ORIGINAL ARTICLE   **EXPERIMENTAL/SPECIAL TOPICS**

Is There Good Simulation Basic Training for End-To-Side Vascular Microanastomoses?

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Abstract

Background Microvascular anastomosis is the cornerstone of free tissue transfers. Irrespective of the microsurgical technique that one seeks to integrate or improve, the time commitment in the laboratory is significant. After extensive previous training on several animal models, we sought to identify an animal model that circumvents the following issues: ethical rules, cost, time-consuming and expensive anesthesia, and surgical preparation of tissues required to access vessels before performing the microsurgical training, not to mention that laboratories are closed on weekends.

Methods Between January 2012 and April 2012, a total of 91 earthworms were used for 150 microsurgical training exercises to simulate vascular end-to-side microanastomosis. The training sessions were divided into ten periods of 7 days. Each training session included 15 simulations of end-to-side vascular microanastomoses: larger than 1.5 mm ($n = 5$), between 1.0 and 1.5 mm ($n = 5$), and smaller than 1.0 mm ($n = 5$). A linear model with the main variables being the number of weeks (as a numerical covariate) and the size of the animal (as a factor) was used to determine the trend in time of anastomosis over subsequent weeks as well as the differences between the different size groups.

Results The linear model shows a significant trend ($p < 0.001$) in time of anastomosis in the course of the training, as well as significant differences ($p < 0.001$) between the groups of animals of different sizes. For microanastomoses larger than 1.5 mm, the mean anastomosis time decreased from 19.3 ± 1.0 to 11.1 ± 0.4 min between the first and last week of training (decrease of 42.5 %). For training with smaller diameters, the results showed a decrease in execution time of 43.2 % (diameter between 1.0 and 1.5 mm) and 40.9 % (diameter <1.0 mm) between the first and last periods. The study demonstrates an improvement in the dexterity and speed of nodes execution.

Conclusion The earthworm appears to be a reliable experimental model for microsurgical training of end-to-side microanastomoses. Its numerous advantages are discussed here and we predict training on earthworms will significantly grow and develop in the near future.

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Keywords Earthworms · Microanastomoses · Microsurgery · Experimental model

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Microvascular anastomosis is the cornerstone of free tissue transfers [1–5]. Great progress has been made since the pioneering work of Jacobson and Suarez [6] in discovering factors that affect the patency of vascular microanastomoses.

This progress stems from technical improvements in microsurgical devices, optical instrumentation, and especially in the training and education of microsurgeons [7]. Surgical education has traditionally been built on the Halstedian apprenticeship model, where experts teach skills to novices using real patients. Although well-established, this process comes with limitations and areas for improvement remain to maximize the educational benefit for residents and the safety of patients. This is especially true of microsurgery, where regular training is necessary and should be achieved in the laboratory before any clinical procedure is performed [8]. Several microsurgical training models are available that can impart skill and provide an appropriate level of training. Models range from basic devices [9] to live animals. However, the texture of inert models substantially differs from live clinical situations and the use of animal models is limited by ethical rules, cost, time-consuming and expensive anesthesia, and surgical preparation of tissues required to access vessels before performing the microsurgical training. Since 2010 we have been working toward developing an effective model to circumvent these difficulties and foster regular and easy accessible training. Based on the literature and our previous observations [10], we found that the earthworm is a reliable model for microsurgical training because of the following: (1) anesthesia is not required; (2) the texture of the earthworm is comparable to that of the arterial wall; (3) the wall tends to collapse, perfectly mimicking the behavior of mammalian blood vessels during anastomoses; (4) breeding earthworms is very easy and does not require expensive equipment; (5) their ubiquity makes it is possible to use animal sizes matched to the desired training difficulty; and (6) no assistance is needed, which facilitates regular training.

In this article we present a prospective series of microsurgical end-to-side anastomoses training with earthworms and discuss the numerous advantages but also the technical limitations of this animal model for basic microsurgical training.

Material and Methods

Animals

Between January 2012 and April 2012, a total of 150 microsurgical training exercises were performed on 91 *Lumbricus terrestris* (order Haplotaxida; phylum Annelida). The earthworms weighed between 1 and 8 g. The mean length of the animals was 16 cm (range = 4–34 cm). The training sessions were divided into ten periods of 1 week each and included 15 simulations of end-to-side vascular microanastomoses: larger than 1.5 mm ($n = 5$),

from 1.0 to 1.5 mm ($n = 5$), and smaller than 1.0 mm ($n = 5$).

Surgical Technique

After killing the earthworms by immersion in 5 % ethanol [11, 12], the body of the animal was sectioned proximally and distally. The animal was washed with a thin steel wire. Microvascular clips were placed at the level of the desired training. The microsurgical end-to-side training exercise was then performed using the biangulation technique. There were about ten sutures used in the group in which diameter was larger than 1.5 mm and eight sutures in the other two groups. Each exercise was performed by the same operator (FML).

Objective Parameters

The external diameter of the animal was measured with an eyepiece reticule at ×40 magnification prior to division. The time from the first to the last suture was systematically recorded. An O'Brian patency test was not possible and was replaced by a permeability test conducted by injecting water into the earthworm using a syringe. Furthermore, a longitudinal incision allowed for visualization of the inner quality of the sutures for each microsurgical training exercise.

Subjective Parameters

A subjective evaluation was conducted by the expert surgeon at the end of the training by rating the following parameters as excellent, very good, good, and bad: dexterity, speed of nodes execution, improvement in the precision of movement, and improvement in the quality of microanastomoses.

Statistical Analysis

This prospective study involved 150 microsurgical training exercises performed on 91 earthworms spread over 10 weeks of practice, each with three subgroups based on the size of the animals. A linear model with the main variable the number of the week (as a numerical covariate) and the size of the animal (as a factor) was used to determine the trend in time of anastomosis over subsequent weeks as well as differences between the different size groups. A p value of <0.05 was considered to be statistically significant. Statistical analysis was performed using the SPSS Stat program (SPSS, Inc., Chicago, IL, USA). Data are presented as mean ± standard error of the mean (SEM).

Results

Microsurgical training exercises (150 occurrences) were performed on 91 earthworms (Figs. 1, 2). All the micro-anastomoses were patent, as evidenced by our permeability test. The results are presented in Tables 1, 2.

Anastomosis Time

The results are presented in Table 1. The linear model shows a significant trend ($p < 0.001$) in time of anastomosis in the course of the training as well as significant differences ($p < 0.001$) between the groups of different sizes.

For microanastomoses larger than 1.5 mm, the mean anastomosis time decreased from 19.3 ± 1.0 to 11.1 ± 0.4 min between the first and last week of training (decrease of 42.5 %). For training with smaller diameters, the results showed a decrease in execution time of 43.2 % (diameter between 1.0 and 1.5 mm) and 40.9 % (diameter <1.0 mm) between the first and last periods.

Subjective Parameters

The subjective evaluation of training is presented in Table 2. The study noted a subjective improvement for all subjective criteria, especially for the group in which size was <1 mm.
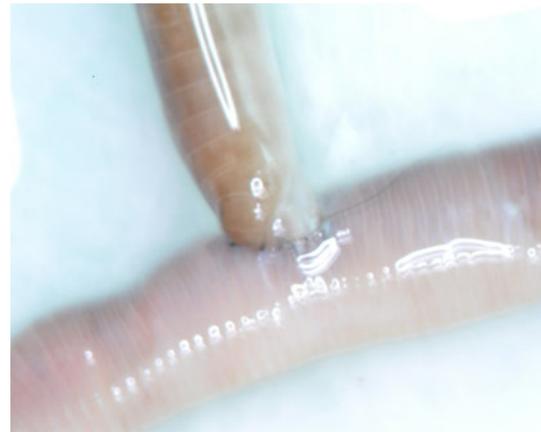
Fig. 2 Result after microsurgical end-to-side training (diameter = 2.2 mm, magnification ×40) and permeability test conducted by injecting water into the earthworm using a syringe

Discussion

Regular training is essential to acquire a sound foundation in microsurgery skills and should be done in the laboratory prior to performing clinical procedures. Basic microsurgical techniques are end-to-end and end-to-side microanastomosis but other techniques also deal with vessel size variations. These include invaginating anastomoses, fishmouth incision, oblique section, and wedge excision. Irrespective of the microsurgical technique, whether the purpose of training is to integrate new skills or improve on

Fig. 1 Microsurgical training using the biangulation technique. **a** Clamping the *Lumbricus*. **b** Dilatation of the smaller *Lumbricus*. **c** Placement of the two cardinal microsutures. **d** Microanastomosis of the anterior wall
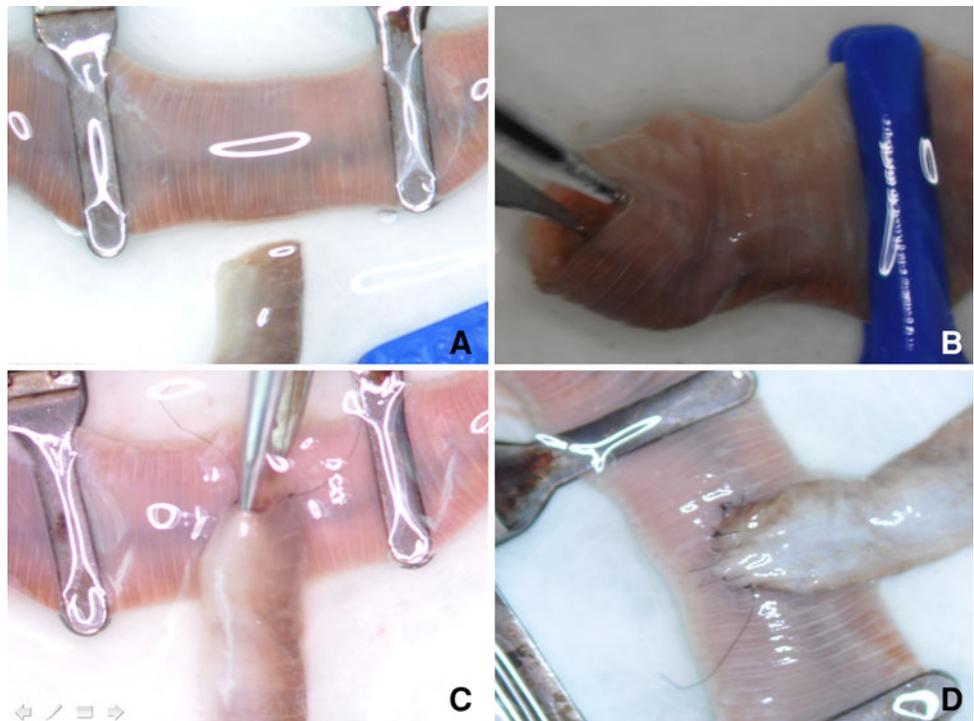
Table 1 Average time necessary for the training exercise in the different groups and periods of training

	Time for training		
	(Ø > 1.5 mm)	(Ø = 1–1.5 mm)	(Ø < 1.0 mm)
1	19.3 ± 1.0	19.9 ± 1.3	23.0 ± 2.7
2	18.1 ± 0.5	19.1 ± 0.7	20.2 ± 1.0
3	17.0 ± 1.0	18.8 ± 0.6	19.1 ± 0.8
4	15.5 ± 0.4	16.5 ± 1.2	18.3 ± 0.9
5	15.1 ± 0.8	16.2 ± 1.0	17.2 ± 0.7
6	15.2 ± 0.7	16.0 ± 0.8	17.7 ± 0.6
7	13.5 ± 0.9	13.9 ± 0.6	15.8 ± 1.2
8	11.5 ± 0.4	12.2 ± 0.7	14.3 ± 0.9
9	11.2 ± 0.6	11.4 ± 0.3	14.7 ± 0.7
10	11.1 ± 0.4	11.3 ± 0.4	13.6 ± 0.6

Values are mean ± SD in min

Table 2 Subjective evaluation of the end-to-side microsurgical training

Criterion	Excellent	Very good	Good	Bad	Remarks
Dexterity	X				For all groups
Speed of nodes execution	X				For all groups
Improvement in the precision of movement	X				Especially for the groups in which size was <1 mm
Improvement in the quality of microanastomoses		X			This model does not assess any intimal injuries

existing ones, significant amounts of time must be invested, which conflicts with the constraints faced by residents [13, 14]. After extensive training on different animal models such as pigs, rats, rabbits, chicken, and fish [15], and also on discarded abdominoplasty specimens, we have been searching for a new model that can provide a solution to the following issues associated with basic training: ethical rules, cost, time-consuming and expensive anesthesia, and surgical preparation of tissues required to access vessels before performing the microsurgical training, not to mention laboratories that are closed on weekends.

In this prospective study, 150 microsurgical end-to-side microvascular training exercises were performed on 91 earthworms. The results underline an improvement in speed of execution and microsurgical dexterity for all sizes

of animals. Our series objectively confirmed the numerous benefits associated with the annelid model for basic microsurgical training: (1) The storage of the animal is simple and inexpensive. (2) Their ubiquity makes it possible to use animal sizes matched to the desired training difficulty. (3) Several training exercises may be performed with only a few centimeters of the animal and the remainder may be stored for future use. This was demonstrated by our studies, where only 91 animals were used for 150 exercises. (4) No anesthesia is required because the animal is killed before the procedure. In this context it is important to note that despite its death, the texture of the animal remains similar to that of the arterial wall. (5) The training can begin swiftly as no lengthy preparation is required. (6) Training can also be performed with magnifying glasses at home during the weekend if the surgeon is motivated.

In spite of the advantages mentioned above, there are some downsides in technique and methodology. First, a conventional patency test such as an O'Brian patency test is not possible. We used a permeability test as an alternative by injecting water into the earthworm using a syringe. A longitudinal incision allowed for visualization of the inner quality of the sutures for each training exercise. Second, adventicectomy, essential for obtaining patent microanastomosis, cannot be mimicked. Third, since the models are not followed over time, intimal injuries cannot be assessed. However, it was possible to assess the lumen of the vessel and control the inner injuries with a longitudinal incision of the earthworm. Fourth, the texture of the wall is similar to that of vertebrate arteries but is significantly different from that of veins. Moreover, only training exercises of end-to-side microanastomoses are presented here. Additional exercises that incorporate end-to-end microanastomoses and other techniques to manage size discrepancies (invaginating anastomoses, fishmouth incision, oblique section, and wedge excision) can be performed with this animal model. Current prospective studies are being performed in our laboratory. Finally, it is not possible to become familiar with alternative techniques of conventional microvascular microanastomoses such as laser [16, 17]. Despite the above limitations, the simplicity, effectiveness, and low price all suggest that training with this animal model will significantly grow and develop in the near future.

Conclusion

The earthworm appears to be a reliable animal model for microsurgical training of end-to-side microanastomosis. Its numerous advantages discussed in this report all suggest

that this training will significantly develop and grow in the near future.

Conflict of interest The authors have no conflicts of interest to disclose.

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