Prospective Trial of Low-Fidelity Deliberate Practice of Aortic and Coronary Anastomoses (TECoG 002)

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OBJECTIVE: We sought to examine the feasibility of a home practice curriculum of vascular anastomosis in cardiovascular surgery using a low-fidelity simulation platform and to examine its effectiveness in skill acquisition in senior surgical trainees.

DESIGN: We organized a multicenter prospective randomized study of senior residents and fellows, who were oriented to a low-fidelity cardiac simulator and an 8-week curriculum of independent practice of aortic and coronary anastomosis. "Treatment" trainees received a simulator and the curriculum. Control trainees received only their usual operative experience. The groups then crossed over; all were studied for 16 weeks in total. Video skill assessments were captured at 0, 8, and 16 weeks and were scored by one blinded investigator using the Joint Council on Thoracic Surgery Education Assessment tool. A post-hoc survey was distributed to invited participants following study completion.

SETTING: University of Minnesota Department of Surgery, Mayo Clinic Department of Cardiovascular Surgery, and the University of Texas Health Science Center at Houston. Participants used the simulator in offices, call rooms, and their homes.

PARTICIPANTS: Program participation in the study was solicited through the Thoracic Education Cooperative Group. Four institutions expressed interest and a total of 29 trainees were invited to the study and randomized. Of these, 12 (38%) completed the curriculum and submitted the requisite 3 sets of videos (6 treatment, 6 control). All were senior residents and fellows in general and cardiothoracic surgery.

RESULTS: No significant differences were detected in assessment scores before and after the curriculum nor before or after the control period in the overall or postgraduate year-stratified populations. Participant case numbers during the study did not have a significant effect on assessment scores. Randomized participants reported strong interest in deliberate practice of technical skills but identified competing clinical and personal obligations and significant barriers to simulation.

CONCLUSIONS: Considerable variability in performance existed among participants who completed the study, but overall, the curriculum alone was insufficient to improve simulator Joint Council on Thoracic Surgery Education scores compared to those not undergoing the curriculum. Among senior residents and fellows, provision of a practice curriculum and simulator for repeated practice is feasible but clinical and personal responsibilities were barriers to repetitive practice. (J Surg Ed 76:844−855. © 2018 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Cardiovascular surgery, cardiothoracic surgery, aorta, coronary, simulation, deliberate practice

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ABBREVIATIONS: JCTSE, Joint Council on Thoracic Surgery Education; TECoG, Thoracic Education Cooperative Group; CVS, Cardiovascular Surgery; TSDA, Thoracic Surgery Directors Association; OR, Operating room; LAD, Left anterior descending; OM, Obtuse marginal; PDA, Posterior descending artery; PGY, Post-graduate year

INTRODUCTION

The practice of cardiovascular surgery is growing more difficult as patient and procedural complexity increases. More stringent work hour restrictions and an emphasis on shortening residency programs have increased the need for cardiac surgery simulation curricula for practice outside the operating room (OR). Several studies have demonstrated improvements in resident technical performance using artificial anastomosis simulators.[1–3] Unfortunately, most simulation experiences are expensive, brief, and not designed for repetitive practice.

A sizable body of literature exists on the subject of simulation in surgical training.[4] Ericsson et al reported a direct and reproducible correlation between number of hours practiced and achievement of expert performance. The primary mechanism of development of these skills is through practice activities with full concentration aimed at improving a particular aspect of performance, called *deliberate practice.* This is directly applicable to simulation in surgical training because of the opportunity for dedicated focus on psychomotor skills, which are immediately transferrable to patient care.[5,6]

Many complex tasks in cardiovascular surgery (CVS) require a series of specialized maneuvers that can be mastered through repetition, but opportunities for deliberate practice of such techniques are limited by clinical and time constraints on trainees and a paucity of readily-accessible simulation platforms. The annual "Boot Camp" event organized by the Thoracic Surgery Directors Association, a weekend-long course in which new trainees develop basic proficiency with many specialized skills related to CVS using high-fidelity simulators under the tutelage of senior faculty is highly rated by attendees and has been demonstrated to improve the technical skills of trainees and the teaching skills of faculty.[1,7–10] However, access to this level of dedicated instruction and simulation is generally not available past the conclusion of the event.

We have previously described a novel low-fidelity multistation simulator for cardiovascular surgery techniques, which provides the opportunity for out-of-OR practice of aortic and coronary anastomoses (Synaptic Design, Minneapolis, MN).[11] Surgical trainees may be able to improve their performance of these techniques through a prescribed program of home simulation. To this end, we performed a prospective, randomized study of fellows and senior residents in cardiothoracic and general surgery to determine the effect of home deliberate practice on cardiothoracic surgical skill acquisition.

MATERIALS AND METHODS

Study Population

Senior residents and fellows in CVS, along with several senior general surgery residents and abdominal transplant and vascular surgery fellows, at participating institutions (part of the Thoracic Education Cooperative Group), were invited to participate in the study. Consent was obtained from all participants. This study was determined by the University of Minnesota IRB to be exempt from full review (Study Number #1409E53585).

Simulation Platforms

The simulator used by most study participants, described in detail previously, allows the simulation of aortic anastomosis and coronary anastomosis to a variety of distal targets, including the left anterior descending artery (LAD), the obtuse marginal branches (OM), and the posterior descending artery (PDA) (Fig. 1).[11] One participant opted to use alternate aortic (described previously by Helder et al.) and coronary (Heart Case, The Chamberlain Group, Great Barrington, MA) simulation platforms.[12]

Technical Assessment

At predetermined intervals during the study period, described below, short (~2 minutes each) smartphone video clips of participants performing aortic and coronary anastomoses were recorded. These were captured either by the lead investigator or by the participants themselves, who would then submit clips for review. All clips were evaluated by a single experienced surgeon (M.B.) using the Joint Council on Thoracic Surgical Education (JCTSE) Assessment Tool to tabulate an overall score for each clip. The JCTSE tool has previously been validated and shown to have a high level of interrater reliability when completed by experienced faculty in a simulation setting, which is consistent with the conditions of our study.[13] The categories describing the quality of the arteriotomy, graft positioning, and knot tying were omitted because of simulator design and video clip length, allowing a maximum score of 50.

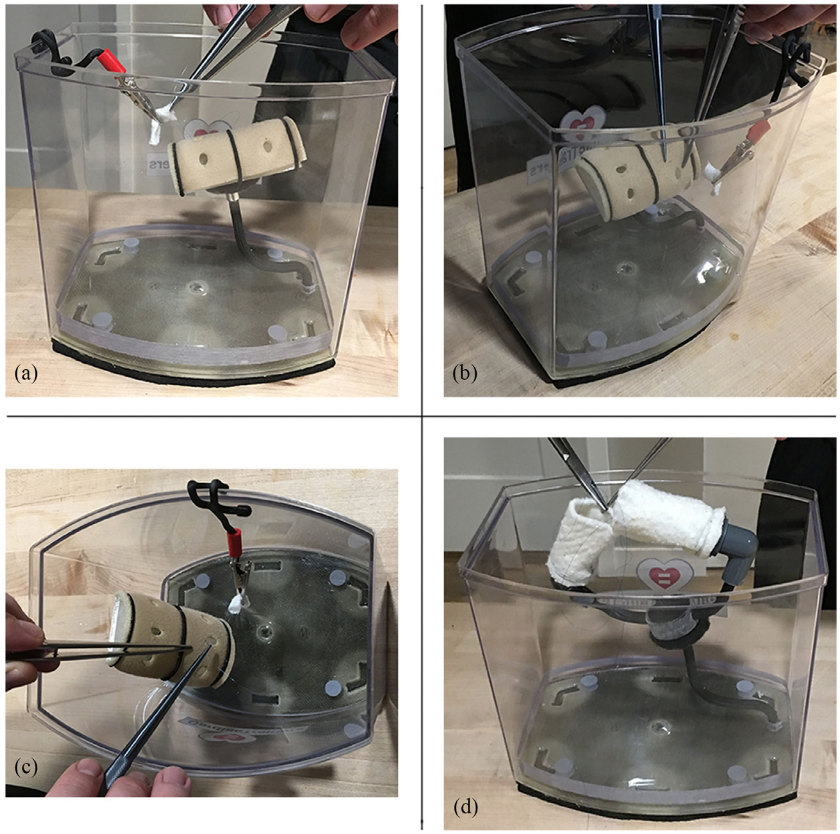

FIGURE 1. Representative home setup of multistation cardiac simulator for use in practice curriculum. (a) Setup for LAD anastomosis. (b) Setup for OM anastomosis. Note that the simulated coronary target is rotated away from the operator. (c) Setup for PDA anastomosis. The simulated coronary target is situated almost vertically. (d) Setup for aortic anastomosis. LAD: left anterior descending artery; OM: obtuse marginal branch; PDA: posterior descending artery.

Study Design

At each study site, participants attended an in-person orientation with local investigators, where they received an introduction to the study and the simulator. All had the opportunity to perform simulated aortic and coronary anastomoses, which were filmed as a baseline assessment. All participants also had access to an online portal with long-form narrated video demonstration of relevant techniques (Fig. 2).

Participants were then randomized to one of two groups. Each member of the treatment group was loaned a simulator and given a standardized curriculum for practice outside the OR. This curriculum, which was generated through two rounds of review and development by an expert panel of practicing cardiothoracic surgeons, mandated a minimum of 20 to 30 minutes of dedicated technical practice, three times a week for 8 weeks (Table 1). Treatment group participants were asked to submit video clips to their corresponding local investigators for informal feedback at the midway point of this interval and were encouraged to repeat this as often as desired, facilitating "remote mentorship." Formal video assessments were repeated and submitted to the lead investigator 8 weeks after the baseline video assessment was recorded.

Members of the control group underwent the same baseline assessment as the treatment group, but were not initially loaned simulators and did not initially participate in the home practice curriculum. Video assessment was repeated after 8 weeks, during which time these participants were exposed only to their usual operative experience. Following repeat assessment, the groups were crossed over: participants initially randomized to the control group were loaned simulators and took part in the home practice curriculum and participants initially randomized to the treatment group were exposed to their usual operative experience only. Assessments were repeated in both groups after another 8 weeks (week 16 overall).

When participating in the home practice curriculum, participants were asked to track the number and type of practice activities performed using a dedicated tracking form distributed at orientation sessions. Practice beyond that required by the curriculum was encouraged so long as it was tracked. Participants were asked to return their tracking forms at study completion. All simulator

FIGURE 2. Representative sample of online didactic content.

assessments were either video-recorded by the lead investigator or recorded by participants and submitted electronically. Participants had to submit at least 2 sequential video clips in a given category (aortic or coronary) to be included in analysis. Finally, participants were asked to obtain, when possible, written assessments of intraoperative anastomotic technique using the

TABLE 1. Home Simulation Curriculum

Week 1	Day 1	One Aortic Anastomosis
	Day 2	One LAD anastomosis (50% only)
	Day 3	One complete aortic anastomosis
Week 2	Day 1	One complete LAD anastomosis
	Day 2	One complete aortic anastomosis
	Day 3	One complete LAD anastomosis
Week 3	Day 1	One complete aortic anastomosis
	Day 2	One OM anastomosis (50% only)
	Day 3	One complete OM anastomosis
Week 4	Day 1	One complete LAD anastomosis
	Day 2	One complete OM anastomosis
	Day 3	One large vessel anastomosis
Week 5	Day 1	One PDA anastomosis (50% only)
	Day 2	One complete PDA anastomosis
	Day 3	One complete aortic anastomosis
Week 6	Day 1	One complete LAD anastomosis
	Day 2	One complete LAD anastomosis
	Day 3	One complete aortic anastomosis
Week 7	Day 1	One complete OM anastomosis
	Day 2	One complete aortic anastomosis
	Day 3	One complete aortic anastomosis
Week 8	Day 1	One complete OM anastomosis
	Day 2	One complete LAD anastomosis
	Day 3	One complete aortic anastomosis

JCTSE tool from attending surgeons around the same time as simulator assessments. All participants worked under an honor system, providing verbal affirmation of their adherence to the curriculum. However, we analyzed separately the group of individuals that were extremely compliant, providing complete written attestations, personal logs, and video assessments. This group was referred to as the '"completionist" cohort.' At the end of the entire study, a multiple-choice survey examining attitudes toward deliberate practice and possible impediments was sent to participants using a free online service (www.surveymonkey.com). Paired Student's t-testing and Pearson's correlation (r) were used where appropriate with ($\alpha = 0.05$). GraphPad Prism 7 (GraphPad Software, La Jolla, CA) was used for all statistical testing.

RESULTS

Study Cohort and Completion Rate

A total of 29 trainees from 4 institutions were invited to participate in the study and randomized (15 CVS, 5 general surgery, 5 transplant surgery, 4 vascular surgery). Of these, 19 attended an orientation session and 13 (11 CTS, 2 general) submitted at least 2 video assessments, qualifying them for inclusion in the analysis (n = 5 post-graduate year [PGY] 3-4, n = 8 PGY 6-8). Twelve trainees (6 treatment, 6 control) submitted the requisite 3 sets of videos. Six participants (5 treatment, 1 control) returned their tracking forms

TABLE 2. Overall Cohort Assessment Results

Treatment Group	**Aortic**	**Coronary**
Pretest	41.0 ± 5.7	37.8 ± 6.4
Postcurriculum	41.8 ± 5.0	31.7 ± 4.7
P (Pretest vs Postcurriculum)	0.7916	0.0858
Post-observation	40.3 ± 3.1	35.2 ± 4.7
P (Postcurriculum vs Postobservation)	0.5452	0.2254
Control Group		
Pretest	36.2 ± 8.0	35.4 ± 6.1
Postobservation	38.2 ± 3.5	37.2 ± 6.7
P (Pretest vs Postobservation)	0.6238	0.6685
Postcurriculum	37.8 ± 6.5	37.0 ± 3.4
P (Postobservation vs Postcurriculum)	0.906	0.9541
Overall Treatment Effect		
Pretreatment	38.8 ± 6.6	37.7 ± 5.9
Post-treatment	40.0 ± 5.5	34.4 ± 4.8
P (Pretreatment vs Post-treatment)	0.6202	0.1528
Observation Effect	*Treatment Group*	
Preobservation	41.6 ± 4.6	31.7 ± 4.7
Postobservation	40.3 ± 3.1	35.2 ± 4.7
P (Preobservation vs Postobservation)	0.5881	0.2254
	Control Group	
Preobservation	37.7 ± 8.0	35.3 ± 5.4
Postobservation	39.8 ± 5.1	38.0 ± 6.3
P (Preobservation vs Postobservation)	0.5891	0.4514

at case completion, which attested to completion of the home curriculum. Only 3 participants, all in the treatment group, submitted at least 2 intraoperative evaluations.

Overall Cohort Assessments

Trainees assigned to the control group tended to be more senior (PGY 6.0 ± 1.7) than those assigned to the treatment group (PGY 4.7 ± 1.9, p = 0.2243). Among subjects initially assigned to the treatment group, there was no significant difference in scores on both the aortic and coronary exercises between the initial assessment (pretest) and repeat assessment at the end of the 8-week practice curriculum (postcurriculum). There was also no significant difference between the postcurriculum scores and those at the end of the 8-week observation period that followed (postcurriculum). A similar set of findings was observed in the control group (Table 2, Fig. 3a-d).

The precurriculum and postcurriculum scores of the treatment and control groups were combined into 2 larger "before and after" groups to characterize the effect of the curriculum in the overall study cohort (treatment effect). A small score increase was seen in the aortic group and a small decrease was seen in the coronary group, but neither of these differences were statistically significant (Table 2, Fig. 3e-f).

Finally, scores from before and after the observation period in the treatment and control groups were compared to determine if, in the control group, performance improved over time without the curriculum or if, in the treatment group, there was a notable decline in performance over the observation period after completion of the curriculum (observation effect). In both the treatment and control groups, there were no significant differences in preobservation and postobservation scores in both the aortic and coronary exercises (Table 2, Fig. 3g-h).

Subgroup Assessments

Participants in the study verbally committed to completing the study curriculum as described and our above analysis is based on the assumption of curriculum completion, but this was not possible to verify rigorously. The treatment and observation effects in the subgroup of study participants who submitted written attestations of completion ("completionist" cohort) of the home practice curriculum were analyzed separately to assess differences in skill acquisition (Table 3). A small score increase in the aortic exercise was observed before and after the treatment period (41.8 ± 4.9 vs 44.2 ± 2.1, p = 0.3114), but this was not statistically significant. There was no significant treatment effect in the coronary exercise and there was no significant observation effect seen in either exercise (Fig. 4).

Participant performance was also analyzed by training level (PGY 3-4 vs PGY 6-8). No significant treatment or observation effect was seen in either group in either exercise (Table 3, Fig. 5). Participant case experience during the treatment and control phases of the study is reported in detail in Table 4. No PGY 3-4 trainee performed an open cardiac case during the study, although this group on average performed a greater number of open and overall cases during both phases. In the overall study cohort, there was no meaningful correlation between the number of open cardiac, all other open, or total number of cases performed and changes in measured performance scores in either the treatment or control phases.

Intraoperative Assessments

Faculty evaluations of intraoperative performance of a coronary anastomosis were submitted by three participants (PGY 6.7 ± 0.6) before and after completion of the home practice curriculum. A non-significant increase in scores was seen (42.0 ± 16.5 vs 53.0 ± 8.5, p = 0.3469).

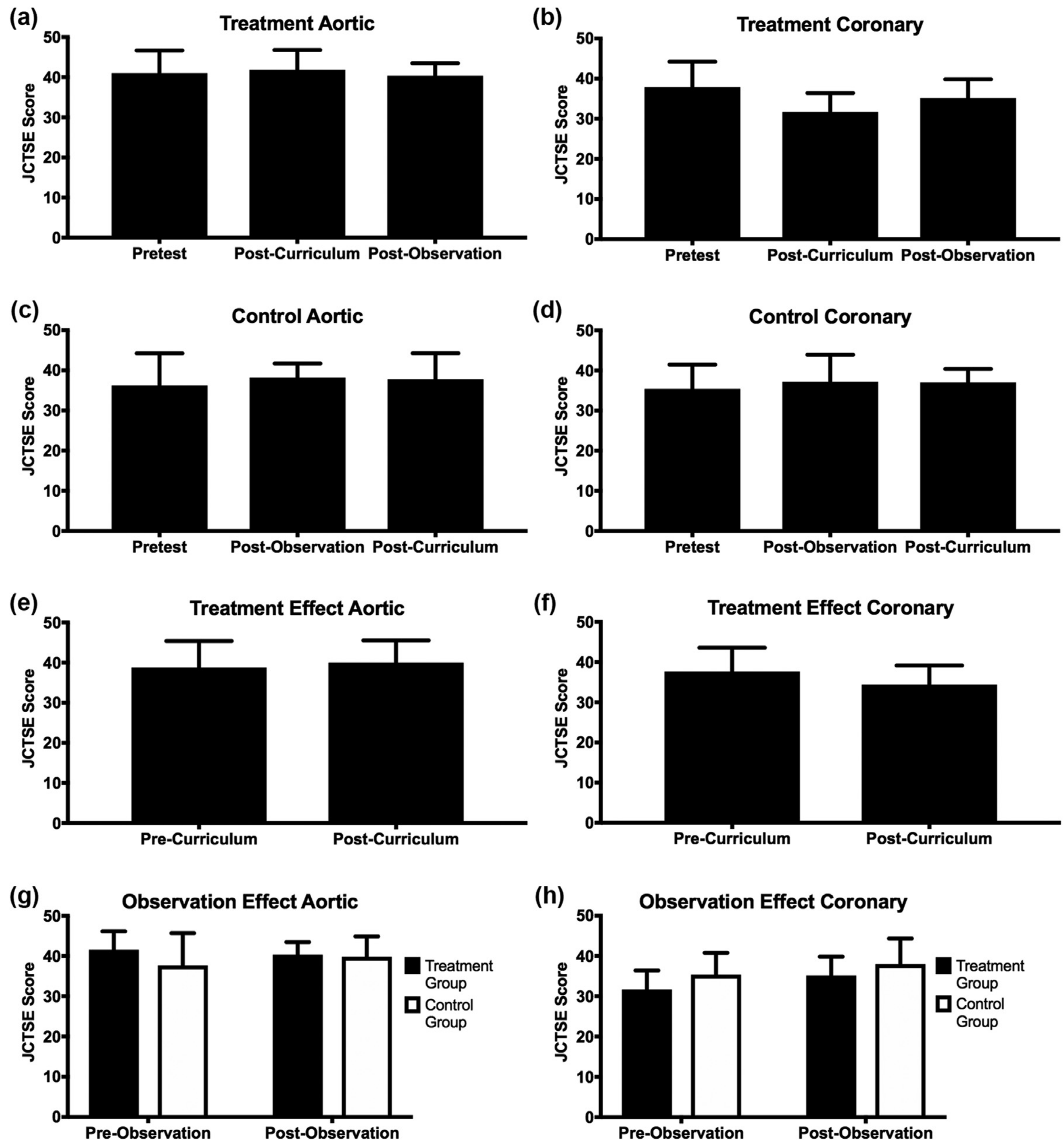

FIGURE 3. Overall cohort results. (a) Aortic anastomosis performance in treatment group. (b) Coronary anastomosis performance in treatment group. (c) Aortic anastomosis performance in control group. (d) Coronary anastomosis performance in control group. (e) Aggregate (treatment and control groups) precurriculum and postcurriculum performance of aortic anastomosis. (f) Aggregate precurriculum and postcurriculum performance of coronary anastomosis. (g) Aggregate preobservation and postobservation performance of aortic anastomosis. (h) Aggregate preobservation and postobservation performance of coronary anastomosis. JCTSE, Joint Council on Thoracic Surgery Education.

Survey Responses and Participant Comments

Survey questions sent to study participants and aggregated responses are presented in Figure 6. The survey was sent to all randomized subjects, regardless of their level of study participation. The response rate was 55%. Overall, trainees were interested in deliberate practice and recognized its importance in skill acquisition. However, daily clinical responsibilities and competing personal obligations were reported as significant barriers to further participation in a program of home practice. Notably, half of respondents reported that pre-existing educational obligations, including lectures and conferences, were either moderately or extremely important barriers to further curriculum participation (Fig. 6). Written comments were solicited from participating trainees regarding the simulation experience at its conclusion and a selection of these are presented in Table 5.

TABLE 3. Subgroup Assessment Results

Completionist Cohort	**Aortic**	**Coronary**
Treatment Effect		
Pretreatment	41.8 ± 4.9	37.8 ± 6.9
Post-treatment	44.2 ± 2.1	35.0 ± 3.4
P (Pretreatment vs Post-treatment)	0.3114	0.3889
Observation Effect		
Preobservation	41.4 ± 8.1	32.6 ± 2.7
Postobservation	41.0 ± 3.0	34.4 ± 4.7
P (Preobservation vs Postobservation)	0.9199	0.4806
PGY-Stratified Cohorts		
Treatment Effect	*PGY-3-4*	
Pretreatment	40.0 ± 4.4	38.4 ± 3.0
Post-treatment	38.4 ± 3.6	33.0 ± 6.1
P (Pretreatment vs Post-treatment)	0.5496	0.5741
	PGY 6-8	
Pretreatment	39.3 ± 5.1	40.0 ± 6.4
Post-treatment	41.1 ± 6.6	35.4 ± 3.6
P (Pretreatment vs Post-treatment)	0.5644	0.1188
Observation Effect	*PGY-3-4*	
Preobservation	37.6 ± 4.4	31.4 ± 5.6
Postobservation	39.5 ± 2.6	35.3 ± 5.3
P (Preobservation vs Postobservation)	0.4742	0.3252
	PGY 6-8	
Preobservation	41.1 ± 7.4	35.4 ± 4.6
Postobservation	40.4 ± 4.7	37.3 ± 5.8
P (Preobservation vs Postobservation)	0.8124	0.4865

DISCUSSION

We report the results of a prospective, randomized study of skill acquisition in cardiovascular surgery using low-fidelity simulators. Overall, we were not able to demonstrate a statistically-significant benefit to a home program of deliberate practice despite the use of a uniform curriculum and a blinded grader using a validated scoring tool for both coronary and aortic anastomoses. Post-hoc survey data indicated that trainees were interested in this mode of skill acquisition but that competing clinical and personal obligations represented a significant barrier to home practice.

Resource-intensive one-time simulation experiences such as the Boot Camp are valuable for initial exposure to new technology or complex techniques but usually do not allow repetitive practice. The use of low-fidelity simulation to teach or hone specific "low-tech" skills in cardiovascular surgery is an attractive idea. Comfort with well-defined techniques such as coronary anastomosis allows trainees to be more efficient over the course of an entire operation instead of struggling with single steps, which can consume valuable minutes on bypass, and allows attending surgeons to focus limited time available for teaching on more advanced concepts. However, the amount of discretionary time trainees must devote to simulation to realize a meaningful benefit is unclear. Our study design allowed us to observe a real-world scenario for integration of a practice curriculum across several

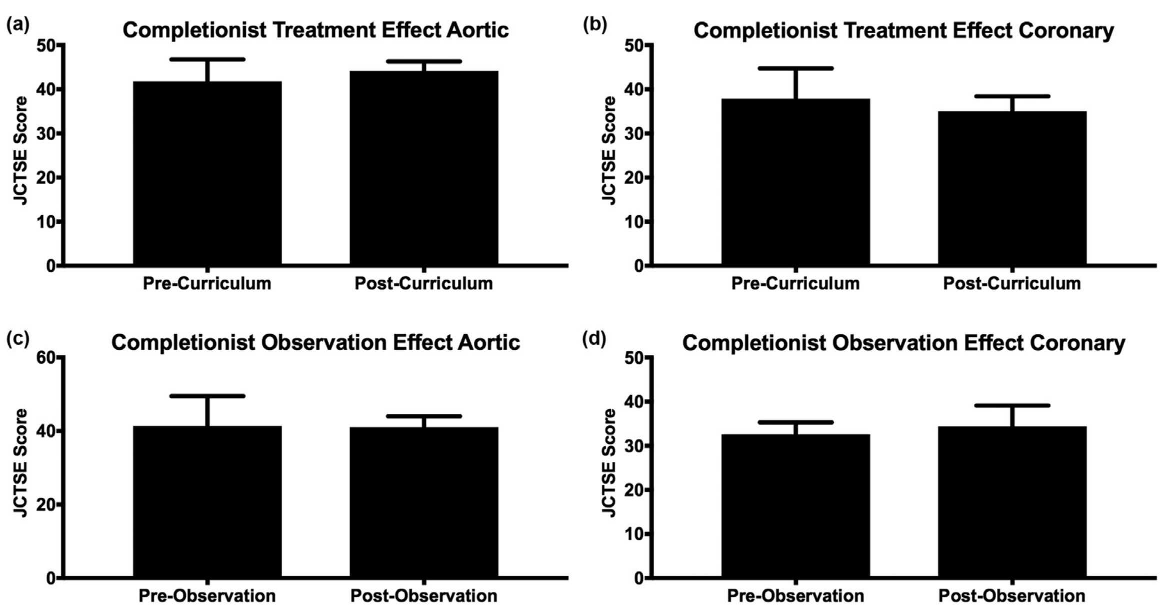

FIGURE 4. Completionist cohort results. (a) Aggregate (treatment and control groups) precurriculum and postcurriculum performance of aortic anastomosis. (b) Aggregate precurriculum and postcurriculum performance of coronary anastomosis. (c) Aggregate preobservation and postobservation performance of aortic anastomosis. (d) Aggregate preobservation and postobservation performance of coronary anastomosis. JCTSE, Joint Council on Thoracic Surgery Education.

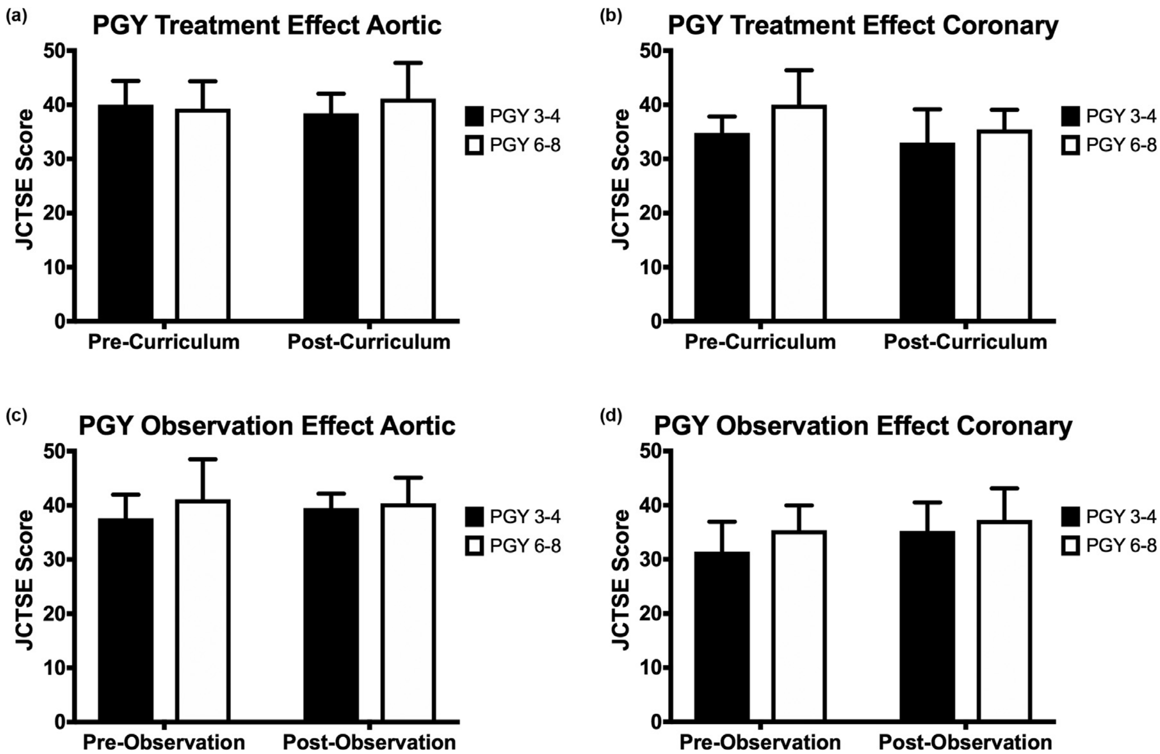

FIGURE 5. PGY-stratified cohort results. (a) Aggregate (treatment and control groups) precurriculum and postcurriculum performance of aortic anastomosis. (b) Aggregate precurriculum and postcurriculum performance of coronary anastomosis. (c) Aggregate (treatment and control groups) preobservation and postobservation performance of aortic anastomosis. (d) Aggregate preobservation and postobservation performance of coronary anastomosis. JCTSE, Joint Council on Thoracic Surgery Education. PGY: Post-graduate year.

sites. We relied on an honor system whereby participants agreed that they would and did complete the program, but not all provided written attestation of curriculum completion. Some may not have met the requisite number of hours of practice or the requirements may have been insufficient to show an effect.

Previous work has examined the effect of home or unsupervised simulation on skill acquisition in cardiovascular surgery. Helder et al demonstrated that a homemade low-fidelity model of aortic anastomosis, coupled with high-fidelity pre- and post-testing, improved technical performance in aortic anastomosis in a group of 20 trainees (including 16 medical students and/ or junior residents). The greatest improvements were realized in the medical student and junior resident cohorts, often after only a few practice attempts over a five-week study period.[12] Enter et al demonstrated that both supervised and unsupervised repetitive practice using a low-fidelity simulator were effective in skill acquisition in coronary anastomosis in a group of 45 medical students.[14]

Limitations

Our study has some notable limitations. Prior studies of this type made use of medical students and junior surgery residents, while key elements of our study design were aimed at accommodating a population of senior surgical trainees. These included a reliance on remote submission of video clips by study subjects, intended to provide participants flexibility with regard to location and timing of practice and submission of recordings, the prolonged study period, which was aimed at minimizing the weekly time burden of practice, and a multicenter design, which was used to maximize the number of participants. These elements of study design differ from those of Helder and Enter, who made exclusive use of scheduled in-person sessions for data collection before and after relatively brief (4-5 weeks vs 16 weeks in our study) periods of home simulation.[12,14]

Our use of senior trainees, a significant component of the target population for the type of simulation platform we describe, was a paradoxical limitation.[12,14] Senior trainees are subject to more extensive clinical demands and may have less flexibility in their personal lives, limiting discretionary time available for home simulation and similar activities. These circumstances, along with a prolonged study period, likely contributed to our comparatively lower rate of study participation and high rates of incomplete data submission, as demonstrated by the low rates of complete submission of video files (41% of randomized cohort) and documentation (21% of randomized cohort), introducing participation bias into our

TABLE 4. Participant Case Experience and Performance Effects

Case Experience

			Treatment Period		
Training Level	Open Cardiac	Other Open	VATS/ Lap	Endo/Perc	Total
PGY 3-4	0 ± 0	39 ± 17	13 ± 11	10 ± 10	65 ± 23
PGY 6-8*	29 ± 6	9 ± 11	8 ± 8	4 ± 5	48 ± 10
Overall	17 ± 15	22 ± 20	11 ± 10	7 ± 8	55 ± 19
p value (PGY 3-4 vs 6-8)	<0.05	<0.05	0.269	0.158	0.142
			Control Period		
Training Level	Open Cardiac	Other Open	VATS/Lap	Endo/Perc	Total
PGY 3-4•	0 ± 0	41 ± 11	12 ± 6	2 ± 3	54 ± 17
PGY 6-8°	24 ± 13	3 ± 3	12 ± 17	4 ± 4	43 ± 7
Overall	13 ± 16	20 ± 20	12 ± 13	3 ± 4	48 ± 14
p value (PGY 3-4 vs 6-8)	<0.05	<0.05	0.989	0.326	0.287

Case Experience and JCTSE Score Change Correlation

	Treatment Period			
	Aortic		Coronary	
Case type	r	p value	r	p value
Open cardiac	0.3907	0.2349	−0.0679	0.8428
Other open	−0.1421	0.6768	−0.1202	0.7248
Total cases	0.0564	0.8692	0.0219	0.9489
	Control Period			
	Aortic		Coronary	
Case type	R	p value	R	p value
Open cardiac	−0.4620	0.2106	−0.6035	0.0853
Other open	−0.0362	0.9264	0.2157	0.5772
Total cases	−0.0596	0.8789	−0.0243	0.9504

Correlation analysis comparing number of cases performed to change in JCTSE score. (*) data available for 7/8 participating residents. (•) data available for 4/5 participating residents. (°) data available for 5/8 participating residents. Endo/Perc: endoscopic/ percutaneous; JCTSE: Joint Council on Thoracic Surgery Education; PGY: post-graduate year; r: Pearson correlation coefficient; VATS/ Lap: video-assisted thoracoscopic surgery/ laparoscopic.

results. No direct incentives (e.g., retail gift cards or some equivalent) were offered to subjects in our study; doing so may have improved our rate of participation.

This stands in contrast to medical students interested in surgery and junior surgical residents, who are more likely to participate more fully in such a study because of the opportunities for subspecialty resident/ faculty interaction and the opportunity to learn a novel and advanced technical skill. Although post-hoc power calculations are not advisable, our results were certainly affected by our small sample size, limiting our ability to draw firm conclusions about the effect of low-fidelity home simulation on skill acquisition in this setting.[15] Study participants reported that competing clinical and personal obligations were impediments to spending time on simulation in general and on complete study participation specifically,

TABLE 5. Sampled Study Participant Comments (prompts in italics).

Were you able to achieve the goals that you laid out at the start of the simulation program? How? If not, why?
"Yes, practice time outside OR gave [me] more time for trying new ways to do things and to work on improving."
"Overall yes. Combination of simulator [and] live cases."
Did you encounter any obstacles to improvement associated with the program?
"The felt veins weren't very realistic."
"Not always able to devote extended time to simulation due to work schedule."
Do you have any general feedback about the program or the trainer?
"The felt wore out quickly otherwise trainer was adequate."
"Trainer frustrating at times due to differences from live cases (no assistant, retraction, exposure, suture follow)."
Would you recommend this program and trainer for other senior trainees? What about junior trainees?
"Yes for junior trainees, no for senior trainees."
"Seems appropriate for all levels of training. Likely derive more benefit in setting of having done similar procedures previously to fully grasp technical goals of the simulation exercises."

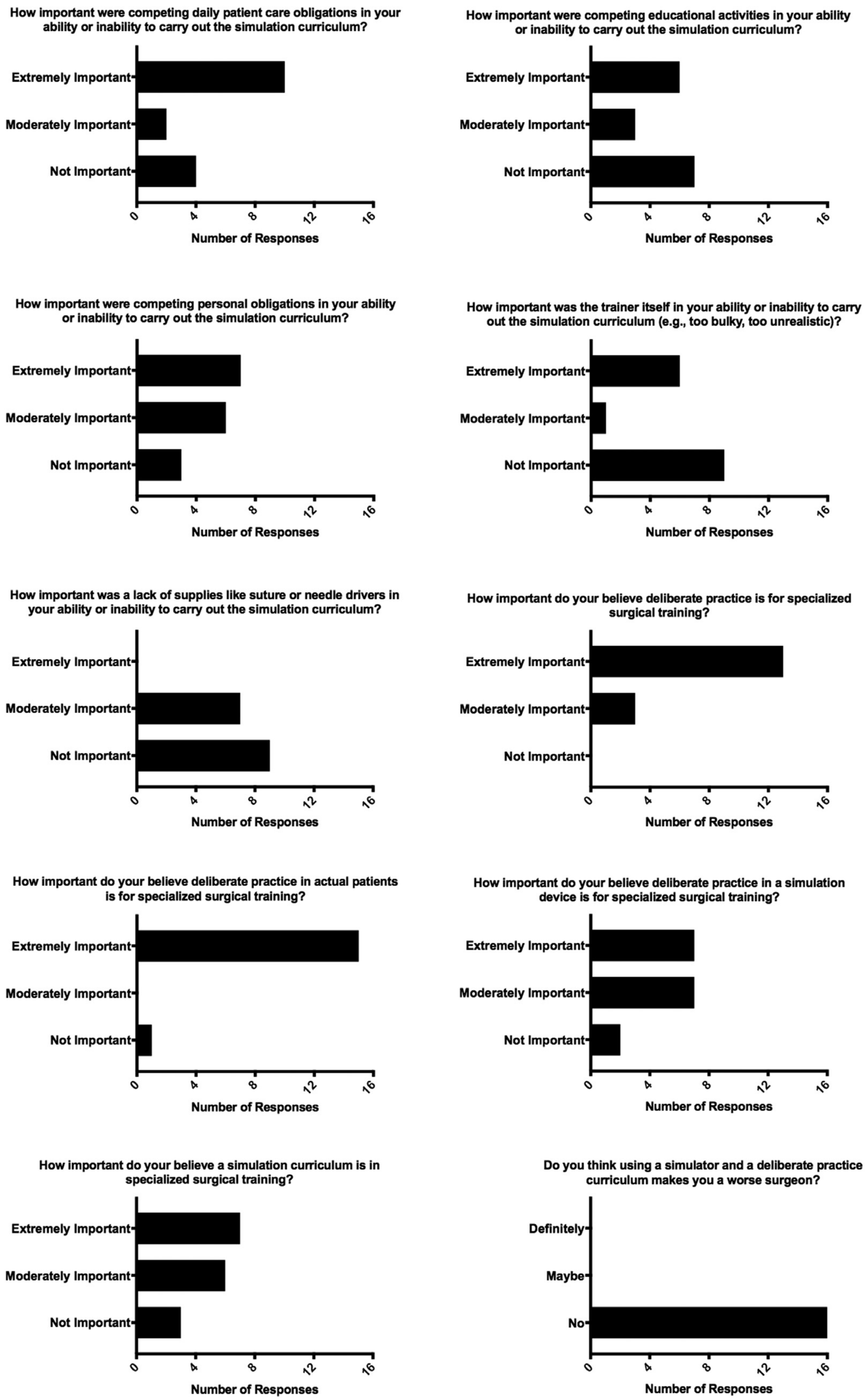

FIGURE 6. Survey responses.

which is consistent with prior examinations of barriers to participation in simulation activities.[16]

Future Directions

We believe that simulation is an important part of cardiovascular surgery training. However, in order to properly integrate a simulation curriculum into existing fellowship training, programs should incorporate the following elements: dedicated time allotted to practice, easy access to materials for simulation, consistent faculty mentorship and support for dedicated practice time, and a practice curriculum developed by experts but routinely re-evaluated and revised based on resident performance.

Future studies of this type (prospective, randomized, using senior trainees) are possible but may yield the highest-quality results when data collection and simulation participation can be guaranteed and with minimal time and paperwork burden to the participants. An intentional allotment of time during weekly educational conferences, with appropriate faculty and administrative support, for practice and data collection would decrease reliance on self-reported participation and would streamline data collection, but program-specific strategies should be identified by investigators. Regardless, incorporating simulation and assessment into existing protected educational time is likely to increase trainee participation and may also introduce a collaborative (or competitive) element amongst trainees that will further encourage simulation.[16]

CONCLUSIONS

In a multicenter cohort of senior trainees in general and cardiovascular surgery, a home curriculum of deliberate practice of aortic and coronary anastomosis using a low fidelity simulator was feasible but did not lead to statistically-significant increases in technical proficiency scores. Senior residents and fellows are interested in simulation and deliberate practice as a means of skill acquisition but sustained involvement may be hampered by competing clinical and personal obligations. This barrier may be overcome through the use of existing protected educational time for simulation and assessment, but further investigation is needed We would also like to thank Claire Hvass for assistance with simulator photography.

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SUPPLEMENTARY INFORMATION

Supplementary material associated with this article can be found in the online version at https://doi.org/:10.1016/j.jsurg.2018.09.007.