Case Difficulty, Postgraduate Year, and Resident Surgeon Stress: Effects on Operative Times

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OBJECTIVE: We aimed to evaluate resident operative times in relation to postgraduate year (PGY), case difficulty and resident stress while performing a single surgical procedure.

DESIGN: We prospectively examined operative times for 268 laparoscopic cholecystectomies, and analyzed relationships between PGY, case difficulty, and resident surgeon stress utilizing electrodermal activity. Each case operative times were divided into 3 separate time periods. Case Start and End times were recorded, as well as the time between the start of the operation and the time until the cystic structures were divided (Division). Case difficulty was determined by multiple trained observers with a high inter-rater concordance.

SETTING: University of Missouri, a tertiary academic medical institution.

PARTICIPANTS: All categorical general surgery residents at our institution.

RESULTS: For each operative time period examined during laparoscopic cholecystectomy, operative time increased, with each incremental increase in difficulty resulting in approximately 130% longer times. Minimal differences in operative times were seen between PGY levels, except during the easiest cases (Start-End times: 38.5 ± 10.4 minutes vs 34.2 ± 10.8 minutes vs 28.9 ± 10.9 minutes, p 0.002). Resident stress poorly correlated with operative times regardless of case difficulty (Pearson coefficient range 0.0-0.22).

CONCLUSIONS: Operative times are longer with increasing case difficulty. PGY level and resident surgeon stress appear to have minimal to no correlation with operative times, regardless of case difficulty. (J Surg Ed 76:354−361. © 2018 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Surgical education, Electrodermal activity, Stress, Operative time

COMPETENCIES: Practice-Based Learning and Improvement, Patient Care

INTRODUCTION

Operative times are often the subject of discussion and debate amongst surgeons, administrators, and third-party payers. Cost is frequently the driving interest for all groups, with the goal to decrease expenditures through improved operating room utilization and overhead minimization.[1,2] Additionally, longer cases result in decreased case volume, both for the surgeon and the institution, which further impacts the bottom line. While monetary cost is important, the physiologic toll paid by patients undergoing protracted procedures is significant, as evidenced by higher complication and mortality rates.[3−5]

In teaching hospitals, resident surgeons regularly shoulder the blame for longer operative times, creating a conflicted environment to facilitate surgical education.[4,6−10] Resident surgeon impact on operative times has been examined in a variety of surgical procedures, with much of the literature suggesting residents increase operative time.[1,2,6,7] Further, many faculty surgeons believe that residents in the early years of training increase operative time more than senior residents.[2] Data regarding the effect of specific post-graduate year

This work was supported by the Association of Program Directors in Surgery and the Association for Surgical Education.

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1931-7204/$30.00
https://doi.org/10.1016/j.jsurg.2018.08.002

(PGY) residents on operative times, however, is sparse.[11,12]

Faculty and resident surgeon expertise, patient factors, surgical technique, as well as operative characteristics such as acute inflammation or intraoperative hemorrhage, have all been suggested as potential causes for longer operation duration.[13-15] Logically, operative case difficulty has long been considered a major determinant of operative times. However, defining a "difficult" vs "easy" operation can be problematic. Probable features contributing to operative complexity include imaging findings such as ascites or anatomical variation and postoperative histology revealing severe inflammation or necrosis.[16,17] As some of this information is not necessarily available at the time of the operation, preoperative, and intraoperative scoring systems have been suggested to identify more difficult cases to better forecast operation times.[18-20]

Stress, and its effect on surgical performance, may also contribute to prolonged operative time. Nonmedical industries have examined the relationship between stress and task performance, finding both positive and negative effects.[21-23] Elucidating the true effect of psychological stress on surgeons has proven difficult, and has historically been examined utilizing survey data.[24-27] While achieving an optimal level of stress may improve performance, high levels of stress may have negative consequences leading to decreased efficiency.[28,29] Further complicating the examination of stress, is the wide human response variant related to coping with stress.

With this study, we aimed to evaluate the effects of procedural case difficulty, resident training level, and resident surgeon stress on operative times during a single type of surgical procedure performed by residents.

MATERIALS AND METHODS

Following Institutional Review Board approval, we prospectively examined operative times during laparoscopic cholecystectomies performed by categorical general surgery residents (PGY 1-5). Resident surgeons participated after completing voluntary informed consent. No information from the study was utilized toward formal program review, and the results were blinded to the program. Resident surgeons were divided into 3 groups to aid in meaningful analysis: junior (PGY 1-2), midlevel (PGY 3), and senior (PGY 4-5). Laparoscopic cholecystectomy was chosen due to its relatively standardized steps and high-volume availability. Only those cases, where the operating resident completed the entire operation from the patient's left side were included for analysis. If, during the operation, a portion of the procedure was performed by a different resident, or faculty surgeon, it was excluded from analysis. Three time periods were measured and analyzed. First, Start-Division times were measured from the point of first intra-abdominal tissue contact with a laparoscopic instrument, to the point that cystic structures were divided. Next, the time between cystic structure division and gallbladder removal from the abdomen (Division-End). Finally, the duration from the beginning of the case as above, to the point of gallbladder removal was recorded (Start-End). Initial port placement, insufflation, port removal, and closure were not included in the analyzed time segments, as these tasks are frequently performed by students or other residents. Dedicated study personnel were present during the entirety of each operation to ensure accurate time coding of the data.

Procedural case difficulty was determined intraoperatively and recorded immediately postoperatively by trained faculty observers utilizing the modified Cuschieri scale (Table 1).[20] Training sessions were conducted with faculty prior to, and during the study using previously published methods.[30] Video analysis of multiple operative cases was completed with observers as a group. Each video was independently scored by each faculty member. Scores were reviewed, and outliers discussed until consensus amongst the group was reached. This process was completed for all grades of difficulty multiple times until concordance (Cohen's kappa >0.8) was achieved 3 times in a row without further discussion. To aid accuracy of operative grade determinants, the cloud-based evaluation system included lists of required elements and sample images for each difficulty

TABLE 1. Modified Cuschieri Cholecystectomy Intraoperative Grading Scale

Grade 1	Grade 2	Grade 3
Easy, uncomplicated, adhesions <15% of gallbladder, and minimal dissection required	Moderate difficulty, adhesions 15%-50% of gallbladder, slight gallbladder enlargement, moderate dissection necessary, structures partially obscured, andmild cholecystitis	Severe difficulty, adhesions >50% of gallbladder, inflamed >50% gallbladder, distended or shrunken, extensive dissection, structures obscured, andsevere cholecystitis

TABLE 2. Participant and Study Characteristics

	Junior PGY 1-2	Midlevel PGY 3	Senior PGY 4-5	Total
Resident positions (n)	12	10	17	39
Grade 1	23	33	54	110
Grade 2	13	34	48	95
Grade 3	2	21	40	63
Total cases	38	88	142	268

A total of 39 resident positions participated. Operative case difficulty grade and total operations performed are listed above.

grade. Concordance >80% was achieved between faculty observers, and maintained throughout the study to ensure standardized grading of case difficulty during real-time evaluation. Periodic meetings with observers revealed improved concordance between observers over time, with Cohen's ƙ increasing over time.

Operative stress was determined through measurement of electrodermal activity (EDA) utilizing noninvasive sensors placed on both wrists of the operating resident. Electrodermal activity has been an established method of stress and engagement evaluation for many years, and is widely utilized in psychophysiological research.[31−33] We utilized noninvasive wearable sensors (Affectiva Q Sensor, Affectiva Inc., Waltham, Massachusetts) to measure changes in skin conductivity, known as the galvanic skin response. Increased skin conductivity is associated with increased stress. Sensors were calibrated daily and data were collected at 32 Hz. EDA was measured in microsiemens. We analyzed fractional changes from baseline in EDA during each case using both phasic responses (rapidly changing, peak arousal, or stress), and tonic levels (slowly varying, global stress level during the entire operation). Fractional change (FC_{EDA}) is a dimensionless quantity defined as FC_{EDA} = (EDA Response − Baseline Response)/Baseline Response. Data collection and analysis techniques were similar to the methods we have previously published.[30,34,35] EDA data were collected simultaneously as a part of a separate study, from which we have previously published, and thus some data overlap specifically regarding EDA, exists.[30] However, EDA relationship to operative times is unique to the current study, and has not been previously reported. Data were analyzed utilizing Student's t test, ANOVA and Pearson's rho coefficients. Standard deviations are listed following the mean (±X). Statistical significance was defined as $p < 0.05$.

RESULTS

Twenty categorical residents participated in the study, including all residents at our institution spanning 3 academic years of data. Data from 12 resident positions during the junior years (PGY 1-2), 10 resident positions during the midlevel year (PGY 3), and 17 resident positions during the senior years (PGY 4-5) of training were analyzed. Three hundred-one operative cases were performed. Cholangiography was performed in 23 cases and 10 operations required additional assistance which were excluded leaving 268 operative cases available for analysis. There were 110 Grade 1 cases, 95 Grade 2, and 63 Grade 3 cases that were analyzed. Junior residents completed 38 operations, 88 were performed by midlevel (PGY 3) residents, and senior residents completed 142 laparoscopic cholecystectomies (Table 2).

Case Difficulty

When considering all residents as a group, all three time periods (Start-Division, Division-End, Start-End) exhibited longer durations with each incremental increase in operative difficulty (Table 3). Operative time increased proportionally with each incremental increase in case difficulty, with all residents taking an average of 132.8% (range 125%-142%) longer to complete each portion of progressively difficult cases. Specifically regarding Start-End times, Grade 2 cases took 133% longer (32.5 ± 11.3 minutes vs 43.3 ± 19.4 minutes) to complete than Grade 1, and Grade 3 operations took approximately 132% more time to complete (43.3 ± 19.4 minutes vs 57.3 ± 15.2 minutes) than Grade 2 operations. Similar increases were seen with the other 2 time series.

PGY Level

Regarding all difficulty grades as a single group (ie, all operative cases), only Start-Division times showed significant differences between PGY levels. This is also one of only 2 time segments measured across groups, where a higher PGY level (PGY 3) had a longer mean time, than more junior residents (24.8 ± 8.4 minutes vs 25.4 ± 12.4 minutes vs 20.7 ± 12.2 minutes, p 0.008). The other was not statistically significant. When case difficulty was considered, several times showed significant differences across PGY levels. Grade 1 cases showed significant differences with both Start-Division (22.2 ± 8 minutes vs 19.7 ± 6.6 minutes vs 15.7 ± 9.2 minutes, p 0.004) and Start-End (38.5 ± 10.4 minutes vs 34.2 ± 10.8 minutes vs 28.9 ± 10.9 minutes, p 0.002) times across PGY levels. There were no differences between PGY levels with any of the 3 time segments during Grade 2 cases. Significant differences between Start-Division (37.5 ± 13.5 minutes vs 35.4 ± 13.5 minutes vs 27.4 ± 11.5 minutes, p 0.04) times were seen with Grade 3 cases (Table 4).

Psychological Stress

Operative times showed overall poor correlation with psychological stress, and stress did not appear to affect operative times. Statistical significance was reached however, between both tonic levels (global stress) and phasic responses (peak stress) during the Start-Division time series. Higher phasic responses weakly correlated with longer operative times (ρ 0.18, p 0.0047, 95% CI 0.05, 0.31). Longer operative times were also weakly correlated with higher tonic levels (ρ 0.16, p 0.014, 95% CI 0.03, 0.28). There were no significant correlations with operative time and psychological stress when subset analysis was performed for each grade of difficulty (Table 5).

DISCUSSION

We have shown that more difficult operations take more time for residents to complete. This expected finding was seen when all residents were evaluated as a group, regardless of PGY level. There appears to be a relationship between PGY level and operative time that is most pronounced during relatively easy operations. There was minimal correlation between psychological stress, as quantified by EDA, and length of the operation.

While we expected operative times to lengthen with cases of increased difficulty, the proportional increase in time was an interesting finding that has not previously been reported. All residents as a group showed a time increase of approximately 130% with each advancing level of difficulty. Further, the proportional increases were seen in each measured time series with progressively difficult cases. For example, Start-Division and Division-End times increased at nearly the same rate. This suggests that difficult cases are not more complex at specific portions of the case, but rather the entire case. While this may seem obvious, surgeons frequently regard removing the gallbladder from the liver bed as a relatively simple task, and many view it as an opportunity for junior trainees to complete a portion of the case.[36] Our data suggests this belief may be incorrect.

Examining the time-difficulty relationship across PGY levels reveals interesting and unexpected findings. One would predict that the differences in time across grades of difficulty, would be greater in junior residents, than in senior residents. For example, we might expect a PGY 2 resident to take twice as a long to complete a Grade 3 case, as opposed to a Grade 2 case. In contrast, a PGY 5 who is theoretically more skilled, may only see a moderate increase in time when completing a more difficult operation. Our data shows the otherwise. The mean incremental changes in operative time remained relatively constant for all PGY levels as case difficulty increased. There are several causes that may explain this somewhat unusual finding. First, junior level residents often proceed at the pace of the supervising faculty member. Rigorous oversight and verbal direction limits hesitation of the trainee and moves the case along. Conversely, senior level residents are frequently empowered to perform operations at their *own* pace, even if it takes longer. While we did not specifically monitor immediate intraoperative feedback and faculty intervention, this is a plausible explanation for our findings. Second, senior level residents are presumed to have a greater understanding of the risks of technical performance, and therefore may perform operations at a slower pace while gaining confidence in their own skills, despite theoretically having more autonomy and control of the operation. The same reasoning can explain the 2 time segments where more senior residents performed slower than their junior counterparts.

When considering all cases regardless of difficulty, we saw no significant differences in total operative times between PGY level. This is contrary to previous studies that showed an inverse correlation of operating time and PGY level.[12,35] Conversely, one study involving laparoscopic ventral hernia repair found shorter operative times in junior residents, as compared with senior residents and fellows. The authors were unable to determine if the unexpected findings were due to increased trainee participation or difficulty of the operation.[37] In our study, we examined each PGY level with respect to operative difficulty. Additionally, our inclusion criteria required the entirety of the operation to be performed by the resident, eliminating these confounders. While it may be the inclination of faculty to preferentially work with senior residents, there appears to be minimal to no difference in operative time based on that desire, except in the most easy operations, where senior residents performed cases significantly faster than more junior trainees.

Psychologic stress experienced during demanding tasks, such as performing surgery, continues to be a point of interest for both medical and nonmedical fields.[22−24,38] To identify possible correlations between operative time and stress experienced during an operation, we utilized EDA. EDA measures the change in skin conductivity elicited by stress, between 2 electrodes from a baseline level. Higher EDA values correspond to higher levels of stress.[33] One would expect stress to have a negative impact on operative time, as high levels of psychologic stress are often associated with poor performance.[28] However, in our study, we saw relatively poor correlations overall between stress and operative time, suggesting stress played little role in the duration of operations. While we have shown previously that

TABLE 3. Operative Time: Effect of Case Difficulty Grade

	All Residents			Junior PGY 1-2			Midlevel PGY 3			Senior PGY 4-5		
	Start-Division	**Division-End**	**Start-End**	**Start-Division**	**Division-End**	**Start-End**	**Start-Division**	**Division-End**	**Start-End**	**Start-Division**	**Division-End**	**Start-End**
Grade 1 Cases	18.3	14.3	32.5	22.2	16.3	38.5	19.7	14.5	34.2	15.7	13.3	28.9
Grade 2 Cases	22.9	20.3	43.3	27.3	24.3	51.6	24.4	19.0	43.4	20.8	20.1	40.9
Grade 3 Cases	30.5	26.8	57.3	37.5	29.5	67.0	35.4	23.0	58.4	27.4	28.9	56.3
p value	<0.001	<0.001	<0.001	0.02	0.01	<0.001	<0.001	0.012	<0.001	<0.001	<0.001	<0.001
All Grades	22.8	19.2	42.0	24.8	19.7	44.5	25.4	18.3	43.7	20.7	19.9	40.6

Increasing case difficulty resulted in statistically longer operative times for all residents, in each measured time series. Mean times expressed in minutes.

TABLE 4. Operative Time: Effect of PGY Level

	All Operative Cases			Grade 1 Cases			Grade 2 Cases			Grade 3 Cases		
	Start-Division	**Division-End**	**Start-End**	**Start-Division**	**Division-End**	**Start-End**	**Start-Division**	**Division-End**	**Start-End**	**Start-Division**	**Division-End**	**Start-End**
PGY 1-2	24.8	19.7	44.5	22.2	16.3	38.5	27.3	24.3	51.6	37.5	29.5	67.0
PGY 3	25.4	18.3	43.7	19.7	14.5	34.2	24.4	19.0	43.4	35.4	23.0	58.4
PGY 4-5	20.7	19.9	40.6	15.7	13.3	28.9	20.8	20.1	40.9	27.4	28.9	56.3
p value	0.008	NS	NS	0.004	NS	0.002	NS	NS	NS	0.04	NS	NS
All residents	22.8	19.2	42.0	18.3	14.3	32.5	22.9	20.3	43.3	30.5	26.8	57.3

PGY level has minimal effect on operative times, with most time series showing no statistical difference between training levels. Mean times expressed in minutes.

TABLE 5. Operative Time: Effect of Physiologic Stress (EDA)

	All Operative Cases			Grade 1 Cases			Grade 2 Cases			Grade 3 Cases		
	Start-Division	Division-End	Start-End	Start-Division	Division-End	Start-End	Start-Division	Division-End	Start-End	Start-Division	Division-End	Start-End
Phasic Δ EDA	0.18*	−0.03	0.10	0.09	−0.14	−0.01	0.02	0.01	0.02	0.22	−0.11	0.07
Tonic Δ EDA	0.16*	−0.04	0.07	0.00	−0.12	−0.07	0.00	0.05	0.04	0.22	−0.13	0.05

Operative times showed poor correlations with psychological stress. Values expressed as Pearson's rho correlation coefficients. EDA: Electrodermal activity.
*Denotes statistical significance.

phasic and tonic EDA is higher in less competent resident surgeons, the interactions between stress and operative time are complex. To explain the lack of correlation seen in this study, we offer a hypothetical example. For instance, an individual may perform an operation efficiently, albeit at a slow pace. The individual is competent, but slow. Conversely, a different individual may perform inefficiently, or even erratically, but complete the case quickly. From an EDA standpoint, the competent individual exhibits low fractional changes in both tonic and phasic EDA, but takes longer to complete the task. This example illustrates how the poor relationship between psychologic stress and operative times observed in this study may be rationalized.

This study is limited to findings at a single institution's general surgery residency program, and may not be applicable to all surgery residents. Junior residents performed fewer operations than their senior counterparts, which may have skewed the data in regard to PGY-level comparisons. Although our resident participant sample size was small, it provides meaningful information regarding determinants of operative time and forms a basis for a large-scale study of these relationships.

CONCLUSIONS

Advanced levels of operative case difficulty are associated with longer operative times, regardless of PGY level. When controlling for case difficulty, there are minimal overall differences in operative times between PGY levels. Psychologic stress appears to have minimal correlation with operative times.

ACKNOWLEDGMENTS

The authors would like to thank Jeffrey P. Coughenour MD, Jeffrey Litt DO, Christopher S. Nelson MD, Arthur L. Rawlings MD and Roger A. de la Torre MD who aided in data acquisition, and the general surgery residents who participated.

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SUPPLEMENTARY INFORMATION

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jsurg.2018.08.002.