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ORIGINAL ARTICLE

Complications and mortality in older surgical patients in Australia and New Zealand (the REASON study): a multicentre, prospective, observational study*

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Summary

We conducted a prospective study of non-cardiac surgical patients aged 70 years or more in 23 hospitals in Australia and New Zealand. We studied 4158 consecutive patients of whom 2845 (68%) had pre-existing comorbidities. By day 30, 216 (5%) patients had died, and 835 (20%) suffered complications; 390 (9.4%) patients were admitted to the Intensive Care Unit. Pre-operative factors associated with mortality included: increasing age (80–89 years: OR 2.1 (95% CI 1.6–2.8), $p < 0.001$; 90+ years: OR 4.0 (95% CI 2.6–6.2), $p < 0.001$); worsening ASA physical status (ASA 3: OR 3.1 (95% CI 1.8–5.5), $p < 0.001$; ASA 4: OR 12.4 (95% CI 6.9–22.2), $p < 0.001$); a pre-operative plasma albumin < 30 g.l^{-1} (OR: 2.5 (95% CI 1.8–3.5), $p < 0.001$); and non-scheduled surgery (OR 1.8 (95% CI 1.3–2.5), $p < 0.001$). Complications associated with mortality included: acute renal impairment (OR 3.3 (95% CI 2.1–5.0), $p < 0.001$); unplanned Intensive Care Unit admission (OR 3.1 (95% CI 1.9–4.9), $p < 0.001$); and systemic inflammation (OR 2.5 (95% CI 1.7–3.7), $p < 0.001$). Patient factors often had a stronger association with mortality than the type of surgery. Strategies are needed to reduce complications and mortality in older surgical patients.

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In a study of 1100 older surgical patients in three hospitals in one Australian city (Melbourne) we previously found that 208 (19%) patients had complications and 61 (6%) died within 30 days [1]. This was one of a few prospective studies to examine the association of mortality with both patient factors and defined complications across a wide range of surgical specialties [2]. Our findings were broadly consistent with the small number of published North American and European studies [3–6]. Previous studies, including ours, have found that high rates of complications were associated with prolonged hospitalisation, increased hospital costs, and mortality [1, 7, 8].

The American College of Surgeons [9, 10] has data on millions of patients and is the largest source of information on peri-operative risk; however the data may not reflect hospitals outside the US.

In overall structure, medical care in Australia and New Zealand is similar to that in the UK with general practitioner based primary care, universal health care provided at public hospitals and with many surgical procedures also undertaken at private hospitals [11]. Medical specialists often undertake advanced training in either the UK or North America. As in the UK, specialty medical colleges in Australia and New Zealand (covering both countries) oversee training in anaesthesia, surgery, intensive care, and internal medicine. We proposed that the high rates of complications and mortality found in Melbourne would also be found if we extended the study to other hospitals in Australia and New Zealand. Further, we planned to identify more precisely the association of postoperative mortality with patient and operative factors and postoperative complications. We therefore extended our previous prospective observational study of elderly surgical patients [1] at three Melbourne hospitals to public hospitals across Australia and New Zealand.

Methods

The first part of this study, previously reported [1, 12], was conducted at three Melbourne hospitals between June and September 2004. We combined the data from this previous study with new data from a broader group of hospitals, using the same inclusion criteria and definitions for comorbidity and complications. The Trials Group at the Australian and New Zealand College of Anaesthetists (ANZCA) recruited another 20 hospitals to take part in this new broader phase (Appendix 1). To make this study easily identifiable we called it the REASON study (Research into Elderly Patient Anaesthesia and Surgery Outcome Numbers). Hospitals from all Australian states and New Zealand participated. We collected the additional data between December 2007 and December 2008. To balance workload and sample sizes from each hospital, hospitals were asked to collect data on all eligible patients for two months or up to a sample of 200 patients. The Human Research Ethics Committee from each hospital approved this study and waived the need for informed consent from individual patients.

We studied consecutive patients aged 70 years or older, undergoing non-cardiac surgery who were expected to require a stay of at least one night in hospital. Surgical specialties were classified in a manner similar to other Australian surgical audits [13]. A research nurse or medical trainee at each hospital identified patients from operation lists, operating room records, and surgical unit liaison nurses. Data were collected prospectively for the first five days after surgery, or until hospital discharge (whichever was longer), both in the Intensive Care Unit (ICU) and the general wards. The High Dependency Unit (HDU) [14] was considered to be part of the ICU. Planned ICU admissions were those where admission was planned before surgery; unplanned admissions were those where the decision to admit the patient to ICU was made during or after the surgical procedure.

We collected data on non-scheduled surgery, comorbidities (Appendix 2) [1, 15, 16], serious complications (Appendix 3) and 30-day mortality [7, 16]. Non-scheduled surgery was defined as an operation added to a routine elective operating list or performed after hours. Our definitions for serious complications were based on those used in our previous studies [7, 15–17]. We used patients' ASA physical status (Appendix 1) as a general marker of comorbidity. Patients staying longer than 30 days in hospital were recorded as staying 30 days. Mortality was determined from daily bedside review on weekdays during hospitalisation, from the medical record, or from telephone follow-up at 30 days.

Site investigators de-identified the study data which were centrally collated by the ANZCA Trials Group. The Biostatistics Unit at the Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia conducted the statistical analyses. We used Fisher's exact tests to compare the relationship between pre-operative patient factors, surgical specialty factors, and postoperative complications, with 30-day mortality. We used *t*-tests, Mann-Whitney, or chi-squared tests to compare patients who died by day 30 with those who did not. Because both the mortality and complication rates were similar in the original group of patients from Melbourne and the new broader group, we combined the groups to increase the sample size and number of participating hospitals. Univariate predictors of 30-day mortality were entered into multivariate logistic regression analyses, comparing pre-operative factors, then operative factors, then postoperative complications. An initial assessment of variability in 30-day mortality rates across the 23 hospitals using a random intercept logistic model revealed no evidence of heterogeneity ($p = 0.50$, chi-squared mixture 0–1 test), and hence logistic regression without hospital random effects were considered in all further analyses. Multivariate analyses of predictors of 30-day mortality were conducted by defining predictors into three classes: pre-operative patient factors; operative factors; and postoperative complications. Multivariate analyses involved adjustment of each predictor for all predictors in the same class and earlier classes, in order to avoid interpretational difficulties with adjusting for variables occurring later in time [18]. In the operative class,

general surgical patients combined with the small multi-trauma group and gynaecology patients formed the reference group. A p-value of < 0.05 was considered to be statistically significant. Analyses were conducted using STATA (Version 10, Stata Corporation, College Station, TX, USA).

This report complies with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [19].

Results

Our original Melbourne study included 1102 patients from three hospitals [1]. In this new phase we collected data on another 3056 patients from a further 20 hospitals. Both mortality and complication rates were similar in the Melbourne group and new, broader group. In the Melbourne group 63 (5.7%) patients died, and in the broader group 153 (5.0%) patients died, the difference being 0.7% (95% CI −0.7–2.4%, p = 0.36). In the Melbourne group, 208 (18.9%) patients had at least one complication and in the broader group 627 patients, (20.4%) had a complication, the difference being 1.5% (95% CI −1.3–4.2%, p = 0.27).

When combined, the data from the Melbourne and broader groups included all eligible patients from 23 hospitals: 4158 patients, 50% of whom were women, with a median age of 78 years (IQR [range] 74–83 [70–104] years) (Tables 1–4, Fig. 1). Patients underwent a wide variety of surgical procedures (Table 2). Sixty-one patients (1.5%) died within the first five postoperative days, and 216 (5.2%) died by 30 days after surgery (30-day mortality). Complications within the first five postoperative days occurred in 835 patients (20%), who had a total of 1302 complications: 31 complications per 100 patients. Patients suffering at least one complication had a 30-day mortality rate of 14% and stayed for a median (IQR [range]) of 13 (7–30 [0–30]) postoperative days, while those without complications stayed of 5 (2–10 [0–30]) days, the difference between groups being 7 days (95% CI 6–8 days; $p < 0.001$).

Table 1 Comparison of survivors and patients who died within 30 days of surgery. Values are number (proportion), mean (SD), or median (IQR [range]).

Variable	Survivors	Non-survivors	p value
Patients	3942 (95%)	216 (5%)	
Age; years	78 (6)	81 (6)	<0.001
Male	1982 (50%)	117 (54%)	<0.001
Non-scheduled surgery	1279 (32%)	134 (62%)	<0.001
ASA physical status			
1, 2	1300 (33%)	15 (7%)	< 0.001
3	2081 (53%)	96 (44%)	
4	450 (11%)	90 (42%)	
5	21 (1%)	11 (5%)	
Comorbidities			
0	1282 (35%)	31 (14%)	< 0.001
1	1255 (31%)	51 (24%)	
2	771 (20%)	58 (26%)	
3+	634 (16%)	65 (35%)	
Complications ≥ 1	704 (18%)	131 (26%)	< 0.001
Length of stay; days*	6 (2–12 [0–30])	30 (9–30 [0–30])	< 0.001

*Patients staying longer than 30 days were recorded as staying 30 days.

Patients who died by day 30 tended to be older, sicker, had more complications, and stayed longer in hospital (Table 1). Men were at greater risk than women (Tables 1 and 2). Sixty-eight percent of all patients had at least one pre-operative comorbidity: 52% were ASA status 3, 13% ASA 4, and 34% had non-scheduled surgery (Table 2). Many pre-operative, operative, and postoperative factors were associated with increased mortality (Tables 1–4, Fig. 1). With multivariate analysis (Table 2, Fig. 1) we found that independent pre-operative patient factors associated with 30-day mortality included: increasing age (80–89 years: OR 2.1 [95% CI 1.6–2.8]; 90+ years: OR 4.0 [95% CI 2.6–6.2]), worsening ASA status (ASA 3: OR 3.1 [95% CI 1.8–5.5]; ASA 4: OR 12.4 [95% CI 6.9–22.2]; ASA 5: OR 40.8 [95% CI 16.5–101.2]), and male gender (OR 1.3; 95% CI 1.0–1.8). Specific comorbidities with significant association with mortality included a plasma albumin level $< 30\ g.l^{-1}$ (OR 2.5; 95% CI 1.8–3.5) and respiratory insufficiency (OR 1.8; 95% CI 1.2–2.6).

Multi-trauma surgery with a small sample (17 patients) and gynaecology (99 patients), with no mortality, were combined with general surgery (1088 patients) to form the surgical reference group (Table 3). When non-scheduled surgery and each surgical specialty were adjusted for patient factors, only non-scheduled surgery (OR 1.8; 95% CI 1.3–2.5) and thoracic surgery (OR 2.6; 95% CI 1.3–5.3) were associated with increased mortality (Table 3). Several surgical specialties were, however, associated with decreased mortality: urology; orthopaedics; and plastics (Table 3). Of the factors known before surgery, patient factors, particularly ASA 4, had the strongest association with mortality (Fig. 1).

Most postoperative complications remained significantly associated with mortality when adjusted for patient and surgical factors. The three most frequent complications were systemic inflammation (OR 2.5; 95% CI 1.7–3.7), acute renal impairment (OR 3.3; 95% CI 2.1–5.0), and unplanned ICU admission (OR 3.1; 95% CI 1.9–4.9). There were 390 patients (9.4%) admitted to ICU or HDU during the first five postoperative days. Of these, 5% were planned admissions and 4.4% were unplanned.

Table 2 Association between 30-day mortality and patient factors. Odds ratios are adjusted for age, ASA status and comorbidity. Comorbidities are ranked by frequency. Values are number (proportion) or number (95% CI).

Variable		Mortality	OR	p value	Adjusted OR	p value
Age						
70–79	2532 (61%)	90 (4%)	1.0 Reference	Reference	Reference	Reference
80–89	1380 (33%)	96 (7%)	2.0 (1.5–2.7)	< 0.001	2.1 (1.6–2.8)	< 0.001
90+	246 (6%)	30 (12%)	3.8 (2.5–5.9)	< 0.001	4.0 (2.6–6.2)	< 0.001
Sex						
Male	2086 (50%)	117 (6%)	1.2 (0.9–1.5)	0.25	1.3 (1.0–1.8)	0.04
Comorbidity						
Diabetes	913 (22%)	47 (5%)	1.0 (0.7–1.3)	0.97	0.9 (0.6–1.2)	0.38
Ischaemic heart disease	826 (20%)	53 (6%)	1.4 (1.0–1.6)	0.06	0.8 (0.5–1.1)	0.15
Albumin <30 $g.l^{-1}$	556 (17%)	82 (15%)	4.2 (3.1–5.8)	< 0.001	2.5 (1.8–3.5)	< 0.001
Renal impairment	687 (16%)	63 (9%)	2.2 (1.6–2.9)	< 0.001	1.3 (0.9–1.8)	0.15
Cerebrovascular disease	592 (14%)	43 (7%)	1.5 (1.0–2.1)	0.01	1.1 (0.8–1.6)	0.75
Cognitive impairment	551 (13%)	58 (10%)	2.5 (1.8–3.5)	< 0.001	1.4 (1.0–2.0)	0.06
Obesity	496 (12%)	15 (3%)	0.5 (0.3–0.9)	0.02	0.7 (0.4–1.2)	0.17
Cardiac failure	401 (9%)	46 (11%)	2.7 (1.9–3.8)	< 0.001	1.4 (0.9–2.0)	0.13
Respiratory insufficiency	353 (8%)	39 (11%)	2.5 (1.7–3.6)	< 0.001	1.8 (1.2–2.6)	0.006
Aortic stenosis	136 (3%)	12 (9%)	1.8 (1.0–3.3)	0.49	1.0 (0.5–2.0)	0.99
ASA physical status						
1,2	1315 (32%)	15 (1%)	1.0 Reference	Reference	Reference	Reference
3	2177 (52%)	96 (4%)	4.0 (2.3–6.9)	< 0.001	3.0 (1.7–5.2)	< 0.001
4	540 (13%)	90 (17%)	17 (9.9–30.3)	< 0.001	12.4 (6.9–22.1)	< 0.001
5	32 (1%)	11 (34%)	45 (18.6–111.2)	< 0.001	40.8 (16.5–101.2)	< 0.001

Table 3 Thirty-day mortality by type of surgery. The odds ratios for 30-day mortality are adjusted for patient factors (Table 2), each type of surgery, and whether surgery was non-scheduled. Values are number (proportion) or number (95% CI).

Surgery		Mortality	Univariate OR	p value	Adjusted OR	p value
Non-scheduled surgery	1413 (34%)	134 (10%)	3.4 (2.6–4.6)	< 0.001	1.8 (1.3–2.5)	< 0.001
General	1088 (26%)	67 (6%)	1.2 (0.9–1.7)	0.09	Reference	Reference
Multiple trauma	17 (< 1%)	2 (12%)	2.4 (0.2–10.6)	0.22	Reference	Reference
Gynaecology	99 (2%)	0 (0%)	< 0.1 (0.0–0.6)	0.01	Reference	Reference
Otolaryngology, head and neck	142 (3%)	7 (5%)	0.9 (0.4–2.0)	0.85	1.1 (0.4–2.5)	0.91
Neurosurgery	248 (6%)	18 (7%)	1.4 (0.8–2.3)	0.16	1.2 (0.7–2.3)	0.65
Orthopaedic	1265 (30%)	57 (4%)	0.8 (0.6–1.1)	0.21	0.6 (0.4–0.9)	0.018
Plastic and reconstructive	224 (5%)	5 (2%)	0.4 (0.1–0.9)	0.47	0.3 (0.1–0.8)	0.021
Thoracic	91 (2%)	13 (14%)	3.1 (1.6–5.7)	< 0.001	2.6 (1.3–5.3)	0.007
Urology	371 (9%)	8 (2%)	0.4 (0.1–0.7)	0.007	0.4 (0.2–1.0)	0.04
Vascular	474 (11%)	30 (6%)	1.2 (0.8–1.87)	0.25	0.7 (0.4–1.1)	0.13
Ophthalmology	52 (1%)	1 (2%)	0.3 (0.0–2.0)	0.28	0.4 (0.1–1.3)	0.16
Other	87 (2%)	8 (9%)	2.0 (0.9–4.1)	0.07	1.2 (0.5–2.8)	0.62

Table 4 Association between 30-day mortality and postoperative complications. Complications were prospectively defined and are ranked by frequency. The odds ratios for 30-day mortality were adjusted for patient and operative factors (Tables 2 and 3). Values are number (proportion) or number (95% CI).

Complication		Mortality	Univariate OR	p value	Adjusted OR	p value
Systemic inflammation	305 (7%)	46 (15%)	3.9 (2.7–5.5)	< 0.001	2.5 (1.7–3.7)	< 0.001
Acute renal impairment	244 (6%)	42 (17%)	4.4 (3–6.4)	< 0.001	3.3 (2.1–5.0)	< 0.001
Unplanned admission to ICU	173 (4%)	34 (20%)	5.0 (3.3–7.6)	< 0.001	3.1 (1.9–4.9)	< 0.001
Acute pulmonary oedema	125 (3%)	25 (20%)	5.0 (3.1–7.9)	< 0.001	3.0 (1.7–5.0)	< 0.001
Return to operating theatre	120 (3%)	19 (16%)	3.6 (2.1–6)	< 0.001	2.5 (1.4–4.4)	0.002
Acute myocardial infarction	105 (2%)	21 (20%)	5.0 (3–8.2)	< 0.001	2.9 (1.6–5.2)	< 0.001
Wound infection	85 (2%)	6 (7%)	1.4 (0.6–3)	0.4	0.8 (0.3–2.2)	0.57
Re-intubation	42 (1%)	10 (24%)	5.7 (2.7–11.9)	< 0.001	5.0 (2.2–11.3)	< 0.001
Cardiac arrest	18 (< 1%)	14 (77%)	70 (22.7–214)	< 0.001	66.2 (17.7–247.2)	< 0.001
Pulmonary embolism	14 (< 1%)	1 (7%)	1.4 (0.3–9.4)	0.7	0.3 (0.0–3.9)	0.36
Stroke	10 (< 1%)	4 (40%)	12 (2.5–52.5)	< 0.001	Sample too small	Sample too small

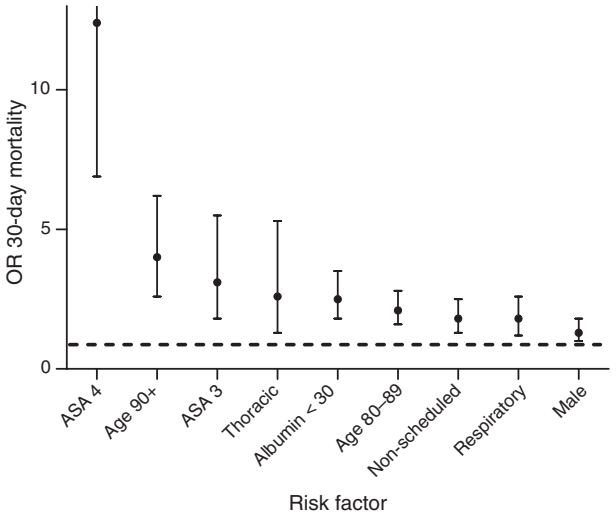

Figure 1 Adjusted odds ratios (OR) for 30-day mortality (dots) with 95% CI (bars) for pre-operative and operative factors associated with increased mortality ranked by OR point estimate. The dotted line represents an OR of 1. Thoracic, thoracic surgery; non-scheduled, non-scheduled surgery.

Discussion

In a prospective, observational study of older patients undergoing inpatient non-cardiac surgery in hospitals in Australia and New Zealand, we found that 20% of patients had at least one complication within five days of surgery and 5% died within 30 days of surgery. Those with a complication stayed, on average, a week longer in hospital, and 14% died within 30 days. Almost 10% of all patients were admitted to critical care services. The type of surgery had a weaker association with increased mortality than patient factors, except for thoracic surgery and non-scheduled surgery.

This study is an extension of a previous study of 1100 patients conducted in three Melbourne hospitals [1, 12]. The overall mortality and complication rates are similar to those in our previous study; however, in this extended study unscheduled surgery had a stronger association with mortality and a smaller proportion of patients had planned admissions to critical care services [1]. Our findings from the combined data sets are consistent with the results from the limited North American and European studies [2–6] over the last 15 years. Our results help quantify more precisely the association of postoperative mortality with patient factors, operative factors, and postoperative complications across a range of surgical specialties. In particular, we identify specific complications and their associated mortality risks. The largest existing peri-operative database is the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) which reviews histories from random patients from selected surgical groups after hospital discharge [1, 9, 10]. One NSQIP study of US patients aged 80 years or more reported a complication rate of 25% and a 30-day mortality rate of 8% [5], comparable with our results.

Among pre-operative factors, we found that age, ASA physical status and decreased albumin had important associations with 30-day mortality. The Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM risk score) and its derivatives [20], popular in the UK, adjusts the age related risk up to 70 years of age [20]. We found that the odds ratio for mortality doubled with each age decade beyond 70 years [2]. We also found that the odds ratio for mortality approximately tripled with each increase in ASA status from ASA 2. The ASA status classification is a measure of the overall severity of systemic disease and has long been used to assess peri-operative risk [20, 21]. Some, particularly in the UK, doubt the objectivity of the ASA score [20] and subsequently ASA status is not used in the POSSUM score [20]. We found that, even when compared with specific pre-operative comorbidities, the ASA status had a strong association with mortality in older patients [20–22]. We also found that a pre-operative plasma albumin of < 30 g.l^{-1} had an important association with mortality. Others have found that hypo-albuminemia also has a strong association with surgical site infection [23]. Decreased plasma albumin can be a measure of chronic disease or malnutrition [24]. Some pre-operative risk assessments include albumin [5, 25] while others, including POSSUM, do not [22, 26]. We suggest that albumin should be used in peri-operative risk assessment.

Like others, we found that non-scheduled surgery had an important association with mortality [5, 20]. Once we adjusted for patient factors and non-scheduled surgery, we found that only thoracic surgery was associated with increased mortality when general surgical patients were used as the reference group. The NSQIP also reported that thoracic surgery had the greatest mortality [5]. This association is likely to be multifactorial, including the nature of thoracic surgery as well as patient factors. Researchers in Texas [25] found that only more complex surgery, such as pancreatectomy, added to patient factors for estimating peri-operative risk. In a recent study of all age groups, the 30-day mortality following pancreatectomy was 4% [27] compared to our 30-day mortality of 5% for all types of surgery. Rather than downplaying the importance of surgery, our findings probably highlight the high quality of operative care [25].

Most postoperative mortality risk scores concentrate on pre-operative and intra-operative factors [28], rather than the association of subsequent postoperative complications with mortality. A large NSQIP study concluded that timely recognition of postoperative complications is

needed to decrease postoperative mortality [10]. We found that many of the 20% of patients who had postoperative complications had more than one complication. We found that systemic inflammation, acute renal impairment and unplanned ICU admission were the most frequent complications, and that these had odds ratios for mortality > 2.5. Our definition of systemic inflammation (Appendix 3) included patients with mild systemic inflammation [29]. Similarly, we defined renal impairment with a smaller increase in creatinine (> 20%) than is increasingly used to define acute kidney injury (> 50%) [30]. We, like others, question whether a 50% increase in creatinine excludes some postoperative patients with clinically important acute kidney injury [31]. Many patients with systemic inflammation or renal impairment may have gone unnoticed by medical and nursing staff because of relatively mild manifestations [30, 32]. Unplanned ICU admission is not measured in the NSQIP database [5] but in a recent Australian study was found to be a valid indicator of peri-operative patient safety [33]. In our study, 390 patients (9.4%) spent at least one night in ICU or HDU: 5% planned and 4.4% unplanned, during the first five postoperative days. In 2006–2007, across Australia, 3.8% of all inpatients (excluding day-stay patients) were admitted to ICU [14]. This comparison suggests that, proportionally, older surgical patients place greater demands on ICU resources.

This study has several limitations. First, the results may not be generalisable to younger patients. Second, we cannot easily identify the specific risks of complex but less frequent operations, such as pancreatectomy, where operation type is more likely to be important for mortality risk [25]. Third, while we have included 23 hospitals in our study, their self-selection may not make them representative of all 200 medium to large public hospitals across Australia and New Zealand [11]. Fourth, like other studies [10], large teaching hospitals are over-represented. Last, we collected data on some but not all complications for five days. Therefore other complications, and complications after day five, may have contributed to 30-day mortality. The major strengths of our study are that it has a large patient sample with prospective, consecutive data for all eligible patients, and includes a wide variety of operations from the 23 hospitals included. This is the largest study of this type to have been conducted in Australia and New Zealand [32] and one of the few worldwide [2–6].

With an ageing population, clinicians will increasingly be faced with treating older patients [34, 35]. We found that among older patients in Australia and New Zealand, one in five had at least one complication and one in twenty died after surgery, with almost 1 in 10 admitted to critical care services. With similar, but more precise and generalisable results, our current study reinforces our previous conclusions [1]. We identified some pre-operative factors associated with postoperative outcome that may assist planning peri-operative care, including increasing age and ASA physical status. Albumin should be included with routine pre-operative blood tests and used in pre-operative risk assessment. Improved postoperative surveillance is warranted to detect complications, particularly the early manifestations of systemic inflammation and renal impairment [8, 10, 32]. Further, the cumulative effect of pre-operative status and subsequent complications needs to be better understood [8, 12]. Future management strategies may include system changes such as co-management of older surgical patients with doctors trained in hospital medicine [36], and greater use of critical care services including critical care outreach [17, 37]. Finally, ASA status and unplanned ICU admission should be routinely collected in anaesthetic and surgical audits [1, 33, 38].

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References

1 McNicol L, Story DA, Leslie K, et al. Postoperative complications and mortality in older patients having non-cardiac surgery at three Melbourne teaching hospitals. *Medical Journal of Australia* 2007; **186**: 447–52.
2 Massarweh NN, Legner VJ, Symons RG, McCormick WC, Flum DR. Impact of advancing age on abdominal surgical outcomes. *Archives of Surgery* 2009; **144**: 1108–14.
3 Leung JM, Dzankic S. Relative importance of preoperative health status versus intraoperative factors in predicting postoperative adverse outcomes in geriatric surgical patients. *Journal of the American Geriatrics Society* 2001; **49**: 1080–5.
4 Liu LL, Leung JM. Predicting adverse postoperative outcomes in patients aged 80 years or older. *Journal of the American Geriatrics Society* 2000; **48**: 405–12.
5 Hamel MB, Henderson WG, Khuri SF, Daley J. Surgical outcomes for patients aged 80 and older: morbidity and mortality from major noncardiac surgery. *Journal of the American Geriatrics Society* 2005; **53**: 424–9.
6 Bufalari A, Ferri M, Cao P, Cirocchi R, Bisacci R, Moggi L. Surgical care in octogenarians. *British Journal of Surgery* 1996; **83**: 1783–7.
7 Bellomo R, Goldsmith D, Russell S, Uchino S. Postoperative serious adverse events in a teaching hospital: a prospective study. *Medical Journal of Australia* 2002; **176**: 216–8.

8 Khuri SF, Henderson WG, DePalma RG, Mosca C, Healey NA, Kumbhani DJ. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Annals of Surgery* 2005; **242**: 326–41.
9 Henderson WG, Daley J. Design and statistical methodology of the National Surgical Quality Improvement Program: why is it what it is? *American Journal of Surgery* 2009; **198**: S19–27.
10 Ghaferi AA, Birkmeyer JD, Dimick JB. Variation in hospital mortality associated with inpatient surgery. *New England Journal of Medicine* 2009; **361**: 1368–75.
11 Australian Institute of Health and Welfare. *Australian Hospital Statistics*. Canberra: Australian Institute of Health and Welfare, 2009.
12 Story DA, Fink M, Leslie K, et al. Perioperative mortality risk score using pre- and postoperative risk factors in older patients. *Anaesthesia and Intensive Care* 2009; **37**: 392–8.
13 Semmens JB, Aitken RJ, Sanfilippo FM, Mukhtar SA, Haynes NS, Mountain JA. The Western Australian Audit of Surgical Mortality: advancing surgical accountability. *Medical Journal of Australia* 2005; **183**: 504–8.
14 Drennan K, Hart G, Hicks P. *Intensive Care Resources & Activity: Australia and New Zealand 2006/2007*. Melbourne: Australian and New Zealand Intensive Care Society Centre for Outcomes and Resource Evaluation, 2008.
15 Rigg JR, Jamrozik K, Myles PS, et al. Design of the multicenter Australian study of epidural anesthesia and analgesia in major surgery: the MASTER trial. *Controlled Clinical Trials* 2000; **21**: 244–56.
16 Rigg JR, Jamrozik K, Myles PS, et al. Epidural anaesthesia and analgesia and outcome of major surgery: a randomised trial. *Lancet* 2002; **359**: 1276–82.
17 Story DA, Shelton AC, Poustie SJ, Colin-Thome NJ, McIntyre RE, McNicol PL. Effect of an anaesthesia department led critical care outreach and acute pain service on postoperative serious adverse events. *Anaesthesia* 2006; **61**: 24–8.
18 Cole SR, Hernan MA. Fallibility in estimating direct effects. *International Journal of Epidemiology* 2002; **31**: 163–5.
19 von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *British Medical Journal* 2007; **335**: 806–8.
20 Chandra A, Mangam S, Marzouk D. A review of risk scoring systems utilised in patients undergoing gastrointestinal surgery. *Journal of Gastrointestinal Surgery* 2009; **13**: 1529–38.
21 Davenport DL, Bowe EA, Henderson WG, Khuri SF, Mentzer RM Jr. National Surgical Quality Improvement Program (NSQIP) risk factors can be used–validate American Society of Anesthesiologists Physical Status Classification (ASA PS) levels. *Annals of Surgery* 2006; **243**: 636–41.
22 Brooks MJ, Sutton R, Sarin S. Comparison of surgical risk score, POSSUM and p-POSSUM in higher-risk surgical patients. *British Journal of Surgery* 2005; **92**: 1288–92.
23 Haridas M, Malangoni MA. Predictive factors for surgical site infection in general surgery. *Surgery* 2008; **144**: 496–501.
24 Gibbs J, Cull W, Henderson W, Daley J, Hur K, Khuri SF. Preoperative serum albumin level as a predictor of operative mortality and morbidity: results from the National VA Surgical Risk Study. *Archives of Surgery* 1999; **134**: 36–42.
25 Aust JB, Henderson W, Khuri S, Page CP. The impact of operative complexity on patient risk factors. *Annals of Surgery* 2005; **241**: 1024–7.
26 National Institute for Clinical Excellence. *Preoperative Tests*. London: NICE, 2003.
27 Glasgow RE, Jackson HH, Neumayer L, et al. Pancreatic resection in Veterans affairs and selected university medical centers: results of the patient safety in surgery study. *Journal of the American College of Surgery* 2007; **204**: 1252–60.
28 Goldhill D, Waldmann C. Excellent anaesthesia needs patient preparation and postoperative support–influence outcome. *Current Opinion in Anesthesiology* 2006; **19**: 192–7.
29 Levy MM, Fink MP, Marshall JC, et al. 2001 SCCM/ESICM/ACCP/ATS/SIS International Sepsis Definitions Conference. *Critical Care Medicine* 2003; **31**: 1250–6.
30 National Confidential Enquiry into Patient Outcome and Death. *Adding Insult to Injury: A review of the care of patients who died in hospital with a primary diagnosis of acute kidney injury (acute renal failure)*. London: NCEPOD, 2009.
31 Lassnigg A, Schmid ER, Hiesmayr M, et al. Impact of minimal increases in serum creatinine on outcome in patients after cardiothoracic surgery: do we have–revise current definitions of acute renal failure? *Critical Care Medicine* 2008; **36**: 1129–37.
32 Bellomo R, Goldsmith D, Uchino S, et al. Prospective controlled trial of effect of medical emergency team on postoperative morbidity and mortality rates. *Critical Care Medicine* 2004; **32**: 916–21.
33 Haller G, Myles PS, Wolfe R, Weeks AM, Stoelwinder J, McNeil J. Validity of unplanned admission–an intensive care unit as a measure of patient safety in surgical patients. *Anesthesiology* 2005; **103**: 1121–9.
34 Office for National Statistics Ageing. www.statistics.gov.uk/cci/nugget.asp?id=949 (accessed 30/05/2010).
35 Australian Goverment. *Intergenerational Report 2010*. Canberra: Commonwealth of Australia, 2010.
36 Merli GJ. The hospitalist joins the surgical team. *Annals of Internal Medicine* 2004; **141**: 67–9.
37 Expert Group. *Comprehensive Critical Care: A Review of Adult Critical Care Services*. UK: Department of Health, 2000: 1–31.
38 Watters DA, Green AJ, van Rij A. Guidelines for surgical audit in Australia and New Zealand. *ANZ Journal of Surgery* 2006; **76**: 78–83.

Appendix 1

Participating hospitals

Hospital	Location	Patients (*n*)	Investigators
Auckland City Hospital	Auckland, New Zealand	125	V. Beavis, D. McAllister
Alfred Hospital	Melbourne, Victoria	290	P. Myles, R. Major
Austin Health	Melbourne, Victoria	401	D. Story, A. Shelton
Cairns Base Hospital	Cairns, Queensland	304	J. Sartain, L. Munroe
Coffs Harbour Base Hospital	Coffs Harbour, New South Wales	99	J. Sutherland
Dubbo Base Hospital	Dubbo, New South Wales	78	S Yap, C. Gorringe
Flinders Medical Centre	Adelaide, South Australia	200	P. Doran, K. Lee
John Hunter Hospital	Newcastle, New South Wales	199	R. Kerridge, J. Douglas
Lismore Base Hospital	Lismore, New South Wales	256	J. Hosking, C. Lowry
Middlemore Hospital	Auckland, New Zealand	287	S. Walker, S. Oliff
North West Regional Hospital	Burnie, Tasmania	96	M. Reeves, D. Nithyanandam
Princess Alexandra Hospital	Brisbane, Queensland	150	P. Moran, P. Sqivalingam
Prince of Wales Hospital	Sydney, New South Wales	69	S. Yap, B. Nham
Redcliffe Hospital	Redcliffe, Queensland	24	S. Sawheny
Royal Brisbane and Womens' Hospital	Brisbane, Queensland	100	M. Styen, M. Bishop
Royal Darwin Hospital	Darwin, Northern Territory	65	B. Spain
Royal Hobart Hospital	Hobart, Tasmania	149	D. McGlone, P. Turner
Royal Melbourne Hospital	Melbourne, Victoria	411	K. Leslie, C. McMullen
Royal Perth Hospital	Perth, Western Australia	197	M. Paech, S. March
St Vincent's Hospital	Melbourne, Victoria	201	D. Scott, S. Said
Western Hospital	Melbourne, Victoria	122	A. Jefferies, R. Cook
Westmead Hospital	Sydney, New South Wales	273	R. Halliwell, L. Cope
Woolongong Hospital	Woolongong, New South Wales	62	S. Yap, C. Gorringe

Appendix 2

Comorbidities

- Myocardial ischaemia
  A documented history, within 2 years, of a positive exercise test or thallium scan or a documented history of exertional angina. This excludes patients with angioplasty or coronary grafting within the last 2 years without ongoing ischaemia
- Renal impairment
  Serum creatinine ≥ 130 μmol.l^{-1}
- Diabetes mellitus
  Previously diagnosed
- Cardiac failure
  Documented symptoms and signs of left or right heart failure and receiving heart failure therapy, or measured left ventricular ejection fraction of 35% or less within the past 2 years, or at least moderate left ventricular failure on echocardiogram.
- Respiratory insufficiency
  $P_aO_2 \leq 8$ kPa on room air or $P_aCO_2 \geq 6$ kPa, or obstructive disease ($FEV_{1.0} \leq 1.0$ l or $FEV_{1.0}/VC$ ratio ≤ 0.30), or restrictive disease (VC ≤ 1.0 l or VC $\leq$ 50% of predicted), or an admission (within 2 years of surgery) for acute respiratory failure that required non-invasive or invasive ventilation.
- Aortic stenosis
  Documented valve area of ≤ 1.5 cm^2 or peak gradient of ≥ 30 mmHg
- Obesity
  Body mass index ≥ 30 kg.m^{-2}
- Cerebrovascular disease
  Stroke or transient ischaemic attacks
- Cognitive impairment
  Documented impairment of short-term memory or abnormal cognition; or Mini Mental State Examination score < 24 out of 30, or receiving treatment with donepezil or galantamine
- Plasma albumin ≤ 30 g.l^{-1}
- ASA physical status
  1: normal healthy patient
  2: patient with mild systemic disease
  3: patient with severe systemic disease
  4: patient with severe systemic disease that is a constant threat to life
  5: moribund patient who is not expected to survive without the operation

Appendix 3

Complication definitions

- Acute myocardial infarction
  - At least two of:
    - New onset or worsening of ischaemic symptoms (e.g. chest pain, shortness of breath) lasting longer than 20 min
    - ECG changes consistent with ischaemia including:
      - Acute ST elevation followed by the appearance of *Q* waves or loss of *R* waves
      - New left bundle branch block
      - New persistent *T* wave inversion for at least 24 h
      - New ST segment depression which persists for at least 24 h
    - A positive troponin or peak CK-MB ≥ 4% of an elevated total CK with characteristic rise and fall
- Cardiac arrest
  - Documented sudden cessation of cardiac output maintaining effective circulation
- Re-intubation
- Acute pulmonary oedema
  - Respiratory compromise with chest radiograph showing extravascular fluid in lung tissues and alveoli
- Pulmonary embolus
  - High probability ventilation/perfusion scan or pulmonary angiogram
- Stroke
  - Positive CT scan and clinical symptoms such as paralysis, weakness or speech difficulties, first documented postoperatively
- Systemic inflammation
  - New finding of at least two of the following:
    - Temperature > 38.3 or < 36 °C
    - White cell count > 12 000 cells.μl^{-1}
    - Respiratory rate > 20 breaths.min^{-1}
    - Heart rate > 90 beats.min^{-1}
  - Or a positive blood culture alone
- Wound infection
  - Purulent discharge or redness, or serous discharge and positive culture or antibiotic treatment
- Unplanned return to operating room
  - Related to original surgery eg. surgical bleeding
- Acute renal impairment
  - Creatinine increase > 20% of pre-operative value or, admission to ICU for renal replacement therapies
- Unplanned ICU admission
  - Unplanned admission to the Intensive Care Unit, Coronary Care Unit or High Dependency Unit
- Death