Implications of transitioning to a resident night float system in neurosurgery: mortality, length of stay, and resident experience

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OBJECTIVE Many neurosurgical training programs have moved from a 24-hour resident call system to a night float system, but the impact on outcomes is unclear. Here, the authors compare length of stay (LOS) for neurosurgical patients admitted before and after initiation of a night float system at a tertiary care training hospital.

METHODS The neurosurgical residency at the University of Alabama at Birmingham transitioned from 24-hour call to a night float resident coverage system in July 2013. In this cohort study, all patients admitted to the neurosurgical service for 1 year before and 1 year after this transition were compared with respect to hospital and ICU LOSs, adjusted for potential confounders.

RESULTS A total of 4619 patients were included. In the initial bivariate analysis, night float was associated with increased ICU LOS ($p = 0.032$) and no change in overall LOS ($p = 0.65$). However, coincident with the transition to a night float system was an increased frequency of resident service transitions, which were highly associated with hospital LOS ($p < 0.01$) and ICU LOS ($p < 0.01$). After adjusting for resident service transitions, initiation of the night float system was associated with decreased hospital LOS ($p = 0.047$) and no change in ICU LOS ($p = 0.35$).

CONCLUSIONS This study suggests that a dedicated night float resident may improve night-to-night continuity of care and decrease hospital LOS, but caution must be exercised when initiation of night float results in increased resident service transitions.

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KEY WORDS length of stay; neurosurgery; patient handoff; patient outcome assessment

IN 2003, the Accreditation Council for Graduate Medical Education (ACGME) imposed 80-hour work week restrictions on all residency programs in the United States.² Even though neurosurgical training programs may apply for an 88-hour work week exemption,⁶ providing 24-hour in-house resident coverage while meeting strict work hour requirements often proves difficult, particularly for programs with smaller resident corps. In partial response, many training programs have moved from a 24-hour resident call system to a night float system.³⁴ A night float resident typically provides in-house overnight coverage 5 or 6 nights per week, with other residents taking 24-hour call shifts on the remaining days. These residents provide night-to-night continuity of care for neurosurgical

patients, see and manage consults, and perform emergent bedside procedures. Residents usually spend from 1–3 consecutive months on a night float rotation, with the total duration of night float for each resident dependent on the number of residents and number of hospitals requiring in-house coverage.

Critics of the night float system have expressed concern over what they view as weaker clinical and operative training due to “lost” months spent on night float rotations, increased number of resident handoffs with resultant potential for medical errors, and risk of engendering a shift-work mentality among neurosurgical residents.²⁰ Irrespective of the underlying argument, in this era of training, the ability of neurosurgical residents to

ABBREVIATIONS ACGME = Accreditation Council for Graduate Medical Education; ANCOVA = analysis of covariance; DRG = diagnosis-related group; LOS = length of stay; PGY = postgraduate year; UAB = University of Alabama at Birmingham.

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provide quality care while receiving adequate training has been scrutinized.^{20,23} Following implementation of duty-hour restrictions, multiple studies have reported increased postoperative complications and hospital charges in neurosurgical patients, with no improvement in outcomes.^{7,8,21,32} Additionally, the ACGME mandates that residents have a minimum break period between shifts, which necessitates an increased frequency of handoffs and fragments continuity of care.²⁴

The influence of a night float system on patient outcomes in neurosurgery has never been rigorously evaluated. Here, we compare hospital and neurosurgical ICU lengths of stay (LOSs) for neurosurgical patients admitted before and after initiation of a night float system at an academic tertiary care training hospital, adjusting for potential confounders.

Methods

Patient Selection and Sample Size Determination

The neurosurgical training program at the University of Alabama at Birmingham (UAB) transitioned from a 24-hour call to a night float resident coverage system in July 2013. All patients admitted to the neurosurgical service for 1 calendar year before and after this transition were identified from billing records. Only patients for whom a neurosurgeon was the primary attending of record were included. Patients for whom neurosurgery was a consulting service only were excluded. Sample size was determined by the availability of complete resident call schedules, which were not preserved prior to July 2012. The follow-up period ended at hospital discharge. Investigators collecting data on outcomes of interest were blinded to presence/absence of exposure to the night float system as well as coincident resident service transition. Data were collected from the electronic medical record.

Data Collection

Data collected for this study included patient age, sex, comorbidities, hospital LOS, ICU LOS, coincident resident service transition, admission status (elective admission for surgery, admission through the emergency department, admission from clinic, transfer from outside hospital), admission unit (ICU, stepdown unit, floor), diagnosis-related group (DRG), discharge disposition (home, died, hospice, left against medical advice, another acute hospital, inpatient rehabilitation, skilled nursing facility, psychiatric hospital, other long-term hospital), whether the stay included a weekend, 30-day readmission rates, and mortality. We additionally collected overall LOS for the 5 most common DRGs for the past 7 years, the period for which accurate data were available. Data were collected retrospectively via chart review. The exposure of interest was the night float call system. The primary outcome of interest was overall LOS. ICU LOS and mortality were secondary outcomes in the initial study design. A service transition was defined as any point when a resident handed off coverage of a service for longer than a weekend. Transitions occurred when residents switched between attending services, during vacations, and other absences. These transitions refer to day-coverage residents only, as

night float residents cover all patients on the neurosurgical service. Previous work demonstrated that resident service transitions were highly associated with LOS.²⁶ Dates of service transitions were collected from resident service, meeting, and vacation schedules. Patients admitted for outpatient surgery who did not stay overnight were excluded due to no chance of exposure to the night float system.

Resident Experience

Operative case logs were obtained from the ACGM on-line data collection system for all postgraduate year (PGY) 2 through 6 residents at the UAB during the years under study. Reported duty hours were additionally collected for the same resident cohorts during the years under study. Resident perception on the overall utility of the night float system was assessed via questionnaire using a 5-point Likert scale, where 1 = significantly decreases/worsens, 2 = somewhat decreases/worsens, 3 = no effect, 4 = somewhat increases/improves, and 5 = significantly increases/improves. Residents were queried using an electronic survey sent to all 19 residents at our institution. Reminder emails were sent every 5–10 days until 100% response had been achieved. No incentive was provided to respondents. Responses were de-identified and kept anonymous.

Bias

The following steps were taken to address potential sources of bias. Investigators were blinded to exposure to night float and the occurrence of resident service transitions. A single large group, consisting of all neurosurgical patients admitted to UAB Hospital during the study period, was used for identification of both cohorts to limit selection bias. Recall bias was limited by collecting data solely from the electronic medical record rather than dependence on patient or provider memory.

Statistical Analysis

Patients admitted before initiation of night float ($n = 2173$) were compared with patients admitted after initiation of night float ($n = 2446$) with respect to the following: overall hospital LOS, ICU LOS, mortality, admission status, admission unit, age, sex, comorbidities, occurrence of resident service transition, discharge disposition, and 30-day readmission rates. There were no missing data. Chi-square tests (or Fisher's exact tests when assumptions were not met) were used to assess statistical significance of differences for categorical variables. Differences between continuous variables were compared using 2-sample independent t-tests. Analysis of covariance (ANCOVA) multivariate analysis was performed to determine the independent effect of introducing the night float system on the outcomes of interest. Only variables found to be significantly associated with the outcome of interest were included in the multivariate analysis. Furthermore, a matched-pairs design subset analysis was performed for 2 patient groups: patients undergoing cervical fusion (DRG codes 471–473) and patients undergoing pituitary surgery (DRG codes 614). These procedure subsets were selected as they were performed at high frequency and were likely to consist of similar patient populations. The exposure of

interest was exposure to the night float system. Groups were matched by DRG, age (within 3 years), and sex. The outcome of interest was overall hospital LOS and ICU LOS. All statistical analyses were performed using JMP (version 11.0.0, SAS Institute Inc.).

Preanalysis data screening was performed to determine whether an ANCOVA was appropriate. Normality of distribution of LOS was confirmed using the Kolmogorov-Smirnov test. The relationship between the covariates and dependent variable was not influenced by the independent variable, thus confirming the homogeneity of slopes assumption. The assumptions of independence and normality were met. The assumption of homogeneity of variance was tested using Levene's test, and the results were not found to be significant (F ratio = 0.007; p = 0.93), indicating that the assumption of homogeneity of variance was met.

Post hoc linear regression analysis was performed for overall hospital LOS from 2008 through 2014 for the 5 most common admission DRG codes of patients included in the study, to assess for trends in LOS over an extended period of time. Matched pairs Student t -tests were performed for the above DRG codes for the 2 years immediately prior to initiation of night float. Finally, we assessed the distribution of the 5 most common admission DRG codes for pre-night float and night float years.

This study was approved by the Institutional Review Board at the University of Alabama at Birmingham. The manuscript was prepared following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist for cohort studies.

Results

Study Population

A total of 5497 patients met criteria for inclusion in the study; 878 patients were excluded as they underwent outpatient surgery and did not stay overnight. This left 4619 patients who were included in the final analysis. There were 2173 patients admitted before the initiation of night float, compared with 2446 patients admitted after the initiation of night float. Among the pre-night float group, the mean patient age was 55.0 ± 16.1 years (SD), and 51.1% were male. Among the night float group, the mean patient age was 54.9 ± 15.6 years and 49.3% were male. There was no statistically significant difference in age (p = 0.8) or sex (p = 0.2) between the groups. Furthermore, there was no difference in admission status (p = 0.08), admission unit (p = 0.5), whether the hospital stay included a weekend (p = 0.3), or comorbidities (Table 1).

Resident Service Transitions

In the pre-night float era, there were 253 service transitions (11.6%), while there were 346 transitions in the night float era (14.2%). The proportion of transitions was significantly higher in the night float era (p = 0.01), and concomitant resident service transition was associated with prolonged hospital LOS (p < 0.01) and ICU LOS (p < 0.01). The magnitude of the observed effect of service transitions on length of ICU LOS (p = 0.7) and overall hospital LOS (p = 0.8) was not significantly different between pre- and

post-night float groups. Figure 1 demonstrates the changes to resident service coverage that accompanied moving to a night float system. Figure 2 demonstrates the day-to-day call structure in the pre-night float and night float eras.

Overall Length of Stay

The mean LOS in the pre-night float group was 5.2 days (95% CI 4.8–5.5), while the mean LOS in the night float group was 5.1 days (95% CI 4.7–5.4). Bivariate analysis using 2-sample independent Student t -tests indicated that there was no significant impact on overall LOS after initiation of night float (p = 0.7, Table 2). Adjusting for the increased number of service transitions in the night float era, there was a significant decrease in the overall LOS after the institution of night float (R^2 = 0.25, root-mean-square error = 7.05, p = 0.047). To further characterize the effect of night float on LOS in the absence of resident service transition, we examined the subgroup of patients who did not have a resident service transition. Within this subgroup, the effect was consistent. The mean LOS in the pre-night float group was 3.7 days (95% CI 3.5–3.9 days), while the mean LOS in the night float group was 3.4 days (95% CI 3.2–3.6 days). Bivariate analysis using 2-sample independent t -tests indicated that there was a significant decrease in overall LOS after the initiation of night float among those patients who had not experienced a resident service transition (p = 0.01).

We performed additional post hoc linear regression analysis of overall hospital LOS from 2008 through 2014 for the 5 most common admission DRG codes for patients included in the study. We found a significant trend in decreased overall LOS during this period for DRG code 25 (intracranial procedure with major comorbidities/complications, R^2 = 0.72, p = 0.02), DRG 27 (intracranial procedure without comorbidities/complications or major comorbidities/complications, R^2 = 0.75, p = 0.01), and

TABLE 1. Demographics and clinical variables of the cohorts*

Variable	Night Float (n = 2446)	No Night Float (n = 2173)	p Value†
Mean age in yrs $\pm$ SD	55.0 $\pm$ 16.1	54.9 $\pm$ 15.6	0.8
Male sex, %	51.1	49.3	0.2
Admission via ED	443 (18)	439 (20)	0.08
Admission to neurosurgical ICU	470 (19)	441 (20)	0.5
Elective admission for surgery	1289 (53)	1110 (51)	0.09
Hospital stay extending over weekend	559 (23)	516 (24)	0.3
Atrial fibrillation	114	118	0.7
Hypertension	1128	1107	0.2
Type II diabetes mellitus	339	308	0.6
Coronary artery disease	71	59	0.5
Morbid obesity	111	96	0.7
Tobacco use	445	421	0.13
Congestive heart failure	93	73	0.3

* Values represent the number of patients (%) unless noted otherwise.

† Student t -test was used for comparison of means; chi-square was used for comparison of proportions.

Pre-Night Float									
	July	August	Sept	Oct	Nov	Dec	Jan	Feb	March
Resident A	Attending 1&4	Attending 1&4	Attending 1&4	Attending 2	Attending 2	Attending 2	Attending 3	Attending 3	Attending 3
Resident B	Attending 3	Attending 3	Attending 3	Attending 1&4	Attending 1&4	Attending 1&4	Attending 2	Attending 2	Attending 2
Resident C	Attending 2	Attending 2	Attending 2	Attending 3	Attending 3	Attending 3	Attending 1&4	Attending 1&4	Attending 1&4
Night Float									
	July	August	Sept	Oct	Nov	Dec	Jan	Feb	March
Resident A	Attending 1&4	Attending 2&3	Night Float	Attending 1&4	Attending 2&3	Night Float	Attending 1&4	Attending 2&3	Night Float
Resident B	Night Float	Attending 1&4	Attending 2&3	Night Float	Attending 1&4	Attending 2&3	Night Float	Attending 1&4	Attending 2&3
Resident C	Attending 2&3	Night Float	Attending 1&4	Attending 2&3	Night Float	Attending 1&4	Attending 2&3	Night Float	Attending 1&4

FIG. 1. Changes in month-to-month resident service coverage following transition to a night float system. Arrows represent resident service transitions. Figure is available in color online only.

DRG 460 (spinal fusion except cervical without comorbidities/complications, $R^2 = 0.61$, $p = 0.04$). We then ran a matched pairs Student t-test for the above DRG codes for the 2 years immediately prior to the initiation of night float, which was not statistically significant ($p = 0.7$). Thus, while the mean LOS for our most common DRGs had indeed trended down over a 7-year period, the effect had plateaued prior to initiation of the night float system and would not be expected to confound our results. Finally, we assessed the distribution of the 5 most common admission DRG codes for pre-night float and night float years, to confirm that the patients under study did not differ significantly between each year. The proportions of our 5 most common admission DRGs did not differ significantly between years (all p values > 0.4).

Length of ICU Stay

The mean ICU LOS in the pre-night float group was 4.5 days (95% CI 4.1–4.8 days), while the mean length of ICU stay in the night float group was 5.0 days (95% CI 4.7–5.4 days). On bivariate analysis, there was a significant increase in ICU LOS after initiation of night float ($p = 0.03$). Adjusting for the increased number of service transitions in the night float era, there was no longer a significant difference in the ICU LOS after the institution of night float ($R^2 = 0.17$, root-mean-square error = 5.68, $p = 0.3$). Again examining the subgroup of patients without a resident service transition, the effect was consistent. The mean ICU LOS in the pre-night float subgroup was 3.3 days (95% CI 3.2–3.6), while the mean ICU LOS in the

night float subgroup was 3.6 days (95% CI 3.4–3.8). Bivariate analysis indicated that there was no significant difference in ICU LOS after the initiation of night float ($p = 0.06$) among those patients who had not experienced a resident service transition.

Finally, we performed an additional matched pair analysis for 2 commonly performed procedures, cervical fusion and pituitary surgery. There were 34 matched pairs among patients undergoing cervical fusion. Among these patients, those treated prior to night float had no significant difference in overall hospital ($p = 0.30$) or ICU ($p = 0.84$) LOS relative to patients treated after initiation of night float. Among 24 matched pairs of patients undergoing pituitary surgery, there was again no significant difference in overall hospital ($p = 0.79$) or ICU ($p = 0.90$) LOS between cohorts.

Mortality, Discharge Disposition, and 30-Day Readmission

There were 62 deaths in the pre-night float group (2.9%) and 53 deaths in the night float group (2.2%). These groups were not significantly different ($p = 0.1$), although the small number of events may have masked a statistically significant effect. Overall, 11.2% of patients were readmitted within 30 days during the 2-year study period. Exposure to the night float system was not associated with readmission rates ($p = 0.43$) or discharge disposition ($p = 0.45$) on bivariate analysis.

Resident Experience

We found no significant difference between the num-

Pre-Night Float							
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Day	Green	Red	Blue	Orange	Green	Red	Blue
Night	Green	Red	Blue	Orange	Green	Red	Blue
Night Float							
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Day	Orange	Blue	Red	Blue	Red	Blue	Blue
Night	Green	Green	Green	Green	Green	Orange	Blue

FIG. 2. Changes in day-to-day resident call structure following transition to a night float system. In the 24-hour resident call structure, call periods for each resident are represented as an individual color block for that resident. Figure is available in color online only.

TABLE 2. Effect of a night float system on LOS and mortality

Analysis	Before Night Float (n = 2173)	After Night Float (n = 2446)	Comparison
Bivariate analysis*			
LOS	5.16 days (95% CI 4.80–5.52)	5.05 days (95% CI 4.74–5.35)	t-test: p = 0.65
ICU LOS	4.47 days (95% CI 4.10–4.84)	5.03 days (95% CI 4.68–5.38)	t-test: p = 0.03
No. of deaths	62 (2.85%)	53 (2.17%)	$\chi^2 = 2.23$, p = 0.14
No. of handoffs	253 (11.6%)	346 (15.2%)	$\chi^2 = 6.37$, p = 0.012
Multivariate analysis†			
LOS	LSM = 9.82 (0.19 SE)	LSM = 9.41 (0.18 SE)	p = 0.047
ICU LOS	LSM = 6.58 (0.19 SE)	LSM = 6.81 (0.19 SE)	p = 0.35

LSM = least squares method.

* Continuous dependent variables were compared using 2-sample independent t-tests, while categorical dependent variables were compared using the chi-square test.

† Effect of night float on overall and ICU LOSs adjusted for resident service handoffs. Multivariate analysis was performed using ANCOVA.

ber of cases logged by PGY 2 residents between pre–night float and night float years (mean 140 cases pre–night float, mean 187 cases night float, p = 0.17). Additionally, there was no significant difference between cases logged by PGY 3 and 4 residents between pre–night float and night float years (mean 313 cases pre–night float, mean 323 cases night float, p = 0.47). PGY 5 was excluded as it consists of a dedicated research year at this institution, and PGY 6 was excluded as these residents do not take primary in-house call and would not be expected to experience any change in operative experience due to initiation of the night float system. Furthermore, there was no significant difference between duty hours reported among all residents on clinical services between pre–night float and night float years (mean 61.5 hours per week pre–night float, mean 64.4 hours per week night float, p = 0.39). An online questionnaire was sent to the 19 residents at our institution for the 2014–2015 academic year. There was 100% survey response. Seven residents (37%) had experience as the primary night float resident, and 18 (95%) preferred the night float system to the previous 24-hour call system. Residents felt that the night float system improved adherence to duty hours, quality of life, time for independent study, patient outcomes, and overall residency training. Night float was felt to decrease resident fatigue and had no effect on resident case volume or educational opportunities. Full survey results are found in Table 3 and are demonstrated in Fig. 3.

Discussion

Historical Basis

The initial impetus for instituting resident duty hour restrictions stemmed from a New York City grand jury finding that Libby Zion's death in 1984 resulted in part from resident fatigue.⁵ By 2001, federal legislation regulating resident work hours was drafted (HR3236 and S2614), leading to implementation of work hour restrictions in 2003 by the ACGME. Despite over a decade of national work hour restrictions, resident duty hours remain controversial,^{1,28} in part because of the scarcity of prospective trials comparing medical error rates between residents training under each system. Duty hour restrictions were primarily intended to reduce resident sleep deprivation,

improve clinical performance, and thereby reduce medical errors. Improving resident quality of life and job satisfaction, and decreasing risk of motor vehicle crashes or needle stick injuries, were entirely secondary goals.^{15,27,30,31,35,42} Studies of the effect on patient outcomes have been decidedly mixed, with a recent meta-analysis showing negative effects of duty hour restrictions on patient outcomes and certification examinations for surgical residents.³ Multiple large national database retrospective studies have reported increased postoperative complications and hospital charges in neurosurgical patients following the implementation of duty hour restrictions, with no improvement in outcomes.^{7,8,14,21,32} While compelling, these studies are unable to parse out which factors accompanying work hour restrictions are responsible for the associated decline in outcomes. Decreased resident experience, increased frequen-

TABLE 3. Resident perspectives on a night float system

Effects of night float on...	Mean (SD)*	Likert Scale†
Resident case volume?	2.84 (0.96)	No effect
Educational opportunities/learning?	3.47 (0.77)	No effect
Quality of life?	4.11 (0.74)	Somewhat improves (p < 0.01)
Continuity of care?	3.58 (1.02)	Somewhat improves (p < 0.01)
Adherence to duty hours?	4.47 (0.70)	Somewhat improves (p < 0.01)
Resident fatigue?	4.00 (0.67)	Somewhat improves (p < 0.01)
Time for independent study?	3.74 (0.73)	Somewhat improves (p < 0.01)
Patient outcomes (e.g., complications, LOS, mortality)?	3.53 (0.70)	Somewhat improves (p < 0.01)
Residency training overall	3.84 (0.60)	Somewhat improves (p < 0.01)

* Using a Likert Scale where 1 = significantly decreases/worsens; 2 = somewhat decreases/worsens; 3 = no effect; 4 = somewhat increases/improves; 5 = significantly increases/improves.

† p value shown reflects 1-sample t-test comparing mean to a value of 3 (e.g., no effect).

FIG. 3. Distribution of resident survey responses on implementation of night float. Figure is available in color online only.

cy of handoffs, and changes in billing and coding could all contribute to the observed difference in outcomes over this period.⁴¹ Documentation of complications and medical errors is highly variable and prone to inaccuracy even in electronic medical records, and a recent large study of coding accuracy in surgical patients identified inaccuracy in 51% of patients, including changes in morbidity and incidence of complications.³³ Within the neurosurgical literature, extant studies on complication rates following initiation of ACGME work hour restrictions use large administrative databases, which are subject to these inaccuracies.^{6–8,21} Furthermore, differences in patient outcomes between hospitals have been shown to result not from variations in complication rates, but rather from reduced speed and accuracy in identifying and responding to these complications.^{17,18} As a result, we attempted to limit our study to those outcomes that are reliable and uncontestable. We therefore posit that hospital LOS, ICU LOS, mortality, discharge disposition, and 30-day readmission rates may be a reasonable proxy for clinically significant complications. While work hour restrictions were a contributing factor in the decision to transition to a night float system at our institution, many factors are weighed in ultimately moving to night float coverage. Work hour restrictions predated the night float transition in this study, and thus would not be expected to directly influence our findings.

Implication of Findings

Rigorous evaluation of a night float system must account for effects on both patient outcomes and resident training. The primary goal of a night float system must be to promote high-quality patient care without sacrificing resident education, all while remaining within the bounds of the ACGME

duty hour restrictions. High-quality studies have failed to convincingly demonstrate a positive impact of night float on patient outcomes,³ with several studies showing negative perceived effects of night float on patient safety.^{2,13,38} Studies on the influence of night float on resident education and wellness are similarly mixed, with both positive and negative effects having been demonstrated.^{2,13,15,19}

The stability of the UAB neurosurgical program was essential to demonstrating the impact of instituting the night float system. During the period under study, there were no significant changes in neurosurgical faculty, facilities, electronic medical record, hospital coverage, or patient population. To our knowledge, there have been no studies in the neurosurgical literature evaluating the relationship between night float and LOS, and as such this is a novel contribution. Importantly, coincident with the transition to a night float system was an increased frequency of resident service transitions, which were highly associated with LOS and ICU stay. In switching to a night float system, the resident rotation structure was altered to accommodate the new night float system. As a result, residents changed services more frequently. We demonstrate herein that, after adjusting for resident service transitions, institution of a night float system is associated with decreased hospital LOS among neurosurgical patients, with no observed correlation with ICU LOS, mortality, discharge disposition, or 30-day readmission rates. The same effect was observed when considering only patients who did not experience a resident service transition.

It is essential to distinguish between resident service transitions—the change from one resident to another of a large number of patients for whom they have primary day-to-day responsibility—from the end-of-day handoff of care to a single resident providing care to all neurosurgi-

cal patients overnight. Even under a 24-hour resident call system, there is still a twice-daily handoff that occurs for all patients except those for whom the on-call resident holds primary responsibility. Additionally, due to ACGME work hour restrictions, even in a 24-hour call system the on-call resident must hand off responsibility for their patients for the postcall day. In a 24-hour call system, each resident will be on call every 3rd to 6th night. By contrast, in a night float system, the same resident typically provides overnight coverage 5–6 nights in a row. Therefore, the key difference with a night float system is that the resident providing overnight coverage is likely to be more familiar with all neurosurgical inpatients than a resident who is only on call every 4th or 5th night. We hypothesize that this improved night-to-night continuity of care may be the driving force behind our findings.

Even in the absence of demonstrable errors in patient care, when a new resident assumes coverage of a large service, there is an inevitable lag period before the resident becomes knowledgeable about each patient and his or her potential barriers to discharge. Previous work demonstrated that resident service transitions were associated with increased LOS in neurosurgical patients at our institution.²⁶ We suspect this adjustment period results in delays in patient discharge, with resultant unnecessary medical resource utilization. Seemingly minor factors such as prompt involvement of ancillary services such as physical therapy or social work may result in delays in discharge, without identifiable complications. In the bivariate analysis alone, night float appeared to be associated with increased ICU LOS, with no effect on overall LOS. Only after adjusting for resident service transitions was the night float system associated with reduced hospital LOS. A primary factor distinguishing our findings from prior studies is the inclusion of resident service transitions as a key confounding variable. This finding highlights a potential unintended consequence of switching to a night float system—an increased frequency of resident service transitions.

Impact of Handoffs

Provider handoffs are nuanced exchanges encompassing a wide range of subjective and objective clinical measures for the transition of patient care to another provider.¹² Optimizing the handoff process has been evaluated in medical specialties,^{16,22} but scant attention has been paid to handoff effects in neurosurgery.^{6,36} Among medical residents, duty hour restrictions are associated with increased rates of self-reported medical errors, related to more handoffs.⁴⁰ Discontinuity of care in any form contributes to medical complications and increased LOS, whether from handoffs, short versus long call period, or hospital stay encompassing a weekend.^{9,29,39,45,46} In the surgical ICU, increased fragmentation of care through handoffs has been associated with higher rates of reintervention, ICU readmission, and complications.¹⁰ Resident handoffs are largely unstructured, have significant deficiencies, and frequently fail to convey essential patient information.⁴³ High patient acuity, large censuses, and reliance on the inherently subjective nature of the neurological examination may render neurosurgical patients at particular risk for handoff-related errors.⁴⁴ Standardized tools, deliberate practice, and mini-

mizing distractions may be used to improve the quality of resident handoffs.⁴

Night Float and Resident Training

Most general surgery residents perceive that systemic flaws are responsible for the majority of medical errors, and that further work hour restrictions will not further improve medical care.¹¹ An abundance of caution must be exercised when considering the transition to night float, so as not to diffuse patient ownership, limit operative experience, and increase noneducational activities. Residents in our program take a nearly universally positive stance toward the night float system, citing improved adherence to duty hours, quality of life, time for independent study, patient outcomes, and overall residency training. Night float was felt to decrease resident fatigue and have no effect on resident case volume or educational opportunities. At our institution, under the 24-hour call system, the on-call resident was unable to reliably participate in operative cases during the day, and, due to ACGME work hour restrictions, was unable to participate in operative cases on the postcall day. However, no studies to date have formally evaluated the effect of night float on operative case volume in neurosurgery, and data from other surgical disciplines are mixed.^{25,37} While we found no significant difference in resident reported duty hours or number of operative cases logged, the small number of residents involved limits the generalizability of our findings. Future investigations into the effect of implementing a night float system must consider patient-centered outcomes as well as metrics of resident training.

Limitations

Limitations of this study include retrospective data collection, lack of long-term outcomes or specific complication rates, and performance at a single institution. Length of stay was initially selected as our primary outcome of interest because it is uncontested and can be considered a proxy for significant complications. It is not known if the results from our study are generalizable to other neurosurgery residency programs. There are likely modest regional variations in patient populations and composition of neurosurgical services. There is also variation between institutions on how resident coverage is distributed and assignment of responsibilities of residents and advanced practitioners. Finally, we did not include patients for whom neurosurgery was a consulting service, including polytrauma patients with neurological injuries. Length of stay for these patients is dictated by a multitude of factors for which it would be difficult to control, and as such only patients for whom a neurosurgeon was the primary physician were included. For these reasons, our findings warrant validation by future studies.

Conclusions

Transitioning to a resident night float system increases the number of resident service transitions, the inevitable sequelae of which includes a heightened risk of medical errors. Previous studies have focused on the deleterious influence of duty-hour restrictions, with the premise that

resident education has declined in the post-2003 era, with patient outcomes suffering as a result. We find that transitioning to the night float system increased ICU LOS with no effect on hospital LOS, and only by adjusting for resident service transitions do we observe decreased overall hospital LOS, with no effect on ICU LOS.

Patient mortality, discharge disposition, and readmission rates were not impacted by the institution of the night float system in our population. Furthermore, resident perception of the night float system was that it was positive for patient care, resident training, and decreasing resident fatigue, while resident duty hours and operative cases logged were unaffected. This study supports the argument that increased frequency of service transitions, not poor quality of resident training, may be the cause of poorer outcomes among neurosurgical patients in the modern era of training. Prospective cohort studies are needed to definitively establish associations between night float and patient outcomes. Futures studies should also prospectively analyze means of improving continuity of care, enhancing the night float system, and mitigating the effect of resident service transitions on patient outcomes.

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Disclosures

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Author Contributions

Conception and design: Davis, Markert. Acquisition of data: Davis, Kuhn. Analysis and interpretation of data: Davis, Kuhn. Drafting the article: Davis, Kuhn. Critically revising the article: Davis, Kuhn. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Davis. Statistical analysis: Davis, Kuhn, Agee, Oster. Study supervision: Markert.

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