Original articles

The Epidemiology of Major Early Adverse Physiological Events After Surgery

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ABSTRACT

Objective: *To study the incidence of major post-operative adverse physiological events in a tertiary hospital.*

Methods: *Non-cardiac, surgical in-patients were studied for the first three post-operative days. Daily assessment was by patient visit, chart review and laboratory result analysis. Pre-determined diagnostic criteria for the identification of adverse physiological events were used.*

Results: *One hundred and seven patients were studied. The mean age was 61 ± 20 years. Forty-four were female and 63 were male. Pre-operatively, 48 patients had one or more of 34 different co-morbidities. Forty three (40%) of the 107 patients had one or more major adverse physiological events. These events included hypotension 24 (22%), altered mental state 16 (15%), oliguria 9 (8.4%), abnormal heart rate 8 (7.5%) and abnormal respiratory rate 5 (4.7%). Morbidity associated with these events included respiratory failure 5 (4.7%), prolonged altered mental state 5, (4.7%), and septic shock 3 (2.8%). There were two deaths. Adverse physiological events were common in thoracic 5/9 (56%), neurosurgical 4/10 (40%) and vascular 8/13 (62%) patients. Prolonged altered mental state was most common among orthopaedic patients 5/22 (23%). Adverse physiological events were more frequent in the elderly than the young: 14/52 (27%) in those who were less than 65 years of age versus 29/55 (53%) in those who were 65 years and older ($p < 0.025$). There was a non-significant increase ($p < 0.1$) in adverse physiological events in patients having emergency surgery 16/28 (57%) compared with those having elective surgery 27/79 (34%)*

Conclusions: *This study reveals a high incidence of post-operative adverse physiological events in surgical patients in a university teaching hospital and identifies several high-risk groups. Further studies are needed to define the clinical significance of these events, appropriate management and prognosis.*
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Key Words: Adverse physiological events, critical illness, morbidity, complications, mortality, epidemiology

The early post-operative period can be associated with important physiological disturbances.[1] These disturbances are more likely in patients who have co-morbidities or complex surgery or both. There is, however, little information on the epidemiology of adverse physiological events and their association with morbidity. This information would help identify the size of the problem and the need for additional strategies to reduce post-operative morbidity.

There are few definitions of clinically important physiological disturbances. Lee and colleagues[2] recently published a report proposing criteria for adverse physiological events that, in their institution, led to the attendance of a medical emergency team. These investi-

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Table 1. Criteria used to diagnose specific conditions in the postoperative period

Conditions	*Diagnostic criteria*
Cardiovascular	
Acute myocardial infarction	Definite electrocardiography changes or increased CK > 2 x upper limit with CK-MB > 6%
Pulmonary oedema	Confirmed on chest X-ray
New dysrhythmia	Diagnosed on electrocardiography
Shock	Systolic BP < 90mmHg for > 2 hr OR need for inotropic support plus evidence of organ dysfunction (e.g. oliguria, confusion, peripherally cold and 'shutdown')
Hypovolaemic shock	Decreased filling pressures (e.g. low jugular venous pressure) plus clinical evidence of intravascular volume loss
Cardiogenic shock	Increased JVP/ filling pressures $\pm$ pulmonary oedema
Anaphylactic shock	Shock with obvious oedema, rash, bronchospasm or a precipitant drug
Septic shock	Shock with vasodilation, temperature < 35.5 or > 38°C $\pm$ septic focus
Respiratory	
Acute respiratory failure	Need for mechanical ventilation OR need for F_IO_2 > 0.6
Pneumonia	New infiltrate on chest X-ray plus - one or more of acute onset of cough/ sputum/ temp >38°C OR - two or more of dyspnoea, pleuritic chest pain, altered mental status, wcc > 12000 x 10^9/L plus no other septic focus
Pulmonary embolus/DVT	Confirmed on V/Q scan, pulmonary angiogram, calf doppler ultrasound or venogram
Metabolic	
Acute diabetic emergencies	BSL < 2mmol/L OR BSL > 30mmol/L BSL > 20mmol/L plus one or more of plasma -pH < 7.2 -bicarbonate < 10mmol/L -decreased consciousness -shock
Poisoning	
Excessive narcosis	Need for naloxone
Epidural induced hypotension	BP < 90 mmHg for > 2 hr and no other cause
Surgical	
Excessive bleeding	Bleeding requiring > 2 units post-operatively in any 24 hr period

CK = creatinine kinase, BSL = blood glucose level, DVT = deep vein thrombosis

gators felt that they could identify patients at risk of complications such as respiratory failure, renal failure and cardiorespiratory arrest. We used these criteria with slight modifications to study the incidence of post-operative adverse physiological events in our institution.

METHODS

This study was conducted as a prospective, anonymous, confidential and non-interventional audit in a large university teaching hospital. We proposed to study approximately 100 consecutive elective and emergency, non-cardiac, surgical in-patients who stayed at least one night in hospital post-operatively. Patients were identified from operating theatre lists. The patients were followed prospectively for the first three post-operative days, unless they were discharged earlier. Daily assessment started 12 to 24 hours after returning to the ward or the intensive care unit (ICU). The assessment included a patient visit, chart analysis of nursing notes, medical notes and laboratory results with diagnostic criteria for post-operative disorders tabulated in table 1 and criteria for the presence of physiological adverse events (using slightly modified criteria from Lee *et al*[2]), shown in table 2. We did not follow patients after discharge nor did we look for the incidence of readmission. Our hospital Ethics Committee waives a

need for informed consent for this kind of study.

Statistical analysis was by descriptive statistics and the Chi-square test was used to compare ordinal variables. A p value of < 0.05 was considered statistically significant.

Table 2. Criteria for the presence of physiological adverse events

Clinical criteria	
Temperature	< 35.5 or > 39.5°C
Systolic blood pressure	< 100 or > 200 mmHg
Respiratory rate	< 10 or > 30/min
Pulse rate	< 40 or > 120/min
Urine output over 24 hr	< 500 mL
Altered mental state	reduced conscious state, confusion, delirium
Laboratory criteria	
Serum potassium	< 3 or > 6 mmol/L
Serum sodium	< 125 or > 155 mmol/L
Blood glucose	< 2 or > 20 mmol/L
Arterial pH	< 7.2 or > 7.55
Base excess	< -15 or > 10
Bicarbonate	< 10 or > 35 mmol/L
Urea*	> 30 mmol/L
Creatinine*	> 0.170 mmol/L
White cell count*	> 20,000 /mL
Bilirubin*	> 100 μmol/L

* Additions to criteria used by Lee and colleagues.[2]

RESULTS

Over 9 days, one hundred and seven patients were studied. Figure 1 shows the number of patients per surgical group. Because some patients were discharged before the third post-operative day, the total number of patient days studied was 284 rather than 321. The mean patient age was 61 ± 20 years. Forty-four patients were female and 63 were male. Forty-eight patients had one or more of 34 different pre-operative co-morbidities (Table 3).

The overall incidence of predefined adverse physiological events during the 3-day study period was 40% with 43 of 107 patients having one or more events. The development of adverse physiological events after surgery was more common in patients with pre-existing co-morbidities. Twenty-seven of the 48 (56%) patients with pre-existing co-morbidities had adverse physiological events compared with 16/59 (27%) without ($p < 0.005$).

Disturbances of clinically measured variables, especially blood pressure and mental state, were more common than abnormalities of laboratory tests (Table 4).

Table 3. Co-morbidities in the cohort under study

Disorder	Number of patients
Neurological	
Dementia	3
Intellectual impairment	1
Chronic anxiety	1
Spinal cord lesion	3
Blind	1
Deaf	1
Schizophrenia	1
Stroke	6
Epilepsy	3
Cardiovascular	
Hypertension	12
Ischaemic heart disease	7
Peripheral vascular disease	2
Atrial fibrillation	3
Valvular disease	2
Congestive heart failure	3
Previous thromboembolism	1
Respiratory	
Current heavy smoker	10
Asthma	1
Chronic airway disease	8
Sleep apnoea	1
Partial airway obstruction	1
Renal	
Chronic renal impairment	2
End-stage renal failure	12
Gastrointestinal	
Peptic ulcer	1
Alcohol abuse	1
Liver failure	3
Metabolic	
Obesity	2
Diabetes mellitus	7
Hypothyroidism	2
Parathyroid disease	2
Infective	
HIV positive	1
Hepatitis B positive	1
Hepatitis C positive	1
Malignancy	5

An alteration in mental state occurred in 16 (15%) patients and was most common in orthopaedic patients (5/22; 23%). An altered mental state was also more common in patients who had hypotension (7/22; 22%) compared with those who were not hypotensive (9/85; 11%) ($p < 0.05$) and more common in the elderly: (4/52; 7.7%) in patients < 65 years old compared with (12/55; 22%) in patients who were > 65 years old, but this

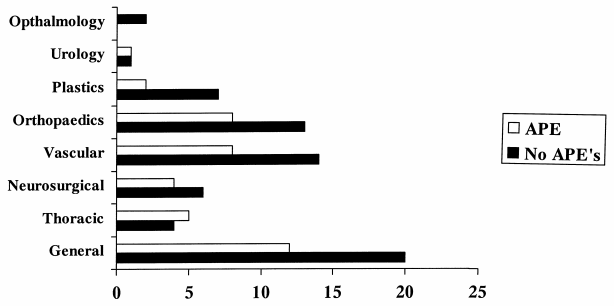

Figure 1. Number of patients per surgical group. The clear columns represent the number of patients who had an adverse physiological event (APE) and the dark columns represent the number of patients who did not have an adverse physiological event (No APE).

Table 4. Type and frequency of physiological adverse events

Physiological variable	*Number of cases*
Abnormal temperature	5 (4.7%)
Abnormal blood pressure	24 (22%)
Abnormal respiratory rate	5 (4.7%)
Abnormal heart rate	8 (7.5%)
Decreased urine output	9 (8.4%)
Altered mental state	16 (15%)
Abnormal serum potassium	1 (1%)
Abnormal blood glucose	1 (1%)
Elevated urea	1 (1%)
Elevated creatinine	2 (2%)
Elevated white cell count	5 (4.7%)
Elevated bilirubin	1 (1%)

Table 5. Incidence of specific complications in cohort under study

Parameter	*In patients <65 years*	*In patients >65 years*
Cardiopulmonary arrest	0	2 (3.7%)
Dysrrhythmia	0	2 (3.7%)
Hypovolaemic shock	0	1 (2%)
Septic shock	0	3 (5.6%)
Respiratory failure	1 (2%)	4 (7.3%)
Diabetic emergencies	1 (2%)	0
Excessive narcosis	0	1 (2%)
Epidural hypotension	0	3 (5.6%)
Status epilepticus	0	1 (2%)
Altered mental state	4 (7.7%)	12 (22%)
Excessive bleeding	1 (2%)	0
Re-operation	0	1 (2%)

difference was not statistically significant ($p < 0.1$).

Post-operative morbidity following surgery included respiratory failure in 5 patients (4.7%) and septic shock in 3 (2.8%) patients. Adverse physiological events were particularly common in thoracic (5/9; 56%), neurosurgical (4/10; 40%), and vascular patients (8/13; 62%) (Figure 1). Patients with adverse physiological events had a longer hospital stay. Ninety-three percent (40/43) of patients who experienced at least one adverse physiological event were still in hospital at day three compared with 66% (40/64) of patients who did not. Adverse physiological events were more frequent in patients more than 65 years old compared with those who were less than 65; 29/55 (53%) versus 14/52 (27%) ($p < 0.025$). The specific complications in patients < 65 years compared with those > 65 years are shown in table 5.

Emergency surgery had a higher rate of adverse physiological events (16/28; 57%), than elective surgery (26/79; 34%); but this difference was not statistically significant ($p < 0.1$). Nine of the eleven patients admitted to ICU had one or more adverse physiological events while in ICU. The surgical sub-groups admitted to ICU were: general (4), vascular (2), plastics (1) thoracic (2) orthopaedic (2). Of the two patients who did not have an adverse physiological event, one was orthopaedic and one was thoracic. When these 11 ICU patients were excluded from the total of 107, the rate of adverse physiological events for thoracic, neurosurgical and orthopaedic patients did not change. The overall incidence of adverse physiological events, however, decreased from 40% to 35%, particularly in general surgery (37.5% to 26%) and vascular surgery (36% to 30%). If patients having renal access vascular surgery are excluded, the rate of adverse physiological events for vascular patients increases to 54% (6/11).

Intra-abdominal surgery had a higher rate of physiological instability (10/22; 45%) than more superficial operations (1/7; 14%). Hypotension occurred in 3 of 7 patients with an epidural block, although only 3 of 22 hypotensive patients were receiving epidural analgesia.

There were two deaths in our group. These two patients were over 70 years old with pre-existing co-morbidities and both developed adverse physiological events. One died from complications of a myocardial infarction and one died from multiple organ failure.

DISCUSSION

We found a 40% post-operative incidence of adverse physiological events. This finding has major implications because patients who have post-operative complications have increased mortality rates, longer

hospital stays and increased use of resources.[3] The identification of high-risk patients is important for developing preventative and interventional strategies.

The predictive value of adverse physiological events for morbidity and mortality is unknown. In a recent retrospective study, Buist and colleagues[4] used a set of physiological criteria similar to ours, for the diagnosis of clinical instability. These investigators found that 'critical events' (cardiac arrests or unplanned admissions) in the general hospital population were preceded by a median of two episodes of physiological instability and these episodes could already be identified more than 6 hours before the critical event. Buist and colleagues, however, provide no information about the background incidence of major physiological events. Data on the incidence of these adverse physiological events are vital in understanding how many adverse physiological events progress to morbidity, how many are adequately treated in the ward and how many improve spontaneously.

Extrapolating from our data, at our hospital over a one-year period, about 1,700 patients would experience one or more adverse physiological events with about 80 deaths. The ability to prevent these deaths is speculative. Excluding renal access patients, our study identified two high-risk groups: thoracic and vascular surgery patients. This finding may help in planning further studies.

We found a high rate of altered mental state in our cohort (15/107; 16%). This finding is consistent with previous studies. Williams-Russo and colleagues,[5] studied 262 patients undergoing total knee joint replacement and found an 11% incidence of acute delirium after surgery. A European multicentre study[6] found that, one week after surgery, patients aged between 60 - 69 years had a 23% incidence of post-operative cognitive dysfunction, while patients seventy years and older had an incidence of 29%. O'Keefe and Chonchubhair[7] found the major risk factors for post-operative delirium were - advanced age, multiple medical problems and severe physical and sensory impairment. These factors often occur together. The higher relative rate of altered mental state (which includes post-operative cognitive dysfunction) among our orthopaedic, plastic and urology patients reflects the older average ages in these groups. Our results agree with previous studies that have shown twice the rate of post-operative delirium in elderly patients undergoing orthopaedic surgery (20%) compared with elderly general surgery patients (10%).[7,9] Berggren and colleagues[10] found that post-operative changes in conscious state occurred in 44% of elderly patients after surgical fixation of a fractured neck of femur.

Persisting altered mental state (including delirium) is associated with a higher post-operative mortality rate.[7,11] Pressure sores and chest infections are common due to immobility and sedation. Affected patients are at increased risk of accidents. Long term post- operative cognitive dysfunction correlates with decreasing activity of daily living and increasing need for assistance after surgery.[6] Some studies have shown no association between hypotension and post- operative cognitive dysfunction[6,12] In contrast, our study showed an increased incidence of altered mental state in patients with hypotension, suggesting that hypotension may be a target for therapeutic intervention.

We found a clinically important and statistically significant increase in adverse physiological events in patients who had pre-operative co-morbidity and a clinically important (but statistically non- significant) increase in post-operative incidence of adverse physiological events after emergency surgery compared with elective surgery. Both these findings were expected and agree with a recent study by Lee *et al.*[13] These investigators found risk factors for early post-operative adverse events included; high American Society of Anaesthesiologists physical status and surgical procedures performed outside normal working hours. Studies on intensive care patients have shown that limited physiological reserve is an important determinant of mortality and quality of survival. The greater the number of co-morbidities, the greater the risk of death.[14] Elderly patients are at increased risk of peri-operative morbidity and mortality because of a high incidence of coexisting age-related disease and reduced functional reserve in major organ systems.[15] A recent Spanish study found that the major risk factors for post-operative mortality are advanced age, emergency surgery and high American Society of Anaesthesiologists score.[16]

There is some evidence in high-risk surgical patients that optimising physiological variables before surgery may decrease mortality,[18] although further studies in this area should be conducted. There is also a need to test whether the availability of high dependency unit beds for post-operative patients requiring a level of care intermediate to that of the general ward and intensive care would decrease post-operative adverse physiological events and morbidity.[19] A non-randomised trial showed that establishing a high dependency unit reduced complications.[14] Another intervention for investigation is the development of teams of 'hospitalists',[20-22] providing 24-hour cover as post-operative physicians. The impact of 'hospitalists' on adverse physiological events and subsequent morbidity and mortality requires further investigation. No matter what strategies are tried to reduce the incidence of adverse physiological events in the early post operative period, the problem of optimising post-operative care

remains an acute care issue needing urgent attention. This attention should address clinical and research issues together.

In summary, we have conducted the first prospective study of the epidemiology of post-operative adverse physiological events in an Australian hospital. These events affected approximately 40% of post-operative patients in a tertiary institution and were associated with a 2% in-hospital mortality within 3 days. We have found that vascular and thoracic patients are high-risk groups that experience a greater than 50% incidence of events. Our findings reinforce the idea that pre-operative co-morbidity increases the risk of adverse physiological events. We have identified hypotension as a potential trigger of post-operative altered mental state. This information constitutes the first step in a progressive strategy aimed at studying and modifying post-operative morbidity and mortality.

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REFERENCES

1. Ralley FE. Post-operative anaesthetic care. Can J Anaesth 1996;43;759-763.
2. Lee A, Bishop G, Hillman K, Daffurn K. The Medical Emergency Team. Anaesth Intensive Care 1995;23:183-186.
3. Kazmers A, Jacobs L, Perkins A. The implications of complications after vascular surgery in Veterans Affairs Medical Centres. J Surg Res 1997;67:62-66.
4. Buist MD, Jarmolowski E, Burton PR, Bernard SA, Waxman BP, Anderson J. Recognising clinical instability in hospital patients before cardiac arrest or unplanned admission to intensive care. A pilot study in a tertiary care hospital. Med J Aust 1999;171:22-25.
5. Williams-Russo P, Sharrock NE, Mattis S, Szatrowski TP, Charlson ME. Cognitive effects after epidural versus general anaesthesia in older adults. A randomised trial. JAMA 1995;274:44-50.
6. Moller JT, Cluitmans P, Rasmassen L, et al. Long-term postoperative cognitive dysfunction in the elderly: ISPOCD1 study. Lancet 1998;351;857-861.
7. O'Keefe S, Ni Chonchubhair A. Post-operative delirium in the elderly. Br J Anaesth 1994;73;673-687.
8. Seymour DG, Vaz FG. A prospective study of elderly general surgical patients: II. Postoperative complications. Age Ageing 1989;18:316-326.
9. Ni Chonchubhair A, Valacio R, Kelly J, O'Keefe S. Use of the abbreviated mental test to detect postoperative delirium in elderly patients. Br J Anaesth 1995;75:481-482.
10. Berggren D, Gustafson Y, Eriksson B, et al. Postoperative confusion after anaesthesia in elderly patients with femoral neck fractures. Anaesth Analg 1987;66:497-504.
11. Franklin C, Mathew J. Developing strategies to prevent in hospital cardiac arrest: Analysing responses of physicians and nurses in the hours before the event. Crit Care Med 1994;22:244-247.
12. Dodds C, Allison J. Post-operative cognitive deficit in the elderly surgical patient. Br J Anaesth 1998;81:449-462.
13. Lee A, Lum ME, O'Regan WJ, Hillman KM. Early postoperative emergencies requiring an intensive care team intervention. The role of ASA physical status and after-hours surgery. Anaesthesia 1998;53:529-535.
14. Franklin CM, Rackow EC, Mamdani B, Nightingale S, Burke G, Weil MH. Decreases in mortality on a large urban medical service by facilitating access to critical care. An alternative to rationing. Arch Intern Med 1988;148:1403-1405.
15. Muravchick S. The ageing process: anaesthetic implications. Acta Anaesthesiol Belg 1998;49:85-90.
16. Suan C, Peres–Torres C, Herrera A. Postoperative mortality in a general hospital. Rev Esp Anestesiol Reanim 1997;44:267-272.
17. Prause G, Ratzenhofer-Komenda B, Smolle-Juettner F, et al. Operations on patients deemed "unfit for operation and anaesthesia": what are the consequences? Acta Anaesthesiol Scand 1998;42:316-322.
18. Heyland DK, Cook DJ, King D, Kernerman P, Brun-Buisson C. Maximising oxygen delivery in critically ill patients: A methological appraisal of the evidence. Crit Care Med 1996;24:517-524.
19. Nasraway SA, Cohen IL, Dennis RC, et al. Guidelines on admission and discharge for adult intermediate care units. American College of Critical Care Medicine. Crit Care Med 1998;26:607-610.
20. Hillman K.The changing role of acute-care hospitals. Med J Aust 1999;170:325-328.
21. Kelly WJ. The changing role of acute-care hospitals. Med J Aust 1999;171:223-224.
22. Scott IA, Phillips PA. Hospitals and hospitalists: an alternative view.Internal Medicine society of Australia and New Zealand. Med J Aust 1999;171:312-314.