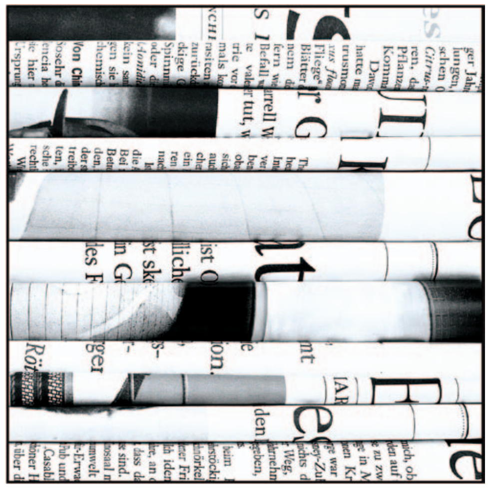
Intensive Care after High-risk Surgery

What's in a Name?

Michael A. Gillies, M.D., F.R.C.A., Rupert M. Pearse, M.D., F.R.C.A.

MORE than 310 million patients undergo surgical treatments each year.[1] Although many such procedures are uneventful, we know that a proportion of patients will develop serious complications that impact on their survival and quality of life, both in the days that follow surgery and in the long term.[1,2] There are many components to a safe and effective perioperative care pathway, but postoperative admission to an intensive care unit (ICU) is commonly regarded as an important standard for many complex major procedures.[3] Indeed, differences in availability and use of an ICU are often cited as a cause of variation in patient outcomes after surgery.[3,4] Nevertheless, the evidence base for this expensive treatment remains far from clear. In this issue of Anesthesiology, Wunsch *et al.*[5] report the findings of an important analysis of a large Medicare data set exploring the association between mortality, length of hospital stay, and healthcare costs with ICU admission for patients older than 65 yr undergoing one of five major surgical procedures between 2004 and 2008. Although they demonstrate a wide variation in rates of surgical ICU admission between hospitals, there was no associated reduction in mortality. Limitations of the data set precluded any discrimination between patients admitted directly to an ICU after surgery and those admitted on an emergency basis, having developed life-threatening complications. In other respects, the analysis is rigorous and objective. The findings, however, are perplexing to those of us who work in this field. Could it possibly be that ICU admission after major surgery does not confer benefit? It is worth noting the caution with which the authors interpret their findings. As much as we would like one, there is no simple headline message. As clinicians, we must carefully consider how these findings should affect our practice. There may be more than one reason why postoperative admission to an ICU does not appear to benefit patients in this study.



"As much as we would like one, there is no simple headline message. ... There may be more than one reason why postoperative admission to an ICU does not appear to benefit patients in this study."

The first point to consider is that ICU is not a treatment we can test in a randomized trial; few patients would agree to take part. We must, therefore, use Health Services Research analyses of large data sets to perform what is often called a "natural trial," comparing outcomes for similar patients allocated to different standards of care as part of their routine treatment. This approach can be very powerful, but the real challenge is to understand enough about each patient to allow robust statistical adjustment for baseline risk. Some patients may be admitted to an ICU as a routine part of the care package for a specific procedure, but others are admitted because the treating clinician has spotted something that suggests that they are more likely to die. If baseline data fail to describe this risk, then important differences between patients are not accounted for, and unmeasured confounding results. In the case of postoperative ICU, this form of bias is likely to result in the erroneous suggestion that the treatment either does not work, or may even be harmful. The second important consideration for interpreting our natural trial is the difference between the intervention and control treatments. The traditional role of an ICU is to provide organ support, such as invasive ventilation, inotropic therapy, and renal replacement therapy. Yet, few surgical patients require organ support after surgery, even among the high-risk group. What these patients do need is the prompt and effective treatment of pain, hypothermia,

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Corresponding article on page 899.

Accepted for publication November 4, 2015. From the Department of Anaesthesia, Critical Care, and Pain Medicine, Royal Infirmary of Edinburgh, Edinburgh, United Kingdom (M.A.G.); and Barts and The London School of Medicine and Dentistry, Queen Mary University London, London, United Kingdom (R.M.P.).

 Anesthesiology 2016; 124:761-2

mild cardiorespiratory compromise, and fluid imbalance, with early mobilization and enteral nutrition where possible.[3] Patients may be admitted to an ICU because staff there are used to addressing these needs, but this proactive care is also delivered in less intensive environments. We know that adequate staffing of surgical wards with qualified nurses improves patient safety and may reduce the incidence of postoperative complications.[6] In hospitals that deliver excellent ward-based care, the incremental benefit of ICU admission will be reduced.

Wunsch *et al.* must be congratulated on tackling this complex problem and for providing a robust analysis with a balanced interpretation. We agree that this work should not drive any immediate change in patient care but instead a global research strategy to define the ideal care pathway for high-risk patients after major surgery and the role of an ICU within this. In particular, we need to study the value of specific treatments traditionally provided in an ICU, for example, minimally invasive cardiovascular and respiratory support,[7] and to consider the best environment for their delivery. Postanesthesia care units and specialist high-dependency units may offer the desired benefits of an ICU at a much lower cost. We must also explore what it is about an ICU that we believe may help. Those who have experienced major surgery will agree that the importance of excellent proactive nursing care must not be underestimated, even it is not called intensive care.

Competing Interests

The authors are not supported by, nor maintain any financial interest in, any commercial activity that may be associated with the topic of this article.

Correspondence

Address correspondence to Dr. Pearse: r.pearse@qmul.ac.uk

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Use of Intensive Care Services for Medicare Beneficiaries Undergoing Major Surgical Procedures

Hannah Wunsch, M.D., M.Sc., Hayley B. Gershengorn, M.D., Colin R. Cooke, M.D., M.Sc., Carmen Guerra, M.P.H., Derek C. Angus, M.D., M.P.H., John W. Rowe, M.D., Guohua Li, M.D., Dr.P.H.

ABSTRACT

Background: Use of intensive care after major surgical procedures and whether routinely admitting patients to intensive care units (ICUs) improve outcomes or increase costs is unknown.

Methods: The authors examined frequency of admission to an ICU during the hospital stay for Medicare beneficiaries undergoing selected major surgical procedures: elective endovascular abdominal aortic aneurysm (AAA) repair, cystectomy, pancreaticoduodenectomy, esophagectomy, and elective open AAA repair. The authors compared hospital mortality, length of stay, and Medicare payments for patients receiving each procedure in hospitals admitting patients to the ICU less than 50% of the time (low use), 50 to 89% (moderate use), and 90% or greater (high use), adjusting for patient and hospital factors.

Results: The cohort ranged from 7,878 patients in 162 hospitals for esophagectomies to 69,989 patients in 866 hospitals for endovascular AAA. Overall admission to ICU ranged from 35.6% (endovascular AAA) to 71.3% (open AAA). Admission to ICU across hospitals ranged from less than 5% to 100% of patients for each surgical procedure. There was no association between hospital use of intensive care and mortality for any of the five surgical procedures. There was a consistent association between high use of intensive care with longer length of hospital stay and higher Medicare payments only for endovascular AAA.

Conclusions: There is little consensus regarding the need for intensive care for patients undergoing major surgical procedures and no relationship between a hospital's use of intensive care and hospital mortality. There is also no consistent relationship across surgical procedures between use of intensive care and either length of hospital stay or payments for care.

(ANESTHESIOLOGY 2016; 124:899-907)

MILLIONS of major surgical procedures are performed every year around the world,[1,2] and improving perioperative outcomes involves identification of best practices.[3] Recent data from Europe found higher than expected hospital mortality (4%) for patients undergoing surgery, with substantial variation in mortality across countries even after adjustment for patient factors and complexity of the surgery.[1] Only 5% of all patients received intensive care, and a substantial proportion of the patients who died (70%) were never admitted to an intensive care unit (ICU), raising the question of whether more aggressive use of intensive care services may improve postoperative care and outcomes for patients at high risk of death after surgery.[4] However, observational studies are limited in the ability to assess the benefits of intensive care because patients selected for admission to ICU are inherently sicker and have higher mortality than patients who are not admitted to the ICU thus creating large biases in populations to be compared.[5] A number of studies have examined high-intensity interventions, such as inotropic support,[6,7] for which the use of intensive care might optimize outcomes; but, none has addressed the specific use of intensive care for surgical patients.[8] Therefore,

What We Already Know about This Topic

- The impact of intensive care unit utilization after major surgical procedures on mortality, length of hospital stay, and cost is unclear
- The U.S. Medicare database provides hospitalization data on a large proportion of citizens older than 65 yr

What This Article Tells Us That Is New

- For a large cohort of patients undergoing selected major surgical procedures, there was a wide variation in intensive care unit utilization for each procedure, with no relation to mortality
- Greater systematic use of intensive care for older surgical patients in the United States undergoing selected major surgeries does not improve survival outcomes

This article is featured in "This Month in Anesthesiology," page 1A. Corresponding article on page 761. Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org).

Submitted for publication August 16, 2015. Accepted for publication December 17, 2015. From the Department of Critical Care Medicine and Sunnybrook Research Institute, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada (H.W.); Department of Anesthesia, University of Toronto, Toronto, Ontario, Canada (H.W.); Department of Anesthesiology, Columbia University, New York, New York (H.W., C.G., G.L.); Department of Medicine, Albert Einstein College of Medicine, Montefiore Medical Center, New York, New York (H.G.); Department of Medicine, University of Michigan, Ann Arbor, Michigan (C.R.C.); Department of Critical Care Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania (D.C.A.); and Department of Health Policy and Management (J.W.R.) and Department of Epidemiology (G.L.), Mailman School of Public Health, Columbia University, New York, New York.

the assumption that greater rates of admission to an ICU may reduce morbidity and mortality in the surgical patient population is reasonable, but unproven.[8–10]

Care in ICUs is substantially more expensive than that on general hospital wards and represents a limited resource.[11,12] Determining whether high-quality postoperative care should include routine use of intensive care has large ramifications for perioperative quality improvement initiatives and the potential costs of care. We sought first to assess the variation in use of intensive care after a range of major surgical procedures to determine whether there is agreement across hospitals regarding the need for intensive care services. Second, we sought to determine whether use of intensive care services at the hospital level is associated with hospital mortality, length of hospital stay, or Medicare payments for patients undergoing major surgery.

Materials and Methods

This research involved secondary analyses of deidentified data and was deemed not human subjects research by the Columbia University Medical Center Institutional Review Board, New York, New York.

We performed a retrospective study using 5 yr of the MedPAR file from the Centers for Medicare and Medicaid Services. This data set contains data on all Medicare hospitalizations from 2004 to 2008, which we linked with data from the American Hospital Association annual survey from 2007.[13]

Patients and Variables

Medicare provides health insurance for Americans aged 65 yr and older who have worked and paid into the system. It also provides health insurance to selected younger people with disabilities, end-stage renal disease, and amyotrophic lateral sclerosis. We included all patients 65 yr or older undergoing five select surgical procedures during a hospitalization and excluded Medicare beneficiaries under age 65 yr because they represent a highly selected group of individuals with specific diagnoses, as previously described.[13] The procedures were elective endovascular repair of abdominal aortic aneurysm (AAA), cystectomy, pancreaticoduodenectomy, esophagectomy, and elective open repair of an AAA (open AAA). We chose these surgical procedures from a larger list of possible procedures after initial inspection of the data because they are (1) commonly performed in patients over the age of 65 yr, (2) well circumscribed and usually not associated with another surgery, and (3) associated with a range of different hospital mortality rates (see Supplemental Digital Content 1, http://links.lww.com/ALN/B245, table 1, listing individual *International Classification of Diseases*, Ninth Revision, Clinical Modification and procedure codes used).

We defined ICU admission using critical care–specific resource utilization codes, including intensive care and/or coronary care. We could not confirm whether intensive care admission definitely occurred after a surgical procedure, rather than before. Therefore, we refer to patients as having received intensive care during the hospitalization. We also could not assess whether an ICU admission was planned or occurred on an emergent basis as a "rescue" therapy.

Statistics

We excluded patients cared for in any hospital that performed the procedure in Medicare beneficiaries less than 20 times over 5 yr or did not have information on the availability of ICU beds or number of hospital beds (Supplemental Digital Content 1, http://links.lww.com/ALN/B245, fig. 1). Of note, the exclusions were performed separately for each surgical procedure so that a hospital could be included in the analysis of some or all surgical procedures.

Hospital and Patient Characteristics

We summarized hospital and patient characteristics and outcomes for each surgical procedure by using percentages, means with standard deviation (±SD), and medians with interquartile ranges, as appropriate. We then summarized the frequency of admission to an ICU for each surgical procedure overall and by individual hospital. These data have been published previously.[13]

For each surgical procedure, we categorized hospitals as admitting patients to the ICU 0 to 49% of the time (low use), 50 to 89% (moderate use), or 90% or greater (high use). We chose not to use percentiles, as we wished to ensure clinically meaningful differences in use of intensive care between groups, and the cutoffs for percentiles would have shifted depending on the surgical procedure. We next summarized patient characteristics for patients who received each surgical procedure, stratified by hospital ICU use.

Outcomes

Outcomes included hospital mortality, hospital length of stay, and total Medicare payments, as defined by the total hospital charges covered by Medicare, with all payments reported in 2008 dollars using an inflation correction.[14] Our first objective was to describe the degree of variation in use of intensive care services for different surgical procedures. Our second objective was to assess the hospital-level outcomes for patients cared for in high- *versus* low-use hospitals. We assessed unadjusted differences using chi-square test, t test, and Spearman rank correlation, as appropriate. For adjusted analyses, we adjusted for patient- and hospital-level characteristics using multilevel modeling, with clustering by hospital. We assessed the association with hospital length of stay and Medicare payments using multilevel linear regression. Data on length of stay variables were log transformed due to their skewed nature. Costs were assessed using means.[15] We report results as either odds ratios or regression coefficients. Because of unexpected findings regarding Medicare payments, we *post hoc* examined the mean Medicare payments for patients in high *versus* low ICU-use hospitals stratified by whether or not patients went to the ICU. We assessed differences between groups with the use of ANOVA.

Our secondary analysis included assessment of outcomes for individual patients using multilevel modeling, clustering on hospital, and propensity-based matched analyses to determine whether we found the same associations between use of intensive care and outcomes. All available patient- and hospital-level independent variables were included in each final multivariate model and the model to create propensity scores. Propensity matching was performed to match patients who did or did not receive intensive care based on their likelihood (propensity) to receive intensive care. After randomly ordering patients, we used the "psmatch2" algorithm in Stata 11.1 (StataCorp LP, USA) with one-to-one nearest-neighbor matching without replacement and with maximal caliper distance of 25% of the SD of all propensity scores.[16] In addition, exact matching was used for each covariate for which the propensity score did not achieve appropriate balance; cystectomy: 3,962 pairs with imbalance in sex, comorbidity index, weekend admission, and hospital procedure volume; pancreaticoduodenectomy: 1,103 pairs with imbalance in age and race; esophagectomy: 1,742 pairs with imbalance in weekend admission and age; and open AAA: 3,673 pairs with imbalance in sex, comorbidity index, weekend admission, age, and race. We assessed differences in hospital mortality between propensity-matched patients using logistic regression.

We conducted analyses in Excel (Microsoft, USA), Stata 11.1 (StataCorp LP), and SAS 9.1.3 (SAS Institute, USA).

Results

Cohort Characteristics

After exclusions (see Supplemental Digital Content 1, http://links.lww.com/ALN/B245, fig. 1, flowchart of exclusions), the number of patients receiving each surgical procedure varied from 7,878 patients in 162 hospitals for esophagectomy up to 69,989 patients in 866 hospitals for endovascular AAA (tables 1 and 2). The majority of hospitals performing these surgical procedures were categorized as teaching hospitals (table 1). Most were hospitals with over 400 beds, and most hospitals had more than 7.5% of their beds designated as ICU beds (table 1).

The overall admission rate to ICU ranged from 35.6% of patients undergoing endovascular AAA up to 71.3% of patients undergoing open AAA (table 2). Hospital mortality

Table 1. Characteristics of Hospitals Performing Each Surgical Procedure over 5 Yr

	Procedures				
	Endovascular AAA	Cystectomy	Pancreaticoduodenectomy	Esophagectomy	Open AAA
No. of hospitals in cohort, n	866	254	156	162	549
Academic status, n (%)					
Nonteaching	329 (38.0)	39 (15.4)	7 (4.5)	13 (8.0)	183 (33.3)
Teaching	537 (62.0)	215 (84.7)	149 (95.5)	149 (92.0)	366 (66.7)
Hospital beds, n (%)					
< 200	126 (14.6)	15 (5.9)	6 (3.9)	7 (4.3)	47 (8.6)
200–399	426 (49.2)	60 (23.6)	24 (15.4)	22 (13.6)	245 (44.6)
400–599	197 (22.8)	96 (37.8)	53 (34.0)	58 (35.8)	152 (27.7)
600–799	78 (9.0)	48 (18.9)	45 (28.9)	43 (26.5)	68 (12.4)
800–999	23 (2.7)	21 (8.3)	17 (10.9)	20 (12.4)	23 (4.2)
1,000+	16 (1.9)	14 (5.5)	11 (7.1)	12 (7.4)	14 (2.6)
Average daily census, median (IQR)	230 (161–351)	376 (270–519)	446 (319–603)	429 (329–604)	272 (183–417)
No. of surgeries annually, median (IQR)*	5,097 (3,405–8,047)	8,720 (6,196–11,704)	10,218 (7,392–13,729)	10,389 (7,472–13,594)	6,364 (4,238–9,201)
Percentage of hospital beds designated as ICU beds, n (%)					
< 2.5	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)
2.5–4.9	28 (3.2)	13 (5.1)	6 (3.9)	6 (3.7)	20 (3.6)
5–< 7.4	181 (20.9)	49 (19.3)	24 (15.4)	25 (15.4)	100 (18.2)
7.5–9.9	300 (34.6)	88 (34.7)	62 (39.7)	57 (35.2)	191 (34.8)
10–12.4	180 (20.8)	49 (19.3)	30 (19.2)	36 (22.2)	110 (20.0)
12.5–14.9	94 (10.9)	31 (12.2)	20 (12.8)	23 (14.2)	68 (12.4)
≥ 15%	82 (9.5)	24 (9.5)	14 (9.0)	15 (9.3)	59 (10.8)
Trauma center					
No	389 (45.0)	75 (29.5)	40 (25.6)	45 (27.8)	217 (39.5)
Yes	476 (55.0)	179 (70.5)	116 (74.4)	117 (72.2)	332 (60.5)

Hospital characteristics data are from the American Hospital Association.

*Number of surgeries annually is defined by the number of patients undergoing surgery who stay overnight in the hospital.

AAA = abdominal aortic aneurysm; ICU = intensive care unit; IQR = interquartile range.

Table 2. Frequency of Surgical Procedures Performed on Medicare Beneficiaries, Outcomes, and Resource Use

	For Patients in All Hospitals							By Individual Hospital		
	Patients (n)	No. Hospitals (n)	Overall Admission to ICU (%)	Overall Hospital Mortality (%)	One or More Complications (%)	Hospital Length of Stay (Days), median (IQR)	Medicare Payments per Patient (Thousands of U.S. Dollars), Mean (SD)	Median Volume of Surgical Cases	Median ICU Admission Rate (%)	Range of ICU Admission Rates (%)
Endovascular AAA	69,989	866	35.6	1.0	12.1	2 (1–4)	$76.1 (54.7)	56.0	52.6	0.0–100.0
Cystectomy	13,779	254	44.5	2.5	23.1	9 (7–13)	$86.0 (85.0)	35.0	50.0	3.9–100.0
Pancreaticoduodenectomy	9,805	156	59.3	4.0	30.2	11 (8–18)	$117.4 (138.6)	43.5	71.4	0.0–100.0
Esophagectomy	7,878	162	65.1	6.9	43.7	12 (9–20)	$156.2 (214.3)	36.0	80.0	3.6–100.0
Open AAA	27,776	549	71.3	4.8	31.0	7 (6–11)	$84.6 (98.5)	38.0	92.0	0.0–100.0

AAA = abdominal aortic aneurysm; ICU = intensive care unit; IQR = interquartile range.

rates ranged from 1.0% for endovascular AAA up to 6.9% for esophagectomy. The percentage of patients with one or more complications was lowest for endovascular AAA (12.1%) and highest for esophagectomy (43.7%). Median hospital length of stay and costs of care were similarly lowest for endovascular AAA and highest for esophagectomy (see Supplemental Digital Content 1, http://links.lww.com/ALN/B245, table 2 for detailed characteristics of patients undergoing each surgical procedure).

Variation in Use of Intensive Care

Use of intensive care varied markedly across hospitals. Overall use of intensive care ranged from 0 to 100% of admissions in each hospital undergoing endovascular AAA, pancreaticoduodenectomy, and open AAA and 3.6 to 100% and 3.9 to 100% of admissions in each hospital for esophagectomy and cystectomy, respectively (table 2). There were a substantial number of hospitals in the low-use (0 to 49%), medium-use (50 to 89%), and high-use (90% or greater) categories for each surgical procedure (fig. 1).

We examined characteristics for patients who underwent each surgical procedure, stratified by their care in a hospital with low, medium, or high use of intensive care for the specific surgical procedure. There were a few differences in the distributions of age, or race for patients cared for in hospitals with high *versus* low use of intensive care (see Supplemental Digital Content 1, http://links.lww.com/ALN/B245, tables 3–7 showing patient characteristics for each procedure, stratified by hospital ICU use). Of particular note, the number of patients with 2+ Charlson comorbidity index was not substantially higher in the high-use hospitals compared with the low-use hospitals for any of the surgical procedures: 52.5 *versus* 51.0% for endovascular AAA; 17.0 *versus* 18.1% for cystectomy; 22.2 *versus* 22.2% for pancreaticoduodenectomy; 14.9 *versus* 16.0% for esophagectomy; and 51.4 *versus* 49.3% for open AAA.

Hospital Mortality

Individual patient admission to intensive care was associated with a substantially increased risk of hospital death, as assessed by both multilevel multivariable logistic regression and propensity matching of patients for the likelihood of admission to ICU (table 3). We then assessed the outcomes for patients based on their care in a hospital with high, medium, or low use of intensive care for the specific surgical procedure. In unadjusted analysis, there was no association between mortality for patients cared for in hospitals belonging to a high *versus* low ICU admission group for endovascular AAA (1.1 *vs.* 1.0%, P = 0.54), cystectomy (2.8 *vs.* 2.3%, P = 0.31), pancreaticoduodenectomy (3.7 *vs.* 3.3%, P = 0.36), or open AAA (4.6 *vs.* 4.3%, P = 0.51), but there was a significantly increased hospital mortality for patients undergoing esophagectomies in hospitals with high ICU use *versus* low use (7.5 *vs.* 5.4%, P = 0.007) (table 4). After multivariable adjustment, there was no association for any surgical

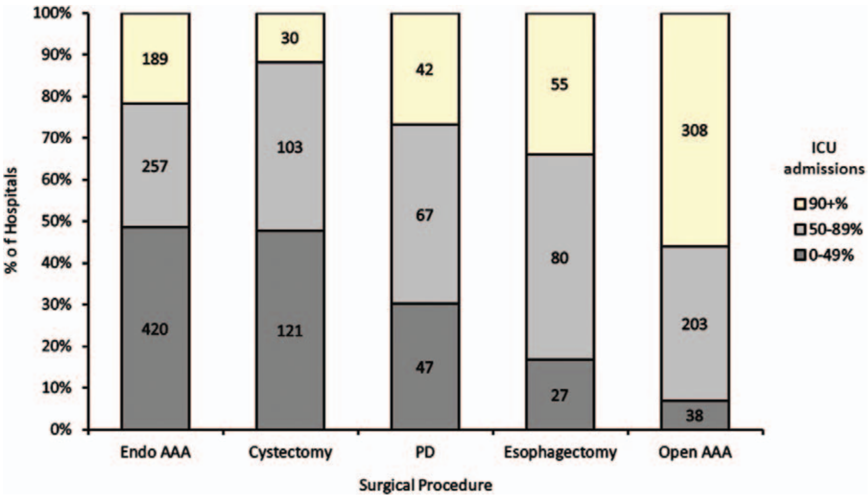

Fig. 1. Distribution of use of critical care across hospitals for patients undergoing five major surgical procedures. AAA = abdominal aortic aneurysm; Endo = endovascular; ICU = intensive care unit; PD = pancreaticoduodenectomy.

Table 3. Association between Use of Intensive Care and Hospital Mortality Adjusted for Patient and Hospital Factors

	Multivariable Adjustment			Propensity Matched		
	Total (n)	Odds Ratio (95% CI)	*P* Value	Total (n)	Odds Ratio (95% CI)	*P* Value
Endovascular AAA						
No ICU	45,973	Ref		NA	Ref	
ICU	24,916	9.83 (7.88–12.28)	< 0.001	NA	NA	
Cystectomy						
No ICU	7,647	Ref		3,962	Ref	
ICU	6,132	6.68 (4.84–9.20)	< 0.001	3,962	6.70 (4.59–9.78)	< 0.001
Pancreaticoduodenectomy						
No ICU	3,991	Ref		1,103	Ref	
ICU	5,814	5.63 (3.97–7.99)	< 0.001	1,103	7.00 (4.07–12.03)	< 0.001
Esophagectomy						
No ICU	2,749	Ref		1,742	Ref	
ICU	5,129	4.64 (3.39–6.35)	< 0.001	1,742	4.93 (3.46–7.03)	< 0.001
Open AAA						
No ICU	19,804	Ref		3,673	Ref	
ICU	7,972	2.30 (1.87–2.84)	< 0.001	3,673	3.11 (2.43–3.97)	< 0.001

AAA = abdominal aortic aneurysm; ICU = intensive care unit; NA = model would not converge; Ref = reference.

procedure between hospital mortality and care in a high *versus* low ICU-use hospital (table 5; for the full model with all variables for each surgical procedure, see Supplemental Digital Content 1, http://links.lww.com/ALN/B245, table 8).

Hospital Length of Stay and Hospital Costs

In unadjusted analyses, hospital length of stay and Medicare payments were higher in high ICU-use hospitals compared with low ICU-use hospitals for all procedures (table 4). However, after multivariable adjustment, hospital length of stay and Medicare payments were greater only for patients who underwent endovascular AAA in hospitals with high admission to ICU *versus* low admission (table 5). Patients in low ICU-use hospitals who *did* receive intensive care had substantially higher Medicare payments compared with patients who received ICU care in high-use hospitals; this finding was consistent across all surgical procedures (table 6).

Discussion

These data demonstrate a substantial variation across U.S. hospitals in the use of intensive care services for elderly patients receiving major surgery. There was no association between greater use of intensive care at the hospital level and hospital mortality, a finding that was robust when examined across five different surgical procedures that were performed with varying frequency and with variable overall risk of hospital death. There were also no consistent differences in length of hospital stay or Medicare payments associated with systematically more or less use of intensive care. The lack of difference in payments was explained by higher payments

Table 4. Association between Hospital Use of Intensive Care, Hospital Mortality, Length of Stay, and Costs of Care (Unadjusted)

No. Patients Admitted to ICU in the Hospital	N	Hospital Mortality		Hospital Length of Stay (Days)		Medicare Payments (Thousands of U.S. Dollars)	
		N (%)	*P* Value	Median (IQR)	*P* Value	Mean (SD)	*P* Value
Endovascular AAA							
0–49%	43,057	438 (1.0)	Ref	2 (1–3)	Ref	$72.2 (51.2)	Ref
50–89%	16,232	169 (1.0)	0.80	2 (1–4)	< 0.001	$83.8 (60.7)	< 0.001
≥ 90%	10,700	116 (1.1)	0.54	2 (1–4)	< 0.001	$80.3 (57.4)	< 0.001
Cystectomy							
0–49%	7,401	169 (2.3)	Ref	9 (7–12)	Ref	$80.9 (76.4)	Ref
50–89%	5,184	136 (2.6)	0.22	9 (7–13)	< 0.001	$95.4 (99.5)	< 0.001
≥ 90%	1,194	33 (2.8)	0.31	9 (8–14)	< 0.001	$76.8 (61.0)	0.08
Pancreaticoduodenectomy							
0–49%	3,419	111 (3.3)	Ref	10 (8–16)	Ref	$105.9 (132.4)	Ref
50–89%	3,977	187 (4.7)	0.002	12 (8–19)	< 0.001	$137.8 (158.8)	< 0.001
≥ 90%	2,409	89 (3.7)	0.36	12 (9–18)	< 0.001	$100.2 (102.5)	0.08
Esophagectomy							
0–49%	1,621	87 (5.4)	Ref	10 (8–17)	Ref	$119.4 (155.4)	Ref
50–89%	3,786	268 (7.1)	0.02	13 (9–21)	< 0.001	$170.1 (250.0)	< 0.001
≥ 90%	2,471	186 (7.5)	0.007	12 (9–20)	< 0.001	$158.8 (183.6)	< 0.001
Open AAA							
0–49%	1,990	85 (4.3)	Ref	7 (6–11)	Ref	$88.9 (137.0)	Ref
50–89%	9,725	511 (5.3)	0.07	7 (6–11)	0.66	$85.1 (96.1)	0.14
≥ 90%	16,061	738 (4.6)	0.51	7 (6–11)	0.10	$83.7 (94.1)	0.03

P values for outcomes calculated by using chi-square test for mortality, Spearman rank test for length of stay, and ANOVA for costs.
AAA = abdominal aortic aneurysm; ICU = intensive care unit; IQR = interquartile range; Ref = reference.

for the fewer patients who did receive intensive care in low-using hospitals compared with ICU patients in the high-use hospitals.

A substantial number of hospitals admitted more than 90% of patients to the ICU, even for a surgical procedure (endovascular AAA) with an overall hospital mortality of 1%. This finding of variable, and sometimes aggressive admission of patients to ICU with relatively low predicted risk of death, is similar to the recent observation regarding variation in use of intensive care for medical patients. Wide variability was found for ICU admission for patients with diabetic keto-acidosis—a diagnosis with a risk of hospital death of just 0.7%.[17] Similarly, a study from the Veterans Affairs hospitals also found very large variations in admission of "low-risk" medical patients to the ICU from the emergency room, with anywhere from 1.2 to 38.9% of patients with a predicted risk of death of less than 2% receiving intensive care.[18]

There are many possible reasons for a lack of association between use of intensive care services and hospital mortality for patients undergoing major surgery. First, greater use of intensive care may actively reduce mortality in higher-risk patients. This would be the case if there was a greater severity of illness in patients cared for in the higher ICU-using hospitals. However, we found no substantial difference in age or comorbidity profile of the patients in higher-use hospitals. Moreover, our analysis investigating outcomes based on ICU use on the hospital rather than on individual patient level removes some of this patient-level confounding. But, it remains possible that the hospitals that use more intensive care may have a higher "rescue" rate for high-risk patients, and the hospitals with lower use of intensive care are experiencing a greater frequency of "failure to rescue"—the concept of taking inappropriate care of patients who develop complications, leading to death.[19] Because our data did not include dates of ICU admission, we could not investigate whether ICU use was used more or less often to rescue patients in certain hospitals in our cohort. Other possibilities are that the benefits of intensive care, which include support for specific organ failure, and high nurse-to-patient ratios may not be realized until the risk of death for patients is well above 1 to 6% seen for patients undergoing these major surgical procedures. Alternatively, it may be that the most important components of high-quality postoperative care that are gained in an ICU, such as high nurse-to-patient ratios,[20,21] may be adequately delivered in other settings such as a postoperative recovery room or step-down unit.

Studies of surgical outcomes in the United Kingdom and across Europe found higher than expected mortality and low overall use of intensive care for patients who died.[1,10] Such findings raised the question of whether more aggressive use of intensive care for surgical patients might reduce some of the observed excess mortality rate. Our findings suggest that greater systematic use of intensive care for all patients undergoing a given surgery alone may not improve survival outcome for older surgical patients. However, these data must be placed in the context of overall high availability of

Table 5. Association between Hospital Use of Intensive Care and Hospital Mortality, Hospital Length of Stay, and Hospital Costs Adjusted for Patient and Hospital Factors*

	Hospital Mortality		Hospital Length of Stay		Hospital Costs	
Admissions to ICU	Odds Ratio (95% CI)	*P* Value	Regression Coefficient (95% CI)	*P* Value	Regression Coefficient (95% CI)	*P* Value
Endovascular AAA						
0–49%	Ref		Ref		Ref	
50–89%	1.01 (0.82–1.24)	0.92	0.16 (0.12–0.21)	< 0.001	0.13 (0.06–0.19)	< 0.001
≥ 90%	1.05 (0.82–1.34)	0.71	0.15 (0.09–0.20)	< 0.001	0.013 (0.06–0.20)	< 0.001
Cystectomy						
0–49%	Ref		Ref		Ref	
50–89%	1.07 (0.83–1.39)	0.59	0.02 (−0.02 to 0.06)	0.35	0.12 (0.02–0.22)	0.02
≥ 90%	1.02 (0.67–1.56)	0.93	0.07 (0.01–0.14)	0.02	0.08 (−0.07 to 0.24)	0.29
Pancreaticoduodenectomy						
0–49%	Ref		Ref		Ref	
50–89%	1.24 (0.93–1.65)	0.14	0.07 (0.00–0.13)	0.04	0.09 (−0.06 to 0.24)	0.22
≥ 90%	0.91 (0.64–1.30)	0.61	0.07 (−0.00 to 0.14)	0.07	−0.01 (−0.19 to 0.24)	0.87
Esophagectomy						
0–49%	Ref		Ref		Ref	
50–89%	1.22 (0.87–1.70)	0.25	0.09 (0.02–0.16)	0.01	0.22 (0.03–0.41)	0.02
≥ 90%	1.25 (0.87–1.79)	0.24	0.05 (−0.02 to 0.13)	0.15	0.15 (−0.06 to 0.35)	0.15
Open AAA						
0–49%	Ref		Ref		Ref	
50–89%	1.18 (0.88–1.58)	0.27	−0.02 (−0.08 to 0.04)	0.50	−0.01 (−0.15 to 0.14)	0.92
≥ 90%	1.08 (0.82–1.44)	0.58	0.01 (−0.05 to 0.06)	0.84	−0.02 (−0.16 to 0.12)	0.79

*Adjusted for patient-level factors: age, sex, race, comorbidities, weekend *vs.* weekday admission; hospital-level factors: academic *vs.* nonacademic, number of hospital beds, average daily hospital census, number of surgeries performed annually, percent of hospital beds that were intensive care beds, whether the hospital was a trauma center, and the volume of the given procedure performed.

AAA = abdominal aortic aneurysm; ICU = intensive care unit; Ref = reference.

intensive care beds in the United States in comparison with other countries such as the United Kingdom.[22] Although the most appropriate use of intensive care services may not involve default admission of all patients undergoing major surgical procedures, the ability to admit patients identified as requiring organ support in a timely manner remains important. Recent data on medical patients in France suggest that delayed admission to ICU of patients deemed in need of intensive care was associated with worse outcomes.[5] Therefore, our generalizability to countries, and systems of care, that may be on the lower end of overall availability of intensive care remains limited, and the "benefits" of more frequent use of intensive care services postoperatively remains unexplored in lower-resource settings.[4]

We expected greater use of intensive care services to be associated with both longer hospital length of stay and higher costs, as has been seen for patients undergoing carotid endarterectomies.[23,24] Our hypothesis was confirmed for patients undergoing endovascular AAA but was not consistently seen for any other surgical procedure examined. Our findings are consistent with a similar assessment of patients with pneumonia that found no difference in costs with greater use of intensive care.[25] It is also notable that admission to an ICU did not seem to lengthen care time by increasing length of stay, which is also consistent with the data on ICU admission for patients with diabetic ketoacidosis.[17] The majority of the Medicare payment is driven by the diagnosis-related group of the patient, which itself is driven by the surgical procedure performed. It is possible that other costs, such as the physician billing in Medicare part B, would be different. We also found that, for hospitals that infrequently admitted patients to the ICU, the average costs for the patients who did require intensive care was very high, suggesting that there is an "averaging" effect that cancels out the potential benefit from providing more care on the wards.

Our study has a number of limitations. First, due to the use of Medicare data, we were limited to examination of patients over the age of 65 yr. It is possible that patterns of care for younger patients after surgery could differ. We were also unable to determine whether admission to ICU occurred before, immediately following, or days after the surgical procedure. However, many of the hospitals with 90% or greater use of intensive care admitted 100% of the patients, suggesting a routine or "default" use of intensive care for all patients undergoing the surgical procedure. The fact that we could not assess whether hospitals that used intensive care sparingly (less than 50% of the time) sent the patients immediately after the surgery or used the ICU as a "rescue" option for patients who developed complications is a substantial limitation and warrants further investigation

Table 6. Mean Medicare Payments per Patient across Hospitals with High *vs.* Low Use of Intensive Care, Stratified by Use of Intensive Care for Individual Patients

		No ICU		ICU	
Percentage of Patients Admitted to ICU in the Hospital	N	Mean Medicare Payments (Thousands of U.S. Dollars) (SD)	*P* Value*	Mean Medicare Payments (Thousands of U.S. Dollars) (SD)	*P* Value*
Endovascular AAA					
0–49%	43,057	$66.1 (35.1)	< 0.001	$97.3 (86.4)	< 0.001
50–89%	16,232	$78.8 (47.1)		$85.8 (65.3)	
≥ 90%	10,700	$80.8 (56.6)		$80.2 (57.4)	
Cystectomy					
0–49%	7,401	$67.3 (48.6)	< 0.001	$121.6 (118.7)	< 0.001
50–89%	5,184	$74.6 (57.0)		$104.4 (111.7)	
≥ 90%	1,194	$48.3 (24.5)		$78.1 (61.8)	
Pancreaticoduodenectomy					
0–49%	3,419	$85.3 (66.1)	< 0.001	$166.4 (226.5)	< 0.001
50–89%	3,977	$108.6 (96.3)		$148.8 (175.6)	
≥ 90%	2,409	$79.7 (64.2)		$100.9 (103.5)	
Esophagectomy					
0–49%	1,621	$84.9 (81.6)	< 0.001	$194.9 (232.6)	< 0.001
50–89%	3,786	$112.7 (112.3)		$193.9 (284.9)	
≥ 90%	2,471	$101.3 (138.5)		$161.7 (185.1)	
Open AAA					
0–49%	1,990	$69.8 (68.7)	0.67	$124.0 (206.8)	< 0.001
50–89%	9,725	$71.2 (74.0)		$89.8 (102.0)	
≥ 90%	16,061	$73.0 (65.9)		$84.1 (94.9)	

**P* value is for comparison of three ICU admission categories (0–49%, 50–89%, and ≥ 90%) using one-way ANOVA.
AAA = abdominal aortic aneurysm; ICU = intensive care unit.

using other data sources.[19] We also did not have detailed information on severity of illness, limiting the conclusions we can draw from the analysis. Finally, the analysis was also limited to the acute hospitalization and focused on hospital mortality. It is possible that potential benefits from one care model may be evident with longer follow-up.

Our choice of which surgical procedures to include was partly driven by concern for power, as we were limited by the frequency of surgical procedures performed in the data set. We chose to group hospitals into categories of use of intensive care for three reasons: to provide meaningful cut-offs; to assess the greater than 90% group as a reference for "default" use of intensive care; and to maximize our power for a patient-level analysis. However, for the lower-volume procedures, the possibility of a type II error remains a concern. We recognize that there are many possible approaches to this analysis, including more general linear models and/or distance to hospitals as an instrumental variable.[25]

Some patients, such as those undergoing coronary artery bypass grafting, are routinely admitted to an ICU after surgery, despite a relatively low risk of death in comparison with most of the surgical procedures we examined. These patients usually require elements of intensive care, such as mechanical ventilation and monitored rewarming, that necessitate admission to ICU. Such patients are also at high risk of events, such as arrhythmias and cardiac tamponade, that must be acted on very quickly to ensure favorable outcomes.[26] However, we can only speculate that the routine admission to ICU of these patients has helped to drive down mortality associated with these specific surgical procedures.

Pathways representing optimal postoperative care are complex and often different for each surgical procedure. As we seek to provide high-quality care for surgical patients, these data provide important information that care for patients undergoing major surgical procedures need not necessarily involve frequent use of intensive care services to achieve good outcomes. Such options may have important benefits for other patients who require critical care services in situations where ICU bed availability is limited.[27] Importantly, though, cost savings and reductions in length of stay may not run in parallel with a reduction in use of intensive care. Moreover, the care pathways that may need to be in place to ensure appropriate care if an ICU bed is not used remain to be elucidated. Further research is needed to determine the best options for individual patients, with the recognition that care requirements may differ dramatically for different high-risk surgical procedures.

Acknowledgments

Funding was received from the National Institute on Aging, Bethesda, Maryland (award number: K08AG038477 to Dr. Wunsch) and from the Agency for Healthcare Research and Quality, Rockville, Maryland (award number: K08HS020672 to Dr. Cooke).

Competing Interests

The authors declare no competing interests.

Correspondence

Address correspondence to Dr. Wunsch: Department of Critical Care Medicine, Sunnybrook Health Sciences Centre, 2075 Bayview Avenue, Rm D1.08, Toronto, Ontario, M5R 3B2 Canada. hannah.wunsch@sunnybrook.ca. This article may be accessed for personal use at no charge through the Journal Web site, www.anesthesiology.org.

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