Utilizing a Simulated Tendon to Teach Tendon Repair Technique

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Abstract To evaluate the effectiveness of teaching core tendon repairs using a simulation model, ten surgical residents with no prior experience repairing flexor tendons were taught a four-strand cruciate repair. The residents then performed ten repairs each on a simulated tendon (a round synthetic bait worm 10 mm in diameter) while being timed and graded by a hand surgeon using a global rating scale (1 to 5). Six residents also performed a zone IV flexor tendon repair on a fresh frozen cadaver—three residents who had practiced and three other residents who had no practice on the simulated tendon. The mean initial quality score was 2.4/5.0 which improved to 4.8/5.0 by the tenth trial. There was a significant incremental improvement in mean performance from trial 1 to 10 ($p < 0.0001$). The mean times to complete the first and last repairs were 5.4 and 3.0 min, respectively. In the cadaver trial, there was statistically significant evidence ($p = 0.05$, one-sided Wilcoxon exact test) that the three residents previously trained with the simulated tendon had a higher median performance (4.4, min=4.3, max=4.8) than the three who had not been trained (1.8, min=1.7, max=2.1). The mean times to

complete the repairs were 4.0 and 5.8 min, respectively. In conclusion, this inexpensive model mimics an in vivo tendon repair experience with sufficient fidelity to justify its use in training residents to perform a tendon repair.

Keywords Simulation · Tendon repair

Introduction

The training of surgical residents presents the challenge of teaching psychomotor skills on live patients. The early part of the learning curve fraught with errors and mistakes due to inexperience has real morbidity, yet inexperience can only be remedied by operating. Ensuring that this interface between trainee and patient occurs safely is one of the biggest responsibilities given to academic surgeons. Surgical simulation is therefore a necessary educational tool [5, 6, 11], allowing the trainee to develop technical skill sets without the added pressure and risk of learning or improving a technique on a living patient. Teaching a resident how to repair a flexor tendon is particularly difficult since the surgical skill is technically demanding, and ultimate function is directly proportionate to surgical skill; there is little room for error, but the learning surgeon commits many mistakes. Developing the fine motor skills needed to repair a tendon via surgical simulation while removed from the stress of the operating room is ideal and should enhance the trainee's ability to focus on and combine those other aspects of being a well-rounded surgeon when in the operating room.

The purpose of this study was to evaluate the effectiveness of teaching residents how to repair a tendon using a simulation model designed to be efficient, simple, and inexpensive [11].

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Materials and Methods

The study was conducted with the approval of the Institutional Review Board. Ten post-graduate, years 1 through 4 surgical residents with little or no prior experience repairing tendons, were taught how to perform a four-strand cruciate flexor tendon repair [7] by watching a 5-min instructional video. The video, created by the authors, showed a stepwise diagrammatic description of the repair. A single repair was then demonstrated using the simulated tendon (Fig. 1). The residents then performed ten repairs each on the simulated tendon while being timed and graded by a hand surgeon using a standardized checklist and global rating scale (Figs. 2 and 3) [11]. The global rating scale contains nine categories; each category is graded on a scale from 1 to 5 ranging from “extremely poor” to “outstanding/mastery”, respectively. The majority of the residents accomplished their repairs in one to three sessions; one resident required four sessions. Three additional residents were not trained and did not practice on the simulated tendon.

The simulated tendon was a white, round, flexible, synthetic bait worm 10 mm in diameter and 6 cm long (Gary Yamamoto Custom Baits, Page, AZ, USA). The rubber worm was transected at its midpoint and pinned to a foam board taped securely to the underlying table. The residents used standard surgical instruments and a 4-0 monofilament suture for the repair. A reference diagram was placed adjacent to the repair station. When necessary, verbal guidance was given during the first repair only.

To assess the value of the simulated training experience, each resident was asked to evaluate the training exercise after the first repair. In addition, approximately 6 months later, six residents performed a single zone IV flexor tendon

repair on a fresh frozen cadaver. Three residents were chosen at random from the ten who had simulation practice. The other three residents were those who had no simulation practice; they were given only a brief description of the repair technique (no video was shown) and active instruction as needed during the repair. All six residents could look at a repair diagram. They were timed and graded in the same manner as previously described.

Statistical Methods

All continuous variables of interest were summarized by trial using descriptive statistics (mean $\pm$ SD). The data on primary outcomes including mean performance was analyzed using a linear mixed model with trial effect (i.e., 1, 2, ..., 10 trial) and group effect (group 1, all 10 trials were done on 1 day; group 2, all 10 trials were done on two different days; and group 3, all 10 trials were done on three or more different days) modeled as fixed effects; the ten residents were modeled as random effect.

Different correlation structures were tried in the model under the assumption that unequal time difference among trials had no effect on primary outcomes; the most appropriate model was chosen based on Akaike's information criterion.

Two groups of residents, with and without previous training, were compared using the Wilcoxon exact test. A designated p value of 0.05 or less indicated a statistical significance, and SAS 9.1.3 (Cary, NC, USA) was used for data analysis.

Results

All ten residents demonstrated improvement in repair time and quality over the course of ten repairs. Student performance as measured by the stepwise checklist increased for the first two repairs but then leveled off at 100% correct for the remainder of the repairs (Fig. 4). While the checklist did not provide any statistically meaningful data regarding resident improvement, the global rating scale did provide a valid assessment. The mean initial quality score using the global rating scale was 2.4/5.0 which improved to 4.8/5.0 by the tenth trial. There was a significant incremental improvement in mean performance from trial 1 to 10 ($p < 0.0001$; Fig. 5) without clear evidence of leveling off before trial 9 where mean performance reached 4.6/5.0.

The mean time to complete the first repair was 5.4 min; this decreased to 3.0 min by the last repair (Fig. 6). There was a significant decreasing trend in completion time from trial 1 to 10 ($p < 0.0001$). Three residents completed all ten

Figure 1 Simulated tendon repair setup with transected bait worm pinned to foam base.

Figure 2 Simulated tendon repair stepwise checklist and student evaluation form.

EVALUATOR _____	DATE _____		
STUDENT _____	TRIAL # _____	TRIAL TIME _____	

INSTRUCTION TO STUDENTS:
Please repair this simulated tendon using a four-strand cruciate repair.

	Item	Done Correctly	Done Incorrectly
1	1 st suture placed parallel to tendon with entrance and exit 1 cm from cut ends		
2	1 st grasping stitch holding 10-25% of area, 1 cm from cut end		
3	2 nd suture entering and exiting 1cm from cut ends and crossing through center of tendon at the repair site		
4	2 nd grasping stitch holding 10-25% of area, 1 cm from cut end		
5	3 rd suture placed parallel to tendon with entrance and exit 1 cm from cut ends		
6	3 rd grasping stitch holding 10-25% of area, 1 cm from cut end		
7	4 th suture entering and exiting 1cm from cut ends and crossing through center of tendon at the repair site		
8	4 th grasping stitch holding 10-25% of area, 1 cm from cut end		
9	Simulated tendon edges abutting, not bunching or gaping		
10	Knot tied appropriately		

Student Evaluation:
Please evaluate the first tendon repair you performed.

Experience	1	2	3	4	5
Totally fake			Totally real		

Value	1	2	3	4	5
Complete waste of time			Extremely useful		

trials in one sitting, and seven residents required two to four sittings; subjectively, it was observed that the latter group usually needed only one repair to recover their previous knowledge base before continuing with trends similar to the former group. The residents who worked with the simulated tendon stated that the experience was extremely useful and worthwhile (mean=4.9/5.0).

For the cadaver portion of the study, there was statistically significant evidence ($p=0.05$, one-sided Wilcoxon exact test) that the three residents who had previously been trained with the simulated tendon had a higher median performance (4.4, min=4.3, max=4.8) than the three who had not been trained (1.8, min=1.7, max=2.1). The median times to complete the repairs were 3.8 (min=3.5, max=4.6) and 5.5 min (min=5.3, max=6.7), respectively ($p=0.05$, one-sided Wilcoxon exact test).

Discussion

Surgical simulation is a successful and important part of the modern surgical residency curriculum [1–4, 8–10]. To our knowledge, we are the first to report a surgical simulator designed to teach flexor tendon repairs. For such a simulation to be effective, it must express similarities to the actual operating room environment, have ease of application for novice users, be challenging enough for intermediate users, utilize effective assessment scales, and be transferable to the actual procedure being simulated.

A rubber bait worm serves as a good tendon simulator in its general appearance and feel. It is inexpensive and simple to set up. The fact that the model is more fragile than a real tendon is advantageous in helping the examiner assess for damage due to unnecessary or improper use of forceps, for

Figure 3 Simulated tendon repair global ratings scale.

Respect for Tendon	1	2	3	4	5
	Frequently used unnecessary force on tendon or caused damage		Careful handling of tendon but occasionally caused inadvertent damage		Consistently handled tendon appropriately with minimal damage
Time in Motion	1	2	3	4	5
	Many unnecessary moves		Efficient time/motion but some unnecessary moves		Clear economy of movement and maximum efficiency
Instrument Handling	1	2	3	4	5
	Repeatedly makes awkward moves with instruments by inappropriate use of instruments		Competent use of instruments but occasionally appeared stiff or awkward		Fluid moves with instruments and no awkwardness
Flow of Operation	1	2	3	4	5
	Frequently stopped operating and seemed unsure of next move		Demonstrated some forward planning with reasonable progression of procedure		Obvious planned course of operation and effortless flow from one move to the next
Knowledge of Procedure	1	2	3	4	5
	Deficient knowledge		Knew all important steps of operation		Demonstrated familiarity with all aspects of operation
Dexterity	1	2	3	4	5
	Consistently showed poor manual dexterity throughout procedure		Demonstrated adequate motor dexterity throughout procedure		Demonstrated superior motor dexterity throughout procedure
Visual Spatial Ability	1	2	3	4	5
	Showed inability to visualize planning and tendon repair		Showed average ability to visualize planning and tendon repair		Showed superior ability to visualize planning and tendon repair
OVERALL PERFORMANCE	1	2	3	4	5
	Very Poor		Competent		Clearly Superior
FINAL PRODUCT	1	2	3	4	5
	Final product of unacceptable quality		Final product of average quality		Final product of superior quality

Figure 4 Mean student performance as measured by the stepwise checklist versus trial (the blue dashed line represents the mean at each trial).

Figure 5 Mean student performance as measured by the global rating scale versus trial (the blue dashed line represents the mean at each trial).

example. From tendon handling to proper alignment to adequate tension in the repair, this model provides measurable steps. While actual flexor tendons are not round and are of smaller diameter than the simulated tendon, the latter still shares sufficient characteristics with the real-world counterpart to serve as a useful simulator. Other possible options for tendon repair practice would include cadaveric or animal sources; these options, while more authentic, are more expensive and labor intensive and less practical as a measurable teaching tool due to their variable size and consistency.

The global rating scale which was previously validated by a similar type of simulation study [11] served well to assess resident progress towards trial 10. The checklist, however, failed to distinguish progress because the residents tended to achieve 100% of the procedural steps early on in their number of repairs; thus, nothing further could be measured by the checklist. This trait was seen in other simulation

models as well [11]. Actual surgical repair time does not necessarily correlate with the quality of the flexor tendon repair. In this study, however, the repairs were timed to provide an independent means for demonstrating incremental improvement; this was shown to be statistically significant.

A weakness of this study was the non-standard number of repairs done per resident sitting. This was related to the logistics of coordinating with busy surgical residents and will largely be avoided when integrated into a standard teaching curriculum. A perceived weakness could pertain to the fact that the training video was not shown to the simulator-naïve residents; this was purposefully done to better simulate an authentic operative setting in which training and operating often occur simultaneously. In the cadaver portion of the study, the one-sided Wilcoxon exact test provided significant results in comparing trained and untrained residents in performance and time to complete the

Figure 6 Trial time (in seconds) versus trial (the blue dot represents the mean at each trial).

repair; a sample size greater than three in each group would have been even more valuable.

The questions which remain are the following: What is the optimum number of simulated repairs needed to achieve a plateau in skills and efficiency? How often should such a simulator be utilized to maintain these skills? What other such simulators can we develop?

Employing this inexpensive-simulated tendon in teaching a repair technique allowed residents to perform their first repair on a cadaver more efficiently and with higher quality than those residents who did not practice on the simulated tendon. A total of ten simulated repairs per resident is sufficient and represents only 1 to 1.5 h of training time. Residents who trained with the simulated tendon have subsequently reported good confidence and minimal anxiety in performing their first true operative flexor tendon repair. This is gratifying evidence that we have achieved our intended goal: to provide a safer, more productive, and more efficient interface between the surgical resident and their first flexor tendon repair on a real patient.

References

1. Andreatta PB, Woodrum DT, Birkmeyer JD, et al. Laparoscopic skills are improved with LapMentor training: results of a randomized, double-blinded study. *Ann Surg* 2006;243:854–60. doi:10.1097/01.sla.0000219641.79092.e5.
2. Banks EH, Chudnoff S, Karmin I, et al. Does a surgical simulator improve resident operative performance of laparoscopic tubal ligation. *Am J Obstet Gynecol* 2007;197:541.e1–5.
3. Chaer RA, Derubertis BG, Lin SC, et al. Simulation improves resident performance in catheter-based intervention: results of a randomized, controlled study. *Ann Surg* 2006;244:343–52.
4. Cooke JM, Larsen J, Hamstra SJ, et al. Simulation enhances resident confidence in critical care and procedural skills. *Fam Med* 2008;40:165–7.
5. Grober ED, Hamstra SJ, Wanzel KR, et al. Laboratory based training in urological microsurgery with bench model simulators: a randomized controlled trial evaluating the durability of technical skill. *J Urol* 2004;172:378–81. doi:10.1097/01.ju.0000123824.74075.9c.
6. Leach DC (ed. Philibert, I). Simulation and rehearsal. *ACGME Bulletin* 2005;Dec:1–10.
7. McLarney E, Hoffman H, Wolfe SW. Biomechanical analysis of the cruciate four-strand flexor tendon repair. *J Hand Surg [Am]* 1999;24:295–301. doi:10.1053/jhsu.1999.0295.
8. Passman MA, Fleiser PS, Dattilo JB, et al. Should simulator-based endovascular training be integrated into general surgery residency programs. *Am J Surg* 2007;194:212–9. doi:10.1016/j.amjsurg.2006.11.029.
9. Satava RM. Virtual reality surgical simulator. The first steps. *Surg Endosc* 1993;7:203–5. doi:10.1007/BF00594110.
10. Scott DJ, Dunnington GL. The new ACS/APDS Skills Curriculum: moving the learning curve out of the operating room. *J Gastrointest Surg* 2008;12:213–21. doi:10.1007/s11605-007-0357-y.
11. Wanzel KR, Matsumoto ED, Hamstra SJ, et al. Teaching technical skills: training on a simple, inexpensive, and portable model. *Plast Reconstr Surg* 2002;109:258–64. doi:10.1097/00006534-200201000-00041.