Impact of the 2003 ACGME Resident Duty Hour Reform on Hospital-Acquired Conditions: A National Retrospective Analysis

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ABSTRACT

Background The Accreditation Council for Graduate Medical Education reforms in 2003 instituted an 80-hour weekly limit for resident physicians. Critics argue that these restrictions have increased handoffs among residents and the potential for a decline in patient safety. "Never events" hospital-acquired conditions (HACs) are a set of preventable events used as a quality metric in hospital safety analyses.

Objective This analysis evaluated post–work hour reform effects on HAC incidence for US hospital inpatients, using the National Inpatient Sample.

Methods Data were collected from 2000–2002 (pre-2003) and 2004–2006 (post-2003) time periods. HAC incidence in academic and non–academic centers was evaluated in multivariate analysis assessing for likelihood of HAC occurrence, prolonged length of stay (pLOS), and increased total charges.

Results The data encompassed approximately 111 million pre-2003 and 117 million post-2003 admissions. Patients were 10% more likely to incur a HAC in the post-2003 versus pre-2003 era (odds ratio [OR] = 1.10; 95% confidence interval [CI] 1.06–1.14; $P < .01$). Teaching hospitals exhibited an 18% (OR = 1.18; 95% CI 1.11–1.27; $P < .01$) increase in HAC likelihood, with no change in nonteaching settings (OR = 1.03; 95% CI 1.00–1.06; $P > .05$). Patients with $\geq$ 1 HAC were associated with a 60% likelihood of elevated charges (OR = 1.60; 95% CI 1.50–1.72; $P < .01$) and 65% likelihood of pLOS (OR = 1.65; 95% CI 1.60–1.70; $P < .01$).

Conclusions Post-2003 era patients were associated with 10% increased likelihood of HAC, with effects noted primarily at teaching hospitals.

Introduction

In July 2003, the Accreditation Council for Graduate Medical Education (ACGME) instituted new requirements that included changes in resident duty hour standards to promote higher quality and safety of care for patients.[1–3] This included an 80-hour weekly limit to reduce medical errors that potentially result from resident sleep deprivation.[3–5] In response, some have noted the potential for increased frequency of patient handoffs in teaching settings.[1,6]

Efforts to reduce errors led the Centers for Medicaid & Medicare Services (CMS) to publish in 2008 a set of egregious, preventable hospital complications termed "never events."[7] These events represented hospital-acquired conditions (HACs), such as catheter-associated urinary tract infections, which are deemed serious, costly, and resulting from preventable medical errors, subsequently not qualifying for CMS reimbursement (BOX).[8–10] Indicators aimed to shift the burden of complications from patients to hospitals as an incentive to accelerate safety programs.[11,12] The CMS recently estimated there have been 50 000 lives and $12 billion saved since the creation of the HAC program (2010–2014), with a 17% decrease in HACs.[13,14] The Agency for Healthcare Research and Quality (AHRQ) noted an 87 000 reduction in patient mortality and $19.8 billion health care costs savings as a result of HAC reductions.[15]

HACs have been utilized as hospital quality outcome measures in studies.[10,11,16,17] No prior study has evaluated the national incidence of HACs before and after the institution of the 2003 ACGME duty hour limits.

Methods

Aggregate analysis was conducted from all discharges between the years of 2000–2002 and 2004–2006 from the National Inpatient Sample (NIS). This database is compiled annually by the AHRQ's Healthcare Cost and Utilization Project. The NIS contains built-in weights allowing calculation of population estimates and extrapolation of the results

DOI: http://dx.doi.org/10.4300/JGME-D-16-00055.1

BOX Hospital-Acquired Conditions

Condition

- Surgical site infection (SSI), mediastinitis, following coronary artery bypass graft
- SSI following certain orthopedic procedures (spine, neck, shoulder, elbow)
- SSI following bariatric surgery for obesity (laparoscopic gastric bypass, gastroenterostomy, laparoscopic gastric restrictive surgery)
- SSI following cardiac implantable electronic device
- Foreign object retained after surgery
- Catheter-associated urinary tract infection
- Vascular catheter–associated infection
- Deep vein thrombosis and pulmonary embolism following certain orthopedic procedures (total knee replacement, hip replacement)
- Falls and trauma
- Manifestations of poor glycemic control
- Air embolism
- Blood incompatibility
- Pressure ulcers
- Iatrogenic pneumothorax with venous catheterization

What is known and gap
Work hour limits instituted in 2003 have increased patient handoffs, and their impact on safety and quality of care is unclear.

What is new
A study using the National Inpatient Sample assessed the effect of work hour limits on the incidence of hospital-acquired conditions (HACs).

Limitations
Use of administrative data limits the ability to draw conclusions.

Bottom line
HACs incidence and the associated impact increased in teaching hospitals, with no corresponding change in non–teaching institutions.

to national estimates.[18] Two time periods were analyzed: 2000–2002, prior to the implementation of the work hour limits (pre-2003 era), and 2004–2006, immediately after implementation of the reforms (post-2003 era). The year 2003 was omitted from analysis to account for possible institutional transition periods for hospitals to adjust to the new mandates.[3]

Each discharge was treated as an independent event due to the lack of unique patient identifiers. Hospital and patient factors were included in NIS as categorical variables. Patient age, length of stay, and total hospital charges were recoded as categorical variables for statistical analyses. Severity of admission was adjusted for use of the admission source, admission type, and Elixhauser comorbidity index variables included in the NIS. The Elixhauser comorbidity index is a set of comprehensive comorbidity measures associated with in-hospital mortality, all-cause mortality, and health care expenditures, designed for the use of large administrative databases and utilized in many prior NIS studies.[10,16,19,20] HACs were defined using CMS-provided criteria by means of International Classification of Disease, ninth revision, Clinical Modification.[8] Outcomes of interest included occurrence of HACs, prolonged length of stay (pLOS), and elevated inpatient costs. The pLOS and elevated inpatient costs were defined as $\geq$ 90th percentile for each category ($\geq$ 9 days, $\geq$ \$51,099.04). Charges were adjusted for inflation to reflect 2014 US dollars.

Multivariable analyses were conducted using SAS version 9.4 (SAS Institute Inc, Cary, NC) to assess the relationships between HAC occurrence with patient, hospital, and severity factors. The CLUSTER statement was used to adjust for patients nested with a hospital. The primary predictor evaluated was admission in the pre-2003 era versus the post-2003 era. Analysis was adjusted for patient (race, payer status, age, and sex) and hospital (location, region, teaching status, and bed size) factors. We stratified analyses by teaching status separately to account for the presence of residents. Additional analyses modeled pLOS and higher inpatient cost occurrence. In our supplementary analysis, we adjusted for admission type and admission source to further adjust for severity of admission. Finally, to account for the missing data, we conducted a multiple imputation analysis using the methods outlined by Berglund[21] and adapted for the NIS as our tertiary analysis.[10]

This study was declared exempt by the University of Southern California Health Sciences Campus Institutional Review Board.

Statistical significance was defined as a *P* value $< .05$. All descriptive and regression analyses were performed using SAS version 9.4.

Results

There were a total of approximately 111 million pre-2003 and 117 million post-2003 hospital admissions. In the post-2003 era, 4.4 million admissions (3.8%) had at least 1 HAC, compared with the pre-2003 era, where 3.9 million (3.5%) had HACs (TABLE 1).

Baseline univariate analyses indicated a 7% increase in the odds of HAC occurrence in the post-2003 era (odds ratio [OR] = 1.07; 95% confidence interval [CI] 1.03–1.11; $P < .01$). Multivariable analysis further supported this in the aggregate

TABLE 1
Sample Demographics

	n	%
Race		
White	114 313 817	50.0
Black	22 525 522	9.9
Hispanic	21 408 183	9.4
Asian Pacific Islander	4 013 583	1.8
Native American	790 087	0.3
Other	5 178 867	2.3
Missing	60 455 051	26.4
Payer information		
Medicare	84 103 409	36.8
Medicaid	41 640 053	18.2
Private insurance	83 676 790	36.6
Self-pay	10 946 941	4.8
No charge	877 926	0.4
Other	6 969 533	3.0
Missing	470 460	0.2
Age category, y		
< 18	41 041 014	17.9
19–30	26 767 143	11.7
30–40	23 285 703	10.2
40–50	22 998 729	10.1
50–65	37 917 128	16.6
65–80	47 716 732	20.9
> 80	28 958 661	12.7
Elixhauser comorbid conditions		
No conditions	88 992 018	38.9
One condition	46 037 724	20.1
Two or more conditions	93 655 369	41.0
Sex		
Male	93 550 548	40.9
Female	134 752 280	58.9
Missing	382 283	0.2
Admission source		
Emergency department	95 799 816	41.9
Another hospital	7 638 288	3.3
Other health care facility	3 325 536	1.5
Court/law enforcement	232 286	0.1
Routine	116 784 709	51.1
Missing	4 904 477	2.1
Admission type		
Emergency	87 458 646	38.2
Urgent	41 968 230	18.4
Elective	51 746 084	22.6
Newborn	21 065 456	9.2
Trauma (beginning 2003)	318 782	0.1
Other	108 594	0.0
Missing	26 019 321	11.4

TABLE 1
Continued

	n	%
Hospital bed size		
Small	27 610 360	12.1
Medium	58 922 724	25.8
Large	142 019 931	62.1
Missing	132 096	0.1
Hospital location		
Rural	32 665 032	14.3
Urban	195 887 984	85.7
Missing	132 096	0.1
Hospital region		
Northeast	45 446 724	19.9
Midwest	52 881 645	23.1
South	86 976 043	38.0
West	43 380 700	19.0
Hospital teaching status		
Nonteaching	126 625 921	55.4
Teaching	101 927 094	44.6
Missing	132 096	0.1

sample, revealing that post-2003 admissions had a 10% increased likelihood of incurring a HAC during admission compared with admissions in the pre-2003 era (TABLE 2). The slope of HAC change per year (OR between 2 consecutive years) remained the same for the pre-2003 (OR = 0.99; 95% CI 0.97–1.02; $P > .05$) and post-2003 (OR = 0.99; 95% CI 0.96–1.02; $P > .05$) eras, indicating no baseline increase. Teaching hospitals were also 29% more likely to be associated with HACs compared to non–teaching hospitals (OR = 1.29; 95% CI 1.22–1.36; $P < .01$).

In a second analysis, we utilized the same model but stratified the data by teaching status. Teaching hospital patients were 18% more likely to have a HAC during admission in the post-2003 compared with the pre-2003 era (OR = 1.18; 95% CI 1.11–1.27; $P < .01$). In contrast, for non–teaching hospitals the post-2003 era revealed a nonsignificant impact on HAC rates (OR = 1.03; 95% CI 1.00–1.06; $P = .05$). Our multiple imputation tertiary analysis noted similar findings, with an aggregate duty hour effect of 10% (OR = 1.10; 95% CI 1.05–1.14; $P < .01$) and stratified results of 19% (OR = 1.19; 95% CI 1.10–1.27; $P < .01$) and 2% (OR = 1.02; 95% CI 0.99–1.06; $P = .25$) for teaching and nonteaching populations, respectively.

The secondary analysis involving severity of admission did not alter the results noted above. Post-2003 patients had a 6% increased odds of HAC occurrence compared with pre-2003 patients (OR = 1.06; 95% CI 1.03–1.10; $P < .01$). In stratification by teaching

TABLE 2
Duty Hour Era Predictors of Hospital-Acquired Conditions

	Odds Ratio	95% Confidence Interval	*P* Value
Patient Predictors			
Duty hour			
Post–duty hour era	1.10	1.06–1.14	$< .0001$
Pre–duty hour era	Reference		
Race			
White	Reference		
Black	0.68	0.65–0.71	$< .0001$
Hispanic	0.75	0.71–0.80	$< .0001$
Asian Pacific Islander	0.61	0.57–0.66	$< .0001$
Native American	1.08	0.90–1.28	.4260
Other	0.87	0.80–0.94	.0006
Payer information			
Medicare	0.92	0.89–0.95	$< .0001$
Medicaid	0.70	0.67–0.73	$< .0001$
Private insurance	Reference		
Self-pay	2.05	1.94–2.16	$< .0001$
No charge	1.69	1.42–2.02	$< .0001$
Other	2.44	2.28–2.61	$< .0001$
Age category, y			
≤ 18	0.17	0.16–0.18	$< .0001$
19–30	0.28	0.26–0.29	$< .0001$
30–40	0.25	0.26–0.29	$< .0001$
40–50	0.31	0.30–0.31	$< .0001$
50–65	0.29	0.28–0.30	$< .0001$
65–80	0.45	0.44–0.45	$< .0001$
> 80	0.45	0.44–0.45	$< .0001$
Elixhauser comorbid conditions			
No conditions	Reference		
1 condition	0.90	0.88–0.92	$< .0001$
2 or more conditions	0.72	0.71–0.74	$< .0001$
Sex			
Female	0.79	0.77–0.82	$< .0001$
Male	Reference		
Hospital Predictors			
Hospital region			
Northeast	Reference		
Midwest	1.14	1.05–1.23	.0017
South	1.12	1.03–1.21	.0053
West	1.24	1.14–1.35	$< .0001$
Hospital location			
Rural	Reference		
Urban	0.99	0.95–1.02	.4184
Hospital teaching status			
Nonteaching	Reference		
Teaching	1.29	1.22–1.36	$< .0001$
Hospital bed size			
Small	Reference		
Medium	1.13	1.06–1.23	.0005
Large	1.19	1.12–1.26	$< .0001$

hospital status, our new results mirrored the prior ones, with patients in teaching hospitals in the post-2003 era experiencing 11% increased odds of HAC occurrence (OR = 1.11; 95% CI 1.03–1.18; $P < .01$) and non–teaching hospital patients showing no significant increase in HACs (OR = 1.02; 95% CI 0.99–1.05; $P = .16$).

The occurrence of HACs was a significant predictor for both elevated inpatient charges and pLOS. HAC occurrence was associated with a 60% increased likelihood of incurring high inpatient charges in this population (OR = 1.60; 95% CI 1.50–1.72; $P < .01$). Similarly, patients seen in the post-2003 era had 92% increased likelihoods of having a higher-cost hospitalization (OR = 1.92; 95% CI 1.83–2.02; $P < .01$). Patients with a HAC had a 65% increased chance of having a hospitalization with a pLOS of 11 or more days compared with those who did not have a HAC (OR = 1.65; 95% CI 1.60–1.70; $P < .01$). Of note, patients admitted in the post-2003 era had a 10% lower likelihood of a pLOS (OR = 0.90; 95% CI 0.87–0.92; $P < .01$). Additionally, in our linear regression analyses, hospital admissions in the post-2003 era cost, on average, $5,546 more than pre-2003 era hospitalizations and also had approximately 14% shorter LOS. HAC occurrence was associated with $12,686 increased cost on average and 140% longer LOS compared to patients with no HACs.

Discussion

This study quantifies the effect associated with the ACGME reforms on preventable HACs in a national sample before (2000–2002) and after (2004–2006) implementation of the reform, as well as effects on pLOS and costs. Aggregate analysis of all US inpatient admissions indicated a HAC prevalence of 3.5% in the pre-2003 and 3.8% in the post-2003 era, and found that patients admitted in the post-2003 era were 10% more likely to incur a HAC.

Our stratified results indicate increases in likelihood of incurring a HAC during hospitalization in teaching centers. These results are similar to those found in prior studies that conducted similar analyses in specific subspecialties.[3,22] The increased likelihood of HAC occurrence in teaching hospitals in the post-2003 era may be attributable to the presence of trainees and compounded by the ACGME work hour reforms, leading to an understaffed training workforce with less time to care for patients.[3,23] As non–teaching hospitals should not be significantly affected by these policies, the small, non–statistically significant change in HAC frequency in these hospitals between the pre- and post-2003 periods serves as a control rate and as a baseline rate of HAC change over time exclusive of postgraduate resident involvement.

Severity of hospital admission could predispose to HAC occurrences. To address this confounder, we incorporated NIS database elements of admission type and source into our analysis. Emergent admission types and sources were associated with up to 3 times increased likelihood of HAC occurrence. Despite these adjustments, our findings of increased HAC occurrence probability remained stable, as did our findings after stratification by teaching status. Similar results were also seen among our multiple imputation analyses to adjust for missing data. Also, socioeconomic factors have been shown to predispose to HACs in prior specialty studies.[24–27] However, this was not found in our study and could be secondary to our cohort's significantly larger sample size, and our results may be representative of the population in general. Our results are consistent with the findings of other aggregate NIS studies.[10,16]

The association of reforms with increased HAC frequency may be due to multiple reasons. Increased number of informational exchanges during handoffs has been cited as a source of medical errors in multiple studies.[4,6,28,29] Another study found wide agreement within surgical resident perception that continuity of care was disrupted and that errors were more likely.[30] Studies have further cited increased cross-coverage, decreased patient exposure, increased reliance on midlevel practitioners, limited operative experience for surgical cases, and inability to develop appropriate situational judgment.[4,22,29–32]

Previous studies have evaluated patient mortality following implementation of reforms.[33,34] Increases in the number of handoffs by medical providers to maintain continuity of care has been noted to increase the risk of adverse events.[35–38] Several studies have also found both equivocal and improved mortality outcomes following implementation of duty hour restrictions.[29,33,34] Due to mixed results, an assessment of morbidity represented by a quality outcome such as HACs, rather than mortality, may be more effective at evaluating patient care and hospital processes following ACGME reform.[10]

The occurrence of complications leading to higher chances of elevated costs and longer LOS is consistent with prior research.[11,39,40] Admission during the post-2003 era was also associated with a 10% decreased likelihood of higher inpatient charges. These results are consistent with other studies,[41,42] potentially indicating an aspect of improvement as a result of duty hour reforms.[41,43] Regardless, our results indicate that HAC occurrences are major drivers of substantially higher costs and LOS, both of which place large burdens on patients and the health care system.

This study is limited by the constraints of an administrative database that may not account for all demographics, acuities, and comorbidities of inpatient populations. Analysis relied on the reporting of HACs, with a risk for errors and bias when determining patient outcomes and HAC status.[42] The use of administrative data limits the conclusions we can draw regarding how hospitals adjusted to the new mandate.[44] Additionally, it is possible that teaching institutions may have been more adept at tracking HACs, which may bias results. Finally, NIS does not include financial aspects of care, which may result in underestimation of total hospital costs.[45]

Conclusion

Assessing HAC frequencies pre– and post–work hour reform revealed that patients admitted to teaching hospitals after implementation of the ACGME reforms were more likely to incur HACs. HACs serve as a proxy for quality of patient care and represent a significant financial and human burden. The latter is reflected in the association between HAC occurrence and increased hospital charges and pLOS.

References

1. Nasca TJ, Day SH, Amis ES. The new recommendations on duty hours from the ACGME Task Force. *N Engl J Med*. 2010;363(2):e3.
2. Philibert I, Friedmann P, Williams WT, et al. New requirements for resident duty hours. *JAMA*. 2002;288(9):1112–1114.
3. Hoh BL, Neal DW, Kleinhenz DT, et al. Higher complications and no improvement in mortality in the ACGME resident duty-hour restriction era: an analysis of more than 107,000 neurosurgical trauma patients in the Nationwide Inpatient Sample Database. *Neurosurgery*. 2012;70(6):1369–1382.
4. Hutter MM, Kellogg KC, Ferguson CM, et al. The impact of the 80-hour resident workweek on surgical residents and attending surgeons. *Ann Surg*. 2006;243(6):864–875.

5. Accreditation Council for Graduate Medical Education. Resident Duty Hours in the Learning and Working Environment. http://www.acgme.org/Portals/0/PDFs/dh-ComparisonTable2003v2011.pdf. Accessed January 23, 2017.
6. Philibert I. Use of strategies from high-reliability organisations to the patient hand-off by resident physicians: practical implications. *Qual Saf Health Care*. 2009;18(4):261–266.
7. Salazar JH, Yang J, Shen L, et al. Pediatric malignant hyperthermia: risk factors, morbidity, and mortality identified from the Nationwide Inpatient Sample and Kids' Inpatient Database. *Pediatr Anesthesia*. 2014;24(12):1212–1216.
8. Centers for Medicaid & Medicare Services. Hospital-acquired conditions (HAC) in Acute Inpatient Prospective Payment System (IPPS) hospitals. https://www.cms.gov/medicare/medicare-fee-for-service-payment/hospitalacqcond/hospital-acquired_conditions.html. Accessed January 23, 2017.
9. Brown J, Doloresco F, Mylotte JM. "Never events": not every hospital-acquired infection is preventable. *Clin Infect Dis*. 2009;49(5):743–746.
10. Attenello FJ, Wen T, Cen SY, et al. Incidence of "never events" among weekend admissions versus weekday admissions to US hospitals: national analysis. *BMJ*. 2015;350:h1460.
11. Joice GA, Deibert CM, Kates M, et al. "Never events": Centers for Medicare and Medicaid Services complications after radical cystectomy. *Urology*. 2013;81(3):527–532.
12. Rosenthal MB. Nonpayment for performance? Medicare's new reimbursement rule. *N Engl J Med*. 2007;357(16):1573–1575.
13. Pronovost PJ, Goeschel CA, Wachter RM. The wisdom and justice of not paying for "preventable complications." *JAMA*. 2008;299(18):2197–2199.
14. Agency for Healthcare Research and Quality. Efforts to improve patient safety result in 1.3 million fewer patient harms. https://www.ahrq.gov/professionals/quality-patient-safety/pfp/interimhacrate2013.html. Accessed April 3, 2017.
15. Agency for Healthcare Research and Quality. Saving lives and saving money: hospital-acquired conditions update interim data from national efforts to make care safer, 2010–2014. 2015. https://www.ahrq.gov/sites/default/files/publications/files/interimhacrate2014_2.pdf. Accessed March 7, 2017.
16. Wen T, Attenello FJ, Wu B, et al. The July effect: an analysis of never events in the nationwide inpatient sample. *J Hosp Med*. 2015;10(7):432–438.
17. Wen T, He S, Attenello F, et al. The impact of patient age and comorbidities on the occurrence of "never events" in cerebrovascular surgery: an analysis of the Nationwide Inpatient Sample: clinical article. *J Neurosurg*. 2014;121(3):580–586.
18. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project (HCUP). https://www.ahrq.gov/research/data/hcup/index.html. Accessed January 23, 2017.
19. Elixhauser A, Steiner C, Harris DR, et al. Comorbidity measures for use with administrative data. *Med Care*. 1998;36(1):8–27.
20. van Walraven C, Austin PC, Jennings A, et al. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. *Med Care*. 2009;47(6):626–633.
21. Berglund PA. An introduction to multiple imputation of complex sample data using SAS v9. 2. Paper presented at the SAS Global Forum Proceedings. Cary, NC: SAS Institute Inc; 2010. http://support.sas.com/resources/papers/proceedings10/265-2010.pdf. Accessed March 7, 2017.
22. Dumont TM, Tranmer BI, Horgan MA, et al. Trends in neurosurgical complication rates at teaching vs nonteaching hospitals following duty-hour restrictions. *Neurosurgery*. 2012;71(5):1041–1046.
23. Raval MV, Wang X, Cohen ME, et al. The influence of resident involvement on surgical outcomes. *J Am Coll Surg*. 2011;212(5):889–898.
24. Wen T, Attenello FJ, He S, et al. Racial and socioeconomic disparities in incidence of hospital-acquired complications following cerebrovascular procedures. *Neurosurgery*. 2014;75(1):43–50.
25. Attenello FJ, Ng A, Wen T, et al. Racial and socioeconomic disparities in outcomes following pediatric cerebrospinal fluid shunt procedures. *J Neurosurg Pediatr*. 2015;15(6):560–566.
26. Attenello FJ, Reid P, Wen T, et al. Evaluation of time to aneurysm treatment following subarachnoid hemorrhage: comparison of patients treated with clipping versus coiling. *J Neurointerv Surg*. 2016;8(4):373–377.
27. Attenello FJ, Wang K, Wen T, et al. Health disparities in time to aneurysm clipping/coiling among aneurysmal subarachnoid hemorrhage patients: a national study. *World Neurosurg*. 2014;82(6):1071–1076.
28. Poulose BK, Ray WA, Arbogast PG, et al. Resident work hour limits and patient safety. *Ann Surg*. 2005;241(6):847–860.
29. de Virgilio C, Yaghoubian A, Lewis RJ, et al. The 80-hour resident workweek does not adversely affect patient outcomes or resident education. *Curr Surg*. 2006;63(6):435–439.
30. Irani JL, Mello MM, Ashley SW, et al. Surgical residents' perceptions of the effects of the ACGME duty hour requirements 1 year after implementation. *Surgery*. 2005;138(2):246–253.

31. Peabody T. The effect of work hour restrictions on the education of orthopaedic surgery residents. *Clin Orthop Relat Res*. 2006;449:128–133.
32. Vaughn DM, Stout CL, McCampbell BL, et al. Three-year results of mandated work hour restrictions: attending and resident perspectives and effects in a community hospital. *Am Surg*. 2008;74(6):542–547.
33. Volpp KG, Rosen AK, Rosenbaum PR, et al. Mortality among hospitalized medicare beneficiaries in the first 2 years following acgme resident duty hour reform. *JAMA*. 2007;298(9):975–983.
34. Morrison CA, Wyatt MM, Carrick MM. Impact of the 80-hour work week on mortality and morbidity in trauma patients: an analysis of the National Trauma Data Bank. *J Surg Res*. 2009;154(1):157–162.
35. Petersen LA, Brennan TA, O'Neil AC, et al. Does housestaff discontinuity of care increase the risk for preventable adverse events? *Ann Intern Med*. 1994;121(11):866–872.
36. Landrigan CP, Rothschild JM, Cronin JW, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med*. 2004;351(18):1838–1848.
37. Horwitz LI, Krumholz HM, Green ML, et al. Transfers of patient care between house staff on internal medicine wards: a national survey. *Arch Intern Med*. 2006;166(11):1173.
38. Schuberth JL, Elasy TA, Butler J, et al. Effect of short call admission on length of stay and quality of care for acute decompensated heart failure. *Circulation*. 2008;117(20):2637–2644.
39. Dominguez TE, Chalom R, Costarino ATJ. The impact of adverse patient occurrences on hospital costs in the pediatric intensive care unit. *Crit Care Med*. 2001;29(1):169–174.
40. Abramson NS, Wald K, Grenvik AA, et al. Adverse occurrences in intensive care units. *JAMA*. 1980;244(14):1582–1584.
41. Gopaldas RR, Chu D, Dao TK, et al. Impact of ACGME work-hour restrictions on the outcomes of coronary artery bypass grafting in a cohort of 600,000 patients. *J Surg Res*. 2010;163(2):201–209.
42. Burns E, Rigby E, Mamidanna R, et al. Systematic review of discharge coding accuracy. *J Pub Health*. 2012;34(1):138–148.
43. Silber JH, Rosenbaum PR, Rosen AK, et al. Prolonged hospital stay and the resident duty hour rules of 2003. *Med Care*. 2009;47(12):1191.
44. Shetty KD, Bhattacharya J. Changes in hospital mortality associated with residency work-hour regulations. *Ann Intern Med*. 2007;147(2):73–80.
45. Sun BC, Emond JA, Camargo CA Jr. Direct medical costs of syncope-related hospitalizations in the United States. *Am J Cardiol*. 2005;95(5):668–671.

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Funding: This project was supported in part by the American Association of Neurological Surgeons' Medical Student Summer Research Fellowship.

Conflict of interest: The authors declare they have no competing interests.

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Received January 24, 2016; revisions received August 7, 2016, and December 13, 2016; accepted December 17, 2016.