Chapter 2. Non-living models in experimental microsurgery

Codrin Nicolae Dobreanu
Nicolae Ghetu
Victor Gheorghe Ilie
Vlad Ionuț Ilie
Dragoș Pieptu

Microsurgery is defined as surgery performed under optical magnification, commonly under the surgical microscope. The term was first used in the 1960s by Jacobson and Suarez. They used the surgical microscope of their otorhinolaryngology colleagues to perform the anastomosis of vessels with a diameter of less than 2 mm, this being considered the origin of microvascular practice. Since then the microvascular techniques, the instruments and microscope design have evolved allowing high permeability rates in small vessels, less than 1 mm diameter.

Microsurgical techniques are used in various fields of surgery-limb replantation or revascularization, free flap transfer in reconstructive plastic surgery, for the reversal of vasectomy or tubal ligation and also in various specialties as neurosurgery, ophthalmology, orthopaedics and otorhinolaryngology.

Apprenticeship was the traditional way of training in surgery. It is not suited for learning microsurgery due to complexity, time, ethical and financial concerns. Proper surgical laboratory practice is required to master the technique prior to its use in clinical practice. Many academic training centres rely on laboratory-based courses to develop the necessary skills. The
models used for microsurgical practice can be split into 3 categories: living animals, nonliving tissue and artificial materials (and leaves).

Living animals (rats, rabbits) are the best models for practice. They provide an experience that resembles closely the clinical one and allow for anastomotic patency tests. The rat femoral vessels are the standard for microvascular model. However these models pose several issues: they require anaesthesia and an animal laboratory, animal preparation and care is costly and time consuming, and ethical problems arise due to animal deaths.

Non-living animal models

Non-living tissue models described include segments of chicken (wing, leg, and neck), pig (heart, leg), placentas, human tissue and cryopreserved vessels.

- Chicken parts are a simple, cheap, available model. Common carotids from the neck and thoracic inlet, brachial artery from the wing, femoral vessels from leg have been used. The size of the chicken carotid and femoral vessels (less than 1 mm) are close to human digital vessels. Also the vessels handling resembles live surgery, and fresh chicken wing model was highly rated by those with experience in in vivo surgery. The nerves are quite different from their human counterparts and don’t constitute a useful model.

- Placenta is easy to get, can be stored in a refrigerator at 4°C up to 10 days, and provides numerous vessels of
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various diameters for anastomosis (from about 4 mm close to the base of the umbilical cord, to 1 mm or less distally). It has to be infused with heparin to prevent clotting. However, most placental vessels have a wide diameter and a thick, adherent adventitia, different from the clinical situations. Also using placentas requires the consent of the mother, and can pose some infectious risks.

• Discarded specimens from the operation theatre can also be used, but their use is limited due to hospital regulations regarding human tissue handling, and the need for consent. Several models have been proposed – cadaver vessels, avulsed skin, vasectomy segments, and excised tissue from abdominoplasty.

• Pig coronary arteries are also a good model. They allow for vessel preparation, end to end, and end to side anastomosis or grafts. Their vascular diameters of 0.5 to 4.0 mm closely resemble human vessels typically encountered in microsurgical settings. They have to be continuously irrigated with saline solution, in order to keep them moist and viable. Pig front legs can also be used in training, since they provide vessels of different calibres, as well as mono and plurifascicular nerves.

• Femoral pedicles, carotid arteries, aorta from rabbit or rat are good models. These must be stripped of their adventitia, the branches ligated or coagulated during harvesting. They must be flushed with heparine in saline solution, and stored in moist saline gauze at 4°C. These cryopreserved vessels have a shelf life of several months and can be used for various exercises.
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Testing for leakage and patency can be performed on all these models using a variety of solutions from simple saline solution, dyes or blood. But these tests don’t replicate the risk of thrombosis and due to greater leakage (produced by low viscosity solutions) might induce the placement of unnecessary stitches. In order to provide a circulatory environment close to the human one, several models of perfused vessels were developed, using infusion or membrane pumps on placenta, pig legs, coronaries, and chicken legs.

Artificial material models

The artificial materials include gauze, silicone and PTFE tubes, latex, leaves and beads. These materials are inexpensive, easily obtained, but bear little resemblance to human tissue. They are used for the initial training steps in microsurgery: working with threads, placing sutures, and tying knots.

- Surgical gauze provides a readily available, safe and cheap material. Various thread manipulations are performed under the microscope, in order to achieve initial dexterity and coordination.
- Single fenestrated beads are threaded on a suture, in order to accustom the trainee to microsurgical instrument handling.
- Latex sheets (commonly made from examination gloves) are used to create different models of various complexities. The trainee performs simple suturing after making longitudinal, transverse, or oblique incisions. Latex strips can be made in tubes, and then used to practice end to end, and end to side anastomosis.
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• Several authors used silicone and PTFE tubes for the practice of anastomosis. Lacrimal silicone tubes with diameters of 0.94, 1.19, and 1.65 mm were used. Hosnuter wrapped polyethylene transparent film membrane around the tubes, thus creating a layer similar to the adventitia, and allowing adventitial stripping to be incorporated in the exercise. PTFE tubes (with external diameter ranging from 0.5 to 1.5 mm) are more pliable and thin, better simulating an arterial wall.

• The Practice-Rat is a system containing a simulated vein, artery, and nerve. It has two polyethylene tubes (1-mm diameter), wrapped with synthetic adventitia, and connected to a pump for blood flow simulation. A more complex model is the PVC rat, where blood vessels and other structures are made from latex, and the organs of polyurethane. It can accommodate different training scenarios, from vessel catheterization, to organ transplantation.

• Virtual reality models have yet to be validated as training tools in microsurgery. Montgomery developed a microsurgical anastomosis simulator that uses real instruments with mounted electromagnetic trackers, to provide orientation and localization to the system. They report it to be responsive. The microsurgery simulator developed by Brown et al. provides a deformable object simulation, a tool simulation, and a collision detection module. It uses real life instruments, but without haptic feedback, which does not seem relevant in microsurgery.
Implementation of non-living models in our laboratory

The initial steps in microsurgical training concern operating the microscope, correct handling of surgical instruments, learning the technique of knot tying, and achieving a good orientation in the microscope field. These models require a usual microsurgery instrument set and monofilament microsurgical sutures 10/0 and 9/0.

1. The gauze model
A piece of gauze is placed on a practice board and fixed at the edges. Under 10x magnification, with 2 microsurgery forceps, the student is required to cut a longitudinal fiber and then to remove it, by gently pulling from under the transverse fibers, which should be kept in place as much as possible (Figure 1).

Fig. 1. The gauze model
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Then, using a needle holder, a 10/0 needle is passed over and under the transverse fibbers and the thread pulled along, respecting their original position. That is followed by performing a simple surgical knot, then a square knot, using a forceps and a needle holder. It will improve coordination and handling of microsurgical instruments.

2. The beads model
Using a micro-forceps and 16x magnification, coloured beads with external diameter of 1-2 mm are gently threaded on a 5cm piece of 9/0 sutures, similar to creating a necklace (Figure 2). For each thread, 7 to 8 beads can be used, while the suture is supported with the micro-forceps. The beads have to be gently handled; otherwise they will slip out the field of vision. The trainee is exposed to precise and gentle tissue handling.

Fig. 2. The beads model
3. The latex model
A sheet of latex is cut from a glove using a scissor. It is placed over a Sun Lee disc or a Petri dish, and fixed with a rubber band. Incisions at various angles (transverse, longitudinal, oblique right and oblique left) are made in the latex. The trainee is asked to suture all the incisions using 9/0 sutures and micro-instruments. The emphasis is set on gentle suture and latex handling, correct knot making and suture placement. The needle should pass perpendicular to the latex, at a correct distance from the edge, the knot should bring the edges together without overlapping or tearing of the latex, and the knots should be symmetrical and evenly spaced. The edges of a straight incision offer an inherent stability and tolerate a considerable force and movement, allowing suture placement even with limited dexterity.

Fig. 3. The latex model
We also used Lahiri’s “I” model, which gives more mobility to the latex sheets, better mimicking the vessel ends during anastomosis. A straight 1-cm incision is made and converted to a capital “I”-shaped incision, by making two horizontal incisions at each end of the vertical one. A horizontal cut measuring 4 mm can be used first and then it is lengthened to 10 mm, to increase instability of the edge. Thus, the student is required to imply stabilization the model when passing a needle, using counter pressure, via a micro-forceps in the non-dominant hand. This exercise can be compared with a large (3-mm-diameter) vessel anastomosis.

4. The “Canniesburn” model
This is a more complex model. Two parallel 10 mm long cuts are made in the latex sheet, 5 mm apart, using a scalpel). The edges are then sutured together with 7–8 interrupted sutures, producing a tube. A double micro-clamp is positioned on the tube so that the seam lies in the middle or to the side. The tube is sectioned between two sutures on the seam that are fairly close together. The student then practices the end-to-end anastomosis, paying attention on proper suture placement. Making a third parallel incision, another strip of glove may be transformed in a tube. This can be used for end-to-side anastomosis with the first tube. The tube design allows the student to handle a 3D object in the microscope field, and a better approximation of dimensions.

5. The chicken leg model
A fresh chicken thigh is skinned and placed on a practice board with the lateral side towards you. The large muscle from the back of the thigh (the posterior part of iliotibialis lateralis) is dissected from the fasciae, and the subjacent muscles and the
femoral pedicle is identified on the deep pubo-ischio- femoral and flexor cruris muscles. Retractors are placed in order to expose the pedicle on a length of about 4 cm. The perivascular fat is removed and the collaterals are ligated. The artery, vein and nerve are dissected separately. The vessels are then ready to be a practice model for an end-to-end, end-to-side, or side-to-side anastomosis using 10-0 or 11-0 monofilament sutures. The femoral nerve can be cut with micro-scissors and repaired with 10-0 suture. The neurovascular bundle in the femoral area is long, has only a few branches and has minimal anatomic variations. The femoral artery is about 2 mm in diameter, similar to human digital artery. The nerve can be used for neurorrhaphy after epineural trimming.

References

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