DOB:

Consultant:

Operating surgeon: ______

Anesthetist: ______

Operation date: ______

Date admitted: ______

Date discharged: ______

Complications

Hemorrhage
- ☐ Wound deep

Infection
- ☐ Chest
- ☐ Wound
- ☐ UTI
- ☐ Deep
- ☐ Septicemia
- ☐ PUO

- ☐ Wound dehiscence
- ☐ Prosthesis loose/ displaced

Thrombosis
- ☐ DVT
- ☐ PE
- ☐ CVA
- ☐ MI

- ☐ Renal failure
- ☐ Respiratory failure
- ☐ Cardiac failure
- ☐ Hypotension
- ☐ Any other

If death, circle

No complications ☐

Figure 2. Orthopedic score sheet for the POSSUM system. Abbreviations are defined in the legend to Figure 1.

Table 2. Examples of Operative Magnitude for Orthopedic Surgery

- Minor
  - Fasciotomy
  - Ganglion/bursa
  - Tenotomy/tendon repair
  - Endoscopic joint surgery
  - Carpal tunnel/nerve release
  - Removal of wire/nail
  - Closed reduction of fracture
- Intermediate
  - Excision/osteotomy of small bone
  - Minor joint replacement
  - Amputation of digit(s)
  - Closed reduction with external fixation
  - Open reduction of small bone fracture
- Major
  - Osteotomy of long bone
  - Ligamentous reconstruction and prosthesis
  - Arthrodesis of large joint
  - Major joint replacement
  - Amputation of limb
  - Disk surgery
  - Open reduction of long bone fracture
- Major +
  - Radical tumorectomy
  - Major spinal reconstruction
  - Revision prosthetic replacement of major joint
  - Hind limb/forelimb amputation

Table 3. Raw and Risk-Adjusted Outcome Measures for 12 Months in One Unit*

	% of Patients		O/E Ratio	
Surgeon/Specialty	Mortality	Morbidity	Mortality	Morbidity
A/Vascular	4.8	13.0	1.02	1.03
B/Hepatobiliary	2.6	10.0	0.96	0.96
C/Colorectal	2.9	15.1	1.00	0.99
D/Vascular	3.5	13.6	0.98	0.98
E/Gastrointestinal	3.1	11.7	1.04	1.03
F/Urology	0.3	2.1	0.50	0.75
G/Urology	1.0	4.9	1.00	1.02

*Results apply to all inpatient surgery. O/E ratio indicates ratio of observed number of adverse outcomes to predicted number of adverse outcomes. An O/E ratio of 1.00 indicates outcomes as expected; less than 1.00, outcomes better than predicted; and greater than 1.00, outcomes worse than predicted.

Table 4. Variability in Raw and Risk-Adjusted Outcome Data in Orthopedic Surgery During 12 Months*

	% of Patients		O/E Ratio	
Orthopedic Surgeon	Mortality	Morbidity	Mortality	Morbidity
A	3.0	12.9	1.00	0.97
B	1.1	10.5	0.83	1.04
C	2.4	11.0	0.90	0.95
D	1.8	4.6	1.00	1.00
E	2.1	9.6	1.00	1.02
F	2.6	13.4	1.00	0.98
G	2.3	14.2	0.98	0.98

*O/E ratio indicates ratio of observed number of adverse outcomes to predicted number of adverse outcomes. An O/E ratio of 1.00 indicates outcomes as expected; less than 1.00, outcomes better than predicted; and greater than 1.00, outcomes worse than predicted.

Table 5. Examples of the Application of the POSSUM System Between Units in Countries With Varying Numbers of Patients per Annum and Variable Case Mix*

Unit	No. of Patients	Mortality, %	O/E Ratio for Mortality
Warrington, England	3096	3.2	0.99
India	560	5.2	1.01
Turkey	1236	3.8	0.99
Malaysia	254	5.6	1.02

*The POSSUM system indicates the Physiological and Operative Severity Score of the enumeration of mortality and morbidity; O/E ratio, ratio of observed number of adverse outcomes to predicted number of adverse outcomes. An O/E ratio of 1.00 indicates outcomes as expected; less than 1.00, outcomes better than predicted; and greater than 1.00, outcomes worse than predicted.

a higher mortality rate; gastroenterological surgeons, the highest morbidity rate; and urologic surgeons, the lowest mortality and morbidity rates. The POSSUM system has found wide application for such comparative purposes, having been used in a wide variety of surgical subspecialities ranging from vascular surgery[3] to gastroenterology[4] and coloproctology,[11,12] and to more specialized areas such as bariatric surgery[13] and lung resection.[14] Examples of its use in orthopedic surgery are illustrated in **Table 4**. The POSSUM system has also been found to have wide application in greatly varying health care systems throughout the world (**Table 5**).

All predictions will have confidence limits dependent on the number of operations performed and on the number of adverse outcomes. Overreaction should be avoided, and the cause of deficiencies in quality should be carefully examined. In a published data set from my own unit, an apparent deficiency in one surgeon was due to a process change at ward level in anticoagulation prophylaxis administration.[5] This was rapidly identified and corrected with minimal morbidity overall and without penalizing the surgeon inappropriately. Variation in outcome will occur over time, but if deteriorating O/E ratios can be identified early, remedial action can be taken. Early trend analysis for morbidity can identify early downturns in performance before this is replaced with mortality. Sudden death after surgery is a rare event, and death usually follows a series of antecedent complications. This fact is often forgotten by systems that assess death only as an end point, and is perhaps one of the major advantages of the POSSUM system over other audit scoring systems.[6,15]

The POSSUM system can assess differences between individual units and departments and allow comparison over time. **Table 6** illustrates minor variations in O/E ratio over time in one surgeon's performance, but more major variation can also occur. **Table 7** illustrates a downturn in performance within one unit, which on closer inquiry was associated with an increase in morbidity, in particular renal and respiratory complications. This appeared to correlate with a sudden local decrease in availability of intensive care unit beds and resulted in a need to transfer patients to neighboring hos-

Table 6. Variations in Annual Performance of One Surgeon During 6 Years*

Year	% of Patients		O/E Ratio	
	Mortality	Morbidity	Mortality	Morbidity
1994	3.8	16.7	0.99	0.97
1995	3.7	15.5	1.01	1.00
1996	3.2	13.9	0.97	0.98
1997	3.8	13.9	0.97	0.98
1998	3.1	12.9	1.02	1.01
1999	3.4	14.2	0.98	0.95

*All patients undergoing scoring represent those undergoing inpatient surgery. O/E ratio indicates ratio of observed number of adverse outcomes to predicted number of adverse outcomes. An O/E ratio of 1.00 indicates outcomes as expected; less than 1.00, outcomes better than predicted; and greater than 1.00, outcomes worse than predicted.

Table 7. Effect of Intensive Care Unit Bed Availability on Risk-Adjusted Outcome of Operative Intervention in One Unit*

Availability of Intensive Care Unit Beds, %	O/E Ratio	
	Mortality	Morbidity
100	0.97	0.98
90	0.99	0.99
70	1.08	1.06
50	1.20	1.08

*Bed availability is expressed as a percentage of the total beds that should have been available at any one time. On occasions when beds were not available, patients were transferred to neighboring units. O/E ratio indicates ratio of observed number of adverse outcomes to predicted number of adverse outcomes. An O/E ratio of 1.00 indicates outcomes as expected; less than 1.00, outcomes better than predicted; and greater than 1.00, outcomes worse than predicted.

pitals. In the transferred group, the O/E ratio was 1.60; in the resident group, the O/E ratio was 0.98. Corrective action was rapidly taken, with a subsequent fall in O/E ratio to acceptable levels. Surgery and in particular resuscitative measures are never static over time. An increasing number of units in North America and Europe are identifying the benefits of preoperative and perioperative resuscitation in high-risk patients.[16-18] With a mortality risk between 20% to 80%,this group of patients has the most to gain from optimization. The POSSUM system can allow for changes over time in our medical treatment. If care should improve significantly, O/E ratios will fall worldwide and simple adjustments in the logistic regression equations can be made to continue to allow comparison over time. Unfortunately, no equation adjustment has been necessary during the past 10 years. At first glance, this may appear disappointing, but on closer review, the number of procedures being performed in the high-risk patient group has steadily increased during the past 3 years. In England, there has been a 30% increase in procedures in patients whose risk for death exceeds 20% and a 12% increase in procedures in patients whose risk exceeds 40.

The POSSUM system, therefore, offers many differing facets. It allows a numerical prediction of mortality and morbidity for an individual patient. It allows comparative audit providing a method of adjustment of case mix. It allows comparison to be made over time and can be easily adjusted to radical changes in health care in the future. Only by using systems of this type will the comparative audit become a reality rather than a fantasy[19,20] and, for the first time, will the public and the medical profession trust in outcome measures. Hammurabi's methods have been in operation for 4000 years; perhaps now is the time to change.

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