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Anesthesiologist Direction and Patient Outcomes

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Background: **Anesthesia services for surgical procedures may or may not be personally performed or medically directed by anesthesiologists. This study compares the outcomes of surgical patients whose anesthesia care was personally performed or medically directed by an anesthesiologist with the outcomes of patients whose anesthesia care was not personally performed or medically directed by an anesthesiologist.**

Methods: **Cases were defined as being either "directed" or "undirected," depending on the type of involvement of the anesthesiologist, as determined by Health Care Financing Administration billing records. Outcome rates were adjusted to account for severity of disease and other provider characteristics using logistic regression models that included 64 patient and 42 procedure covariates, plus an additional 11 hospital characteristics often associated with quality of care. Medicare claims records were analyzed for all elderly patients in Pennsylvania who underwent general surgical or orthopedic procedures between 1991–1994. The study involved 194,430 directed and 23,010 undirected patients among 245 hospitals. Outcomes studied included death rate within 30 days of admission, in-hospital complication rate, and the failure-to-rescue rate (defined as the rate of death after complications).**

Results: **Adjusted odds ratios for death and failure-to-rescue were greater when care was not directed by anesthesiologists (odds ratio for death = 1.08, P < 0.04; odds ratio for failure-to-rescue = 1.10, *P* < 0.01), whereas complications were not increased (odds ratio for complication = 1.00, *P* < 0.79). This corresponds to 2.5 excess deaths/1,000 patients and 6.9 excess failures-to-rescue (deaths) per 1,000 patients with complications.**

Conclusions: **Both 30-day mortality rate and mortality rate after complications (failure-to-rescue) were lower when anesthesiologists directed anesthesia care. These results suggest that surgical outcomes in Medicare patients are associated with anesthesiologist direction, and may provide insight regarding potential approaches for improving surgical outcomes. (Key words: Anesthesiologists; anesthesia care team; quality of care; mortality; failure-to-rescue; complication; Medicare; general surgery; orthopedics.)**

AS hospitals and physicians adapt to new financial challenges, the mix of healthcare providers has been changing. Throughout the healthcare system, there are examples of work traditionally performed by specialists that is now allocated to generalists or nonphysicians. Many of the decisions regarding provider mix have been driven by financial considerations or provider availability, rather than by patient outcome data, which would be valuable for such decision-making. There are limited outcome data regarding provider models in specific ar-

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eas, such as adult primary care office practice.[1] However, generalizations among specialties and provider types may not be valid because of differences in the intensity of the care rendered, the severity of illness of the patient, or the extent of the intervention, among others. Large-scale outcome data regarding the meaningful involvement of the anesthesiologist in surgical outcomes are few, yet the delivery of anesthesia services provides a unique opportunity to observe the influences of provider mix on outcomes in a complex medical environment. Anesthesiologists and nurse anesthetists have worked together or separately for many years, in a variety of provider models, ranging from independent practice to the "anesthesia care team" model.[2]

This study seeks to determine whether general and orthopedic surgical outcomes differ depending on whether the anesthesiologist is involved significantly in the delivery of anesthesia services to elderly Medicare patients. The answer to this question could have a significant impact on overall healthcare delivery because each year approximately 1.3 million Medicare beneficiaries are admitted to United States hospitals for orthopedic and general surgical procedures that necessitate anesthesia.[3]

Materials and Methods

Data

All Pennsylvania Medicare claims records for patients 65 yr or older were analyzed for general and orthopedic surgical admissions between 1991 and 1994. The study involved 194,430 "directed" and 23,010 "undirected" patients in 245 hospitals. Outcomes studied included death rate within 30 days of admission, in-hospital complication rate, and the failure-to-rescue rate (defined as the rate of death after complications). We obtained the Medicare Standard Analytic Files for all general surgical and orthopedic DRGs (diagnosis-related groups) in Pennsylvania between 1991 and 1994 (Medicare Part A data). For each patient we created a longitudinal record by appending all medical and surgical inpatient and outpatient claims and physicians' claims (Medicare Part B data) during that time interval. Data also included the American Hospital Association Annual Surveys for 1991-1993, and the Pennsylvania Health Care Cost Containment Council Data Base for years 1991-1994.

Patient Selection

We developed predictive models for a random sample of 50% of Medicare patients who underwent general surgical or orthopedic procedures in Pennsylvania between 1991-1994 and tested our results on the other 50%. Final results are reported regarding the full sample of 217,440 individual patients. The DRGs included in this study are listed in table 1. The first hospital admission for any one of these DRGs triggered the identification of a study hospital admission.

Table 1. DRGs Included in Dataset

General Surgical DRGs	Orthopedic DRGs
146 & 147; 148 & 149; 150 & 151; 152 & 153; 154 & 155; 157 & 158; 159 & 160; 161 & 162; 164 & 165; 166 & 167; 170 & 171; 191 & 192; 193 & 194; 195 & 196; 197 & 198; 199 & 200; 201; 257 & 258; 259 & 260; 261; 262; 263 & 264; 265 & 266; 267; 268; 286; 287; 288; 289; 290; 291; 292 & 293; 285	209; 210 & 211; 213; 214 & 215; 216; 217; 218 & 219; 221 & 222; 223 & 224; 225; 226 & 227; 228 & 229; 230; 231; 232; 233 & 234

For DRG 483 (tracheostomy), we reassigned the DRG that would have been assigned using the primary procedure code had a tracheostomy not been performed.

DRG = diagnosis-related group.

Definitions

During the years discussed in this study, the Healthcare Financing Administration (HCFA) required that anesthesia care be either medically directed or supervised by a physician (supervision is defined as a level of physician participation that is less than that defined by medical direction). According to HCFA, the supervisor or director must have been a licensed physician, but not necessarily an anesthesiologist.[4] To bill for medical direction, as defined by HCFA,[5] physicians must have met all the criteria listed in table 2. Otherwise, the level of involvement was defined as "supervision" and physicians received markedly reduced payment.

Cases billed to Medicare as "personally performed" or directed by an anesthesiologist were defined in this study as directed. Otherwise, cases were defined as undirected.

Personally performed cases also included those in which an anesthesiology resident was directed by an attending anesthesiologist. (Anesthesiologist cases in which residents were directed were billed as personally performed for the first 3 yr of the study interval, and changes in the HCFA guidelines caused direction of

Table 2. Definition of Anesthesia Direction

Personal medical direction by a physician may be paid if the following criteria are met:
- No more than 4 anesthesia procedures are being performed concurrently.
- The physician does not perform any other services (except as provided below) during the same time period.
- The physician is physically present in the operating suite.
- The physician:
  - performs a pre-anesthetic examination and evaluation
  - prescribes the anesthesia plan
  - personally participates in the most demanding procedures in the anesthesia plan, including induction and emergence
  - ensures that any procedure in the anesthesia plan that he or she does not perform are performed by a qualified individual
  - monitors the course of anesthesia administration at frequent intervals
  - remains physically present and available for immediate diagnosis and treatment of emergencies
  - provides indicated post anesthesia care.

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resident cases to be billed as "directing 2-4 cases" in the final year of the study.)

There were 23,010 patients defined as undirected in this study, of which 14,137 patients (61% of the undirected group) were not billed for anesthesia and 8,873 (39%) were billed for anesthesia. The "no-bill" cases were defined as undirected because there was no evidence of anesthesiologist direction, despite a strong financial incentive for an anesthesiologist to bill Medicare if a billable service had been performed. The cases in which an anesthesiology bill was not submitted showed billing data that indicated that a surgical procedure on our study list was performed. These cases either were supervised by a physician or a staff nurse anesthetist employed directly by the hospital or they represented undirected anesthesiology resident cases. Of these 14,137 no-bill cases, only 1,287 at most were anesthesia resident cases (or 5.6% of all undirected cases), assuming all no-bill cases at institutions with anesthesia residency programs reflected resident cases. The remaining undirected cases consisted of 8,873 patients (39% of the undirected group) for which procedures were supervised but not directed by an anesthesiologist or directed by a nonanesthesiologist physician. None of these cases included residents. Billing codes included "unknown physician specialty" (code 99) or "unknown provider" (code 88) associated with a nurse anesthetist specialty code 43 or nonanesthesiologist physician direction of the nurse anesthetist, including many other specialty designations, such as pathology (code 22) or general medicine (code 11). Of the 217,440 patients, 20,066 (9.9%) patients underwent anesthesia procedures on more than 1 day during their hospital stay. We labeled a patient undirected if on any day of the hospital stay, all anesthesia procedures performed that day were not directed by an anesthesiologist.

In HCFA billing records the specialty code for anesthesiologist is denoted by an "05" designation. Anesthesiologist designation did not imply board certification. We used information from the American Board of Medical Specialties (ABMS) to verify Medicare data. In one instance, Medicare data indicated that the directing physician was a nonanesthesiologist, yet that same physician was noted to be board certified in anesthesiology according to the American Board of Medical Specialties files. We therefore recoded that person as an anesthesiologist for our purposes.

Outcome Statistics

Death within 30 days of admission was determined from the HCFA Vital Status file. Complications (table 3) were identified using a set of 41 events defined by

Table 3. Complications: Defined Using ICD-9-CM and CPT Codes

Cardiac event (*e.g.*, serious arrhythmia)	Perforation
Cardiac emergency (*e.g.*, cardiac arrest)	Peritonitis
Congestive heart failure	GI or internal bleed
Postoperative cardiac complications	Sepsis
Hypotension/shock	Deep wound infection
Pulmonary embolus	Renal dysfunction
Deep vein thrombosis	Anesthesia event
Phlebitis	Gangrene of extremity
Stroke/CVA	Intestinal obstruction
TIA	Return to surgery
Coma/other	Decubitus ulcer
Seizure	Orthopedic complication
Psychosis	Compartment syndrome
Nervous system complications	Malignant hyperthermia
Pneumonia—Aspiration	Hepatitis/jaundice
Pneumonia—Other	Pancreatitis
Pneumothorax	Necrosis of bone/thermal or aseptic
Respiratory compromise	Osteomyelitis from procedure
Bronchospasm	Fat embolism
Postoperative respiratory complications	Electrolyte/fluid abnormality
Internal organ damage	

The algorithms for constructing the complications using ICD-9-CM and CPT codes are available upon request.

CPT = Physician's Current Procedural Terminology, 4th edition; CVA = cerebral vascular accident; GI = gastrointestinal; ICD-9-CM = International Classification of Diseases, 9th revision, Clinical Modification; TIA = transient ischemic attack.

International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) and CPT (Physician's Current Procedural Terminology, 4th edition) codes available from HCFA databases for the hospital stay of interest, previous hospital stays, and outpatient visits within 3 months before the index hospital stay. CPT codes billed before the hospital stay were used to determine long-standing conditions that would aid in distinguishing complications from comorbidities. Failure-to-rescue rate (FR) was defined as the 30-day death rate in those in whom either a complication developed or who died without a recorded complication. It can be expressed mathematically as follows: $FR = D/(C + D|\text{no } C)$ or the number of patients who died (D) divided by the number of patients with complications (C) plus the number of patients who died without complications noted in the claims data (D|no C).[6,7]

Estimates of excess deaths/1,000 patients were derived using a direct standardization approach using the full data set for both the directed and the undirected cases.[8] Using the final fully adjusted model, the probability of death was estimated twice for each of the 217,440 patients in the study, once assuming each case was undirected and once assuming the case was directed. The resultant difference between the sum of the estimated death rates, divided by the sample size, and multiplied by 1,000, provides the number of excess deaths/1,000 patients when cases are not directed. The same method was used to estimate the excess number of failure-to-rescue cases in the undirected group, except the denominator of cases includes only those with complications. The advantage of this standardization approach is that all patients are used for both estimates, hence reducing bias.

Model Development and Validation

We developed three logistic-regression models to adjust for severity of illness and case mix, one for each outcome in the 50% random or "development" sample. Candidate variables were selected if significant at the 0.05 level after univariate analysis for any of the three outcomes. DRG variables were grouped into DRG-principal procedure categories to produce more homogeneous risk groupings based on Haberman residuals[7,9,10] and then included in each model. Each model included 42 DRG-principal procedure variables and 27 patient characteristics. A total of 37 interaction terms were included in the models, having been significant at the Bonferroni adjusted 0.05 level. We validated the derived models for the remaining 50% or "validation" sample. Coefficients were not statistically different between models derived in development and validation sets. Pearson correlation coefficients between predicted outcomes in the development set and the validation set were always greater than 0.93. Final models were constructed using both the development and the validation data sets.

Hospital Analyses

To account for hospital characteristics that may have influenced our results, we adjusted the results using a list of 11 hospital characteristics that we, and others, reported previously.[7,11,12] Further, we constructed an indicator variable for each hospital and report results adjusted for each individual hospital in the logistic-regression modeling. We also performed adjustments for each hospital using Mantel-Haenszel tests[13] in a number of ways. We estimated the odds ratio (OR) associated with outcome and no direction by controlling for each hospital and stratified, in some analyses, using the risk of death or the propensity score[14-18] to predict lack of direction. When stratifying using the risk of death, we refitted the mortality model, deriving new coefficients, using a separate data set of 1995-1996 Pennsylvania Medicare patients. This allowed for unbiased odds ratios derived from the Mantel-Haenszel tests when applied to the main study set comprising 1991-1994 data.

Results

Patient Description

Table 4 describes patient case mix and table 5 displays patient characteristics that were present in at least 1% of the study population among the anesthesia directed and nondirected groups. Two odds ratios are presented in table 5. The first is the unadjusted odds ratio; the second is the Mantel-Haenszel[13] odds ratio after adjusting for DRG category and each of the 245 hospitals in the study. Undirected patients were more likely to be male; to have a history of arrhythmia, congestive heart failure, and non-insulin-dependent diabetes; and to be admitted through the emergency department. Undirected patients were less likely to have cancer.

There were some associations between covariates and direction status that were unexpected. Some of these could be explained when we studied factors that were predictive of direction[14] and factors predictive of procedures. For example, the unadjusted odds ratios in table 5 suggest undirected cases had greater odds of occurrence

Table 4. Medical Diagnostic Categories (MDC) by Direction Status

	Directed		Not Directed	
	N	%	N	%
MDC 6 Diseases and disorders of the digestive system (146 & 147; 148 & 149; 150 & 151; 152 & 153; 154 & 155; 157 & 158; 159 & 160; 161 & 162; 164; 165; 166; 167; 170 & 171)	54,443	28.00	6,805	29.57
MDC 7 Diseases and disorders of the hepatobiliary system (191 & 192; 193 & 194; 195 & 196; 197 & 198; 199 & 200; 201)	24,957	12.84	3,429	14.90
MDC 8 Diseases and disorders of the musculoskeletal system (209; 210 & 211; 213; 214 & 215; 216; 217; 218 & 219; 221 & 222; 223 & 224; 225; 226; 227; 228 & 229; 230; 231; 232; 233 & 234; 257 & 258; 259 & 260; 261; 262; 263 & 264)	111,825	57.51	12,141	52.76
MDC 9 Diseases and disorders of the skin, subcutaneous tissue, and breast (265 & 266; 267; 268)	392	0.20	86	0.37
MDC 10 Endocrine, nutritional, metabolic diseases and disorders (285; 286; 287; 288; 289; 290; 291; 292 & 293)	2,813	1.45	549	2.39
Total	194,430	89.42	23,010	10.58

in patients with insulin-dependent diabetes. However, undirected patients also had greater odds of undergoing wound debridement and skin grafts as a principal procedure, as compared with directed patients (OR = 10.14; 95% confidence interval [CI] = 8.31, 12.36). The higher rate of diabetes in the undirected group may, in part, have been caused by an increased propensity of the caregiver to perform skin graft procedures, and therefore it would not be surprising that there was an association between undirected cases and diabetes. Bickel *et al.*[19] have shown the importance of such adjustments when making inferences concerning selection bias in graduate school admissions policies. Hence, after adjustment, it would appear as though there was far less imbalance in the covariates between directed and undirected cases than was initially appreciated. However, given the remaining differences between groups, careful severity corrections for all outcomes were performed before results could be accurately interpreted.

Hospital Characteristics

The distribution of hospital characteristics according to the presence of anesthesiologist direction is displayed in table 6. Generally, the hospitals in which undirected

Table 5. Comparison of Patient Characteristics (Odds Ratio for Undirected *versus* Directed Cases)*

	Percent of Total Population	Unadjusted		Adjusted by DRG and Hospital	
		Odds Ratio	*P* Value	Odds Ratio	*P* Value
Age older than 85 yr	9.9	1.048	0.040	1.044	0.110
Male	34.7	1.122	0.001	1.053	0.002
Hx congestive heart failure	2.6	1.637	0.001	1.159	0.001
Hx arrhythmia	2.9	1.357	0.001	1.092	0.001
Hx aortic stenosis	1.8	0.979	0.689	0.996	0.946
Hx hypertension	6.6	1.202	0.001	1.017	0.578
Hx cancer	24.2	0.900	0.001	0.903	0.001
Hx COPD	12.1	1.093	0.001	1.024	0.312
Hx noninsulin-dependent diabetes	10.6	1.293	0.001	1.074	0.003
Hx insulin-dependent diabetes	1.7	2.163	0.001	1.046	0.387
Emergency department admission	34.4	1.232	0.001	1.247	0.001

* Odds ratio denotes the odds of a covariate of interest observed in the undirected group *versus* that of the directed group.

COPD = chronic obstructive pulmonary disease; Hx = history.

Table 6. Distribution of Hospital Characteristics by Type of Provider

Hospital Characteristics	Undirected	Directed	*P* Value
No. of beds greater than 200 (%)	32.72	42.49	0.0001
Nurse-to-bed ratio (RNs/bed)	1.38	1.40	0.0001
Percentage of anesthesiology staff board certified (%)	72.70	74.70	0.0001
Percentage of surgical staff board certified (%)	80.40	85.00	0.0001
Trauma Center (%)	21.87	23.90	0.0001
Lithotripsy facility (%)	17.55	15.68	0.0001
MRI facility (%)	33.27	35.90	0.0001
Solid organ/kidney transplant (%)	11.99	13.56	0.0001
Bone marrow transplant unit (%)	5.37	7.22	0.0001
Approved residency training program (%)	40.90	49.20	0.0001
Member, Council of Teaching Hospitals (%)	17.87	21.89	0.0001

MRI = magnetic resonance imaging; RN = registered nurse.

cases occurred tended to be smaller, to have less specialized technology and facilities, and were less likely to be involved with the teaching of medical students and residents.

Adjusting for Patient Characteristics and DRG-Procedure Category

Unadjusted death, complication and failure-to-rescue rates were greater when cases were undirected (table 7). Table 8 displays the influence of anesthesia direction on outcome after results were adjusted for 64 patient characteristics and interaction terms, including demographic information, history variables, whether the patient was transferred from another short-term-care hospital, whether the patient was admitted from the emergency room, and 42 DRG—procedure categories used for this study. As in the unadjusted model, mortality and failure-to-rescue rates were greater when an anesthesiologist did not perform or direct care. The adjusted odds ratios for death and failure-to-rescue were significantly increased: (OR for death = 1.09, $P < 0.021$; OR for failure-to-rescue = 1.12, $P < 0.003$) corresponding to 2.8 excess deaths/1,000 patients and 8.4 excess deaths/1,000 patients with complications. Adding patient race to this model did not change these results.

A second analysis was performed adding admission MedisGroups (MediQual Inc., Westborough, MA) severity score (a physiologic based score) obtained from the Pennsylvania Health Care Cost Containment Council.[6,20–23] During 1991–1994, MedisGroups scores were recorded for only 72.9% of our study patients. The ORs for the anesthesia direction covariate were as follows: (OR for death = 1.09, $P < 0.016$; OR for failure-to-rescue = 1.12, $P < 0.002$; OR for complication = 0.97, $P < 0.052$). These results provided further evidence that the models derived solely from the Medicare data were adequately adjusted.

We also explored whether the increased odds of death and failure-to-rescue in the undirected group were caused by admissions through the emergency department. When the non-emergency department cases were analyzed separately, the odds ratios for death and failure-to-rescue remained greater for those patients who did not receive anesthesiologist direction (adjusted OR for death = 1.17, $P < 0.007$ and adjusted OR for failure-to-rescue = 1.18, $P < 0.005$).

Adjusting for Patient and Hospital Characteristics

The lower portion of table 8 displays the results of anesthesia direction when 11 hospital variables were included in the three outcomes models. Undirected cases were associated with greater death and failure-to-rescue rates: (OR for death = 1.08, $P < 0.040$; OR for failure-to-rescue = 1.10, $P < 0.013$), corresponding to

Table 7. Unadjusted Outcomes

Outcome	Undirected Rate (%) n = 23,010	Directed Rate (%) n = 194,430	Odds Ratio*	95% Confidence Interval	*P* Value
Death	4.53	3.41	1.35	(1.26, 1.44)	0.0001
Complication	47.87	41.15	1.31	(1.28, 1.35)	0.0001
Failure to rescue	9.32	8.18	1.15	(1.08, 1.24)	0.0001

* Odds ratio denotes the odds of an outcome observed in the undirected group *versus* that of the directed group.

Table 8. Logistic Regression Results

Events	No. of Patients	No. of Events	C Statistic	Adjusted Odds Ratio*	95% Confidence Interval	P Value
Adjusting for patient characteristics						
Death	217,440	7,665	0.82	1.09	(1.01, 1.17)	0.0208
Complication	217,440	91,024	0.75	0.97	(0.94, 1.00)	0.0345
Failure-to-rescue	92,170	7,665	0.75	1.12	(1.04, 1.21)	0.0025
Adjusting for patient and hospital characteristics						
Death	217,440	7,665	0.82	1.08	(1.00, 1.15)	0.0399
Complication	217,440	91,024	0.75	1.00	(0.96, 1.03)	0.7941
Failure to rescue	92,170	7,665	0.75	1.10	(1.01, 1.18)	0.0128

* Odds ratio denotes the odds of an outcome observed in the undirected group *versus* that of the directed group.

2.5 excess deaths/1,000 patients and 6.9 excess deaths/1,000 patients with complications, whereas the adjusted OR for the complication rate was insignificant (OR for complication 1.00, $P < 0.796$). When the MedisGroups severity score was added to the analysis, death and failure-to-rescue ORs were stable and the associated P values became slightly more significant. When a variable reflecting the number of anesthesia procedures per hospital stay was added to the model, we again found the odds ratio estimates to be unchanged.

In a further analysis, we calculated the adjusted odds ratios for each outcome using the Mantel-Haenszel odds ratio, adjusting for all DRG categories and for each of the 245 hospitals in the study, and obtained very similar results. The adjusted odds ratio for death was 1.14 ($P < 0.001$), the odds ratio for failure-to-rescue was 1.11 ($P < 0.008$), and the odds ratio for complication was 1.06 ($P < 0.001$). We next constructed a model adjusting for the same patient characteristics as in table 8 plus a hospital identifier variable for each hospital (grouping hospitals with fewer than 10 deaths into one indicator variable to allow for more stable coefficients). The results were almost identical to those in table 8. The adjusted odds ratio for death was 1.09 ($P < 0.033$), OR for failure-to-rescue was 1.10 ($P < 0.016$), and the OR for complication was 1.02 ($P < 0.333$).

Further Analyses Using Mantel-Haenszel Adjustments and the Propensity Score

We conducted an additional set of analyses concerning the influence of the hospital provider on outcome in this study. Using the full model for patient characteristics, as defined in table 8, we refitted the model coefficients for a separate set of 102,781 Pennsylvania Medicare patients from 1995 and 1996, using the same procedures as in the 1991–1994 study data set. We then calculated the initial risk of death before surgery for each patient in our 1991–1994 study data set and, as suggested by Cochran,[24] we divided these risk scores at the quintiles of this distribution, yielding five risk groups of equal sample size. For each of the 245 hospitals in the data set, we then formed 245 × 5 = 1,225 cells using these five risk groups. This gave us a 2 × 2 × 5 × 245 contingency table, recording death by direction status by mortality risk strata by hospital. The associated Mantel-Haenszel odds ratio computed from the 2 × 2 × 5 × 245 cell contingency table was 1.16 (1.077, 1.246). This ratio was almost exactly the same as the Mantel-Haenszel test results with an odds ratio of 1.14, controlling for the individual hospital and DRG (see previous section in Results), whereas the logit model using hospital indicators also found a very similar odds ratio (1.09). Hence, we obtained almost identical results when the ORs were derived from regression models or derived by performing a Mantel-Haenszel analysis, controlling for risk of death, and forcing all comparisons to be stratified within the same hospital, thereby controlling for the "hospital effect."

To control for selection bias associated with direction or lack of direction, we performed an additional set of analyses using the propensity score to predict direction. Similar to the stratification of mortality risk previously discussed, we divided the propensity score at the quintiles of its distribution, yielding five risk groups of equal sample size. For each of the 245 hospitals in the data set, we then formed a 2 (death status) × 2 (direction status) × 5 (propensity score risk strata) × 245 hospital contingency table. The associated Mantel-Haenszel odds ratio computed from the 2 × 2 × 5 × 245 cell contingency table was 1.11 (1.03, 1.19). Again, the odds ratio for death associated with direction status was almost identical to that determined by our previous methods using logit regression or methods without the propensity score.

Finally, we performed an adjustment stratifying by mortality risk, propensity score, and hospital using a 2 ×

Table 9. The Marginal and Partial Influence of Hospital Characteristics and of Direction of Anesthesia Care on Outcome, Adjusting for Patient Covariates

		Adjusted Odds Ratios (95% Confidence Interval)	
Variable	Outcome Measure	Marginal	Partial
Hospital beds (≥200 beds *vs.* <200 beds)	Death	0.90 (0.86, 0.95)[g]	0.90 (0.84, 0.97)[d]
	Failure-to-rescue	0.83 (0.80, 0.88)[g]	0.87 (0.81, 0.94)[f]
	Complication	1.22 (1.20, 1.25)[g]	1.11 (1.08, 1.14)[g]
Registered nurse-to-bed ratio (in units of 25% of the mean)	Death	0.95 (0.93, 0.96)[g]	0.95 (0.92, 0.97)[g]
	Failure-to-rescue	0.94 (0.92, 0.96)[g]	0.95 (0.93, 0.98)[g]
	Complication	1.04 (1.03, 1.04)[g]	0.98 (0.98, 0.99)[f]
Magnetic resonance imaging facility	Death	0.96 (0.92, 1.01)	1.04 (0.98, 1.10)
	Failure-to-rescue	0.93 (0.89, 0.98)[c]	1.05 (0.99, 1.11)
	Complication	1.06 (1.04, 1.00)[g]	0.95 (0.93, 0.98)[g]
Bone marrow transplantation unit	Death	0.89 (0.80, 0.98)[b]	0.99 (0.88, 1.11)
	Failure-to-rescue	0.79 (0.72, 0.88)[g]	0.93 (0.82, 1.04)
	Complication	1.34 (1.29, 1.39)[g]	1.17 (1.12, 1.22)[g]
Organ transplantation unit	Death	0.91 (0.84, 0.98)[c]	1.03 (0.94, 1.12)
	Failure-to-rescue	0.83 (0.77, 0.89)[g]	0.97 (0.89, 1.07)
	Complication	1.26 (1.22, 1.29)[g]	1.12 (1.08, 1.16)[g]
Lithotripsy facility	Death	0.92 (0.86, 0.99)[b]	0.97 (0.90, 1.05)
	Failure-to-rescue	0.88 (0.82, 0.94)[f]	0.97 (0.89, 1.05)
	Complication	1.10 (1.07, 1.13)[g]	1.01 (0.98, 1.05)
Trauma center	Death	0.93 (0.88, 0.99)[b]	1.03 (0.96, 1.11)
	Failure-to-rescue	0.89 (0.84, 0.95)[g]	1.05 (0.98, 1.34)
	Complication	1.10 (1.08, 1.13)[g]	0.94 (0.91, 0.97)[g]
Surgical board certification, % (in units of 25% of the mean)	Death	0.97 (0.94, 1.00)[f]	0.99 (0.96, 1.03)
	Failure-to-rescue	0.94 (0.91, 0.98)[g]	0.98 (0.95, 1.02)
	Complication	1.07 (1.05, 1.08)[g]	1.03 (1.01, 1.04)[f]
Anesthesia board certification, % (in units of 25% of the mean)	Death	0.99 (0.97, 1.01)	1.01 (0.99, 1.03)
	Failure-to-rescue	0.97 (0.95, 0.99)[d]	1.00 (0.98, 1.02)
	Complication	1.05 (1.04, 1.05)[g]	1.01 (1.00, 1.02)[d]
Member, Council of Teaching Hospitals	Death	0.91 (0.85, 0.96)[d]	1.03 (0.94, 1.12)
	Failure-to-rescue	0.84 (0.79, 0.89)[g]	1.02 (0.93, 1.11)
	Complication	1.26 (1.23, 1.29)[g]	1.10 (1.06, 1.14)[g]
Approved residency training program	Death	0.94 (0.89, 0.98)[c]	1.03 (0.97, 1.11)
	Failure-to-rescue	0.87 (0.83, 0.91)[g]	0.99 (0.93, 1.06)
	Complication	1.21 (1.18, 1.23)[g]	1.07 (1.04, 1.10)[g]
Anesthesiologist-directed care[a]	Death	0.92 (0.85, 0.99)[c]	0.93 (0.87, 1.00)[b]
	Failure-to-rescue	0.89 (0.83, 0.96)[d]	0.91 (0.85, 0.99)[b]
	Complication	1.04 (0.87, 1.07)	1.00 (0.97, 1.04)

[a] < 0.1; [b] < 0.05; [c] < 0.01; [d] < 0.005; [e] < 0.001; [f] < 0.0005; [g] < 0.0001.

Odds ratio denotes the odds of an outcome observed in the directed group *versus* that of the undirected group.

Marginal analysis reports the odds ratios associated with hospital characteristics added one at a time in the logit model that includes 64 patient and 42 procedure covariates and interaction terms.

Partial analysis reports the odds ratios associated with hospital characteristics added all together to the logit model that includes 64 patient and 42 procedure covariates and interaction terms.

2 × 5 × 5 × 245 cell contingency table. Mortality risk was again estimated for the separate 1995–1996 patient population to avoid bias. This analysis yielded, again, similar results to the logit model reported in table 8, with an OR of 1.07, (0.99, 1.15). The slightly less significant *P* value of 0.09 may reflect the fact that we were controlling for 5 times more strata than in the previous two analyses.

Table 9 displays the results of the "fully adjusted patient model," with the addition of all 11 hospital characteristics and the direction indicator for the three outcomes. For each hospital variable, and the anesthesiologist direction indicator, we present two results. The "marginal" result is computed by adjusting the OR for direction by all patient covariates and a single hospital variable or direction indicator. The "partial" analysis displays the results of a fully adjusted model using all patient covariates, all hospital covariates, plus the direction indicator (this "partial" model is also shown in table 8). The marginal analysis showed that hospitals with more sophisticated facilities, higher nurse staffing ratios, and more educational programs were consistently associated with reduced death and failure-to-rescue rates, whereas complication rates were greater in these hospitals. We reported this same pattern in other studies.[7,11,22] Simultaneously adjusting for all the hospital variables and the anesthesiologist direction variable, we found that three factors continued to show independent effects on death and failure-to-rescue: hospital size, nurse-to-bed ratio, and direction by an anesthesiologist.

Furthermore, we asked whether the odds ratios associated with direction and outcome would have changed had we used only patients who were billed, rather than all records. The resulting logistic-regression derived odds ratios were unchanged. Finally, we asked whether adding variables denoting the size of the metropolitan area would account for the observed differences in outcome. Adjusting for the 11 hospital variables and for five levels of population size from rural to metropolitan areas greater than 1 million, we found very little difference in results (OR for death = 1.07, $P < 0.057$; OR for failure-to-rescue = 1.09, $P < 0.021$; OR for complication = 1.00, $P < 0.853$).

Discussion

After adjustments for severity of illness and other confounding variables, we found higher mortality and failure-to-rescue rates for patients who underwent operations without medical direction by an anesthesiologist. Adjusted complication rates were not associated with medical direction. This finding is not inconsistent with the finding of higher mortality rates in the absence of medical direction. Our previous work showed that complication rates, as reflected in administrative claims data, are indicators of severity of illness,[7,11,22] but adjusted complication rates are not well-correlated with adjusted death rates.[11,22,23] In Medicare surgical patients, complication rates are poor indicators of quality of care[6,7] and are not accurately coded to discern specific intraoperative events. The complication rate in this study reflects the number of patients who had complications, not the number of complications per patient. The complication list was developed to be inclusive and sensitive to most undesirable occurrences during the hospital stay, but was not specific for perioperative complications. Specific perioperative complications may not appear in the Medicare claims data, in which the limited number of fields and variation in recording patterns may prevent the complication rate from reflecting differences in quality. Hence, it is not surprising that adjusted complication rates were not different among providers, whereas 30-day mortality rate—a measure better defined and recorded—was different.

Because of these limitations in all studies involving the Medicare database, the failure-to-rescue rate was developed and validated,[6,7] and complications were used as an adjustment tool for severity of illness, rather than as an isolated outcome measure. Failure-to-rescue assesses how complications are managed by studying the rate of death only in those patients in whom complications develop or in those who die without recorded complications. Failure-to-rescue may provide better insight regarding quality of care than either mortality or complication rates used alone[6,7] because it can more easily account for differences in severity. For the current study, failure-to-rescue rates showed an even greater association with provider characteristics than did death rates. This suggests that advanced medical training may allow for better management of complications, thereby decreasing the severity of such complications, and leading to fewer subsequent deaths.

Adequate severity adjustment is always necessary for studies of the type reported herein. Given the apparent difference in the prevalence of specific comorbidities between the directed and undirected groups, adequate adjustment was especially important. As seen in table 5, much of the difference between groups could be explained by the different distribution of procedures found in the directed and undirected groups. Hence, looking at unadjusted prevalence rates of comorbidities can be deceiving in data sets such as this. A classic example of this same problem was provided by Bickel *et al.*[19] in their 1975 article of graduate admission bias using data from The University of California at Berkeley. Although unadjusted admission acceptance rates would suggest females had been discriminated against because of the observed overall lower admission rates, after adjustment for the departments to which the female students applied, it was shown that there was no significant bias. This was because the female applicants more often applied to departments with lower rates of acceptance (for both males and females), whereas male applicants more often applied to departments with higher rates of acceptance (for both males and females). Hence, the overall, unadjusted numbers suggested an imbalance in admission rates (a bias against females), whereas such an imbalance was not seen at the individual department level.

It was reassuring that, in our study, after adjustment for DRG and hospital, the difference in the prevalence of covariates between the directed and undirected groups became much smaller. In part, this was caused by a tendency for undirected patients to be involved with slightly more minor procedures in patients with a greater number of comorbidities. Although adjustments in table 5 helped to explain these differences in comorbidity rates among groups, more complete model-based adjustments were made when reporting final results.

There is strong supporting evidence that the model-based adjustments used in our study were adequate. Of interest, unadjusted rates of death, number of complications, and failure-to-rescue rates were all increased in the nondirected group. After using models that contained identical patient covariates for each of the three outcomes, we observed that the adjusted odds of development of complications decreased to 1, whereas ORs of death and failure-to-rescue remained greater than 1. Further, the unadjusted OR associated with no direction and failure-to-rescue (table 7) was almost identical to that in the fully adjusted model (table 8). This finding is consistent with a number of studies showing that a strength of the failure-to-rescue concept is that the failure-to-rescue rate appears to be less sensitive to omissions of severity of illness data than is the death or complication rate.[7,22] Finally, when a physiologic severity adjustment measure, MedisGroups Score, was added to the models, results were virtually unchanged. If the association between anesthesiologist direction and outcome was an artifact of failure of the model to adequately control for critical aspects of patient severity, we would have expected the addition of the physiologic-based patient severity score to alter the results. Together, these findings provide consistent supporting evidence that the model was adjusted adequately for severity of illness among groups.

Without further adjustment, these results might still reflect differences in overall hospital quality, rather than differences in the type of anesthesiologist involvement. Therefore, the results were simultaneously adjusted for patient and hospital characteristics, yet the effect of anesthesiologist direction remained significant. When we adjusted for the individual hospital using Mantel-Haenszel adjustments and logistic-regression models, our results were unchanged. Further, adjustments for selection bias using the propensity score again revealed that our results were very stable. It appeared that the increased risk of death associated with lack of direction was not caused by selection bias at the hospital. Thus, these data support the concept that there is a benefit associated with medical direction by an anesthesiologist that is independent of the hospital effect and not a result of selection bias.

Our results were consistent with other large studies of anesthesia outcomes.[25,26] Some studies suggest that the best outcomes may occur when anesthesia is provided by an anesthesia care team directed by an anesthesiologist.[27] We also found that the single most important hospital variable associated with lower death and failure-to-rescue rates was a higher registered-nurse-to-bed ratio,[7] and the importance of nurse staffing has been noted in several other studies.[7,28-30]

Our results also point to a common misconception when assessing anesthesia safety. Since the early (1954) study of Beecher and Todd[31] reported an anesthesia-related mortality rate of 1 death/1,560 patients, anesthesia-related mortality has been the gold standard of gauging anesthesia safety. By 1982, the anesthesia-related mortality had decreased to 1 death/6,789 patients in the United Kingdom,[32] and, by 1989, the anesthesia mortality rate had decreased to 1 death/185,056 patients[33]; whereas Eichhorn,[34] in 1989, reported anesthesia-related mortality of 1 death/151,400 patients among more than 750,000 healthy (American Society of Anesthesiologists physical status I or II)[35] patients in the United States. These studies supported the concept that the incidence of death directly related to anesthetic events had decreased, but the concept of anesthesia-related mortality was narrowly defined. Modern perioperative intensive care (including that provided by anesthesiologists) often prevents immediate postoperative mortality, yet prolonged morbidity and delayed mortality may result even when the precipitating event occurred preoperatively or intraoperatively. Further, there is increasing evidence that anesthetic practice influences subsequent patient outcomes in ways that were not recognized previously. Even relatively simple measures, such as maintaining normothermia or supplying supplemental oxygen in the perioperative period, can decrease the incidence of subsequent morbid events, including perioperative cardiac morbidity (ischemia, infarction, cardiac arrest),[36] and postoperative wound infection.[37,38] Our study underscores the importance of anesthetic practice in overall surgical outcome, potentially influencing mortality at the rate of 2.5 deaths/1,000 patients or 1 death/400 patients, more than 300 times greater than reported by Eichhorn[34] and others,[32,33] who used a far more narrow definition of "anesthesia related" that did not consider these wider associations.

This was a retrospective analysis based on administrative claims data and is limited by the associated errors inherent in using such data. The accuracy of our definitions for anesthesiologist direction (or no direction) is only as reliable as the bills (or lack of bills) submitted by caregivers. We also cannot rule out the possibility that unobserved factors leading to undirected cases were associated with poor hospital support for the undirected anesthetist and patient. Local, temporal, even psychologic factors may play a part in patient outcome, and such factors may not be noted in the available data set. For example, if anesthesiologists had a tendency not to submit bills for patients who died within 30 days of admission, our results could be skewed in favor of directed cases. Although our clinical experience suggests that this scenario is quite unlikely, we cannot rule out this possibility. We also cannot rule out the possibility that undirected cases occur more often in emergency situations that developed outside of the emergency department. For example, it may be that patients who required multiple anesthesia procedures were more ill and were cared for by an undirected anesthetist because of an emergency reoperation that did not allow time for the anesthesiologist to participate in care. Although we could find no evidence of this, because our study results were unchanged when a variable denoting multiple anesthesia procedures was added to the model, more extensive study involving individual chart review may be helpful for exploring these questions.

Future work will also be needed to determine whether the mortality differences in this report were caused by differences in the quality of direction among providers, the presence or absence of direction itself, or a combination of these effects. To address these limitations, we hope to pursue in-depth, large-scale medical chart review of surgical cases in the next phase of this research. We anticipate that review of medical charts will provide more detailed information that will assist in determining the etiology of differences in outcomes among provider type.

In summary, review of Medicare claims data in Pennsylvania suggests that medical direction by an anesthesiologist was associated with lower mortality and failure-to-rescue rates. In light of the large numbers of Medicare patients undergoing operations each day, future research must carefully identify the etiologic factors associated with these findings to define optimal provider models and improve outcomes.

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