Comparison of the effects of coronary artery anastomosis training between senior and junior surgeons

Bo Li, Xiaokang Luo, Lei Qi, Dong Zhang[1], Fuliang Luo, Bin Li, Yue Tang

Animal Experimental Centre, Beijing Key Laboratory of Preclinical Research and Evaluation for Cardiovascular Implant Materials, State Key Laboratory of Cardiovascular Disease, Fuwai Hospital, National Centre for Cardiovascular Disease, Chinese Academy of Medical Sciences and Peking Union Medical College; Beijing-*China*
[1]Department of Cardiovascular Surgery, Beijing Jishuitan Hospital; Beijing-*China*

Abstract

Objective: Many countries are facing a shortage of cardiac surgeons, who are crucial in meeting the demands of growing number of patients in need of coronary artery bypass grafting. This situation poses a serious challenge, especially in China. The purpose of this study is to determine whether cardiac surgeons are suitable for training in coronary artery anastomosis at an earlier stage in their career.
Methods: We divided 12 cardiac surgeons with no prior experience in coronary artery anastomosis into senior and junior groups for training and assessment. All trainees received training in coronary artery anastomosis for a defined period. We performed *in vivo* and *in vitro* examinations before and after training, respectively. Additionally, we assessed individual surgical performance of surgeons by using performance rating scores, including different aspects of surgical skills rated on a five-point scale.
Results: The post-training scores (overall, junior, senior) were significantly higher than the pre-training scores (overall, junior, and senior). We observed no differences in pre-training and post-training scores between the junior and senior groups.
Conclusion: Senior surgeons did not had any significant advantages over junior surgeons with respect to coronary artery anastomosis in the absence of training. Junior surgeons achieved the same results as the senior surgeons after training. *(Anatol J Cardiol 2020; 24: 153-9)*
Keywords: cardiac surgical procedures, coronary artery bypass, education

Introduction

Coronary artery disease has become the most common noncommunicable disease in China (1). Many studies have projected additional and substantial increases in its incidence and prevalence with the aging and growth of population. Moreover, these studies have forecasted that unfavorable trends in blood pressure, total cholesterol levels, diabetes, and body mass index may accelerate this epidemic (2). A large proportion of these patients require coronary artery bypass grafting (CABG) (3), which remains the most effective and durable approach to coronary revascularization for severe coronary artery disease (4, 5). Most countries face a shortage of cardiac surgeons to meet the growing number of patients in need of CABG (6), and this challenge is especially serious in China.

Compared to cardiac surgeons in developed countries, such as in Europe and the United States, cardiac surgeons from China are allowed to perform CABG only at a later stage of their career. Chinese cardiac surgeons lack formal training in coronary artery anastomosis during their early career stages and are not eligible to start training until they are able to perform general cardiac surgeries, such as valve replacement and ventricular septal defect repair. Because the use of CABG surgery is increasing in China, we assessed whether cardiovascular surgeons could be involved in CABG procedures at an earlier stage.

In this study, we divided cardiac surgeons without experience in coronary artery anastomosis into two groups: a junior group and a senior group. We evaluated their performance and examined whether junior surgeons could achieve the same results as senior surgeons after training.

Address for correspondence: Yue Tang, MD, Animal Experimental Centre, Beijing Key Laboratory of Preclinical Research and Evaluation for Cardiovascular Implant Materials, State Key Laboratory of Cardiovascular Disease, Fuwai Hospital, National Centre for Cardiovascular Disease, Chinese Academy of Medical Sciences and Peking Union Medical College; Beijing-*China*
Phone: +8613910713202 E-mail: tangyue@fuwaihospital.org
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Methods

Trainees

In total, 12 cardiac surgeons who completed standardized training for resident physicians and have at least two years of experience in cardiac surgery participated in the training program. Of these participants, six surgeons with two years of experience in cardiovascular surgery were categorized as junior surgeons, whereas six surgeons with six years of experience were categorized as senior surgeons. None of these surgeons had prior experience in coronary artery anastomosis.

In vitro operation

We used *in vitro* training to simulate pump CABG. We assigned each of the three trainees to a group and provided an isolated pig heart. The pig heart was fixed in a device that simulated the same view as that of an open chest surgery. The carotid artery of a pig was used as a graft. After finishing up the anastomosis, a red liquid was injected into the graft with a syringe to determine the presence of anastomotic leakage (Fig. 1). Then, the graft was ligated at a position closer to the anastomosis and was cut off for the next vascular anastomosis. The anastomosis was performed from the proximal to the distal part of the anterior descending coronary artery.

In vivo operation

We used *in vivo* training to simulate off-pump CABG. We conducted an *in vivo* operation in two male pigs who were approximately 24 months old (with weights between 66 kg and 72 kg) and provided by the animal experimental center of Fuwai Hospital. The Animal Welfare Ethics Committee of Fuwai Hospital of Peking Union Medical College approved all animal procedures, and all experiments were conducted in strict accordance with the National Institutes of Health Guide for the Use of Laboratory Animals. All procedures were performed in the right arm recumbent position of pigs. General anesthesia was provided as described previously in a research (7). The pigs were intubated with a cuffed endotracheal tube. The tidal volume was 10 ml/kg, and the oxygen concentration was 100%. The left carotid artery was accessed via a left cervical incision and temporarily preserved in saline. A left intercostal thoracotomy was performed between the third and fourth ribs. Then,

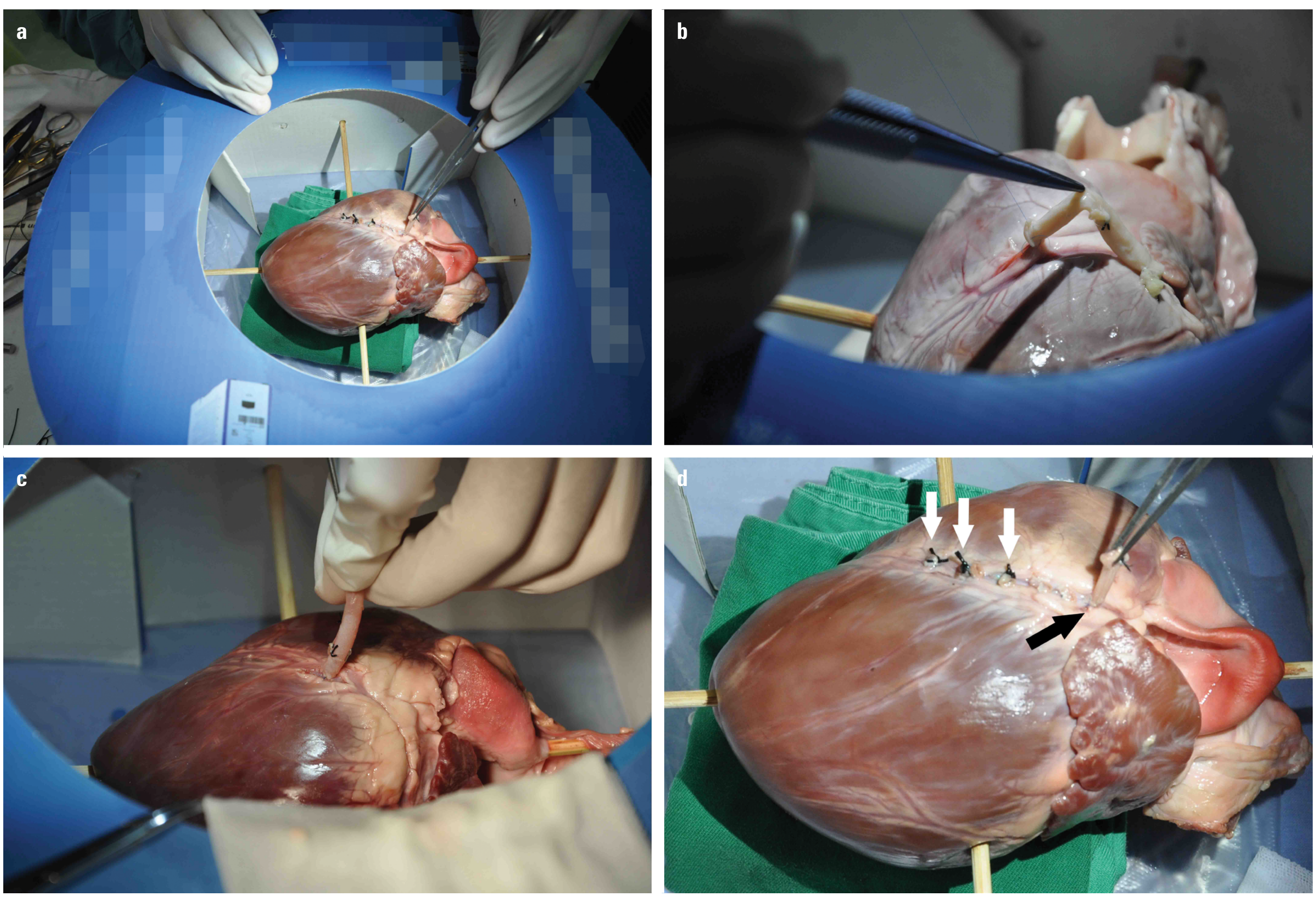

Figure 1. *In vitro* coronary artery anastomosis surgery (a) Operative visual field of coronary artery anastomosis *in vitro* training (b) *In vitro* coronary artery anastomosis surgery (c) Intravascular injection to assess anastomotic blood leakage (d) A heart can be used repeatedly. The white arrow indicates a vessel stump with a completed anastomosis, whereas the black arrow indicates a vessel with a completed anastomosis

the fourth ribs were cut off to extend the incision. The incision was large enough to ensure that the heart and thoracic aorta were clearly exposed. An experienced cardiac surgeon performed bypass surgery between the aorta and the anterior descending artery by using the carotid artery. The carotid artery was attached to the surface of the heart and pulsed with the beating of the heart. Moreover, it was used as the target blood vessel for anastomosis (Fig. 2).

Study protocol

On the first day of training, an experienced cardiovascular surgeon performed a teaching demonstration of vascular anastomosis. Then, participants completed vascular anastomosis procedures *in vitro* and *in vivo*, separately, and were evaluated based on their pre-training scores. For the next four days, trainees were taught under the guidance of a teacher. The training time was at least two hours per day, and the number of anastomotic stoma procedures performed was not less than two per day. At the end of each training day, the instructor noted the deficiencies of the trainees and provided advice for further improvement. On the sixth day, the participants again completed vascular anastomosis procedures *in vitro* and *in vivo*, separately, and were evaluated for their post-training scores.

Performance assessment

The vascular anastomosis surgical procedure was recorded on video, stored on a computer hard disk, and evaluated by two experienced cardiovascular surgeons in a blinded manner. The assessment tool included different aspects of surgical skills rated on a five-point scale (1=poor; 5=excellent). Table 1 provide descriptions for each component (8).

Data analysis

We presented the data as the means±standard deviations. Moreover, we analyzed the impact of groups and training on scores by using two-group and two-replicate ANOVA. A P-value of less than 0.05 was considered statistically significant for this study. We used SPSS 24.0 software for the statistical analysis.

Results

In vitro training

In total, 24 pig hearts were used for *in vitro* training, and 176 anastomoses were completed. Each pig heart was used for anastomosis training 7.3 times on an average, and each trainee

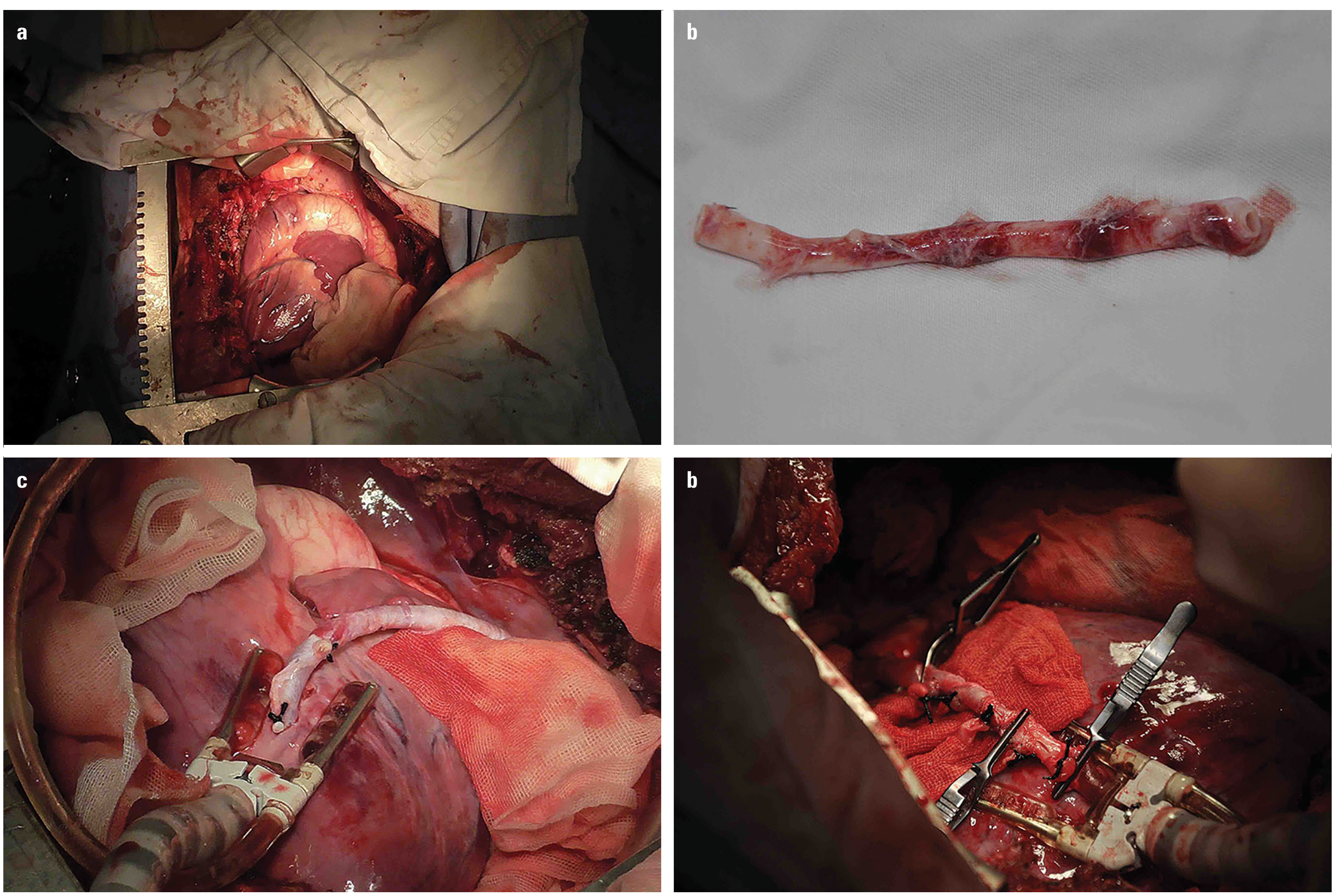

Figure 2. *In vivo* coronary artery anastomosis surgery (a) Left thoracotomy in experimental pigs (b) Free state of the carotid artery (c) Carotid artery connecting the thoracic aorta with the anterior descending branch (d) The residents underwent training for vascular anastomosis

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Table 1. Components of performance rating scores

Basic skills of surgical operation						
1	Use of operation instrument (Use of Castroviejo needle holder: finger placement, instrument rotation, facility, needle placement, pronation and supination, proper finger and hand motion, and lack of wrist motion; Use of forceps: facility, hand motion, assist needle placement, and appropriate traction on tissue)	1	2	3	4	5
2	Suture techniques (suture speed, needle placement and preparation from stitch to stitch, use of instrument and hand to mount needle)	1	2	3	4	5
3	Knot tying (adequate tension, facility, follow for finger and hand to tie deep knots)	1	2	3	4	5
Vascular anastomotic technique						
4	Matching of diameter of graft and incision of target blood vessel	1	2	3	4	5
5	Graft orientation (proper orientation for toe–heel, appropriate start and end points)	1	2	3	4	5
6	Suture management/tension (too loose vs too tight, use tension to assist exposure, avoid entanglement)	1	2	3	4	5
7	Bite appropriate (entry and exit points, number of punctures, even and consistent distance from edge)	1	2	3	4	5
The effect of vascular anastomosis						
8	Anastomotic stricture (Suture the posterior wall of blood vessel, The contralateral edge of the incision was sutured, Take-up too tight)	1	2	3	4	5
9	Anastomotic leakage (Staxis, Single blood leak, Multiple blood leaks)	1	2	3	4	5
10	Anastomotic twisting (Smooth and free of twisting, Slight twisting, Serious twisting	1	2	3	4	5

The scores range from 1 to 10 points and are divided into five grades, as shown below:
5: Excellent, able to accomplish goal without hesitation, showing excellent progress and flow;
4: Good, able to accomplish goal deliberately, with minimal hesitation, showing good progress and flow;
3: Average, able to accomplish goal with hesitation, discontinuous progress, and flow;
2: Below average, able to partially accomplish goal with hesitation;
1: Poor, unable to accomplish goal, marked hesitation.

completed isolated coronary artery anastomoses 14.7 times on an average.

In vivo training

The lengths of the two left carotid arteries resected were 15.1 cm and 13.8 cm, and there was an increase in the length of carotid artery when it was connected to the thoracic aorta and affected by blood pressure. Therefore, the carotid artery had the sufficient length to complete bypass grafting between the thoracic aorta and the anterior descending coronary artery. The inner diameters of the two carotid arteries were 3.5 mm and 3.8 mm, which were similar to the inner diameter of human coronary arteries. After anastomosis, the carotid artery exhibited a good fit with the heart and pulsed with the beating of the heart. After the fixation of heart, a relatively static view of the operation could be obtained to mimic an actual operation.

In total, 12 vascular anastomosis procedures were performed on each pig. The first pig had stable vital signs and no arrhythmias, except for occasional ventricular premature beats during surgery. Ventricular fibrillation occurred in the second pig when the seventh trainee was suturing. An epicardial defibrillator (20 J) was used to convert ventricular fibrillation into a sinus rhythm. Then, the anesthesiologist administered an intravenous drip of lidocaine and potassium supplementation in the pig, and arrhythmia did not occur again.

Technical skill assessment

In vivo analysis of two-group and two-replicate ANOVA showed that there was no significant difference in the scores between senior surgeons group (pre-training, 25.7±1.2 and post-training 34.2±2.1) and junior surgeons group (pre-training 25.3±1.5 and post-training 33.8±1.9) ($p=0.590$) (Fig. 4a); Although training has a significant impact on scores, post-training scores were higher than pre-training scores ($p<0.001$) (Fig. 3a). There were no interaction between the groups and their training. With the progression of training, there was no significant difference in the improvement of the scores between the senior and junior groups ($p=0.447$) (Table 2).

In vitro, there was no significant difference in scores between the senior surgeon group (pre-training, 31.2±2.1 and post-training 35.5±2.3) and junior surgeon group (pre-training 30.0±0.9 and post-training 34.7±0.8) too ($p=0.326$) (Fig. 4b). Although training has a significant impact on scores, post-training scores were higher than pre-training scores ($p<0.001$) (Fig. 3b). There was no interaction between the groups and their training. With the progression of training, there is no significant difference in the improvement of the scores between the senior and junior groups ($p=0.285$) (Table 2).

Discussion

This study included both *in vitro* and *in vivo* training sessions to simulate off-pump and on-pump CABG, respectively. These

Table 2. Scores of pre- and post-training in junior and senior groups, as well as the results of the two-way repeated measures ANOVA with group (junior and senior) and time (pre- and post-training)

	In vivo			***In vitro***		
	Junior		**Senior**	**Junior**		**Senior**
Pre-training	25.3±1.5		25.7±1.2	30.0±0.9		31.2±2.1
Post-training	33.8±1.9		34.2±2.1	34.7±0.8		35.5±2.3
Intergroup		*P*<0.001			*P*<0.001	
Intragroup		*P*=0.590			*P*=0.326	
Interaction		*P*=0.447			*P*=0.285	

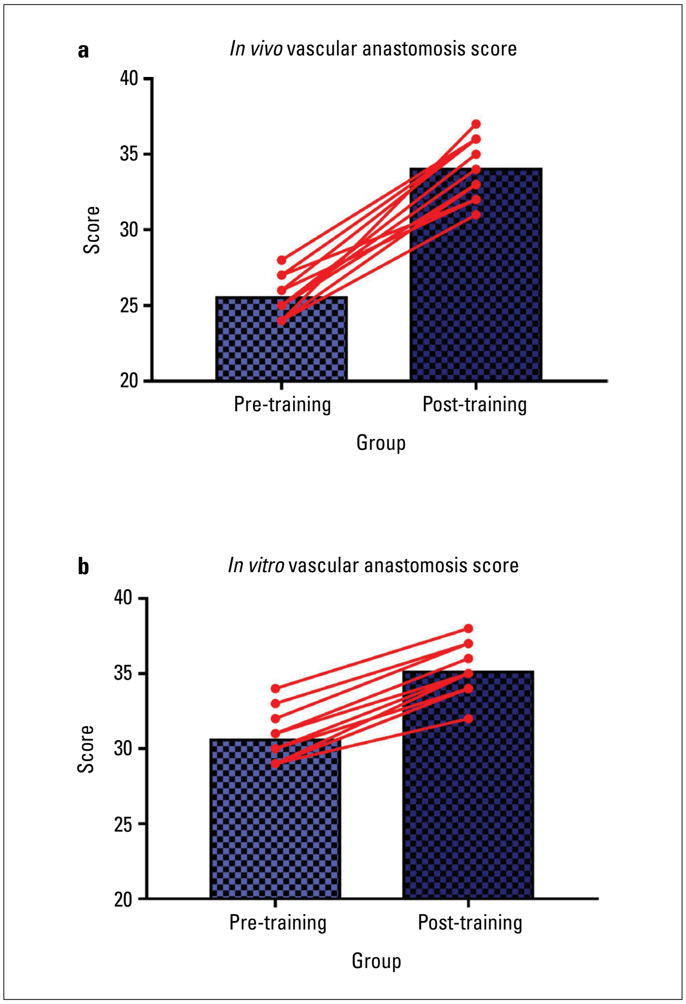

Figure 3. Pre- and post-training scores of each resident. Post-training scores were higher than pre-training scores both *in vivo* (a) and *in vitro* (b)

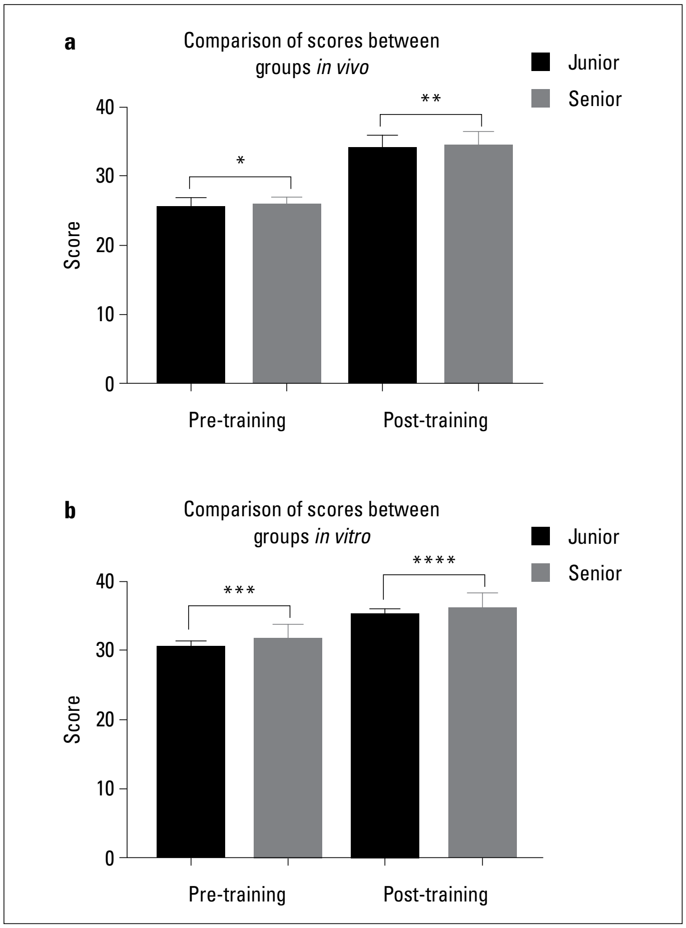

Figure 4. Comparison of scores between junior and senior groups

methods represent the primary CABG techniques and can be applied to different situations (9). However, there is a lack of evidence to determine the better technique (10). The isolated heart provides a good simulation of the on-pump CABG surgery, and the use of living animals for training provides real surgical conditions and closely mimics the off-pump CABG operation (11). We compared the scores before and after training and found that the post-training scores were significantly increased as compared to the pre-training scores in the junior and senior groups. This finding shows that junior and senior participants had improved their skills for coronary artery anastomosis after training. In addition, no difference in pre-training scores was observed between the two groups. Thus, the senior group exhibited no advantage in coronary artery anastomosis in the absence of training over the junior group. Then, we compared the post-training scores of the two groups, and found no difference. These results indicated that training surgeons at an early stage could achieve the same effect as training after a long period of work experience.

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In China, extensive time is required to advance from being a resident to attaining an independent CABG surgeon status. Medical residents from China require three years of standardized training after graduation before entering cardiac surgery, and surgical residents perform different surgeries in rotation during this period. Then, most cardiac surgeons spend five to ten years as a surgical assistant, but this time varies according to hospital levels and policies. After this training period, cardiac surgeons are allowed to perform simple to complex cardiac surgeries in a stepwise manner, and CABG is typically scheduled at a later stage. Most cardiac surgeons begin CABG surgery at an age of approximately 45 years. The junior cardiac surgeons in this study were close to the stage that allowed them to perform simple heart surgeries, such as atrial septal defect repair, whereas the senior surgeons were preparing for more difficult cardiac surgeries, such as ventricular septal defect repair or valve replacement. However, neither group of surgeons have had the opportunity to participate in the training for coronary artery anastomosis, and they were not allowed to perform coronary bypass surgery.

Cardiac surgeons from China can perform CABG only at a very late stage in their career for multiple reasons. First, the development of coronary heart disease surgery in China has lagged behind from other countries (12), and the CABG operation authority is largely monopolized by senior surgeons. Second, the application of percutaneous coronary intervention is developing very rapidly (13) and is even being overused. Patients with coronary heart disease in need of surgical treatment are generally much sicker and have more complex diseases. Third, a greater emphasis on mitigating medical errors and the increasing complexity of cases limit opportunities for young doctors to train in the operating room, and there is a lack of comprehensive training system for cardiac surgery techniques outside the operating room in China (14). Thus, young surgeons can perform coronary surgery only at a later stage in their career.

Allowing cardiac surgeons to start coronary artery anastomosis training at an earlier stage would potentially solve the shortage of cardiac surgeons available to perform CABG. This study shows that both junior and senior physicians performed well after training. Previous studies have shown that providing a special training to surgeons at an earlier stage has yielded promising results (15, 16). It may be unnecessary to consider whether young physicians who start CABG prematurely are able to complete high-quality coronary anastomosis procedures. In addition, the introduction of additional teaching methods has allowed cardiac surgeons to rapidly gain knowledge and experience. Although a few scholars believe that the effect of surgical training is limited (17), most scholars believe that the training of surgical technology is effective for physicians (18) through the use of high-fidelity animal models (9), low-fidelity platform models (19), or even virtual reality (20). This study, with a short duration and low intensity of training, also suggests that training can improve the surgical skills of physicians. Another study has shown that training-even low-intensity training-is beneficial for the skill acquisition process (21). A recent survey of Chinese physicians reported that the number of doctors aged 36–45 years accounted for 32.53% of the total number of doctors. Therefore, earlier training can greatly alleviate the shortage of CABG surgeons.

Study limitations

The training period lasted for less than a week, and each trainee experienced only 12 hours of coronary artery anastomosis practice. Each person performed 12 coronary artery anastomosis procedures during the training, which is considerably less than the workload of a coronary surgeon who completes approximately dozens of coronary artery anastomoses during a week. Inadequate training may result in trainees who are still in the initial stage of the learning curve, along with smaller observable technical differences between the trainees. Longer training periods would generate more convincing data. Moreover, the sample size of the study was limited. It is difficult to recruit larger cohorts of patients who meet the study's requirements in a single research center; however, this study offers a potential solution to the shortage of CABG surgeons.

Conclusion

Senior surgeons had no significant advantage in their performance of coronary artery anastomosis over junior surgeons in the absence of training. Junior surgeons achieved the same results as senior surgeons after training.

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