Surgical mortality and type of anesthesia provider

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Although estimates of anesthesia-related deaths today are as low as 1 in 200,000 to 300,000 cases, questions remain about surgical patients' safety related to types of anesthesia providers. We studied the effect of type of anesthesia provider on mortality rates of Medicare patients undergoing 8 different surgical procedures.

Risk-adjusted mortality rates were analyzed for 404,194 inpatients undergoing surgery and having complete, unambiguous Medicare bills for anesthesia. Mortality was compared for anesthesiologists working alone, Certified Registered Nurse Anesthetists (CRNAs) working alone, and anesthesia care teams. Procedure-specific risk-adjustment models were derived using stepwise logistic regression. Predictions were adjusted for institutional and geographic factors.

Mortality rates for conditions studied ranged from 0.11% to 1.20%. Observed and predicted values by type of provider were not statistically significantly different. Hospitals without anesthesiologists had results similar to hospitals where anesthesiologists provided or directed anesthesia care.

Key words: **Anesthesia mortality, anesthesia providers, nurse anesthetist, quality of care, surgical mortality.**

Success in reducing anesthesia-related mortality has been exemplary, with current estimates of death rates as low as 1 death per 200,000 to 300,000 cases.[1] Despite this commendable record, questions remain about surgical patient safety related to types of anesthesia providers.

On January 18, 2001, the Health Care Financing Administration (now the Centers for Medicare & Medicaid Services) published a rule[2] allowing states and individual hospitals to decide whether physicians must supervise anesthesia administration by Certified Registered Nurse Anesthetists (CRNAs) in order for hospitals to receive Medicare reimbursement. Before this rule could take effect, a new administration invoked "safety issues" as a rationale for replacing it with a rule that mandates physician supervision unless a state governor obtains a waiver, after consultation with the state's boards of medicine and nursing.[3] Currently, 6 states have obtained such waivers. In states considering these waivers, state governors have become immersed in sometimes fierce and expensive political controversies as anesthesiologists pressed for mandatory supervision and CRNAs stoutly defended their professional competence. Without recent valid scientific data, governors must contend with contradictory interpretations of outdated or seriously flawed research studies.[4-7] Furthermore, in states that grant waivers, hospitals and surgeons must decide how the composition of an operative team will affect surgical outcomes.

We studied the effect of type of anesthesia provider on surgical mortality associated with selected surgical procedures performed on Medicare beneficiaries.

Methods

Part A (ie, hospital claims) and Part B (ie, professional claims) Medicare data were analyzed for patients hospitalized in 1995, 1996, or 1997 in 1 of 22 states if they underwent 1 of the following operations: (1) carotid endarterectomy, (2) cholecystectomy, (3) herniorrhaphy, (4) hysterectomy, (5) knee replacement, (6) laminectomy, (7) mastectomy, or (8) prostatectomy. Patients also had to (1) reside in the state where the operation was performed, (2) undergo the procedure within 2 days after admission, and (3) have a principal diagnosis that could be treated appropriately by the procedure performed. Table 1 lists qualifying *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* procedure codes and associated ICD-9-CM principal diagnostic codes. States were selected to yield a reasonable representation of CRNAs practicing in urban and rural facilities across the United States. A total of 586,422 cases met initial inclusion criteria.

The type of anesthesia provider (ie, an anesthesiologist alone, a CRNA alone, or a team of an anesthesiologist and a CRNA) was obtained from part B Medicare billing data. Cases were eliminated from development of risk-adjustment models if they lacked part B data, had invalid provider codes, were coded as emergencies, or came from any hospital that performed fewer than 15 similar operations on Medicare beneficiaries during the 3-year study period. Table 2 shows the number of cases eliminated by each criterion.

Table 1. Qualifying *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* procedure codes and associated *ICD-9-CM* principal diagnosis codes

Surgical procedure	ICD-9-CM codes*
Carotid endarterectomy	Procedure code: 38.12 Principal diagnosis codes: 433.10, 433.30, 435.8x, 435.9x
Cholecystectomy	Procedure code: 51.2x Principal diagnosis codes: 574.xx, 575.0x, 575.1x, 575.2x
Herniorrhaphy (uncomplicated)	Procedure code: 53.xx Principal diagnosis codes: 550.9x, 553.xx
Hysterectomy for benign disease	Procedure codes: 68.3x, 68.4x, 68.5x, 68.6x, 68.7x, 68.8x, 68.9x Principal diagnosis codes: 218.xx, 219.xx, 220.xx, 233.1x, 233.2x, 256.xx, 614.xx, 615.xx, 617.xx, 618.xx, 619.xx, 616.0x, 620.xx, 621.xx, 622.xx, 626.xx, 627.xx, 625.2x, 625.3x, 625.4x, 625.5x, 625.6x
Knee replacement	Procedure codes: 81.54, 81.55 Principal diagnosis codes: 696.0x, 714.xx, 717.xx, 715.x6, 716.x6, 718.x6, 719.x6
Laminectomy	Procedure code: 80.5x Principal diagnosis codes: 721.xx, 722.xx, 723.0x, 724.0x
Mastectomy	Procedure codes: 85.22, 85.23, 85.3x, 85.4x Principal diagnosis codes: 174.xx, 217.xx, 233.0x, 239.3x, 610.xx, 611.xx
Prostatectomy	Procedure codes: 60.2x, 60.3x, 60.4x, 60.5x, 60.6x Principal diagnosis codes: 185.xx, 600.xx

* The symbol "x" in a code indicates a blank or any number between 0 and 9.

Equations were derived to compute the probability of dying before discharge for each patient undergoing a procedure included in this study. Risk factors considered for each procedure were patients' age, sex, principal and secondary diagnoses, and selected information about procedures (eg, laparoscopic vs abdominal surgery). To identify potential risk factors, stepwise logistic regression[8] was applied to New York's Statewide Planning and Research Cooperative System (SPARCS) data for 1996 and 1997. This state database was used exclusively to screen potential risk factors because, unlike the Medicare database, it distinguishes valid risk factors (ie, secondary diagnoses present on admission) from complications that occurred during hospitalization. Only comorbid conditions found to be statistically significant predictors of inpatient mortality (ie, $P < .05$) were selected as candidates for inclusion in final risk-adjustment equations. Finally, secondary diagnoses coded more frequently as complications than as comorbid conditions were eliminated from consideration, even if they were significant predictors of inpatient mortality. Final clinical risk-adjustment models were derived on the Medicare database by applying stepwise logistic regression to select statistically significant risk factors ($P < .05$).[8] Bootstrapping techniques[9] were used to ensure that the final variables

Table 2. Number of cases eliminated from model creation and mortality analysis

Total eligible cases	586,422
Cases with invalid provider codes	2,961
Remaining eligible cases	583,461
Cases coded as emergency	964
Remaining eligible cases	582,497
Cases in hospitals having <15 such operations in 3 y	24,292
Remaining eligible cases	558,205
Cases with no Medicare Part B data	28,627
Total cases used to create models	529,578
Cases with no anesthesia bill	48,316
Remaining eligible cases	481,262
Cases with ambiguous provider codes	27,981
Remaining eligible cases	453,281
Cases with incomplete billing or probably team care	49,087
Total cases included in analysis of mortality rates	404,194

were applicable to the entire range of observed data.

Institutional and geographic variables that might affect predicted mortality also were evaluated using stepwise logistic regression. Hospitals' number of beds, average daily census, total number of inpatient operations, percentage of registered nurses, and teaching status (ie, member of Council of Teaching Hospitals, residency program, or nonteaching hospital) were obtained from the 1997 American Hospital Association (AHA) Annual Survey Database. Hospitals' locations were characterized by state and rural-urban continuum codes (from the AHA database). Each hospital's relative volume of each operation was ranked in quartiles. The degree of a hospital's technological sophistication was ranked according to the following set of mutually exclusive categories: very high (ie, has burn or transplant unit), high (ie, has at least 2 of the following: trauma unit, cardiac catheterization laboratory, lithotripter, radiation therapy), moderate (ie, has at least 1 of the 4 services listed for the high category), low (ie, has magnetic resonance imaging, positron emission tomography, or single photon emission tomography scanning), or absent (ie, has none of the services mentioned).

The final risk-adjustment model contained each patient's predicted mortality rate from the appropriate clinical model and coefficients for the hospital characteristics that added significant predictive power, ie, relative volume of each operation, number of inpatient operations, average daily census, and the hospital's position on the rural-urban continuum. C statistics[10] (ie, areas under receiver-operating characteristic curves) were calculated to assess each model's predictive power (ie, 1.0 equals perfect prediction, 0.5 equals no predictive power).

After development of risk-adjustment models, the database was refined further by excluding cases that had no bill for anesthesia services, had ambiguous anesthesia provider codes, or had bills that suggested team care but lacked corresponding bills for both an anesthesiologist's and a CRNA's services. Table 2 shows numbers excluded for these reasons.

Initial patient-specific mortality predictions were computed using procedure-specific risk-adjustment equations; predicted values then were adjusted using hospital-specific variables. The resulting predicted values were used to compare inpatient mortality rates among the 3 types of providers (anesthesiologists alone, CRNAs alone, anesthesia care teams).

The organization of anesthesia practice in a hospital may contribute to surgical outcomes regardless of which type of anesthesia provider cares for an individual patient. To assess whether differences in the organization of anesthesia practice affected inpatient mortality rates, hospitals were categorized as having only 1 type of anesthesia provider (A1, A2, A3), having only solo practitioners (B), having a single type of solo practitioner and team anesthesia care (C1, C2), or having both types of solo practitioners and team anesthesia care (D).

We computed ^{2} statistics to evaluate differences in distributions of cases among types of anesthesia providers and to examine the relation between types of providers and risk-adjusted inpatient mortality rates.[11]

Results

For the 404,194 cases analyzed, Table 3 shows the distribution of patients among the 8 operations and the unadjusted mortality rate for each operation. Mortality rates ranged from 0.11% for mastectomies and for hysterectomies to 1.20% for cholecystectomies. The average for all patients was 0.38%. Anesthesia care was provided by anesthesiologists alone in 33.2% of cases, by CRNAs alone in 8.2%, and by anesthesia care teams in 58.6% (Table 4).

Table 5 presents the distribution of operations among the 22 states, from 0.6% in Delaware to 13.7% in Michigan. The percentage of cases in which anesthesiologists worked alone ranged from 5.3% in South Dakota to 84.3% in Washington. The percentage in which CRNAs worked alone ranged from 0% in Delaware to 33.6% in Kansas. The percentage of cases receiving care from teams ranged from 5.4% in New Mexico to 85.7% in North Dakota. Almost half the operations were performed within metropolitan areas of 100,000 to 1,000,000 residents (Table 6). Approximately one fourth were performed in metropolitan areas exceeding 1,000,000 residents. Almost 80% of operations in which CRNAs alone provided anesthesia were performed at rural hospitals or in metropolitan areas of fewer than 100,000 residents.

Table 7 lists C statistics for the 8 clinical risk-adjustment models and for the final model incorporating clinical risk and hospital characteristics. Patient factors were most predictive of mortality for patients undergoing cholecystectomy or herniorrhaphy and least predictive for patients undergoing mastectomy or knee replacement.

Table 8 presents risk-adjusted mortality rates by type of anesthesia provider and by hospitals' types of anesthesia practice. There were no significant differences in risk-adjusted mortality rates by type of anesthesia provider or by type of anesthesia practice within the hospital. These findings were not altered when risk-adjustment was performed using equations without hospital or geographic variables.

Table 3. Distribution of cases and unadjusted mortality rates, by procedure

Procedure	No.	% of Total*	Dead	% of Total*	% Dead
Carotid endarterectomy	56,957	14.09	282	18.18	0.50
Cholecystectomy	54,673	13.53	655	42.23	1.20
Herniorrhaphy	15,779	3.90	65	4.19	0.41
Hysterectomy	30,567	7.56	35	2.26	0.11
Knee replacement	111,124	27.49	256	16.51	0.23
Laminectomy	28,999	7.17	67	4.32	0.23
Mastectomy	27,418	6.78	31	2.00	0.11
Prostatectomy	78,677	19.47	160	10.32	0.20
Total	404,194	99.99	1,551	100.01	0.38

* Column totals do not equal 100.00% because of rounding.

Table 4. Number and percentage of cases receiving anesthesia from each type of provider, by procedure

	All cases		Anesthesiologist		CRNA		Team	
Procedure	No.	%*	No.	%	No.	%	No.	%
Carotid endarterectomy	56,957	14.09	22,164	38.91	1,495	2.62	33,298	58.46
Cholecystectomy	54,673	13.53	20,211	36.97	7,147	13.07	27,315	49.96
Herniorrhaphy	15,779	3.90	5,010	31.75	1,041	6.60	9,728	61.65
Hysterectomy	30,567	7.56	9,234	30.21	2,676	8.75	18,657	61.04
Knee replacement	111,124	27.49	33,341	30.00	9,617	8.65	68,166	61.34
Laminectomy	28,999	7.17	9,248	31.89	841	2.90	18,910	65.21
Mastectomy	27,418	6.78	8,342	30.43	2,435	8.88	16,641	60.69
Prostatectomy	78,677	19.47	26,785	34.04	7,899	10.04	43,993	55.92
Total	404,194	99.99	134,335	33.24	33,151	8.20	236,708	58.56

* The column total does not equal 100.00% because of rounding.

Discussion

Although there is a large body of literature delineating patient and hospital factors related to risk-adjusted surgical mortality,[12-16] few studies have addressed the effect of the type of anesthesia provider on these outcomes.

A classic study of anesthesia-related mortality by Beecher and Todd[4] more than 50 years ago found substantially higher mortality rates when anesthesia was administered by anesthesiologists than when it was administered by CRNAs. Because the physical status of patients treated by both types of providers was similar (according to American Society of Anesthesiologists' classifications), the researchers attributed the difference in outcomes to greater but unmeasured complexity of anesthesiologists' cases.

Two decades later, a North Carolina study[5] found "the incidence [of death] among the three major groups (the CRNA, the anesthesiologist, and the combination of CRNA and anesthesiologist) to be rather similar…." However, provider-specific mortality rates in this study could not be risk adjusted because clinical data on surviving patients were unavailable.

Another study published in 1980[6] compared risk-adjusted mortality (both surgical and anesthesia-related) at 9 hospitals "in which anesthesiologists primarily were the providers" with that at 7 hospitals "in which nurse anesthetists were primarily the providers." These authors concluded that "using conservative statistical methods, … there were no significant differences in outcomes between the two groups

Table 5. Number and percentage of cases in each state, by type of anesthesia provider

State	All cases No.	All cases %	Anesthesiologist No.	Anesthesiologist %	CRNA No.	CRNA %	Team No.	Team %
Alabama	26,699	6.61	4,328	16.21	1,242	4.65	21,129	79.14
Delaware	2,272	0.56	1,260	55.46	0	0.00	1,012	44.54
Idaho	7,663	1.90	1,738	22.68	1,701	22.20	4,224	55.12
Kansas	17,417	4.31	4,309	24.74	5,853	33.61	7,255	41.65
Louisiana	18,475	4.57	3,984	21.56	1,472	7.97	13,019	70.47
Maine	6,907	1.71	2,800	40.54	387	5.60	3,720	53.86
Michigan	55,485	13.73	14,721	26.53	3,425	6.17	37,339	67.30
Minnesota	19,481	4.82	1,311	6.73	2,361	12.12	15,809	81.15
Mississippi	15,205	3.76	6,506	42.79	520	3.42	8,179	53.79
Missouri	30,177	7.47	10,181	33.74	2,701	8.95	17,295	57.31
Montana	5,976	1.48	4,668	78.11	860	14.39	448	7.50
Nebraska	10,461	2.59	4,453	42.57	2,883	27.56	3,125	29.87
New Hampshire	4,498	1.11	2,056	45.71	273	6.07	2,169	48.22
New Mexico	6,514	1.61	4,293	65.90	1,869	28.69	352	5.40
North Carolina	34,811	8.61	4,739	13.61	610	1.75	29,462	84.63
North Dakota	4,480	1.11	451	10.07	190	4.24	3,839	85.69
Pennsylvania	54,563	13.50	25,055	45.92	312	0.57	29,196	53.51
South Carolina	17,474	4.32	7,382	42.25	448	2.56	9,644	55.19
South Dakota	6,312	1.56	335	5.31	704	11.15	5,273	83.54
Tennessee	28,837	7.13	9,599	33.29	4,035	13.99	15,203	52.72
Washington	21,904	5.42	18,455	84.25	1,109	5.06	2,340	10.68
West Virginia	8,583	2.12	1,711	19.93	196	2.28	6,676	77.78
Total	404,194	100.00	134,335	33.24	33,151	8.20	236,708	58.56

of hospitals defined by type of anesthesia provider."

In an article that its authors confessed "lacks the scientific credibility of a review or original article and is related to policy making more than science,"[17] Abenstein and Warner[18] reinterpreted the findings of previous researchers. They concluded: "When the data are critically examined, the evidence is very supportive that the anesthesiologist-led anesthesia care team is the safest and most cost-effective method of delivering anesthesia care." However, they presented no original data to support this conclusion.

In a more recent risk-adjusted study of 217,440 surgical cases in Pennsylvania, Silber et al[7] observed an increase of 2.5 deaths per 1,000 patients when an anesthesiologist was not involved in the case. This statistic is alarming in light of the Institute of Medicine's review, which concluded: "today, anesthesia mortality rates are about one death per 200,000-300,000 anesthetics administered…"[1] However, approximately two thirds of cases classified by Silber et al[7] as lacking an anesthesiologist either had no bill at all for anesthesia care or had an anesthesiologist involved in some but not all of a patient's procedures. Cases in which an anesthesiologist worked alone were not distinguished from those in which anesthesia was provided by a team. And only cases in Pennsylvania were studied.

The present study endeavored to avoid these limitations by drawing cases from 22 states, including Pennsylvania. Only cases with clear documentation of type of anesthesia provider were included. Team care was distinguished from anesthesiologists or CRNAs practicing alone. Because patient and surgical risk far outweigh anesthesia risk in hospitalized patients undergoing surgical procedures[14,19] and because risk adjustment using administrative data sets always is

Table 6. Distribution of cases among providers by size of metropolitan area where they worked

Metropolitan population	All cases		Anesthesiologist		CRNA		Team	
	No.	%	No.	%	No.	%	No.	%
>1,000,000	106,479	26.34	32,001	30.05	1,914	1.80	72,564	68.15
100,000-1,000,000	189,270	46.83	68,397	36.14	5,414	2.86	115,459	61.00
<100,000	108,445	26.83	33,937	31.29	25,823	23.81	48,685	44.89
Total	404,194	100.00	134,335	33.24	33,151	8.20	236,708	58.56

suboptimal,[8] only surgical procedures that are performed on relatively homogeneous populations were included. Exclusion of emergency and other higher risk operations substantially reduced variability in predicted outcomes that can confound analyses, particularly when observational data sets are as unbalanced as the one used in this study. Also, because substantial differences in the risk of adverse outcomes remain even within these relatively homogeneous surgical categories, risk-adjustment equations were derived to account for any coexisting clinical conditions that might affect surgical mortality.

Particularly in high-risk emergency patients like those included in the study by Silber et al,[7] a large proportion of postoperative deaths are attributable to patients' underlying conditions rather than to deficiencies in anesthesia care.[14,19] The present study's focus on nonemergency procedures greatly increased the probability that coexisting serious acute conditions were not present at the time of operation. However, because deaths due to surgical complications generally are far more frequent than those due to anesthesia complications,[14,19] even rigorous risk adjustment performed for a diverse set of surgical procedures across a widely dispersed geographic area probably failed to remove all systematic biases. Only a careful review of medical records to determine the actual causes of mortality and morbidity could eliminate these biases.

In the present study, patients were attributed to an anesthesia provider based on data from the operation that qualified them for inclusion in the study. In contrast, Silber et al[7] classified cases as "undirected" if an undirected CRNA administered anesthesia for postsurgical palliative procedures, even when an anesthesiologist or a team administered anesthesia for the original surgical interventions. This difference in assignment may account, at least in part, for the higher risk-adjusted mortality rates observed by Silber et al[7] in undirected cases.

It is important to note several limitations associ-

Table 7. C statistics for risk-adjustment models

Procedure	C statistic
Carotid endarterectomy	0.826
Cholecystectomy	0.883
Herniorrhaphy	0.853
Hysterectomy	0.811
Knee replacement	0.766
Laminectomy	0.787
Mastectomy	0.667
Prostatectomy	0.812
All + hospital characteristics	0.857

ated with any study that compares mortality rates using Medicare and AHA data.

First, non-Medicare cases are not in the database. Also, information about practitioners reflects only services that were billed, and there are no records of services for patients in Medicare health maintenance organizations.

Second, because Medicare data do not distinguish between valid risk factors (ie, comorbid conditions) and inpatient complications, risk adjustment using Medicare data may fail to capture the true preoperative risk of death.[8,20] To enhance further the validity of risk-adjustment models, the present study limited risk variables to those identified using New York's SPARCS database, which distinguishes clearly between comorbid conditions and complications.

Third, information in the AHA database comes from hospitals themselves and is not validated independently. Consequently, this database, although used widely in research studies, may contain inaccuracies about some hospitals. For example, high technology reported by a small rural hospital may actually reside in an affiliated urban medical center 100 miles away, or "number of beds" may include some that were closed years ago.

Table 8. Risk-adjusted mortality rates by type of anesthesia provider

Type*	AA	CRNA	Team	No. of Hospitals	Cases per hospital	No. of cases	Dead	Predicted dead	Observed rate (%)	Predicted rate (%)	O/P
All cases											
A1	1			95	313	29,718	121	115.4	0.41	0.39	1.049
A2		1		191	71	13,592	61	68.0	0.45	0.50	0.897
A3			1	25	333	8,330	24	28.9	0.29	0.35	0.830
B	1	1		112	203	22,770	94	92.8	0.41	0.41	1.013
C1	1		1	574	457	262,289	978	982.0	0.37	0.37	0.996
C2		1	1	9	94	844	4	3.2	0.47	0.38	1.250
D	1	1	1	171	390	66,651	269	260.8	0.40	0.39	1.031
Total				1,177	343	404,194	1,551	1,551.0	0.38	0.38	1.000
Anesthesiologist only											
A1	1			95	313	29,718	121	115.4	0.41	0.39	1.049
B	1	1		112	107	11,970	52	50.1	0.43	0.42	1.037
C1	1		1	574	127	73,046	323	325.6	0.44	0.45	0.992
D	1	1	1	171	115	19,601	108	90.5	0.55	0.46	1.194
Total				952	141	134,335	604	581.6	0.45	0.43	1.039
CRNA only											
A2		1		191	71	13,592	61	68.0	0.45	0.50	0.897
B	1	1		112	96	10,800	42	42.6	0.39	0.39	0.985
C2		1	1	9	18	164	2	0.9	1.22	0.55	2.222
D	1	1	1	171	50	8,595	46	35.0	0.54	0.41	1.316
Total				483	69	33,151	151	146.5	0.46	0.44	1.031
Anesthesia care team											
A3			1	25	333	8,330	24	28.9	0.29	0.35	0.830
C1	1		1	574	330	189,243	655	656.3	0.35	0.35	0.998
C2		1	1	9	76	680	2	2.3	0.29	0.34	0.870
D	1	1	1	171	225	38,455	115	135.4	0.30	0.35	0.849
Total				779	325	236,708	796	822.9	0.34	0.35	0.967

*** Key to types**
A1 = Anesthesiologist as sole provider
A2 = CRNA as sole provider
A3 = Team as sole provider
B = Both anesthesiologist and CRNA, each working alone
C1 = Anesthesiologist alone and team care
C2 = CRNA alone and team care
D = Both types of solo providers and team care

AA indicates anesthesiologist alone; O/P, observed/predicted ratio; CRNA, Certified Registered Nurse Anesthetist.

Finally, the Medicare database does not permit precise identification of the cause of death. Detailed reviews of large numbers of medical records would be required to determine definitively the contribution of anesthesia care to operative and postoperative deaths.

After adjustment for differences in case mix, clinical risk factors, hospital characteristics, and geographic location, the current study found similar risk-adjusted mortality rates whether anesthesiologists or CRNAs worked alone. Furthermore, hospitals without anesthesiologists had results similar to those of hospitals in which anesthesiologists provided or directed anesthesia care. Anesthesia care teams had a slightly lower risk-adjusted mortality rate than did practitioners working alone, but the difference was not statistically significant. Although these findings differ from those of Silber et al,[7] they are more consistent with the earlier research cited and with current data on overall anesthesia-related mortality.[1] They indicate that for the surgical procedures included in this study, the type of anesthesia provider does not affect inpatient surgical mortality.

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