



See one, do one, teach one: A randomized controlled study evaluating the benefit of autonomy in surgical education



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ABSTRACT

Introduction: "See one, do one, teach one" has represented the model for surgical education for over a century, however recent changes in education have reduced autonomy in training. The goal of this study was to assess the impact of autonomy on learning a procedural skill.

Methods: Senior medical students were randomized and trained to performance a vascular anastomosis utilizing progressive autonomy vs. constant supervision. Performance was tested using videotaped technical grading and anastomotic pressure testing.

Results: Mean baseline performance times and technical ratings were similar in both groups. Final completion times was faster in the autonomy group, 14:03min vs. 19:09min ($p = 0.02$). Final technical ratings were similar, 40.0 vs. 39.2points (max = 50), for each group and both demonstrated similar improvement in leak test against a standardized sample.

Conclusion: Teaching a procedure, as a final step in graded autonomy, results in superior performance in timing while maintaining equal technical performance compared to trainees with less autonomy.

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Introduction

"See one, do one, teach one" has represented the traditional mantra of surgical education for over a century. This mantra presents a simplified example of a system designed to progress trainees from passive learners to competent practitioners through graded responsibility and progressive autonomy in surgical practice.^{1–3} Progression of trainees in this manner has been used to successfully train generations of competent surgeons. Yet, recent trends in educational and medical-legal regulation have threatened this model of surgical training. The result has been a slow erosion of the core values of progressive autonomy in training which has called into question the competency of current

surgical residency graduates.^{1,2,4} This is evidenced by recent data demonstrating increased rates of graduating trainees entering into fellowship training.⁵ In addition, survey data from fellowship directors as well as graduates themselves, suggest that surgical residency inadequately prepares trainees for entrance into surgical practice.^{5–7}

The decline of autonomy in surgical training is multifactorial, but includes issues such as residency duty hour restrictions, increased legislation requiring attending surgeons to be present during operative cases, and financial pressure on academic hospitals to increased productivity and generate revenue. The implementation of the work-hour restrictions has reduced the volume of resident exposure to clinical training while the restructuring of training to clinical shift work has affected clinical continuity and responsibility in training.^{8,9} This has occurred simultaneously with the growing breadth of surgical specialty training. Contemporary surgical training has expanded to include a number of surgical subspecialties, which increased variety of training in a fixed length of time. This results in shorter length of time on each rotation which reduces exposure to instructors as well as disease pathology.¹⁰ In addition, with the increasing

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laparoscopic, endoscopic and now robotic cases being taught in residency, the number of repetitions in individual cases is decreasing. Indeed, recent data have demonstrated that while total operative cases have increased in surgical residency, the number of “core surgical” cases being performed more than 5 times has remained low.^{7,11,12}

Resident autonomy in surgical training is further affected by increasing legal pressures which require attending surgeons to be increasingly present in the operating room. Regulations by the Centers of Medicare and Medicaid (CMS) require attending surgeons to be present and scrubbed in for “critical portions” of a surgical procedure in order to bill for services.^{1,2} Additionally, pressure to generate revenue to meet productivity benchmarks has forced many surgeons to be more involved in managing the operations. Resident involvement in a case is known to increase operative times and thus, attendings often feel pressure to step into a case and drive the case forward to meet time and productivity constraints, reducing resident autonomy in the operating room.^{13,14} These pressures often do not allow for the opportunity for residents to “safely struggle” through difficult portions of an operation, enhancing their problem-solving skills and improving their ability and confidence in the operating room.¹⁴

The reduction in resident autonomy is clearly recognized by program and fellowship directors as well as residents themselves, however it is unclear exactly how much this reduction has directly impacted the training of residents and their competency for entering practice after residency.^{3,4,15–17} The concepts of autonomy in general learning are well known and have been studied in theories of education and psychology.¹⁸ Autonomy is a core principle of the intrinsic motivational learning paradigm which refers to a state of self-directed interest and engagement in learning driven by gratification in the achievement of competence in a learned skill. This education theory has been shown to promote better conceptual understanding and increased responsibility in learning.^{18,19} Also, in keeping the core mantra of surgical education, teaching a topic or skill as a final component of learning, has been demonstrated to enhance understanding, improve on one's realization of knowledge gaps and promote retention in general education.²⁰ This concept echoes the words of the essayist Joseph Joubert, “To teach is to learn twice”.

The purpose of this study was to evaluate the hypothesis that teaching a procedure, as a tool for technical learning in a graded system of educational autonomy, improves performance of an operation. Our goal was to objectively evaluate trainees through two different educational models to assess whether autonomy in learning has a measurable benefit in developing psychomotor surgical skills.

Methods

A randomized controlled study was conducted following approval of our institutional IRB. The study was designed to simulate a “miniature residency” model in which trainees were taught an operative procedure in a simulation operative environment. The surgical procedure selected was a vascular anastomosis. To test the acquisition of surgical skills from baseline, we selected trainees with no baseline knowledge or exposure to the procedure. For this reason, we included 4th year students at Vanderbilt University Medical Center (VUMC) who had matched into surgical or procedural based specialties. Inclusion criteria included any 4th year medical student planning to pursue a procedural-based specialty. Exclusion criteria consisted of any prior performance of a vascular anastomosis in a simulation session, operative setting or in research.

Trainees were randomized based on a computer software

generator into two groups. The first group was designated the “see one, do one, teach one” (autonomy) group and the second group was the “see one, do one” (total supervision) group. Trainees were given a basic tutorial and demonstration of the procedure prior to undergoing training. The procedural training was conducted on a simulation platform constructed on a baseboard with clamps designed to hold the vascular model. Vascular anastomoses were conducted utilizing long latex party balloons as our vessel model. Anastomoses were created in an end-to-side fashion with 5–0 monofilament suture and castroviejo needle drivers. Instruction was provided by two senior resident instructors acting in the role of attending surgeons.

All trainees received the same instruction which was standardized and based on a strict rubric which each instructor followed. Trainees were each required to perform the procedure nine times for the study. These nine procedures were broken into three stages of instruction with three repetitions in each stage. Both groups underwent instruction in the same first two categories. The first consisted of the trainee acting in the role of a first assistant following the direction of the attending surgeon. This consisted of learning tissue handling, sewing and the principles of creating an anastomosis. In the second stage, the trainee performed three procedures in the “surgeon jr.” capacity, taking on a more active role in the procedure but still receiving help and direction from the instructor. The final stage consisted of the main intervention between the two study groups. In the total supervision group, trainees performed the final three repetitions in the role of “surgeon chief” where they performed the entire procedure but continued to have the instructor scrubbed in to assist and coach them. The autonomy group, performed their last three repetitions in the role of “teaching assistant”. In this role, they were required to find a novice student to perform the procedure with them. The study trainee was required to teach them the procedure and proper assistant technique. During this stage, the instructor was available in the room for assistance or questions but was not directly participating the procedure. Overall study design is depicted in Fig. 1.

Each student was evaluated using a variety of grading methods to assess their performance and mastery of the procedure. This consisted of three separate testing performances, performed independently from the training sessions, where the student was required to perform the procedure while being videotaped. The first testing evaluation was conducted at the beginning of the training to act as a baseline, the second was performed after completion of the 9 training sessions, and the last evaluation was conducted one month after completion of training to assess retention of the instruction. During the month between the two training sessions, participants agreed to not practice the learned anastomotic skills and none of the participants were exposed to the learned skill in clinical rotations during the month-long interval. The instructor acted as the assistant during the graded video assessments but was required to receive direction from the student to assist. Performance of the procedure was assessed for time to completion and was submission to a blinded grader for video analysis and grading of their technique. This was conducted based on a modified Objective Structured Assessment of Technical Skills (OSATS) grading system which has been previously validated in other studies.^{21–24} OSATS grading criteria are provided in appendix 1 and were based upon performance of procedure steps, technical rating and an overall global assessment. These were scored on a scale of 1–50.

The final assessment was based on structural performance of the anastomosis in a liquid retention and pressure test. Each testing sample was submitted to a grader who was blinded to the original study design. Fluidic testing was performed after outflow

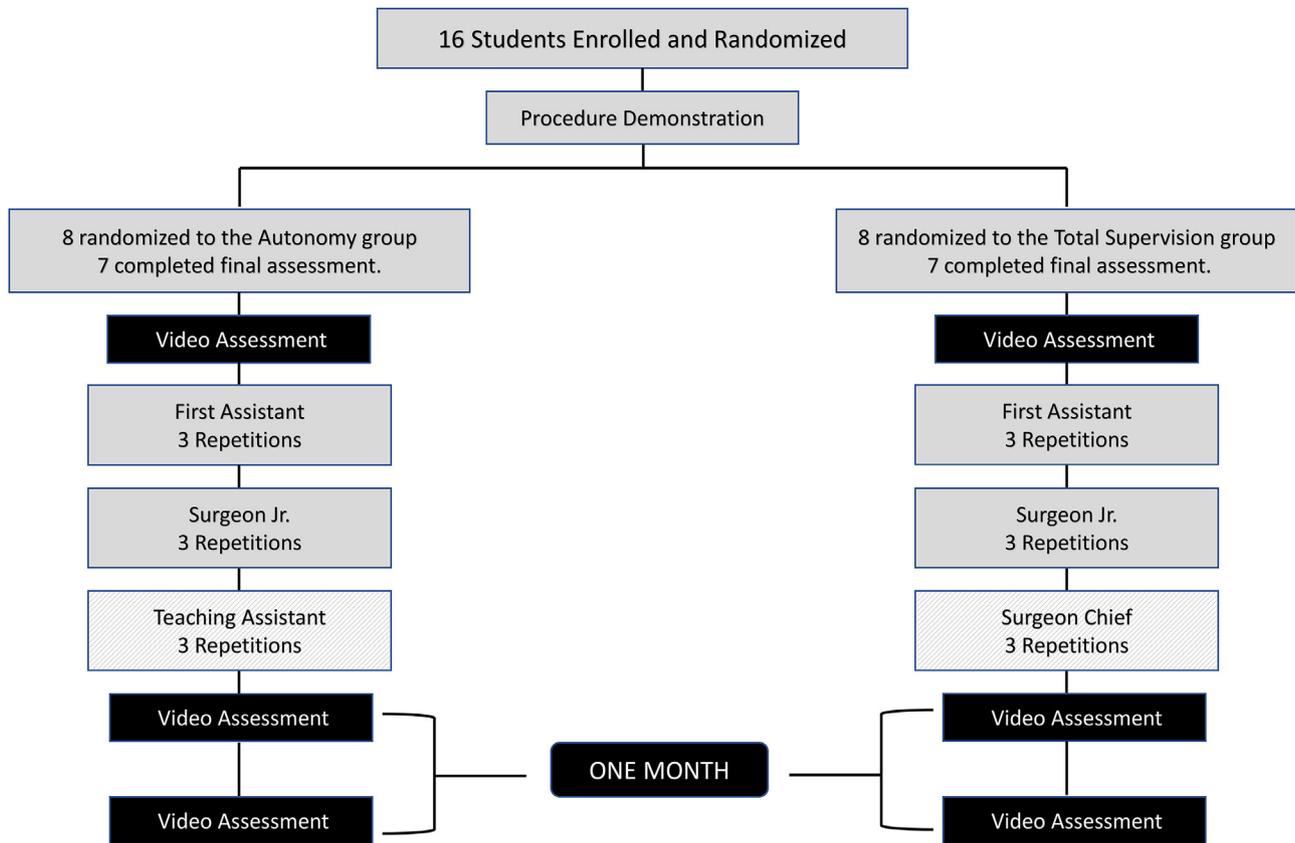


Fig. 1. Study design depicting the phases of the study protocol.

to each sample was occluded and the vessel was connected to a pressurized column of water hung 7 ft above the level of the testing site. Distention of the conduit allowed for assessment of the diameter of the conduit to determine if suture occlusion of the anastomosis had occurred. Pressure within the conduit was measured with a Deltran II Disposable Pressure Transducer System (Utah Medical Products Inc[®]). After completion of the measurement, all anastomoses were opened sharply and examined for further defects. Performance of these samples was anticipated to behave differently than human vascular tissue and all were noted to have some degree of leak. This occurred from needle holes and distention of the elastic balloon material. For standardization, these samples were compared against anastomotic samples performed by attending vascular surgeons at VUMC. The maximum equilibrium pressure was tested for each sample and compared to the measured attending standard.

Statistical analysis was performed using descriptive statistics through Microsoft Excel software (Redmond Washington). Student's t-test was used to compare continuous data between the two groups.

Results

A total of 16 students were recruited into the study and underwent randomization into two groups of eight. There was equal distribution of male and female (50%) in each group. All 16 students started the study but 2 students (one in each group) could not complete the study leaving a total of 14 study participants. The demographics and intended specialties of the study participants are listed in Table 1.

Time assessments

Baseline evaluation of the time to completion was equal in both groups with an average time of 22:59 in the autonomy group and 23:33 in the supervision group. The autonomy group demonstrated a superior improvement in their time performance when compared to their baseline assessment with a post-training assessment time of 14:53 vs. 18:23 in the supervision arm ($p = 0.04$). Average improvement from baseline time was 8:10 in the autonomy group vs. 5:11 in the supervision group.

The final one-month assessments were then compared to the post-training assessments to evaluate the trainees' performance retention over time. The autonomy group demonstrated a mean improvement in time to 14:03 while the supervision group

Table 1
Study participant demographics.

	Number
Total participants	16
Male	8 (50%)
Female	8 (50%)
Age range	25–29
Intended Specialty:	
General Surgery	2
Urology	1
Neurosurgery	2
Emergency Medicine	4
OB/GYN	2
Interventional Radiology	1
Orthopedics	1
Otolaryngology	3

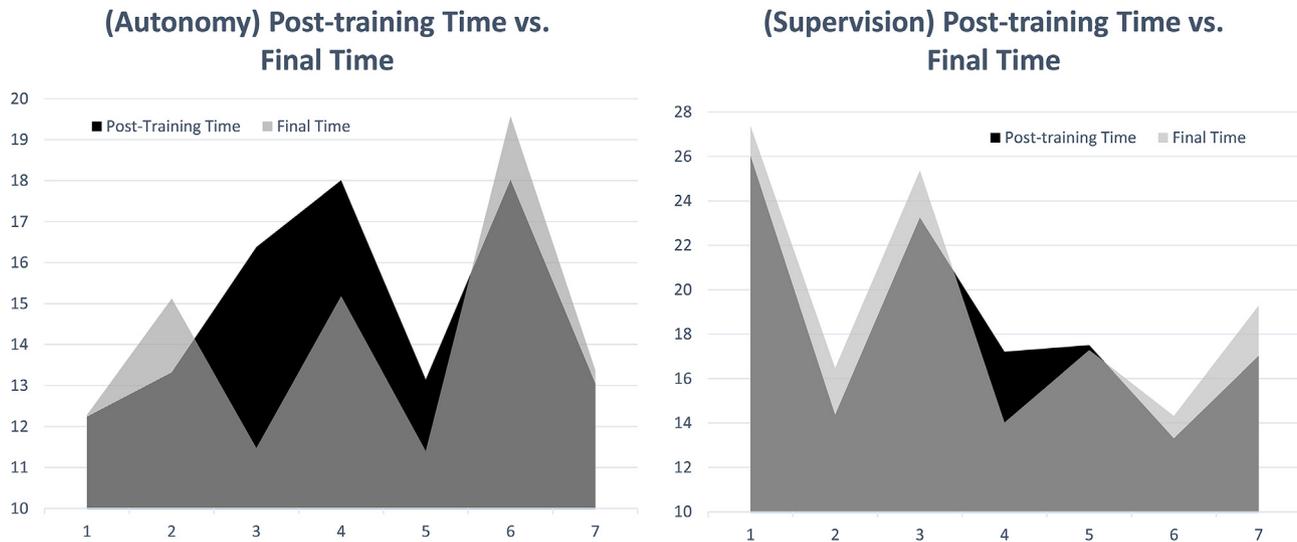


Fig. 2. Results comparing post-training completions times to final times one month after study completion.

demonstrated an overall mean increase in time to completion of 19:09 on the final assessment ($p = 0.02$) (Fig. 2). Overall this revealed a trend towards superior performance in the autonomy group with a mean improvement of 42.6sec in their times while the supervision arm slowed with an average increase in their time of 48.3sec. However, this did not reach a statistically significant difference ($p = 0.11$). In addition, five trainees in the autonomy arm maintained (defined as being within 30 s of their original time) or improved their time compared to only two trainees in the supervision arm.

Technical assessment

Results were analyzed from the three video assessments from each student and were graded on the modified OSATS grading scale. Baseline assessments of technical skill were similar between the two groups with a starting score of 25.40 in the autonomy group and 25.43 in the supervision group. Both groups demonstrated significant improvement from their baseline scores on post-training assessment with the autonomy arm demonstrating a mean improvement of 14.57 points for a total mean of 40.0. Results from the supervision arm showed a mean improvement of 13.85 points for a total mean score of 39.28. No statistical difference was identified between the improvement in technical scores between the two groups ($p = 0.42$) Fig. 3. Change in the individual grading categories were analyzed among the two groups. Improvement in all categories was noted equally among the two groups.

Anastomotic performance

Anastomotic samples were subjected to pressure testing and analyzed for liquid retention. Two of the baseline samples in the supervision group were unable to be tested due to defects in the materials that were unnoticed at the time of assessment, and thus, these samples were not included in the final results. The standardized attending mean pressure was 31.14 mmHg (SD = 14.98). Both groups were similar in baseline performance with mean pressures of 35.17 mmHg in the autonomy group and 25.46 mmHg in the supervision group ($p = 0.031$). In the design of this simulation model, we predicted that better technical performance would translate to improved anastomotic retention which could be

measured and compared between samples. However, we also determined that poor technical performance could also lead to outliers with increased retention. This was observed in trainees who took large or inaccurate suture throws causing kinking or obstruction of the anastomosis. These factors led to higher maximum pressure tolerance accounting for wide variations in the initial sample pressure testing with poor technical ratings. Thus, further comparison between the two samples was limited due to these unexpected performance issues with this model.

Discussion

This study objectively measures the direct effect of teaching a procedural skill as a part of psychomotor learning development in surgical education. This surgical simulation model attempts to recreate a portion of the surgical residency instruction to better characterize methods of intra-operative education. Our results demonstrate that novice trainees with equal baseline characteristics and skills can be taught surgical technique with objectively measured improvement in both groups. Results from this study demonstrated no difference in overall improvement of technical skills or ability to perform a vascular anastomosis between the two groups based on assessment with a modified OSATS grading method. However, with increased autonomy and the opportunity to teach a procedural skill, trainees were able to outperform their counterparts in the supervision arm in timed assessments of their skills.

While overall improvement in technical ratings were similar for both groups, faster performance at an equivalent level of technical ability indicates superior mastery of the learned procedure by the autonomy group. Indeed, trainees in the autonomy group were able to demonstrate improvement from their baseline performance times 46% greater than that of their counterparts while also demonstrating an equivalent technical proficiency. Faster performance of a technical task, often referred to as “muscle memory”, physiologically represents consolidation of acquired skills by the primary motor cortex in psychomotor learning.²⁵ Improvement in technical speed may also represent better confidence, and competence in a performed skill. These findings are significant in translational application to surgical practice as faster operative times often correspond with improved

Baseline vs. Final Performance Scores Autonomy vs. Supervision

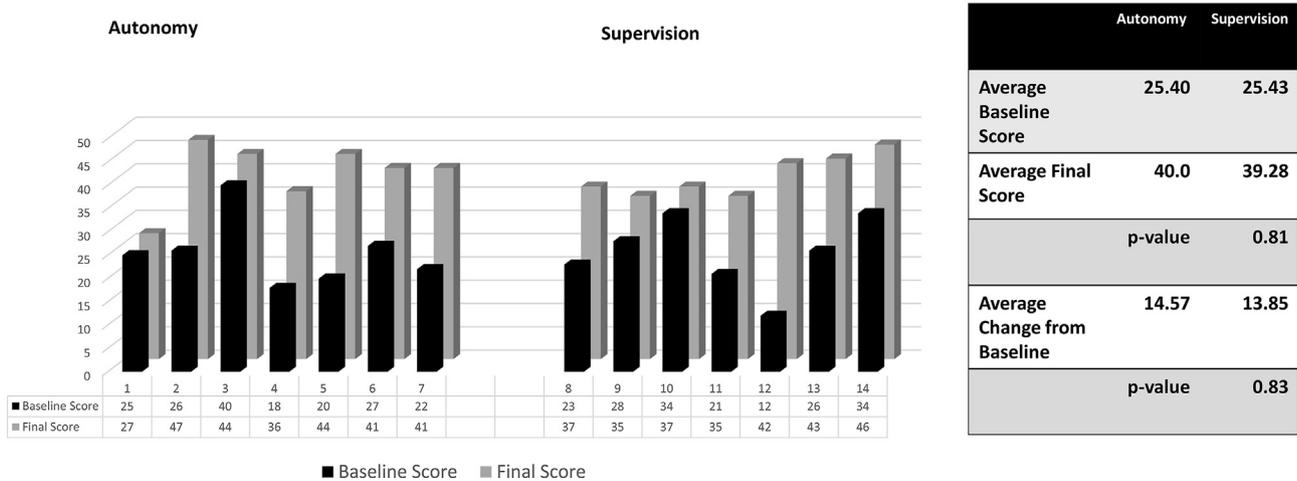


Fig. 3. Comparison of baseline grades vs. final technical grades in the autonomy and supervision groups.

surgical outcomes which are well documented in transplant and vascular disciplines.²⁶

In addition to improvement in performance speed, our results also indicated a trend towards retention of learned skills over time. This is demonstrated by the observed improvement in the autonomy group at the one-month final assessment. Trainees in this group demonstrated a mean improvement in time despite a month of inactivity while the supervision arm showed a mean decline in timed performance. Explanation of these results may lie in understanding the benefits of teaching a technical skill, which requires the instructor to comprehend, internally process, and then verbalize step-by-step instruction to a novice trainee. This requires a different degree of cognitive processing than simply performing a skill or following direction. Working with a novice assistant also makes performance of the task more difficult than when working with skilled help, which promotes problem solving and better understanding of the technical nuances of the procedure through struggle and experience. Together these factors may translate to improved procedure skill retention and performance.

Limitation

This study is not without limitations. First, the sample size was small which ultimately limits our statistical power. Better conclusions may be drawn from a larger study of similar design. It is possible that with additional repetitions, or a longer study, the differences seen between the two arms of the study may be more pronounced as the average number of repetitions for procedural mastery is not known. However, we do feel that our study population and design is representative of many surgical residencies as most match eight or fewer residents per year. Also, a total of nine repetitions was chosen in the study design as national data demonstrates that the majority of what are considered “core surgical procedures” are performed less than 10 times during surgical residency.^{7,27} Thus, it is critical to identify educational features that maximize learning and mastery of technical skills in low repetition procedures. While this may limit the scope of our study on a broader basis, the study conclusions do bear relevancy in today’s academic surgical training.

There were also limitations in the expected performance of the anastomotic testing model that we devised. The differences in the materials used compared to biologic tissue posed a challenge in assessing the true technical performance of the anastomosis. We did not initially anticipate some of the samples constructed with inferior technique to perform better at higher pressures. However, in considering technical errors such as suture bites that are too large in the vessel wall or back-walling an anastomosis in real tissue, these errors would also likely to elevated anastomotic pressures while also impeding flow. These unanticipated outcomes limit the conclusion which can be drawn from this method of assessment, yet our methods and data are included in this study to highlight the difficulties in assessing meaningful outcomes in a simulated model and applying them to performance in human tissue. Future testing with this model could be more beneficial if rates of flow could also be measured through the anastomosis.

Conclusions

The changing climate of surgical practice and regulation are actively encroaching on the core tenant of autonomy in surgical training. Despite recognition of this changing tide, little direct data exist to measure or predict the effect this will have on surgical trainees graduating and practicing in the future. This study demonstrates in a small prospective model the potential effect of abandoning the “See one, do one teach one” model. Novice trainees taught under this model were able to demonstrate superior performance in timed assessment and equal technical performance to those who were trained with complete supervision. These results demonstrate objective data to support the role of autonomy in procedural learning. Further study on a broader scale is needed to assess the true impact on surgical trainees of changing educational paradigms.

Appendix 1

- 1 Procedure Steps.

Study Grading Protocol

Done Correctly Not Done
 – 1 Correctly – 0

Places stay sutures in the middle of the arteriotomy on each side of the vessel and clamps with a hemostat.
 Takes 5-0 double armed suture and places 1st suture inside-out in the heel of the vein. Takes 2nd needle and places it inside-out on artery apex.
 Double armed suture tied with three knots. First 2 throws in the same direction with the last throw in the opposite direction to square the knot.
 Throws first two corner stitches in two bites, taking a stitch outside-in on the vein, resetting the needle and then inside -out on the artery.
 Runs the suture outside in on the vein and inside out on the artery with forehand stitch towards the toe of the vein and opposite apex of the artery.
 Performs corner stitches at the apex with 2 bites. Must perform 3 stitches at the apex. One at on the forehand side of the apex, one at the apex and then reverses the needle and performs backhand stitch on the backhand side of the apex.
 Runs the far wall with the same suture to the middle of the anastomosis with backhand stitch.
 Takes the second needle and passes it under the vein. Performs first two stitches at the corner in 2 bites.
 Runs the far wall using backhand stitch to the middle of the anastomosis.
 Cuts the needles off the suture and ties with 7 throws. 2 in the same direction and 5 alternating.
 Cuts the suture with 1 cm tail.

Total: _____ (0–11).

2 Technique.

Loads the needle properly at 1/2 to 2/3 the distance from the needle tip.
 Single attempt at needle passage through artery or vein on >90% of bites.
 Equally sized bites on each side for >80%
 Needle enters at 90° angle to the tissue on >80% of bites.
 Follows curve of the needle through tissue on >80% of bites.
 Uses correct needle angle >80% of the time. (Does not need to reload needle)
 Uses forceps to handle needle
 Follows suture loop down to ensure proper placement after each throw.
 Places sutures equally, 1–2 mm from each other.

Total: _____ (0–9).

Global Rating Scale For Operative Performance

Time and Motion				
1 Many unnecessary movements and low efficiency	2	3 Efficient flow with a some wasted movements	4	5 Clear economy of motion with no wasted movements
Instrument Handling				
1 Repeatedly makes awkward movements with instruments or uses instrument inappropriately	2	3 Competent use of instruments but occasionally appears stiff or awkward	4	5 Fluid use of instruments
Use of Non-Dominant Hand				
1 Poor use of non-dominant hand. Does not effectively incorporate both hands into the flow of the procedure	2	3 Good use of the non-dominant hand. Infrequently misses opportunities to involve the non-dominant hand.	4	5 Effective use of the non-dominant hand to consistently advance the procedure.
Flow of Operation				
1 Frequently stopped the procedure and seemed unsure of the next move	2	3 Demonstrated some forward planning with reasonable progression of the procedure	4	5 Obviously planned the progression of the procedure with effortless flow from one move to the next.
Use of Assistant				
1 Consistently placed assistants poorly or failed to use assistants	2	3 Appropriate use and direction of assistant most of the time	4	5 Strategically used assistants to best advantage at all times
Knowledge of Procedure				
1 Deficient knowledge of the procedure. Forgot steps or performed steps incorrectly	2	3 Knows most of the important steps of the procedure	4	5 Performed all steps of the procedure correctly

Score _____ (6–30).

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