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ORIGINAL ARTICLE

Intensive care after elective surgery: a survey on 30-day postoperative mortality and morbidity

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ABSTRACT

Background. Postoperative admission to the surgical intensive care unit (S-ICU) is routinely planned in order to prevent and treat early complications. Currently, limited studies have been conducted on this topic, and as such, early morbidity and mortality in patients undergoing postoperative intensive care were investigated.
Methods. This prospective analysis was performed in the S-ICU of a University hospital and included 1 045 consecutive patients. All patients underwent elective surgery and were admitted to the S-ICU on the basis of preoperative clinical assessment. On the second, seventh, and thirtieth postoperative days, the location of the patients was recorded (ICU, surgical ward, or home) as were any complications that occurred. Predicted mortality and morbidity were assessed using the POSSUM score.
Results. The observed postoperative mortality rate was 2.4% (95% CI: 1.5-3.3%), which was much lower than the rate predicted by both POSSUM (6.2%) and P-POSSUM (5.3%) analyses, and 36% of patients experienced complications, a percentage slightly higher than that predicted by POSSUM (30.2%). The first 48 hours following surgery were characterized by the highest mortality rate (2.85 deaths per thousand *vs* 0.7 per thousand by the third postoperative day) as well as the highest morbidity rate (7.7% *vs* 4.3% between the third and seventh postoperative days, and 0.9% between the eighth and thirtieth postoperative days). The presumed causes of early death were primarily secondary to cardiovascular complications (five out of six).
Conclusions. The first 48 hours after surgery is a critical period in high-risk patients, and a stay in the S-ICU should be seriously considered. Planned admission to the S-ICU may effectively decrease postoperative mortality, as suggested by the highly significant difference between expected and observed deaths following S-ICU admission.

Key words: Intensive Care Units - Mortality - Morbidity - Risk reduction behavior.

Several factors contribute to a higher risk of complications and death in the early postoperative course, and, consequently, patients are routinely monitored for a few hours in the Post-Anesthesia Care Unit (PACU) in order to monitor the residual effects of anesthetics, postoperative bleeding, and shivering. In selected cases, more extensive monitoring is performed in the surgical intensive care unit (S-ICU) for one or more days. Admission to the S-ICU may decrease the morbidity and mortality associated with serious illness or high-risk surgery, but S-ICU admission also results in increased cost and, potentially, length of hospital stay since S-ICU beds are a limited resource.[1] Some authors have suggested that admission to the S-ICU should become more selective after certain surgical procedures,[2-5] but others disagree.[6]

The impact of a postoperative intensive care admission depends on the incidence and nature of early morbidity in high-risk surgical patients. Since limited data are available in the literature, a survey was carried out on 30-day mortality and morbidity in patients selected for postoperative admission to the S-ICU.

Materials and methods

Patient population

The study was performed in the hospital of the Catholic University of the Sacred Heart in Rome and enrolled 1 045 consecutive patients who where admitted to the S-ICU after an elective surgical procedure, with the exception of neurosurgical or emergency procedures and admissions not previously planned. Neurosurgical procedures were excluded due to their peculiarities, and emergency surgeries were excluded because they are commonly performed in the presence of preoperative respiratory or circulatory failure. The local Ethical Committee approved the protocol, and patients' consent for data storage and analysis was obtained.

Our S-ICU is a 13-bed ICU, level-3. Admission following surgery was planned preoperatively on the basis of patient functional reserve and operative severity. Judgment for S-ICU placement was essentially clinical and was not based on gravity scores. The risks of early respiratory, cardiovascular, and hemorrhagic complications were primarily taken into account when considering candidates for S-ICU admission. According to internal protocols, patient assessment was made by junior members of the staff who were supervised by a senior member. Comorbidities such as obstructive sleep apnoea and myasthenia gravis were regarded as potential complications even if well-controlled and not limiting physical activity at the time of the study. In a few cases, S-ICU admission was planned because a surgery of long duration (*i.e.* longer than 10 hours) would have ended near or after PACU closing time. In these situations, patients spent at least one night in the S-ICU and were then moved to a surgical ward as soon as clinical and physiological variables were normalized. Chemical, hematological, and coagulative blood tests, chest X-rays, and an electrocardiogram were performed preoperatively and again in the S-ICU according to standard institutional protocols.

Procedures

Upon arrival at the S-ICU, the patient's body mass index (BMI=weight in kg/m^2), American Society of Anesthetists (ASA) class (I: healthy patient, no medical problems; II: mild systemic disease; III: severe systemic disease, but not incapacitating; IV: severe systemic disease that is a constant threat to life; V: moribund, not expected to live 24 hours irrespective of operation),[7] and POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity) score were assessed. POSSUM is a scoring system used to predict perioperative mortality and morbidity,[8, 9] and is comprised of both physiological and surgical partial scores. The physiological score ranges from 12 to 104 and takes into account 12 preoperative parameters (age, cardiac signs, respiratory history, blood pressure, pulse, presence of cardiomegaly or chronic obstructive airway disease at chest radiograph, Glasgow coma score, hemoglobin, white cell count, electrocardiogram, and plasma urea, sodium, and potassium). The surgical score ranges from 6 to 48 and is a composite of six intraoperative parameters (operative severity, multiple procedures, total blood loss, peritoneal soiling, presence of malignancy, and mode of surgery, whether elective or emergency). Operative severity is classified as minor, intermediate, major, or major plus based on examples reported by Copeland *et al.*[8]

On the second, seventh, and thirtieth postoperative days, the location of each patient was determined and recorded (ICU, surgical ward, or home) together with any complications that occurred since the previous assessment or, in the case of postoperative day two, since the surgery. Deaths were also recorded, and presumed causes of death were noted whenever possible.

Statistical analysis

Continuous variables are reported as mean (with standard deviation). Comparisons were performed using the Student's t test, ANOVA, and Scheffe test, as appropriate. Individual risks of mortality and morbidity were derived from POSSUM physiological and surgical scores using POSSUM equations [6] (Appendix I).

The risk of mortality was also calculated using

TABLE I.— *Age, ASA class, and POSSUM score in relation with operative severity.*

Surgery	Age	ASA class				POSSUM		
		I	II	III	IV	Total	Phys	Surg
Minor N.=34, 3.2	63.8 (13.4)	0	11	22	1	28.1 (6.5)	20.9 (6.0)	7.2 (2.0)
Intermediate N.=220, 21.0	62.9 (15.2)	22	75	103	20	28.8 (5.9)	20.8 (5.5)	7.8 (1.4)
Major N.=626, 60.0	69.3 (14.0)	57	212	290	67	34.4 (6.8)	22.6 (6.2)	11.7 (2.8)
Major N.=165, 15.7	65.0 (12.1)	31	67	61	6	37.5 (7.5)	20.0 (6.2)	17.5 (3.8)
Total N.=1 045, 100	67.0 (14.0)	110 10.6	365 34.9	476 45.5	94 9.0	33.5 (7.3)	21.8 (6.0)	11.7 (4.1)

Distribution according to ASA classification does not include class V because patients undergoing emergency surgery were excluded from the study. Age and POSSUM scores are reported as mean (SD). ASA class distribution is reported as number of patients. Values in italics are percentages. ASA: American Society of Aanesthesists; POSSUM: Physiological and Operative Se verity Score for the enUmeration of Mo rtality and morbidity; phys: physiological; surg: surgical.

TABLE II.— *Distribution of the patients in II, VII, and XXX postoperative days according to the surgical severity.*

Surgery	II postoperative day				VII postoperative day				XXX postoperative day				Total
	ICU	SW	HO	d	ICU	SW	HO	d	ICU	SW	HO	d	d
Minor N.=34	1 2.9	29 85.3	4 11.8	0 0	0 0	11 32.3	23 67.7	0 0	0 0	2 5.9	32 94.1	0 0	0 0
Intermediate N.=220	7 3.2	211 95.9	0 0	2 0.9	4 1.8	82 37.3	130 59.1	2 0.9	0 0	17 7.7	198 90.0	1 0.5	5 2.3
Major N.=626	51 8.1	572 91.4	0 0	3 0.5	15 2.4	460 73.5	146 23.3	2 0.3	4 0.6	89 14.2	520 83.1	8 1.3	13 2.1
Major plus N.=165	14 8.5	150 90.9	0 0	1 0.6	6 3.6	134 81.2	24 14.6	0 0	2 1.2	13 7.9	143 86.7	6 3.6	7 4.2
Total N.=1045	73 7.0	962 92.0	4 0.4	6 0.6	25 2.4	687 65.7	323 30.9	4 0.4	6 0.6	121 11.6	893 85.4	15 1.4	25 2.4

ICU: surgical or general intensive care unit (in the case the patient was transferred or admitted to the general intensive care unit); SW: surgical ward; HO: home; d: deceased. Column d refers to the period of time elapsed from the previous observation; hence, for instance, the two deaths reported on VII postoperative day among patients undergoing major surgery occurred from the III and the VII postoperativ days.

the Portsmouth predictor equation (P-POSSUM).[10]

Results

From November 2003 to Febmary 2005, 2 146 patients we re admitted to the S-ICU. Of these patients, 332 were excluded because they underwent neurosurgery, and 769 were excluded because they underwent emergency surgery or because their admission was not planned prior to the procedure. The remaining 1 045 patients ranged in age from 16 to 97 years old (median 67.1), included 585 males and 460 females, had a BMI of 15-69 (median 27), and underwent abdominal (N.=374; 35.8%), orthopedic (N.=214; 20.5%),

TABLE III.—*Causes of death and complications registered in II, VII, and XXX postoperative days.*

	Deaths							Complications						
	II	VII	XXX	Total	ICU	SW	Home	II	VII	XXX	Total	S-ICU	SW	Home
Cardiac failure	5	1	9	15 14.4	6	8	1	33	16	11	60 10.0	15	37	8
Respiratory failure	-	-	1	1 0.9	-	1	-	35	35	28	98 16.3	21	56	21
Sepsis	-	2	-	2 1.9	2	-	-	11	72	48	131 21.8	7	87	37
Hemorrhage	1	-	2	3 2.9	1	2	-	13	9	5	27 4.5	8	15	4
Wound dehiscence	-	-	-	-	-	-	-	4	7	14	25 4.2	2	8	15
Thrombosis	-	-	-	-	-	-	-	-	2	2	4 0.6	0	3	1
Impaired renal function	-	-	-	-	-	-	-	3	4	2	9 1.5	3	5	1
Hypotension (<90 mmHg for 2 h)	-	-	-	-	-	-	-	14	7	5	26 4.3	14	8	4
Unknown cause of death/ other complications	-	1	3	4 3.8	-	1	3	49	72	97	218 36.3	20	121	77
Total	6	4	15	25	9	12	4	162	224	212	598	90	340	168
	5.7	3.8	14.4	23.9	8.6	11.5	3.8	27.0	37.5	35.5	100	15.0	56.9	28.1

The table reports the number of complications, hence two or more complications occurring in the same patients are counted separately. ICU: S-ICU or general ICU; SW: surgical ward.

TABLE IV.— *Comparison between survived and deceased patients and between uncomplicated and complicated patients.*

	N.	Age (yrs)	ASA				POSSUM			BMI (kg/m²)
			I N.=1	II N.=365	III N.=476	IV N.=94	Total	Phys	Surg	
Survived	1 020	67 (14)	108	364	466	82	33 (7)	22 (6)	12 (4)	27 (7)
Deceased	25	71 (14)	2	1	10	12	41 (9)	28 (8)	13 (4)	27 (11)
- 1-2 p.o. day	6	67 (17)	1	0	2	3	37 (5)	25 (7)	12 (4)	22 (5)
- 3-7 p.o. day	4	59 (14)	0	0	1	3	31 (10)	19 (4)	12 (7)	31 (16)
- 8-30 p.o. day	15	76 (9)	1	1	7	6	45 (8)	31 (8)	13 (3)	28 (13)
Uncomplicated	669	67 (14)	70	241	303	55	33 (7)	21 (6)	11 (4)	27 (7)
%	74.0	67 (15)	63.6	66.0	63.7	58.5	34 (7)	22 (6)	12 (4)	26 (8)
Complicated	376		40	124	173	39				
%	36.0		36.4	34.0	36.3	41.5				

The table reports age, ASA class, POSSUM score (phys: physiological score; surg: surgical score), and Body Mass Index (BMI). It was not reported where complications occurred because some patients presented more than one complication. Values are given as mean (standard deviation) or as number of patients. ASA: American Society of Aanesthesists; POSSUM: Physiological and OperativeSeverity Score for the en Umeration of Mortality and morbidity; phys: physiological; surg: surgical.

thoracic (N.=99; 9.5%), vascular (N.=88; 8.4%), urologic (N.=69; 6.6%), endocrine (N.=68; 6.5%), gynaecological (N.=64; 6.1%), bariatric (N.=39; 3.7%), ENT (N.=25; 2.4%), plastic (N.=3; 0.3%), or ophthalmic (N.=2; 0.2%) surgery. No patient matching the inclusion criteria died during the operation.

Table I depicts age, ASA class, and POSSUM

TABLE V.— *Exponential analysis of deaths predicted by POSSUM.*

Mortality group (%)	No. of patients	Observed No. of deaths	Predicted No. of deaths	Observed/predicted (O/E)
10-100	440	20	44	0.45
20-100	178	15	36	0.42
30-100	76	7	23	0.30
40-100	48	4	19	0.21
50-100	27	3	13	0.22
60-100	20	2	12	0.17
70-100	4	0	3	0
80-100	2	0	2	0
0-100	1 045	25	65	0.38

Patients are divided according to the probability of death calculated by POSSUM (first column). Classes overlap because exponential analysis has been performed. The analysis was restarted from 10% probability of death because predicted number of deaths in group 0-9 was lower than predicted number of deaths in group 10-100 (21 *vs* 44; see paragraph Materials and methods). Predicted number of deaths is rounded to the nearest whole number.

TABLE VI.—*Linear analysis of deaths predicted by Portsmouth predictor equation for mortality.*

Mortality group (%)	No. of patients	Observed No. of deaths	Predicted No. of deaths	Observed/predicted (O/E)
0-4	753	8	15	0.54
5-9	159	3	11	0.27
10-19	81	8	11	0.75
20-29	22	2	5	0.37
30-39	12	2	4	0.50
40-59	13	2	6	0.32
> 60	5	0	3	0
0-100	1 045	25	55	0.45

Patients have been divided according to the complication rate calculated by P-POSSUM (first column).

score relative to surgical severity (divided into minor, intermediate, major, or major plus). The majority of patients belonged to ASA classes II and III and underwent major surgery. No ASA class I patients undergoing minor surgery, only 11 ASA class II patients undergoing minor surgery, and 22 ASA class I patients undergoing intermediate surgery were admitted to the S-ICU. Due to the contribution of the surgical component, the total POSSUM scores were significantly higher in the major and major plus surgery groups than in the minor and intermediate surgery groups (ANOVA: P<0.001; Scheffè test: major plus surgery scores higher than major surgery scores P<0.001; both major plus surgery and major surgery scores were higher than minor and intermediate surgery scores: P<0.001).

Table II indicates patient location on the second, seventh, and thirtieth postoperative days. The number of patients deceased is also reported. The majority of patients were discharged from the S-ICU and transferred to a surgical ward on the first day following surgery. On the second postoperative day, only 73 patients (7%) were still admitted in the S-ICU, while 962 (92.0%) had been moved to a surgical ward. On the thirtieth postoperativeday, only six patients (0.6%) were in the S-ICU or in general ICU, and 121 (11.6%) had moved to a surgical ward. Six patients remained in the ICU 30 days after surgery, all of whom were affected by respiratoryfailure secondary to pneumonia (two cases) or abdominal sepsis (four cases). The percentage of patients in the S-ICU was always higher in patients who underwent major or major plus surgery.

The overall mortality was 2.4% (95% CI: 1.5-3.3%). This value can be regarded as a perioperative 30-day mortality rate because no patient scheduled for postoperative admission to the S-ICU died intraoperatively. The 25 patients who died

TABLE VII.—*Exponential analysis of morbidity predicted by POSSUM.*

Mortality group %	N. of patients	Observed N. of patients affected by complications	Predicted N. of patients affected by complications	Observed/predicted
0-29	329	97	45	2.15
10-29	304	90	45	2.00
20-29	147	43	29	1.48
30-39	154	50	46	1.09
40-100	562	229	225	1.02
50-100	424	178	212	0.84
60-100	295	120	177	0.68
70-100	192	75	134	0.56
80-100	102	43	82	0.53
90-100	45	22	40	0.54
0-100	1 045	376	316	1.19

Patients are divided according to the probability of perioperative complications calculated by POSSUM (first column). Classes overlap because exponential analysis has been performed The analysis was restarted from 30% and 40% probability of complications because predicted number of patients affected by complications was higher than that predicted in the previous group. Predicted number of patients affected by complications is rounded to the nearest whole number.

(14 males and 11 females) were aged 44-91 years (mean 71), and underwent abdominal (N.=12 out of 374; 3.2%, 95% CI: 1.4-5.0%), orthopedic (N.=8 out of 214; 3.7%, 95% CI: 1.2-6.3%), thoracic (N.=2 out of 99; 2.0%, 95% CI: 0-4.8%), ENT (N.=1 out of 25; 4.0%, 95% CI: -4.1-12.0%), gynecologic (N.=1 out of 64; 1.6%, 95% CI: -1.5-4.7%), or bariatric surgery (N.=1 out of 39; 2.6%, 95% CI: -2.6-7.7%). No patient who underwent minor surgery died. Mortality associated with intermediate, major, and major plus surgery was 2.3 (95% CI 0.3-4.3%), 2.1 (95% CI 1.0-3.2%), and 4.2% (95% CI 1.1-7.3%), respectively. Six deaths occurred within 48 hours following surgery, two of which occurred in the surgical ward on the second postoperative day and were attributed to cardiovascular causes; both patients fully matched the discharge criteria from the S-ICU, and deaths were completely unexpected and unpredictable. Four deaths occurred between the third and seventh postoperative days, and 15 occurred between the eighth and thirtieth postoperative days. Expressed per day, the mortality rate was higher during the first 48 hours (2.87 per thousand) and then stabilized to around 0.7 per thousand (0.76 per thousand between the third and seventh postoperative days; 0.62 per thousand between the eighth and thirtieth postoperative days). The six patients still in the S-ICU or in the general ICU 30 days following surgery were all successfully discharged.

Table III reports the presumptive causes of death and postoperative complications classified according to Copeland;[8] the location of occurrence and timing are also reported. The majority of the causes of deaths were circulatory; two cases of massive pulmonary embolism were diagnosed within the first 24 hours postoperatively because transthoracic echocardiogram identified acute right ventricular dilation with the presence of an interior thrombus. One patient endured a stroke and died at home on the thirtieth postoperative day. Peritonitis caused two deaths between the third and seventh postoperative days. Uncontrolled hemorrhage was the cause of one death a few hours after surgery, and gastric hemorrhage caused two deaths after the seventh postoperative day. Sepsis, respiratory failure, and cardiac failure were the most frequently observed complications. The rate of complications per day progressively decreased from 7.7% in the first 48 postoperative hours to 4.3% between the third and seventh postoperative days and 0.9% between the eighth and thirtieth postoperative days. Cardiac failure, arterial hypotension, respiratory failure, and hemorrhage all reached a maximum incidence in the first 48 postoperative hours followed by a rapid decrease. The incidence of sepsis was at its highest between the third and seventh postoperative days, and wound dehiscence occurred most frequently after the first postoperative week.

Table IV reports the age, ASA class, POSSUM values, and BMI of deceased, surviving, complicated and uncomplicated patients. Deceased and surviving patients did not significantly differ in BMI, age, or POSSUM surgical score, but the POSSUM physiological score was higher in deceased patients (t-test: P<0.001). The mortality rate was higher in ASA class IV (N.=12; 12.8%; 95% CI: 6.0-19.5%) than in class I (N.=2; 1.8%; 95% CI: 0-4.3%), II (N.=1; 0.3%; 95% CI: 0-0.8%), or III (N.=10; 2.1%; 95% CI: 0.8-3.4%). Morbidity was not associated with statistically significant differences in age, BMI, POSSUM, or ASA.

The actual mortality rate (2.4%; 95% CI: 1.5-3.3%) was lower than that predicted by POSSUM (6.2%; O/E ratio 0.38; Table V) and P-POSSUM (5.3%; O/E ratio 0.45; Table VI). The percentage of patients affected by one or more complications was 36.0% (95% CI: 33.1-38.9%), which was slightly more than the percentage predicted by POSSUM (30.2%; O/E ratio 1.19; Table VII). Morbidity was underpredicted in low-risk patients (O/E ratio associated with a predicted risk of 0-29%: 2.15) and overpredicted in high-risk patients (O/E ratio associated with a predicted risk of 80-100%: 0.53).

Discussion

This survey investigated the 30-day postoperative morbidity and mortality in a large sample of patients admitted to the S-ICU following scheduled surgery after preoperative evaluation. This study focused on the development of early complications because following a surgical procedure a certain amount of postoperative intensive care is often necessary. No previously published data on this topic were found. The results from the study demonstrate that the first 48 hours after surgery are critical because about one-third of postoperative complications and one-fourth of postoperative deaths occur during this time period. Early serious complications were primarily cardiovascular in nature: more than half of the episodes of heart failure and arterial hypotension and one third of cardiovascular deaths occurred during the first 48 hours after surgery. On the other hand, the majority of the patients included in this survey (93%) had an uneventful stay in the S-ICU or presented with only mild complications, and were soon moved to a surgical ward within 48 hours after surgery to continue monitoring.

In this study 598 complications were registered (0.56 per patient), 162 of which (27%) occurred during the first 48 hours after surgery. The incidence of complications was at a maximum immediately following the surgery and afterwards decreased progressively, as clearly demonstrated by the observed rates per day, which were 7.7% in the first 48 hours, 3.6% from the third to seventh postoperative days, and 0.9% after the seventh postoperative day. The specific nature of the complications also correlated with the time elapsed from surgery. About 50% of observed complications involved persistent arterial hypotension and cardiac and respiratory failure observed during the first 48 postoperative hours, while complications such as sepsis and wound dehiscence occurred later. This is a major point because on-line cardiovascular and respiratory monitoring allows for the immediate detection and the treatment of sudden cardiovascular and respiratory deterioration, while discrete evaluation performed in surgical wards may result in a harmful delay. In this study, the majority of patients were moved to the surgical ward within the first postoperative day. However, hypothetically, some of these patients may have benefited from a 48-hour stay in the S-ICU.

Perioperative mortality has been investigated by many authors, but timing/location and presumptive cause of death have seldom been reported. There is only one study in literature that lists myocardial failure and multiple organ failure as the most frequent (34% and 19%) causes of death in a series of 200 perioperative deaths collected in a prospective, multicenter study in Germany.[11] The timing and location of these deaths were not reported. In this study, an even higher percentage of deaths (60%) was attributed to cardiovascular complications, possibly secondary to the enrolment of high-risk patients or because emergency surgery was excluded. An additional interesting finding is the bimodal trend of cardiovascular deaths: five out of 15 deaths occurred within 48 hours of surgery, and 9 out of 15 after the first postoperative week. Postoperative intensive care may potentially prevent early cardiovascular deaths, which are primarily secondary to myocardial infarction or pulmonary embolism. Finally, the present results suggest that patients who are considered to be at an increased risk of sudden cardiovascular complications should remain in the S-ICU for at least 48 hours after surgery. In accordance with this finding, preoperative evaluation of cardiopulmonary reserve, for example by cardiopulmonary exercise testing, may offer valuable data to help detect patients at risk.[12]

Controlled studies evaluating the impact of planned admission to the S-ICU on postoperative mortality and morbidity are extremely limited and probably quite difficult to perform due to ethical conflicts.[13] As an alternative, mortality and morbidity rates were compared with those predicted by POSSUM, a severity score specifically introduced to facilitate surgical audit. Other scoring methods targeting critically-ill patients would be unaffected by surgical procedures and would discriminate poorly in the absence of severe physiological complications. Since POSSUM scoring may overpredict mortality among low-risk patients, the P-POSSUM analysis has been proposed.[9, 14] In this study, both equations were used because POSSUM accuracy is adequate when exponential data analysis is utilized.[10, 15] Since their introduction, POSSUM and P-POSSUM have been validated by several studies [15-22] and extensively employed for surgical audits,[15-18] proving to be the most appropriate of the currently available scoring methods for general surgical practice.[23] However, POSSUM and P-POSSUM accuracy may decrease when applied to single surgical procedures.[24-27] In this study, less than half the perioperative mortality predicted by POSSUM and P-POSSUM actually occurred. This finding agrees with the results of a retrospective study performed on a smaller group of patients in an Australian S-ICU [28] and may suggest a positive impact of planned postoperative intensive care on mortality rates. Observed morbidity was slightly higher than that predicted by POSSUM, perhaps because certain complications such as transitory hypotension or brief paroxysmal atrial fibrillation are more easily detected in the S-ICU than in the surgical ward.

The majority of patients included in this survey experienced an uneventful stay in the S-ICU, suggesting that the need for postoperative intensive care may be overestimated. In agreement with other studies,[29, 30] deceased patients were characterized by higher ASA classes and POSSUM physiological scores, which suggest more severe preoperative physiological complications. Conversely, deceased and surviving patients did not differ in age or BMI. Unfortunately, the gravity scores of deceased *versus* surviving patients and complicated *versus* uncomplicated patients were largely overlapping. Consequently, it seems that gravity scores are valuable for surgical audits, but they appear to be less effective when applied to an individual patient. As such, postoperative outcomes may be better predicted by clinical assessment.[30] Cardiopulmonary reserve assessment is a promising technique for clinical evaluation since a low anaerobic threshold is associated with increased postoperative cardiopulmonary morbidity.[12, 31-34] However, extensive utilization of cardiopulmonary exercise testing may considerably increase the cost of a hospital stay. Finally, although severity scores and cardiopulmonary reserve evaluation are useful tools, planning postoperative intensive care is a clinical decision to be made by balancing the fact that unnecessary admissions increase costs, with the fact that admission criteria that are too restrictive to the S-ICU may increase mortality and morbidity.

Conclusions

In conclusion, this study suggests that the first 48 postoperative hours are critical in high-risk patients since the majority of complications and deaths occurred during this period. Planned admission to the S-ICU may potentially decrease early postoperative mortality, as suggested by the difference observed in this study between observed and expected numbers of deaths. Patients who are at an increased risk of sudden complications should remain in the S-ICU for 48 hours following surgery, while a longer stay in the ICU may be unnecessary.

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APPENDIX I

Calculation of predicted individual risk of mortality and morbidity.

Individual risk of mortality and morbidity was derived from the POSSUM physiological and surgical scores.[8] The percent risk of mortality was calculated using the formula:

$$100 \times b/(1+b), \text{ where } b= e^{(0.13 \times \text{physiological score})+(0.16 \times \text{surgical score})-7.04}$$

and the risk of morbidity with the formula:

$$100 \times a/(1+a)$$

where $a = e^{(0.16 \text{ x physiological score})+(0.19 \text{ x surgical score})-5.91}$

The risk of mortality was also calculated from the POSSUM physiological and surgical scores using the Portsmouth predictor equation (P-POSSUM). According to Whiteley *et al.*, P-POSSUM may offer a more accurate estimate of perioperative mortality than POSSUM.[9] The formula was:

$$100 \text{ x } c/(1+c)$$

where $c=e^{(0.19 \text{ x physiological score})+(0.15 \text{ x surgical score})-9.37}$

Predicted mortality and morbidity were compared to observed mortality and morbidity, respectively. In accordance with the procedure described by Wijesinghe *et al.*,[10] comparisons were performed with exponential analyses of mortality and morbidity predicted by POSSUM and with linear analyses of mortality predicted by P-POSSUM. Multiple analyses were necessary because of the different mathematical procedures by which the aforementioned equations were obtained.

In exponential analysis, a series of cut-off values for mortality (or morbidity) risk were chosen. All of the patients whose risk fell above the cut-off value were grouped together and their number multiplied by the cut-off to calculate the predicted number of deaths in that group. For instance, if 50 patients had a mortality risk greater than 40%, the predicted mortality associated with that cut-off would be 0.4x50, or 8 deaths out of 50. Two difficulties occurred during the analysis: first, in overall evaluation (corresponding to 0 percent cut-off), multiplication by zero was avoided by instead multiplying the total patient number by the median predicted risk of the below-10 percent mortality band, and second, as stated by Wijesinghe *et al.*, "if the calculated number of predicted deaths above a cut-off value falls below the number calculated for a higher cut-off, a second calculation should begin again from the lower cut-off".[10]

In linear analysis, patients were divided by classes according to their mortality risk calculated by P-POSSUM. In each class, the number of subjects was multiplied by the mean mortality risk in order to determine the estimated number of deaths.

The observed/expected ratios between actual and expected deaths (or complications) were calculated.