Section Editor: **Terese T. Horlocker**

Regional Versus General Anesthesia in Surgical Patients with Chronic Obstructive Pulmonary Disease: Does Avoiding General Anesthesia Reduce the Risk of Postoperative Complications?

Mark S. Hausman, Jr., MD, Elizabeth S. Jewell, MS, and Milo Engoren, MD

BACKGROUND: Surgical patients with chronic obstructive pulmonary disease (COPD) are at increased risk of perioperative complications. In this study, we sought to quantify the benefit of avoiding general anesthesia in this patient population.

METHODS: Data from the National Surgical Quality Improvement Program database (2005–2010) were used for this review. Patients who met the National Surgical Quality Improvement Program definition for COPD and underwent surgery under general, spinal, epidural, or peripheral nerve block anesthesia were included in this study. For each primary current procedural terminology code with ≥1 general and ≥1 regional (spinal, epidural, or peripheral nerve block) anesthetic, regional patients were propensity score–matched to general anesthetic patients. Propensity scoring was calculated using all available demographic and comorbidity data. This match yielded 2644 patients who received regional anesthesia and 2644 matched general anesthetic patients. These groups were compared for morbidity and mortality.

RESULTS: Groups were well matched on demographics, comorbidities, and type of surgery. Compared with matched patients who received regional anesthesia, patients who received general anesthesia had a higher incidence of postoperative pneumonia (3.3% vs 2.3%, $P = 0.0384$, absolute difference with 95% confidence interval = 1.0% [0.09, 1.88]), prolonged ventilator dependence (2.1% vs 0.9%, $P = 0.0008$, difference = 1.2% [0.51, 1.84]), and unplanned postoperative intubation (2.6% vs 1.8%, $P = 0.0487$, difference = 0.8% [0.04, 1.62]). Composite morbidity was 15.4% in the general group versus 12.6% ($P = 0.0038$, difference = 2.8% [0.93, 4.67]). Composite morbidity not including pulmonary complications was 13.0% in the general group versus 11.1% ($P = 0.0312$, difference = 1.9% [0.21, 3.72]). Thirty-day mortality was similar (2.7% vs 3.0%, $P = 0.6788$, difference = 0.3% [−1.12, 0.67]). As a test for validity, we found a positive association between pulmonary end points because patients with 1 pulmonary complication were significantly more likely to have additional pulmonary complications.

CONCLUSIONS: The use of regional anesthesia in patients with COPD is associated with lower incidences of composite morbidity, pneumonia, prolonged ventilator dependence, and unplanned postoperative intubation. (Anesth Analg 2015;120:1405–12)

Surgical patients with chronic obstructive pulmonary disease (COPD) are at increased risk of perioperative complications.[1–3] These patients are more likely to require unplanned postoperative intubation,[1] have a higher incidence of postoperative pulmonary infection,[2,3] and have increased length of hospital stay[2] compared with patients without COPD.

Postoperative epidural analgesia for patients with COPD undergoing major abdominal surgery under general anesthesia has been shown to be beneficial in some patient populations.[4,5] Epidural analgesia promoted better postoperative pulmonary function,[4] reduced the risk of postoperative pulmonary infection,[5] and improved 30-day mortality[5] in patients with COPD. A review of 141 prospective, randomized trials comparing neuraxial versus general anesthesia demonstrated decreased mortality and decreased incidence of postoperative pulmonary and cardiac complications, renal failure, and deep venous thrombosis in the patients receiving neuraxial anesthesia.[6] However, 3 more recent trials found modest to no benefit to epidural anesthesia and analgesia,[7–9] and a very recent post hoc subgroup analysis of a large prospective trial of β-blockers found that neuraxial anesthesia was associated with increased adverse cardiovascular outcomes.[10] These studies were not specific to patients with COPD, and the benefits or harms associated with neuraxial/regional anesthesia may be related to non-COPD patients who comprised the majority of subjects in these studies. Therefore, whether using regional (spinal, epidural, or peripheral nerve block) anesthesia and thus avoiding operative endotracheal intubation and mechanical ventilation improves outcomes in surgical patients with COPD remains unknown. We hypothesized that avoiding general anesthesia in patients with COPD would significantly reduce the incidence of postoperative pulmonary

From the Department of Anesthesiology, Division of Critical Care Medicine, University of Michigan Health Systems, Ann Arbor, Michigan.

Accepted for publication October 22, 2014.

Funding: Funding in the form of salary support for authors was provided by the University of Michigan, Department of Anesthesiology.

The authors declare no conflicts of interest.

Reprints will not be available from the authors.

Address correspondence to Mark S. Hausman, Jr., MD, Department of Anesthesiology, University of Michigan Health Systems, 1H247 University Hospital, 1500 E Medical Center Dr., SPC 5048, Ann Arbor, MI 48109. Address e-mail to mhausman@umich.edu.

DOI: 10.1213/ANE.0000000000000574

infection, as well as reduce the incidence of perioperative and postoperative morbidity.

METHODS

The University of Michigan IRB approved this retrospective propensity-matched cohort study (IRB registration number HUM00052066). Data from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) participant use data file from 2005 to 2010 were used for this study. A waiver for informed consent was granted because we used an existing, deidentified data set. NSQIP data were collected from 186 hospitals, across a wide variety of case types. The data were collected prospectively and were subject to the accuracy and completeness of NSQIP data collection and reporting systems. They were collected by trained professionals using standardized definitions, and data entry was audited. This process ensures standard interpretations of the definitions, and the methodology, accuracy, and reproducibility of these data have been documented in previous studies.[11,12] The participant use data file includes multispecialty NSQIP contributions, so a wide range of case types are included in this study.

Inclusion/Exclusion Criteria

Patients were included if they had an NSQIP preoperative diagnosis of severe COPD (Appendix 1) and received general or regional as the principal anesthetic technique. Patients were excluded if they required ventilator-assisted respiration within 48 hours before surgery or if they had a preoperative pulmonary infection (Appendix 1). Patients who did not meet the NSQIP definition of severe COPD were excluded, as were patients undergoing cardiac surgery, solid organ transplant, emergency surgery, reoperation within 30 days of initial operation, or were American Society of Anesthesiologists (ASA) classification 5 or 6. Finally, to ensure that we were analyzing only operations that were done under both general or regional anesthesia, patients were excluded if their primary surgical current procedural terminology (CPT) code did not have ≥1 general and ≥1 regional anesthetic case reported.

Outcomes

The primary outcome for this study was postoperative pulmonary infection reported in the postoperative inpatient setting (Appendix 1). Secondary outcomes included 30-day mortality, ventilator dependence for >48 hours postoperatively, unplanned postoperative intubation, and a composite morbidity consisting of any of these 3 respiratory complications or any of the following: new dialysis requirement, progressive renal failure, postoperative cardiac arrest, postoperative myocardial infarction, sepsis, septic shock, wound infection, stroke, urinary tract infection, significant postoperative bleeding, peripheral nerve injury, deep venous thrombosis, and pulmonary embolus. All outcomes are as defined by the American College of Surgeons NSQIP data sheet, updated April 1, 2009.[13]

Study Design

From within each primary CPT code that had ≥1 qualifying patient who underwent regional anesthesia as the primary technique, and ≥1 qualifying patient who underwent general anesthesia as the primary technique (with or without adjunct regional analgesia), regional patients were matched to general anesthetic patients on the basis of a calculated propensity score. Propensity scores were calculated using a nonparsimonious binary logistic regression for demographic and comorbidity variables (Table 1), with type of primary anesthetic (regional or general) as the dependent variable. Cases missing these data were excluded (Fig. 1). Within each identical surgical procedure (unique CPT code), patients who received regional anesthesia as the primary anesthetic technique were matched to those who received general anesthesia as the primary technique using a caliper width that maximizes the number of matches while maintaining all standardized differences <10%. Area under the curve for the propensity score logistic regression was 0.66. In addition to exact matching by primary CPT code, patients underwent exact matching based on level of dyspnea (none, moderate, or at rest; Appendix 1), as well as history of bleeding disorder. The result of this matching yielded 2644 patients who received regional anesthesia and 2644 patients who underwent identical operations under general anesthesia. All subgroup analyses retained the exact match on primary CPT code, level of dyspnea, and bleeding history.

Power Analysis

A power analysis for our primary outcome given our sample size, assuming that postoperative pulmonary infection occurs in 8% of patients receiving general anesthesia, 2644 patients in each group would detect a difference of 2%, with 80% power at a significance level of $\alpha = 0.05$.

Statistical Analysis

Demographic and comorbidity data in the matched groups were compared using standardized differences. Relative and absolute risk differences were calculated for outcomes of interest, and χ^2 tests were used for comparison. Multivariable logistic regressions were used to further examine the effects of prothrombin time, partial thromboplastin time, and platelet level on 30-day mortality and composite morbidity by type of anesthesia. The regional group was divided into subsets by type of regional anesthesia (spinal, epidural, and peripheral nerve block), and relative and absolute risk differences were used to compare each subset with its general anesthesia matches. In addition, matched pairs were grouped by level of dyspnea (at rest, with moderate activity, and no dyspnea; Appendix 1) and by ASA status, and relative and absolute risk differences for the outcomes were calculated in those subsets. Whereas relative risk and absolute risk differences were calculated for our outcomes of interest, we report the results as absolute risk in the forest plots and as absolute event rates elsewhere.[14] A total of 107 patients (4%) in the general anesthesia group and 64 (2%) in the regional anesthesia group were missing postoperative bleeding data. The relative and absolute risk differences for this outcome were calculated without these subjects. SAS Software, version 9.2 (SAS Institute, Cary, NC) and R version 2.15.2 (R Foundation, Vienna, Austria) were used for the statistical analysis, and SAS gmatch macro was used for the propensity score matching.

Table 1. Demographic and Clinical Characteristics for the Matched Study Population

Clinical variable	General anesthesia (*N* = 2644)		Regional anesthesia (*N* = 2644)		Standardized difference
	N	%	*N*	%	%
Male gender[a]	1591	60	1563	59	2.2
IDDM[a]	400	17	347	15	5.9
DM requiring oral medications[a]	235	11	273	12	4.2
Smoker[a]	998	37	943	36	4.3
Ascites within 30 d[a]	7	0.3	8	0.3	0.7
Esophageal varices[a]	8	0.3	5	0.2	2.3
CHF within 30 d[a]	98	3.7	120	4.5	4.2
MI within 6 mo[a]	49	1.9	44	1.7	1.4
Previous heart surgery[a]	514	19	506	19	0.8
Angina within 30 d[a]	70	2.6	67	2.5	0.7
Hypertension[a]	2123	80	2064	78	5.5
Peripheral revasc/amp[a]	658	25	595	23	5.6
Rest pain/gangrene[a]	434	16	401	15	3.4
ARF (Cr > 3)[a]	26	1.0	30	1.1	1.5
Dialysis dependent[a]	129	4.9	127	4.8	0.4
TIA[a]	243	9.2	248	9.4	0.7
Stroke[a]	394	15	344	13	4.9
Impaired sensorium[a]	22	0.8	27	1.0	2.0
Para-/quadriplegia[a]	23	0.9	16	0.6	3.1
Disseminated cancer[a]	22	0.8	29	1.1	2.7
Steroid therapy[a]	214	8.1	269	10	7.2
>10% body weight loss[a]	37	1.4	64	2.4	7.5
Bleeding disorder[a]	236	8.9	236	8.9	0
Preoperative bleeding[a]	18	0.7	11	0.4	3.6
Chemotherapy within 30 d[a]	13	0.5	12	0.5	0.6
Radiation within 30 d[a]	3	0.1	5	0.2	1.9
Sepsis within 48 h[a]	48	1.8	42	1.6	1.8
	Mean	**SD**	**Mean**	**SD**	
Age (y)[a]	71	± 10	72	± 10	6.9
HCT (%)[a]	38	± 5.6	38	± 5.6	1.5
Platelets (K/μL)[a]	251	± 90	255	± 92	4.6
Protime (s)	13	± 3.3	13	± 3.3	9.9
PTT (s)	32	± 11	31	± 7.9	17.5
Creatinine (mg/dL)[a]	1.3	± 1.2	1.3	± 1.2	0.1
American Society of Anesthesiologists status[a]	3.2	± 0.5	3.2	± 0.5	4.3
Operation time (min)	115	± 81	106	± 72	11.8
Body mass index[a]	28	± 7.4	28	± 7.6	4.7

Definitions for all clinical variables are per American College of Surgeons National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009.

IDDM = insulin-dependent diabetes mellitus; DM = diabetes mellitus; CHF = congestive heart failure; MI = myocardial infarction; revasc/amp = revascularization/amputation; ARF = acute renal failure; TIA = transient ischemic attack; Cr = creatinine; HCT = hematocrit; PTT = partial thromboplastin time.

[a]Variables used in propensity scoring and matching analysis. Functional capacity was also included in the propensity scoring.

RESULTS

More than 1.3 million patients were screened for inclusion in this study and reflect the branch points for our ultimate yield of 2644 patients in each group (Fig. 1). The 2644 pairs of patients were well matched on all factors, with similar age, comorbidities, and laboratory values (Table 1) and exactly matched on primary CPT code. The most common operations were carotid endarterectomy (12%), total knee arthroplasty (8.9%), total hip arthroplasty (5.3%), and open inguinal hernia repair (4.7%). All primary CPT codes associated with matches that occurred at a frequency of >1% appear in Table 2.

The use of general anesthesia in COPD patients was associated with an approximately 43% higher risk of pulmonary infection (3.3% vs 2.3%, $P = 0.0384$, absolute difference with 95% confidence interval = 1.0% [0.09, 1.88]) but no difference in 30-day mortality (2.7% general vs 3.0% regional, $P = 0.6788$, difference = 0.3% [−1.12, 0.67]) (Fig. 2). In addition, general anesthesia was associated with an approximately 133% higher risk of prolonged ventilator dependence (2.1% vs 0.9%, $P = 0.0008$, difference = 1.2% [0.51, 1.83]) and an approximately 44% higher risk of unplanned postoperative intubation (2.6% vs 1.8%, $P = 0.0487$, difference = 0.8% [0.04, 1.62]) (Fig. 2). Furthermore, patients undergoing general anesthesia had a higher composite morbidity, both when including pulmonary complications (15.4% vs 12.6%, $P = 0.0038$, difference = 2.8% [0.93, 4.67]) and when excluding pulmonary complications (13.0% vs 11.1%, $P = 0.0312$, difference = 1.9% [0.21, 3.72]). Both groups had similar odds of individual nonpulmonary complications, including renal failure, deep venous thrombosis, and bleeding (Fig. 2). Patients with ≥1 pulmonary complication had significantly higher mortality (24.0% vs 1.8%, $P < 0.0001$, difference = 22.1% [16.8, 27.5]). Furthermore, associations among pulmonary end points were tested to assess for validity, and Tables 3, 4, and 5 demonstrate that patients who had 1 pulmonary complication were significantly more likely to have additional pulmonary complications.

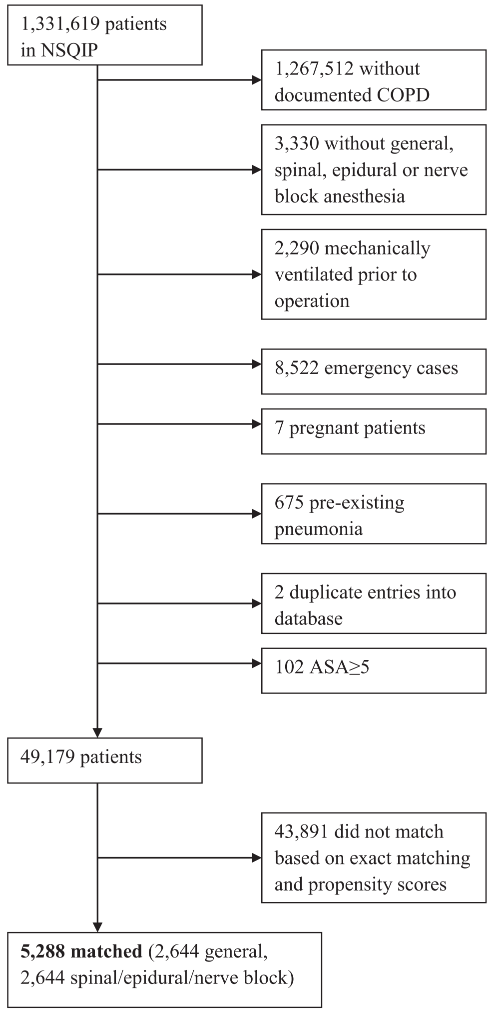

Figure 1. Flow diagram showing >1.3 million patients screened from the National Surgical Quality Improvement Program (NSQIP) database and branch points for exclusion for this study, resulting in 2644 matched pairs of chronic obstructive pulmonary disease patients. COPD = chronic obstructive pulmonary disease.

Subgroup analysis by type of regional anesthesia yielded 341 epidural, 1713 spinal, and 590 peripheral nerve block patients (Fig. 3). Compared with matched epidural patients, patients receiving general anesthesia did not have a higher incidence of pulmonary complications, composite morbidity, or 30-day mortality. However, compared with patients receiving spinal anesthesia, general anesthetic patients had a higher composite morbidity (15.7% vs 11.8%, P = 0.0011, difference = 3.9% [1.61, 6.21]) and higher incidence of prolonged ventilator dependence (2.2% vs 0.8%, P = 0.0013, difference = 1.4% [0.58, 2.22]). Patients undergoing general anesthesia had a higher incidence of unplanned postoperative intubation compared with patients receiving peripheral nerve block anesthetics (3.1% vs 1.2%, P = 0.0432, difference = 1.9% [0.23, 3.50]).

An additional subgroup analysis was performed in which patients were stratified by level of dyspnea (defined in Appendix 1), yielding 201 pairs of patients with dyspnea at rest, 1132 pairs with moderate, and 1131 pairs with none (Fig. 4). In patients with dyspnea at rest, there were no differences in any of the outcomes by type of anesthetic.

Table 2. Most Common Surgical Procedures for the Matched Study Population

CPT code	Surgical procedure	Matched patients (%) (n = 2644)
35301	Carotid/vertebral endarterectomy	12.2
27447	Total knee arthroplasty	8.9
27130	Total hip arthroplasty	5.3
49505	Inguinal hernia repair	4.7
27590	Above knee amputation	3.9
27880	Below knee amputation	3.9
34802	Endovascular AAA repair with 1 docking limb	3.9
35656	Lower extremity arterial bypass	3.7
34803	Endovascular AAA repair with 2 docking limbs	3.1
52601	Transurethral resection of prostate	2.9
35556	Lower extremity arterial bypass	2.8
35371	Lower extremity arterial thrombectomy	2.0
52648	Laser transurethral prostate ablation	1.6
35661	Lower extremity arterial bypass	1.6
27236	ORIF thigh fracture	1.3
52235	Cystoscopy	1.2
28805	Transmetatarsal amputation	1.1
35566	Lower extremity arterial bypass	1.1
35583	Lower extremity vein bypass	1.1
27245	ORIF thigh fracture	1.0
52234	Cystoscopy	1.0
52240	Cystoscopy	1.0

AAA = abdominal aortic aneurysm; CPT = current procedural terminology; ORIF = open reduction and internal fixation.

However, general anesthesia patients with moderate dyspnea were found to have an increased incidence of prolonged ventilator requirement (1.9% vs 0.8%, P = 0.0300, difference = 0.8% [0.19, 2.10]) and a higher composite morbidity [15.5% vs 12.0%, P = 0.0174, difference = 3.5% [0.70, 6.37]) compared with matched regional patients. Of the 1311 matched patients with no dyspnea, general anesthetic patients were more likely to have prolonged ventilator requirement (1.9% vs 0.8%, P = 0.0172, difference = 0.8% [0.27, 2.02]), require unplanned postoperative intubation (2.5% vs 1.4%, P = 0.0477, difference = 1.1% [0.09, 2.20]), and have a higher composite morbidity (15.0% vs 11.7%, P = 0.0186, difference = 3.3% [0.60, 5.80]).

When we analyzed by ASA subgroup, ASA-3 patients who received general anesthesia had a higher composite morbidity (14.1% vs 11.4%, P = 0.0195, difference = 2.7% [0.05, 4.86]) than ASA-3 patients who had regional anesthesia (Fig. 5). ASA-4 patients had similar composite morbidity with either general or regional anesthesia (Fig. 6).

DISCUSSION

Our findings suggest that, compared with general anesthesia, the use of regional anesthesia in patients with severe COPD is associated with a lower incidence of postoperative pulmonary complications. Our findings are novel, in that the improved outcomes are only present in patients receiving spinal or peripheral nerve block and not in epidural anesthetics. Furthermore, the improved outcomes were not present in patients with dyspnea at rest.

Although composite morbidity, as well as nonpulmonary composite morbidity, was lower in patients not receiving general anesthesia, this advantage did not extend to mortality, which was similar between groups. This differs from a meta-analysis of older studies comparing 9559 patients

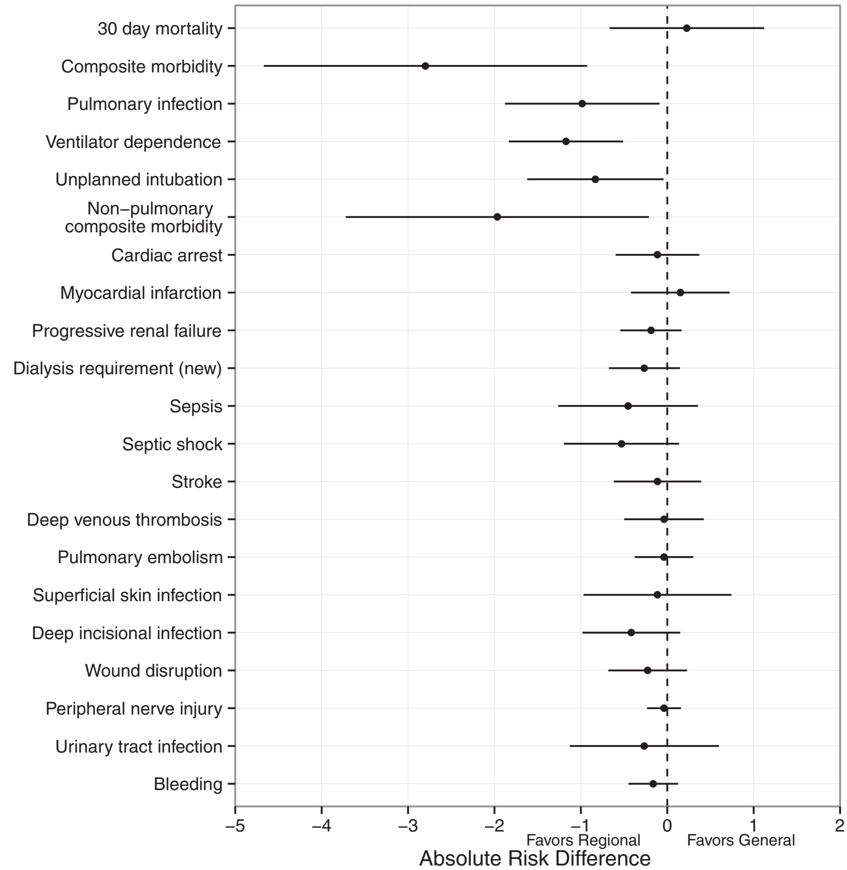

Figure 2. The effect of regional versus general anesthesia on postoperative morbidity and 30-day mortality for patients with chronic obstructive pulmonary disease. All outcomes are as defined by the National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009.

randomized to regional or general anesthesia that found a one-third reduction in mortality with regional anesthesia.[6] However, more recent studies have found no mortality benefit for regional over general anesthesia,[7–9] and 1 very recent study showed potential harm as a result of increased cardiovascular morbidity.[10] These recent studies, as well as our findings, challenge previous data that avoiding general anesthesia provides a mortality benefit. However, those studies[6–10] included non-COPD patients whereas, our study is limited to patients with COPD.

We also found that although patients who received spinal anesthetics had fewer composite morbidities, there was no difference between those who received epidural and general anesthesia. Our study was not designed or powered to find a difference among the different types of regional anesthetics, and therefore, this lack of difference may simply be loss of power from the smaller sample size.

We found better outcomes in the regional anesthesia group only in the subgroups with moderate dyspnea or none but not in those with dyspnea at rest. Although this lack of effect may have been attributable to lack of statistical power or hidden confounders, such as the spectrum of COPD severity in patients with dyspnea at rest, it may also have reflected physiological differences. In severely symptomatic COPD patients, the adverse effects of regional anesthesia, including loss of accessory muscles of respiration, phrenic nerve paralysis, and poor tolerance for supine positioning, tend to negate the potential benefits of avoiding operative endotracheal intubation and mechanical ventilation.[15,16] Given the high rate of composite morbidities (25% vs 23%) and mortality (7.5% vs 9.6%), further study is needed to determine how best to provide anesthesia to COPD patients with dyspnea at rest. Additional subgroup analysis of ASA-3 and ASA-4 patients found that only in ASA-3 patients was receiving general anesthesia found to be associated with a higher composite morbidity than regional patients. This further suggests that the beneficial effects of regional anesthesia may be muted in the sickest patients.

COPD patients with moderate or no reported dyspnea did benefit from avoiding general anesthesia. They were less likely to require prolonged mechanical ventilation and had a lower composite morbidity if they received regional anesthesia. There are several mechanisms by which general anesthesia may result in pulmonary complications in patients with COPD. Residual effect of neuromuscular blocking drugs increases the incidence of hypoxia and unplanned intubation in the postoperative care unit.[15] COPD patients may be particularly sensitive to this effect. General anesthesia and positive pressure ventilation disturb pulmonary physiology, causing atelectasis, gas exchange abnormalities, and ventilation/perfusion mismatch.[16] These disturbances are less likely to be tolerated by patients with COPD.

There were several limitations to this study. COPD was clinically defined, not defined on the basis of pulmonary function tests. Although the clinical definitions were standardized, we cannot exclude the possibility that anesthesiologists had other clinical information that may have influenced their decision on the type of anesthetic to provide. We attempted to mitigate this using exact matching for level of dyspnea to control for varying clinical severities of COPD. Although propensity

Table 3. Validity Assessment: Relationship Among Pulmonary End Points: Association of Pneumonia with Other Pulmonary Complications

	Pneumonia *N* = 150		No pneumonia *N* = 5288		*P* value	Absolute difference (%)	95% Confidence interval
Interval	*n*	%	*n*	%			
Unplanned intubation	41	27.3	75	1.5	<0.0001	25.9	18.7–33.0
Prolonged ventilation	35	23.3	46	0.9	<0.0001	22.4	15.7–29.2

Definitions for all clinical variables are per American College of Surgeons National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009. Absolute difference = absolute risk difference; unplanned intubation = unplanned postoperative intubation; prolonged ventilation = prolonged postoperative mechanical ventilation.

Table 4. Validity Assessment: Relationship Among Pulmonary End Points: Association of Unplanned Intubation with Other Pulmonary Complications

Confidence interval	Unplanned intubation *N* = 116		No unplanned intubation *N* = 5172		*P* value	Absolute difference (%)	95% Confidence interval
	n	%	*n*	%			
Pneumonia	41	35.3	109	2.1	<0.0001	33.2	24.5–41.9
Prolonged ventilation	57	49.1	24	0.5	<0.0001	48.7	39.6–57.8

Definitions for all clinical variables are per American College of Surgeons National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009. Absolute difference = absolute risk difference; unplanned intubation = unplanned postoperative intubation; prolonged ventilation = prolonged postoperative mechanical ventilation.

Table 5. Validity Assessment: Relationship Among Pulmonary End Points: Association of Prolonged Ventilation with Other Pulmonary Complications

Confidence interval	Prolonged ventilation *N* = 81		No prolonged ventilation *N* = 5207		*P* value	Absolute difference (%)	95% Confidence interval
	n	%	*n*	%			
	35	43.2	115	2.2	<0.0001	41.0	30.2–51.8
Unplanned intubation	57	70.4	59	1.1	<0.0001	69.2	59.3–79.2

Definitions for all clinical variables are per American College of Surgeons National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009. Absolute difference = absolute risk difference; unplanned intubation = unplanned postoperative intubation; prolonged ventilation = prolonged postoperative mechanical ventilation.

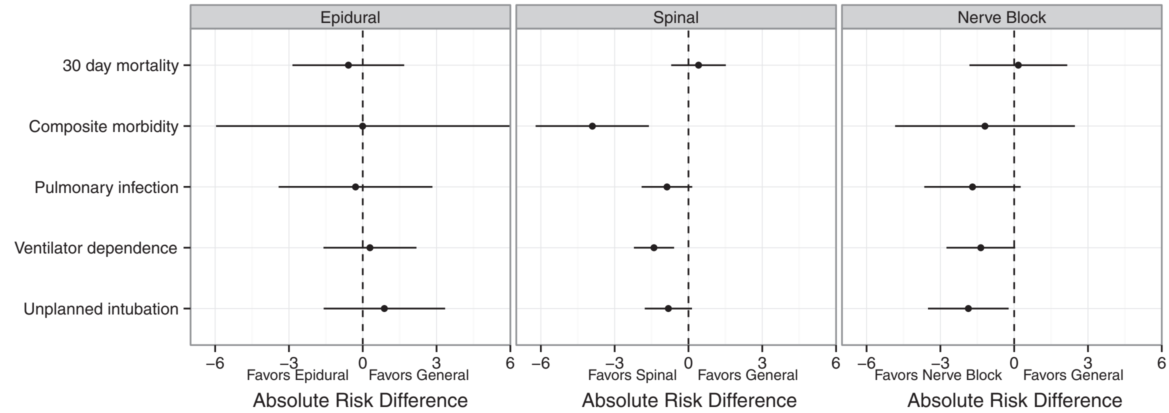

Figure 3. The effect of specific regional anesthetic technique (epidural, spinal, or peripheral nerve block) versus general anesthesia on 30-day mortality, pulmonary morbidity, and composite morbidity in chronic obstructive pulmonary disease patients. All outcomes are as defined by the National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009.

matching is a well-accepted method for controlling for differences in populations, it cannot control for hidden confounders, and these may have introduced unknown biases into our analysis. In addition, because this was a retrospective observational study, we cannot determine causation but only an association between type of anesthesia and outcomes. Furthermore, the results of this study only apply to surgical procedures for which avoiding general anesthesia is feasible.

Finally, postoperative patient management data, including the type, dose, and duration of postoperative analgesia used, are not reported in NSQIP nor are postoperative inflammatory biomarkers or core temperatures, which would have been interesting to correlate with our primary outcome. Postoperative epidural analgesia has been shown to reduce the incidence of pulmonary complications in patients with COPD,[5] and therefore, any confounding effects

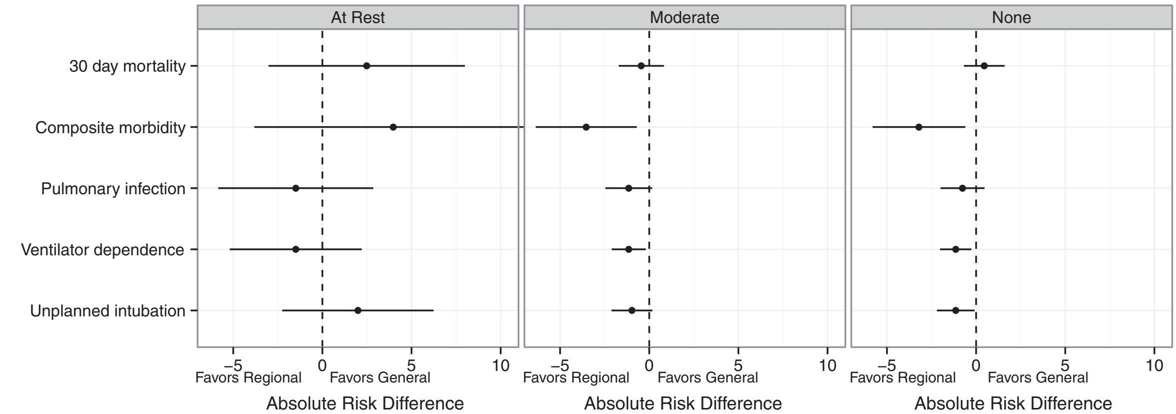

Figure 4. The effect of regional versus general anesthesia on postoperative morbidity and 30-day mortality for patients with chronic obstructive pulmonary disease with varying levels of dyspnea (at rest, moderate, and none). All outcomes are as defined by the National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009.

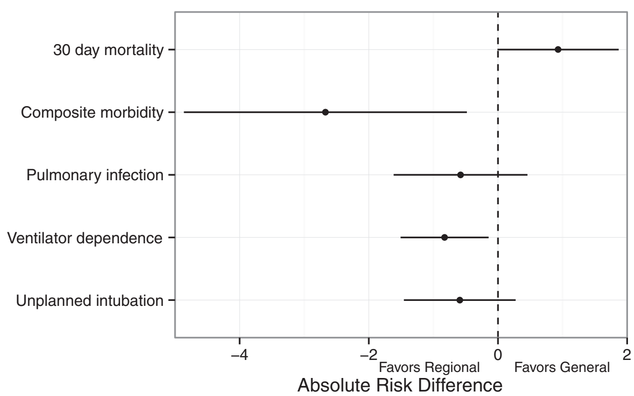

Figure 5. The effect of regional versus general anesthesia on postoperative morbidity and 30-day mortality for American Society of Anesthesiologists-3 patients with chronic obstructive pulmonary disease. All outcomes are as defined by the National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009.

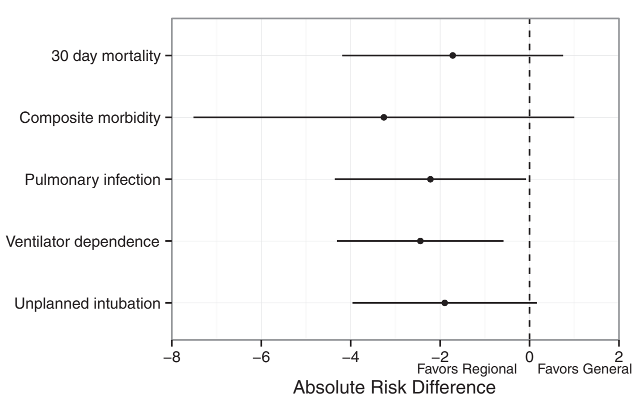

Figure 6. The effect of regional versus general anesthesia on postoperative morbidity and 30-day mortality for American Society of Anesthesiologists-4 patients with chronic obstructive pulmonary disease. All outcomes are as defined by the National Surgical Quality Improvement Program data sheet, chapter 4, updated April 1, 2009.

of postoperative analgesia regimens cannot be determined. Although epidural and peripheral nerve block anesthesia can be converted to postoperative analgesia using the same catheter, spinal anesthesia cannot. Patients receiving spinal anesthesia showed significant reduction in postoperative pulmonary complications, supporting our hypothesis that the type of operative anesthetic is associated with outcome.

One strength of our study is that by using propensity scoring and exact matching, we were able to remove the confounding effects of other factors, such as obstructive sleep apnea, age, and obesity, which can contribute to postoperative pulmonary complications. This allowed us to isolate the association between anesthetic type and outcome. Another strength is that we used a national database with >1.3 million patients from 186 hospitals to assess for our end points of interest. Furthermore, our findings were supported by a validity assessment showing significant relationships among pulmonary end points. This suggests that our findings should be both credible and generalizable.

In conclusion, our results suggest that in patients with severe COPD, the use of regional anesthesia is associated with less composite morbidity, driven by fewer pulmonary complications, as well as less nonpulmonary composite morbidity. This beneficial association was most notable in COPD patients with moderate or no dyspnea and in patients receiving spinal anesthesia.

DISCLOSURES

Name: Mark S. Hausman, Jr., MD.
Contribution: This author helped design the study, interpret the results, and prepare the manuscript.
Attestation: Mark S. Hausman, Jr., has approved the final manuscript, attests to the integrity of the original data and the analysis reported in the manuscript, and is the designated archival author.
Name: Elizabeth S. Jewell, MS.
Contribution: This author helped design the study and statistical analysis, performed the statistical analysis, and helped prepare the manuscript.
Attestation: Elizabeth S. Jewell has approved the final manuscript and attests to the integrity of the original data and the analysis reported in the manuscript.
Name: Milo Engoren, MD.
Contribution: This author helped design the study, interpret the results, and prepare the manuscript.
Attestation: Milo Engoren has approved the final manuscript and attests to the integrity of the original data and the analysis reported in the manuscript.
This manuscript was handled by: Terese T. Horlocker, MD.

APPENDIX 1

From the National Surgical Quality Improvement Program manual (site.acsnsqip.org), definitions for severe chronic obstructive pulmonary disease (COPD), pulmonary infection, and level of dyspnea are provided below.

Severe COPD

Chronic obstructive pulmonary disease (such as emphysema and/or chronic bronchitis) resulting in any one or more of the following: functional disability from COPD (e.g., dyspnea, inability to perform activities of daily living), hospitalization in the past for treatment of COPD, chronic bronchodilator therapy requirement with oral or inhaled agents, or a forced expiratory volume in 1 second (FEV1) of <75% of predicted on pulmonary function testing. The following conditions are not included in definition for severe COPD: patients whose only pulmonary disease is asthma, an acute and chronic inflammatory disease of the airways resulting in bronchospasm, and patients with diffuse interstitial fibrosis or sarcoidosis.

Pulmonary Infection

Patients with pneumonia must meet criteria from both Radiology and Signs/Symptoms/Laboratory sections listed below.

Radiology

One definitive chest radiological examination (x-ray or CT) with at least one of the following: new or progressive and persistent infiltrate, consolidation, opacity, or cavitation. Note in patients with underlying pulmonary or cardiac disease (e.g., respiratory distress syndrome, bronchopulmonary dysplasia, pulmonary edema, or chronic obstructive pulmonary disease), 2 or more serial chest radiological examinations (x-ray or CT) are required.

Signs/Symptoms/Laboratory

For any patient, at least one of the following: fever (>380°C or >100.40°F) with no other recognized cause, as well as leukopenia (<4000 WBC/mm^3) or leukocytosis (>12,000 WBC/mm^3). For adults >70 years old, altered mental status with no other recognized cause and at least one of the following: 5% bronchoalveolar lavage (BAL)–obtained cells contain intracellular bacteria on direct microscopic exam (e.g., Gram stain), positive growth in blood culture not related to another source of infection, positive growth in culture of pleural fluid, positive quantitative culture from minimally contaminated lower respiratory tract specimen (e.g., BAL or protected specimen brushing), or at least 2 of the following: new onset of purulent sputum, or change in character of sputum, or increased respiratory secretions, or increased suctioning requirements, new onset or worsening cough, or dyspnea, or tachypnea, rales or bronchial breath sounds, or worsening gas exchange (e.g., O_2 desaturations [e.g., $Pa{O_2}/F{I}{O_2} < 240$], increased oxygen requirements, or increased ventilator demand).

Dyspnea Level

The patient describes difficult, painful, or labored breathing. Dyspnea may be symptomatic of numerous disorders that interfere with adequate ventilation or perfusion of the blood with oxygen. The dyspneic patient is subjectively aware of difficulty with breathing. The levels and definitions for dyspnea are as follows: no dyspnea, dyspnea upon moderate exertion (e.g., is unable to climb one flight of stairs without shortness of breath), and dyspnea at rest (e.g., cannot complete a sentence without needing to take a breath). The time frame is at the time the patient is being considered as a candidate for surgery (which should be no longer than 30 days before surgery).

REFERENCES

1. Nafiu OO, Ramachandran SK, Ackwerh R, Tremper KK, Campbell DA Jr, Stanley JC. Factors associated with and consequences of unplanned post-operative intubation in elderly vascular and general surgery patients. Eur J Anaesthesiol 2011;28:220–4
2. Manganas H, Lacasse Y, Bourgeois S, Perron J, Dagenais F, Maltais F. Postoperative outcome after coronary artery bypass grafting in chronic obstructive pulmonary disease. Can Respir J 2007;14:19–24
3. McAlister F, Khan N, Straus S, Papaioakim M, Fisher B, Majumdar S, Gajic O, Daniel M, Tomlinson G. Accuracy of the preoperative assessment is predicting pulmonary risk after nonthoracic surgery. Am J Resp Crit Care Med 2003;167:741–44
4. Panaretou V, Toufektzian L, Siafkia I, Kouroukli I, Sigala F, Vlachopoulos C, Katsaragakis S, Zografos G, Filis K. Postoperative pulmonary function after open abdominal aortic aneurysm repair in patients with COPD: epidural versus intravenous analgesia. Ann Vasc Surg 2012; 26:149–55
5. van Lier F, van der Geest P, Hoeks S, van Gestel Y, Hol J, Sin D, Stolker R, Poldermans D. Epidural analgesia is associated with improved health outcomes of surgical patients with COPD. Anesthesiology 2011;115:315–21
6. Rodgers A, Walker N, Schug S, McKee A, Kehlet H, van Zundert A, Sage D, Futter M, Saville G, Clark T, MacMahon S. Reduction of postoperative mortality and morbidity with epidural or spinal anaesthesia: results from overview of randomised trials. BMJ 2000;321:1493
7. Park WY, Thompson JS, Lee KK. Effect of epidural anesthesia and analgesia on perioperative outcome: a randomized, controlled Veterans Affairs cooperative study. Ann Surg 2001;234:560–9
8. Peyton P, Myles P, Silbert B, Rigg J, Jamrozik K, Parsons R. Perioperative epidural analgesia and outcome after major abdominal surgery in high risk patients. Anesth Analg 2003;96:548–54
9. Rigg J, Jamrozik K, Myles P, Silbert B, Peyton P, Parsons R, Collins K. Epidural anesthesia and analgesia and outcome of major surgery: a randomized trial. Lancet 2002;359:1276–82
10. Leslie K, Myles P, Devereaux P, Williamson E, Rao-Melancini P, Forbes A, Xu S, Foex P, Pogue J, Arrieta M, Bryson G, Paul J, Paech M, Merchant R, Choi P, Badner N, Peyton P, Sear J, Yang H. Neuraxial block, death and serious cardiovascular morbidity in the POISE trial. Br J Anaesth 2013;111:382–90
11. Daley J, Khuri SF, Henderson W, Hur K, Gibbs JO, Barbour G, Demakis J, Irvin G III, Stremple JF, Grover F, McDonald G, Passaro E Jr, Fabri PJ, Spencer J, Hammermeister K, Aust JB, Oprian C. Risk adjustment of the postoperative morbidity rate for the comparative assessment of the quality of surgical care: results of the National Veterans Affairs Surgical Risk Study. J Am Coll Surg 1997;185:328–40
12. Khuri S, Henderson W, Daley J, Jonasson O, Jones R, Campbell D, Fink A, Mentzer R, Steeger J. The patient safety in surgery study: background, study design and patient populations. J Am Coll Surg 2007;204:1089–1102
13. The American College of Surgeons. American College of Surgeons National Surgical Quality Improvement Program: User Guide for the Participants Use Data File, April 1, 2009 ed. American College of Surgeons, 2007, pp 4-1 to 4-31
14. Schwartz LM, Woloshin S, Welch HG. Misunderstandings about the effects of race on sex and physicians' referrals for cardiac catheterization. N Engl J Med 1999;341:179–83
15. Grosse-Sundrup M, Henneman JP, Sandberg WS, Bateman BT, Uribe JV, Nguyen NT, Ehrenfeld JM, Martinez EA, Kurth T, Eikermann M. Intermediate acting non-depolarizing neuromuscular blocking agents and risk of postoperative respiratory complications: prospective propensity score matched cohort study. BMJ 2012;345:e6329
16. Bruells CS, Rossaint R. Physiology of gas exchange during anaesthesia. Eur J Anaesthesiol 2011;28:570–9