The American Journal of Surgery (2015) ■, ■–■

The American Journal of Surgery®

Achieving Accreditation Council for Graduate Medical Education duty hours compliance within advanced surgical training: a simulation-based feasibility assessment

Andrea Obi, M.D.[a,*], Jennifer Chung, M.D.[b], Ryan Chen, B.S.E.[c], Wandi Lin, B.S.E.[c], Siyuan Sun, B.S.[c], William Pozehl, M.S.E.[c], Amy M. Cohn, Ph.D.[c,d], Mark S. Daskin, Ph.D.[c], F. Jacob Seagull, Ph.D.[e], Rishindra M. Reddy, M.D., F.A.C.S.[a,e,1]

[a]Department of Surgery, University of Michigan, Ann Arbor, MI, USA; [b]Department of Surgery, University of Pennsylvania Health System, Philadelphia, PA, USA; [c]Department of Industrial and Operations Engineering, University of Michigan, Ann Arbor, MI, USA; [d]Department of Industrial and Operations Engineering, Center for Healthcare Engineering and Patient Safety, Ann Arbor, MI, USA; [e]Department of Medical Education, University of Michigan Medical School, Ann Arbor, MI, USA

KEYWORDS:
Medical education;
Computer simulation;
Regulation;
Heart transplantation;
Lung transplantation

Abstract

BACKGROUND: Certain operative cases occur unpredictably and/or have long operative times, creating a conflict between Accreditation Council for Graduate Medical Education (ACGME) rules and adequate training experience.

METHODS: A ProModel-based simulation was developed based on historical data. Probabilistic distributions of operative time calculated and combined with an ACGME compliant call schedule.

RESULTS: For the advanced surgical cases modeled (cardiothoracic transplants), 80-hour violations were 6.07% and the minimum number of days off was violated 22.50%. There was a 36% chance of failure to fulfill any (either heart or lung) minimum case requirement despite adequate volume.

CONCLUSIONS: The variable nature of emergency cases inevitably leads to work hour violations under ACGME regulations. Unpredictable cases mandate higher operative volume to ensure achievement of adequate caseloads. Publically available simulation technology provides a valuable avenue to identify adequacy of case volumes for trainees in both the elective and emergency setting.

Unrelated to the content of this publication, Dr Reddy has received honorarium from Covidien and has industry grants from Glaxo-Smith-Kline and Blue Cross Blue Shield.

The authors declare no conflicts of interest.

Presented in part at the American College of Surgeons Clinical Congress, October 2, 2012, Chicago, Illinois.

* Corresponding author. Tel.: +1-269-207-7348; fax: +1-734-615-2656.

E-mail address: easta@med.umich.edu

Manuscript received December 10, 2014; revised manuscript February 16, 2015

[1] Present address: Thoracic Surgery, TC2120/5344, 1500 East Medical Center Drive, University of Michigan, Ann Arbor, MI 48109, USA.

http://dx.doi.org/10.1016/j.amjsurg.2015.03.012

Since the implementation of the 80-hour work week by the Accreditation Council for Graduate Medical Education (ACGME) in 2003, numerous studies have documented a decrease in operative volume of general surgery residents, as well as fellowships such as cardiothoracic (CT) surgery.[1–3] Beyond the decreased case volume and time spent in the hospital, another question arises: are we setting up our trainees for inevitable failure? Namely, is it feasible to expect that while engaged in operations which are long and unplanned that residents will be able to meet 2 opposing restrictions set forth by the ACGME: reduced work hours with increasingly rigid schedules and fulfillment of recommended case volume? We hypothesized that it would be impossible for residents who participate in long, emergent cases to consistently comply with ACGME duty hour regulations and to achieve recommended case numbers (graphical abstract). To test these hypotheses, we developed a computer simulation model, based on historical operative data, which enabled us to analyze case volumes and ACGME work hour violations, including 80-hour violations and "day off" violations.

Although the simulator (available at https://goo.gl/Rc47JK) can analyze any type of emergent or elective case distribution, for the purposes of succinct illustration we present here the results of analysis for CT residents training to perform heart and lung transplantations. This analysis is relevant and timely for several reasons: the area of CT transplant encompasses cases that are consistently long and emergent and thus among the most threatened by duty hour regulations. Second, over the last 2 decades, the number of CT transplants increased from 1,500 to over 4,000 cases per year.[4] Consequently, the need to have trained surgeons to meet volume requirements is paramount, but with over 50% of current CT surgeons estimated to be over 55 years old, there is a severe work force shortage predicted by 2020.[5] Furthermore, the number of cases required for certification by the United Network of Organ Sharing (UNOS) has remained unchanged over the past decade.[4] The decrease in time and flexibility available for performing transplants, without a corresponding decrease in the required number, affects the ability of residents to acquire case volume while complying with stricter work hour regulations, and may directly affect the future of CT transplantation, among other advanced surgical training subspecialties.

CT transplantation operative data were obtained retrospectively from institutional billing records and transport logs to build a model for predicting the arrival patterns of emergency operations. This study was approved by the institutional review board (HUM00054073) through a waiver of informed consent, as no identifiable patient information was reported.

An academic tertiary care center which serves as the only CT transplant center in the state was the data source. Data were collected regarding all adults greater than or equal to 18 years of age undergoing lung (January 1, 2009 to June 30, 2011) or heart transplant procedures (July 1, 2008 to June 30, 2011) and heart–lung procurements (April 1, 2009 to June 30, 2011). Time points collected included the following: organ acceptance notification, transportation departure and arrival, and operating room entry/exits. Four (2 junior and 2 senior) residents form the call pool. A standard ACGME compliant call schedule presumes each resident is on a primary service (6 am to 6 pm), 5 days a week with home call occurring every fourth night (6 pm to 6 am) (Table S1). A "primary" resident is on call for transplants, with a "backup" resident on call for procurements. Each resident has 1 day off per week. In this model, work hours range from 60 to 90 hours/week (with a 4-week average of 63 to 79 hours/week), if the resident spent his/her entire call time "in house."

Initial data analysis included calculation of time intervals between critical events and analysis of the distribution of interarrival times between critical events. Using these data, we developed a simulation model using the ProModel simulation language. The model was then run 50 times to simulate 50 years of operations with the same rate of variability as seen in our historic data (Fig. S1), as previously described.[6]

When the simulation is run, it generates the timing of random transplant procedures and matches these procedures to the appropriate resident. The random duration of the procedures is also generated, and this time is mapped to the residents' schedules, determining the amount of call time which is used in participating in the transplant and the amount of time that the procedure carries over into the resident's scheduled rest period. Aggregate calculations are then made over the week and month to determine ACGME compliance and progress toward certification.

Timing data for each step in the process of a transplant from the time of initial organ offer to the time of completion of the transplant and exiting of the operating room were collected and averaged (Table 1) for 118 cardiac transplants, 77 lung transplants, and 132 procurements. Using the operative data, specifically the rate and variability of transplants, 50 years of heart and lung transplants were simulated, resulting in a normal distribution for the number of transplants of each organ per year (Fig. S1). The mean annual volume of heart transplants was 32.82 ± 6.04 (range 24 to 52) and lung transplants was 31.3 ± 6.25 (range 16 to 44).

In total, 53% of cardiac transplants, 56% of lung transplants, and 57% of procurements from the historic operative data began during "off-hours" (6 pm to 6 am). When the simulator was run to replicate 50 years for 4 residents (resulting in 10,400 resident-weeks), assuming transplants/procurements as the only emergent cases, there were an estimated 631 violations of the 80-hour average, resulting in an approximate 6% violation rate (95% confidence interval 5.62 to 6.52). The range of work hours per resident over one sample simulated year is shown in Fig. 1. On average, 6.04% of weeks will have a scheduled day off occupied by work. This translates to a day off violation in up to 22.50% of working months.

Table 1 Mean duration of transplant times (hours:minutes) for each transplant operation

Procedure/step	Time (hours:minutes)	Standard deviation
Heart transplant, operative time*	10:09	1:52
Heart, total transplant process time†	29:19	6:05
Heart, total procurement process time‡	20:43	5:19
Lung transplant, operative time*	11:29	2:36
Lung, total transplant process time†	27:21	8:13
Lung, total procurement process time‡	19:49	8:24

*Operative time = time from skin incision to skin closure.
†Total transplant process time = time from entry to exit the operating room.
‡Total procurement process time = time from departure home institution to return.

The predicted average number of cases for both cardiac (62) and lung (66) transplant cases over a 2-year period was enough for every resident (assuming 2 graduating residents per year) to reach certification requirements for pulmonary transplants if each case was distributed equally between residents. Given the random arrival of transplants, our model predicted that only 53% of residents could achieve certification in pulmonary and 21% in cardiac transplantation (Table 2).

With an aging surgical workforce within CT surgery and a reduced number of trainees over the past 10 to 15 years, there is an impending crisis that may acutely affect the ability to deliver CT transplantation. We have shown with simulated data that strict adherence to an ACGME compliant call schedule combined with a moderate to high volume transplant center volume leads to ACGME rules violations, and a reduced ability to meet certification numbers. Our data show that the transplant process, as are other advanced surgical procedures, is time consuming. Given our institution's moderate to high volume relative to other centers,[4] it would be expected that our residents could achieve certification during their 2-year residency. Unfortunately, even in this idealized scenario with no other emergent cases, we are unable to have residents participate in the transplant program without regularly violating either the day off or 80-hour average rules.

Equally significant are the results that show the inability to achieve certification for all residents, despite the apparent adequate volume to achieve UNOS goals. The unpredictable nature of emergent case arrival leads to inequities in case distribution among residents that does not equal out over the 2-year duration of the program. In our simulation, just over half of residents would achieve UNOS certification numbers for lung transplants, despite having adequate volume on average for all residents to achieve these targets (32 lung transplants per year distributed to 2 residents each year). The results of these simulations should lead to a rethinking of what the adequate program volume is required to train

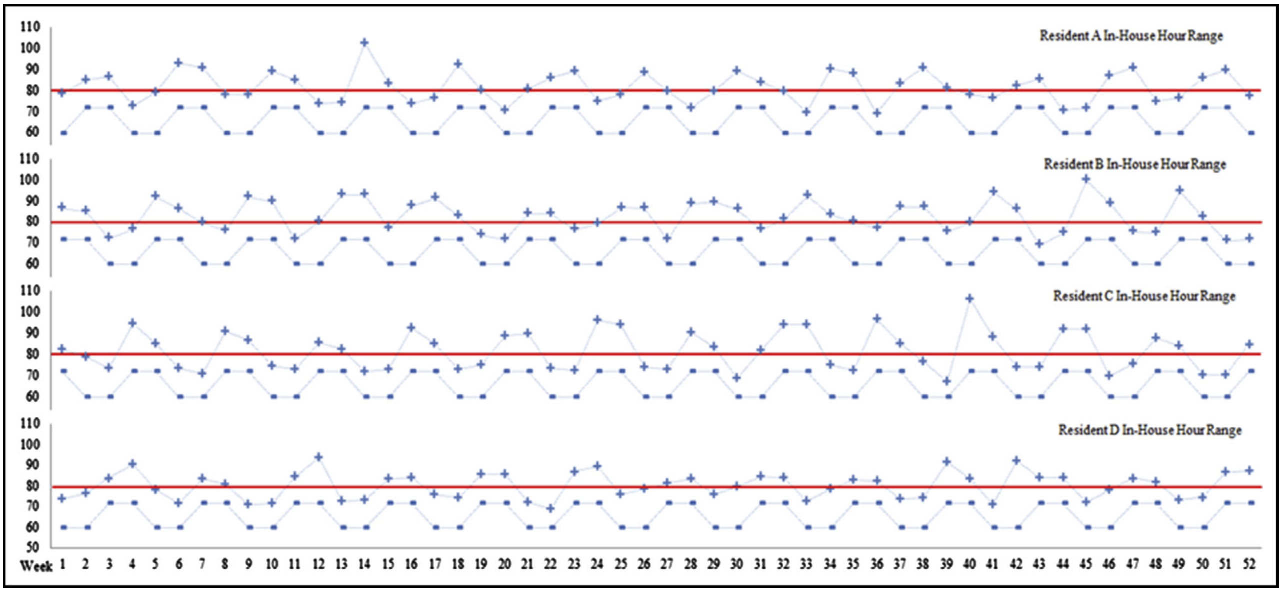

Figure 1 The range of expected hours per week over 1 year for 4 "simulated" residents based on the proposed call schedule and potential influence by transplant cases. The lower range will always be 60 to 72 hours based on the call schedule from Table S1. The higher range involves the possible hours because of both cardiac and lung transplants as the only emergent cases, and does not take into account other responsibilities such as patient care or seeing consults. The red line denotes the 80-hour limit. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 2 Likelihood of achieving UNOS certification case requirement numbers

Certification	Probability (%)	95% CI
Heart and lung	10	±2.60%
Heart only	21	±5.51%
Lung only	53	±9.89%
Neither organ	36	±15.81%

CI = confidence interval; UNOS = United Network of Organ Sharing.

residents for cases with unpredictable arrival rates beyond the example provided here. Our simulator (available at http://goo.gl/gpm4kG) is available for program directors interested in predicting the total number of (emergent or elective) cases required to train a set number of trainees.

Significant national overhaul of residency programs has thus far been based on little direct evidence that these measures will improve patient care. Additionally, there is evidence that the limitations on resident work hours may have a detrimental impact on resident training and patient outcomes.[7] Efforts to define the impact of duty hours on surgical training, such as that undertaken by the investigators in the flexibility in duty hour requirements for surgical trainees' trial (NCT02050789), are needed and should be extended to advanced trainees. Other potential solutions include the following: a modification of certification requirements from a number-based to a competency-based curriculum (perhaps with the use of operative simulators) and spending an extra year of training as a "super-fellow" in a non-ACGME certified year. However, it may be difficult to convince future trainees to spend an extra year of training, on top of a minimum of 6 to 7 to specifically acquire adequate transplant exposure. The use of advanced simulation in conjunction with operations engineering represents a promising multidisciplinary methodology which can be utilized for any complex scheduling scenario.

References

1. Bruce PJ, Helmer SD, Osland JS, et al. Operative volume in the new era: a comparison of resident operative volume before and after implementation of 80-hour work week restrictions. J Surg Educ 2010;67:412–6.
2. Connors RC, Doty JR, Bull DA, et al. Effect of work-hour restriction on operative experience in cardiothoracic surgical residency training. J Thorac Cardiovasc Surg 2009;137:710–3.
3. Watson DR, Flesher TD, Ruiz O, et al. Impact of the 80-hour workweek on surgical case exposure within a general surgery residency program. J Surg Educ 2010;67:283–9.
4. Network OPTN. Transplants by Donor Type. U.S. Department of Human and Health Services; 2012. Available at: http://optn.transplant.hrsa.gov/. Accessed March 8, 2012.
5. Grover A, Gorman K, Dall TM, et al. Shortage of cardiothoracic surgeons is likely by 2020. Circulation 2009;120:488–94.
6. Chung J, Obi A, Chen R, et al. Estimating minimum program volume needed to train surgeons: when 4 × 15 really equals 90. J Surg Educ 2015;72:61–7.
7. Philibert I, Nasca T, Brigham T, et al. Duty-hour limits and patient care and resident outcomes: can high-quality studies offer insight into complex relationships? Annu Rev Med 2013;64:467–83.

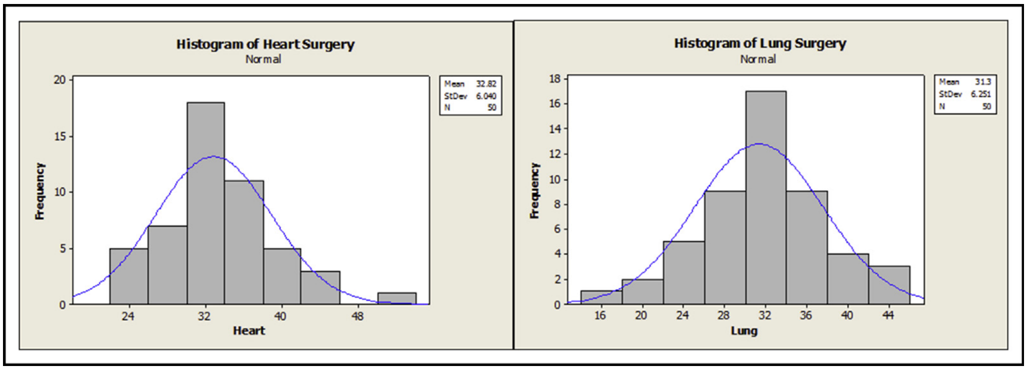

Figure S1 Simulation data for heart and lung transplant cases over multiple years (n = 50) based on historic frequency of transplant case arrivals. Random variability suggests that transplant cases may vary significantly from the mean of 31 to 33 cases per year.

Table S1 Standard ACGME compliance call schedule for 4 senior cardiothoracic residents

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Day (6 am–6 pm)	1/2/3/4	1/2/3/4	1/2/3/4	1/2/3/4	1/2/3/4	2	3
Night (6 pm–6 am)	1	2	3	4	1	2	3
Backup (procurement)	3	4	1	2	4	1	2

ACGME = Accreditation Council for Graduate Medical Education.