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Published Version:
Serenari, M., Lenzi, J., Ricci, C., Odaldi, F., Maroni, L., Laurenzi, A., et al. (2024). The Importance of Multiorgan Procurement in the Improvement of Residents’ Open Surgical Skills. JOURNAL OF SURGICAL RESEARCH, 296, 441-446 [10.1016/j.jss.2024.01.012].

Availability:
This version is available at: https://hdl.handle.net/11585/955795 since: 2024-02-06

Published:
DOI: http://doi.org/10.1016/j.jss.2024.01.012

The Importance of Multiorgan Procurement in the Improvement of Residents' Open Surgical Skills

Matteo Serenari, MD,a,b,* Jacopo Lenzi, PhD,c Claudio Ricci, MD,b,d Federica Odaldi, MD,a Lorenzo Maroni, MD,a Andrea Laurenzi, MD,a Enrico Prosperi, MD,a,b Chiara Bonatti, MD,a,b Guido Fallani, MD,a,b Francesca Caputo, MD,a,b Matteo Rottoli, MD,b,e Matteo Ravaioli, PhD,a,b and Matteo Cescon, PhDa,b

a Hepato-biliary and Transplant Unit, IRCCS Azienda Ospedaliero-Universitaria di Bologna, Bologna, Italy

b Department of Medical and Surgical Sciences, Alma Mater Studiorum - University of Bologna, Bologna, Italy

c Department of Biomedical and Neuromotor Sciences, Alma Mater Studiorum - University of Bologna, Bologna,

Italy

d Division of Pancreatic Surgery, IRCCS Azienda Ospedaliero-Universitaria Di Bologna, Bologna, Italy

e Surgery of the Alimentary Tract, IRCCS Azienda Ospedaliero-Universitaria di Bologna, Bologna, Italy

ABSTRACT

Background

The multiorgan procurement (MOP) represents a chance for the general surgery resident to learn the fundamental steps of open abdominal surgery. The objective of this study was to evaluate the impact of MOP on the residents' open surgical skills.

Materials and Methods

Residents' surgical skills were assessed during a 6-month transplant rotation (October 2020–March 2021) using a modified Objective Structured Assessment of Technical Skills (OSATS) with the global rating scale. The surgeries were self-assessed by residents and tutors on the basis of 9 specific steps (SS) and 4 general skills (GS). Each item was rated from 1 (poor) to 5 (excellent) with a maximum score of 45 points for SS and 20 for GS. A cross-effects linear regression analysis was performed both to evaluate any associations between GS/SS scores and some prespecified covariates, and to study differences in the assessments performed by residents and tutors.

Results

Residents were actively involved in a total of 59 procurements over 6 months. In general, there were no significant differences in SS/GS mean scorings between residents (n=15) and tutors (n=5). There was a significantly positive association between mean GS/SS scorings and number of donor surgeries performed (at least 5). Comparing the evaluations of the tutors with the residents, this significance was retained only when scorings were assigned by the tutors.

Conclusions

MOP has been shown to improve basic open surgical skills among residents. Awareness of the utility of a clinical rotation in transplant surgery should be raised on an institutional level.

Keywords: training, procurement, transplantation, resident.

INTRODUCTION

The advent of minimally invasive surgery (MIS) has revolutionized the field of surgical interventions, offering patients numerous benefits. Techniques such as laparoscopy and robotic-assisted surgery have gained widespread acceptance and have become the standard of care for many procedures.[1] Consequently, surgical training has been affected with a significant decline in open cases over the years.[2] However, amidst the surge in MI approaches, the role of open surgery remains an integral part of the surgical armamentarium. Certain scenarios such as extensive tumor resections, emergency surgeries or multiorgan procurements (MOPs) still necessitate an open approach.

MOP has emerged not only as a vital component of the organ transplantation process but also as a valuable tool for enhancing surgical skills.[3] The complexity and intricacy involved in MOP provide residents with unique opportunities to refine their technical abilities, develop critical decision-making skills, and improve overall surgical proficiency. In particular, MOP within dedicated and structured rotations may allow residents under the guidance of experienced mentors to gain hands-on exposure to the most common open procedures.[5] Recognizing the significance of MOP as a tool to enhance surgical skills will prompt training programs and surgical societies to emphasize the inclusion of transplant rotation as a part of surgical training curricula.[4]

In this paper, we aimed to explore the enduring role of MOP to improve open surgical skills of residents rotating on Transplant surgery at a single institution. Moreover, rating performed by tutors were compared to those performed by residents in order to explore factors that may contribute to gaps in self- and attending assessment of surgical trainees.

MATERIAL AND METHODS

Study population

General surgery residents rotating from October 2020 to March 2021 on Hepatobiliary and Transplant Unit at Sant'Orsola-Malpighi Hospital (Bologna, Italy) were enrolled to participate in this study. General surgery residents of the University of Bologna are required to rotate at least 6 months in Transplant surgery in their first 4 years of residency. In our Unit, attending surgeons are responsible for MOP and are usually assisted by rotating residents who are allowed to perform some steps of the warm phase.

The study was approved by the institutional ethics committee and participation in this study was voluntary.

Multiorgan procurement (MOP) technique

The MOP procedure is a modified technique according to the original description by Starzl et al.[6] Briefly, the operation starts with a midline laparotomy (1) and sternotomy (2). Initially, a medial visceral rotation (Cattel-Braasch - 3 - and Kocher - 4 - Maneuver) is performed to have a better access to the infrarenal aorta, which is encircled (5), and to the inferior mesenteric vein (IMV), which is cannulated (6). If thoracic organs need to be procured, then the supradiaphragmatic aorta is encircled (7). Thereafter, the dissection of the hepatoduodenal ligament is performed (8) including common bile duct and gastroduodenal artery dissection. Splenic artery is also dissected after opening the gastro-colic ligament (9). Cross-clamping, flushing of the organs and the following cold phase are usually performed by the transplant faculty.

Study Design

An electronic form that had to be filled within 24 hours after the end of the operation, was distributed to the residents and to the transplant faculty. The same attendings who tutored the residents during the warm phase of the MOP, were asked to rate them. The residents' surgical skills were evaluated using a modified Objective Structured Assessment of Technical Skills (OSATS) with the global rating scale.[7] Nine Specific Steps (SS) and 4 General Skills (GS) (**Supplementary File 1**) were evaluated, graded from 1 (poor) to 5 (excellent) with a maximum scores of 45 points for the SS scale and 20 points for the GS scale. SS and GS were evaluated separately by residents and tutors to provide a more reliable measure of the learning experience. The difficulty of the case was also evaluated and graded from 1 (straightforward) to 3 (difficult) to adjust comparisons.

Statistical Analysis

Continuous variables were expressed as the median and interquartile range (IQR) or mean ± standard deviation. Categorical data were expressed as counts and percentages. We performed crossed-effects linear regression analysis to investigate differences in mean SS and GS scoring between general surgery residents and their tutors. A crossed-effects model is a mixed-effects model in which the levels of random effects are not nested. Indeed, the structure of our data consisted of 20 surgeons (15 residents and 5 tutors) assigned to 59 resident–tutor pairs, each corresponding to a surgical intervention performed over the study period. Operationally, the entire dataset was treated as one artificial level with only one category consisting of all the observations, and all dummies for surgeries and surgeons ($k = 59 + 20 = 79$) were nested within this "super cluster" by imposing identity covariance structure of the random effects.

The fixed portion of models included the exposure variable (resident vs. tutor) and a set of other covariates of interest (e.g. sex, post-graduate year, number of donor surgeries, prior transplant rotation, perceived level of difficulty). All covariates were treated as factor (dummy) variables. The likelihood-ratio test did not reveal any significant variance in the effect of the exposure variable across surgeries, which means that no random slope was added to the final model specification. SS and GS scorings were also modeled as a function of residency-by-covariate interactions to investigate whether the effects of such covariates were significantly divergent in residents vs. tutors.

The models were fitted using the Kenward–Roger method.[8] No multicollinearity issues were detected by means of the variance inflation factors, and normality of the standardized residuals was visually confirmed by the Q–Q plot. Predicted means resulting from multilevel mixed-effects modelling were presented in conjunction with 95% confidence intervals obtained with the delta method.

Since residents were not expected to perform the same number of steps, a standardized SS score (= total SS score/number of steps) was used.

All analyses were carried out using Stata software, version 17 (StataCorp. 2021. *Stata Statistical Software: Release 17.* College Station, TX: StataCorp LLC). The significance level was set at 0.05, and all tests were two-sided.

RESULTS

During the 6-month rotation, 15 residents and 5 tutors were actively involved in 59 procurements. Seven out of 15 residents (47%) and 1 out of 5 tutors (20%) were females. Three residents (20%) were in their first two post-graduate years (PGY 1–2), while 12 (80%) were PGY 3–4. Among them, 3 had previously rotated on the Transplant Unit.

Residents actively participated in a median of 3 MOPs (IQR 1–4) and performed a median of 4 steps during each procurement (IQR 3–5), while tutors assisted in a median of 12 MOPs (IQR 4-19). Of note, 5 out of 15 residents (33%) were actively involved in 5 or more MOPs over the 6-month period. Residents were assisted by a median of 2 distinct tutors (IQR 1-3), while tutors assisted a median of 8 distinct residents (IQR 3-9).

With regard to SS scores, residents and tutors scored on average 14.3 (95% CI, 11.5 to 17.1) and 14.5 (95% CI, 10.8 to 18.2), respectively, with a nonsignificant mean difference of −0.2 (95% CI, −4.1 to +3.8) (**Table 1**). When GS scores were evaluated, residents and tutors scored on average 12.9 (95% CI, 11.6 to 14.2) and 12.7 (95% CI, 10.7 to 14.7), respectively, with a nonsignificant mean difference of +0.1 (95% CI, −2.5 to +2.8) (**Table 1**).

This finding was confirmed by crossed-effects linear regression analysis, which was used to test the independent association of type of surgeon (resident vs. tutor) and other variables on average levels of residents' surgical skills. As shown in **Table 2**, residents' mean SS scoring was not significantly higher than tutors' (+0.1; 95% CI, −0.5 to 0.8) as well as for GS scoring (+0.5; 95% CI, −2.5 to +3.5). For both GS and SS, 5 or more donor surgeries and prior transplant rotation were the only two variables significantly associated with higher mean GS and SS scores (**Table 2**).

SS and GS scorings were then modeled as a function of residency-by-covariate interactions to investigate whether the effects of such covariates were significantly divergent in residents vs. tutors. With regard to SS scores (**Supplementary Table 1**), we found a significant interaction with prior transplant rotation (*P*-value = 0.042), which means that mean scoring was significantly higher only when residents were rated by tutors (+0.7; 95% CI, +0.4 to +1.1), but not by residents themselves (−0.1; 95% CI −0.8 to +0.6).

We also found evidence of interaction with number of donor surgeries (i.e., significantly higher scorings among those who were involved in ≥5 MOPs only when assigned by tutors, but not when assigned by residents).

Similar findings were found with regard to GS scores (**Supplementary Table 2**). More specifically, we found a significant interaction with prior transplant rotation (*P*-value = 0.029) when residents were rated by tutors (+4.7; 95% CI, +3.2 to +6.1) but not by residents themselves (+0.7; 95% CI, −2.5 to +3.8). We also found evidence of interaction with number of donor surgeries and with tutor's perceived difficulty (i.e., significantly lower scorings for difficult surgeries when assigned by tutors, but not when assigned by residents). **Figure 1** shows SS (**a**) and GS (**b**) total scores assigned by tutors according to the number of donor surgeries performed by residents.

DISCUSSION

The current study confirmed that MOP may enhance residents' open surgical skills, representing a valuable opportunity for hands-on training. In particular, the exposure to a certain number of cases (at least 5) has been shown to significantly increase residents' skills.

MIS has undeniably transformed the field of surgery, offering numerous benefits to patients. However, open surgery remains a vital component in certain cases, where it provides the ability to manage complex cases and obviously, in case of conversion.[9] Among all subspecialties, trauma surgery which shares many steps with MOP in particular for exposure and vascular control, still continues to be performed using an open approach.[10] However, other procedures such as pancreaticoduodenectomy or liver transplantation have similar approaches to MOP. For this reason, improving open surgical skills during residency is of utmost importance for residents' future career especially given that MI procedures are more and more increasing at the expense of open surgery.

MOP is a key component of the transplant process, but may also serve as an invaluable tool for surgeons to increase their surgical skills and competence.[11] The complexity, diversity, and technical demands of the procurement process offer surgeons a unique learning experience that encompasses technical proficiency, decision-making abilities, interdisciplinary collaboration, and a profound understanding of human anatomy. In 2011 the ACGME changed its requirement of a formal rotation in transplant surgery to that of a "formal transplant experience" to allow for greater flexibility but thus limiting its role. To date, only few studies have demonstrated the importance of a transplant rotation in increasing the surgical skills of residents.[3,12,13] In our study, we confirmed these findings but also demonstrating that a 5 or more surgeries should be sought to be achieved by the end of the transplant rotation in order to obtain a consistent increase in technique. We acknowledge that this number may be influenced by several factors.[14] Rotation length has been pointed out as one the main cause as stated by Bayer et al.[3] who failed to demonstrate the association between skills' scorings and number of surgeries due to the low number of procurements attended by the residents during a single 1-month rotation. However, programs and program directors should aim to increase exposure to these procedures. This effort should not solely revolve around extending the rotation length but should also consider factors such as the volume of liver transplantations and the number of residents in rotation. At our Institution, we perform about 120 liver transplants per year. Residents of the University of Bologna are required to rotate a minimum of 6 months in the HB/Transplant Unit to fulfill surgical curricula objectives which means at least 60 procurements. Residents are allowed to rotate more than once in the same Unit upon agreements with program directors, which explains why the analysis had to be adjusted using the variable "prior transplant rotation" but we found that this variable had a positive and significative impact on both SS and GS scorings, confirming however the importance of MOP.

Our paper also aimed to compare the evaluations of the tutors, which should be considered as the reference standard, with those performed by the residents. There are conflicting data on the reliability of residents when asked to rate their operative performances, even if correlations between self-ratings generated by trainees and expert ratings are generally low.[15,16,17,18,19] Similarly, in our study, although residents' evaluations did not significantly differ from tutors when comparing total SS/GS scorings, some variables were found to be significantly associated only when residents were rated by tutors.

This study has some limitations, including the lack of information on the exposure of residents to elective surgery and the ratio of open-to-MIS cases for each participant. Consequently, we cannot provide an exact assessment of the net impact of MOP. Also, there is a potential selection bias to consider, as residents who had previously rotated in our unit might have received higher ratings or been chosen more frequently by tutors. However, these residents accounted for no more than 20% of our entire cohort.

In conclusion, this study showed that MOP is capable of enhancing surgical skills of residents when exposed to an adequate number of surgeries. By integrating transplant rotations into residency programs, institutions can provide well-rounded training that prepares residents for the challenges they will encounter as surgeons, regardless of their ultimate career path. Awareness of the utility of a clinical transplant rotation should be raised on an institutional level.

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TABLES

Table 1. Resident Surgical Skills Scored by Residents and Tutors. Mean Estimates and Differences Between Residents and Tutors Are Presented Along With 95% Confidence Intervals.

Total Scoring	Residents	Tutors	Mean Difference
Specific Steps (SS)	14.3 (11.5, 17.1)	14.5 (10.8, 18.2)	−0.2 (−4.1, 3.8)
General Skills (GS)	12.9 (11.6, 14.2)	12.7 (10.7, 14.7)	0.1 (−2.5, 2.8)

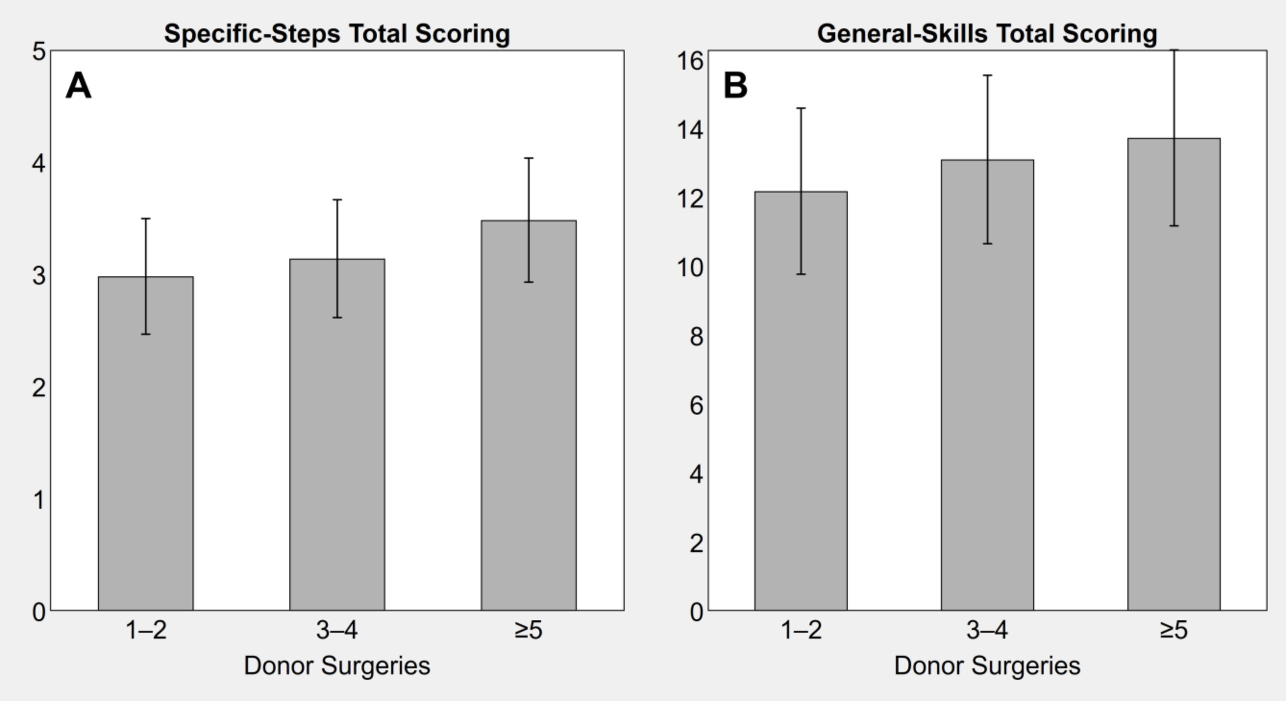
Table 2. Crossed-Effects Linear Regression Model Analyzing the Impact of Surgeon Variables on Average Levels of Resident Surgical Skills Scored by Residents and Tutors.

Characteristic	Specific-Steps (SS)* Total Scoring		General-Skills (GS) Total Scoring	
	Coefficient (95% CI)	*P*-value	Coefficient (95% CI)	*P*-value
Type of Surgeon				
Tutor	Ref.		Ref.	
Resident	0.1 (−0.5, 0.8)	0.657	0.5 (−2.5, 3.5)	0.737
Resident's Sex				
Male	Ref.		Ref.	
Female	0.1 (−0.2, 0.3)	0.653	1.4** (0.2, 2.5)	0.021
Tutor's Sex				
Male	Ref.		Ref.	
Female	0.0 (−0.3, 0.3)	0.886	0.8 (−0.5, 2.1)	0.228
Resident's Post-Graduate Year				
First	Ref.		Ref.	
Second	0.5 (0.0, 1.0)	0.052	1.1 (−0.9, 3.0)	0.277
Third	0.2 (−0.4, 0.7)	0.537	−0.6 (−2.6, 1.5)	0.563
Fourth	0.3 (−0.3, 0.9)	0.289	0.7 (−1.6, 3.1)	0.532
Resident's Number of Donor Surgeries†				
One or Two	Ref.		Ref.	
Three or Four	0.1 (−0.2, 0.3)	0.456	0.6 (−0.4, 1.6)	0.268
Five or More	0.5** (0.2, 0.8)	0.004	1.4** (0.1, 2.6)	0.029
Resident's Prior Transplant Rotation				
No	Ref.		Ref.	
Yes	0.6** (0.3, 1.0)	<0.001	4.2** (2.8, 5.7)	<0.001
Resident's Perceived Difficulty				
Straightforward	Ref.		Ref.	
Intermediate	−0.1 (−0.4, 0.1)	0.319	0.3 (−0.8, 1.4)	0.636
Difficult	0.1 (−0.2, 0.5)	0.420	0.8 (−0.7, 2.2)	0.289
Tutor's Perceived Difficulty				
Straightforward	Ref.		Ref.	
Intermediate	0.0 (−0.3, 0.2)	0.756	−0.2 (−1.3, 0.9)	0.694
Difficult	−0.3 (−0.7, 0.1)	0.092	−1.4 (−2.9, 0.1)	0.073

*Standardized, that is, adjusted for the actual number of procedure steps performed during surgery.
**Regression coefficient is significantly above or below zero (*P*-value ≤ 0.05).
†Categories were obtained using a tercile split. *CI*, confidence interval.

FIGURES

Figure 1. Specific-Steps (SS, **a**) and General-Surgery (GS, **b**) Total Scores Assigned by Tutors According to the Number of Donor Surgeries Performed by Residents. Mean Estimates Are Presented Along With 95% Confidence Intervals.



Notes: All estimates are adjusted for resident's sex, tutor's sex, resident's post-graduate year, resident's prior transplant rotation, resident's perceived level of difficulty, and tutor's perceived level of difficulty. Specific-steps scoring is standardized, that is, adjusted for the actual number of procedure steps performed during surgery.

SUPPLEMENTARY TABLES

Supplementary Table 1. Specific-Steps (SS) Total Scoring According to Surgeon Characteristics, by Resident Vs. Assisting Tutor. Mean Estimates and Differences (Contrasts) Across Surgeon Characteristics Are Presented Along With 95% Confidence Intervals.

Characteristic	Residents	Tutors	Interaction *P*-value
Resident's Sex			0.796
Male	3.2 (2.8, 3.7)	3.1 (2.6, 3.6)	
Female	3.3 (2.9, 3.8)	3.2 (2.6, 3.7)	
(Female Vs. Male)	0.1 (−0.5, 0.8)	0.1 (−0.2, 0.3)	
Tutor's Sex			0.744
Male	3.3 (3.0, 3.6)	3.2 (2.6, 3.8)	
Female	3.3 (2.9, 3.6)	3.0 (1.9, 4.1)	
(Female Vs. Male)	0.0 (−0.3, 0.3)	−0.2 (−1.5, 1.0)	
Resident's Post-Graduate Year			0.976
First	3.1 (2.3, 3.9)	2.9 (2.1, 3.6)	
Second	3.5 (3.0, 4.1)	3.4 (2.8, 4.0)	
Third	3.2 (2.8, 3.5)	3.1 (2.6, 3.6)	
Fourth	3.4 (2.8, 4.0)	3.2 (2.6, 3.8)	
(Second Vs. First)	0.4 (−0.2, 1.1)	0.6 (−0.1, 1.2)	
(Third Vs. First)	0.1 (−0.7, 0.9)	0.2 (−0.4, 0.8)	
(Fourth Vs. First)	0.3 (−0.6, 1.2)	0.3 (−0.3, 1.0)	
Resident's Number of Donor Surgeries‡			0.772
One or Two	3.2 (2.8, 3.5)	3.0 (2.5, 3.5)	
Three or Four	3.2 (2.8, 3.6)	3.1 (2.6, 3.7)	
Five or More	3.6 (3.1, 4.0)	3.5 (2.9, 4.0)	
(Three or Four Vs. One or Two)	0.0 (−0.3, 0.3)	0.2 (−0.1, 0.5)	
(Five or More Vs. One or Two)	0.4 (0.0, 0.8)	0.5* (0.2, 0.8)	
Resident's Prior Transplant Rotation			0.042†
No	3.3 (2.9, 3.6)	2.9 (2.5, 3.4)	
Yes	3.2 (2.6, 3.8)	3.7 (3.1, 4.2)	
(Yes Vs. No)	−0.1 (−0.8, 0.6)	0.7* (0.4, 1.1)	
Resident's Perceived Difficulty			0.784
Straightforward	3.3 (2.9, 3.7)	3.2 (2.7, 3.7)	
Intermediate	3.2 (2.8, 3.5)	3.1 (2.5, 3.6)	
Difficult	3.6 (3.1, 4.0)	3.3 (2.7, 3.9)	
(Intermediate Vs. Straightforward)	−0.1 (−0.5, 0.2)	−0.1 (−0.4, 0.2)	
(Difficult Vs. Straightforward)	0.2 (−0.2, 0.7)	0.1 (−0.4, 0.5)	
Tutor's Perceived Difficulty			0.397
Straightforward	3.3 (2.9, 3.6)	3.3 (2.7, 3.8)	
Intermediate	3.3 (3.0, 3.7)	3.1 (2.6, 3.7)	
Difficult	3.1 (2.6, 3.6)	2.8 (2.2, 3.4)	
(Intermediate Vs. Straightforward)	0.0 (−0.3, 0.4)	−0.1 (−0.5, 0.2)	
(Difficult Vs. Straightforward)	−0.2 (−0.6, 0.3)	−0.5 (−0.9, 0.0)	

Notes: Specific-steps scoring is standardized, that is, adjusted for the actual number of procedure steps performed during surgery.
*Scoring difference across surgeon characteristics is significantly above or below zero (P-value ≤0.05).
†Interaction P-value ≤ 0.05, i.e., scoring differences across surgeon characteristics are significantly different from each other (difference-in-differences ≠ 0).
‡Categories were obtained using a tercile split.

Supplementary Table 2. General-Skills (GS) Total Scoring According to Surgeon Characteristics, by Resident Vs. Assisting Tutor. Mean Estimates and Differences (Contrasts) Across Surgeon Characteristics Are Presented Along With 95% Confidence Intervals.

Characteristic	Residents	Tutors	Interaction *P*-value
Resident's Sex			0.877
Male	12.5 (10.4, 14.6)	12.1 (9.6, 14.6)	
Female	14.1 (12.0, 16.2)	13.5 (11.0, 15.9)	
(Female Vs. Male)	1.6* (0.0, 3.2)	1.3* (0.2, 2.5)	
Tutor's Sex			0.527
Male	13.0 (11.5, 14.5)	13.0 (10.3, 15.6)	
Female	13.9 (12.2, 15.6)	11.9 (6.7, 17.0)	
(Female Vs. Male)	0.9 (−0.4, 2.1)	−1.1 (−6.9, 4.7)	
Resident's Post-Graduate Year			0.662
First	12.7 (9.2, 16.1)	13.6 (10.2, 17.0)	
Second	14.4 (11.8, 17.1)	13.9 (11.3, 16.6)	
Third	13.1 (11.4, 14.7)	12.3 (9.8, 14.7)	
Fourth	13.5 (10.9, 16.0)	14.1 (11.2, 17.1)	
(Second Vs. First)	1.8 (−0.8, 4.4)	0.3 (−2.3, 3.0)	
(Third Vs. First)	0.4 (−3.2, 4.1)	−1.3 (−3.9, 1.2)	
(Fourth Vs. First)	0.8 (−3.4, 5.0)	0.6 (−2.4, 3.5)	
Resident's Number of Donor Surgeries‡			0.701
One or Two	13.0 (11.5, 14.5)	12.2 (9.8, 14.6)	
Three or Four	13.1 (11.5, 14.8)	13.1 (10.7, 15.6)	
Five or More	14.1 (12.1, 16.1)	13.7 (11.2, 16.3)	
(Three or Four Vs. One or Two)	0.2 (−1.2, 1.5)	0.9 (−0.4, 2.2)	
(Five or More Vs. One or Two)	1.1 (−0.7, 2.8)	1.5* (0.1, 3.0)	
Resident's Prior Transplant Rotation			0.029†
No	12.9 (11.4, 14.4)	11.5 (9.4, 13.6)	
Yes	13.5 (10.8, 16.3)	16.2 (13.8, 18.5)	
(Yes Vs. No)	0.7 (−2.5, 3.8)	4.7* (3.2, 6.1)	
Resident's Perceived Difficulty			0.751
Straightforward	13.0 (11.3, 14.7)	12.6 (10.2, 15.1)	
Intermediate	13.5 (11.9, 15.0)	12.8 (10.4, 15.1)	
Difficult	13.4 (11.3, 15.5)	13.7 (11.0, 16.4)	
(Intermediate Vs. Straightforward)	0.5 (−1.0, 2.0)	0.1 (−1.2, 1.4)	
(Difficult Vs. Straightforward)	0.4 (−1.5, 2.3)	1.1 (−0.8, 2.9)	
Tutor's Perceived Difficulty			0.454
Straightforward	13.5 (12.0, 15.1)	13.2 (10.8, 15.6)	
Intermediate	13.1 (11.4, 14.8)	13.0 (10.6, 15.5)	
Difficult	12.9 (10.8, 15.1)	11.2 (8.5, 13.9)	
(Intermediate Vs. Straightforward)	−0.4 (−1.8, 1.0)	−0.1 (−1.6, 1.3)	
(Difficult Vs. Straightforward)	−0.6 (−2.5, 1.4)	−2.0* (−3.9, −0.1)	

*Scoring difference across surgeon characteristics is significantly above or below zero (*P*-value ≤ 0.05).
†Interaction *P*-value ≤ 0.05, i.e., scoring differences across surgeon characteristics are significantly different from each other (difference-in-differences ≠ 0).
‡Categories were obtained using a tercile split.