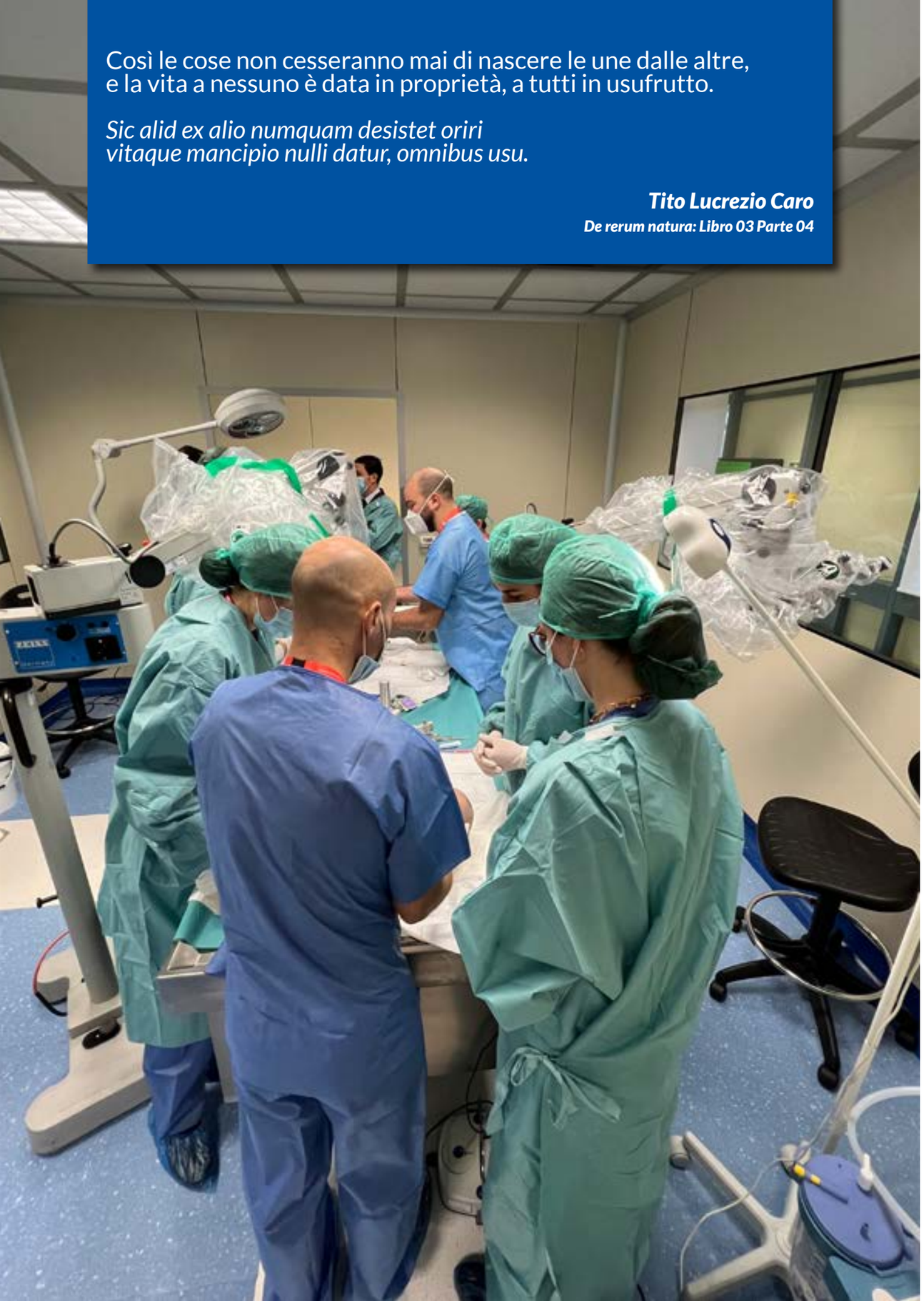
CENTRO DI MEDICINA NECROSCOPICA

NEUROMED
I.R.C.C.S.
ISTITUTO NEUROLOGICO MEDITERRANEO



Così le cose non cesseranno mai di nascere le une dalle altre,
e la vita a nessuno è data in proprietà, a tutti in usufrutto.

Sic alid ex alio numquam desistet oriri
vitaque mancipio nulli datur, omnibus usu.

Tito Lucrezio Caro
De rerum natura: Libro 03 Parte 04

Centro di Medicina Necroscopica IRCCS Neuromed

Presso l'**IRCCS Neuromed** è attivo il **Centro di Medicina Necroscopica - Unità di Chirurgia Formativa**, uno spazio innovativo per la dissezione e lo studio dell'anatomia umana nella sua globalità. Uno spazio in cui gli operatori del mondo medico possono studiare, sperimentare, perfezionare le pratiche chirurgiche, approfondire le conoscenze anatomiche, ma anche riscontrare nuove tecniche e affinare quelle più valide su preparati anatomici *fresh/frozen*, grazie all'utilizzo di tecnologie avanzate e un team di professionisti pronti a supportare dal punto di vista tecnico e organizzativo l'intero percorso formativo.

Il **Centro di Medicina Necroscopica - Unità di Chirurgia Formativa** è diviso in **due sezioni**: una si trova presso la **sede ospedaliera** dell'IRCCS Neuromed, ubicata in Via Atinense Pozzilli (IS) ed è dotata di un'ampia sala autoptica e l'altra è situata presso il **Parco Tecnologico** in località Camerelle, in via dell'Elettronica.

Questa centro di dissezione anatomica all'avanguardia, nato per la **formazione "pratica"** dei medici chirurghi è **altamente professionalizzante** e articolato su due livelli: **anatomia chirurgica** e **tecnica chirurgica**.

Partendo dall'approfondimento anatomico, specializzandi e chirurghi già specializzati sperimentano, sotto la guida di una equipe di massimi esperti, come eseguire in modo ottimale le tecniche chirurgiche su regioni di specifiche parti anatomiche derivate da cadaveri.

L'IRCCS Neuromed è *best practice* per lo studio e la cura di patologie afferenti alla **Neurochirurgia, Neurologia, Neuroriabilitazione** per tutte le applicazioni relative alle **Neuroscienze**. Inoltre è anche **Polo nazionale per la Neurochirurgia** con un'attività operatoria in costante aumento: in media vengono effettuati 2000 interventi all'anno.

Molta strada è stata fatta nella **storia della medicina necroscopica**: dalle prime dissezioni, praticate a scopo di ricerca anatomica già nel III secolo a.C., passando attraverso lo studio vinciano della "macchina umana" in epoca Rinascimentale, l'analisi dell'anatomia umana 2.0 si apre oggi a modalità di apprendimento scientificamente avanzate per consentire al medico chirurgo di affinare le proprie capacità di intervento sul paziente.

Nel mondo i centri dedicati a questa branca medica sono pochissimi e ancor più rari in Italia. Ma l'IRCCS Neuromed da sempre attento all'alta formazione ha deciso di intraprendere questa sfida grazie al **Prof. Giampaolo Cantore** che ha trasmesso ai suoi discepoli l'importanza della formazione "pratica" specializzata soprattutto nell'ambito della neurochirurgia.

Il **Professor Giampaolo Cantore** ha evidenziato da sempre il **valore aggiunto della struttura di anatomia neurochirurgica a scopo didattico**. La peculiarità principale del **Centro di Medicina Necroscopica - Unità di Chirurgia Formativa** dell'IRCCS Neuromed è il suo inserimento all'interno della struttura ospedaliera.

Offrire una formazione dedicata ai colleghi neurochirurghi e chirurghi facendoli operare sul cadavere, illustrare allo specializzando come si studia un cervello e come si interagisce con un tumore cerebrale sono **"attimi dell'insegnamento pratico"** che faranno la differenza in sala operatoria quando **in gioco ci sarà la vita di pazienti**.

L'apprendimento, non soltanto teorico, è essenziale per la professione medica. Esercitarsi su parti anatomiche è fondamentale per acquisire la necessaria manualità e per evitare il più possibile di commettere errori. Importante esempio della dedizione dell'IRCCS Neuromed verso la Chirurgia Formativa Sperimentale è l'**articolo scientifico del 2007,** il primo lavoro dedicato a questo topic, degli autori Pichierri A., Frati A., **Cantore G.B.** pubblicato su ***"Neurosurg Rev (2009) 32:101–110"*** dal titolo ***"How to set up a microsurgical laboratory on small animal models: organization, techniques, and impact on residency training"***.

Dall'*abstract* dell'articolo si comprende la lungimiranza dei nostri studi: *"La formazione in microchirurgia è obbligatoria per la formazione ottimale dei neurochirurghi moderni. Anche se questa è una dichiarazione ampiamente riconosciuta e molte istituzioni in tutto il mondo praticano la formazione in laboratorio, di recente la letteratura non ha consigli e trucchi su come avviare un laboratorio di microchirurgia (quale sarebbe ad esempio un'anestesia conveniente e di che tipo di esercizi sono appropriati). Nell'articolo vi presentiamo la nostra esperienza di 16 corsi di formazione in microchirurgia attivati presso la nostra istituzione.*
Duecentoundici roditori sono stati sezionati. Descriveremo l'organizzazione del laboratorio e dei corsi di formazione e discuteremo il suo impatto pratico".

Neurosurg Rev (2009) 32:101–110
DOI 10.1007/s10143-008-0154-4

ORIGINAL ARTICLE

How to set up a microsurgical laboratory on small animal models: organization, techniques, and impact on residency training

A. Pichierri · A. Frati · A. Santoro · J. Lenzi · R. Delfini · L. Pannarale · E. Gaudio · G. D'Andrea · G. P. Cantore

Received: 1 December 2007 /Revised: 2 May 2008 /Accepted: 29 June 2008 / Published online: 12 September 2008

Abstract Microsurgical training is mandatory for the optimal education of modern neurosurgeons. Even though this is a widely acknowledged statement and a lot of institutions around the world practice training in laboratory, the recent literature lacks tip and tricks on how to start a laboratory from scratch, what would be a convenient anesthesia, and what kind of exercises are appropriate. We present our experience in 16 microsurgical training courses settled up at our institutions. Two hundred eleven rodents were dissected. We will describe the organization of the laboratory and of the training courses and we will discuss its practical impact on the residency program.

A. Pichierri · A. Santoro · J. Lenzi · R. Delfini
Neurosurgery I, DPT of Neurological Sciences,
"Sapienza" University of Rome,
Rome, Italy

A. Frati · G. P. Cantore
IRCCS Neuromed. Pozzilli (IS), DPT of Neurosurgery,
"Sapienza" University of Rome,
Rome, Italy

G. D'Andrea
Neurosurgery III "Sapienza", DPT of Neurological Sciences,
"Sapienza" University of Rome,
Rome, Italy

L. Pannarale · E. Gaudio
Institute of Normal Human Anatomy,
"Sapienza" University of Rome,
Rome, Italy

A. Pichierri (✉)
via Gian Bistolfi, 74 int.12,
00157 Rome, Italy
e-mail: angelopichierri@gmail.com

Keywords Microsurgery · Neurosurgery · Training · Laboratory · Techniques

Introduction

Donaghy et al. [14] have been the first to introduce microsurgery in the neurological surgery performing the first microsurgical middle cerebral artery endarterectomy in 1962. He settled up a laboratory for vivisection at the University of Vermont in 1948, with a total cost of 25 USD of that time (approximately 1,225.36 USD of our days!). He started using more and more accurate and small instruments, as well as 10.0 and 11.0 suture strands. Practicing, he modified camber and diameter of the needles. He instructed Dr. Littman on how to modify surgical microscopes to enhance their handling and to fit them to requirements of vascular surgeons. Many eminent American and European surgeons built up their skills in his laboratory [3, 19, 23]. Among them, there was Yasargil who developed the microsurgical techniques now unanimously considered the milestones of neurosurgery [3, 23].

Nowadays, the modern neurosurgery is based on microsurgery. During the last four decades, the use of the microscope led to an extraordinary reduction of both morbidity and mortality [3, 16, 23]. Therefore, a complete training for young microsurgeons should include laboratory sessions where they can perform microsurgical techniques until excellence [4, 6, 7, 9–13, 15, 24]. Nevertheless, a laboratory is the optimal environment where they can plan new techniques and procedures and use new materials.

Even though the utility of such a training is unquestioned, the recent literature lacks tip and tricks on how to start a laboratory from scratch and what kind of exercises

are appropriate to increase progressively the surgical skills. The primary target of this works lies in supplying the readers with a compendium which would allow every authorized institution to create a laboratory and to start a microsurgical training program. We will eventually discuss the impact of our courses on the professional training of our residents.

Materials and methods

We settled one laboratory for each Neurosurgical Institution of "Sapienza" University of Rome (laboratories A, B, and C). Rodents (rats and mice) have been used for vivisection. Laboratories A and B were both furnished with a stabularium and it was therefore possible to keep the animals alive in order to evaluate the efficacy of the vascular anastomoses (e.g., graft patency, absence of thromboses and stenoses of the treated vessels) with a second operation made generally after 48 h. In the third laboratory (laboratory C) the animals were sacrificed at the end of the sessions to allow our colleague anatomists to perform tracing of visceral organs for their experimental purposes.

Ethical issues and institutional authorization

We consulted a veterinarian for the choice of the drugs to be administered intraoperatively and postoperatively. The aim of the consultation was to assure immobilization and analgesia of the rodents during interventions and to provide an optimal state of absence of pain in the postoperative period.

The local ethical committee of our university is composed of a counsel, a biologist, a doctor of pharmacology, a doctor of medicine, and a veterinarian. It approved our program after the analysis of the following documents:

- A detailed description of the course, location, instrumentation, drugs, and materials;
- The origin of the rodents: our small animals all originated from the research laboratories of our Department of Histology. All the bureaucratic stuff had been already accomplished by our colleagues as it was necessary to allow them to perform their experiment.
- The purposes of the trainee and the practical impact on the residents' training

Laboratory

The room should be well ventilated because of the use of ethyl ether in the first phase of anesthesia; the table should be large enough to place all the instrumentation; optionally, an audio–video recording system is applied to the microscope allowing the tutor to follow the apprentice and to record the sessions; a stabularium should be collocated in a divided room with someone who deals with litters, cages, food, and postoperative drugs (Fig. 1).

Instrumentation and materials

We referred to a factory producing instruments for research on animals. These factories offer a good surgical instrumentation at lower prices in comparison with companies for human surgery.

Macroset includes a scalpel, two pairs of forceps, scissors, and cotton fioc®.

Microset comprises a pair of microscissors, one microscalped or sharp point, two pairs of microforceps (possibly with a variable width of the tip), and one vascular approximator. We have also two small straight clips, one clip applier and one microneedle holder, even if they are not essential for the sessions (Table 1).

Threads Threads included 3.0 monofilament–silk for skin and muscle, 4.0–6.0 monofilament for vessel ligatures, and 8.0–11.0 for microvascular sutures and anastomoses.

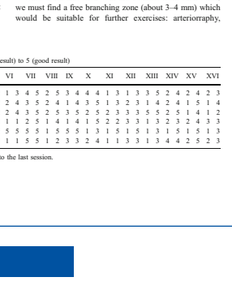


Fig. 1 The ideal laboratory should have a comfortable table with a microscope with an audio–video recording system. The trainee must correct the height of the seat to find the most comfortable position. The wrists must lay at the edge of the table: this greatly reduces intraoperative tremor shaking

Table 1 Average costs of instrumentation and items needed to start a microsurgical laboratory

Item	Cost (euros)
Microscope	6,000
Instrumentation (macrosets and microsets, two vascular clips and one approximator)	800
Threads	300
Phenobarbital 100mg/ml	2.2
Rodents	0
Laboratory rent	0 (settled inside the department)

Anesthetics Anesthetics used were phenobarbital, zolpidem tartrate, and xylazine chlorohydrate.

Microscope A Zeiss surgical microscope with adjustable focus and magnifying lens (to ×40) was used.

The instrumentation used for the dissections is similar to what we used for human microsurgery. For example, the temporary clamping of major vessels is performed with the same types of clips and clip appliers used in vascular microneurosurgery; microforceps and microscissors are very similar to the instruments used for blunt and sharp dissections on humans.

The 4.0–6.0 (occasionally 8.0 and 10.0) monofilament threads are used to legate the vessels; Prolene 8.0 and nylon 10.0 threads are used for sutures on vessels.

Anesthesia

The rodents are placed in a bell glass with ethyl-ether-soaked cotton wool. Once they fall asleep, two types of anesthesia can be administered:

For mice (100 g), intramuscular injection of 1 ml of a solution with zolpidem tartrate 10% and xylazine 6%; For rats (600 g), intraperitoneal injection of 1 ml of a solution with phenobarbital 50% strengthened with intramuscular injection of the same preparation. This kind of anesthesia takes about 30 min: after 15 min, to shorten the wait, a local infiltration with bupivacaine chlorohydrate 2% may be administered 5 min before skin incision.

Organization and rules

Every course was intended for one resident and lasted 1 month: it was subdivided in ten sessions for a total amount of 50 working hours. The sessions follow the workflow showed in Table 2.

All the residents attending our departments have been invited to join the sittings.

Table 2 Ideal workflow for training session

Sessions	Exercises
I session	(t) Dissection of abdominal compartment (T) Dissection of aorta–cava complex (T) Aortorraphy (t) Dissection of cervical region (t) Dissection of vasculonervous structures of the neck (t) Dissection of the thigh (t) Dissection of vasculonervous structures of the Scarpa's triangle (t) Neurolysis (T) Neurorrhaphy
II session	((t)Dissection of abdominal compartment (t) Dissection of aorta–cava complex (T) Terminoterminal anastomosis (t) Dissection of cervical region (t) Dissection of vasculonervous structures of the neck (t) Dissection of the thigh (t) Dissection of vasculonervous structures of the Scarpa's triangle (t) Neurolysis (t) Neurorrhaphy
III session	((t)Dissection of abdominal compartment (t) Dissection of aorta–cava complex (t) Aortorraphy (t) Dissection of the thigh (t) Dissection of vasculonervous structures of the Scarpa's triangle (t) Neurolysis (t) Neurorrhaphy
IV Session	((t)Dissection of abdominal compartment (t) Dissection of aorta–cava complex (t) Terminoterminal anastomosis (t) Dissection of cervical region (t) Dissection of vasculonervous structures of the neck (t) Arteriorraphy
V–VIII Sessions	The exercises can be combined as desired
IX–X Sessions	(t) Dissection of abdominal compartment (t) Dissection of aorta–cava complex (t) Creation of artificial aneurysm (t) Dissection of the thigh (t) Dissection of vasculonervous structures of the Scarpa's triangle (t) Neurorrhaphy or exercises on femoral artery

The dissection includes vessel's ligation procedures. The tutor performs and explains to the trainee the execution of some crucial exercises at the first sessions.
T tutor, *t* trainee

All the rodents came from other laboratories where they have been previously used for medical or pharmacological experimentations; all of them would be otherwise addressed to disposal.

At the beginning of every course, the apprentice was instructed on how to use the microscope (zooming, focusing, balancing), the scalpel (choice of the blade, cutting

angles), and the microsurgical instrumentation (position, support, tremor management).

We voluntarily suppressed the use of bipolar cautery to allow the operator both to perform a bloodless dissection, respecting the anatomy of the rodent, and to use vessel's ligation as a surgical exercise.

If the forecast sessions were not sufficient to reach a satisfactory result in terms of correctness and number of exercises, the course was prolonged for another 15 h (three sessions more).

Disposal of the animals

The major parts of the small animals are sacrificed at the end of the session to allow our colleague anatomists to inject vascular or bile systems with acrylic resin. In these cases, the rodents are left in the laboratory for a few days. The organs of interest are subsequently removed.

All the animals are addressed to a refrigerating room (−18°C). They are collected periodically by a disposal company as hazardous waste.

Assessment

Every trainee received an evaluation score from 1 to 5 for each of the following parameters (Table 3):

1. Intraoperative tremor shaking
2. Bleeding during dissection
3. Surgical technique of microsurgical ligatures and sutures
4. Effectiveness of the anastomoses
5. Intraoperative death of the rodent not related to anesthesiological pitfalls
6. Status of sutures and anastomoses after 48 h (in cases of stabulation)

Anatomical compartments

For dissections, we used the following anatomical models: abdominal, cervical, and thigh region.

Abdominal compartment

Skin incision is made along the linea alba (Fig. 2). The thin muscular wall together with the parietal peritoneum is cut with a 15-blade scalpel starting from the inferior aspect of the abdomen and exposing the urinary bladder inferiorly and the liver superiorly. A wider opening of the cavity would result in failure of the diaphragmatic contraction. Urinary bladder is emptied with an insulin syringe to widen the surgical field. Gut is displaced laterally; the descending colon, which lies on a median area, is separated from its mesentery to access the aorta–cava complex. The two ureters should be identified in transparency in the retroperitoneum: peristalsis may help their determination (Fig. 2a). Ureters must be preserved to prevent death due to hydronephrosis. The complex aorta–cava is then exposed and dissected away from the retroperitoneal fat (Fig. 2b). Abdominal aorta of a rat has a diameter of 1 to 3 mm (comparable to the diameter of the arteries of the circle of Willis). Aorta is covered from adventitia which also embraces inferior cava vein making the two vessels tenaciously adherent. So, the next step is the dissection of the aorta from the cava vein along the arterial interface, gently seizing the adventitia of the aorta with microtweezers and staying away from the vein which has a very fragile wall (Fig. 2c). A 3.0 thread is passed beneath the aorta, as soon as a hole is gained through the vessels. The wire is used to elevate the artery: this will stretch the adventitia between the aorta and cava, simplifying the dissection. Some collateral vessels lead off the abdominal aorta: inferior mesenteric artery is one of these. This artery is therefore ligated and cut to avoid annoying bleeding. Another important branch of the aorta of the rodents is the median sacral artery. It leaves the aorta from its posterior aspect with a main trunk and an early shoulder branch. The dimensions of the artery are consistent because it feeds the tail: nevertheless, this artery can be ligated (Fig. 2d).

Once aorta and cava vein are isolated from each other, we must find a free branching zone (about 3–4 mm) which would be suitable for further exercises: arteriorraphy,

Table 3 Individual assessment of the training: scores from 1 (poor result) to 5 (good result)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
Intraoperative tremor shaking	1	4	1	4	2	5	3	5	2	4	1	3	4	5	2	5	3	4	4	4	1	3	3	1	3	5	2	4	2	4	2	3
Bleeding during dissection	1	4	1	5	1	5	1	4	1	3	2	4	3	5	2	4	1	4	3	5	1	3	2	3	1	4	2	4	1	5	1	4
Microsurgical ligatures and sutures	1	3	2	5	2	5	1	4	2	4	2	4	3	5	2	5	3	5	2	5	2	5	2	3	3	3	5	5	2	5	1	4	1	2
Seal and pervicity of anastomoses	1	1	1	1	3	4	1	1	1	1	1	1	2	5	1	4	1	4	4	1	5	2	2	2	3	3	1	3	2	3	2	4	3	3
Intraoperative death	5	5	1	5	5	5	1	3	1	5	5	5	5	5	1	3	5	5	5	1	3	1	5	1	5	1	3	1	5	1	5	1	3	
Status of sutures after 48 h	1	1	1	1	1	3	1	1	1	1	1	1	5	5	1	2	3	3	2	4	1	1	1	3	3	1	1	3	4	4	2	5	2	3

The first score refers to the first session, the second result is related to the last session.

How to set up a microsurgical laboratory on small animal models: organization, techniques, and impact on residency training. Neurosurg Rev.

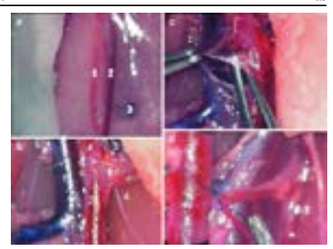


Fig. 2 Abdominal compartment: **a** The trainee must be used to identifying visceral and vascular structures as the ureters (*1*), the right genital vein (*2*) and the right iliolumbar vein (*3*). **b** The aorta is in a very tight relationship with the inferior cava vein and with the proximal portion of its afferent veins: inferior cava vein (*1*), aorta (*2*), left renal vein (*3*) and left genitofemoral nerve upon the psoas major muscle (*4*). **c** The adventitia and the connective tissue wrap the artery and make it adherent to the inferior cava vein and are similar in consistence and appearance to the arachnoid. **d** Ligation of the median sacral artery with its shoulder branch. This artery leaves the aorta from its posterior face and it has voluminous dimensions because it feeds the tail of the rat

terminoterminal, lateroterminal, and laterolateral anastomoses, bypass, and creation of artificial aneurysms.

Cervical district

The region slightly differs from human neck. Salivary glands and lymph nodes are more represented and widely occupy the subcutaneous tissue. Muscles are more stocky and bulky and do not allow a clear recognition of the classical anatomical landmarks and routes. The external jugular vein drains the major part of the blood from the head of the rodent. Hence, only a small internal jugular vein runs within the neurovascular axis of the neck nearby the carotid artery and the fragile vagus nerve.

In this region, the most important exercise consists of the dissection of the connective fascias of the neck to reach the anterior vertebral plain without interfering with the anatomic continuity of the muscular and vascular structures. Another important work is the dissection of the internal carotid artery from the surrounding structures (namely the vagus nerve and the internal jugular vein) and from its adventitia. Ligations and sutures are possible in this region too.

Thigh region

The Scarpa's triangle permits the performance of neurolyses and neurorrhaphies of the femoral nerve, dissections of the femoral artery, and arterial bypasses using the contralateral femoral artery (Fig. 3).

Exercises

Vessel ligation

The vessel of interest is isolated from surrounding structures. A small curve forceps is passed underneath the vessel. Two threads are passed under the vessel with the small forceps. The strands are fastened on two different points of the vessel with microsurgical techniques. Two forceps of different width are used to perform a knot: the wider forceps maintains the right wire. After the first loop is tied, the maneuver is repeated in a counterclockwise fashion. After three throws, the vessel is cut between the knots.

Vascular suture

This technique is used principally to perform the aortorraphy (see later). The vessel is freed from its adventitia and it is cut along its major axis for about 1 cm. The trainee can perform the suture using single stitches or with a running suture.

Single stitch The lumen of the vessel is inspected to be sure it was cut correctly. The endothelium appears as a sharp white layer. Equal bites of tissue should be taken on each margin of the vessel. One thread is looped around the forceps: it is of paramount importance to tie the knot having the other extremity of the thread directly in front of the forceps. This way, the thread can be easily grabbed (Fig. 5a). Do not hesitate to change the instruments stance in order to recognize this ideal position.

Fig. 3 Thigh region: **a** A frame of the dissection of the femoral artery away from the femoral vein. Only the connective tissue is seized with pliers to avoid damage to venous wall. **b** At the end of the dissection, the artery is completely freed from nerve and vein. In this case, the femoral vein was cut with a microscalpel in order to perform a laterolateral anastomosis with the adjacent artery. The proximal clip appears in the picture

Running suture Continuous sutures provide a more rapid and leak-proof closure than interrupted sutures because the tension along the suture strand is distributed evenly around the vessel's circumference. On the other hand, this technique is burdened of a greater the risk of stenoses: care must be taken to apply a firm tension, rather than tight tension, to avoid tissue strangulation. Furthermore, suture breakage could disrupt the entire line of a continuous suture.

Aortorraphy

A small piece of latex (cut from a glove) is inserted below the aorta, after isolating it from surrounding structures (Fig. 4). This maneuver allows a greater contrast between the vessel and the rest of the surgical field. The artery must be freed from its tunica adventitia. A clip approximator or two little straight vascular clips are placed: the proximal one is placed just after the origin of the inferior mesenteric artery; the distal clip is placed before the aortic bifurcation. Aorta is gently seized with pliers and a longitudinal incision is performed with a sharp point for about 1 cm. Traction and pressure applied on the vessel wall should be proportioned: excessive pressure will create pseudoaneurysms or even break the vessel. A traction on the vessel should be opposed to the pressure applied with the sharp point when the vessel is incised in order to obtain an accurate median incision without double borders. An interrupted or, alternatively, a running suture is performed using 9.0 or 10.0 threads.

Terminoterminal anastomosis

In this exercise the aorta, once prepared, is sectioned transversally (Fig. 5).

Running suture Two cardinal points are placed at 0° and 180°. Only the needleless extremity of the two threads is cut. In fact, we need both the needles to be attached to the threads in order to complete the suture along the posterior and anterior aspect of the borders. If we suture first the posterior borders, it will be easier to control the vessel being pervious during the suture of the anterior wall.

Interrupted suture Once the two cardinal points are posed, each thread is cut with one extremity being a little longer than usual: this will allow the manipulation and rotation of the vessel pulling the threads. The first stitches are placed between the posterior borders of the vessel, as explained above.

Fig. 4 Arteriorraphy with an interrupted suture

Fig. 5 **a** Artist's drawing depicting the technique of the terminoterminal anastomosis with the two stumps brought nearer with the aid of particular clips and with the application of the first cardinal stitch. **b** The final result of the exercise before removing the clips

Terminolateral anastomosis

Classical technique A median longitudinal aortorraphy is performed for about 3–4 mm. The graft could be obtained from the femoral artery, from the aorta of another rodent, or from the inferior cava vein. In the latter case, all the procedure is more challenging.

The graft should have the same diameter of the aortorraphy. The extremity of the graft can be cut in a flute-shaped fashion to widen the capacity of the anastomosis. Cardinal stitches are placed at 0°, 180°, 90°, and 270°. Other stitches are ligated among the cardinal points. A total of eight stitches is generally enough. Alternatively, a running suture can be performed.

Alternative technique Aortorraphy is performed only after the positioning of the first two cardinal points at 0° and 180° which are therefore placed on an integral arterial wall and without clips on the vessel. This alternative procedure is more difficult because some bleeding always occurs while the stitches are confectioned, but it allows the reduction of the clipping time. The next steps are identical to the technique previously described (Fig. 6).

Laterolateral anastomosis

The exercise is generally performed between inferior cava vein and aorta. The vessels are prepared as usual and freed from adventitia. A longitudinal paramedian incision is made on the vein and on the artery. Two cardinal stitches are placed to ligate the walls of the vessels at 90° and 270°. The suture continues with an interrupted or with a running suture. This exercise should be the last in the training course as it is the most difficult.

The suture of the artery with the vein with this laterolateral suture also configures the arteriovenous fistula (Fig. 7a).

Artificial aneurysm

Once the arteriovenous fistula has been created, two strong fastenings (4.0 threads) are placed on the inferior cava vein just above and below the laterolateral anastomosis with aorta. Arterial blood will pass turbulently in the saccular part of the vein which communicates with the artery. In minutes, the vein wall will slowly broaden creating an artificial aneurysm (Fig. 7b).

Neurorrhaphy

The exercise is performed after the dissection of the delicate femoral nerve away from the femoral artery and vein. There are a few simple rules to respect when a nerve is sutured: suture must be tensionless; the perineurium should not abut inside the stumps (somewhat like adventitia issues previously mentioned) and the thin vasa nervorum on each side should be rejoined: this will help to orientate and rotate the extremities correctly and reconstruct them with the original continuity.

Fig. 6 A bypass with an arterial graft confectioned with two terminolateral anastomoses

Fig. 7 **a** Laterolateral anastomoses between aorta and inferior cava vein with consequent arteriovenous fistulation; **b** creation of an artificial aneurysm

Results

The anesthetics used for the rodents permitted the obtainment of a deep anesthesia for several hours (mean of about 6 h for each dissection) without respiratory or cardiovascular pitfalls.

Sixteen residents joined the courses; 211 rodents (rats and mice) have been used. Fifteen residents declined the opportunity. Twelve trainees correctly performed all the expected procedures at the end of the course. Positional and postural tremors during the dissection were present in 13 out 16 residents (80%) but the major part of the trainees hugely reduced them after three sessions.

Abdominal compartment has been used during 135 dissections, 26 regarded the neck and 50 the thigh region.

Ligatures, simple microvascular sutures (single stitches or running sutures for aortorraphy), neurolyses, and neurorrhaphies have been performed by all the trainees without particular pitfalls.

The most complex exercises resulted to be:

1. The dissection of aorta from the inferior cava vein (135 rats). A laceration or an overly rupture of the vein happened in 37 procedures (27,4%). In seven of these cases (19%), the bleeding led the rodent to death.
2. The aortic bypass (39). Nine leaked blood after clip removal with the need of revision. At the end of the procedures, 32 were pervious, six significantly stenotic, and one occluded.
3. The creation of an arteriovenous fistula between aorta and inferior cava vein (36). Only 7/16 residents have been able to perform the procedure in the times and with the correct technique at the first time.

Discussion

Anesthesia

Once authorization, location, microscope, and instrumentation have been obtained, one of the main issues has been the anesthetic drugs and techniques.

Our knowledge about anesthesia and analgesia on small animals is based on two sources:

- The direct experience and knowledge of the researchers of the laboratories of our university;
- The complete and deep review present on the Internet at the following address: http://www.ahc.umn.edu/rar/anesthesia.html.

Indirect signs of pain have been primarily used in the evaluation of analgesia in the rodents. Intraoperatively, these criteria were essentially the absence of muscular contractions and the regularity of heart rate and respiratory function. Postoperatively, we based on the following criteria:

- Decreased activity
- Abnormal postures, hunched back, and muscle flaccidity or rigidity
- Poor grooming
- Decreased food or water consumption
- Decreased fecal or urine output
- Decrease or increase in pulse or respiratory rate
- Physical response to touch (withdrawal, lameness, abnormal aggression, abdominal splinting, increase in pulse or respiration)
- Self-aggression
- Photophobia
- Vomiting or diarrhea

Use of phenoburbital is common in neurosurgery. It is easily available and affordable. In the laboratory, it always guaranteed a prolonged and deep anesthesia without particular cardiovascular and respiratory issues. Other drugs are more difficult to obtain and prepare (urethane, sodium pentothal, zolpidem tartrate, xylazine chlorohydrate) and may cause, in our experience with rats, severe hemodynamic and respiratory decompensation which can lead the rat to death.

In case of stabulation, postoperative pain in the rodents was managed with use of nonsteroidal anti-inflammatory drug: for example, 0.7 mg/kg IM of ketorolac tromethamine, three times per day.

Compartments

It is well known that some tissues and organs of rats and mice share interesting similitude with human structures [2, 5]. Abdominal aorta of a rat is about 2 mm in diameter which is approximately the size of the vessels that lead off the circle of Willis; the adventitia which wraps the artery and which makes it adherent to the inferior cava vein is similar in consistence and appearance to the arachnoid.

There is no doubt that the carotid artery dissection is more affordable both for the lack of collateral vessels and for a less tight adherence with the small internal jugular vein and the vagus nerve. So, the cervical district should be chosen at the beginning of the course as it offers an easy way to perform straightaway the subsequent procedures on the artery.

The abdominal compartment is optimal to learn all the basics of microsurgery: how to distribute the pressure when mobilizing the mesentery or other visceral structures and how to manage vessels and nerves. A multitude of microsurgical procedures can be performed: blunt dissections of vessels and retroperitoneum, vascular ligations, and suturing. Moreover, the trainee must get used to identifying visceral and vascular structures (namely the ureters and the major collateral vessels of the cava vein and aorta).

Exercises

The dissection of aorta from the inferior cava vein is a difficult and demanding exercise. It requires patience, coordination, and delicate movements because the vein has a very fragile wall lacking the tunica media. In this phase, hemorrhages can easily occur (27.4% of dissected rats), can be hard to control and time-consuming, and may eventually result in death (19% of the bleedings). Therefore, the dissection of the adventitia must be carried out along the arterial side. Dissection of this structure is similar to the leptomeningeal dissection of cerebral vessels because the adventitia is very tight to the surrounding structures.

Cerebral arterial bypass are nowadays used for some specific diseases such as intracavernous aneurysms, tumors of the parasellar region, vascular reconstructions, and in a subgroup of patients hit by an ischemic stroke. In this case over the others, the correct execution of the technique requires great surgical skills and experience. Its perfect execution is of paramount importance for the final outcome. A failure of the procedure always leads to catastrophic results and often to the death of the patient [8, 17, 18, 20–22]. Our senior surgeons have performed the major number of cerebral bypass in Italy (115 procedures, unpublished data) and they are very skilled in vascular fixing techniques. They explained techniques and tips of the vascular sutures to the trainees (single stitch, cardinal points, running sutures, etc.).

The preliminary circumferential dissection of the artery and of the graft from their adventitia is very important for the correct execution of an anastomosis because the risk of stenoses and thromboses is greater if this tunica remains constrained among the stitches (Fig. 6).

The creation of an arteriovenous fistula between the aorta and the inferior vena cava has been the last exercise of the course. This is a very complex exercise and requires a fast and accurate dissection of the vessels and an extreme ability in the execution of sutures. This technique can be put in practice in other anatomical districts and in other animal models. It may also be useful for experimental purposes because it allows the testing of new materials or endovascular techniques.

Role of the laboratory on a resident's professional training

In Italy, surgical technique training takes place predominantly in the operating room and it is based on the relationship between the senior surgeon and his younger assistant. This method of transmission of the practical knowledge is similar to the way with which classical arts and handicraft have been handed on from father and son for centuries. Nonetheless, even if masters follow and instruct their apprentice about the correct techniques, the maxim: "You learn from your mistakes" has always been the strongest means of progression for artists and artisans. But, if in the arts a faulty result can be destroyed or replaced, in surgery, it is the patient who pays for a defective procedure. So, it is a moral and ethical need to find a way to shorten the learning curve of junior surgeons. This is even more true when we talk about microsurgery. Moreover, the laboratory offers the chance to practice without strict time limits, psychological pressures, and medicolegal responsibilities which can be derived from incidental mistakes. Stress, anxiety, hurry, and inexperience are some of the worst enemies for a microsurgeon. They cause inaccuracy, insecurity, and tremors which represent an absolute drawback to the execution of those delicate and precise movements mandatory in microsurgery. They eventually could stop any contingent initiative of the young surgeon. We can go over all those issues only with practice. All our trainees minimized those problems after three or four sessions in the laboratory.

This discourse could seem obvious and some English-speaking reader could think "You are a bit late, are you not?". Even if in the US impressive laboratories on human models have been created to simulate live surgery [1, 16], in Italy, it is almost impossible to prepare laboratories on human cadaveric specimens for the weighty legal restrictions foreseen by our laws [8]. Moreover, the overcomplicated bureaucracy and the poor public founds granted to

university and research often stop every attempt to set a laboratory up. We could settle our laboratories up only on asking as little as possible to institutions, using rodents already destined to be suppressed, and making the most of existing structures and instrumentations.

On the whole, all the participants were satisfied with the course and noticed a subjective improvement of their surgical skills. They were more firm and confident in the operating room and less anxious. All the trainees executed all the exercises foreseen by the course, testifying that even the most difficult exercises are more accessible with practice, regardless of the individual predispositions and deftness at the starting point. The senior surgeons too noted the improvements of the residents who attended the course.

Conclusions

Settling up a microsurgical laboratory on animal models in Italy is feasible and relatively cheap, if we succeed to go over the bureaucratic stuff, fixing things as best we can. Laboratory training is very useful for the learning process of young microsurgeons. Nonetheless, it would represent an outstanding medium for research in vascular surgery for senior surgeons too.

References

1. Aboud E, Al-Mefty O, Yasargil MG (2002) New laboratory model for neurosurgical training that simulates live surgery. J Neurosurg 97(6):1367–1372
2. Al-Mefty O, Yasargil MG (1999) The time in little rock. Neurosurgery 45(5):1019–1024
3. Akyurek M, Safak T, Ozteke C, Sargon M, Kecik A (2002) Dorsal penile vein as a new training model for microvenous anastomosis in rats. Ann Plast Surg 49(3):280–284
4. Benjamin L (2005) Selection, teaching and training in ophthalmology. Clin Experiment Ophthalmol 33(5):524–530
5. Blain B, Zhang F, Jones M, Richards L, Fischer K, et al (2001) Vascular grafts in the rat model: an anatomic study. Microsurgery 21(3):80–83
6. Brath E, Nemeth N, Papp L, Bekesi L, Varga S, Toth A, Miko I, Furka I (2005) Teaching of microsurgery—in service of research and clinical practice. Magy Seb 58(2):111–115
7. Cabrol C, Gilbert A (1991) Training of microsurgery in the laboratory of the Hopitaux de Paris. Chirurgie 117(2):145–148
8. Cantore GP, Santoro A (1998) Treatment of aneurysms unsuitable for clipping or endovascular therapy. J Neurosurg Sci 42(1 Suppl 1):71–75
9. Di Cataldo A Trombatore G Giraldo R, Rodolico M, Sorbello M, Li Destri G (2001) Experimental research and surgery: why, how, and when? Microsurgery 21(4):118–120
10. Furka I, Brath E, Nemeth N, Miko I (2006) Learning microsurgical suturing and knotting techniques: comparative data. Microsurgery 26(1):4–7
11. Grober ED, Hamstra SJ, Wanzel KR, Reznick RK, Matsumoto ED, Sidhu RS, Jarvi KA (2004) Laboratory based training in urological microsurgery with bench model simulators: a randomized controlled trial evaluating the durability of technical skill. J Urol 172(1):378–381
12. Hernesniemi J, Niemela M, Karatas A, Kivipelto L, Ishii K et al (2005) Some collected principles of microneurosurgery: simple and fast, while preserving normal anatomy: a review. Surg Neurol 64(3):195–200
13. Hui KC, Zhang F, Shaw WW, Taylor A, Komorowska-Timek E, Lineaweaver WC (2002) Assessment of the patency of microvascular venous anastomosis. J Reconstr Microsurg 18(2):111–114
14. Jacobson JH, Wallman LJ, Schumacher GA, Flanagan M, Suarez EL, Donaghy RMP (1992) Microsurgery as an aid to middle cerebral artery endarterectomy. Microsurgery 13(3):112–117
15. Klein I, Stoger U, Timmermann W, Thiede A, Gassel HJ (2003) Microsurgical training course for clinicians and scientists at a German University hospital: a 10-year experience. Microsurgery 23(5):461–465
16. Lee S, Frank DH, Choi SY (1983) Historical review of small and microvascular vessel surgery. Ann Plast Surg 11(1):53–62
17. Newell DW, Vilela MD (2004) Superficial temporal artery to middle cerebral artery bypass. Neurosurgery 54(6):1441–1448
18. Newell DW (2003) Superficial temporal artery to middle cerebral artery bypass. Skull Base 15(2):133–141
19. Post KD (2006) Leonard I Malis (1919–2005). Neurosurgery 58(1 Suppl):ONS–E187
20. Santoro A, Guidetti G, Dazzi M, Cantore G (1999) Long saphenous-vein grafts for extracranial and intracranial internal carotid aneurysms amenable neither to clipping nor to endovascular treatment. J Neurosurg Sci 43(4):237–250
21. Spetzler RF, Fukushima T, Martin N, Zabramski JM (1990) Petrous carotid-to-intradural carotid saphenous vein graft for intracavernous giant aneurysm, tumor, and occlusive cerebrovascular disease. J Neurosurg 73(4):496–501
22. Srinivasan J, Ellenbogen RG, Ivnitr GW, Newell DW (2001) Techniques for cerebral bypass: practical laboratory for microvascular anastomosis. Neurosurg Clin N Am 12(3):509–517, VIII
23. Yasargil MG (1999) A legacy of microneurosurgery: memoirs, lessons, and axioms. Neurosurgery 45(5):1025–1092
24. Yasargil MG (2005) From the microsurgical laboratory to the operating theatre. ACTA Neurochir (Wien) 147(5):465–468

Comments

Boris Krischek, Marcos Tatagiba, Tübingen, Germany

The authors Pichierri et al. nicely describe their experience of microsurgical training courses held within their department. Now more than ever, it is of utmost importance that residents become accustomed to the handling of microsurgical instruments at the earliest stage possible. There is hardly any better or more cost-efficient means for a trainee than to practice his technical skills under the supervision of an in-house experienced surgeon in the surroundings of a microsurgical laboratory and to eventually be assessed by him.

In this article, different possible tasks and techniques in the according anatomical regions are meticulously described in a fathomable fashion including possible performance assessment methods. Every major neurosurgical department should strive to offer such a possibility to their trainees and to give them the opportunity to train their microsurgical skills in such a "real operation" simulating atmosphere.

How to set up a microsurgical laboratory on small animal models: organization, techniques, and impact on residency training. Neurosurg Rev.

Alta formazione per gli esperti di oggi e quelli di domani

Le parti anatomiche di studio, sulle quali si effettuano le esercitazioni sono importate dagli Stati Uniti, dove vengono conservate e preparate per la dissezione tramite enti ai quali, nel rispetto di uno specifico codice etico, i volontari scelgono di donare il proprio corpo dopo la morte, proprio per porlo al servizio del progresso scientifico. In Italia non esisteva ancora una legislazione che consentisse l'utilizzo dei corpi di coloro che desideravano donare le proprie spoglie alla ricerca scientifica, quindi i nostri chirurghi hanno sempre dovuto recarsi all'estero per sperimentare le tecniche d'intervento: trasferte i cui costi ricadono anche sul Servizio Sanitario Nazionale.

Avere la possibilità di usufruire di un centro italiano di alta formazione sul cadavere, dove è possibile apprendere e simultaneamente mettere in atto manovre di chirurgia su preparato anatomico all'interno di un ospedale, è una grande opportunità non solo per le nuove generazioni di chirurghi ma anche per l'aggiornamento di professionisti già affermati.

Il **Centro di Medicina Necroscopica - Unità di Chirurgia Formativa** è pronto ad accogliere diversi operatori, è stata infatti pensata come una struttura aperta a tutti i chirurghi che possono accedere ai corsi di alta formazione. Vi sono diverse postazioni, su ciascuna di esse possono posizionarsi 2-3 persone a seconda del livello del corso. Il relatore dal tavolo master d'insegnamento è collegato attraverso un impianto audio-video a tutte le postazioni, le quali sono dotate di telecamere, consentendo una visione non solo in tempo reale ma anche molto dettagliata delle tecniche d'intervento. Attraverso un approccio 'step by step' ciascuna postazione è inoltre seguita da un tutor, chirurgo esperto dell'equipe di formazione, che verifica e supporta l'operato dei corsisti, intervenendo, se necessario, senza interferire con l'attività degli altri discenti.

L'obiettivo primario è dunque la riduzione del gap tra l'apprendimento delle tecniche d'intervento e la loro applicazione in sala operatoria.

A rendere più complesso l'apprendimento delle tecniche chirurgiche, infatti, interviene oggi una crescente mancanza di tempo a disposizione degli operatori. I corsi sono pensati, nel rispetto delle norme, proprio in un'ottica di ottimizzazione del tempo a disposizione: in 24 ore un chirurgo può acquisire le nuove tecniche d'intervento, praticarle in prima persona e osservarle in sala operatoria applicate direttamente sul paziente. Si tratta di una formazione completa, che per la prima volta i chirurghi italiani possono ricevere nel proprio paese senza doversi recare all'estero.

Organigramma
Centro di Medicina Necroscopica


NEUROMED
CENTRO DI MEDICINA NECROSCOPICA
L'anatomia è il destino.

I.R.C.C.S. NEUROMED

Ospedale
Via Atinense 18 - 86077 Pozzilli (IS)
Tel. +39 0865.9291
CUP +39 0865.929600 anche su WhatsApp
prenotazioni@neuromed.it

Centro Ricerche - Parco Tecnologico
Via dell'Elettronica - 86077 Pozzilli (IS)
Tel. +39 0865.915321
direzionescientifica@neuromed.it

Neurobiotech - Polo di Ricerca e Innovazione
Viale Thomas Alva Edison - 81100 Caserta
Tel. +39 0823.1548814
www.neurobiotech.it

Polo Didattico
Via dell'Elettronica - 86077 Pozzilli (IS)
Tel. +39 0865.915408
segreteriapolodidattico@neuromed.it

www.neuromed.it