Skill acquisition process in vascular anastomosis procedures: a simulation-based study

Murat Tavlasoglu, Ahmet Baris Durukan, Hasan Alper Gurbuz, Artan Jahollari and Adem Guler

Abstract

OBJECTIVES: There is growing evidence that practice on simulation models can improve technical skills in surgery. The aim of this study is to assess the effects of our tissue-based simulation model of vascular anastomosis on skill acquisition.

METHODS: Five junior (Group I) and five senior (Group III) cardiovascular surgery residents, and five surgeons from different surgical departments (Group II) attended the study. A total of 180 vascular anastomoses on a bovine heart simulation model were performed in a 3-month period; each group performed 20 anastomoses per month (each participant in each group conducted four anastomoses per month). The anastomoses were evaluated according to criteria including, duration of the procedure, existence of anastomotic leak, additional suture requirements, matching between graft diameter and arteriotomy length, patency rates and inadvertent posterior wall injuries. Each practice was recorded with a video camera and eventually reviewed by three cardiovascular surgeons, who were blinded to groups. Results were compared for analysing the skill acquisition process in each group.

RESULTS: The mean anastomosis time (Group I: 22.25 ± 2.02, 18.10 ± 0.78, 15.00; Group II: 17.05 ± 1.39, 15.45 ± 0.82, 13.00 ± 0.79; Group III: 13.65 ± 0.67, 11.45 ± 1.14, 10.50 ± 1.10) and additional suture requirements (Group I: 1.95 ± 0.68, 1.30 ± 0.80, 1.00 ± 0.32; Group II: 1.80 ± 0.41, 1.45 ± 0.60, 1.45 ± 0.60; Group III: 0.65 ± 0.48, 0.40 ± 0.50, 0.40 ± 0.50) decreased gradually (P < 0.0001 for each) in all groups. There was statistically significant improvement over time in anastomotic leakage (Group I: 90, 65, 20%; Group II: 50, 25, 5%; Group III: 20, 25, 5%), match between the arteriotomy and the graft (Group I: 35, 25, 75%; Group II: 60, 45, 85%; Group III: 85, 65, 95%), posterior wall injury (Group I: 70, 50, 15%; Group II: 50, 30, 5%; Group III: 30, 30, 5%) and patency (Group I: 45, 15, 75%; Group II: 60, 50, 95%; Group III: 80, 85, 95%) in all groups, except for the occurrence of anastomotic leaks and patency rates in the senior cardiovascular resident group (Group III).

CONCLUSIONS: Although the most significant improvement was observed in Group I, all groups demonstrated improved skills with the simulation model. Therefore, it can be suggested that anastomosis training on tissue-based simulation models may be beneficial for the skill acquisition process.

Keywords: Vascular anastomosis • Education • Bypass • Simulation • Surgical training

INTRODUCTION

Vascular anastomosis training is a technically challenging issue, and necessitates a long learning curve. The priority approach in residency and fellowship programmes should avoid patients being exposed to undue risks and complications. Simulation-based learning can provide necessary training and practice outside the operation room. Therefore, simulation models are designed to provide opportunities for practising microvascular anastomosis prior to clinical applications by residents or surgeons.

Existing studies have been conducted with live animal models, cadaveric or synthetic bench stations, and harvested vessels [1–5]. In this study, we tried to create a bovine heart simulation model for microvascular anastomosis that can be employed during residency training programmes. Objective Structured Assessment of Technical Skills (OSATS) is focused on the surgical manoeuvres performed during simulation studies [5]. OSATS was modified for vascular anastomosis by Fann et al. [6]. Those approaches are important for surgical education. We decided to focus on the results of ‘completed anastomoses’ in light of previously published articles [5, 6] defining the manoeuvres performed in the training of vascular anastomosis. A different rating scale was used for testing skill acquisition in vascular anastomosis. In this article, we intended to focus on the applicability of our model and rating scale. This approach may provide a different perspective for simulation studies.

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METHODS

Following approval of the study by The Hospital Ethics Committee, 180 vascular anastomoses on the bovine heart model were performed by three separate groups. Group I included five junior cardiovascular surgery residents (postgraduate year 1 and 2). Group II included five surgeons from various surgical disciplines (two general surgeons, one urologist, one orthopaedic surgeon, and one obstetrics and gynaecology specialist). Group III included five senior cardiovascular surgery residents (postgraduate year 4 and 5). Every participant within each group performed surgical procedures independently, and each participant performed 12 vascular anastomoses in 3 months (four vascular anastomoses/month/participant).

Simulator

The simulator consists of a surgical table, a pressure system and a bovine heart bought from the slaughterhouse (Fig. 1). The table is constructed with a tray, two rods and two atrial retractors capable of 3D mobility [7]. In this model, the surgical table, which is a cheap and simple-design tool, is employed for immobilization of the bovine heart throughout the surgical procedures. The atrial retractors are fixed to the heart by the aid of simple sutures. This manoeuvre provides immobilization of the heart during circumflex (Cx) coronary artery harvesting. After harvesting, the proximal end of the Cx artery was ligated (Fig. 2A). The retractors were used to hold the graft during distal anastomosis (Fig. 2B and C). The highest point of the pressure system used for testing the anastomoses was open to the atmosphere. The pressure was 178 cmH2O (equal to 130 mmHg). If the coaptation lines among the aortic cusps were optimum and there was no regurgitation, ligation of the pulmonary veins was not necessary during the testing procedure. There was also no need for a surgical assistant and this allowed the performer to easily practice surgery with the portable apparatus anywhere.

The bovine hearts were more or less identical, since hearts of animals slaughtered at the age of 1–1.5 were used in the model. This age group represents that of the standard bovine heart sold at the butcher shop; therefore the hearts were not weighed for standardization.

Study protocol

The supervising surgeon instructed all participants about the procedure in each practice. Moreover, all participants were taught the best and most expeditious way for performing an anastomosis before each practice. For this purpose, participants were informed about all factors affecting the quality of the anastomosis: graft orientation, appropriate suture spacing, use of Castroviejo needle holder, use of forceps, suture management and tension and respect for tissue, needle orientation etc.

As soon as the harvesting was completed, the side branches were closed with simple sutures, the Cx artery was detached from the left main coronary artery at the bifurcation level, and the stump of the Cx artery was ligated (Fig. 2A). While the left ventricle of the bovine heart was statically pressurized, arteriotomy was performed on the left anterior descending coronary artery (LAD) (see Supplementary Video 1, which demonstrates the statically pressurized heart and the performed arteriotomy). Atrial retractors were used to anchor the Cx artery while performing distal anastomosis (Fig. 2B and C). End-to-side distal anastomoses were performed by the trainees by using the parachute technique with 7/0 or 8/0 polypropylene sutures. However, proximal anastomoses were performed by the supervising cardiovascular surgeon using 6/0 or 7/0 polypropylene sutures because any occlusions in proximal anastomoses would lead to incorrect assessment of patency rates of distal anastomoses. Completion of proximal anastomoses by the supervising surgeon thus prevented potential misinterpretations about distal anastomosis patency rates.

Finally, after completing the proximal anastomosis to the aorta (Ao), the grafts were tested under pressure to reveal anastomotic leaks and graft patency. (See Supplementary Video 2, which demonstrates the control of the Ao-LAD bypass.) Afterwards, the graft was cut just over the distal anastomosis to examine the existence of any injury on the posterior wall of the target vessel (Fig. 3). The formative feedbacks were provided after each practice by the supervising surgeon while discussing results such as symmetrical and correct suturing and the correct arteriotomy technique.

Performance assessment

All anastomoses were recorded on video, and then reviewed by three cardiac surgeons at the end of the study. The surgeons, who
were blinded to the randomization, independently graded the performances of the participants using defined criteria, including duration of the procedure, existence of anastomotic leaks, additional suture requirements, matching between graft diameter and arteriotomy length, patency rates and inadvertent posterior wall injuries. The detailed components of performance assessment scores are depicted in Table 1. We tried to be objective while defining criteria for the quality of anastomosis. On the other hand, the reviewers were briefed about the evaluation process to minimize interobserver bias.

### Table 1: Components of performance rating scores

<table>
<thead>
<tr>
<th>Score</th>
<th>Present</th>
<th>Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anastomosis leakage</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Match</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Posterior wall injury</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Anastomosis patency</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Additional suture</td>
<td>Number of sutures to cease leakage</td>
<td>Minutes</td>
</tr>
<tr>
<td>Anastomosis time</td>
<td>Minutes</td>
<td></td>
</tr>
</tbody>
</table>

were expressed as numbers and percentages. To compare the three groups, \( \chi^2 \) test for categorical variables and Kruskal-Wallis test for continuous variables were used. In cases of significant difference (for continuous variables) between three groups, Bonferroni-adjusted Mann-Whitney \( U \)-test was used to explore the difference between each group. The progression within each group was evaluated by using Cochrane \( Q \) and Friedman tests for categorical and continuous variables, respectively. Statistical significance was set as \( P < 0.05 \). Additionally, for the establishment of inter-rater reliability, Cronbach’s \( \alpha \) test was performed for five parameters, except for mean duration of anastomosis. Scales with reliability indices >0.8 exhibit strong reliability and can be used with confidence for high-stakes examinations [8].

### RESULTS

Each participant in each group conducted four anastomoses per month (12 anastomoses in total for the 3-month study period). One hundred and eighty grafts were anastomosed during the 3-month study period by three separate groups. Each group performed 20 anastomoses per month (Table 2). Within each group, the mean duration of anastomosis became shorter throughout the study period (Group I: 22.25 ± 2.02, 18.10 ± 0.78, 15.00; Group II: 17.05 ± 1.39, 15.45 ± 0.82, 13.00 ± 0.79; Group III: 13.65 ± 0.67, 11.45 ± 1.14, 10.50 ± 1.10; \( P < 0.0001 \) for each group). Meanwhile, the additional suture requirements for anastomotic leaks were also decreased (Group I: 1.95 ± 0.68, 1.30 ± 0.80, 1.00 ± 0.32; Group II: 1.80 ± 0.41, 1.45 ± 0.60, 1.45 ± 0.60; Group III: 0.65 ± 0.48, 0.40 ± 0.50, 0.40 ± 0.50; \( P < 0.0001 \) for each group).

When the leaks from the anastomotic site, matching between graft and target vessel, posterior wall injury and graft patency were examined, statistically significant improvement was noted.

![Figure 2](https://example.com/image2.png)

**Figure 2:** Procedural steps: (A) After the Cx artery was dissected and separated from LMCA (arrow) bifurcation, the proximal end of the Cx artery was closed in the LMCA bifurcation (arrow head). (B and C) The atrial retractors were used for hanging the Cx artery while performing distal anastomosis. Cx: circumflex; LMCA: left main coronary artery.

![Figure 3](https://example.com/image3.png)

**Figure 3:** Evaluation of posterior wall injury: The graft is transected just over the anastomosis to examine any injuries on the posterior wall of the target vessel.
throughout the study period with the exception of the anastomotic leaks and graft patency rates in the senior resident group. Although increased skill acquisition was demonstrated by a majority of the defined criteria in all groups, the most obvious progress was observed in Group I (junior resident group) when compared with Group II (surgeons) and Group III (senior resident group). The mean anastomosis time decreased from 22.25 ± 2.02 to 15.00 ± 0.00 min in Group I (the rate of change: 33.3%), from 17.05 ± 1.39 to 13.00 ± 0.79 min in Group II (the rate of change: 23.7%) and from 13.65 ± 0.67 to 10.50 ± 1.10 min in Group III (the rate of change: 23.1%). The progression rates for the additional suture requirement in Groups I, II and III were 49, 19.5 and 38.5%, respectively. Likewise, the progression rate for anastomotic leakage parameter in Groups I, II and III were 70, 45 and 15%, respectively; in the posterior wall injury parameter, the progression rates were 55, 45 and 25%; and finally, in the anastomosis patency parameter, the progression rates were 30, 35 and 15%, respectively. Those results suggest that the junior resident group was the group that benefited the most.

When we compared the three groups regarding anastomosis time; there was a statistically significant difference each month. The anastomosis time was the longest in Group I compared with the other two groups in every month (in the first month 22.25 ± 2.02 vs 17.05 ± 1.39, 13.65 ± 0.67; in the second month 18.10 ± 0.78 vs 15.45 ± 0.82, 11.45 ± 1.14; in the third month 15.00 ± 0.00 vs 13.00 ± 0.79, 10.50 ± 1.10, P < 0.016; Bonferroni-adjusted Mann–Whitney U-test). Additional suture numbers differed between groups in the first month (1.95 ± 0.68, 1.80 ± 0.41, 0.65 ± 0.48, respectively, P < 0.0001); it was higher in Group I than the others in the first month (P < 0.016; Bonferroni-adjusted Mann–Whitney U-test); there was no statistically significant difference between groups in the second and third months (Table 2).

Anastomotic leakage, match and anastomosis patency rates differed between groups in the first and second months, but in the third month there was not a statistically significant difference between groups. The anastomotic leakage rate was higher; match and anastomosis patency rates were lower in Group I than the others in the first and second months. The posterior wall injury rate showed statistically significant difference between groups only in the first month; it was higher in Group I (Table 2).

### Table 2: Comparison of the three groups

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>P-value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anastomosis time (min)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First month</td>
<td>22.25 ± 2.02</td>
<td>17.05 ± 1.39</td>
<td>13.65 ± 0.67</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Second month</td>
<td>18.10 ± 0.78</td>
<td>15.45 ± 0.82</td>
<td>11.45 ± 1.14</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Third month</td>
<td>15.00 ± 0.00</td>
<td>13.00 ± 0.79</td>
<td>10.50 ± 1.10</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Additional suture #</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First month</td>
<td>1.95 ± 0.68</td>
<td>1.80 ± 0.41</td>
<td>0.65 ± 0.48</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Second month</td>
<td>1.30 ± 0.80</td>
<td>1.55 ± 0.60</td>
<td>0.40 ± 0.50</td>
<td>0.126</td>
</tr>
<tr>
<td>Third month</td>
<td>1.00 ± 0.32</td>
<td>1.45 ± 0.60</td>
<td>0.40 ± 0.50</td>
<td>0.194</td>
</tr>
<tr>
<td><strong>Anastomotic leakage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First month</td>
<td>18 (90)</td>
<td>10 (50)</td>
<td>4 (20)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Second month</td>
<td>13 (65)</td>
<td>5 (25)</td>
<td>5 (25)</td>
<td>0.010</td>
</tr>
<tr>
<td>Third month</td>
<td>4 (20)</td>
<td>1 (5)</td>
<td>1 (5)</td>
<td>0.117</td>
</tr>
<tr>
<td><strong>Match</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First month</td>
<td>7 (35)</td>
<td>12 (60)</td>
<td>17 (85)</td>
<td>0.001</td>
</tr>
<tr>
<td>Second month</td>
<td>5 (25)</td>
<td>9 (45)</td>
<td>13 (65)</td>
<td>0.012</td>
</tr>
<tr>
<td>Third month</td>
<td>15 (75)</td>
<td>17 (85)</td>
<td>19 (95)</td>
<td>0.079</td>
</tr>
<tr>
<td><strong>Posterior wall injury</strong></td>
<td>0.004</td>
<td>0.002</td>
<td>0.115</td>
<td></td>
</tr>
<tr>
<td>First month</td>
<td>14 (70)</td>
<td>10 (50)</td>
<td>6 (30)</td>
<td>0.012</td>
</tr>
<tr>
<td>Second month</td>
<td>10 (50)</td>
<td>6 (30)</td>
<td>6 (30)</td>
<td>0.193</td>
</tr>
<tr>
<td>Third month</td>
<td>3 (15)</td>
<td>1 (5)</td>
<td>1 (5)</td>
<td>0.257</td>
</tr>
<tr>
<td><strong>Anastomosis patency</strong></td>
<td>0.001</td>
<td>0.006</td>
<td>0.044</td>
<td></td>
</tr>
<tr>
<td>First month</td>
<td>9 (45)</td>
<td>12 (60)</td>
<td>16 (80)</td>
<td>0.024</td>
</tr>
<tr>
<td>Second month</td>
<td>3 (15)</td>
<td>10 (50)</td>
<td>17 (85)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Third month</td>
<td>15 (75)</td>
<td>19 (95)</td>
<td>19 (95)</td>
<td>0.051</td>
</tr>
</tbody>
</table>

<sup>a</sup>Kruskal–Wallis test.<br><sup>b</sup>Friedman test.<br><sup>c</sup>χ<sup>2</sup> test.<br><sup>d</sup>Cochrane Q test.
The measured Cronbach’s α values for the parameters, including existence of anastomotic leaks, additional suture requirements, matching between graft diameter and arteriotomy length, patency rates, inadvertent posterior wall injuries were 0.992, 1, 0.989, 0.997 and 1, respectively, among the three different cardiac surgeons.

DISCUSSION

In many areas of practical skill acquisition (musicians, sportsmen), it is accepted that many hours of practice in their own time is accepted as part of training. The same approach should be considered for residents in surgery, and practice outside the operation theatre and even at home might be beneficial. Simulated skills training has been proposed as a tool to enhance the competency of residents in vascular surgical procedures. Such simulation-based studies permit trainees to interact in a less stressful environment, which may further improve the development of surgical skills.

In a prospective randomized controlled trial, Franzcek et al. concluded that, when compared with traditional approaches, the use of simulators has been proved to equip trainees with better skills in general surgery. In a meta-analysis by Al-Kadi et al., combined effect size estimates showed that novice students who trained on simulators were superior in their performance and skill scores; were more careful in handling various body tissues; and had higher accuracy scores in conducting laparoscopic tasks. The studies on surgical simulators should mimic actual operation conditions to improve the quality of the simulation. This study evaluated the utility of the portable anastomosis model as well as the effectiveness on trainees with respect to skill acquisition. In this model, the CX artery was used as a graft anastomosed to the LAD in an end-to-side fashion. In addition to the duration of procedure, multiple parameters of anastomosis quality including adequacy between arteriotomy and graft size, presence of posterior wall injury in target vessels, patency of the anastomosis, existence of anastomotic leaks and additional suture requirements could be evaluated under pressure.

Each resident’s performance was reviewed and rated by two experienced surgeons in a blinded fashion. The scales used in our study for assessing the performance were quite simple and easy to track and were not open to interpretations. Such simple scales in a checklist format may prevent interobserver bias. This prediction was confirmed by the high degree of the Cronbach’s α for the parameters among the raters who suggesting perfect agreement on the given scores in each practice; all Cronbach’s α values were >0.98.

The parameters used in the study by Fann et al. focus on the surgical manoeuvres which have to be performed during simulation of anastomosis. This approach is important for surgical education. However, focusing on a ‘completed anastomosis’ may be another option for evaluating skill acquisition. Therefore, we preferred to use a different rating scale focused on assessment of the completed anastomosis. This approach may add a different perspective in simulation studies. On the other hand, combining the approaches of ‘surgical manoeuvres to be done in simulation’ and the ‘assessing completed anastomosis’ might be the precursors of new studies.

One of the advantages of our simulation model is CX artery harvesting. Although it was not a primary goal in this study, this procedure may also aid in developing surgical skills in radial artery and saphenous vein harvesting.

Our simulation model also offers the trainees the opportunity to cross-check their performance by evaluating their mistakes objectively. All of our study participants agreed that this model provided a very useful environment for their training in vascular anastomotic techniques and allowed an awareness and more objective assessment of the errors committed. The model can be used for self-training tasks at home or in the research laboratory since surgical assistance is not needed. The participants in Group I (junior cardiovascular surgery residents) declared that such improvement resulted in perceived improvement in the operating theatre. On the other hand, the participants in Group II declared that they felt more confident with repairing simple vascular injuries they confronted in their daily surgical procedures after the study. The participants in Group III (senior cardiovascular surgery residents) declared that the study was helpful in the operation theatre.

Involvement of an expert group would be very valuable in terms of providing feedback for the trainees to meet their training goals (proficiency-based paradigm), but the already intense patient care schedule and restriction due to their working hours made it difficult to involve sufficient experts in our study. However, the senior resident group (Group III) can be accepted as a reference group, especially for the parameters including anastomotic leakage and anastomotic patency since the expected progression could not be achieved in Group III in these parameters. This result can be explained by the fact that senior residents in Group III are already experienced enough for vascular anastomosis techniques since they have been performing anastomosis in the operation theatre under the supervision of senior surgeons on routine practice and they are almost at their highest level of the learning curve before being enrolled in the study (P = 0.115 and 0.368, respectively; Cochrane Q test). In addition, if the results of each group are compared on a monthly basis, it is observed that the results of Group III are better than Group I and II. Although progression in Group II is not as good as in Group I, members of the second group achieved relatively better results than the first group. This was probably because the surgical theoretical background of Group II was better than Group I. Lack of expected progression in Group II can be explained by the fact that these surgeons are not routinely performing vascular anastomosis. However, participants in Group I are observers or sometimes assistants during vascular anastomosis procedures, so that explains why they did progress on the bovine heart model. The strikingly high rate of posterior wall injury and low rate of anastomotic patency in the senior resident group (Group III) in the first and second months can be explained by the fact that during their practice there is always someone supervising them at the operation theatre throughout the whole procedure, commenting on how they do and correcting them. But in the study, they were alone while performing the procedure. Nobody intervened during the procedure. Likewise, the high rate of posterior wall injury in the non-cardiovascular surgeon group in the first and second months can be explained by the fact that their daily surgical practice does not include vascular anastomosis.

As a general rule, practice always brings experience, and it is not surprising that the progression of the inexperienced group in the skill acquisition process is more evident. The anastomotic technique, used in this study, has been observed or partially implemented by both junior and senior residents in their routine practice. Therefore, in order to predict the source of the
progression in the skill acquisition’, a non-cardiovascular group of surgeons, not performing vascular anastomosis in daily surgical practice, were also included in the study. Predicting the progress in the non-cardiac surgeon group would help us to make a comment on the validity of the model. Improvement was also noted in the non-cardiovascular surgeons (Group II), and we had enough reason to believe that the progress in skills during the study was not only the result of daily practice; instead, it can also be attributed to skill acquisition gained by working with the simulation model as in the non-cardiac surgeon group. Nesbitt et al. [14] reported that fourth-year medical students, who can be assumed to be very inexperienced, demonstrated comparable results with senior general surgery residents after 4 months of training for coronary anastomosis in a simulation-based study.

Simulation of coronary artery anastomosis can certainly be performed on a bovine heart simulator; in addition many different surgical procedures can also be simulated. Those procedures include (but are not limited to) mitral valve repair [15, 16] and aortic root enlargement. Since other cardiac structures are not damaged during the vascular anastomosis, practising on valves can also be possible with the same heart. As the design of the table is also simple, performance of multiple tasks on the same heart may further reduce the expenses associated with surgical simulation.

We believe that the most remarkable development of anastomotic skills can be obtained in the initial years of cardiovascular surgery residency. However, not only surgical residents, but also surgeons from various specialties who wish to improve vascular anastomotic techniques can use this practical model without requiring any assistance.

LIMITATIONS

The number of participants was small and the number of anastomoses performed was also small. A larger sample size could have resulted in more significant differences between groups which could modify our conclusions. The major limitation of this study is the static nature of the model in contrast to live animal models and beating-heart models. These circumstances increase cost and resource utilization, which opposes the philosophy of simulation-based models. More sophisticated models are affordable only in very well-situated centres. Hence our model revealed the rationale for developing easily applicable models; if desired, a beating heart model for coronary anastomosis may be provided simply by introduction of an intra-aortic balloon pump inside the left ventricle.

The format of the checklist may sound like a limitation at first glance since ‘a slightly less than perfect anastomosis’ and ‘a poorly performed anastomosis’ were given the same score when anastomotic leakage was considered. However, although the same scores were given to both the anastomoses, the numbers of sutures to repair the leakage were not the same (Table 2), which demonstrated the difference of quality between ‘a slightly less than perfect anastomosis’ and ‘a poorly performed anastomosis’.

Anastomosis on animal tissues rather than synthetic materials were chosen for this study for the following reasons: (i) residents and surgeons were more familiar with real tissue than a synthetic material; (ii) the anastomosis technique and the orientation of the heart were similar to real surgical conditions; (iii) the bovine hearts, which are larger than the human hearts, had bigger vessels to anastomose; (iv) instruments used in those anastomoses were identical to those used by residents and surgeons in the operating theatre.

The rating scale used in this study to evaluate skills might not be as complete as the other studies on this subject; however, this performance scale was developed by us and every effort was made to bring objectivity to the performance assessment and to reduce inter-rater variability as much as possible.

Inclusion of an expert group could also be valuable for comparison of the results but, as mentioned in the Discussion section, it was not possible due to time restrictions and the intense working pace.

SUPPLEMENTARY MATERIAL

Supplementary material (Videos 1 and 2) is available at EJCTS online.

Video 1: Video of arteriotomy in a statically pressurized heart. While the left ventricle of the bovine heart was statically pressurized, arteriotomy was performed on LAD.

Video 2: Video of patency control. After completing proximal anastomosis, the heart was statically pressurized again to check the anastomotic leakage and patency.

Conflict of interest: none declared.

REFERENCES


