The PVC-Rat and Other Alternatives in Microsurgical Training

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The number of animals used in educational training programs in experimental microsurgery can be reduced by using artificial devices such as the anastomoses device and the MD PVC-Rat. Such *in vitro* methods allow development of technical skills, making the transition to *in vivo* models much easier.

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Long confined to use in human clinical medicine, including hand surgery and organ transplantation, microsurgery has recently gained acceptance as a means of performing surgical procedures on small laboratory animals, including mice. The application of microsurgical technique to rodents can replace large animal models for surgery research and allow surgical manipulation of genetically altered mice. However, if researchers are to take advantage of the benefits of using microsurgery, they need tools for learning proper technique. Hence, we describe the development of several nonanimal tools for microsurgical training.

Work in experimental microsurgery began in the early 1960s. In previous years, Lee tried to establish a portacaval end-to-side anastomosis in an animal as small as the rat[1]. With the help of new suturing material technology, such as the microneedle swaged with 7-0 siliconized braided silk, and miniature vascular clamps (Satinsky)[2], the anastomosis was perfected in 1958.

Over the past 40 years, a great number of transplantation and experimental techniques were developed. However, it took a long time before nonclinical biomedical researchers discovered the added advantages of using the microscope along with microsurgical techniques. With few exceptions, in the early 1970s, *in vivo* pharmacological research was done in anesthetized animals. Freely moving animal models were rarely seen. Researchers physically restrained the animals in case the anesthetics had major effects on the parameters to be measured. [PLEASE CLARIFY THIS? HOW DOES THE FACT THAT RESEARCHERS WERE RELUCTANT TO USE ANASTESTHICS IN SURGICAL MODELS RELATE TO MICROSURGERY?]

Interest in the application of microsurgical techniques was stimulated in the mid-1980s during the revival of the concept of the "three Rs," originally suggested in 1959 by William M.S. Russell and Rex L. Burch in their book, *The Principles of Humane Experimental Technique*[3]. Experiments began to refine surgical techniques leading to an eventual reduction of the number of animals used[4].

In 1990, a group of researchers founded Microsurgical Developments (MD) (www.microdev.nl). The main objective of this nonprofit organization is the production of educational tools for life sciences research. Since early papers in the field often lacked a clear and detailed description of a technique, we compiled a manual which described and illustrated experimental and microsurgical techniques in great detail. Since skills involved in microsurgery cannot be mastered purely through books, MD compiled detailed and explicit videotapes of several operations and general techniques used in rats.

MD was also involved in setting up a basic course on microsurgery at Utrecht University (The Netherlands). When one is learning microsurgical techniques, it is important to develop the ability to concentrate on the visual images seen through the microscope, to use fine instruments, and to coordinate one's movements[5]. At that time, the use of anesthetized animals was often advocated for training purposes, but it is difficult for students to divide their attention between mastering a technique and taking proper care of the animal. The animals often die and, after a few attempts, the

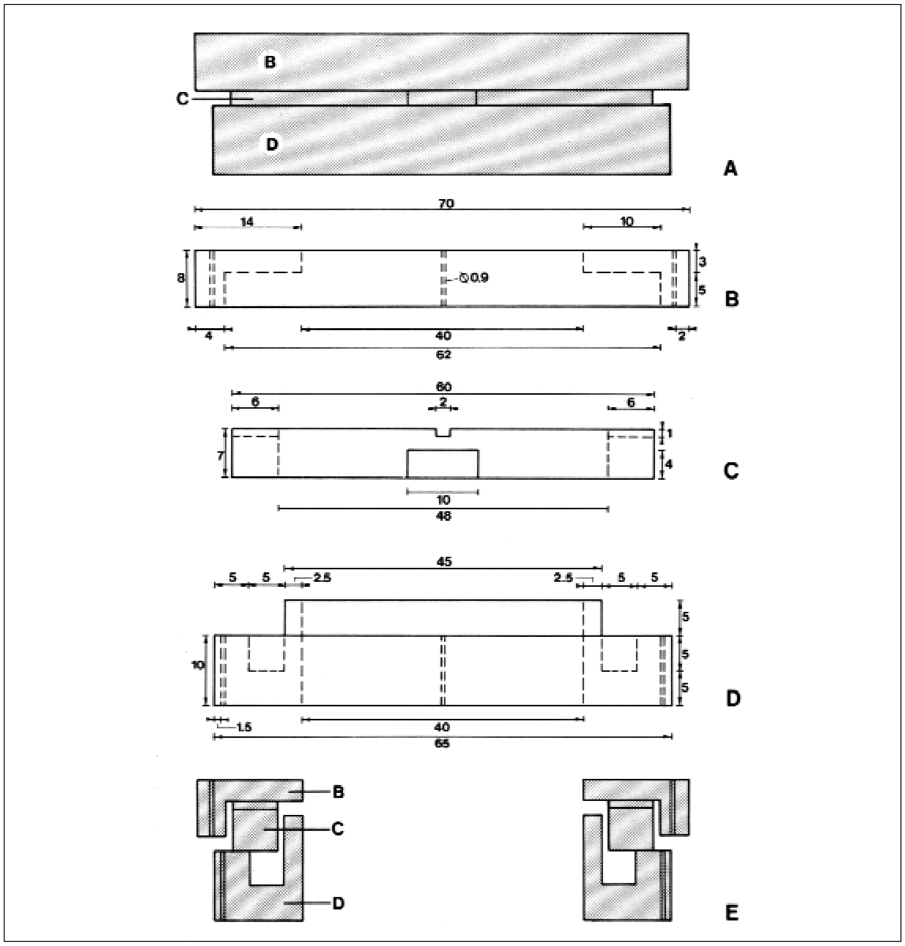

FIGURE 1. Schematic side view of the anastomoses device (A). The device consists of three rings (B, C, and D). Drawings B, C, and D show the dimensions of the respective rings, while E shows the cross section of the stacked rings.

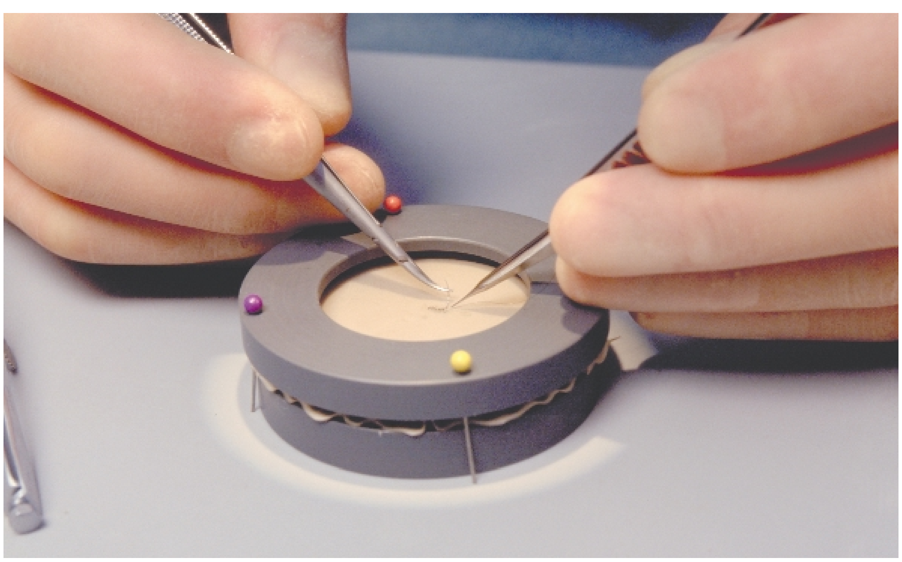

FIGURE 2. The anastomoses device in use

student becomes disappointed. Due to these and other factors, the number of animals needed in the initial training phase is often very high. Therefore, it became apparent during these courses that there was a need for a simple device to practice eye-hand coordination, basic knot tying, and suture techniques.

The Anastomoses Device

Kaufman's group made one of the first attempts to replace the use of animals for training purposes[6], and thus introduced the foliage leaf in microvascular surgery. In the same year, Awwad[7] introduced the so-called Practi-Card, which contains 16 small compartments consisting of two pieces of cardboard with a small piece of rubber in between. Freys and Koob[8], described a training procedure that trained the students in increasingly difficult procedures without the use of live animals. They started with rubber gloves, continued with silicon tubing and the ischiatic nerve of the chicken, and ended with a coronary arterial vascular anastomosis of a pig's heart. Ayouby[9] reported using placentas in microvascular exercises. Korber[10] described the use of small-calibre Gore-Tex grafts as another alternative for microsurgical training.

Our anastomoses device (**Figs. 1 and 2**) is made of PVC, which is smooth, easy to manufacture, and easy to clean. The device consists of three rings. A surgical glove is clamped between two rings and the third ring is pinned over it[11]. Using this device, students can be trained in details such as inserting a needle, guiding a thread through a stitch-hole, and knotting. After mastering these basics, they are able to establish interrupted and continuous sutures in various directions. The device can also be used to clamp small-diameter silicone or latex tubing to practice suturing and knotting procedures in standard end-to-end and end-to-side anastomoses. By turning the device upside down, the students can simulate suturing in a deep cavity.

The MD PVC-Rat

After some years of experience with the

anastomoses device, we felt there was a need for a model in which we could simulate a complete surgical technique. Again, the goal was separation of attention between the technique and the animal. We discussed several options ranging from a stylistic approach to a true-to-life rat model and decided to apply for a grant from the Platform Alternatives to Animal Use Program, Ministry of Public Health, Welfare and Sport in the Netherlands (PAD). We were successful in receiving funding and started the development in 1994 in close cooperation with Solvay Pharmaceuticals, Solvay Plastics, Unilever, and Museum Technical Works Foundation in Groningen.

Several difficulties had to be addressed, such as the most suitable material to use to make the blood vessels and the way to fixate these vessels in a proper way into the model. We also wanted to be able to produce the MD PVC-Rat in a cost-efficient way to allow as many people as possible to buy the rat at cost. The final model is made of PVC; blood vessels and other structures are made of latex and the organs are made of polyurethane (**Fig. 3**). The model was evaluated by experienced microsurgeons, and we used their comments to improve it. A prototype of the model was introduced at the Second World Congress on Alternatives and Animal Use in the Life Sciences, held in Utrecht, The Netherlands, in 1996. The final model became available in 1999.

The MD PVC-Rat can be used in conjunction with the anastomoses device to train students in more than 25 advanced experimental and microsurgical techniques (*e.g.*, cannulation of portal, renal, and jugular veins; making portacaval shunts using button and suture techniques; and transplantation of blood vessels, kidney, and heart). After mastering the technique, students must be trained in perioperative care (patient monitoring). Here, it is important to realize that, unlike physicians or veterinarians, most scientists are not trained in surgery. Therefore, we decided to develop a computer program that would simulate the anesthetic process and problems that could occur during surgery. This project was also funded by the PAD; the Product-Group Bio-Simulations of the Van Hall Institute in Leeuwarden paid for the software. Depending on the skill of the surgeon, the program will generate problems with such parameters as body temperature, respiratory rate, and heart rate. The student must concentrate on the animal's welfare, correct the problem, and continue with the technique. The prototype program is called REMOTE and is part of the boxed-set (see below).

We must also make sure that future scientists, whose research involves surgical intervention in an animal, are familiar with the basic principles of aseptic technique. This often-neglected part of the surgery can easily be learned using the MD PVC-Rat.

More than 250 boxed sets containing a PVC-Rat, spare parts, an instruction video, and the REMOTE program have been sold worldwide. The rat is used for training purposes under our direct guidance within Solvay Pharmaceuticals, Utrecht University, Groningen University, and Odense University (Denmark).

After introducing the MD PVC-Rat in our courses on microsurgery, we clearly see an improvement in the performance of our students. Numerous mistakes that would normally cost animal lives are circumvented and students feel much more at ease when they perform their first operation on a living animal. The use of the model reduces the number of animals used during training of scientists and animal technicians by roughly 90%.

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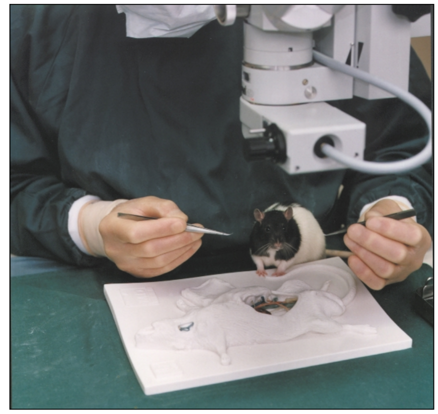

FIGURE 3. The MD PVC-Rat as an alternative.

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