Transfer of Learning from Practicing Microvascular Anastomosis on Silastic Tubes to Rat Abdominal Aorta

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■ OBJECTIVE: **Learning to perform microvascular anastomosis is difficult. Laboratory practice models using artificial vessels are frequently used for this purpose. However, the efficacy of such practice models has not been objectively assessed for the performance of microvascular anastomosis during live surgical settings. This study was conducted to assess the transfer of learning from practicing microvascular anastomosis on tubes to anastomosing rat abdominal aorta.**

■ METHODS: **Ten surgeons without any experience in microvascular anastomosis were randomly assigned to an experimental or a control group. Both groups received didactic and visual training on end-to-end microvascular anastomosis. The experimental group received 24 sessions of hands-on training on microanastomosis using Silastic tubes. Next, both groups underwent recall tests on weeks 1, 2, and 8 after training. The recall test consisted of completing an end-to-end anastomosis on the rat's abdominal aorta. Anastomosis score, the time to complete the anastomosis, and the average time to place 1 stitch on the vessel perimeter were compared between the 2 groups.**

■ RESULTS: **Compared with the control group, the experimental group did significantly better in terms of anastomosis score, total time, and per-stitch time. The measured variables showed stability and did not change significantly between the 3 recall tests.**

■ CONCLUSION: **The skill of microvascular anastomosis is transferred from practicing on Silastic tubes to rat's abdominal aorta. Considering the relative advantages of Silastic tubes to live rodent surgeries, such as lower cost and absence of ethical issues, our results support the widespread use of Silastic tubes in training programs for microvascular anastomosis.**

INTRODUCTION

The treatment strategy for complex cerebrovascular lesions frequently requires a bypass, which is probably the most technically demanding part of the procedure. Nevertheless, such cases are not common, and with the increasing number of lesions treated with endovascular techniques, fewer microsurgical procedures may be needed over time.[1-7] However, the demand for training cerebrovascular surgeons cannot be eliminated by endovascular techniques. On the contrary, even more competent open cerebrovascular surgeons armed with bypass skills are needed to tackle the most complex and challenging lesions.[8]

The decreasing number of patients undergoing bypass procedures may negatively affect the training of residents and fellows, especially regarding bypass-related skills. In addition, the most challenging parts of these procedures are rarely performed by residents or fellows. It has been said that "An unspoken contract exists between neurosurgeons, their patients, and the referring physician, with the goal of achieving the optimal result…residents have no place in this contract, and if anything, threaten it."[1]

Even with the availability of a large pool of patients requiring cerebral bypass, it is not ethically acceptable to go through the first stages of learning by performing bypass on patients. This situation leads to a dearth of learning opportunities for aspiring trainees, especially when it comes to cerebral bypass skills. Therefore, training for bypass skills is usually started in laboratory settings. The fundamental skill in a cerebrovascular bypass procedure is performing a microvascular anastomosis, which can be learned through a variety of methods. These methods include

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- Aorta bypass
- Artificial vessel
- Bypass surgery
- Cerebral revascularization
- Microanastomosis
- Practice model
- Rodent surgery

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using nonliving (low-fidelity) and living (high-fidelity) models. High-fidelity models include anesthetized animals (commonly rodents). Despite several advantages, animal models are costly and require a relatively complex laboratory setting, which is not universally available. Exposure of the target vessel is not always easy, and inadvertent vascular damage can lead to massive hemorrhage and early animal demise. Ethical issues on the use of animals for practicing purposes are another major limitation of high-fidelity models.[9-13]

Common low-fidelity models include artificial vessels, simulated animal models, and even noodles or worms.[12,14-16] Practicing with artificial vessels, such as Silastic tubes (Biomet Inc., Palm Beach Gardens, Florida, USA), has been traditionally considered an efficient way of learning to perform a microvascular anastomosis in various medical specialties, including gynecologic, plastic, urologic, and neurologic surgery.[12,17-19] Silastic tubes (or similar materials) have several advantages. First, their use is less expensive compared with live surgeries performed on animals. Second, they do not require time-consuming preparations (e.g., anesthesia and vessel exposure). Third, their use does not involve ethical dilemmas. Fourth, the evaluation of anastomosis in Silastic tubes is more straightforward and accurate than that in live animal surgeries. However, objective data supporting their efficacy in learning of the microvascular anastomosis skill is scarce, and surgical trainees are sometimes skeptical about their utility.[20] In addition, Grober et al. believe that low-fidelity laboratory settings (i.e., settings that do not maximally simulate live surgery) might not be useful adjuncts to training programs.[19] They argue that low-fidelity settings do not respect the "realistic" settings of live surgery. In other words, it is not known whether a transfer of learning occurs between the low- and high-fidelity models.

The idea of transfer of learning is applied to a wide variety of fields, from management paradigms to the learning of motor and nonmotor skills.[21] Transfer of learning is seen when practice on one task or in one setting contributes to performance capability in other tasks, other settings, or both.[22] Using a flight simulator system in pilot training is a good example of transfer of learning. However, transfer from lessons learned in training programs to the real-life situations may or may not happen, depending on the subject under training, task characteristics, and environment characteristics.[21,23,24] In fact, only a small percentage of transferred learning outcomes have been reported in various training fields.[25,26] On the other hand, several authors have questioned the existence of learning transfer,[27,28] while others have confirmed its existence.[29] Therefore, we attempted to quantify learning transfer for the complex skill of microvascular anastomosis. Given the lack of objective evidence of transfer of learning from practicing on low-fidelity models (e.g., Silastic tubes) to high-fidelity models, we assessed this transfer from practice on Silastic tubes to performing microvascular anastomosis on live rats.

METHODS

Subjects

Ten surgeons with experience in microsurgery participated in the study; they were randomly divided into experimental ($n = 5$) and control ($n = 5$) groups. Participants were general neurosurgeons (without fellowship training or subspecialty practice) with experience in general microsurgical techniques, including subarachnoid dissection, tumor resection, aneurysm clipping, and peripheral nerve surgery (including microsurgical neural grafting). They did not have any previous experience in performing microvascular anastomosis or practicing anastomosis on artificial vessels.

Pretest

To compare the baseline microsurgical bypass training skills in all subjects, and to minimize selection bias through matching, both groups underwent a pretest. In brief, the pretest consisted of 1 trial of end-to-end microvascular anastomosis on the abdominal aorta of an anesthetized rat. The pretest was designed, and results were analyzed in the same manner as the posttraining test protocol (discussed later).

Training Protocol

Subjects in both groups received written and visual didactic training. They were provided with an instruction form describing the basic steps of the end-to-end anastomosis technique as described previously.[30] The technique is based on placing the first and second sutures at the 2- and 10-o'clock positions, followed by a third suture placed at the 6-o'clock position on the vessel perimeter. Next, sutures would be placed in the spaces between the first 3 sutures. Subjects were also shown a short video depicting the technique of an end-to-end microanastomosis on the rat's abdominal aorta using interrupted sutures.[31]

Hands-on training sessions using Silastic tubes were held every other day at 1:00 PM local time for the experimental group. Subjects were provided snacks before each session to eliminate the confounding factors, such as hunger, affecting their performance. A dedicated microanastomosis instrument set was used for all subjects containing a pair of microscissors, a pair of jeweler's forceps, a pair of microneedle appliers, and a pair of vessel approximators. Subjects were seated on a standard arm chair to perform microanastomosis using a surgical microscope (Leica, Wetzlar, Germany). The training began with a track of 6 consecutive sessions of microanastomosis on 2-mm Silastic tubes, followed by 12 sessions of microanastomosis on 1-mm tubes. Finally, the subjects performed 6 sessions of microanastomosis on 0.7-mm Silastic tubes (measurements represent the outer diameter of the tubes). All anastomoses (including pretests, training, and tests on Silastic tubes and rat aorta) were performed using Ethilon 2830G 10-0 nylon sutures (Ethicon, Somerville, New Jersey, USA). The microanastomosis field was set up by the study supervisor (P.M.), and it included a Silastic tube with vessel approximators, mounted on a green 5×5-cm foam base (**Figure 1**). Next, the participant was asked to place a cross-sectional cut on the Silastic tube and complete the anastomosis as previously instructed. Anastomosis time was recorded from cutting the tube until completion of the last suture.

Posttraining Testing Protocol

Following the training, both groups underwent 3 recall tests consisting of performing an end-to-end microvascular anastomosis on the abdominal aorta of an anesthetized rat. The recall tests were given at weeks 1, 2, and 8 following the hands-on training sessions