Anesthesia Technique, Mortality, and Length of Stay After Hip Fracture Surgery

Mark D. Neuman, MD, MSc; Paul R. Rosenbaum, PhD; Justin M. Ludwig, MA; Jose R. Zubizarreta, PhD; Jeffrey H. Silber, MD, PhD

IMPORTANCE More than 300 000 hip fractures occur each year in the United States. Recent practice guidelines have advocated greater use of regional anesthesia for hip fracture surgery.

OBJECTIVE To test the association of regional (ie, spinal or epidural) anesthesia vs general anesthesia with 30-day mortality and hospital length of stay after hip fracture.

DESIGN, SETTING, AND PATIENTS We conducted a matched retrospective cohort study involving patients 50 years or older who were undergoing surgery for hip fracture at general acute care hospitals in New York State between July 1, 2004, and December 31, 2011. Our main analysis was a near-far instrumental variable match that paired patients who lived at different distances from hospitals that specialized in regional or general anesthesia. Supplementary analyses included a within-hospital match that paired patients within the same hospital and an across-hospital match that paired patients at different hospitals.

EXPOSURES Spinal or epidural anesthesia; general anesthesia.

MAIN OUTCOMES AND MEASURES Thirty-day mortality and hospital length of stay. Because the distribution of length of stay had long tails, we characterized this outcome using the Huber M estimate with Huber weights, a robust estimator similar to a trimmed mean.

RESULTS Of 56 729 patients, 15 904 (28%) received regional anesthesia and 40 825 (72%) received general anesthesia. Overall, 3032 patients (5.3%) died. The M estimate of the length of stay was 6.2 days (95% CI, 6.2 to 6.2). The near-far matched analysis showed no significant difference in 30-day mortality by anesthesia type among the 21 514 patients included in this match: 583 of 10 757 matched patients (5.4%) who lived near a regional anesthesia–specialized hospital died vs 629 of 10 757 matched patients (5.8%) who lived near a general anesthesia–specialized hospital (instrumental variable estimate of risk difference, −1.1%; 95% CI, −2.8 to 0.5; *P* = .20). Supplementary analyses of within and across hospital patient matches yielded mortality findings to be similar to the main analysis. In the near-far match, regional anesthesia was associated with a 0.6-day shorter length of stay than general anesthesia (95% CI, −0.8 to −0.4, *P* < .001). Supplementary analyses also showed regional anesthesia to be associated with shorter length of stay, although the observed association was smaller in magnitude than in the main analysis.

CONCLUSIONS AND RELEVANCE Among adults in acute care hospitals in New York State undergoing hip repair, the use of regional anesthesia compared with general anesthesia was not associated with lower 30-day mortality but was associated with a modestly shorter length of stay. These findings do not support a mortality benefit for regional anesthesia in this setting.

Supplemental content at jama.com

Author Affiliations: Author affiliations are listed at the end of this article.

Corresponding Author: Mark D. Neuman, MD, MSc, Department of Anesthesiology and Critical Care, Perelman School of Medicine at the University of Pennsylvania, 1119 Blockley Hall, 423 Guardian Dr, Philadelphia, PA 19104 (neumanm @mail.med.upenn.edu).

Each year, 300 000 hip fractures occur in the United States,[1,2] leading to functional disability[3] and mortality.[2] Regional anesthesia for hip fracture surgery via spinal or epidural blockade plus sedation may reduce postoperative complications,[4-6] and practice guidelines have called for broader use of regional anesthesia for hip fracture surgery.[7-9]

Most studies assessing the relationship between anesthesia technique and outcomes are observational and not prospective. Recent observational studies regarding the association of anesthesia technique with hip fracture outcomes have shown conflicting results.[6,10-13] Typically, clinicians select the anesthesia technique based on their practice style and a variety of patient-related factors. For example, impaired coagulation is a contraindication to spinal and epidural anesthesia.[14] Because it is believed there is less morbidity associated with regional anesthesia, patients with hip fracture receiving regional anesthesia tend to be older and sicker than those treated with general anesthesia.[13] Consequently, analyses of observational data may be limited because of the nonrandom selection of patients for one form of anesthesia or another. This limitation can potentially be addressed using instrumental variable analysis, which capitalizes on differences in practice patterns across providers or facilities to approximate the structure of a randomized trial within the setting of an observational study.[15]

We assessed the association of anesthesia technique with 30-day mortality and hospital length of stay among older adults undergoing hip fracture surgery in New York between 2004 and 2011. To go beyond prior observational studies, we used 2 statistical techniques intended to address selection bias, multivariable matching, and instrumental variable analysis. We hypothesized that regional anesthesia would be associated with improved outcomes compared with general anesthesia.

Methods

Data Sources

We obtained data on acute care hospital discharges between January 1, 2004, and December 31, 2011, from New York's Statewide Planning and Research Cooperative System (SPARCS). Our data set included unique patient identifiers and indicators of 30-day mortality. We obtained hospital characteristics data from the 2006 American Hospital Association Survey and data on zip code area characteristics from census files. The study was approved by the Perelman School of Medicine institutional review board, which waived the requirement for participant informed consent.

Population

Our starting population included adults 50 years or older hospitalized with a hip fracture and a principal procedure of open reduction, internal fixation, hemiarthroplasty, or total hip arthroplasty, which were identified using *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) codes (eAppendix in the Supplement). We

used 50 years as an age cutoff because osteoporotic hip fractures are uncommon among those younger than this age. To allow for examination of hospital discharge data from the 180 days preceding the index admission, we studied hospitalizations between July 1, 2004, and December 31, 2011. For patients with multiple hip fracture admissions, the first admission was the index.

We excluded patients with diagnosis related group codes indicating multiple trauma and patients with secondary *ICD-9-CM* procedure codes indicating selected other surgeries (eAppendix in the Supplement). We excluded patients who had missing data, who received local anesthesia, who were transferred from another hospital, and who lived outside New York.

Outcomes

Our primary outcome was death at 30 days after admission. Inpatient length of stay in days was our secondary outcome.

Exposure Variable

Hospitals voluntarily report data on anesthesia care to SPARCS. Anesthesia type is recorded as regional, general, local, other, or none. General anesthesia plus another type of anesthesia is coded as general anesthesia. Of 195 hospitals reporting hip fracture discharges over the study period, 36 did not report any data on anesthesia type.

Key Covariates

Data from SPARCS included age, sex, fracture location, surgical procedure, nursing facility residence, and 18 comorbidities identified by *ICD-9-CM* codes[16-18] and present-on-admission indicators for the index admission and hospitalizations in the preceding 180 days. As a proxy for factors related to Medicaid eligibility, we collected data on Medicaid insurance status. Because hip fracture care[18] and outcomes[19] may differ for black and white patients, we obtained data on patient race, which we coded as white, black, or other. We collected census data on the median income of each patient's residential zip code, the percentage of residents completing high school or some college, and the percentage below the poverty line. We obtained data from the American Hospital Association survey on hospital bed size, nurse to bed ratio, nurse skill mix (registered nurses plus licensed practical nurses out of all nurses), teaching status, and level I trauma center status.

Near-Far Matching

Prior observational studies of anesthesia for hip fracture have used regression to adjust for observed differences between patients. However, these methods cannot adjust for unobserved factors that may influence anesthesia care, such as illness severity, cognitive impairment, or fracture displacement.

To address this issue, our primary analysis used near-far matching, a matched-pair instrumental variable study design.[20-22] Use of regional anesthesia varies across hospitals.[11] Because patients seek care for hip fractures at hospitals near their homes, someone who lives closer to a hospital where re-

gional anesthesia is used heavily may be more likely to receive regional anesthesia for hip fracture surgery than someone who lives closer to a hospital where regional anesthesia is avoided. After matching for observed patient factors, proximity to a hospital that often uses regional anesthesia is an instrumental variable if it affects outcomes only by promoting use of regional anesthesia (the so-called exclusion restriction) and if proximity is otherwise unrelated to unmeasured risk factors conditionally given measured risk factors.[23] An instrumental variable estimate, such as the Wald estimate, attributes effects of proximity to the greater use of regional anesthesia at some hospitals.[23]

Our instrumental variable was the difference between the linear distance from each patient's residence to the nearest in-state hospital that specialized in general anesthesia and the distance from each patient's residence to the nearest in-state hospital that specialized in regional anesthesia. We classified hospitals as specializing in regional or general anesthesia based on the percentage of their patients with a hip fracture who received regional anesthesia over the full study period. Because the median rate of regional anesthesia across all hospitals was one-third, this value was our cutoff for specialization toward regional vs general anesthesia. Out of 159 hospitals that reported anesthesia data to SPARCS, we classified 63 as regional anesthesia-specialized and 96 as general anesthesia-specialized. Characteristics of study hospitals appear in eTable 1 in the Supplement. Because we lacked patient addresses, distances were calculated from the center of each patient's residential zip code area.

We paired each patient who lived relatively closer to a regional anesthesia–specialized hospital to a similar patient who lived relatively closer to a general anesthesia-specialized hospital. We matched pairs exactly for sex, fracture type, procedure type, procedure year, and chronic lung disease. We used fine balance[24] (a method of constraining 2 groups to be balanced on a particular variable without restricting matching on the variable within individual pairs) for comorbidities, race, Medicaid eligibility, nursing home residence, and hospital trauma center and teaching status. We paired patients who were most similar in terms of measured covariates. Specifically, we minimized the total over pairs of the within-pair distances on covariates. We used the Mahalanobis distance,[25,26] which is the difference in covariate values for patients living near regional anesthesia and patients living near general anesthesia, divided by the covariate's standard deviation, this quantity squared, summed over the various covariates, with an allowance for correlation among the covariates.

Our distance incorporated all study variables and penalized large distances on a propensity score that we estimated with logit regression using the same variables to predict the likelihood of living closer to a regional anesthesia than to general anesthesia. We used optimal subset matching[27] to avoid individually poor matches. Optimal subset matching solves an optimization problem to pick the most similar individuals from treated and control groups, omitting treated subjects without similar control and controls without similar treated subjects. To ensure that paired individuals differed meaning-

fully in terms of the instrumental variable,[20,28] we excluded all patients who resided in zip codes where the absolute value of the instrumental variable was less than 2 miles. Within pairs, we required individual patients to differ by at least 15 miles in their relative proximity to hospitals specializing in regional vs general anesthesia.

Data Analysis

To assess the quality of our match, we used standardized differences, which we calculated for a given variable by dividing the mean difference between matched patients by the pooled standard deviation before matching.[29-31] We used a benchmark of 0.10, or one-tenth of a standard deviation, as a maximum acceptable standardized difference.[29-32]

We first present an unadjusted, unmatched comparison of mortality and length of stay according to anesthesia type among patients who received regional vs general anesthesia. Next, we present the appropriate analysis that controls for measured and unmeasured patient-level confounders through our near-far matched analysis. This analysis used instrumental variable methods to rescale any differences in outcomes between matched patients to account for the difference in rates of actual treatment with regional anesthesia across groups.[23] Without use of an instrumental variable estimator, our near-far comparison would estimate the effect of living near a hospital that often uses regional anesthesia, not the effect of actually receiving regional anesthesia. The instrumental variable estimate is a consequence of attributing to use of regional anesthesia any benefit or harm associated with living near a hospital that often uses regional anesthesia.

We also present 2 supplementary analyses. A within-hospital match-paired patients who received regional and general anesthesia within the same hospital as a means of accounting for potential differences between facilities specializing in one or another type of anesthesia. An across-hospital match used standard propensity-score methods to pair patients who received regional and general anesthesia across different hospitals. Details of these matches appear in the eAppendix in the Supplement. Outcomes were examined only after matching was completed.[33] An overview of our study design appears in **Figure 1**.

We tested for differences in 30-day mortality using the McNemar test for matched pairs and the χ^2 statistic for the unmatched comparison. As an outcome, length of stay had long tails, so we used the Huber M estimate with Huber weights,[34-36] the standard robust estimator similar to a trimmed mean, to estimate the length of stay within each group and the within-pair difference in length of stay. We used its permutation distribution to obtain confidence intervals for instrumental variable estimates by the standard pivotal method[20,37] applied to this permutation distribution.[37] For binary outcomes, the pivotal method reports an instrumental variable confidence interval that excludes the null hypothesis of no effect only if the McNemar test rejects no effect when testing the effect of living near a regional hospital.[20]

All hypothesis tests were 2-sided. We used a significance threshold of $P < .05$. We conducted sensitivity analyses for all significant findings to assess the magnitude of

Figure 1. Overview of Study Design, Showing the Near-Far Match, the Across-Hospital Match, and the Unadjusted, Unmatched Comparison
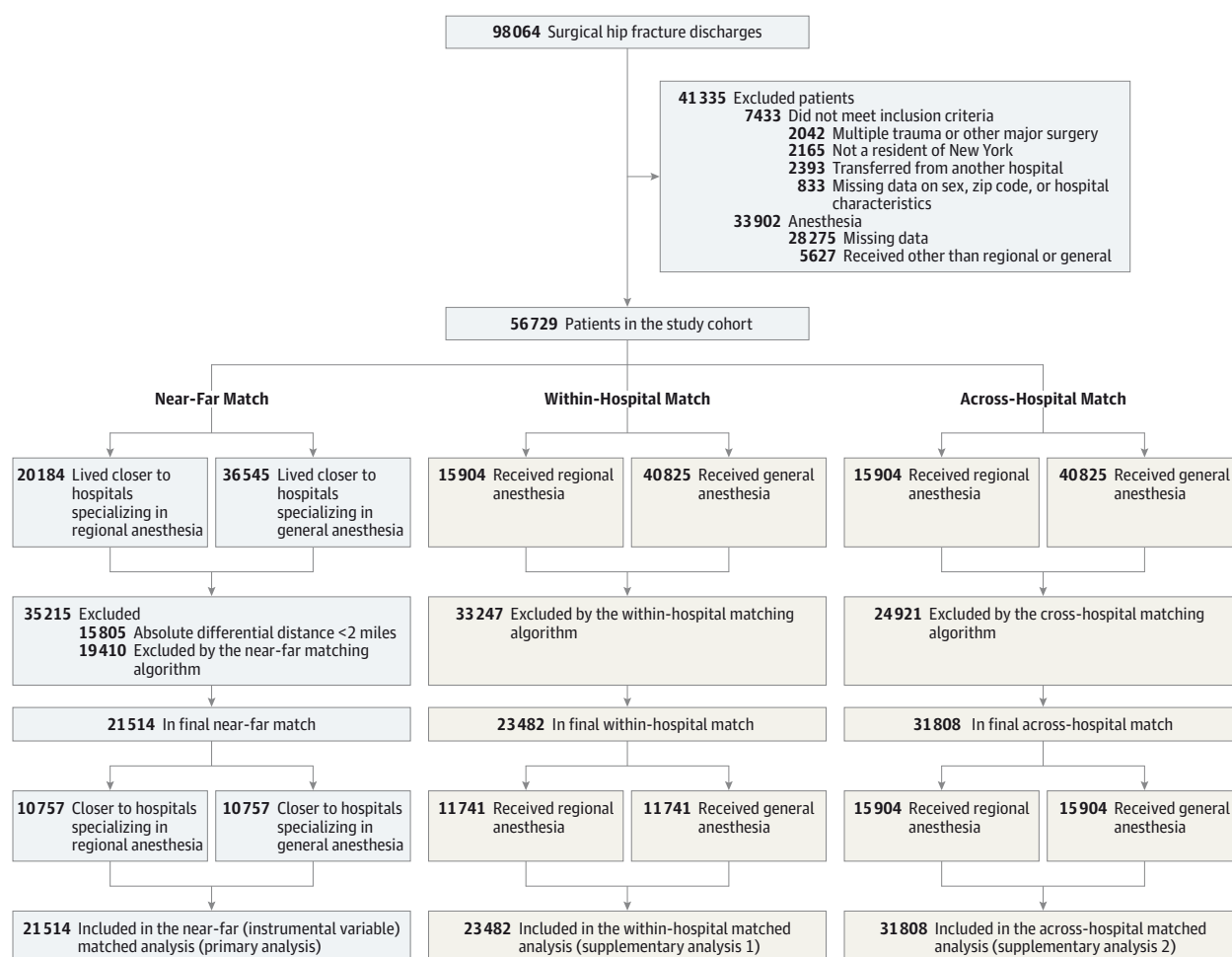
Our study incorporated 3 matched comparisons. The primary analysis was a "near-far" instrumental variable match that included 10 757 pairs of patients who differed in terms of their residential proximity to hospitals specializing in regional or general anesthesia for hip fracture but were similar in terms of all other observable characteristics. Supplementary analyses included a within-hospital match that paired patients receiving regional vs general anesthesia within the same hospital and an across-hospital match that paired patients receiving regional vs general anesthesia across different hospitals.

bias from unmeasured confounders that would need to be present to alter our conclusions.[38,39] Analyses were conducted by *R 2.13.1* (R Foundation) and SAS software version 9.3 (SAS Institute Inc), using the R *mipmatch* package[40] and the SAS PROC ASSIGN function.

Results

Unadjusted, Unmatched Comparison
After exclusions (Figure 1), our study cohort included 56 729 patients; 28 275 patients were excluded due to missing anesthesia data (eTable 2 in the Supplement). Compared with patients with available anesthesia data, patients with missing data were more likely to have come from an area with lower educational attainment and greater poverty, to be of black race, to be covered by Medicaid, and to be treated in a trauma center.

Among patients with available anesthesia data, 28% received regional anesthesia (n = 15 904) and 72% received general anesthesia (n = 40 825). Compared with patients receiving general anesthesia, those receiving regional anesthesia were older, more often had chronic lung disease, resided in areas with higher incomes, and were treated in hospitals that were smaller, had less skilled nursing staffs, and were not teaching hospitals or trauma centers (**Table 1**). Overall, 3032 patients died, for a mortality rate of 5.3%. The M estimate of the length of stay (a robust measure of location similar to a trimmed mean[34-36]) was 6.2 days (95% CI, 6.2-6.2).

Thirty-day mortality for regional anesthesia was 5.3% and 5.4% for general anesthesia (difference, −0.1%; 95% CI, −0.5 to 0.3; *P* = .55); regional anesthesia was associated with a shorter unadjusted length-of-stay of 6 days (95% CI, 6.0 to 6.1) vs 6.3 days with general anesthesia (95% CI, 6.2 to 6.3). The difference in length of stay for regional vs general anesthesia was −0.2 days (95% CI, −0.3 to −0.2; *P* < .001).

Near-Far Match

Our near-far match comprised 10 757 pairs of patients drawn from across New York State (**Figure 2**) that were similar in terms of observable factors. Selected variables used in the match appear in **Table 2**; detailed results appear in eTable 3 in the Supplement. Differential distance was strongly associated with the type of anesthesia received: 53.5% of patients who lived closer to a hospital that specialized in regional anesthesia received it whereas 16.1% of those who lived closer to a hospital that specialized

Table 1. Baseline Characteristics of Patients Receiving Regional and General Anesthesia for Hip Fracture Surgery[a]

|	No. (%) of Patients Receiving Anesthesia		Absolute Standardized Difference[b]	P Value
	Regional (n = 15 904)	General (n = 40 825)		
Demographics, nursing home residence, and Medicaid coverage				
Age, mean (SD), y	82.2 (9.5)	81.1 (10.1)	0.11	<.001
Women	4059 (74.5)	10 686 (73.8)	0.01	.11
Race				
White	14 235 (89.5)	35 945 (88.1)	0.05	<.001
Black	399 (2.5)	1433 (3.5)	0.06	<.001
Other	1270 (8.0)	3447 (8.4)	0.02	<.001
Nursing home resident	617 (3.9)	1517 (3.7)	<0.01	.36
Medicaid eligible	2536 (16.0)	6900 (16.9)	0.03	.006
Common comorbidities, present in more than 3% of the study population				
Dementia	4060 (25.5)	10 411 (25.5)	<0.01	.95
Prior stroke	1116 (7.0)	2989 (7.3)	0.01	.21
Congestive heart failure	2546 (16.0)	6770 (16.6)	0.02	.10
Myocardial infarction	957 (6.0)	2301 (5.7)	0.02	.100
Past cardiac arrhythmia	3392 (21.3)	9237 (22.6)	0.03	<.001
Cardiac valvular disease	1861 (11.7)	5336 (13.1)	0.04	<.001
Hypertension	10 500 (66.0)	27 521 (67.4)	0.03	.002
Chronic lung disease	3206 (20.2)	6443 (15.8)	0.11	<.001
Renal failure	127 (7.0)	485 (8.2)	0.05	<.001
Diabetes mellitus	3218 (20.2)	8810 (21.6)	0.03	<.001
Electrolyte abnormality	2771 (17.4)	7298 (17.9)	0.01	.21
Thrombocytopenia	396 (2.5)	1383 (3.4)	0.05	<.001
Cancer	2117 (13.3)	5032 (12.3)	0.03	.002
Fracture type				
Femoral neck	7647 (48.1)	19 157 (46.9)	0.02	.95
Intertrochanteric	7312 (46.0)	18 919 (46.3)	<0.01	.44
Subtrochanteric	617 (3.9)	1698 (4.7)	0.04	<.001
≥2	328 (2.1)	838 (2.1)	<0.01	.01
Procedure				
Total hip arthroplasty	596 (3.8)	1698 (4.2)	0.02	.03
Hemiarthroplasty	5394 (33.9)	13 184 (32.3)	0.03	<.001
Internal fixation	9914 (62.3)	25 943 (63.6)	0.02	.008
Residential zip code area characteristics, mean (SD)				
Median income, $	53 802 (22 512)	50 746 (19 770)	0.14	<.001
Below poverty, %	11.0 (7.8)	11.2 (8.6)	0.03	.06
Completing college, %	29.6 (16.7)	28.4 (14.9)	0.08	.01
Completing high school, %	82.7 (9.4)	82.6 (9.4)	0.02	.72
Hospital characteristics, mean (SD)				
No. of beds	381 (376)	524 (422)	0.35	<.001
Nurse skill mix[c]	90.7 (7.2)	91.7 (7.2)	0.13	<.001
Nurse to bed ratio[d]	1.56 (0.4)	1.55 (0.5)	0.03	<.001
Teaching hospital, %	3720 (23.4)	13 939 (34.1)	0.24	<.001
Trauma center, %	2264 (14.2)	7239 (17.7)	0.10	<.001

[a] Data are unadjusted. Selected variables shown; additional results appear in the Appendix.

[b] The standardized difference for each variable is the mean difference between patients in each group as a fraction of the pooled standard deviation across both groups.

[c] Nurse skill mix equals the total number of full-time-employee registered nurses and licensed practical nurses divided by total number of full-time employee nurses.

[d] Nurse to bed ratio calculated as total number of full-time employee nurses divided by total number of hospital beds.

Figure 2. Geographic Distribution of Patients Included in the Near-Far Matched Sample
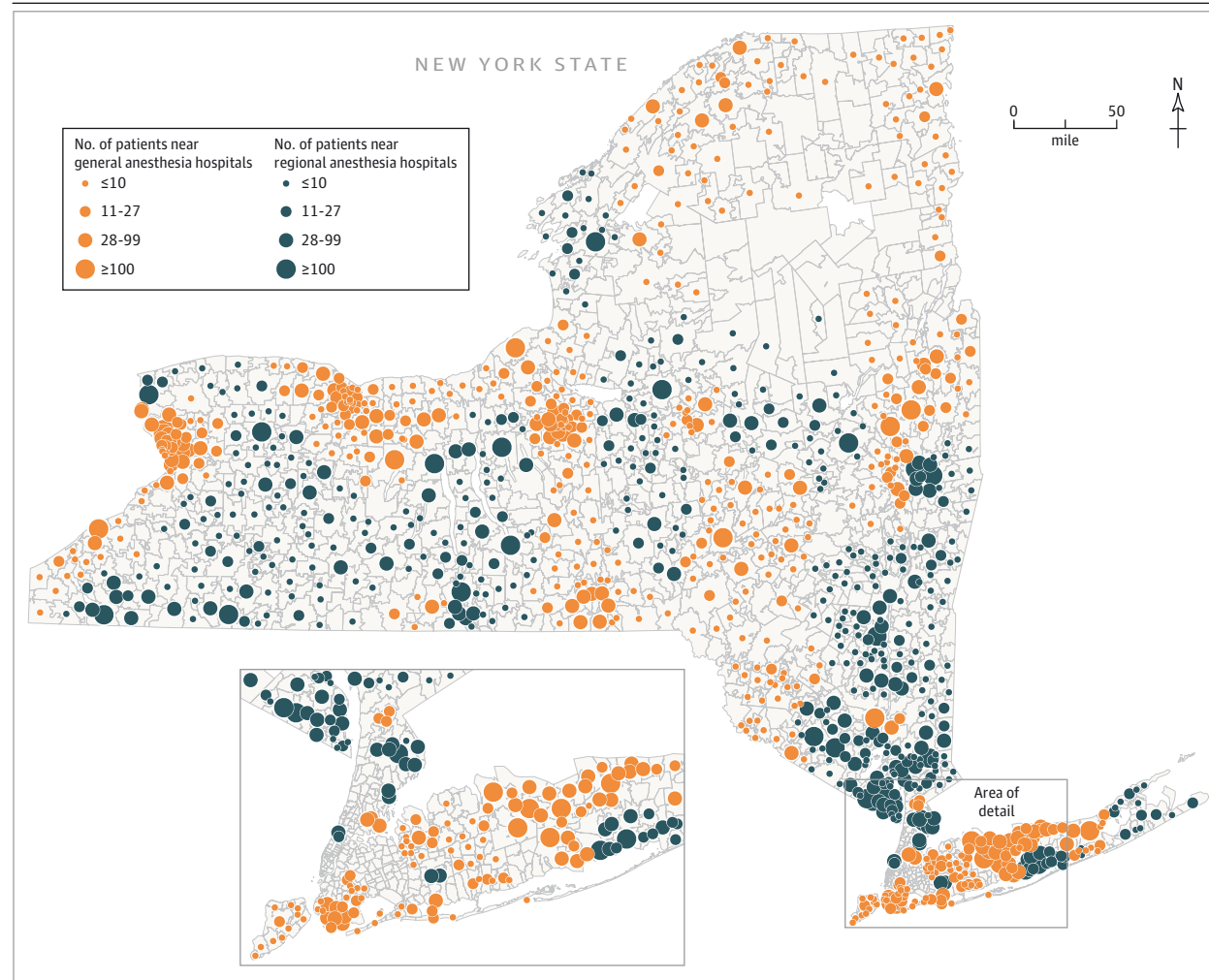
Orange circles correspond to patients residing in areas located relatively closer to hospitals that specialized in general anesthesia; blue circles correspond to patients residing in areas located relatively closer to hospitals that specialized in regional anesthesia. The interior borders represent zip code area boundaries.

in general anesthesia received regional anesthesia ($P < .001$).

Before matching, unadjusted 30-day mortality was 5.7% (790 of 13 842) among patients living closer to hospitals that specialized in regional anesthesia vs 5.6% (1527 of 27 082) among those living closer to hospitals that specialized in general anesthesia ($P = .79$). After matching, mortality was 5.4% among patients living closer to hospitals that specialized in regional anesthesia vs 5.8% among those living closer to hospitals that specialized in general anesthesia, for a difference of −0.4% (95% CI, −1.0 to 0.2; $P = .18$; Table 3). In the instrumental variable analysis, we did not observe a statistically significant association between anesthesia type and mortality (absolute risk difference, regional vs anesthesia, −1.1%, 95% CI, −2.8% to 0.5%; $P = .18$).

The robust estimate of the length of stay among matched patients residing nearer to hospitals that specialized in regional anesthesia was 5.8 days (95% CI, 5.8 to 5.9) vs 6.1 days among patients residing closer to hospitals that

specialized in general anesthesia (95% CI, 6.2 to 6.2; difference, −0.3 days; 95% CI, −0.3 to −0.2; $P < .001$; Table 3). In instrumental variable analysis, regional anesthesia was associated with a 0.6-day shorter length of stay (95% CI, −0.8 to −0.4; $P < .001$).

Supplementary Analyses

Supplementary analyses were consistent with our near-far match (eTables 4 and 5 in the Supplement and Table 3). Thirty-day mortality was similar among patients receiving regional vs general anesthesia within the same hospital (regional, 5.2%; 95% CI, 4.8% to 5.6% vs general, 5.3% (95% CI, 4.9% to 5.7%; $P = .70$k), although mortality was lower among patients who received regional vs general anesthesia across different hospitals (regional, 5.3%; 95% CI, 4.9% to 5.6% vs general, 5.8%;95% CI, 5.4% to 6.2%; $P = .04$). Regional anesthesia was associated with shorter length of stay in the within-hospital match (difference, regional vs general, −0.2 days; 95% CI, −0.3 to −0.2; $P < .001$) and the

across-hospital match (difference, regional vs general, −0.3 days; 95% CI, −0.3 to −0.2; P < .001).

Sensitivity Analysis

Sensitivity analyses (eTables 6-9 in the Supplement) indicated that the length-of-stay findings from our near-far match would remain statistically significant in the presence of a confounder that increased the odds of both general anesthesia and a longer length of stay by 40%, suggesting that our length of stay findings would not be qualitatively changed by small biases from unmeasured confounders.

Table 2. Characteristics of Patients Included in the Near-Far Match[a]

| | No. (%) of Patients Receiving Anesthesia | | | |
	Near Regional Anesthesia (n = 10 757)	Near General Anesthesia (n = 10 757)	Absolute Standardized Difference[b]	P Value
Demographics, nursing home residence, and Medicaid coverage				
Age, mean (SD), y	81.3 (10.0)	81.2 (9.9)	0.02	.10
Women	2864 (73.4)	2864 (73.4)	<0.01	>.99
Race				
White	10 107 (94.0)	1 107 (94.0)	<0.01	>.99
Black	173 (1.6)	173 (1.6)	<0.01	>.99
Other	477 (4.4)	477 (4.4)	<0.01	>.99
Nursing home resident	449 (4.2)	449 (4.2)	<0.01	>.99
Medicaid eligible	1457 (13.5)	1457 (13.5)	<0.01	>.99
Common comorbidities, present in more than 3% of the study population				
Dementia	2862 (24.9)	2862 (24.9)	<0.01	>.99
Prior stroke	740 (6.9)	740 (6.9)	<0.01	>.99
Congestive heart failure	1680 (15.6)	1680 (15.6)	<0.01	>.99
Myocardial infarction	615 (5.7)	615 (5.7)	<0.01	>.99
Past cardiac arrhythmia	2359 (21.9)	2359 (21.9)	<0.01	>.99
Cardiac valvular disease	1391 (12.9)	1391 (12.9)	<0.01	>.99
Hypertension	7267 (67.6)	7267 (67.6)	<0.01	>.99
Chronic lung disease	2004 (18.6)	2004 (18.6)	<0.01	>.99
Renal failure	738 (6.9)	738 (6.9)	<0.01	>.99
Diabetes mellitus	2268 (21.1)	2268 (21.1)	<0.01	>.99
Electrolyte abnormality	1909 (17.8)	1909 (17.8)	<0.01	>.99
Thrombocytopenia	301 (2.8)	301 (2.8)	<0.01	>.99
Cancer	1377 (12.8)	1377 (12.8)	<0.01	>.99
Fracture type				
Femoral neck	5307 (49.3)	5307 (49.3)	<0.01	>.99
Intertrochanteric	4810 (44.7)	4810 (44.7)	<0.01	>.99
Subtrochanteric	442 (4.1)	442 (4.1)	<0.01	>.99
≥2	198 (1.8)	198 (1.8)	<0.01	>.99
Procedure				
Total hip arthroplasty	394 (3.7)	394 (3.7)	<0.01	>.99
Hemiarthroplasty	3721 (34.6)	3721 (34.6)	<0.01	>.99
Internal fixation	6642 (61.8)	6642 (61.8)	<0.01	>.99
Residential zip code area characteristics, mean (SD)				
Median income, $	49 523 (18 298)	50 263 (20 549)	0.04	.78
Below poverty, %	10.6 (5.9)	10.7 (7.6)	0.02	<.001
Completing college, %	25.6 (12.8)	25.7 (12.4)	0.02	.006
Completing high school, %	83.6 (6.3)	83.6 (8.0)	<0.01	<.001
Hospital characteristics				
No. of beds, mean (SD)	270 (200)	269 (167)	<0.01	<.001
Nurse skill mix, mean (SD)[c]	89.0 (7.4)	89.2 (8.7)	0.03	<.001
Nurse to bed ratio, mean (SD)[d]	1.5 (0.4)	1.5 (0.6)	0.01	.09
Teaching hospital, %	471 (8.6)	471 (8.6)	<0.01	>.99
Trauma center, %	925 (4.4)	925 (4.4)	<0.01	>.99

[a] Selected variables are shown; full match results are presented in the Appendix.

[b] The standardized difference for each variable is the mean difference between patients in each matched group as a fraction of the pooled standard deviation before matching..

[c] Nurse skill mix calculated as total number of full-time-employee registered nurses and licensed practical nurses divided by total number of full-time employee.

[d] Nurses to bed ratio calculated as total number of full-time employee nurses divided by total number of hospital beds.

Table 3. Study Outcomes for the Near-Far, Within-Hospital, and Across-Hospital Matches and the Unmatched, Unadjusted Comparison[a]

Comparison	Anesthesia Type[b]		Risk Difference (95% CI)	Difference in Days (95% CI)	P Value	Instrumental Variable Estimate,		P Value
	Regional Anesth	General				Risk Difference (95% CI)	Difference in Days (95% CI)	
Near-far, instrumental variable match								
No. of patients	10 757	10 757						
30-Day mortality, No. (%)	583 (5.4)	629 (5.8)	−0.4 (−1.0 to 0.2)		.18	−1.1 (−2.8 to 0.5)		.18
Hospital length of stay, estimate (95% CI), d[c]	5.8 (5.8 to 5.9)	6.1 (6.1 to 6.2)		−0.3 (−0.3 to −0.2)	< .001		−0.6 (−0.8 to −0.4)	< .001
Within hospital match								
No. of patients	11 741	11 741						
30-Day mortality, No. (%)	608 (5.2)	622 (5.3)	−0.1 (−0.7 to 0.4)		.70			
Hospital length of stay, estimate (95% CI), d[c]	6.1 (6.1 to 6.2)	6.3 (6.3 to 6.4)		−0.2 (−0.3 to −0.2)	< .001			
Across hospital match								
No. of patients	15 904	15 904						
30-Day mortality, No. (%)	835 (5.3)	920 (5.8)	−0.5 (−1.0 to −0.0)		.03			
Hospital length of stay, estimate (95% CI), d[c]	6.0 (6.0 to 6.1)	6.3 (6.3 to 6.4)		−0.3 (−0.3 to −0.2)	< .001			
Unadjusted, unmatched comparison								
No. of patients	15 904	40 825						
30-Day mortality, No. (%)	835 (5.3)	2197 (5.4)	−0.1 (−0.5 to 0.3)		.54			
Hospital length of stay, estimate (95% CI), d[c]	6.0 (6.0 to 6.1)	6.3 (6.2 to 6.3)		−0.2 (−0.3 to −0.2)	< .001			

[a] Data are shown on 30-d mortality and hospital length of stay with regional vs general anesthesia from 4 comparisons; please see Methods section for a description of individual comparisons. For the near-far match, we present instrumental variable estimates of the association of regional vs general anesthesia with mortality and length of stay. As is always true, the instrumental variable estimate is larger than the simple between-groups difference, reflecting the fact that only some additional patients received regional anesthesia by virtue of living near hospitals that used it more frequently.

[b] The near-far instrumental variable match compares patients living closer to hospitals specializing in regional anesthesia with patients living closer to hospitals specializing in general anesthesia. The within-hospital match, the across-hospital match, and the unmatched comparison compare patients who received regional anesthesia with patients who received general anesthesia.

[c] Cells show Huber's M-estimates and 95% confidence intervals for the length of stay among patients receiving regional vs general anesthesia and for the within-pair difference in the length of stay.

Discussion

Among 56 729 patients undergoing hip fracture surgery in New York between 2004 and 2011, we did not observe a statistically significant difference in mortality according to anesthesia technique. Nevertheless, we found regional anesthesia to be associated with hospital length of stay that was shorter by a half day for a representative patient. These findings came from an instrumental variable analysis that accounted for observed and unobserved differences between patients receiving regional vs general anesthesia; we obtained consistent results from supplementary analyses, including a match that paired similar patients who received regional vs general anesthesia within the same hospital.

Our work adds to previous research on anesthesia for hip fracture. A meta-analysis of 8 small trials published between 1978 and 1998 found equivocal evidence of lower mortality with regional vs general anesthesia and no difference in hospital length of stay.[4] The present study includes groups that were excluded from certain trials, such as patients with dementia[41,42] and those undergoing hemiarthroplasty or total hip arthroplasty.[43] Furthermore because our database extends through 2011, our findings may be more relevant than historical studies to current practice.

Observational studies by our group[11] and others[6,10] have been conflicted regarding the association of anesthesia technique with hip fracture outcomes, although the interpretation of these studies is limited by their lack of adjustment for potentially important confounders. In contrast to prior observational studies, our near-far analysis compared patients whose anesthesia care varied as a result of their residential proximity to specific types of hospitals instead of a process of clinical selection. This analysis not only adjusted for observed patient factors but also potentially addressed confounding due to unobserved differences among patients who received regional vs anesthesia. As such, our findings suggest an association between regional anesthesia and shorter length-of-stay, which could relate to reductions in complications[41,44-46] or more effective rehabilitation.[47]

Our study has limitations. We examined one state, and could not assess outcomes among patients with missing anesthesia data. The observational design of our study precludes causal conclusions because we cannot fully rule out the possibility of residual confounding. In particular, our main results could be explained by residual confounding if proximity to regional anesthesia is not a perfect instrument. If hospital specialization toward regional anesthesia were associated with other differences in quality, for example, the length-of-stay differences observed in the near-far analysis could reflect such quality differences rather than an effect of regional anesthesia per se. Nevertheless, our observation of consistent findings in our within-hospital match, which explicitly accounted for hospital-level factors, provides reassurance regarding the validity of our main results. Also, as general anesthesia–specialized hospitals in our near-far match had features commonly associated with *higher* quality, such as higher nurse-to-bed ratios and trauma center designation, we would expect such hospital-level differences to bias our findings toward the null hypothesis. Finally, because we lacked detailed intraoperative data, we could not examine the degree to which regional anesthesia outcomes might vary according to the type of block performed or the depth of sedation.[45,48]

Our findings may have implications for clinical practice and health policy. Regional anesthesia is used as the primary anesthetic technique in a minority of hip fracture surgeries performed in the United States and in other countries,[11,49] and increasing its use has been proposed as a strategy to improve the quality of hip fracture care.[7-9] We found an association between greater use of regional anesthesia and a reduction in length of stay after hip fracture; however, we did not find regional anesthesia to be associated with statistically significant differences in mortality.

Conclusions

Among adults in acute care hospitals in New York State undergoing hip repair, the use of regional anesthesia compared with general anesthesia was not associated with a lower 30-day mortality, but was associated with a modestly shorter length of stay. These findings do not support a mortality benefit for regional anesthesia in this setting.

REFERENCES

1. Blackman DK, Kamimoto LA, Smith SM. Overview: surveillance for selected public health indicators affecting older adults—United States. *MMWR CDC Surveill Summ*. 1999;48(8):1-6.

2. Brauer CA, Coca-Perraillon M, Cutler DM, Rosen AB. Incidence and mortality of hip fractures in the United States. *JAMA*. 2009;302(14):1573-1579.

3. Magaziner J, Hawkes W, Hebel JR, et al. Recovery from hip fracture in eight areas of function. *J Gerontol A Biol Sci Med Sci*. 2000;55(9):M498-M507.

4. Parker MJ, Handoll HH, Griffiths R. Anaesthesia for hip fracture surgery in adults. *Cochrane Database Syst Rev*. 2004;(4):CD000521.

5. UK National Clinical Guideline Centre. *The Management of Hip Fracture in Adults.* London, England: UK National Clinical Guideline Centre; 2011.

6. O'Hara DA, Duff A, Berlin JA, et al. The effect of anesthetic technique on postoperative outcomes in hip fracture repair. *Anesthesiology*. 2000;92(4):947-957.

7. Griffiths R, Alper J, Beckingsale A, et al; Association of Anaesthetists of Great Britain and Ireland. Management of proximal femoral fractures 2011: Association of Anaesthetists of Great Britain and Ireland. *Anaesthesia*. 2012;67(1):85-98.

8. Boulton C, Currie C, Griffiths R, et al. *National Hip Fracture Database: Anaesthesia Sprint Audit of Practice.* London, England: Royal College of Physicians; 2014.

9. Scottish Intercollegiate Guidelines Network. *Management of Hip Fracture in Older People.* Edinburgh, Scottland: Scottish Intercollegiate Guideline Network; 2009.

10. Radcliff TA, Henderson WG, Stoner TJ, Khuri SF, Dohm M, Hutt E. Patient risk factors, operative care, and outcomes among older community-dwelling male veterans with hip fracture. *J Bone Joint Surg Am*. 2008;90(1):34-42.

11. Neuman MD, Silber JH, Elkassabany NM, Ludwig JM, Fleisher LA. Comparative effectiveness of regional versus general anesthesia for hip fracture surgery in adults. *Anesthesiology*. 2012;117(1):72-92.

12. Regan EA, Radcliff TA, Henderson WG, et al. Improving hip fractures outcomes for COPD patients. *COPD*. 2013;10(1):11-19.

13. White SM, Moppett IK, Griffiths R. Outcome by mode of anaesthesia for hip fracture surgery. An observational audit of 65 535 patients in a national dataset. *Anaesthesia*. 2014;69(3):224-230.

14. Horlocker TT, Wedel DJ, Rowlingson JC, et al. Regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy: American Society of Regional Anesthesia and Pain Medicine Evidence-Based Guidelines (Third Edition). *Reg Anesth Pain Med*. 2010;35(1):64-101.

15. Sheffield KM, Riall TS, Han Y, Kuo YF, Townsend CM Jr, Goodwin JS. Association between cholecystectomy with vs without intraoperative cholangiography and risk of common duct injury. *JAMA*. 2013;310(8):812-820.

16. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998;36(1):8-27.

17. Silber JH, Romano PS, Rosen AK, Wang Y, Even-Shoshan O, Volpp KG. Failure-to-rescue: comparing definitions to measure quality of care. *Med Care*. 2007;45(10):918-925.

18. Neuman MD, Fleisher LA, Even-Shoshan O, Mi L, Silber JH. Nonoperative care for hip fracture in the elderly: the influence of race, income, and comorbidities. *Med Care*. 2010;48(4):314-320.

19. Polsky D, Jha AK, Lave J, et al. Short- and long-term mortality after an acute illness for elderly whites and blacks. *Health Serv Res*. 2008;43(4):1388-1402.

20. Baiocchi M, Small DS, Lorch S, Rosenbaum PR. Building a stronger instrument in an observational study of perinatal care for premature infants. *J Am Stat Assoc*. 2010;105(492):1285-1296.

21. Baiocchi M, Small DS, Yang L, Polsky D, Groeneveld PW. Near/far matching: a study design approach to instrumental variables. *Health Serv Outcomes Res Methodol*. 2012;12:237-253.

22. Lorch SA, Baiocchi M, Ahlberg CE, Small DS. The differential impact of delivery hospital on the outcomes of premature infants. *Pediatrics*. 2012;130(2):270-278.

23. Angrist JD, Imbens GW, Rubin DB. Identification of causal effects using instrumental variables. *J Am Stat Assoc*. 1996;91(434):444-455.

24. Rosenbaum PR, Ross RN, Silber JH. Minimum distance matched sampling with fine balance in an observational study of treatment for ovarian cancer. *J Am Stat Assoc*. 2007;102(477):75-83.

25. Mahalanobis P. On the generalised distance in statistics. *Proc Nat Inst Sci India*. 1936;2(1):49-55.

26. Rubin DB. Bias reduction using mahalanobis-metric matching. *Biometrics*. 1980;36(2):293-298.

27. Rosenbaum PR. Optimal matching of an optimally chosen subset in observational studies. *J Comput Graph Stat*. 2012;21(1):57-71.

28. Small DS, Rosenbaum PR. War and wages: the strength of instrumental variables and their

sensitivity to unobserved biases. *J Am Stat Assoc*. 2008;103(483):924-933.

29. Silber JH, Rosenbaum PR, Trudeau ME, et al. Multivariate matching and bias reduction in the surgical outcomes study. *Med Care*. 2001;39(10):1048-1064.

30. Rosenbaum PR, Rubin DB. Constructing a control-group using multivariate matched sampling methods that incorporate the propensity score. *Am Stat*. 1985;39(1):33-38.

31. Cochran WG, Rubin DB. Controlling bias in observational studies. *Sankhya-Indian J Stat Ser A*. 1973;35(Dec):417-446.

32. Rosenbaum PR. *Design of Observational Studies.* New York, NY: Springer; 2010.

33. Rubin DB. The design versus the analysis of observational studies for causal effects: parallels with the design of randomized trials. *Stat Med*. 2007;26(1):20-36.

34. Huber PJ. *Robust Statistics.* New York, NY: John Wiley; 1981.

35. Huber PJ. Robust estimation of location parameter. *Ann Math Stat*. 1964;35(1):73-101.

36. Maritz JS. *Distribution-Free Statistical Methods.* London, England: Chapman & Hall; 1995.

37. Imbens GW, Rosenbaum PR. Robust, accurate confidence intervals with a weak instrument: quarter of birth and education. *J R Stat Soc Ser A Stat Soc*. 2005;168:109-126.

38. Rosenbaum PR. Sensitivity analysis for M-estimates, tests, and confidence intervals in matched observational studies. *Biometrics*. 2007;63(2):456-464.

39. Rosenbaum PR, Silber JH. Amplification of sensitivity analysis in matched observational studies. *J Am Stat Assoc*. 2009;104(488):1398-1405.

40. Zubizarreta JR. Using mixed integer programming for matching in an observational study of kidney failure after surgery. *J Am Stat Assoc*. 2012;107(500):1360-1371.

41. Berggren D, Gustafson Y, Eriksson B, et al. Postoperative confusion after anesthesia in elderly

patients with femoral neck fractures. *Anesth Analg*. 1987;66(6):497-504.

42. Valentin N, Lomholt B, Jensen JS, Hejgaard N, Kreiner S. Spinal or general anaesthesia for surgery of the fractured hip? a prospective study of mortality in 578 patients. *Br J Anaesth*. 1986;58(3):284-291.

43. Davis FM, McDermott E, Hickton C, et al. Influence of spinal and general anaesthesia on haemostasis during total hip arthroplasty. *Br J Anaesth*. 1987;59(5):561-571.

44. Scheinin H, Virtanen T, Kentala E, et al. Epidural infusion of bupivacaine and fentanyl reduces perioperative myocardial ischaemia in elderly patients with hip fracture—a randomized controlled trial. *Acta Anaesthesiol Scand*. 2000;44(9):1061-1070.

45. Sieber FE, Zakriya KJ, Gottschalk A, et al. Sedation depth during spinal anesthesia and the development of postoperative delirium in elderly patients undergoing hip fracture repair. *Mayo Clin Proc*. 2010;85(1):18-26.

46. Lee HB, Mears SC, Rosenberg PB, Leoutsakos JM, Gottschalk A, Sieber FE. Predisposing factors for postoperative delirium after hip fracture repair in individuals with and without dementia. *J Am Geriatr Soc*. 2011;59(12):2306-2313.

47. Foss NB, Kristensen MT, Kristensen BB, Jensen PS, Kehlet H. Effect of postoperative epidural analgesia on rehabilitation and pain after hip fracture surgery: a randomized, double-blind, placebo-controlled trial. *Anesthesiology*. 2005;102(6):1197-1204.

48. Sieber FE, Gottshalk A, Zakriya KJ, Mears SC, Lee H. General anesthesia occurs frequently in elderly patients during propofol-based sedation and spinal anesthesia. *J Clin Anesth*. 2010;22(3):179-183.

49. White SM, Griffiths R, Holloway J, Shannon A. Anaesthesia for proximal femoral fracture in the UK: first report from the NHS Hip Fracture Anaesthesia Network. *Anaesthesia*. 2010;65(3):243-248.