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# Association of the 2011 ACGME Resident Duty Hour Reforms With Mortality and Readmissions Among Hospitalized Medicare Patients

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## Abstract

**IMPORTANCE—**Patient outcomes associated with the 2011 Accreditation Council for Graduate Medical Education (ACGME) duty hour reforms have not been evaluated at a national level.

**OBJECTIVE—**To evaluate the association of the 2011 ACGME duty hour reforms with mortality and readmissions.

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**Author Contributions**: Dr Patel had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
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**DESIGN, SETTING, AND PARTICIPANTS—**Observational study of Medicare patient admissions (6 384 273 admissions from 2 790 356 patients) to short-term, acute care, nonfederal hospitals (n = 3104) with principal medical diagnoses of acute myocardial infarction, stroke, gastrointestinal bleeding, or congestive heart failure or a Diagnosis Related Group classification of general, orthopedic, or vascular surgery. Of the hospitals, 96 (3.1%) were very major teaching, 138 (4.4%) major teaching, 442 (14.2%) minor teaching, 443 (14.3%) very minor teaching, and 1985 (64.0%) nonteaching.

**EXPOSURE—**Resident-to-bed ratio as a continuous measure of hospital teaching intensity.

**MAIN OUTCOMES AND MEASURES—**Change in 30-day all-location mortality and 30-day all-cause readmission, comparing patients in more intensive relative to less intensive teaching hospitals before (July 1, 2009–June 30, 2011) and after (July 1, 2011–June 30, 2012) duty hour reforms, adjusting for patient comorbidities, time trends, and hospital site.

**RESULTS—**In the 2 years before duty hour reforms, there were 4 325 854 admissions with 288 422 deaths and 602 380 readmissions. In the first year after the reforms, accounting for teaching hospital intensity, there were 2 058 419 admissions with 133 547 deaths and 272 938 readmissions. There were no significant postreform differences in mortality accounting for teaching hospital intensity for combined medical conditions (odds ratio [OR], 1.00; 95% CI, 0.96–1.03), combined surgical categories (OR, 0.99; 95% CI, 0.94–1.04), or any of the individual medical conditions or surgical categories. There were no significant postreform differences in readmissions for combined medical conditions (OR, 1.00; 95% CI, 0.97–1.02) or combined surgical categories (OR, 1.00; 95% CI, 0.98–1.03). For the medical condition of stroke, there were higher odds of readmissions in the postreform period (OR, 1.06; 95% CI, 1.001–1.13). However, this finding was not supported by sensitivity analyses and there were no significant postreform differences for readmissions for any other individual medical condition or surgical category.

**CONCLUSIONS AND RELEVANCE—**Among Medicare beneficiaries, there were no significant differences in the change in 30-day mortality rates or 30-day all-cause readmission rates for those hospitalized in more intensive relative to less intensive teaching hospitals in the year after implementation of the 2011 ACGME duty hour reforms compared with those hospitalized in the 2 years before implementation.

On July 1, 2011, the Accreditation Council for Graduate Medical Education (ACGME) implemented new duty hour reforms for all ACGME-accredited residency programs.[1] The revisions maintain the weekly limit of 80 hours set forth by the 2003 duty hour reforms[2] but reduced the work hour limit from 30 consecutive hours to 16 hours for first-year residents (interns) and 24 hours for upper-year residents (with an additional 4 hours to perform transitions of care and participate in educational activities).[1] In parallel, new standards for enhanced faculty supervision were also introduced to further efforts to improve patient safety.

Initial duty hour reforms in 2003 were prompted by wide-spread concern about the effects of resident fatigue, including deaths due to medical errors.[3] However, previous research evaluating the 2003 duty hour reforms has found no significant associations of the reforms with changes in mortality,[4–7] hospital readmission rates,[8] indicators of patient safety,[9] or probability of prolonged length of stay[10] in the first few years after reforms.

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Program directors and residents remain concerned that the 2011 duty hour reforms may adversely affect the quality of resident education, increase handoffs in care, and put both patient safety and outcomes at risk.[11–13] One year before the reforms went into effect, 94% of residency programs reported exceeding the 16-hour limit for first-year residents,[12] indicating that teaching hospitals in the United States would need to undergo a major restructuring to become compliant. Further-more, such changes are associated with significant cost burdens without additional funding available.[14,15] Given the significance of duty hour reforms, it is of vital importance that the immediate associations of these changes be evaluated. In this study, our objective was to evaluate the association of the 2011 ACGME duty hour reforms with mortality and readmissions among hospitalized Medicare patients during the first year after the reforms.

## Methods

This study was approved by the institutional review boards at the University of Pennsylvania and The Children's Hospital of Philadelphia. A waiver of consent was approved by the institutional review boards because this study, which analyzes millions of patients, poses minimal risk to confidentiality and it would not have been feasible to obtain informed consent from each individual.

### Main Outcome Measures

The main outcome measure was all-location mortality within 30 days of hospital admission for patients admitted with a principal medical diagnosis of acute myocardial infarction, stroke, gastrointestinal bleeding, or congestive heart failure or a Diagnosis Related Group (DRG) classification of general, orthopedic, or vascular surgery. We assessed all-location mortality (both in-hospital and post discharge deaths) within 30 days of admission because it is a measure that eliminates bias due to length-of-stay differences between hospitals or over time.[16] This measure is consistent with previous research[4–7] and supported by the Centers for Medicare & Medicaid Services (CMS).[17]

A secondary outcome measure was all-cause readmission within 30 days of hospital discharge for all patients discharged alive after admission with a principal medical diagnosis of acute myocardial infarction, stroke, gastrointestinal bleeding, or congestive heart failure or a DRG classification of general, orthopedic, or vascular surgery. This measure is consistent with previous research[8] and supported by the CMS.[17]

### Study Sample

Patients were selected using an approach described in previous studies[4–8] and included all Medicare patients admitted to short-term, acute care, general US nonfederal hospitals from July 1, 2009, to June 30, 2012. Admissions were excluded from analysis if any of the following criteria were met: (1) a hospital was non–acute care, not in a US state or the District of Columbia, or opened or closed during the study period; (2) a hospital had fewer than 350 Medicare admissions in any year (a mean of less than 1 admission per day across all conditions), to eliminate those too small to yield stable estimates in a fixed-effects analysis; (3) Medicare Cost Report data or resident-to-bed (RB) ratio were missing; (4) a

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patient was enrolled in a health maintenance organization at any point during the study period, because these admissions did not have complete claims data for our analysis; (5) a hospital was missing more than 2 months of data in the prereform period or 1 month of data in the postreform period; (6) a patient's hospitalizations spanned July 1, 2011 (the timing of the implementation of new duty hour reforms); (7) a patient had a reported date of death before an admission date; (8) a patient was younger than 66 years (to allow a 180-day look back for risk adjustment) or older than 90 years (because changes in the proportion of such patients treated aggressively may not be well reflected in administrative data); (9) a patient admitted for acute myocardial infarction was discharged alive in fewer than 2 days (because such cases may not represent actual acute myocardial infarctions)[18,19]; or (10) a patient was transferred from one hospital to another for a qualifying condition or surgical procedure (in which case the entire episode of care was evaluated as a single admission rather than 2 admissions). Additional details are available in eTable 1 in the Supplement.

To evaluate 30-day all-cause readmissions, each admission was considered an index admission if there were no admissions for that patient in the previous 30 days. A 30-day look back was instituted to reduce the likelihood that read-missions were selected as index admissions, which otherwise might have skewed readmission rates.[8] When there was a transfer of care during an index admission from one hospital to another, the admission date from the first hospitalization was used along with the discharge date from the second hospitalization. This allowed us to capture the entire episode of care and removed the possibility that the second hospitalization could be counted as a readmission for the index admission at the first hospitalization.

## Risk Adjustment and Hospital Control Measures

The risk adjustment approach was identical to previous studies,[4–10] a modification of methods of Elixhauser et al.[20] The Elixhauser method used 27 comorbidities excluding fluid and electrolyte disorders and coagulopathy, which should not be used in quality indicator risk adjustment,[21,22] and has been shown to achieve better discrimination than other approaches.[23,24] This was augmented with adjustments for age, sex, and race/ethnicity. For surgical categories, we also adjusted for DRGs, grouping DRGs with and without complications or comorbidities into 1 variable. We performed a 180-day look back, including data from previous hospitalizations, to obtain more comprehensive information on comorbidities than available by using the index admission alone.[25]

## Data

Data on patient characteristics were obtained from the Medicare Provider Analysis and Treatment File (MEDPAR), which included information on principal and secondary diagnoses, age, sex, comorbidities, and discharge status, including dates of death.[26] Data on health maintenance organization enrollment were obtained from the CMS Denominator files. Data on self-reported race/ethnicity was obtained from the CMS Master Beneficiary File and coded by the study team as white, black, Hispanic, and other (included other, Asian, and North American Native). The number of residents a teach hospital was obtained from CMS Medicare Cost Reports.

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The primary measure of teaching intensity was the RB ratio, calculated at a defined point in time as the number of interns plus residents divided by the mean number of staffed beds. The RB ratio has been used to differentiate hospitals by teaching intensity in previous studies[27–29] and in the approach used in previous research.[4–10] Teaching hospitals were defined as hospitals with RB ratios greater than 0 as follows: very minor (RB ratio, >0 to <0.05), minor (RB ratio, 0.05 to <0.25), major (RB ratio, 0.25 to <0.60), and very major (RB ratio, ≥0.60).

## Statistical Analysis

We used a multiple time series research design,[4–10,30] also known as difference in differences, and examined whether the implementation of duty hour reforms was associated with a change in the underlying trend in patient outcomes for more intensive relative to less intensive teaching hospitals, an approach that reduced potential biases from unmeasured variables.[31,32] The multiple times series research design compared each hospital with itself, contrasting the changes in more intensive teaching hospitals to the changes in less intensive teaching hospitals, and adjusted for observed differences in patient risk factors. The design also adjusted for changes in outcomes over time (trends) common to all hospitals and minimized bias from 3 possible sources. First, a difference between hospitals that is stable over time cannot be mistaken for an effect of the reform because hospital fixed effects are used to compare each hospital with itself before and after reform. Second, universal changes affecting all hospitals similarly, such as technological improvements or pay-for-performance initiatives, cannot be mistaken for an effect of the reform because the logit model includes year indicators. Third, if the mix of patients is changing differently among hospitals, and if these changes are accurately reflected in measured risk factors, this cannot be mistaken for an effect of the reform because the logit model adjusts for these measured risk factors. Although the difference-in-differences model offers these advantages, it has limitations. Any diverging trend in mortality or readmission rates over time for more intensive relative to less intensive teaching hospitals already in progress or coincident with the initiation of the reform could be mistaken for an effect of the reform, although we adjusted for any observed differences in prereform trends.

Logistic regression models were fit with patient outcomes data from July 1, 2009, to June 30, 2012, using the RB ratio as a continuous variable to measure hospital teaching intensity. The dependent variables in the models were all-location mortality within 30 days of hospital admission and all-cause readmission within 30 days of hospital discharge. We report the C statistic, which represents model fit.[33] Similar to previous research,[4–10] 30-day all-location mortality and 30-day all-cause readmissions were assumed to have a common time trend until implementation of the duty hour reforms, after which the trends were allowed to diverge. To assess whether underlying trends in 30-day all-location mortality and 30-day all-cause readmissions were similar among more intensive relative to less intensive teaching hospitals during the 2 years before duty hour reform, a test of controls was performed.[34] Parameters were added to the model for interactions between the RB ratio and indicators for prereform year 2 and prereform year 1. A Wald test was used to determine whether these interactions significantly improved model fit,[35] which would suggest that more intensive teaching hospitals relative to less intensive teaching hospitals had differing trends in the 2

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years before reform independent of the reform. Similar to previous research,[4–10] if a test of controls was significant for differing prereform trends, then instead of using both prereform years as a control, only prereform year 1 (July 1, 2010, to June 30, 2011) was used as a control in the main model.

The association of duty hour reforms with patient outcomes was estimated using the coefficients of RB ratio interacted with a dummy variable representing postreform year 1 (July 1, 2011, to June 30, 2012). These coefficients, presented as odds ratios (ORs), measure the degree to which 30-day all-location mortality and 30-day all-cause readmissions differed over time in more intensive relative to less intensive teaching hospitals. Medical conditions were assessed both individually and together as combined medical conditions. Surgical categories were also assessed individually and as combined surgical categories. All hypothesis tests were 2-sided and used a significance level of $P<.05$. All statistical analyses were conducted using SAS version 9.3 (SAS Institute Inc).

We performed a series of independent sensitivity analyses to further evaluate model estimates. First, we excluded patients from the state of New York, where duty hour reforms have historically been implemented differently from other states. Second, we excluded patients transferred from nursing homes, whose care may be less aggressive. Third, we used the bootstrap procedure to estimate confidence intervals and *P* values that account for the correlation between patients with multiple observations.[7,36–38] Fourth, we estimated outcomes for 30-day in-hospital mortality. Fifth, we estimated all-cause 7-day readmissions, which may more directly reflect associations with inpatient care.[39]

## Results

The study sample comprised 2 790 356 patients with 6 384 273 admissions from 3104 hospitals. The number and proportion of hospitals and associated admissions by teaching intensity were as follows: 96 very major teaching hospitals (3.1% of all hospitals in the sample) comprising 353 040 admissions (5.6% of all admissions in the sample), 138 major teaching hospitals (4.4%) comprising 513 704 admissions (8.1%), 442 minor teaching hospitals (14.2%) comprising 1 330 993 admissions (20.9%), 443 very minor teaching hospitals (14.3%) comprising 784 125 admissions (12.3%), and 1985 non teaching hospitals (64.0%) comprising 3 402 411 admissions (53.3%). Table 1 and Table 2 show patient characteristics and comorbidities for the sample during the entire study period. Sample patient characteristics by study year are available in eTables 2 through 4 in the Supplement.

In the 2 years before duty hour reforms, there were 4 325 854 admissions with 288 422 deaths and 602 380 read-missions. In the first year after the reforms, there were 2 058 419 admissions with 133 547 deaths and 272 938 read-missions. Unadjusted trends in 30-day all-location mortality and 30-day all-cause readmissions declined over time for most medical conditions and surgical categories (Table 3). Unadjusted trends for both outcomes also declined when evaluated by hospital teaching intensity (Table 4).

Between prereform year 2 and prereform year 1, a test of controls did not find diverging trends for 30-day all-location mortality for any medical conditions or surgical categories. For

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30-day all-cause readmissions, a test of controls found diverging trends only for the surgical categories of orthopedic surgery and vascular surgery (estimates available in eTables 5 and 6 in the Supplement), so for these categories, prereform year 1 was used as the reference group in adjusted analyses.

In adjusted analyses of 30-day all-location mortality, there were no significant differences over time in more intensive relative to less intensive teaching hospitals for combined medical conditions (OR, 1.00; 95% CI, 0.96–1.03; *P* = .75), combined surgical categories (OR, 0.99; 95% CI, 0.94–1.04; *P* = .64), or any of the individual medical conditions or surgical categories (Table 5). In adjusted analyses of 30-day all-cause readmissions, there were no significant differences over time in more intensive relative to less intensive teaching hospitals for combined medical conditions (OR, 1.00; 95% CI, 0.97–1.02; *P* = .71) or combined surgical categories (OR, 1.00; 95% CI, 0.98–1.03; *P* = .88) (Table 6). There were higher odds of 30-day all-cause readmissions for the medical condition of stroke (OR, 1.06; 95% CI, 1.001–1.13; *P* = .047) but not for any other individual medical condition or surgical category. The C statistics for the 30-day all-location mortality models ranged from 0.68 to 0.86, while the C statistics for the 30-day all-cause readmission models ranged from 0.59 to 0.68. This indicates that the available covariates were reasonably strong predictors of mortality but less strong predictors of readmission.

Sensitivity analysis for combined medical conditions and combined surgical categories did not differ from the main models for 30-day all-location mortality or 30-day all-location readmissions (eTables 7–14 in the Supplement). Thirty-day all-cause readmission estimates had significantly higher odds for stroke when excluding the state of New York but were not significant when excluding patients transferred to nursing homes, when using the bootstrap procedure, or for 7-day all-cause readmission estimates.

## Discussion

Duty hour reform is arguably one of the largest efforts ever undertaken to improve the quality and safety of patient care in teaching hospitals. To our knowledge, this is one of the first national evaluations of the association of the 2011 ACGME duty hour reforms with patient outcomes. In the first year after the reforms, we found no significant positive or negative associations of duty hour reforms with 30-day all-location mortality for any of the medical conditions or surgical categories in this study. We also found no significant positive or negative associations of duty hour reforms with 30-day all-cause readmissions for combined medical conditions or combined surgical categories. We did find that patients admitted with stroke had higher odds of 30-day all-cause readmission after reform for more intensive relative to less intensive teaching hospitals. However, this finding was not found to be significant in several of the sensitivity analyses.

There are several potential reasons why duty hour reforms were not found to be significantly associated with changes in patient outcomes, as measured by 30-day all-location mortality and 30-day all-cause readmissions. First, although the 2011 duty hour reforms were a major change for US teaching hospitals, they may not have been larger in magnitude than the 2003 duty hour reforms, in which there has also been little evidence of associations of reforms

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with mortality or readmissions.[4–8] Second, although 94% of residency programs reported exceeding 2011 duty hour reform work limits in the year before implementation, little is known about adherence to the new reforms. Some programs may not have yet adapted to the new reforms, thereby decreasing their potential association with patient outcomes.

Third, hospitals that did adopt the new reforms may have leveraged faculty or hospitalists with greater experience than residents to care for Medicare patients. Fourth, the 2011 reforms focused on improving faculty supervision that could have resulted in improved patient outcomes, potentially compensating for any adverse effects of increased patient handoffs. Fifth, although our study focused on mortality and readmissions, measurements of other outcomes such as patient safety indicators or complications may better elucidate the relative effects of decreased resident fatigue and increased patient handoffs.

Sixth, unadjusted trends for mortality and readmissions were declining throughout the study period. This trend is consistent with other analyses of outcomes for Medicare beneficiaries evaluating mortality[40] and readmissions[40,41] during a similar period. This may reflect other concurrent policy initiatives by the CMS targeted toward Medicare beneficiaries, such as Partnership for Patients[42] or the Hospital Readmissions Reduction Program.[43] If these initiatives led to general improvements in outcomes across all hospitals, duty hour reforms may be less likely to be directly associated with changes in patient outcomes at more intensive relative to less intensive teaching hospitals.

Despite these potential considerations, our findings suggest that in the first year after the 2011 duty hour reforms, the goals of improving the quality and safety of patient care,[1] as measured by decreased 30-day all-location mortality and 30-day all-cause readmissions, were not being achieved. Conversely, concerns[11–13,44–46] that outcomes might actually worsen because of decreased continuity of care have not been borne out.

This study is subject to several limitations. First, we evaluated the outcomes of 30-day all-location mortality and 30-day all-cause readmissions. Although the duty hour standards were an attempt to improve the quality and safety of patient care,[1] measurements of other outcomes such as patient safety indicators or complications may better elucidate the relative effects of decreased continuity of care compared with decreased resident fatigue. Nonetheless, we chose to report 2 outcomes that are most accurately observed with claims data to minimize the likelihood of underreporting or over reporting. Second, any observational study is susceptible to unmeasured confounding. We used administrative data, so risk adjustment is more limited than with clinical data; however, by comparing outcomes over time within each hospital in more intensive relative to less intensive teaching hospitals, potential bias from unmeasured confounders is diminished. Third, survival bias associated with admissions resulting in death being differentially more likely after reform than before reform in more intensive relative to less intensive teaching hospitals could still have affected the study results. Fourth, the study population was limited to Medicare beneficiaries and, therefore, our sample may not be representative of the general US population. Fifth, we are unable to disentangle other major policy initiatives directed at this population concurrent with implementation of duty hour reforms. Sixth, this study evaluated outcomes in only the first year after the reforms, and these findings should be considered to be representative only of this time period. Further analysis of changes in patient outcomes several years after the reforms will be important to evaluate changes in associations over time.

## Conclusions

Among Medicare beneficiaries, there were no significant differences in changes in 30-day mortality rates or 30-day all-cause readmission rates for those hospitalized in more intensive relative to less intensive teaching hospitals in the year after implementation of the 2011 ACGME duty hour reforms compared with those hospitalized in the 2 years before implementation.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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**Table 1**

Sample Patient Characteristics for Combined Medical Conditions in All Hospitals and by Hospital Teaching Intensity, July 1, 2009–June 30, 2012

| Characteristics | All (n = 3104) | Nonteaching Hospitals (n = 1985) | Very Minor Teaching Hospitals (n = 443) | Minor Teaching Hospitals (n = 442) | Major Teaching Hospitals (n = 138) | Very Major Teaching Hospitals (n = 96) |
|---|---|---|---|---|---|---|
| Resident-to-bed ratio | | 0 | >0 to <0.05 | 0.05 to <0.25 | 0.25 to <0.60 | ≥0.60 |
| Overall sample, No. | 2 790 356 | 1 491 584 | 353 713 | 579 413 | 223 090 | 142 556 |
| Age, mean (SD), y | 78.9 (7.0) | 78.9 (6.9) | 78.9 (7.0) | 78.9 (7.0) | 78.6 (7.0) | 77.9 (7.1) |
| Male, No. (%) | 1 324 524 (47.5) | 701 313 (47.0) | 168 483 (47.6) | 277 085 (47.8) | 106 657 (47.8) | 70 986 (49.8) |
| Race/ethnicity, No. (%) | | | | | | |
| White | 2 328 509 (83.4) | 1 279 258 (85.8) | 297 919 (84.2) | 479 923 (82.8) | 167 340 (75.0) | 104 069 (73.0) |
| Black | 322 807 (11.6) | 144 955 (9.7) | 36 710 (10.4) | 67 189 (11.6) | 44 963 (20.2) | 28 990 (20.3) |
| Hispanic | 50 926 (1.8) | 25 046 (1.7) | 6883 (2.0) | 11 467 (2.0) | 3600 (1.6) | 3930 (2.8) |
| Other | 88 114 (3.2) | 42 325 (2.8) | 12 201 (3.5) | 20 834 (3.6) | 7187 (3.2) | 5567 (3.9) |
| Comorbidities, No. (%) | | | | | | |
| Congestive heart failure | 491 239 (17.6) | 259 273 (17.4) | 59 490 (16.8) | 101 671 (17.5) | 43 317 (19.4) | 27 488 (19.3) |
| Valvular disease | 148 013 (5.3) | 78 970 (5.3) | 17 893 (5.1) | 31 652 (5.5) | 11 675 (5.2) | 7823 (5.5) |
| Hypertension | 1 952 924 (70.0) | 1 040 180 (69.7) | 248 613 (70.3) | 405 093 (69.9) | 157 932 (70.8) | 101 106 (70.9) |
| Peripheral vascular disease | 296 585 (10.6) | 159 729 (10.7) | 38 124 (10.8) | 60 813 (10.5) | 23 255 (10.4) | 14 664 (10.3) |
| Diabetes | | | | | | |
| With chronic complications | 201 678 (7.2) | 106 507 (7.1) | 25 081 (7.1) | 42 675 (7.4) | 16 493 (7.4) | 10 922 (7.7) |
| Without chronic complications | 860 524 (30.8) | 461 509 (30.9) | 110 021 (31.1) | 175 656 (30.3) | 69 574 (31.2) | 43 764 (30.7) |
| Chronic pulmonary disease | 779 566 (27.9) | 428 554 (28.7) | 101 697 (28.8) | 158 992 (27.4) | 58 090 (26.0) | 32 233 (22.6) |
| Pulmonary circulation disease | 88 570 (3.2) | 45 942 (3.1) | 10 367 (2.9) | 18 758 (3.2) | 7955 (3.6) | 5548 (3.9) |
| Renal failure | 706 472 (25.3) | 376 839 (25.3) | 88 906 (25.1) | 147 569 (25.5) | 57 635 (25.8) | 35 523 (24.9) |
| Liver disease | 49 597 (1.8) | 25 598 (1.7) | 6026 (1.7) | 10 049 (1.7) | 4239 (1.9) | 3685 (2.6) |
| Peptic ulcer disease with bleeding | 1002 (0.04) | 527 (0.04) | 123 (0.03) | 210 (0.04) | 81 (0.04) | 61 (0.04) |
| AIDS | 1042 (0.04) | 379 (0.03) | 100 (0.03) | 206 (0.04) | 192 (0.1) | 165 (0.1) |
| Metastatic cancer | 52 725 (1.9) | 27 117 (1.8) | 6280 (1.8) | 10 857 (1.9) | 4768 (2.1) | 3703 (2.6) |
| Solid tumor without metastasis | 84 321 (3.0) | 43 581 (2.9) | 10 382 (2.9) | 17 530 (3.0) | 7302 (3.3) | 5526 (3.9) |

| Characteristics | All (n = 3104) | Nonteaching Hospitals (n = 1985) | Very Minor Teaching Hospitals (n = 443) | Minor Teaching Hospitals (n = 442) | Major Teaching Hospitals (n = 138) | Very Major Teaching Hospitals (n = 96) |
|---|---|---|---|---|---|---|
| Lymphoma | 32 264 (1.2) | 16 630 (1.1) | 3871 (1.1) | 6753 (1.2) | 2896 (1.3) | 2114 (1.5) |
| Other neurological disorders | 202 751 (7.3) | 111 283 (7.5) | 26 085 (7.4) | 39 857 (6.9) | 15 830 (7.1) | 9696 (6.8) |



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## Table 2

Sample Patient Characteristics for Combined Surgical Categories in All Hospitals and by Hospital Teaching Intensity, July 1, 2009–June 30, 2012

| Characteristics | All (n = 3104) | Nonteaching Hospitals (n = 1985) | Very Minor Teaching Hospitals (n = 443) | Minor Teaching Hospitals (n = 442) | Major Teaching Hospitals (n = 138) | Very Major Teaching Hospitals (n = 96) |
|---|---|---|---|---|---|---|
| Resident-to-bed ratio | | 0 | >0 to <0.05 | 0.05 to <0.25 | 0.25 to <0.60 | ≥0.60 |
| Overall sample, No. | 3 593 917 | 1 910 827 | 430 412 | 751 580 | 290 614 | 210 484 |
| Age, mean (SD), y | 76.0 (6.7) | 76.1 (6.8) | 76.2 (6.8) | 76.1 (6.7) | 75.7 (6.7) | 75.2 (6.5) |
| Male, No. (%) | 1 412 806 (39.3) | 740 794 (38.8) | 168 764 (39.2) | 295 192 (39.3) | 117 199 (40.3) | 90 857 (43.2) |
| Race/ethnicity, No. (%) | | | | | | |
| White | 3 239 685 (90.1) | 1 744 957 (91.3) | 389 609 (90.5) | 674 571 (89.8) | 250 876 (86.3) | 179 672 (85.4) |
| Black | 213 122 (5.9) | 95 753 (5.0) | 23 178 (5.4) | 45 301 (6.0) | 28 122 (9.7) | 20 768 (9.9) |
| Hispanic | 43 674 (1.2) | 22 457 (1.2) | 5781 (1.3) | 9467 (1.3) | 2909 (1.0) | 3060 (1.5) |
| Other | 97 436 (2.7) | 47 660 (2.5) | 11 844 (2.8) | 22 241 (3.0) | 8707 (3.0) | 6984 (3.3) |
| Comorbidities, No. (%) | | | | | | |
| Congestive heart failure | 310 179 (8.6) | 163 985 (8.6) | 35 610 (8.3) | 66 195 (8.8) | 26 018 (9.0) | 18 371 (8.7) |
| Valvular disease | 172 664 (4.8) | 89 265 (4.7) | 20 389 (4.7) | 37 717 (5.0) | 14 905 (5.1) | 10 388 (4.9) |
| Hypertension | 2 443 471 (68.0) | 1 300 698 (68.1) | 294 149 (68.3) | 512 666 (68.2) | 197 259 (67.9) | 138 699 (65.9) |
| Peripheral vascular disease | 267 075 (7.4) | 135 887 (7.1) | 32 070 (7.5) | 58 237 (7.7) | 22 761 (7.8) | 18 120 (8.6) |
| Diabetes | | | | | | |
| With chronic complications | 130 451 (3.6) | 66 656 (3.5) | 15 388 (3.6) | 28 369 (3.8) | 11 243 (3.9) | 8795 (4.2) |
| Without chronic complications | 751 844 (20.9) | 400 676 (21.0) | 91 081 (21.2) | 157 876 (21.0) | 60 003 (20.6) | 42 208 (20.1) |
| Chronic pulmonary disease | 632 035 (17.6) | 338 922 (17.7) | 77 163 (17.9) | 132 930 (17.7) | 49 258 (16.9) | 33 762 (16.0) |
| Pulmonary circulation disease | 84 929 (2.4) | 43 332 (2.3) | 9430 (2.2) | 18 383 (2.4) | 7583 (2.6) | 6201 (2.9) |
| Renal failure | 287 086 (8.0) | 150 121 (7.9) | 34 254 (8.0) | 62 131 (8.3) | 23 332 (8.0) | 17 248 (8.2) |
| Liver disease | 44 180 (1.2) | 21 219 (1.1) | 4981 (1.2) | 9061 (1.2) | 4348 (1.5) | 4571 (2.2) |
| Peptic ulcer disease with bleeding | 1782 (0.05) | 912 (0.05) | 221 (0.05) | 345 (0.05) | 170 (0.1) | 134 (0.1) |
| AIDS | 655 (0.02) | 228 (0.01) | 70 (0.02) | 142 (0.02) | 110 (0.04) | 105 (0.05) |
| Metastatic cancer | 118 218 (3.3) | 55 809 (2.9) | 12 001 (2.8) | 24 036 (3.2) | 12 865 (4.4) | 13 507 (6.4) |
| Solid tumor without metastasis | 91 933 (2.6) | 44 446 (2.3) | 10 112 (2.4) | 18 591 (2.5) | 9507 (3.3) | 9277 (4.4) |

| Characteristics | All (n = 3104) | Nonteaching Hospitals (n = 1985) | Very Minor Teaching Hospitals (n = 443) | Minor Teaching Hospitals (n = 442) | Major Teaching Hospitals (n = 138) | Very Major Teaching Hospitals (n = 96) |
|---|---|---|---|---|---|---|
| Lymphoma | 28 801 (0.8) | 14 310 (0.8) | 3230 (0.8) | 6057 (0.8) | 2845 (1.0) | 2359 (1.1) |
| Other neurological disorders | 253 049 (7.0) | 138 909 (7.3) | 31 386 (7.3) | 51 543 (6.9) | 18 327 (6.3) | 12 884 (6.1) |

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## Table 3

Unadjusted Mortality and Readmission Rates for Medical Conditions and Surgical Categories Relative to the Implementation of the 2011 ACGME Duty Hour Reforms

| | Prereform Year 2 (July 1, 2009–June 30, 2010) | Prereform Year 1 (July 1, 2010–June 30, 2011) | Postreform Year 1 (July 1, 2011–June 30, 2012) | Absolute Change, Prereform Year 2 to Postreform Year 1, % (95% CI) |
|---|---|---|---|---|
| Medical conditions | | | | |
| Acute myocardial infarction | | | | |
| Admissions, No. | 173 594 | 168 210 | 163 482 | |
| Unadjusted mortality rate, No. (%) | 22 721 (13.1) | 21 801 (13.0) | 20 357 (12.5) | −0.64 (−0.87 to −0.41) |
| Unadjusted readmission rate, No. (%) | 30 863 (17.8) | 29 709 (17.7) | 27 034 (16.5) | −1.24 (−1.49 to −0.99) |
| Stroke | | | | |
| Admissions, No. | 191 671 | 188 655 | 186 408 | |
| Unadjusted mortality rate, No. (%) | 34 195 (17.8) | 33 731 (17.9) | 32 231 (17.3) | −0.55 (−0.79 to −0.31) |
| Unadjusted readmission rate, No. (%) | 26 276 (13.7) | 25 605 (13.6) | 24 178 (13.0) | −0.74 (−0.96 to −0.52) |
| Gastrointestinal bleeding | | | | |
| Admissions, No. | 182 323 | 182 561 | 179 641 | |
| Unadjusted mortality rate, No. (%) | 11 476 (6.3) | 11 632 (6.4) | 11 216 (6.2) | −0.05 (−0.21 to 0.11) |
| Unadjusted readmission rate, No. (%) | 28 648 (15.7) | 28 666 (15.7) | 27 510 (15.3) | −0.40 (−0.64 to −0.16) |
| Congestive heart failure | | | | |
| Admissions, No. | 412 941 | 394 404 | 366 466 | |
| Unadjusted mortality rate, No. (%) | 39 923 (9.7) | 39 384 (10.0) | 36 500 (10.0) | 0.29 (0.16 to 0.42) |
| Unadjusted readmission rate, No. (%) | 94 712 (22.9) | 89 456 (22.7) | 80 641 (22.0) | −0.93 (−1.12 to −0.74) |
| Combined medical conditions | | | | |
| Admissions, No. | 960 529 | 933 830 | 895 997 | |
| Unadjusted mortality rate, No. (%) | 108 315 (11.3) | 106 548 (11.4) | 100 304 (11.2) | −0.08 (−0.18 to 0.001) |
| Unadjusted readmission rate, No. (%) | 179 173 (18.7) | 172 138 (18.4) | 158 191 (17.7) | −1.00 (−1.10 to −0.88) |
| Surgical categories | | | | |
| General surgery | | | | |
| Admissions, No. | 360 934 | 347 667 | 327 976 | |
| Unadjusted mortality rate, No. (%) | 16 667 (4.6) | 15 511 (4.5) | 14 139 (4.3) | −0.31 (−0.41 to −0.21) |
| Unadjusted readmission rate, No. (%) | 46 917 (13.0) | 44 830 (12.9) | 41 199 (12.6) | −0.44 (−0.60 to −0.28) |
| Orthopedic surgery | | | | |
| Admissions, No. | 799 955 | 783 755 | 770 798 | |
| Unadjusted mortality rate, No. (%) | 13 380 (1.7) | 13 094 (1.7) | 12 437 (1.6) | −0.06 (−0.10 to −0.02) |
| Unadjusted readmission rate, No. (%) | 68 684 (8.6) | 66 690 (8.5) | 62 915 (8.2) | −0.42 (−0.52 to −0.34) |
| Vascular surgery | | | | |
| Admissions, No. | 71 027 | 68 157 | 63 648 | |
| Unadjusted mortality rate, No. (%) | 7602 (10.7) | 7305 (10.7) | 6667 (10.5) | −0.23 (−0.56 to 0.10) |
| Unadjusted readmission rate, No. (%) | 12 465 (17.6) | 11 787 (17.3) | 10 752 (16.9) | −0.66 (−1.06 to −0.26) |

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| | Prereform Year 2 (July 1, 2009–June 30, 2010) | Prereform Year 1 (July 1, 2010–June 30, 2011) | Postreform Year 1 (July 1, 2011–June 30, 2012) | Absolute Change, Prereform Year 2 to Postreform Year 1, % (95% CI) |
|---|---|---|---|---|
| Combined surgical categories | | | | |
| Admissions, No. | 1 231 916 | 1 199 579 | 1 162 422 | |
| Unadjusted mortality rate, No. (%) | 37 649 (3.1) | 35 910 (3.0) | 33 243 (2.9) | −0.20 (−0.24 to −0.16) |
| Unadjusted readmission rate, No. (%) | 127 909 (10.4) | 123 160 (10.3) | 114 747 (9.9) | −0.51 (−0.59 to −0.43) |

Abbreviation: ACGME, Accreditation Council for Graduate Medical Education.

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## Table 4

Unadjusted Mortality and Readmission Rates for Combined Medical Conditions and Combined Surgical Categories by Teaching Intensity Relative to the Implementation of the 2011 ACGME Duty Hour Reforms[a]

| | Prereform Year 2 (July 1, 2009–June 30, 2010) | Prereform Year 1 (July 1, 2010–June 30, 2011) | Postreform Year 1 (July 1, 2011–June 30, 2012) | Absolute Change, Prereform Year 2 to Postreform Year 1, % (95% CI) |
|---|---|---|---|---|
| Combined medical conditions | | | | |
| Very major teaching hospitals (n = 96) | | | | |
| Admissions, No. | 47 989 | 47 756 | 46 811 | |
| Unadjusted mortality rate, No. (%) | 5641 (11.8) | 5759 (12.1) | 5531 (11.8) | 0.06 (−0.34 to 0.48) |
| Unadjusted readmission rate, No. (%) | 9487 (19.8) | 9351 (19.6) | 8833 (18.9) | −0.90 (−1.40 to −0.40) |
| Major teaching hospitals (n = 138) | | | | |
| Admissions, No. | 76 090 | 74 812 | 72 188 | |
| Unadjusted mortality rate, No. (%) | 8450 (11.1) | 8188 (10.9) | 7849 (10.9) | −0.23 (−0.56 to 0.08) |
| Unadjusted readmission rate, No. (%) | 15 169 (19.9) | 14 499 (19.4) | 13 342 (18.5) | −1.45 (−1.86 to −1.06) |
| Minor teaching hospitals (n = 442) | | | | |
| Admissions, No. | 200 239 | 193 897 | 185 277 | |
| Unadjusted mortality rate, No. (%) | 22 356 (11.2) | 22 011 (11.4) | 20 543 (11.1) | −0.08 (−0.27 to 0.13) |
| Unadjusted readmission rate, No. (%) | 37 164 (18.6) | 35 496 (18.3) | 32 163 (17.4) | −1.20 (−1.44 to −0.96) |
| Very minor teaching hospitals (n = 443) | | | | |
| Admissions, No. | 121 850 | 117 373 | 114 490 | |
| Unadjusted mortality rate, No. (%) | 13 781 (11.3) | 13 429 (11.4) | 12 621 (11.0) | −0.29 (−0.54 to −0.04) |
| Unadjusted readmission rate, No. (%) | 22 762 (18.7) | 21 690 (18.5) | 20 229 (17.7) | −1.01 (−1.32 to −0.70) |
| Nonteaching hospitals (n = 1985) | | | | |
| Admissions, No. | 514 361 | 499 992 | 477 231 | |
| Unadjusted mortality rate, No. (%) | 58 087 (11.3) | 57 161 (11.4) | 53 760 (11.3) | −0.03 (−0.15 to 0.09) |
| Unadjusted readmission rate, No. (%) | 94 603 (18.4) | 91 114 (18.2) | 83 634 (17.5) | −0.87 (−1.02 to −0.72) |
| Combined surgical categories | | | | |
| Very major teaching hospitals (n = 96) | | | | |
| Admissions, No. | 70 977 | 70 250 | 69 257 | |
| Unadjusted mortality rate, No. (%) | 2237 (3.2) | 2112 (3.0) | 2010 (2.9) | −0.25 (−0.43 to −0.07) |
| Unadjusted readmission rate, No. (%) | 9130 (12.9) | 8992 (12.8) | 8459 (12.2) | −0.65 (−1.00 to −0.30) |
| Major teaching hospitals (n = 138) | | | | |
| Admissions, No. | 99 176 | 97 328 | 94 110 | |
| Unadjusted mortality rate, No. (%) | 3003 (3.0) | 2868 (3.0) | 2617 (2.8) | −0.25 (−0.40 to −0.10) |
| Unadjusted readmission rate, No. (%) | 11 363 (11.5) | 10 975 (11.3) | 10 317 (11.0) | −0.50 (−0.78 to −0.21) |
| Minor teaching hospitals (n = 442) | | | | |
| Admissions, No. | 258 811 | 250 847 | 241 922 | |
| Unadjusted mortality rate, No. (%) | 7778 (3.0) | 7560 (3.0) | 6938 (2.9) | −0.14 (−0.23 to −0.05) |
| Unadjusted readmission rate, No. (%) | 26 671 (10.3) | 25 670 (10.2) | 24 209 (10.0) | −0.30 (−0.47 to −0.13) |

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| | **Prereform Year 2 (July 1, 2009–June 30, 2010)** | **Prereform Year 1 (July 1, 2010–June 30, 2011)** | **Postreform Year 1 (July 1, 2011–June 30, 2012)** | **Absolute Change, Prereform Year 2 to Postreform Year 1, % (95% CI)** |
|---|---|---|---|---|
| Very minor teaching hospitals (n = 443) | | | | |
| Admissions, No. | 146 932 | 143 389 | 140 091 | |
| Unadjusted mortality rate, No. (%) | 4549 (3.1) | 4445 (3.1) | 4131 (3.0) | −0.15 (−0.28 to −0.02) |
| Unadjusted readmission rate, No. (%) | 15 202 (10.4) | 14 646 (10.2) | 13 483 (9.6) | −0.72 (−0.95 to −0.51) |
| Nonteaching hospitals (n = 1985) | | | | |
| Admissions, No. | 656 020 | 637 765 | 617 042 | |
| Unadjusted mortality rate, No. (%) | 20 072 (3.1) | 18 925 (3.0) | 17 547 (2.8) | −0.22 (−0.28 to −0.16) |
| Unadjusted readmission rate, No. (%) | 65 551 (10.0) | 62 887 (9.9) | 58 290 (9.5) | −0.55 (−0.64 to −0.44) |

Abbreviation: ACGME, Accreditation Council for Graduate Medical Education.

[a]Hospital teaching intensity was classified using the resident-to-bed (RB) ratio as follows: very major teaching (RB ratio ≥0.60), major teaching (RB ratio, 0.25 to <0.60), minor teaching (RB ratio, 0.05 to <0.25), very minor teaching (RB ratio, >0 to <0.05), and nonteaching (RB ratio = 0).

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## Table 5

Adjusted Odds of 30-Day All-Location Mortality After Duty Hour Reforms in More Intensive Relative to Less Intensive Teaching Hospitals[a]

| | All Hospitals (July 1, 2009–June 30, 2012) | | More Intensive Relative to Less Intensive Teaching Hospitals in the Postreform Period (RB Ratio × Postreform Year 1) | |
|---|---|---|---|---|
| | **Admissions, No.** | **Events, No.** | **Odds Ratio (95% CI)** | ***P* Value** |
| Medical conditions | | | | |
| Acute myocardial infarction | 505 286 | 64 879 | 1.05 (0.97–1.14) | .20 |
| Stroke | 566 734 | 100 157 | 1.02 (0.96–1.07) | .54 |
| Gastrointestinal bleeding | 544 525 | 34 324 | 0.98 (0.87–1.09) | .65 |
| Congestive heart failure | 1 173 811 | 115 807 | 0.95 (0.89–1.01) | .09 |
| Combined medical conditions | 2 790 356 | 315 167 | 1.00 (0.96–1.03) | .75 |
| Surgical categories | | | | |
| General surgery | 1 036 577 | 46 317 | 0.99 (0.91–1.07) | .75 |
| Orthopedic surgery[b] | 2 354 508 | 38 911 | 1.08 (0.97–1.21) | .18 |
| Vascular surgery[b] | 202 832 | 21 574 | 0.98 (0.87–1.11) | .80 |
| Combined surgical categories | 3 593 917 | 106 802 | 0.99 (0.94–1.04) | .64 |

[a]The resident-to-bed (RB) ratio is a continuous variable that reflects hospital teaching intensity. Odds ratios represent the regression coefficients from the interaction term (RB ratio × postreform year 1). This term represents the change in the odds of an event (eg, death) for a 1-unit change in the RB ratio, from an RB ratio of 0 to an RB ratio of 1. Using death as an example, an odds ratio of 0.7 suggests that the odds of dying decreased 30% when comparing a hospital with an RB ratio of 1 vs an RB ratio of 0 before and after the change in the duty hour reforms. C statistics were as follows: for acute myocardial infarction, 0.73; stroke, 0.68; gastrointestinal bleeding, 0.75; congestive heart failure, 0.68; combined medical conditions, 0.71; general surgery, 0.82; orthopedic surgery, 0.86; vascular surgery, 0.73; and combined surgical categories, 0.85.

[b]The test of controls for orthopedic surgery and vascular surgery found that the RB × prereform year 2 and RB × prereform year 1 were statistically different, so in these models RB × prereform year 1 alone was used as the referent group.

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**Table 6**

Adjusted Odds of 30-Day All-Cause Readmission After Duty Hour Reforms in More Intensive Relative to Less Intensive Teaching Hospitals[a]

| | All Hospitals (July 1, 2009–June 30, 2012) | | More Intensive Relative to Less Intensive Teaching Hospitals in the Postreform Period (RB Ratio × Postreform Year 1) | |
|---|---|---|---|---|
| | **Admissions, No.** | **Events, No.** | **Odds Ratio (95% CI)** | ***P* Value** |
| Medical conditions | | | | |
| Acute myocardial infarction | 486 072 | 87 607 | 0.94 (0.88–1.001) | .05 |
| Stroke | 543 359 | 76 060 | 1.06 (1.001–1.13) | .047 |
| Gastrointestinal bleeding | 502 846 | 84 824 | 0.95 (0.89–1.02) | .17 |
| Congestive heart failure | 1 028 931 | 264 810 | 1.02 (0.97–1.06) | .49 |
| Combined medical conditions | 2 561 208 | 509 502 | 1.00 (0.97–1.02) | .71 |
| Surgical categories | | | | |
| General surgery | 1 013 488 | 132 946 | 1.01 (0.97–1.05) | .80 |
| Orthopedic surgery | 2 313 150 | 198 289 | 1.02 (0.98–1.06) | .27 |
| Vascular surgery | 195 211 | 35 004 | 0.95 (0.88–1.04) | .25 |
| Combined surgical categories | 3 521 849 | 365 816 | 1.00 (0.98–1.03) | .88 |

[a]The resident-to-bed (RB) ratio is a continuous variable that reflects hospital teaching intensity. Odds ratios represent the regression coefficients from the interaction term (RB ratio × postreform year 1). This term represents the change in the odds of an event (eg, readmission) for a 1-unit change in the RB ratio, from an RB ratio of 0 to an RB ratio of 1. Using readmission as an example, an odds ratio of 0.7 suggests that the odds of being readmitted decreased 30% when comparing a hospital with an RB ratio of 1 vs an RB ratio of 0 before and after the change in the duty hour reforms. C statistics were as follows: for acute myocardial infarction, 0.61; stroke, 0.60; gastrointestinal bleeding, 0.63; congestive heart failure, 0.59; combined medical conditions, 0.62; general surgery, 0.65; orthopedic surgery, 0.67; vascular surgery, 0.65; and combined surgical categories, 0.68.