Published in final edited form as:

World Neurosurg. 2018 February ; 110: e689–e698. doi:10.1016/j.wneu.2017.11.071.

Association of hospital teaching status with neurosurgical outcomes: an instrumental variable analysis

Kimon Bekelis, M.D.^{1,2,3,4}, Symeon Missios, M.D.⁵, Shannon Coy, M.D.⁶, and Todd A. MacKenzie, Ph.D.^{2,4,7}

¹Department of Neurosurgery, Thomas Jefferson University Hospital, Philadelphia, PA

²The Dartmouth Institute for Health Policy and Clinical Practice, Lebanon, NH

³Population Health Research Institute of New York at CHS, Melville, NY

⁴Geisel School of Medicine at Dartmouth, Hanover, NH

⁵Center for Neuro and Spine, Akron General – Cleveland Clinic, Akron, OH

⁶Department of Pathology, Brigham and Women's Hospital, Boston, MA

⁷Department of Community and Family Medicine, Dartmouth-Hitchcock Medical Center, Lebanon, NH

Abstract

Background—The interpretation of the results of prior studies on the association of hospital teaching status with surgical outcomes is limited by selection bias. We investigated whether undergoing surgical operations in teaching hospitals is associated with improved outcomes.

Methods—We performed a cohort study of all patients undergoing spine and cranial operations who were registered in the New York Statewide Planning and Research Cooperative System (SPARCS) database from 2009-2013. We examined the association of teaching status (defined as academic affiliation for the primary analysis) with inpatient case-fatality, discharge to a facility, and length of stay (LOS). An instrumental variable analysis was used to control for unmeasured confounding and simulate the effect of a randomized trial.

Results—During the study period, 186,483 patients underwent surgical operations that met the inclusion criteria. Instrumental variable analysis demonstrated that hospitalization in teaching hospitals was associated with higher rates of case-fatality (Adjusted difference, 25%; 95% CI, 4% to 46%), discharge to a facility (Adjusted difference, 5.7%; 95% CI, 4.5% to 7.0%), and longer LOS (Adjusted difference, 31.4%; 95% CI, 16.0% to 46.1%) in comparison to non-teaching hospitals. The same associations were present in propensity score adjusted mixed effects models. These persisted in pre-specified subgroups stratified on particular operations and for different definitions of teaching hospitals.

Corresponding Author: Kimon Bekelis, M.D., The Dartmouth Institute for Health Policy and Clinical Practice, One Medical Center Drive, Lebanon, NH 03755, T. 6036505110, F. 6036504547, kbekeles@gmail.com.

Conflicts of interest

The authors have no conflicts to disclose

Conclusions—Using a comprehensive all-payer cohort of surgical patients in New York State we identified an association of treatment in teaching hospitals with increased case-fatality, rate of discharge to rehabilitation and longer LOS. Further research into the factors contributing to superior outcomes in non-teaching institutions is warranted.

Keywords

surgery; teaching hospitals; center of excellence; public reporting; SPARCS

INTRODUCTION

Teaching hospitals are the backbone of healthcare delivery. Their mission includes medical education and residency training, research, and treatment of indigent patients.² These institutions are highly regarded by the public, as reflected in national opinion surveys such as the rankings of *U.S. News and World Report*. This is likely secondary to the perception that teaching hospitals provide treatment for rare diseases and complex patients, while employing specialized services and advanced technology.² However, concerns have been raised about the quality of care provided by trainees in this setting. Highly publicized cases about the “July effect”,²⁵ or the impact of concurrent surgeries,^{19,24} conducted by trainees, have fueled the debate about the quality of surgical interventions performed in teaching institutions. Recently, the expansion of subspecialized services, and complex interventions in non-teaching facilities adds a new dimension to this controversy.

The results of prior studies examining the association of hospital teaching status with surgical and medical outcomes have been conflicting. Some researchers have demonstrated superior outcomes for patients hospitalized in teaching hospitals,^{1,3,9,16,20–22,29,31,37,41} whereas others failed to show such benefit.^{7,8,10,13,18,28,30,34,40} The main limitation of these and other retrospective analyses is the lack of control for unmeasured confounding, stemming from the non-random allocation of patients to particular hospitals. There has been no previous investigation attempting to answer this question in a comprehensive all-payer cohort of surgical patients while controlling for unmeasured confounding.

We used the New York Statewide Planning and Research Cooperative System (SPARCS)¹⁷ to study the association of hospitalization in a teaching hospital with case-fatality, discharge to a facility, and length of stay (LOS) for patients undergoing surgical operations. An instrumental variable (IV) analysis was used to control for unmeasured confounding and simulate the effect of randomization.

METHODS

New York Statewide Planning and Research Cooperative System (SPARCS)

This study was approved by our institutional Committee for Protection of Human Subjects. This study is based on de-identified data and therefore the consent process was waived by the committee. All patients who were hospitalized for spine or cranial operations, and were registered in the SPARCS (New York State Department of Health, Albany, NY)¹⁷ database between 2009 and 2013 were included in the analysis. For these years, SPARCS contains

patient-level details for every hospital discharge, ambulatory surgery, and emergency department admission in New York State as coded from admission and billing records. More information about SPARCS is available at <https://www.health.ny.gov/statistics/sparcs/>.

Cohort Definition

In order to establish the cohort of patients, we used *International Classification of Disease-9-Clinical Modification* (ICD-9-CM) codes to identify adult (18 years and older) patients in the database, who were hospitalized after spinal (lumbar fusion, anterior cervical decompression and fusion, posterior cervical decompression and fusion, cervical laminectomy, lumbar laminectomy, and lumbar discectomy) and cranial operations (craniotomy for tumor resection, craniotomy for aneurysm clipping, endovascular aneurysm treatment) (Table S1) between 2009 and 2013.

Outcome variables

The primary outcome variable was case-fatality during the initial hospitalization after the surgical operations above. Secondary outcomes were LOS during the initial hospitalization and discharge to a facility. The latter included all locations of disposition other than the patient's home.

Exposure variables

The primary exposure variable was whether the patient was admitted to a teaching hospital for their operation. For our primary analysis this was defined as hospitals with university affiliations, during the years of the study. For our sensitivity analysis, teaching hospitals were defined as hospitals with active neurosurgery residency programs or hospitals with any residency program (including medicine programs), during the years of the study.

Covariates (Table S1) used for risk-adjustment were age, gender, race (African-American, Hispanic, Asian, Caucasian, other), insurance (private, Medicare, Medicaid, uninsured, other), provider case-specific volume, and the specific type of procedure performed.

The comorbidities used for risk adjustment were diabetes mellitus (DM), smoking, chronic lung disease, hypertension, hypercholesterolemia, peripheral vascular disease (PVD), congestive heart failure (CHF), coronary artery disease (CAD), history of ischemic stroke, history of transient ischemic attack (TIA), alcohol abuse, obesity, chronic renal failure (CRF), and coagulopathy. Only variables that were defined as "present on admission" were considered part of the patient's comorbidity profile.

Statistical analysis

The association of teaching status with our outcome measures was examined in a multivariable setting. Patients admitted to a teaching hospital or a non-teaching institution were non-randomly directed to either facility. In order to account for this unmeasured confounding, and to simulate the effect of randomization, we used an instrumental variable analysis, an econometric technique (Supplementary Methods).³⁵ The percentage of teaching hospitals in the patient's county was used as an instrument. This advanced observational technique has been used before by clinical researchers, to answer comparative effectiveness

questions for different interventions or treatment facilities. The goal is to simulate randomization, especially when the baseline functional characteristics of the patients are unknown (similar to our application).^{26,36,39}

A good instrument is not associated with the outcome other than through the exposure variable of interest (a requirement known as the exclusion restriction criterion).¹⁵ In our case it is unlikely that our instrument would be associated with case-fatality in any way other than the choice of treatment facility. A two stage least squares (2SLS) method was used for the calculation of the coefficients. The value of the F statistic in the first stage of the 2SLS approach was 125, which is consistent with a strong instrument (F statistic>10), based on a practical rule.³⁵

A probit regression was used for the categorical outcomes (case-fatality, discharge to a facility),¹⁴ and a linear regression for the linear outcomes (LOS). The values of LOS were positively skewed and therefore were log transformed for the purpose of the analysis. The covariates used for risk adjustment in these models were: age, gender, race, insurance, provider case-specific volume, the specific type of procedure performed and all the comorbidities mentioned previously. Fixed effects were used for procedure type. Since the coefficients produced by the probit function are not interpretable, we used the marginal effects of our independent variables instead.

In order to demonstrate the robustness of our data in a sensitivity analysis, we used standard techniques to account for measured confounding, while accounting for clustering at the hospital level. For categorical outcomes we used a probit regression model with hospital ID as a random effects variable, while controlling for all the covariates mentioned previously. In an alternative way to control for confounding, we used a propensity adjusted (with deciles of propensity score) probit regression model. We calculated the propensity score of undergoing treatment in a teaching hospital with a separate probit regression model, using all the covariates mentioned previously. For continuous outcomes, we performed similar analyses using linear models. Finally, we repeated the above analyses in pre-specified subgroups, specific to the procedure performed including lumbar fusion, anterior cervical decompression and fusion, posterior cervical decompression and fusion, cervical laminectomy, lumbar laminectomy, and lumbar discectomy, craniotomy for tumor resection, craniotomy for vascular procedures, and endovascular interventions. We also repeated our analyses using alternative definitions of teaching hospitals (hospitals with a neurosurgery program, or hospitals with any residency program, including medicine programs). The direction of the observed associations did not change and therefore these results are not reported in detail. Instead, we report some iterations of our sensitivity analyses grouped in cranial and spinal procedures (Table S2).

Regression diagnostics were performed for all models. All results are based on two sided tests, and the level of statistical significance was set at 0.05. This study, based on 186,483 patients, has sufficient power (80%) at a 5% type I error rate to detect differences in case-fatality, as small as 0.07%. Statistical analyses were performed using Stata version 13 (StataCorp, College Station, TX).

RESULTS

Patient characteristics

In the selected study period there were 186,483 patients hospitalized after cranial and spinal operations (mean age was 55.1 years, with 50.7% females), who were registered in SPARCS. 158,288 (84.9%) were hospitalized in teaching hospitals, and 28,195 (15.1%) in non-teaching institutions. The characteristics of the two cohorts at baseline can be seen in Table 1.

Inpatient case-fatality

Overall, 1,175 (0.74%) inpatient deaths were recorded in teaching hospitals and 101 (0.36%) in non-teaching institutions. Hospitalization in a teaching hospital after surgical procedures was associated with higher case-fatality in comparison to non-teaching institutions (Difference, 0.4%; 95% CI, 0.3% to 0.5%) in unadjusted analysis. Likewise, using a probit regression with instrumental variable analysis, we identified that teaching hospitals were associated with a 0.3% higher (adjusted absolute difference) case-fatality (95% CI, 0.2% to 0.4%), in comparison to non-teaching institutions (Table 2). This persisted in a mixed effects probit regression model (Adjusted difference, 0.5%; 95% CI, 0.4% to 0.6%) and a propensity score adjusted probit model (Adjusted difference, 0.3%; 95% CI, 0.2% to 0.4%).

Length-of-stay

The average LOS was 5.8 days (SD 17.2) in teaching hospitals, and 4.2 days (SD 9.6) in non-teaching institutions. Teaching hospitals were associated with longer LOS than non-teaching institutions (Percentage change, 44.2%; 95% CI, 29.3% to 59.0%) in the unadjusted analysis. Using a linear regression with instrumental variable analysis we demonstrated (Table 2) that hospitalization in a teaching hospital was associated with 31.4% longer (percentage change) LOS in comparison to non-teaching institutions (95% CI, 16.0% to 46.1%). We found similar results in a mixed effects linear regression model (Percentage change, 42.5%; 95% CI, 25.0% to 54.3%).

Discharge to a facility

Overall, 56,172 (35.9%) patients were discharged to a facility after hospitalization in teaching hospitals and 6,915 (24.7%) in non-teaching institutions. Hospitalization in a teaching hospital after surgical procedures was associated with higher rate of discharge to a facility in comparison to non-teaching institutions (Difference, 9.6%; 95% CI, 9.1% to 10.0%) in unadjusted analysis. Likewise, using a probit regression with instrumental variable analysis, we identified that teaching hospitals were associated with a 10.6% increased rate (adjusted absolute difference) of discharge to a facility (95% CI, 6.6% to 14.8%), in comparison to non-teaching institutions (Table 2). This persisted in a mixed effects probit regression model (Adjusted difference, 19.2%; 95% CI, 15.0% to 23.3%) and a propensity score adjusted probit model (Adjusted difference, 9.9%; 95% CI, 9.2% to 10.3%).

DISCUSSION

Using a comprehensive all-payer cohort of patients undergoing cranial and spinal operations in New York State we identified an association of hospitalization in a teaching hospital with increased case-fatality, rate of discharge to a facility, and LOS. These results were consistent across techniques to control for confounders. As the practice of medicine is shifting from authority to accountability, increasing public scrutiny has drawn attention to the impact of trainee provided care on the outcomes of surgical operations.¹⁰ However, the association of hospital teaching status with the outcomes of surgical procedures has not been studied before in a way that accounts for unmeasured confounders.

Prior retrospective investigations have demonstrated conflicting results regarding the association of teaching status with patient outcomes. Several researchers have used medical record reviews to identify the impact of teaching status.^{1,3,7,18,20,30,31,38,41} Some demonstrated superior outcomes in teaching institutions, whereas others have shown higher complication rates and worse nursing care in these facilities. Similarly conflicting results have been identified in prior regional and national investigations of administrative databases.^{8–10,12,13,16,21,22,28,29,32–34,37,40} Dimick et al¹⁰ in a study of the Nationwide Inpatient Sample (NIS) was not able to demonstrate a survival benefit of teaching institutions for patients undergoing complex surgical procedures. Hospital volume was a more important determinant of outcomes than teaching status in their analysis. Zafar et al⁴⁰ reached the same conclusions for emergency general surgery procedures. A similar study in spine patients using the NIS demonstrated inconclusive results.⁹ In a similar study in NSQIP²³ no difference was identified in cases with resident participation in patients undergoing craniotomies for tumor resection. All these prior investigations have significant methodologic drawbacks. Those mainly stem from the lack of rigorous control for measured and unmeasured confounders, particularly the fact that patients were non-randomly selected for either treatment center. The lack of accounting for this selection bias significantly restricts the interpretation of these findings and likely explains the variability in outcomes.

Our study purposefully addresses many of these methodologic limitations. First, we created a comprehensive statewide cohort, in order to accurately represent practice in the community. Second, we used advanced observational techniques to control for confounding. An instrumental variable analysis was used to control for unmeasured confounders (mainly the a priori selection of treatment facility), and simulate the effects of randomization. The instrumental variable analysis is expected to control for selection bias and report results for patients of similar functional status. Previous studies have used this technique to compare the performance of different institutions. Bekelis et al⁶ demonstrated that Primary Stroke Centers (PSC) offer a survival benefit for stroke patients, using the differential distance to a PSC as an instrument. Propensity score stratification was also used to adjust our regressions for known confounders, whereas the possibility of clustering was accounted for by using mixed effects methods. Our results were robust across techniques, supporting the validity of the observed associations.

There are several potential reasons behind the superiority of non-teaching institutions in our analysis. Prior investigations have demonstrated inferior care provided by residents treating

patients undergoing cranial and spinal operations after the implementation of the Accreditation of Graduate Medical Education duty-hour restrictions.^{4,5,11} These researchers cite decreased resident experience in medical management, poorer operative skills, increased number of hand-outs, and fragmentation of care as the reasons behind their observations. The possibility of concurrent surgeries and limited supervision can also not be excluded. We used multiple different definitions of a teaching hospital in our sensitivity analyses. Those include university affiliation, presence of a neurosurgery residency program, and presence of any residency program. Our results were remarkably consistent among all definitions. It is unlikely that the observed associations can only be explained by the presence of residents. Alternative, and not mutually exclusive, etiologies include the chronic underfunding of academic medicine, and the impact of trainees in other levels of the academic medical enterprise. From a policy perspective, it is important to further investigate the reasons behind these discrepancies. Correcting such disparities is critical both for patient wellbeing and the viability of our resident training system.

Our study has several limitations. Residual confounding could account for some of the observed associations. However, this is minimized to the extent that we are using a good instrument for treatment facility. The F statistic in our analysis suggests a strong instrument. In addition, coding inaccuracies will undoubtedly occur and can affect our estimates. However, it is unlikely that coding for procedures is inaccurate since it is a revenue generator and is under scrutiny by payers. Although SPARCS includes all hospitals from the entire New York State, the generalization of this analysis to the entire US population is uncertain. SPARCS does not provide any clinical information on the functional status of the patients, which can affect the choice of institution. Additionally, it does not provide any information on the specialty of the primary operator performing the procedures. However, the use of the instrumental variable analysis is attempting to control for unknown confounders such as these, and has been used before in SPARCS.^{26,36,39}

Additionally, we were lacking post-hospitalization, and long-term data on our patients. Quality metrics are also not available through SPARCS, and therefore we cannot compare the two hospital settings on these outcomes. The definitive comparison of the two hospital settings on functional outcomes can only be done in prospective registries. In this direction, the NeuroPoint Alliance has created the first neurosurgical registry, with results expected in the near future.²⁷ Most of the patients in our primary analysis were hospitalized in teaching institutions. We employed multiple different methods to test the sensitivity of our conclusions, including a propensity-matched analysis that balances the sample. Our results were remarkably robust despite the different definitions of teaching institutions and the different versions of our analysis. Therefore, it is unlikely that the results would be affected by the difference in numbers of patients treated in either type of institution. Finally, causality cannot be definitively established based on observational data, despite the use of advanced techniques, such as the instrumental variable analysis.

Conclusions

The interpretation of the results of prior studies on the association of hospital teaching status with surgical outcomes is limited by selection bias. We investigated whether undergoing

surgical operations in teaching hospitals is associated with improved outcomes, using an instrumental variable analysis to simulate the effects of randomization. Using a comprehensive all-payer cohort of surgical patients in New York State we identified an association of treatment in teaching hospitals with increased case-fatality, rate of discharge to rehabilitation and longer LOS. Further research into the factors contributing to superior outcomes in non-teaching institutions is warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

None

Funding: Supported by grants from the National Institute on Aging (PO1- AG19783), the National Institutes of Health Common Fund (U01-AG046830), and the National Center for Advancing Translational Sciences (NCATS) of the NIH (Dartmouth Clinical and Translational Science Institute-UL1TR001086). The funders had no role in the design or execution of the study.

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Table 1

Patient characteristics

	All Patients N= 186,483			Teaching hospitals* 118 facilities N= 158,288			Non-teaching hospitals 57 facilities N= 28,195			P-Value
	Mean	SD		Mean	SD		Mean	SD		
	N	%		N	%		N	%		
Age	55.07	14.85		55.05	14.93		55.17	14.38		0.212
Female gender	94519	50.69		80156	50.64		14363	50.94		0.349
Race	130758	70.31	Caucasian	107523	68.08		23235	82.86		<0.0001
	18482	9.94	African-American	16544	10.47		1938	6.91		<0.0001
	14124	7.59	Hispanic	13051	8.26		1073	3.83		<0.0001
	3804	2.05	Asian	3675	2.33		129	0.46		<0.0001
	18816	10.12	Other	17149	10.86		1667	5.94		<0.0001
Insurance	49907	26.81	Medicare	42012	26.60		7895	28.00		<0.0001
	8365	4.49	Medicaid	6861	4.34		1504	5.33		<0.0001
	97601	52.44	Private	84166	53.29		13435	47.65		<0.0001
	4481	2.41	Uninsured	4127	2.61		354	1.26		<0.0001
	25777	13.85	Other	20772	13.15		5005	17.75		<0.0001
Comorbidities										
Transient Ischemic Attack	224	0.12		221	0.14		3	0.01		<0.0001
Ischemic Stroke	278	0.15		257	0.16		21	0.07		<0.0001
Coronary Artery Disease	17993	9.65		15148	9.57		2845	10.09		0.006
Chronic Obstructive Pulmonary Disease	27836	14.93		23107	14.60		4729	16.77		<0.0001
Congestive Heart Failure	3951	2.12		3371	2.13		580	2.06		0.436
Diabetes Mellitus	28306	15.18		23743	15.00		4563	16.18		<0.0001
Coagulopathy	2267	1.22		1970	1.24		297	1.05		0.007
Chronic Renal Failure	4527	2.43		3880	2.45		647	2.29		0.116
Hypertension	83620	44.84		70539	44.56		13081	46.39		<0.0001
Smoking	26855	14.40		21587	13.64		5268	18.68		<0.0001

	All Patients N= 186,483		Teaching hospitals* 118 facilities N= 158,288		Non-teaching hospitals 57 facilities N= 28,195		P-Value
	Mean	SD	Mean	SD	Mean	SD	
Hypercholesterolemia	53930	28.92	45130	28.51	8800	31.21	<0.0001
Obesity	19391	10.40	16548	10.45	2843	10.08	0.060
Alcohol	3095	1.66	2715	1.72	380	1.35	<0.0001
Peripheral Vascular Disease	3928	2.11	3247	2.05	681	2.42	<0.0001

* Hospitals with academic affiliation

Table 2

Multivariable models examining the association of teaching hospitals with outcomes

	Inpatient Mortality [¶]	P-value	Discharge to a facility [¶]	P-value	Length-of-stay [§]	P-value
	Adjusted Difference (95% CI)		Adjusted Difference (95% CI)		Adjusted difference (95% CI)	
Instrumental variable analysis [*]	0.3% (0.2% to 0.4%)	<0.001	10.6% (6.6% to 14.8%)	<0.001	0.3% (0.2% to 0.5%)	<0.001
Mixed effects regression ^{##}	0.5% (0.4% to 0.3%)	<0.001	19.2% (15.0% to 23.3%)	<0.001	0.4% (0.3% to 0.5%)	<0.001
Propensity score adjusted regression ^{##}	0.3% (0.2% to 0.4%)	<0.001	9.9% (9.2% to 10.3%)	<0.001	NA	NA

CI: confidence intervals

^{*} Differential distance to teaching hospital was used as an instrument of treatment hospital

^{##} Hospital ID was used as a random effects variable

[¶] Regressions based on probit models

[§] Regressions based on linear models