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Influence of Patient and Hospital Characteristics on Anesthesia Time in Medicare Patients Undergoing General and Orthopedic Surgery

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Background: **Procedure time is a clinically important variable that is often analyzed when studying quality and efficiency. Norms for procedure length have not been reported from Medicare data sets, nor has the influence of patient and hospital characteristics on procedure time been estimated using Medicare data.**

Methods: **The authors obtained Medicare claims on all patients aged 65–85 years who underwent general surgical and orthopedic surgical procedures in Pennsylvania. Anesthesia procedure time was estimated from anesthesia time units bills supplied from Medicare on 20 common general and orthopedic surgery procedures, and models to determine the influence of hospital and patient characteristics were developed.**

Results: **Of the 77,638 patients, 31,472 had general surgery and 46,166 underwent orthopedic procedures. The median anesthesia time for general surgery was 133 min, and for orthopedic surgery it was 146 min. After adjusting for principal procedure, hospital, and physiologic severity, covariates associated with increased anesthesia time included: multiple procedure on same day + 18.3 min ($P < 0.0001$); transfer-in + 6.7 min ($P = 0.0002$); black race + 5.5 ($P < 0.0001$); coagulation disorders + 4.9 ($P = 0.0012$); and paraplegia + 4.5 ($P = 0.0006$). Lower-income black patients had significantly longer procedure times than lower-income white patients (+ 7 min; $P < 0.0001$). Among the 15 hospitals with the largest black surgical populations, 5 hospitals had statistically significant procedure lengths for black *versus* white patients, ranging from + 9 to + 16 min.**

Conclusions: **In addition to variation by patient comorbidities and procedure, anesthesia procedure time varies with hospital, medical history, and sociodemographic characteristics.**

PROCEDURE time is a common variable reported in the anesthesia and surgical literature.[1–10] However, because the study of procedure time generally requires chart abstraction, the variable is usually reported from single institutions where such information is more easily abstracted. Utilizing an algorithm to estimate anesthesia procedure time from the Medicare anesthesia bill, we report the influence of specific principal procedure, patient characteristics, and hospital characteristics on procedure time. Use of anesthesia bills from Medicare allows for large samples of cases to be studied, among many different hospital settings; in so doing, one can better estimate patient and hospital effects that may be lost, or poorly estimated, in a smaller single-institution study.

Materials and Methods

Patients and Databases

Medicare data for patients 65 yr and older comprise the most representative sample of healthcare data in the United States because Medicare is an entitlement. The only significant group of elderly citizens not represented in the Medicare claims data is those who opt out of the Medicare fee-for-service program and join a Medicare-approved prepaid health maintenance organization. As part of the Surgical Outcomes Study,[11–13] we obtained the Medicare Inpatient (Part A), Outpatient Standard Analytic Files, and Physician Part B files for all admissions in general and orthopedic surgical Diagnosis Related Groups in Pennsylvania during 1995 and 1996 for patients between the ages of 65 and 85 yr. These files represent the fee-for-service Medicare population, comprising approximately 90% of all beneficiaries for 1995-1996.[14,15] We created a longitudinal record by including all inpatient and outpatient claims and physicians' claims during that time interval for each patient. Data also included the Medicare Vital Status File, American Hospital Association Annual Surveys for 1996, and the Pennsylvania Health Care Cost Containment Council Hospital Discharge Database for similar years, which included the MedisGroups (MediQual, Inc., Marlborough, MA) severity score to supplement the Medicare record.[16] Medicare electronically stores all bills submitted by hospitals and physicians and all other caregivers, and stores all payments made. These billing data include limited diagnosis codes collected using International Classification of Diseases (ICD9-CM) coding and other procedure specific codes.

When anesthesiologists and anesthetists bill Medicare for services performed, these bills include time

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units. Before January 1, 1994,‖# anesthesia time was reported in units of 15-min intervals. Thereafter, actual anesthesia time in minutes is reported on the claims in Medicare Physician Part B, the file that includes physicians' claims. By noting the time units in the physicians' Medicare claims and by abstracting the medical records that generated them, one can develop a model to estimate the number of chart minutes for each procedure based on the anesthesia bill.

The claims data set consisted of 102,781 Medicare beneficiaries collected as part of the Surgical Outcomes Study. Patients were aged 65-85 yr and had undergone general surgical or orthopedic procedures. If more than one surgical admission was recorded for a patient, we chose the first surgical admission of that patient, so that each patient was represented only once in the data set. We then identified the 20 most common procedures in general surgery and the 20 most common orthopedic procedures. We excluded patients that did not have Part B anesthesia bills or who had anesthesia bills less than or equal to 10 min or anesthesia bills greater than 600 min. We also excluded patients from small hospitals, which in our data set had fewer than 50 patients per hospital. The final data set contained 77,638 patients.

Estimating Anesthesia Time from the Medicare Bill

We used the Anesthesia Time Units‖ as a measure of anesthesia procedure time for each patient in the sample. Data were derived from Medicare Part B claims obtained from the Centers for Medicare and Medicaid Services. We defined "anesthesia chart time" as time of recovery room entrance minus time of induction and expressed this in minutes.[17] In previous work, we utilized chart abstraction on 1,931 patients to test the validity of the information from the Medicare bill and the abstracted anesthesia chart time. This work has been published elsewhere in ANESTHESIOLOGY,[17] and our algorithm for relating the billed time denoted in the Part B claim requires the selection of the anesthesia provider who billed the most minutes on the day that the principal procedure was performed. Using such a method, we achieved a Kendal's τ of 0.85, or produced a probability of concordance of 0.93 between the length of the longest anesthesia bill from Medicare and the anesthesia time recorded in the chart.[17]

Statistical Methods

We report the anesthesia time in minutes for each of the 20 general surgical and orthopedic procedures, based on the anesthesia bill (claim) using the methods described above. We also performed an accompanying analysis that included only patients with one surgical procedure noted on the day of the principal procedure. An indicator variable describing whether there were single or multiple procedures on the day of the principal procedure was also included in all regression modeling. When performing multiple regression, we used Huber's robust m-estimation as implemented in SAS Version 9 (SAS Institute, Inc., Cary, NC) using Huber weights.[18–20] For these regressions, we report as R^2 the square of the Spearman rank correlation between the observed and fitted dependent variables. We defined income levels based on patient ZIP code. Utilizing the median household income at the ZIP code level in the 2000 Census and the patients' ZIP codes from our Medicare claims file, we appended to each patient's record in our analysis file an income category based on the following definitions that divided our sample into three equal parts: Lower-Income (< $31,388), Middle-Income ($31,388–$41,858), and Higher Income (>$41,858). MedisGroups Severity Score on admission was used as a physiologic severity adjustment. The score was abstracted on admission for all patients in the data set.[16] We used MedisGroups score 0 as the reference category and compared this to scores 1, 2, and grouped 3 + 4 (due to low numbers in the two highest severity scores).

Results

Length of Anesthesia Time in General Surgical and Orthopedic Procedures

Table 1 displays the distribution of anesthesia times in the 20 general surgical procedures, and table 2 displays the distribution of times for orthopedic procedures. For each procedure, we report the 25th, 50th, and 75th percentiles for all cases, and we also report these same percentiles for cases in which no other procedure was billed except the principal procedure for the date the principal procedure was performed. These are unadjusted times, so that variations across hospitals and patient characteristics may account for some of the dispersion in anesthesia minutes. As can be observed, the median (50th percentile) time varied greatly among procedures. Furthermore, multiple procedures had some influence on the median lengths noted for each procedure.

Estimating the Influence of Patient Factors: Models to Adjust for Procedure and Hospital

We next developed a model to explore how patient characteristics influenced anesthesia time, adjusting for procedure and hospital. In the model, we combined general surgery and orthopedic surgery populations and adjusted for a hospital effect using an indicator for 182 of the 183 hospitals in the study with at least 50 patients. The

‖ Medicare Claims Processing Manual, Chapter 12: Physicians/Nonphysician Practitioners; Section 50: Payment for Anesthesiology Services; Part G: Anesthesia Time and Calculation of Anesthesia Time Units, pp. 91-92. Available at: http://www.cms.hhs.gov/manuals/downloads/clm104c12.pdf. Accessed July 7, 2006.

Anesthesia Billing Guide, Section F: Time Units. Available at: http://www.hgsa.com/professionals/bguides/anesthesia.shtml. Accessed April 2004.

Table 1. Estimated Anesthesia Time for the 20 Most Frequent Surgical Procedures in the Surgical Outcomes Study

		All Patients				Only One Procedure			
ICD9 Code	Procedure	n	25th Percentile	Median	75th Percentile	n	25th Percentile	Median	75th Percentile
485	Abdominoperineal resection of rectum	422	210.0	259.5	319.5	84	205.5	240.0	285.0
4863	Anterior resection of rectum	685	165.0	205.5	255.0	222	145.5	175.5	217.5
4575	Left hemicolectomy	1307	154.5	195.0	241.5	262	142.5	180.0	220.5
4579	Partial large bowel excision	507	150.0	190.5	250.5	77	130.5	157.5	205.5
4576	Sigmoidectomy	2922	139.5	175.5	220.5	678	124.5	154.5	195.0
4652	Large bowel stoma closure	326	115.5	164.3	220.5	159	100.5	124.5	180.0
4562	Partial small bowel resection	1253	120.0	154.5	208.5	112	105.0	130.5	169.5
4573	Right hemicolectomy	3450	120.0	154.5	195.0	940	110.3	135.0	169.5
062	Unilateral thyroid lobectomy	370	109.5	135.0	175.5	286	108.0	135.0	166.5
5122	Cholecystectomy	3883	105.0	135.0	175.5	978	90.0	115.5	145.5
545	Peritoneal adhesiolysis	1268	94.5	124.5	173.3	316	79.5	100.5	124.5
8543	Unilateral extended simple mastectomy	2692	100.5	124.5	154.5	2024	100.5	120.0	148.5
5361	Incisional hernia repair-graft	961	94.5	120.0	160.5	655	85.5	115.5	145.5
5411	Exploratory laparotomy	405	85.5	118.5	162.0	82	70.5	90.0	109.5
8521	Local excision of breast lesion	559	91.5	115.5	145.5	53	55.5	75.0	90.0
8523	Subtotal mastectomy	426	90.0	115.5	142.5	43	55.5	75.0	94.5
5123	Laparoscopic cholecystectomy	7267	90.0	112.5	139.5	3772	88.5	105.0	130.5
5351	Incisional hernia repair	479	75.0	100.5	124.5	269	70.5	90.0	109.5
470	Appendectomy	726	75.0	91.5	120.0	482	70.5	85.5	108.0
8622	Excisional wound debridement	1564	55.5	78.0	120.0	562	49.5	70.5	105.0

n = 31,472.

median hospital in the data set served as the reference group. Table 3 displays the model coefficients on patient characteristics, adjusting for procedure and hospital. For a given procedure, there were some patient covariates that were associated with longer anesthesia procedure times and others that were associated with shorter times. For example, covariates associated with longer anesthesia time included: multiple procedures on the same day as the principal procedure, +18.3 min ($P < 0.0001$); transfer in from another acute care facility, +6.7 min ($P = 0.00002$); black race, +5.5 min ($P < 0.0001$); paraplegia, +4.5 min ($P = 0.0006$); male sex +4.4 min ($P < 0.0001$); cancer, +2.7 min ($P < 0.0001$); diabetes, +2.4 min ($P < 0.0001$); and hypertension, +2.0 min ($P < 0.0001$). Factors associated with shorter anesthesia time included age older than 80 yr *versus* ages 65–70 yr, -4.1 min ($P < 0.0001$); and history of stroke, -3.5 min ($P < 0.0001$).

We also studied the individual hospital effect after

Table 2. Estimated Anesthesia Time for the 20 Most Frequent Orthopedic Procedures in the Surgical Outcomes Study

		All Patients				Only One Procedure			
ICD9 Code	Procedure	n	25th Percentile	Median	75th Percentile	n	25th Percentile	Median	75th Percentile
8108	Lumbar/lumbosacral fusion posterior	273	235.5	298.5	379.5	41	199.5	240.0	294.0
8102	Other cervical fusion anterior	152	182.3	240.0	342.8	30	154.5	195.0	244.5
8153	Revision of hip replacement	971	180.0	234.0	310.5	639	180.0	225.0	300.0
0309	Spinal canal exploration	3166	138.0	180.0	240.0	1478	130.5	169.5	217.5
8155	Revision of knee replacement	1110	142.5	180.0	229.5	792	139.5	178.5	226.5
8051	Excision of intervertebral disc	2565	130.5	165.0	220.5	1529	121.5	154.5	195.5
8151	Total hip replacement	6215	139.5	165.0	196.5	4770	139.5	165.0	195.0
8154	Total knee replacement	12718	130.5	150.0	180.0	10551	130.5	150.0	180.0
7931	Open reduction-internal fixation humerus	690	106.5	142.5	190.5	459	100.5	130.5	169.5
8152	Partial hip replacement	4735	105.0	129.0	154.5	4102	105.0	124.5	150.0
8183	Shoulder arthroplasty	909	105.0	124.5	157.5	129	100.5	130.5	175.5
7932	Open reduction-internal fixation radius/ulna	381	94.5	120.0	157.5	255	88.5	112.5	138.0
7936	Open reduction-internal fixation tibia/fibula	1919	90.0	115.5	145.5	1493	90.0	109.5	135.0
8363	Rotator cuff repair	716	94.5	115.5	145.5	241	93.0	114.0	135.0
7935	Open reduction-internal fixation femur	7439	90.0	109.5	139.5	6292	90.0	109.5	135.0
7855	Internal fixation-femur	795	79.5	100.5	135.0	675	78.0	94.5	124.5
7915	Closed reduction-internal fixation femur	857	79.5	100.5	124.5	729	79.5	100.5	120.0
7865	Remove implanted device-femur	131	75.0	94.5	150.0	87	64.5	85.5	105.0
7912	Closed reduction-internal fixation radius/ulna	214	55.5	64.5	85.5	175	49.5	64.5	79.5
8411	Toe amputation	210	49.5	60.8	79.5	180	47.3	60.0	75.0

n = 46,166.

Table 3. The Contribution of Patient Characteristics to Anesthesia Time

Parameter	Estimate (min)	Standard Error	95% Confidence Limits		*P* Value
Age > 70 and < 75 yr	–1.348	0.419	–2.170	–0.526	0.0013
Age > 75 and < 80 yr	–2.744	0.433	–3.593	–1.895	< 0.0001
Age > 80 and < 86 yr	–4.106	0.468	–5.024	–3.188	< 0.0001
Age > 65 and < 70 yr	Reference group				
Multiple procedures	18.270	0.364	17.558	18.983	< 0.0001
History of alcoholism	–0.023	1.970	–3.884	3.837	0.9905
History of angina	–0.840	0.693	–2.198	0.517	0.2249
History of arrhythmia	–0.127	0.499	–1.105	0.852	0.7994
History of aortic stenosis	1.271	0.899	–0.492	3.034	0.1578
History of cancer	2.706	0.420	1.882	3.530	< 0.0001
History of cardiac heart failure	0.683	0.624	–0.540	1.904	0.2737
History of coagulopathy	4.856	1.503	1.910	7.802	0.0012
History of chronic obstructive pulmonary disease	–0.831	0.411	–1.636	–0.026	0.0430
History of diabetes	2.396	0.382	1.649	3.144	< 0.0001
History of hypertension	1.962	0.302	1.370	2.554	< 0.0001
History of liver disease	0.269	0.984	–1.659	2.197	0.7847
History of myocardial infarction	–0.875	0.655	–2.158	0.409	0.1817
History of postinflammatory pulmonary fibrosis	–0.720	1.263	–3.196	1.757	0.5689
History of paraplegia	4.458	1.307	1.896	7.020	0.0006
History of renal disease	–1.463	1.640	–4.677	1.751	0.3724
History of renal failure	–2.168	1.213	–4.547	0.210	0.0739
History of seizures	–0.602	0.982	–2.527	1.323	0.5398
History of stroke	–3.499	0.737	–4.944	–2.054	< 0.0001
History of thrombosis	–3.814	2.711	–9.128	1.500	0.1595
History of angina	0.690	1.203	–1.668	3.047	0.5665
History of vascular surgery	2.069	2.103	–2.054	6.191	0.3254
Admit from ER	0.046	0.437	–0.811	0.903	0.9167
Transfer in	6.731	1.810	3.184	10.278	0.0002
Male sex	4.427	0.328	3.784	5.070	< 0.0001
Black race (ref = white)	5.456	0.846	3.799	7.114	< 0.0001
Low income	1.657	0.497	0.683	2.631	0.0009
Middle income	0.802	0.442	–0.064	1.669	0.0696
High income	Reference group				
Severity Score 1	0.923	0.704	0.457	2.303	0.1898
Severity Score 2	–0.510	0.810	–2.097	1.078	0.5292
Severity Score 3 and 4	1.135	1.011	0.846	3.115	0.2616
Severity Score 0	Reference group				

The regression model included 77,638 patients, controlling for 39 surgical procedures and 183 hospitals. The model was fit using m-estimation and had an overall rank R^2 of 40%. The median absolute error was 25 min.

adjusting for procedure and patient characteristics. Figure 1 displays the distribution of hospital coefficients in the regression used to produce table 3. There were 182 hospital coefficients in this regression, with the reference hospital coded as a 0. The first box plot uses all 183 hospitals and provides a view of the variability in hospital procedure times. The next two plots are subsets of the first plot, describing hospitals with and without residency programs. There is considerable variation among hospital procedure times, adjusting for patient characteristics. Some of the variation seems to be explained by the presence of residency programs; however, within the groups of hospitals with and without residents, there continued to be considerable variation.

Taking a Closer Look at Race and Income

We next explored the interaction between race and income. We created three groups of income: Higher, Middle, and Lower Income (defined in Materials and Methods) and interacted these groups with race. We found an interesting pattern (table 4). After adjusting for patient characteristics and hospital identifiers, the lowest adjusted anesthesia time was found in the higher-income white group. Compared with this group, lower-income black patients had, on average, 8.5 min longer anesthesia time ($P < 0.0001$). To place this in context, history of paraplegia contributed 4.5 additional minutes to anesthesia time ($P < 0.0001$). Middle-income black patients displayed 4.8-min longer anesthesia time ($P = 0.011$) than higher-income white patients, whereas higher-income black patients showed no difference in anesthesia time compared with the higher-income white group (-0.28 min, $P = 0.880$). Anesthesia time for the lower-income white group was 1.25 min longer than that for the higher-income white group ($P < 0.016$), but middle-income white patients showed no significant difference from higher-income white patients (0.67 min, $P = 0.146$).

To better appreciate the impact of the selection of hospitals by race and income groups, we presented

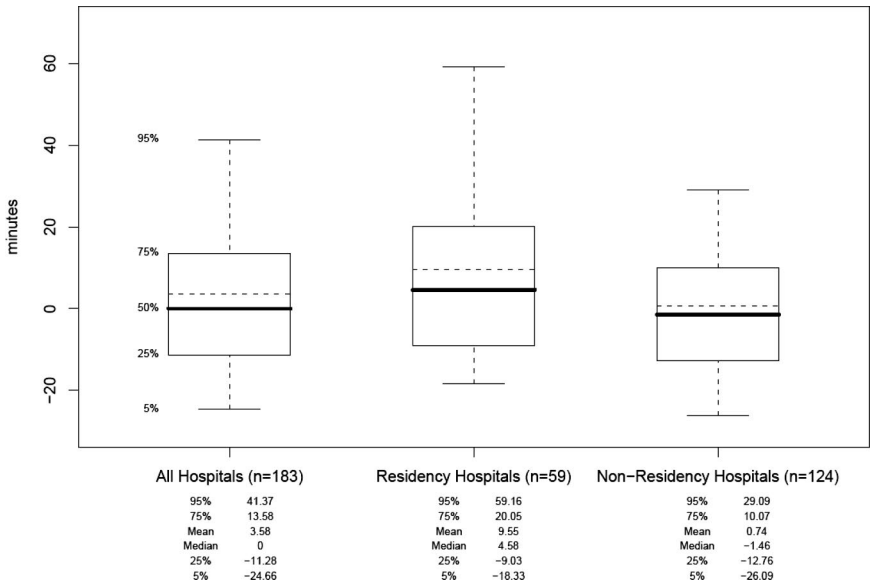

Fig. 1. Differences in hospital-adjusted procedure time. Box plots of the 183 hospitals (with at least 50 patients). As shown from the median values, the typical procedure performed in hospitals with residency programs was approximately 6 min slower than those performed in hospitals without residency programs.

the race and income procedure times in two comparative analyses in table 5. Each cell in the table provides two results, both adjusted for patient characteristics and procedures as in table 3. The top value provides the difference in minutes between the row group and the column group, and the associated *P* value. The bottom result displays the same result also adjusted for the 183 hospitals in the data set, providing the within-hospital differences. For example, low-income black patients had an extra 29 min of procedure time compared with low-income white patients, and this was significant at the $P < 0.0001$ level. However, after adjusting for the hospital, the difference in time decreased to 7 min ($P < 0.0001$). It is interesting to note that before adjustment by hospital, there seems to be a large difference in the procedure times between black and white patients for each income level, but this disappears after adjusting by hospital. This suggests that black patients are going to hospitals that are generally associated with longer procedure times than white patients, for all income levels. Overall, even after adjusting for the hospital, there was a significant effect of race and income on operative time.

Exploring Difference in Procedure Time between Black and White Patients within Hospitals

Although we have seen large differences in procedure time among hospitals, we have not yet closely examined differences in procedure time in individual hospitals by race. Table 6 examines the 15 hospitals with the largest population of black surgical patients in Pennsylvania. Not surprisingly, most of these hospitals had residency programs. For each hospital, we provide the numbers of black and white patients, the type of hospital (Very Major Teaching; Major Teaching; Minor Teaching; and Very Minor or Non-Teaching), the hospital's excess procedure time for its white patients compared with the "other nonresident hospital" white patients, the hospital's excess procedure time for its black patients compared with "other nonresident hospital" white patients, and the adjusted difference in procedure time (black *vs.* white) with the associated *P* value. Within-hospital differences were modeled using the same model as in table 3 but included hospital by race interaction terms. The overall Wald test of race-by-hospital interaction[21] was significant at the 0.029 level (suggesting 15 hospitals plus two hospital groups differed in black *versus* white

Table 4. The Influence of Patient Race and Income on Anesthesia Time

Parameter	Estimate (min)	Standard Error	95% Confidence Limits		*P* Value
Black race/lower income	8.47	1.09	6.35	10.60	< 0.0001
Black race/middle income	4.81	1.90	1.09	8.53	0.0113
Black race/higher income	–0.28	1.83	–3.87	3.31	0.8798
White race/lower income	1.25	0.52	0.23	2.28	0.0164
White race/middle Income	0.67	0.46	–0.23	1.57	0.1462
White race/higher Income	Reference group	—	—	—	—

Each variable reflects a race-income group interaction, using the high-income white group as the reference group. The model includes exactly the same parameters as in table 3 except the race and income terms have been substituted with the following interactions. The model included 77,638 patients, controlling for 39 surgical procedures and 183 hospitals. The model was fit using m-estimation and had an overall rank R^2 of 40%. The median absolute error was 26 min.

Table 5. The Influence of Patient Race and Income on Anesthesia Procedure Time

	WL (n = 9,324)	BM (n = 513)	WM (n = 25,060)	BH (n = 547)	WH (n = 27,473)
BL (n = 2,002)	29 (< 0.0001)	16 (<0.0001)	31 (< 0.0001)	15 (< 0.0001)	27 (< 0.0001)
BL adjusted by 183 hospitals	7 (< 0.0001)	4 (0.0801)	8 (< 0.0001)	9 (< 0.0001)	8 (< 0.0001)
WL (n = 9,324)	—	−14 (< 0.0001)	1 (0.0015)	−14 (< 0.0001)	−2 (< 0.0001)
WL adjusted by 183 hospitals		−4 (0.0614)	1 (0.1853)	2 (0.4124)	1 (0.0164)
BM (n = 513)		—	15 (< 0.0001)	−1 (0.8243)	12 (< 0.0001)
BM adjusted by 183 hospitals			4 (0.0283)	5 (0.0491)	5 (0.0113)
WM (n = 25,060)			—	−16 (< 0.0001)	−3 (< 0.0001)
WM adjusted by 183 hospitals				1 (0.6108)	1 (0.1462)
BH (n = 547)				—	12 (< 0.0001)
BH adjusted by 183 hospitals					0 (0.8798)

Each cell reflects a race-income status group comparison displaying the row variable minus the column variable in minutes. Each cell provides two estimates: the top estimate adjusts for all patient characteristics found in table 3 (including procedures and an indicator for multiple procedures) but does not include adjustments for each hospital. The bottom estimate adjusts for each of the 183 hospitals in the data set. For example, low-income black patients had an extra 29 min of procedure time than low-income white patients (significant at the $P < 0.0001$ level). However, after adjusting for the hospital, the difference in time decreased to 7 min ($P < 0.0001$).

B = Black; H = high income; L = low income; M = middle income; W = White.

excess procedure times). Adjusted procedure times in hospitals 4, 5, 6, 10, 11, other resident hospitals, and other nonresident hospitals were significantly longer for their black patients than their white patients. The pattern is complex, however. Hospital 3 is much slower than most others, but the difference between black and white procedure times is negligible and much smaller than at most hospitals. Hospital 5 is faster than most other hospitals, even for black patients, but there is 15-min difference between procedure times for black *versus* white patients.

There was considerable variability in hospital procedure length within this group of hospitals. For example, when comparing hospitals 5 and 11 in table 6, we see

Table 6. Exploring Differences in Operative Procedure Time between Black and White Patients within Hospitals

Hospital	Teaching Type*	Black (n)	White (n)	Hospital Effect for Black Patients, min	Hospital Effect for White Patients, min	Excess Minutes (B – W)	*P* Value
1	Major	153	352	19.4	16.0	3.4	0.404
2	V Major	147	322	48.2	40.7	7.5	0.093
3	V Major	130	326	91.0	89.7	1.3	0.786
4	V Major	125	108	39.6	27.2	12.4	0.034
5	Major	118	1319	-6.3	–21.3	15.0	0.0005
6	Major	112	437	49.2	36.6	12.6	0.0008
7	Minor	112	43	38.7	42.4	–3.7	0.641
8	Non-Teaching	111	1006	4.7	0.4	4.3	0.334
9	V Major	109	71	64.8	57.9	6.9	0.314
10	Major	107	505	13.7	3.8	9.9	0.037
11	V Major	105	178	106.3	90.2	16.1	0.003
12	V Major	100	1007	64.7	69.4	–4.7	0.321
13	V Major	97	144	41.4	48.5	–7.1	0.225
14	V Major	95	445	42.3	35.8	6.5	0.199
15	V Minor	94	78	26.3	25.8	0.5	0.948
Other resident	Other resident	689	27,437	7.9	–0.6	8.5	< 0.0001
Other nonresident	Other nonresident	678	39,503	9.3	Reference = 0	9.3	< 0.0001

This table represents the 15 hospitals with the largest population of black patients in Pennsylvania. For each hospital, we provide the numbers of black and white patients, the type of hospital (Very Major Teaching [V Major] = resident to bed ratio >0.60; Major Teaching [Major] = resident to bed ratio 0.25–0.60; Minor Teaching (Minor) = resident to bed ratio 0.05–0.25; Very Minor or Non-Teaching (V Minor or Not Teaching) = resident to bed ratio <0.05.), the "hospital effect for white patients" and the "hospital effect for black patients" (which represent the excess minutes for a typical procedure compared with 39,503 white patients at the "other nonresident" reference group), adjusted excess procedure time (black minus white patient time within each hospital), and the associated *P* value. The Wald test for race by hospital interaction was significant at the 0.029 level (suggesting hospitals differed in excess procedure times for black *vs.* white patients). Black patients at hospitals 4, 5, 6, 10, and 11 had procedure times significantly longer than white patients. Excess times were modeled using the same model as in table 3 but including hospital by race interaction terms.

* All teaching hospitals had a designation of residency training approval by the Accreditation Council for Graduate Medical Education according to the AHA Annual Survey.

that hospital 11's adjusted procedure time was more than 1.5 hours longer than that of hospital 5. For white patients, hospital 11 procedures were 90 min longer than the "other nonresident" hospital reference white group; for black patients, procedures took 106 min longer than that for white patients in the "other nonresident" group, compared with hospital 5, where procedures for white patients were 21 min faster and black patients were 7 min faster than the white "other nonresident" group. Other large differences in procedure length among individual hospitals were common.

We also fit a separate regression (results not shown) in which the 15 hospitals in table 6 were combined into a single group and found that procedure times were 24 min slower for white patients in this group ($P < 0.0001$) than for white patients at both "other residency hospitals" and "other nonresidency hospitals," whereas for black patients, the difference was 41 min longer than the white patients at the "other residency hospitals" and "other nonresidency hospitals," which corresponds to an additional 17 min for black patients over the difference for white patients ($P < 0.0001$) (that is, 24 + 17 = 41 min).

The Influence of Race and Obesity on Procedure Time

One possible explanation to account for slower procedure times in black patients as compared to white patients could relate to obesity. If there was differential obesity between groups, and if obesity were responsible for longer surgery, then this may have lead to a spurious relationship between race and procedure length. Although Medicare claims did not record height and weight, we did have such information on a subset of the data set consisting of 1931 charts that were abstracted for the Surgical Outcomes Study. This was the data set used in the companion paper in this issue[17] and in previous publications.[12,13] Following convention, a body mass index (BMI) in the recommended range 18.5 to <25 is considered normal (used as the reference group), 25 to <30 is overweight, 30 to <35 is obese, >35 is severely obese, and <18.5 is underweight. In a model that included patient characteristics and procedures and hospital identifiers for the 19 largest hospitals in the data set, the black *versus* white procedure time difference was 43.8 min ($P < 0.0001$). When BMI information was added to the model, the black *versus* white procedure time difference remained almost unchanged at 44.8 min ($P < 0.0001$). BMI did have an effect on procedure time (consistent with others[22–24]): patients with BMI <18.5 had procedures 12.4 min ($P = 0.02$) faster than the reference group; those with BMI 25-30 had 11.9 min slower procedure time ($P = 0.0017$) than the reference group. Patients with BMI 30-35 had procedures 17.2 min slower than the reference group ($P = 0.003$), and those with BMI >35 had a 14.4-min longer procedure time than the reference group ($P = 0.066$). Despite the association of BMI with procedure time, we found that including BMI information did not influence the longer procedure time associated with black patients compared with white patients in this Medicare population. Of note, 10.6% of black patients had BMI values ≥30 *versus* 11.4% in white patients ($P = 0.20$).

The Influence of Other Hospital Characteristics on Procedure Length

After adjustment for patient characteristics, principal procedure, multiple procedures, race, and income, we next explored whether other hospital factors were associated with procedure length as measured through anesthesia time units. We found that the presence of a trauma center predicted an additional 9.6 min of procedure length ($P < 0.0001$); however, hospitals with 200 or more beds (compared with smaller hospitals) had only slightly shorter procedure length (-2.0 min, $P < 0.0001$). Location of a hospital in an urban *versus* rural setting (metropolitan area population ≥100,000 *vs.* <100,000) had a slightly longer length (+1.8 min, $P = 0.0006$).

Discussion

After adjusting for procedure, we found that specific patient and hospital characteristics predicted anesthesia time. Whereas anesthesia and surgical times are often discussed and analyzed in the anesthesia and surgical literature, few large-scale studies have been reported, in part because costly chart review would be necessary at most institutions. To our knowledge, estimates of anesthesia time by procedure using Medicare claims have not been reported on a large scale among multiple institutions before this study. Results from the Veteran's Administration studies have explored variations in procedure time among hospitals in the Veteran's Administration system,[2] but studies utilizing Medicare claims obtained through Medicare, allowing for modeling using a vast number of hospitals and patients, has not been previously reported.

There are a number of important findings that should be noted from this analysis. First, we have identified specific medical conditions that may influence procedure length as defined using Anesthesia Time Units from Medicare. Although not surprising, such differences can be considerable, as we have reported the independent effect of these comorbidities, each adding some time to the procedure. One mechanism by which time is influenced by the presence of comorbidities may be in the set-up time, in that patients with comorbidities may require more monitoring before incision. However, the most important factor associated with procedure length based in Anesthesia Time Units is the incision to closure

time, as we demonstrated in the companion article, in which the Spearman correlation between the time from induction to entrance to the recovery room time *versus* the time from incision to closure was 90%.[17]

We observed important variation in adjusted procedure length among hospitals. This was especially striking when we observed variation in procedure length among some individual large teaching hospitals. For example, when comparing hospitals 5 and 11 in table 6, we found that hospital 11's adjusted procedure time was more than 1.5 hours longer than that of hospital 5. Other large differences in procedure length between individual hospitals were not unusual. The question then becomes what explains these differences. As we have described in figure 1, the mere presence of a residency program cannot explain the magnitude of the differences in procedure length—indeed, there seems to be great variability inside hospitals with residency programs. Clearly, there is considerable heterogeneity in what we mean by "residency program," and we have learned from this analysis that defining a hospital by whether it has residents does little to help to explain our findings.

We also found striking differences in the procedure length of black patients *versus* white patients, and income level also played an important role. For example, we observed that black patients with lower incomes had adjusted procedure times that were 29 min longer than those in similar lower-income white patients. However, this difference decreased to 12 min when comparing high-income black patients with high-income white patients. More important, the 29-min difference between lower-income black patients and white patients decreased to 7 min when adjusting for the individual hospital, and the 12-min difference between higher-income black patients and white patients vanished completely after accounting for the hospital in which each patient underwent surgery. This suggests that black patients seem to be going to hospitals with very different procedure lengths than white patients. When examining the disparity in procedure time between black and white patients, differences in procedure length between where the patients had surgery explains far more of the disparity than differences between how black patients and white patients are actually treated inside of hospitals. Efforts to understand why hospitals where black patients undergo surgery (often the large urban teaching hospitals listed in table 6) require so much longer procedure time for both black and white patients may aid in helping to reducing this apparent disparity. Such reductions in procedure length would benefit both black and white patients but have a disproportionately larger benefit for black patients, simply because a greater percentage of black patients are admitted to these slower hospitals.

Although most of the differences between procedure lengths for black and white patients can be explained by where patients are undergoing surgery, we also found significant differences between white and black patients inside some hospitals, as shown in table 6. In Pennsylvania, of the 15 hospitals with the largest black populations in the state, 5 had significant differences in adjusted procedure time ranging from 9 to 16 min. There were also considerable (and statistically significant differences) between black and white patients in some hospitals with smaller black populations not displayed in table 6.

Although our analysis may shed light on individual procedure lengths, it does not directly allow us to analyze hospital efficiency or clinical productivity.[1,25–28] Our data only involve Medicare patients, so we do not know how many and when other non-Medicare patients are being treated.

In summary, we used the Medicare anesthesia bill to analyze information on anesthesia time in a large sample of surgical patients among many hospitals. We have attempted to control for patient characteristics and procedures and to explore how different patient and hospital characteristics influence procedure time. In the process, we found that hospital and patient characteristics do influence anesthesia procedure time. Important variables include patient characteristics such as multiple procedures, transfer status, paraplegia, male sex, hypertension, diabetes, and, perhaps surprisingly for this insured Medicare population, race and income. The most important factor explaining why race and income influence procedure time was the hospital in which these patients underwent surgery, not differential treatment inside hospitals. Lower-income black patients tended to go to hospitals that had longer procedure times for both black and white patients. Analysis within hospitals displayed far less differences in procedure times for black and white patients, but we did observe some significant differences between black and white patients inside a number of hospitals. Reducing the procedure length in large urban teaching hospitals may benefit both black and white patients at these hospitals and would have a disproportionately beneficial effect on black patients simply because a greater percentage of the black patient population is admitted to these hospitals than the white patient population.

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