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Original Research

An Equitable Electronic Scheduling System for Anesthesiology Residents: A Quality Improvement Project

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Introduction

Residency training programs in graduate medical education are time-limited experiences that require resident trainees to achieve competence in a variety of medical domains before graduation and independent practice. Further, the Accreditation Council for Graduate Medical Education, the accrediting body for medical training, requires minimum surgical procedure exposure for a variety of index cases-types in surgical specialties and anesthesiology[1] while mandating that residents adhere to specific work-hour limitations.[2] Given the time-limited nature of training and the requirement for specific experiences, it is imperative that work distribution is fair and equitable.

Nevertheless, the process to achieve trainee schedule equity is often delegated to novices in operations management. At our institution, a senior resident in the final year of training takes on the added responsibility of developing the resident work schedule, known as the "call" schedule. The senior, or "chief" resident is expected to create a schedule without much training, tools, or expertise to ensure a fair distribution of assignments. Often, resident physicians at our institution informally report that scheduled work is distributed inequitably.

Manpower scheduling has presented a challenge in various industries that require meeting a demand for services while abiding within specific scheduling constraints. The concept of using a mathematical model to help assign work shifts was introduced as early as 1954, when integer programming was used to ensure toll booths were adequately and fairly staffed during traffic rush hour.[3] A goal programming approach was described in 1988 that took into account nurses' preferences when creating a hospital staffing schedule.[4] Airline and mass transit industries eventually presented scheduling challenges involving work-hour limitations. A scheduling decision support tool needed to incorporate parameters, or "rules," while taking into account industry demands, worker preferences, and experience levels. Several studies showed how computing programs could be used to solve a scheduling problem.[5,6]

Assigning work shifts to resident physicians presents similar challenges, where a schedule must balance work hours restrictions, medical trainee experience, case exposure requirements, and hospital staffing needs. This article describes an improvement project focused on the equity of work distribution in a medical training context through optimization of the anesthesiology resident call scheduling over an academic year. The aim of this study was to implement a novel, computer-generated scheduling system and evaluate the new schedules for improved equity in work distribution.

Methods

We piloted the equitable work distribution project with the anesthesiology residents at a modestly sized (n = 24), urban, academic medical center. The schedules for anesthesiology residents postgraduate year (PGY) 2 through PGY4 (first year clinical anesthesiology resident [CA-1] through CA-3) were used in this project. PGY1 anesthesiology residents do not patriciate in taking call. Residents on off-site rotations were exempt from taking call at George Washington (GW) hospital, and therefore any months at off-site locations were excluded from the scheduling system. The GW Institutional Review Board granted exemption to report findings of this quality intervention.

Pre-Point System Scheduling Model (Pre-PS)

Before July 2015, a chief resident created the work schedule following an unwritten tradition of rules passed down from prior chief residents. These rules included the following: (1) avoid violation of work-hour limits; (2) prerequisite experience required for certain assignments; (3) honor resident requests, including vacations and special requests, if possible; and (4) each resident should be scheduled "off" at least 2 weekends per month. Vacation assignments conformed to the rule that each resident be off at least 1 major holiday (Thanksgiving Day, Christmas Day, or New Year's Day). A 1-month schedule was manually created without external review or oversight, and historical effort was not guaranteed to

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be reflected in future assignments. Shifts were designated with a call number that determined the order in which a resident would be relieved from clinical activity. This system is described in Table 1.

Post-Point System Scheduling Model (Post-PS)

A needs assessment of work schedule strengths and weaknesses was obtained by informal stakeholder interviews by authors (C.S., J.S.B.). Key factors identified were subsequently incorporated into a survey that was administered to all residents in the program (n = 24). Themes, noted as multiple comments on the same topic, were recorded and agreed by authors (E.C., A.K.H.). Results of the residents' needs assessment survey to evaluate all potential call-types were tabulated (Appendix 1). Qualitative themes for resident score valuation were reported as follows: day of the week, number of evening hours worked, likelihood of being recalled to clinical duty after release, anticipated intensity of workload, and ability to extend non-work periods.

The chief resident–derived point system incorporated resident preferences into a final scoring system that was implemented in July 2015. From the survey in early 2015, 32 unique shifts were identified for classification in 19 discrete point assignments. Points ranged from 1 to 40 (Appendix 2). Vacation assignments were prioritized to reflect the complexity of multiple, consecutive low point-value workdays (Appendix 3) and special requests were also addressed (Appendix 4). In the first year the tool was used, the algorithm produced 5 to 10 draft schedules before a satisfactory schedule was found and published. The number of drafts needed has decreased as the model has been refined over the years, and now the program is able to produce acceptable schedules on the first or second attempt. Each academic year since the initial development year (2015-16), the new chief residents met with faculty in the Department of Computer Engineering (HA, AC) to adjust rules or goals of the model based on annual resident feedback.

The model was solved for 12 months and published in 3-month increments. During each quarterly scheduling session, the chief residents would review the best schedule found, along with the supporting reports. Quarterly, data were updated to reflect manual swaps or rule modifications and re-solved for accurate accounting before publishing the next increment of the call assignments.

Computer Algorithm

Basic rules were codified and weighted 1 to 4, 1 = maximal importance, requiring enforcement, as a computer programming algorithm (Appendix 5). These rules were formulated into a mixed-integer programming model with both hard and soft constraints and a blended objective function. Mixed-integer programming is a method of problem solving in which some variables are defined as integer values while other variables are left as continuous values. In this study, the main integer variables are binary (0,1) and assigned to each resident, day, and call shift. The variable is 1 if that specific assignment is made or fulfilling a weekend-off request, 0 if otherwise. The main continuous variables relate to the points assigned, call shifts worked, monthly point totals, averages, and annual totals. These variables were used in the objective function to squeeze the averages for residents in each class, and to enforce workload upper and lower bounds. Continuous variables were also used to penalize breaking "soft" constraints.

Due to the complexity of the model, several solving heuristics were also implemented to aid the commercial optimization solver (Gurobi Optimization, LLC, Beaverton, OR). To quickly obtain a high-quality solution, all the hard constraints were relaxed by adding the penalty variables, as mentioned previously. This would produce a mathematically feasible, although not practically feasible, solution. The program objective was then set to minimize the number of hard constraints violated. Subsets of variables were then locked in their values in the current solution and optimized over the reduced space. Increasingly better solutions could be found by iteratively solving different smaller portions of the models rather than solving the full model at once. Once all hard constraints were satisfied, the penalty variables (permission to violate hard constraints) were removed. The iterative solving approach was used again to then produce a practically feasible solution. When new solutions became hard to find, the full model was solved either until optimality, or until there was no improvement for an hour.

Statistical Analysis

The call valuation model was retrospectively applied to 9 months of manually created call schedules (July 2014 to March 2015). April to June 2015 were excluded due to piloting the computer-generated, point-based schedule. Call-shift points per month and SDs were prospectively tracked in the 4 academic years from 2015 to 2019.

Pre-post intervention SD variation was compared over time, by class and in aggregate. Levene's test for equality of variance was used to evaluate for statistical significance (SAS 9.4; SAS Inc, Cary, NC). P values < .05 were considered significant.

Results

Analysis of call schedule variance over time revealed, for the pre-PS year (2014), the SD of point distribution for all trainees was 13.4. Following the implementation of the computerized point system, call point distribution for all residents (CA-1, CA-2, and CA-3) trended toward reductions in SD, with significant reduction achieved at 63% in 2016 (SD 4.9, $P < .01$) and 57% in 2017 (SD 5.8, $P < .01$). Call point variance trended toward reduction in 2015 (SD 8.9, $P = .39$) and in 2018 (SD 7.9, $P = .38$; Table 2).

The SD of the CA-1 class decreased by 73% in 2016 (SD 2.5, $P < .01$), by 67% in 2017 (SD 3.1, $P = .04$), and 65% in 2018 (SD 3.3, $P = .02$) compared with the pre-PS year in 2014. The CA-2 class SD decreased by 56% in 2015 (SD 5.9, $P < .01$), 41% in 2016 (SD 7.9, $P = .02$), and 49% in 2017 (SD 6.9, $P < .01$). The CA-3 class showed a trend toward a reduction in variance for all the studied years, most notably in 2016 (SD 4.5, $P = .06$; Figure 1).

Discussion

The PS scheduling program created a schedule for anesthesiology residents that fulfilled all requirements (ie, hard constraints) while demonstrating a trend toward improved equity in distribution of shifts and vacation requests over manual

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scheduling. The equity of call distribution was significantly improved in 2016 and 2017 for all classes with a trend toward improvement in all 4 years post-PS implementation. Significant improvement, by class, was noted for the CA-1 (2016, 2017, and 2018) and CA-2 (2015, 2016, and 2017) classes compared with the pre-PS implementation (2014). This represents the first successful launch of a year-long, computer-generated anesthesiology resident schedule, in actual practice (ie, adjusting to dynamic scheduling demands), that trended toward improvement in call schedule equity over a range of 19 distinct point assignments representing 32 unique shifts.

A successful computer-generated schedule required flexibility for real-world feasibility. Our scheduling system allows residents to address personal emergencies or unforeseen scheduling changes. Post creation of a computer-generated schedule, inclusive of day-to-day adjustments, the software was able to re-optimize, as necessary, to ensure that changes were reflected in future point allocation at the next quarterly schedule release. In addition, the release of call schedules in 3-month increments was a noted improvement from pre-PS call scheduling implementation when manual schedules would often be released with less than 1 month of notice and for only 1-month increments.

Feasibility of this PS scheduling program may also hinge on access to a computer scientist, or similarly inclined individual, to generate the schedule using appropriate software. Although the initial effort to input constraints may take 10 to 20 hours of programming and testing, steady-state schedule generation may take only an hour or 2. Institutions, particularly those sponsoring a School of Engineering, may already license an optimization software; however, if not, this may be an additional expense to consider.

Despite costs, we believe that transparency in resident scheduling equity may complement work-hour restrictions to improve workplace conditions and mitigate resident burnout across specialties.[7] Factors that may contribute to job stress are the unpredictability of one's work schedule, and the subjective feeling of inequitable call schedules among residents.[8] Before the implementation of a computerized point system in our training program, there was poor transparency regarding call distribution between resident classes and individuals. Since the implementation of the computerized PS, the point values for shifts, schedule rules, and holiday request formula are widely distributed in a transparent manner. In addition, an organized point total of each individual's call schedule to date is available to residents. By improving schedule equity, the potential exists for reducing resident burnout. However, burnout was not addressed in the present study and merits consideration for future investigation.

Previous studies have been published using computer algorithms to improve the medical trainee call scheduling process. However, much of the literature published on this topic involved creating and comparing hypothetical schedules without actually implementing the computerized system.[9-11] For example, a study by Sherali et al[9] used a mix integer program to find solutions for different scheduling scenarios faced by residents. The solutions presented were theoretical. Similarly, a study by Smalley and Keskinocak[10] used a 2-integer programming model to create monthly rotation assignments and a night and weekend call-shift schedule for individual rotations. This model was used to generate a theoretical call-shift schedule for 1 month for 1 class of surgery residents. Finally, a study by Brunner et al[11] used mixed-integer programming to create a theoretical shift schedule for anesthesia physicians. This model was implemented on a trial basis by the hospital, but the success of the implementation was not discussed.

Three studies have been published that describe actual implementation of a computerized schedule-writing tool. An anesthesiology residency program implemented an automated decision support tool that recommended a daily prioritized relief list.[12] This system was not designed to create year-long schedules and did not have to take into account added complexities such as vacation requests and holidays. A pediatrics residency program implemented an automated scheduling system for visiting residents rotating in their pediatric emergency department.[13] The computer algorithm generated a feasible schedule that the scheduler could review and implement. However, because these residents were rotating for only 1 month, this program would only need to generate a schedule for that month and did not need to account for equal distribution of call assignments throughout an entire year. Finally, a psychiatry residency program developed a computer program to assist with developing a year-long schedule.[14] The methods described by Cohn et al[14] are similar to those presented in this article; however, the call shifts were all uniform and equally weighted, ignoring discreet shift-types.

Findings should be interpreted with caution, as there were limitations to this study. A statistically significant improvement in variance, in terms of SD, was not consistently noted for each year the computer-generated schedule was used. In addition, examination by class failed to consistently demonstrate improvement in variance, particularly in the CA-3 class. We explain these findings by noting that trends toward improvement were commonly identified and that larger samples would potentially confirm our suspicion that a more equitable schedule was achievable for all groups over time. In addition, practical considerations confounded the findings to some extent. For example, informal requests made by trainees to guarantee a particular scheduled shift to accommodate personal needs may limit equity in point distribution. In addition, anesthesiology residency often entails off-site rotations that are not incorporated into the point scheduling system; discrepancies in variability may have been influenced by the degree of assigned off-site rotations for residents. In the CA-3 year, off-site elective rotations may explain the lack of significance in our findings of reduced variation in call point totals.

Finally, in both 2015 and 2018, although the data trended toward reduction in call point variation, significance was not reached. In 2015, we attribute the lack of significance to the novel implementation and necessary adjustments to resident expectations. Closer examination of 2018 revealed that

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the CA-1 class had only 7 residents, whereas the CA-2 class had 10 residents in this year. As is the case in most anesthesiology training programs, the CA-2 year explores subspecialty rotations, such as chronic pain medicine and critical care medicine, which displaced residents outside of the call point scheduling system. Accordingly, the skew in class size accounted for the larger variation in call points among trainees, as fewer total trainees were available over the course of the year to receive the total point allocation.

Implementation of a computer-generated point system has enabled the creation of anesthesiology resident call schedules that, over several years, have demonstrated a trend toward less variation in work schedules. In some years, and for some classes, the reduction in variability was significant; however, further investigation will be required to clarify the impact of these findings. Although this system has been successfully deployed, future study should evaluate the sustainability of this model, modifications over time, implications for work hours, and the perceptions of fairness among participants.

Acknowledgments

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References

1. Accreditation Council for Graduate Medical Education (ACGME). ACGME program requirements for graduate medical education in anesthesiology; 2002. www.acgme.org. Accessed December 11, 2021.
2. Philibert I. New requirements for resident duty hours. *JAMA*. 2002;288(9):1112-4.
3. Dantzig GB. Letter to the editor—a comment on Edie's "Traffic Delays at Toll Booths." *Oper Res*. 1954;2(3):339-41.
4. Ozkarahan I, Bailey JE. Goal programming model subsystem of a flexible nurse scheduling support system. *IIE Trans*. 1988;20(3):306-16.
5. Graves GW, McBride RD, Gershkoff I, Anderson D, Mahidhara D. Flight crew scheduling. *Manage Sci*. 1993;39(6):736-45.
6. Barnhart C, Johnson EL, Nemhauser GL, Sigismondi G, Vance P. Formulating a mixed integer programming problem to improve solvability. *Oper Res*. 1993;41(6):1013-9.
7. Rodrigues H, Cobucci R, Oliveira A, et al. Burnout syndrome among medical residents: A systematic review and meta-analysis. *PLoS One*. 2018;13(11):e0206840.
8. Taris TW, Peeters MCW, Le Blanc PM, Schreurs PJG, Schaufeli WB. From inequity to burnout: the role of job stress. *J Occup Health Psychol*. 2001;6(4):303-23.
9. Sherali HD, Ramahi MH, Saifee QJ. Hospital resident scheduling problem. *Prod Plan Control*. 2002;13(2):220-33.
10. Smalley HK, Keskinocak P. Automated medical resident rotation and shift scheduling to ensure quality resident education and patient care. *Health Care Manag Sci*. 2016;19(1):66-88.
11. Brunner JO, Bard JF, Kolisch R. Flexible shift scheduling of physicians. *Health Care Manag Sci*. 2009;12(3):285-305.
12. Bhutiani M, Jablonski PM, Ehrenfeld JM, McEvoy MD, Fowler LC, Wanderer JP. Decision support tool improves real and perceived anesthesiology resident relief equity. *Anesth Analg*. 2018;127(2):513-9.
13. Perelstein E, Rose A, Hong Y-C, Cohn A, Long MT. Automation improves schedule quality and increases scheduling efficiency for residents. *J Grad Med Educ*. 2016;8(1):45-9.
14. Cohn A, Root S, Kymissis C, Esses J, Westmoreland N. Scheduling medical residents at Boston University School of Medicine. *Interfaces*. 2009;39(3):186-95.

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Abstract

Background: Most postgraduate medical education occurs in hospitals in an apprenticeship model with actual patients. Creating a work shift schedule must account for complex factors, including hospital needs, work-hour restrictions, trainee qualifications, and case distribution in order to fairly allocate the resident workload. In this study, we report the first successful implementation of an equitable, computer-generated scheduling system for anesthesiology residents.

Methods: A total of 24 residents at a single, urban training program were surveyed in 2015 to rank work shift difficulty. Shifts were categorized and translated into a weighted point system by program leadership based on the survey results. An automated and modifiable scheduling system was created to incorporate rule-based assignment of prerequisites and evenly distribute points throughout the academic year. Point values were retrospectively calculated in 2014, and prospectively calculated from 2015 to 2018. The equality of variance test was used to evaluate the variation of the SD of monthly average point distributions year-over-year and within each class of trainees.

Results: Year-over-year analysis revealed that post-point system implementation, call point distribution trended toward reduced variance in all 4 years, with significant reductions of 63% in 2016 (SD 4.9, $P < .01$), and 57% in 2017 (SD 5.8, $P < .01$). Analyzed by class, first-year trainees' SD decreased by 73% in 2016 (SD 2.5, $P < .01$), by 67% in 2017 (SD 3.1, $P < .04$), and 65% in 2018 (SD 3.3, $P < .02$) compared with the pre-point system year in 2014. The second year clinical anesthesia resident class SD decreased by 56% in 2015 (SD 5.9, $P < .01$), 41% in 2016 (SD 7.9, $P < .02$), and 49% in 2017 (SD 6.9, $P < .01$).

Conclusion: The computerized point system improved work distribution equity year-over-year and within trainee cohort groups.

Keywords: Shift scheduling, operational management, mixed-integer programming, resident scheduling

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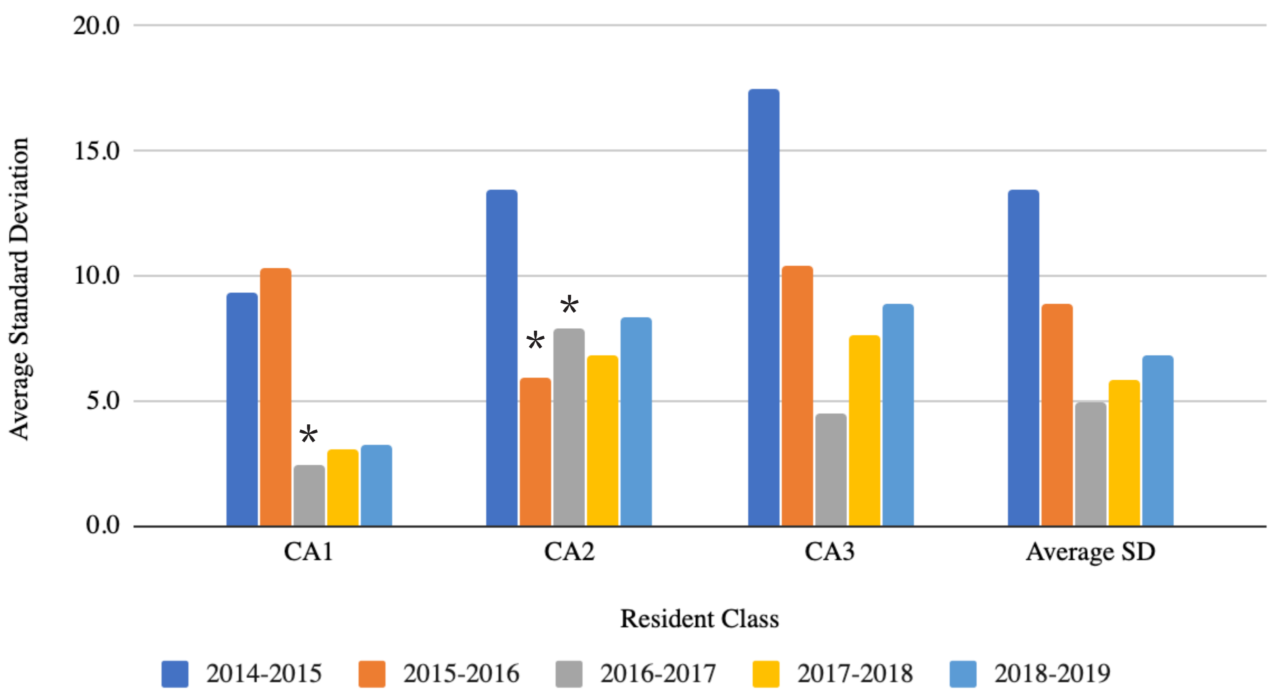
Figure

Figure 1. *Standard deviation of average points per month per class, 2014 to 2019.*
Abbreviation: CA, clinical anesthesiology resident (first year, second year, third year).

**P < .05.*



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Tables

Table 1. *Description of Numbered Shifts*

Call Number	Description
Unnumbered	Typically work shift of 6:30 AM to 3:30 PM. Will not be called to return to the hospital.
1	24-h shift of 6:30 AM to 6:30 AM the next day.
2	24-h shift of 6:30 AM to 6:30 AM the next day.
3	Work shift of 6:30 AM to 8-10 PM. Is the first to be called back if more staff is needed.
4	Work shift of 6:30 AM to 8-10 PM. Is the second to be called back if more staff is needed.
5	Work shift of 6:30 AM to 6-8 PM. Unlikely to be called back into the hospital.
6	Work shift of 6:30 AM to 6-8 PM. Unlikely to be called back into the hospital.
7	Work shift of 6:30 AM to 4-6 PM. Unlikely to be called back into the hospital.
8	Work shift of 6:30 AM to 4-6 PM. Unlikely to be called back into the hospital.

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Tables *continued*

Table 2. *Analysis of Pre-Post Point System Implementation, by Residency Class*[a]

Class	2014 Manual	2015 Computer	2016 Computer	2017 Computer	2018 Computer
First year					
Average points per month	122.2	143.5	141.6	119.4	130.2
No. of residents	8	8	8	10	7
SD	9.3	10.3	2.5	3.1	3.3
P value	—	.80	**<.01**	**.04**	**.02**
% Change in SD from 2014	—	10	**−73**	**−67**	**−65**
Second year					
Points per month	136.2	158.1	167.0	177.5	173.6
No. of residents	8	8	8	7	10
SD	13.5	5.9	7.9	6.9	11.6
P value	—	**<.01**	**.02**	**<.01**	.29
% Change in SD from 2014	—	**−56**	**−41**	**−49**	−14
Third year					
Points per month	130.7	132.4	145.1	140.3	143.0
No. of residents	9	9	8	8	7
SD	17.5	10.4	4.5	7.6	8.9
P value	—	.81	.06	.35	.70
% Change in SD from 2014	—	−41	−74	−57	−49
Average of all classes					
Ave SD for all classes	13.4	8.9	4.9	5.8	7.9
P value	—	.39	**<.01**	**<.01**	.38
% Change in SD from 2014	—	−34	**−63**	**−57**	−41

[a] Boldface indicates statistically significant ($P < .5$).

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Appendices

Appendix 1. Resident Valuation Survey by Unique Call

Valuation of call according to factors (column headings). Ratings for average extra hours and adjusted extra hours were numerical, > 1. Chance of call was rated as a percent, 0-100. Potential loss of day off, post-call day off, downtime, and 3-day weekend were rated as likely "X," very likely "XX," unlikely "-X," and very unlikely "-XX."

Call, Including Holidays (n = 32)	Avg Extra Hours (no.)	Chance of Call (%)	Adjusted Extra Hours	Potential Loss of Day Off	Post-Call Day Off	Loss of 3/2 Combo	Ability to Sleep	3-Day Weekend
6 (Monday-Friday)	1	1	1					
5 (Monday-Friday)	2	1	2					
4 (Saturday, Sunday)	4	0.25	1	X				
4 (Monday-Friday)	3	1	3					
3 (Monday-Thursday)	6	1	6					
8 (only)	6	0.75	4.5	X				
3 (Friday)	6	1	6			X		
7 (only)	7	0.8	5.6	X				
3 (Sunday)	7	0.75	5.25	X		X		
6 (only)	8	0.9	7.2	X				
1 (Thursday)	14	1	14	X	-X		-XX	-X
5 (only)	9	0.9	8.1	X				
3 (holiday)	7	0.9	6.3	X		X		
2 (Thursday)	9	1	9	X	-X		-X	-X
4 (only)	9	0.95	8.55	X				
3 (Saturday)	10	0.9	9	X		X		
3 (only)	10	1	10	X		X		
1 (Monday-Wednesday)	14	1	14		-X		-XX	
2 (Tuesday-Wednesday)	9	1	9		-X		-X	
2 (Monday)	14	1	14		-X	X	-X	
1 (Friday)	14.5	1	14.5		X		-XX	
2 (Friday)	9.5	1	9.5		X		-X	
1 (Sunday)	23.5	1	23.5	XX	-X		-XX	
1 (Monday, holiday)	23.5	1	23.5	XX	-X		-XX	
2 (Sunday)	23.5	1	23.5	XX	-X	X	-X	
2 (Monday, holiday)	23.5	1	23.5	XX	-X	X	-X	
1 (major holiday)	24	1	24	XX	X		-XX	
2 (major holiday)	24	1	24	XX	X	X	-X	
1 (Saturday)	24	1	24	XX	X		-XX	
1 (only)	24	1	24	XX	X		-XX	
2 (Saturday)	24	1	24	XX	X	X	-X	
2 (only)	24	1	24	XX	X	X	-X	

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Appendices *continued*

Appendix 2. Final Point Values for Each Call Assignment (2014)

N = 19 discrete point assignments for 32 unique calls; range 1-40; median 22.

Call	Points
8 (Monday-Friday)	1
7 (Monday-Friday)	2
6 (Monday-Friday)	4
5 (Monday-Friday) or 4 (Saturday or Sunday)	6
4 (Monday-Friday)	10
3 (Monday-Thursday) or 8 (only)	14
3 (Friday) or 7 (only)	16
3 (Sunday) or 6 (only)	18
1 (Thursday) or 5 (only) or 3 (Holiday)	20
2 (Thursday) or 4 (only)	22
3 (Saturday and only)	24
1 (Monday-Wednesday)	26
2 (Tuesday-Wednesday)	28
2 (Monday)	30
1 or 2 (Friday)	32
1 (Sunday or Holiday)	34
2 (Sunday or Holiday)	36
1 (Saturday and only)	38
2 (Saturday and only)	40

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Appendix 3. Holiday Requests Formula

Residents rank preferences at beginning of academic year. Consideration for seniority given.

Major Holiday Request (Thanksgiving/Christmas/New Year's)

1. Each holiday weekend is a Thursday to Sunday.
2. Holiday call schedule priorities

a. 1st: Overnight on Tuesday; Post-call Wednesday. Unnumbered Thursday to Sunday.
b. 2nd: Unnumbered Wednesday to Sunday
c. 3rd: Unnumbered Thursday to Sunday (essentially off each of those days)
d. 4th: Overnight Wednesday; Post-call Thursday; Unnumbered Friday, Saturday, and Sunday
e. 5th: Unnumbered on the Holiday (11/26, 12/25, or 1/1)

Minor Holiday requests: All Minor Holidays except July 4th have a Monday off (Labor Day, Martin Luther King Day, President's Day, and Memorial Day)

1. 1st: If not taken by a vacation, Overnight Thursday of that coming weekend, so Post-call Friday and Unnumbered Sat to Monday.
2. 2nd: Unnumbered Friday, Saturday, Sunday, and Monday
3. 3rd: Unnumbered Saturday, Sunday, and Monday
4. 4th: Overnight Friday; Post-call Saturday and then Unnumbered Sunday and Monday
5. 5th: Unnumbered Monday, the Holiday day

July 4th requests

1. 1st: On-call Wednesday; Post-call Thursday and Unnumbered Friday, Saturday, and Sunday
2. 2nd: Unnumbered Thursday, Friday, Saturday, and Sunday
3. 3rd: Unnumbered Friday, Saturday, and Sunday
4. 4th: Overnight Thursday; Post-call Friday and Unnumbered Sat and Sun.
5. 5th: Unnumbered Sat and Sun
6. 6th: Unnumbered on Sat, July 4th

Appendix 4. Rules for Special Requests

Additional requests for time off not covered by holiday or vacation requests were considered by the chief residents according to the following guidelines.

Weekend-Off Requests:

- 1 Weekend request per month.
- No request or request not honored = 20 points.

Call Trades:

- Chiefs will ensure trade equity by applying point differentials to future schedules.
- If unable to cover assigned call or find a colleague to cover the call, chiefs may find a replacement.
  - Resident replacement: gains 1.5×'s points for that call.
  - Resident unable to fulfill call obligation: activation of chief support will lose 0.25×'s points for that call.

Weekday Unnumbered Requests:

- Does not include holidays.
- No point penalty for up to 2 requests per month.

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Appendices *continued*

Appendix 5. Call Schedule Rules in Order of Priority

Rules ranked from 1-4, based on importance, for computer algorithm. Rules ranked "1" were required.

Call Rules	Rank	Note
1 & 2 Call cannot work next day	1	
3 Call becomes 2 Call next day	1	Except Friday, Saturday, and Sunday
2 Call must be obstetrics (OB) Certified	1	
1 Call should have at least 7 weeks experience in residency	1	
On Monday-Thursday 3 Call has to be OB Certified	1	
Friday-Saturday 3 Call cannot work the next day	1	Exception: Sunday #3 resident will work in OR Monday, and can be numbered (1-8)
4 Call Weekend same person for Saturday and Sunday (Resident must be 1 Call certified)	1	
Off-Site Residents cannot be on schedule for that particular month	1	
2 Weekends off per month for every resident	1	Weekend OFF = not working Sat 0730-Mon 0730
There should be at least 2 seniors on 1 or 2 or 3 Call each day (July-December) [ie, Only ONE 1st year allowed to be either 1 or 2 or 3 each day]	1	Senior = 2nd year or 3rd year
There should be at least 1 senior on 1 or 2 or 3 Call each day (January-June) [ie, No more than TWO CA-1's allowed to be either 1 or 2 or 3 Call each day]	1	Senior = 2nd year or 3rd year
Residents on Clinical Rotations (Chronic Pain/Acute Pain/Health Policy) can only be 1 Call Friday and Saturday	2	Weekday 4-8 is fine.
Residents on Clinical Rotations (Chronic Pain/Acute Pain/Health Policy) can only be 2 Call Saturday	2	Weekday 4-8 is fine.
Residents on Clinical Rotations (Chronic Pain/Acute Pain/Health Policy) can only be 3 Call Friday and Saturday and Sunday	2	Weekday 4-8 is fine.
No (Monday-Friday) 4 Calls for 2 consecutive days	2	If Monday-Friday #4 × 2, must have day off with no number in between (eg, Monday #4, Tuesday #0, Wednesday #4). No issues with consecutive #5-#8.
In one week, 2 maximum 1 and 2 Call assignments	2	Sunday-Sunday
In one week, 3 maximum 3-8 Call assignments (If two 4's are from Sat/Sun combo, then 4×'s Max)	2	Sunday-Sunday
4-8 on Friday should not work the next day	3	
Residents with lectures cannot be 1-8 that day	4	1st year resident = Monday lecture and 2nd and 3rd year resident = Tuesday lecture. Exception is July: 1st year resident lectures everyday (Monday-Friday) for the first 2 weeks. Normal lecture rotation starts the second half of July.