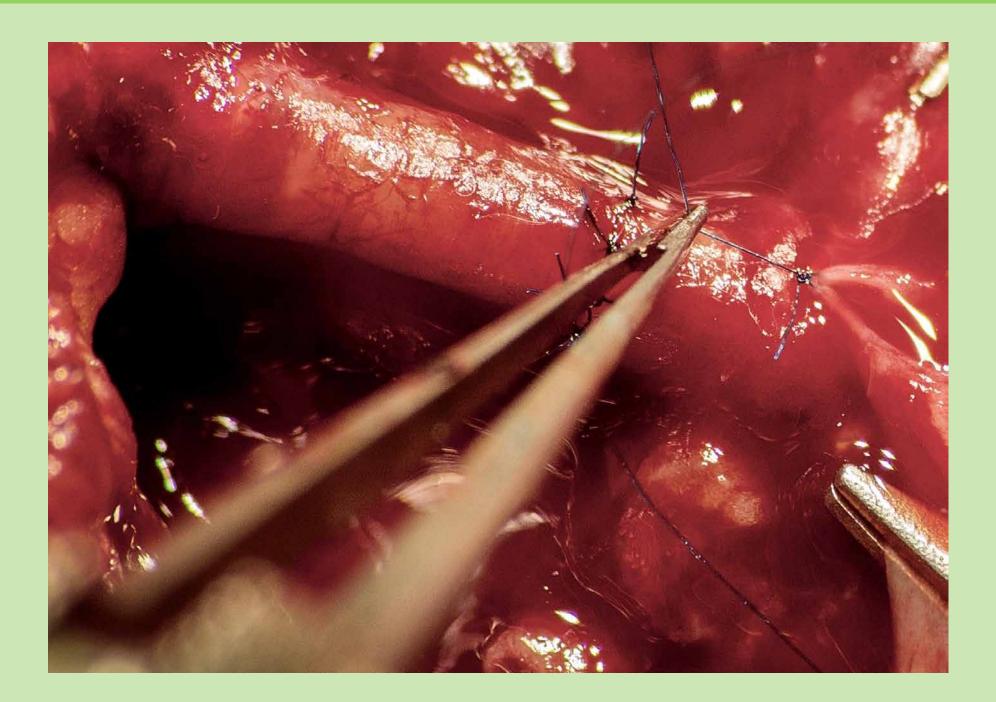
Microsurgical Skills

A Handbook of Experimental Microsurgical Techniques



Pablo Valle - Michel Chammas

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A handbook of experimental microsurgery techniques

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Dedication

To my children

To my wife for standing by me in every adventure

To my family for helping me get started

To those who taught me expecting nothing in return

To those who have given me the opportunity to become a better professional

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Preface

Whoever wishes to adopt microsurgery as a technique within their therapeutic repertoire should know that it demands skills that develop in the microsurgery laboratory. This handbook intends to aid in the acquisition and development of those skills necessary to perform a microsurgical procedure of excellence.

Keeping up with the changes observed in educational processes, this guide uses explanatory videos in all the techniques described making the reading of the handbook more dynamic and provides unequaled and detailed descriptions of each technique, through the tips the author offers in the different gestures.

The techniques introduced increase in complexity, ranging from artificial models to free flap making in live models. The Handbook begins with simple exercises and leads you through complex practices so that the reader gains the necessary skills and abilities progressively.

This handbook is intended for human and animal health professionals of different areas. Therefore, it can be used by veterinarians, dentists and surgeons of different specialties. This paper aims at coping with the lack of teachers in the microsurgery laboratories, which hinders good training, and can be used as reference material for various activities throughout the microsurgical learning process at university or for individual learning.

Pablo Valle, MD



Pour tous ceux qui portent un intérêt réel et passionné à la microchirurgie, jeunes en formation ou praticiens chevronnés et transmetteurs de savoir, la réalisation de Pablo Valle vaut vraiment un détour attentif et prolongé. Pablo Valle qui est chirurgien orthopédiste à Cordoba, Argentine, a fait, il y a quelques années, l'effort d'une formation complémentaire en France, centrée sur la microchirurgie et la chirurgie de la main. Il a obtenu les diplômes les plus réputés des Universités Montpellier et Paris. Surtout il a su tirer toutes les leçons des pièges techniques que recèle le geste microchirurgical. Mieux: poussé par un instinct pédagogique hors norme il a entrepris de consigner son expérience dans un ouvrage didactique présentant les notions essentielles de la technique microchirurgicale. Le résultat est là sous une forme qui emprunte aux nouvelles technologies de la communication : un e-Book qui réussit le tour de force d'alterner de façon harmonieuse l'enchaînement dynamique des gestes à accomplir, notamment pour réaliser une micro-anastomose vasculaire, et des schémas destinés à expliciter des difficultés particulières.

Le souci qui transparait dans cette façon d'aborder l'apprentissage d'un savoir faire pratique est plus profond qu'il n'y paraît. En effet, les schémas qui complètent le film technique ne sont pas de simples arrêts sur image. A l'instar des traditionnels manuels livresques de technique chirurgicale, les schémas de Pablo Valle condensent une séquence gestuelle que l'esprit appréhende intuitivement.

Par un étrange paradoxe qui est le signe de l'excellence, c'est l'animation du film qui expose l'analyse des gestes et ce sont les dessins soigneusement choisis qui offrent la synthèse. Cette heureuse et singulière association de genres est éclairante.

Assurément, au delà de l'enseignement de la gestuelle microchirurgicale, Pablo Valle a mis en scène une technique pédagogique qui mérite d'être transposée à d'autres domaines. De cela nous lui sommes redevables.

Alain C Masquelet

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Foreword

For all those who are really interested in and passionate about microsurgery, whether young surgeons in training or experienced practitioners and bearers of knowledge, this work by Pablo Valle is really worth a long, careful look.

Pablo Valle works as an orthopedic surgeon in Cordoba, Argentina. A few years ago he made a great effort and underwent further training in microsurgery and hand surgery in France. He was awarded prestigious diplomas from the Universities of Montpellier and Paris.

During this training, he managed to learn the technical subtleties to better face the technical difficulties that the microsurgical gesture holds. Even better, encouraged by an extraordinary pedagogical instinct, he undertook to document his experience in an educational work that puts forward essential notions of the microsurgical technique.

Making use of the new information technologies, we hereby present the result of such a process; an e-book in which Pablo has managed to smoothly present the dynamic sequence of gestures to be performed, especially during vascular microanastomosis, and in which he incorporates diagrams to put forward possible difficulties.

The author's concern regarding the teaching of practical skills is far deeper than it seems. Therefore, the diagrams that support the technical videos are not simply still images.

Just like the traditional surgical techniques texts, Pablo Valle's descriptions summarize a sequence of surgical gestures that are learnt intuitively and by a rare paradox that reflects excellence, the films depict the analysis of the gestures and the carefully selected drawings offer the synthesis. This fortunate and particular association of resources is enlightening.

Indeed, beyond the teaching of microsurgical gestures, Pablo Valle has come up with a pedagogical approach which deserves to be extrapolated to other domains. We can be extremely grateful to him for that.

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Introduction

Microsurgery is an area of general surgery which requires visual magnification to perform precision procedures.

Microsurgery's boom goes back to the second half of the twentieth century due to:

- Technological advances
- Surgical instruments
- Means of magnification (surgical magnifiers and microscope)
- The spread of microsurgical techniques training centers
- The increase in the success of surgical procedures.

Nowadays, microsurgery is one more resource available in the therapeutic repertoire and is used in different specialties involving human and animal health.

The learning of microsurgery has to occur in the lab and training is a must before it is clinically applied.

This handbook aims at providing guidance in the learning of microsurgery laboratory techniques. We will begin by explaining basic procedures and later deal with more complex ones. Said techniques will be described step by step and accompanied by explanatory videos to support the learning process.

There are countless microsurgical techniques. Here we analyze those that we consider necessary to learn: microsurgical dissection; end-to-end and end-to-side arterial and venous suture; vein grafts and bypasses use; flap manipulation; and anastomosis techniques in vessels of different sizes. Thus, the trainee will become capable of facing technical problems arising in a given microsurgical procedure.

We will begin with basic procedures in artificial models. It is not advisable to start with live models until proper handle of microsurgical instruments and the microscope.

To achieve a high rate of success in anastomosis, between 30 to 45 in lab microsurgical procedures should be performed, with some degree of continuity between them to maintain the acquired habit. The procedures should have a sensible length of 3 or 4 hours maximum, with a pause every hour or every two hours. Full-day procedures are not recommended since fatigue is a negative factor in microsurgery. There are many typical recommendations when performing microsurgical procedures such as: being rested, not drinking coffee or caffeinated beverages, avoiding strength sports, tobacco, stress. All of them are important, only that some are hardly compatible with the life of a trainee. A key recommendation, in our experience, is to keep motivation up. Motivation is essential and should not cave in to frustration, which usually comes when practice on live models starts.

It should be highlighted that the development and up keeping of microsurgery training centers is expensive. Therefore, operator awareness is necessary to avoid excessive costs and delicate and expensive instrument damage.

Microscope

Probably, the most important factor in microsurgery is to "see correctly". Therefore, learning how to use the microscope properly is of utmost importance.

First, we should be in a comfortable and stable working position. That is to say, back straight, lower limb joints flexed 90° and forearms and ulnar edge of the hands on the table since, for greater accuracy and less tremor, movement should occur only in the upper limbs end (*Figure N°1*).

We must become familiar with the microscope. For this reason we describe 4 elements you should handle well:

- Light. Usually generated by a 75-100 watt lamp.
- Lens. It will determine the focal length. That is to say, the distance between the microscope and the surgical field, which is generally of 200mm or 250mm.
- Eyepieces. They are the basis of magnification. The most widely used are 10x, 16x, 20x and 40x. Please note these numbers do not correspond to real magnification.

 Assemblage. There are many types of assemblage: ceiling, floor, table or wall. The wall and table ones are the most used in the lab and are manually adjusted.

To correctly adjust the microscope, it is necessary to follow some basic steps before starting any lab procedure and after having found a comfortable position at the working table:

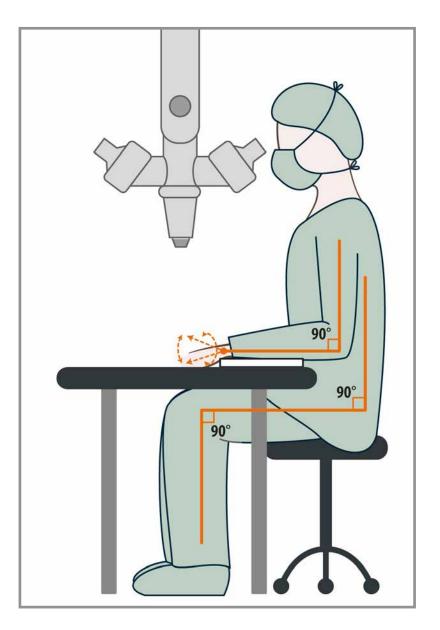


Figure N° 1: Proper working position

- 1. Turn on the lights.
- 2. Check that the eyepiece focal point is in 0 for both eyepieces. Place any instrument on the table under the light of the microscope to perform the adjustment. We recommend using major magnification for adjustment, for example 20x.
- 3. It is not advisable to be in direct contact with the eyepieces. It is suggested to be 10mm apart approximately.
- 4. Adjust first with one eye, using the zoom and the eyepiece focal point, until good picture is reached.

- 5. Do the same with the other eye, just modifying the eyepiece focal point.
- 6. Finally, regulate interocular distance, which depends on interpupillary distance, until a single image is attained, avoiding diplopia.

Operators who wear glasses may keep or lose them depending on the degree of their condition, which may be replaced by the microscope or not.

Surgical instruments

When doing a surgical procedure, there are macro and micro instruments involved. The macro-surgical instruments are used at the beginning and end of each procedure, that is to say, at surgery start and closure. Micro-surgical instruments should not be used in these moments because they would only cause damage to the instruments themselves and their loss of precision.

The basic macro surgical instruments are the following (*Figure* $N^{\circ}2$):

- Scalpel (N°15 or 23)
- forceps with dissecting teeth (Adson)
- dissecting scissors (blunt tips)
- strong scissors (Mayo)
- needle holder



Figure N° 2: Basic macro surgical instruments

• retractors (small self-retaining).

The micro surgical instruments should always be handled with special care by the operator, avoiding impact or rough handling. They should be used under magnification.

The basic micro surgical instruments are the following (*Figure N°3*):

- Dumont N°.3-like forceps: They come with blunt or sharp tips. Preferably, we will use the blunt tipped to avoid causing damage during blood vessels handling and dissection.
- Sharp ends N°5 forceps: They are necessary for adventicectomy and for performing small size vessels sutures.
- Dissection scissors: ideally curve and blunt tipped.
- Needle holder: A curved tip needle holder is recommended. We use an O'brien-like needle holder because its low weight and easy handling make it convenient when starting microsurgery training. We do not recommend using a breech block needle holder. Ikutalike needle holders are very functional because their round handle allows precision in twisting movements; but it is a bit heavier.
- Clamps: They must be easy to handle and atraumatic. There are several types of vascular clamps:

- Fixed pressure clamps: have the disadvantage of losing closure pressure with use and, depending on the diameter of the vessels, it is necessary to have different clamps.
- Variable pressure clamps: rely on operator regulated pressure so some degree of experience is needed to avoid damaging the vessels.

These clamps may be single or double. As we will see later on when developing the techniques, they have different uses, depending on the procedure to perform.

 Bipolar forceps. Although we must learn to handle it, we do not recommend its use in lab practice. We suggest systematic vessel ligation, which will give us certainty by reducing risk of errors and more practice in knot tying and in microsurgical vessel manipulation. It is important to mention that for comfortable handling, 13cm long instruments are recommended. The quality of the instruments is essential and it is directly related to its precision and durability. These surgical instruments are costly and require careful maintenance.

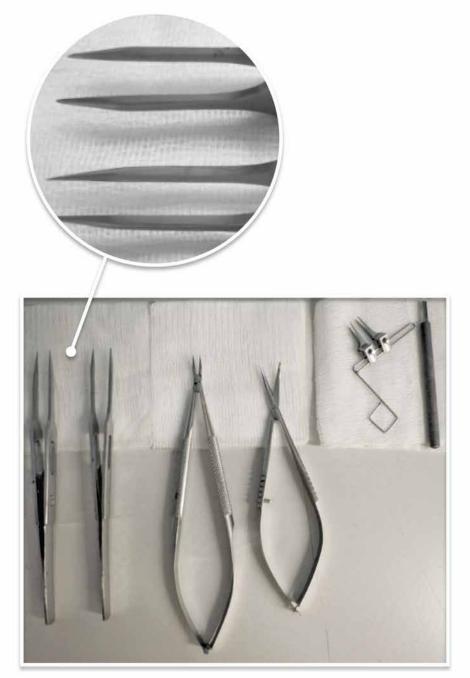


Figure N° 3: Basic micro surgical instruments

Suture material

Generally, non absorbable monofilament nylon is used in the lab. Threads come in different diameters and the choice will depend on the vessel to anastomise.

To make it the least traumatic, in vascular microsurgery curved needles with a 3/8 needle circle of 3 or 4 mm and conical tip are used.

Generally we use 8/0 or 9/0 threads for ligation; and 10/0 or 11/0 for sutures. The smaller the needle and thread, the more difficult their handling. In most of the lab procedures videos the 10/0 thread is used to provide better visibility. The table below may serve as reference for thread choice depending on vessel diameter.

Vessel diameter	Thread reference
> de 2mm	9/0
1 mm a 2 mm	10/0
< de 1mm	11/0

2 Initial steps in microsurgery procedures

The first thing to bear in mind is the position of the hands. Hands must be in writing position (*Figure* $N^{\circ}4$), i.e. forearm and ulnar edge resting on the table. Instruments should be held between the thumb and index finger. The middle finger (the lower component of the digital tripod holding the instrument) rests on the working surface, directly or through the ring finger (*Figure* $N^{\circ}5$). Although this position is essential when starting, there are techniques in which it is impossible, mainly in clinical practice. With further training we will acquire the ability to adapt to other positions more freely. Only when

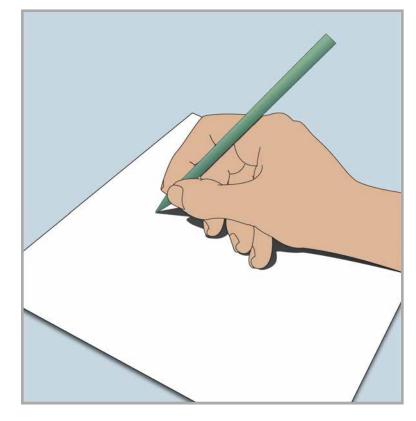


Figure Nº 4: Writing position

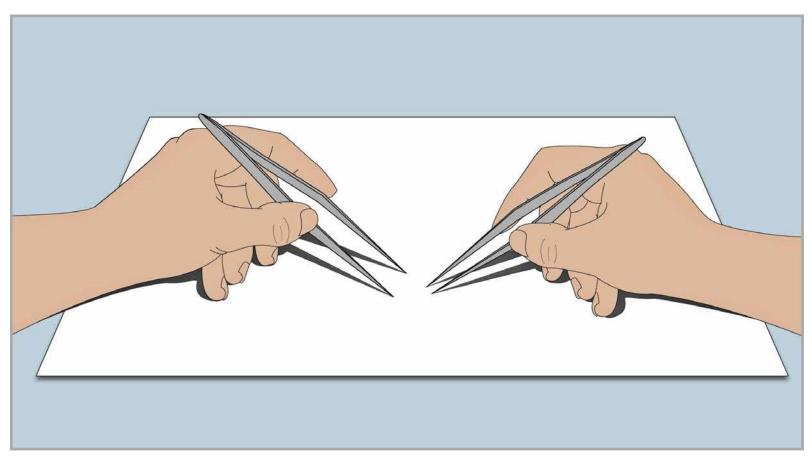


Figure N° 5: Bimanual position

our working position is the correct one and we have proper vision through the microscope must we begin to manipulate the thread and small needle. We recommend getting hold of the thread with the left-hand forceps to place the needle in the desired position in the area, aiding ourselves with surrounding tissues, and grasping it by its midpoint with the righthand needle holder (*Video* $N^{\circ}1$). It is important to avoid tension between needle and thread; otherwise, we will tear the crimp between them. The correct manipulation of the needle is critical for a good angle when making the stitches. Ideally, the tip of the needle should be parallel to the vessel longitudinal plane, which will reduce the risk of transfixiating stitches and allow for a more comfortable working position thereby decreasing unwanted movements (tremors).





Exercises on artificial models

When starting micro surgical training, it is suggested to come up with an easy and inexpensive artificial model to practise needle and thread manipulation and main knots. Such is the case of simply a piece of glove fixed peripherally on a surface, ideally not rigid, like a piece of EVA foam (*Figure N°6*).

To begin with, we will do a longitudinal incision on this artificial model that runs from top-left to bottom-right. First, we will practise passing the needle through and tying knots. At this point we can use 8/0 or 9/0 thread, which are easier to manipulate than 10/0. To pass the needle through, we must aid ourselves with the forceps in our left hand, always trying to make smooth movements and to be the least traumatic so that later we can be atraumatic with live models, avoiding damage to the intima of the vessels and thrombosis. To make the first pass, introduce the forceps into the "opening" of the model and pass the needle through the tips of the forceps. Then remove the needle (it is recommended to avoid making stitches in a single step to reduce the risk of transfixiating stitches). To pass the stitch through the second edge, also aid yourself with the forceps but only as countersupport. It is important that the stitches have been made at the same distance from the edge; said distance should be

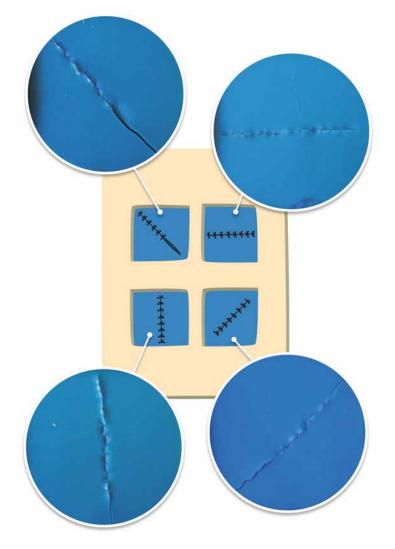


Figure N° 6: Artificial model to practise on

approximately twice the width of the vessel wall.

Once the stitch has been made, pull from the thread until leaving only an end. It is advisable that this end is not too long, as this would require larger movements when tying the knot. We should always place the needle within view, so as not to waste time looking for it to make the next move.

There are several knot tying techniques. What should be kept in mind is that flat knots must be tied, that they should be blocked and that three knots are enough. We recommend tying simple knots blocked in threes. In clinical practice, we are sometimes forced to start with a double knot when suturing a vessel or nerve under some degree of tension, but this should be exceptional as suture under tension is not recommended. In *Video N°2* you can observe the knot tying technique as used by the author, in which the change of pole allows for knot blocking and for tying without crossing the forceps, generating smaller amplitude more controlled movements.

A common mistake is to tie the knots too tight. Knots should be tightened under visual control and not under tactile sensitivity as when suturing the skin or other more resistant tissue. It is hard to sense in the hands the tension applied to the suture and usually when we feel it is because the knot is too tight. This is particularly true for the first two knots; the third one can be tied a little tighter to reduce the risk of the knot getting untied.

In this model, we must pay attention to the distance between the stitches. We start with one stitch per millimeter and then two stitches per millimeter, approximately. It is also suggested to start with slight magnification and then move on to higher magnification to perfect movement and microscope handling. Once you have made enough stitches in this plane, rotate the model anti-clockwise and place the incision in right-left direction (horizontal), then place it in top-bottom direction (vertical) and finally in a top-right to bottom-left direction. This will increase



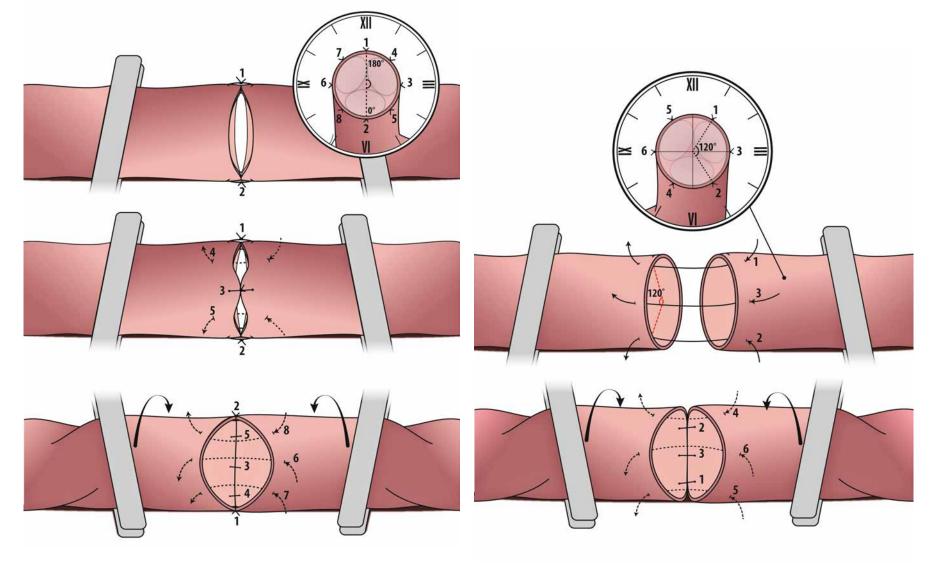
the complexity of stitch making and will give us different plane needle handling practice (*Video N°2*).

Now, closer to the shape of a vessel, we will practise suture in a silicone tube. We will try to go through all the steps that will later be followed in the anastomosis of live model vessels. First, place the double clamp, which should be as open as possible so that we have a comfortable and spacious working area. In the artificial model this is not a problem, but in a live model the opening of the double clamp will depend on our dissection and exposure of the vessel to be sutured. Therefore, dissection is a key moment. While in the artificial model it has no importance whatsoever, in the live model the double clamp should always be placed

in the direction of the flow. That is to say, first close proximal clamp to flow direction and to withdraw it do so in the opposite direction. This is particularly true for arteries and is less important for veins, as they operate at lower pressure.

There are many end-to-end anastomosis techniques. The main ones are:

- Symmetric bi-angulation (lkuta) (*Figure* N°7).
- Asymmetric bi-angulation (Cobbet) (Figure N°8).
- Oblique symmetric bi-angulation (Oschimura) (*Figure N°9*).
- Technique without turning over anastomosis, stitch by stitch (Nathan) (*Figure N°10*).







These techniques can also be applied, in terms of their concept, for end-to-side anastomosis.

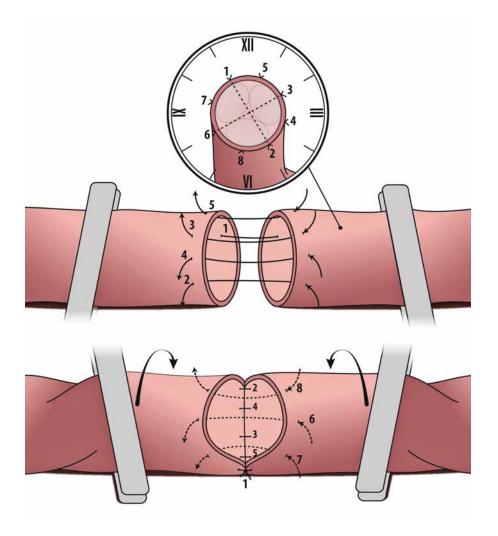


Figure N° 9: Oblique symmetric bi-angulation

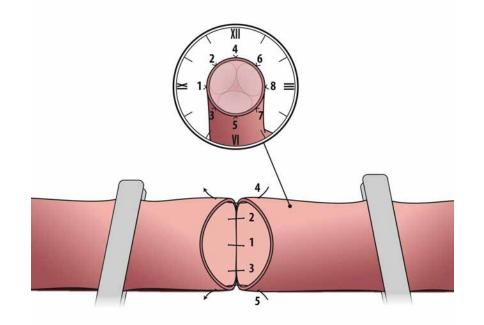


Figure N° 10: Stitch to stitch technique (Nathan)

We will use symmetric bi-angulation almost exclusively, unless the procedure does not allow for it. This technique can also be used in end-to-side anastomoses. We suggest adopting this technique to follow the handbook, but remember that once you master this technique you will be able to choose the one you wish for and to move from one technique to another with no difficulty. Changing the suturing technique for each training exercise may make the learning process difficult and frustrating.

We will also describe the suturing technique when the clamp cannot be turned over, stitch to stitch, for micro surgical techniques that require so.

When performing anastomosis with the symmetric bi-angulation technique, the first two stitches are the most difficult ones and we must devote the necessary time for their placing to be the correct one. This will save time later when making the remaining stitches. The first stitch must be at the upper end of the vessel (180° or 12 o'clock position) and the second stitch at the lower end (0° or 6 o'clock). Then, proceed to completely suture the anterior wall of the vessel. Turn over the double clamp to access the posterior wall. Control suture of the anterior wall from within the vessel and proceed to suture the posterior wall (*Figure N°7*). Remove the clamp in reverse direction as placed, i.e., first the distal clamp to flow direction (Video N°3).

We should not advance to working on live models unless we have achieved good mastery of these basic techniques. Moving

Video N°3: Exe©cise on silicone tube

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from artificial models to rats is usually difficult. Therefore, we should not hurry and should only do it when we have achieved good handling of microsurgical instruments and make stitches and knots easily. As an intermediate step we can perform anastomosis in cadaveric models. For this purpose we can use chicken wings or thighs, which can be easily acquired. Chicken wings or thighs may be used as an initial model for basic techniques too. This intermediate step will familiarize you with tissue firmness of live models, honing the skills acquired in the exercises on artificial models. (*video N°4*).

Video Nº4: Exercise on cadaver©c model. Chicken thighs.

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Microsurgical techniques in rats

Rat manipulation should be careful and respectful. Rats raised for this purpose should be used and should be manipulated in quiet noise-free environments.

Anesthesia techniques are beyond the scope of this handbook, but it is important to mention that all the techniques herein described can be performed with parenteral sedation. Sometimes it may be necessary to use anesthesia, depending on how long the technique takes and on room and animal temperature, among other factors. It is important to monitor the rat permanently; its breathing rate and heart rate, to prevent complications and to complement with anesthesia if necessary so as to avoid unwanted rat movement that can damage our work and cause animal suffering.

All the techniques herein described will be divided into basic steps which will be repeated. These steps are the following:

- Macroscopic dissection.
- Microscopic dissection.
- Clamping.
- Suture or anastomosis.

- Suture control.
- Closure.

For more complex techniques some steps are added to describe graft or recipient site preparation, for example.

Each step is of fundamental importance. The complexity of the different techniques is not due to anastomosis itself but to dissection, graft grasping, flap transfer, and so on. Often, failure in more complex techniques depends not only on anastomosis but also on flap handling, for instance.

The techniques described are the following:

- 1. End-to-end femoral artery and vein anastomosis.
- 2. End-to-end aortic anastomosis.
- 3. End-to-end carotid and jugular vein anastomosis.
- 4. End-to-end caudal artery anastomosis.
- 5. Carotid artery with jugular vein bypass.
- 6. Carotid artery-jugular vein fistula.
- 7. Femoral artery with the epigastric vein graft.

8. Inguinal flap

9. Other techniques.

- in situ.
- to the opposite side.
- to neck.

Femoral artery and femoral vein anastomosis

In this exercise we will perform anastomosis on a 1mm vessel approximately, although this may vary depending on the size of the rat and its anatomy.

It is important to understand that each step is essential to achieve a good outcome and not just the anastomosis, i.e. setting, dissection and preparation are as important as suture itself to obtain permeable anastomosis at the end of the procedure.

We will begin with a brief anatomic description of the area for proper dissection, mistake free. The common femoral artery is approximately 1.5 cm long; it starts at the inguinal ligament and ends in its superficial and deep terminal branches. On its way, it gives off different collateral branches, varying in number. A permanent collateral branch is the epigastric artery, which will serve as vascular support to the inguinal flap discussed later. Each artery is always accompanied by its corresponding vein.

Setting of the rat

After anesthesia, position the animal on its back with the head up. Secure the hind legs with tape exerting slight traction to get a better working area. Secure front legs as well but tension free to avoid interfering in the animal's airway. If desired, secure the tail also (*figure* N° 11).

Macroscopic dissection

To be performed without microscope or with very little magnification. Magnifiers can be useful, but are not essential.





Make an incision all along the inguinal fold. Then proceed to delicate dissection with forceps and scissors. Right away we will see the femoral and epigastric vessels towards medial side. In all these techniques try to retain epigastric vessels to start training in inguinal flap grasping. Following the femoral vessels towards the cephalic vein, we must recognize the inguinal ligament that crosses femoral vessels perpendicularly. Distally, it is enough with recognizing where epigastric vessels arise from, so far. We suggest placing a retractor at abdominal level to expose the proximal end of the femoral vessels and the inguinal ligament (video *N*°5).

Microscopic dissection

In this stage the use of the microscope is compulsory, as well as the use of microsurgical instruments. At first, we begin dissection with N°3 forceps in our left hand and curved blunt tipped scissors in our right hand. It is important to always follow the same direction of vessel dissection. This will save us time once we are used to the technique. For the femoral artery we recommend distal to proximal dissection, i.e. in this case starting from the epigastric vessels to the inguinal ligament.



For all microscopic dissection procedures it is important to bear in mind these recommendations:

- Always keep the site irrigated. It is advisable to shower the working site with saline solution frequently.
- Do not grasp vessels with the forceps to avoid damaging them. Be careful and grasp them form the adventitia or their collateral branches.
- At the moment of dissection be the least traumatic with the vessel to avoid damage or vasoconstriction, which will hinder anastomosis.
- Never place the tip of the scissors perpendicular to the vessel we are dissecting because the risk of damaging it is very high.
- Never cut if you do not see, it is important to keep permanent visual control of our movements to avoid complications.
- Do not use very large magnification for dissection because with large magnification the working site becomes smaller and dissection becomes too slow.
- Whenever an artery has a collateral branch, the accompanying vein will also have it.
- Prefer ligation of collateral branches to electro coagulation. This not only does away with difficulties but also serves as training for dissection and knot tying.

- Defatten the vessel to work properly at the time of anastomosis.
- Dissection should always be as wide as possible, using the entire length of the vessel, which will give us a comfortable working area for the suture.

For dissection of the femoral artery, as we have already said, we will start from the epigastric vessels and go up. First, we will separate the artery from the vein. Then, we will recognize the collateral branches, ligate them and finally place a contrasting background under the femoral artery which will also protect the femoral vein (*video* N° 6).

Clamping and anastomosis

Clamping should be performed with a double clamp that will be placed as open as possible, using the full length of the dissected vessel starting from proximal to distal (following the flow direction of the artery).

Once the clamp is placed, proceed to section of the vessel. Before doing the section bring closer the ends of the double clamp as to perform the section of the vessel this should not be under tension. To do the section we will use the straight scissors, ideally.

It is important at this moment to see to the position of the collateral branches. If they are too close or where we will perform the section (between the double clamp) we can directly resect them as the elasticity of

Video Nº6 Microscopis dissection of femoral vessels

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the artery allows for this without any problems, or shift from the section to get away from the collaterals as anastomosis performed next to a ligated collateral branch has high chances of thrombosis due to flow turbulence.

After the section, irrigate the vessel completely as there should be no red blood cells in the vessel lumen. We recommend no to channel the vessel through a catheter. In general, irrigating from the outside with saline solution is enough to avoid damage of the intima. Then proceed to adventisectomy if it is an artery. This is not always necessary and should be limited to the edge of the section. It is better to avoid vessel widening: the less we manipulate the intima, the fewer chances of damaging it thus preventing thrombosis.

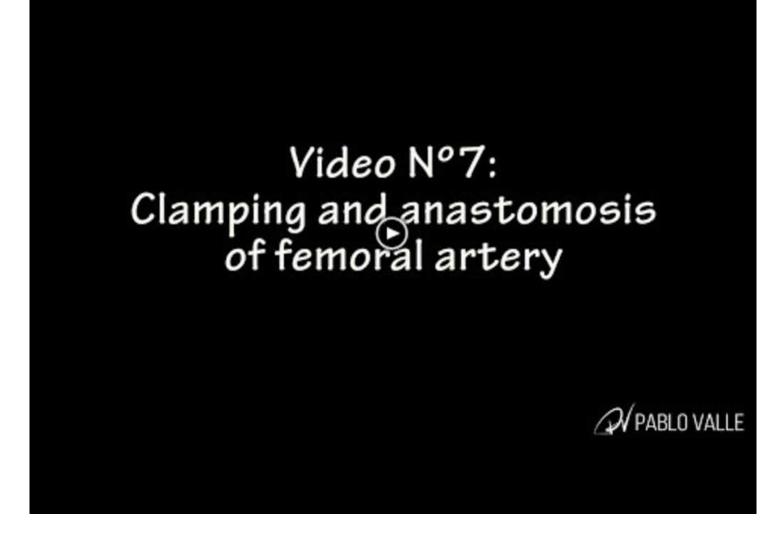
Before suturing, slightly close the clamp so that the anastomosis is not under tension. We use the technique of symmetric bi-angulation, described above. The stitches are simple (we do not use continuous suture) and the number of stitches can vary between 6 and 8. The fewer stitches we make, the more perfect their distribution should be. When making the stitches keep in mind the following recommendations, which apply to all microsurgical anastomosis:

- Pass the needle edge to edge. Avoid, at least initially, making the stitch in one single step.
- The position of the needle tip must be parallel to the vessel. This decreases the risk of transfixiating stitches.
- Always place the forceps into the vessel to pass the first edge. Then, revert the second edge to pass the stitch.
- Make flat and secure knots. Three are enough.
- Avoid tightening knots too much. It is rare for a stitch to come loose. On the other hand, damage to the intima due to very tight knots is very common. Through vessel wall transparency we must see the loop the thread forms.
- Turn over the clamp to control the anterior wall suture from inside the vessel.
- Always work in a saline solution wetted site (it can be used with heparin, although not essential).
- The first two stitches are the most difficult ones, but will facilitate the completion of the remaining stitches.
- We must take the time to make stitches correctly because correcting a bad stitch is difficult or impossible. It is preferable to perform a resection of the vessel edges and restart suture from the beginning.

Once the suture is finished, remove double clamp in the opposite direction it was placed, i.e. distal first and then proximal in relation to the flow direction of the artery. Generally, anastomosis bleeds at first. This should not alarm us: cover the suture with a wet pad and wait for 3 minutes. Then, remove the pad, irrigate with saline solution and observe. What you will first see is the beat of the artery. Then carry out permeability test.

While several tests are available, we suggest emptying the vessel with forceps and observing how it fills up. To do this, place the two forceps distal to the vessel anastomosis, compress with the forceps, advance the most distal forceps and notice how the vessel portion between the two forceps is collapsed. Release the proximal forceps and you should see a rapid filling of the vessel. (*Video* $N^{\circ}7$). We recommend watching also the video of aortic vessel suture (*video* $N^{\circ}11$) since as it is a larger diameter vessel, the suture technique can be appreciated more clearly.

If anastomosis is permeable, repeat permeability test after 5 and 10 minutes. If it is still permeable proceed to close the incision by making separate stitches. Keep the animal for eventual re-examination of the anastomosis in a 5-7 day interval. If anastomosis is not permeable, it is suggested to make proximal and distal ligations of the femoral artery anastomosis, resect the anastomosis and explore it under a microscope. In this way we can see suture defects like transfixiating



stitches, very tight knots, stitches that did not go through the entire wall, illdistributed stitches, among others, as shown at the end of *video N^o 3*.

At this point we consider it advisable to describe anastomosis of the femoral vein. Clearly, in a first practical instance it may not be easy to perform both anastomoses, but eventually we should be able to do the complete technique in less than two hours.

The end-to-end suture technique of the femoral vein is similar to the one of the artery, with only the following differences, inherent to micro surgical vein anastomosis:

• The vein walls are thinner, therefore more fragile and require even more delicate handling.

- It is difficult to see the vessel lumen, so you should always work in a saline solution well irrigated site.
- Veins are low pressure vessels, i.e. they require fewer stitches in relation to their diameter.
- Even more attention should be paid not to close the knots too tight as the walls are fragile.
- When placing the double clamp we can do it following flow direction as with the artery or we can first place the distal clamp in relation to vein flow to cause vasodilation that can help in some procedures. Clamp removal is done as with the artery, keeping in mind that vein flow occurs in the opposite direction (*video N° 8*)

Video Nº8: Clamping and anastomosis of femoral vein

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End-to-end aortic anastomosis

With this technique we will perform endto-end aortic anastomosis, distal to the renal artery. While the aorta is thicker than the femoral artery, its closeness to the vena cava makes dissection difficult. The walls of the vena cava are very fragile to handling so contact with said vessel should be avoided to reduce damage risk, which is difficult to repair and produces major bleeding that can rapidly kill the animal.

Setting of the rat

Position the animal on its back with the head towards the left of the operator (*Figure N°12*). Secure it as described in the previous exercise.

Macroscopic dissection

Make a xypho-pubic abdominal longitudinal incision, after having set aside sternum and pubis by palpation. Incise the skin and subcutaneous tissue. Raise the abdominal wall with the forceps and incise over the muscle, avoiding damage to peritoneal organs. Once we get an opening of the abdominal muscular plane we may end its section with scissors to reduce the risk of injuring intra-abdominal noble organs. Then, place retractors at both sides of our access site. In a wet gauze place the abdominal organs removed from the abdominal cavity and have them to the left of the animal. By now we should already have in view the retroperitoneal abdominal vascular system. To finish macroscopic dissection, dissect the



Figure N° 12: Head left rat setting



parietal peritoneum that covers abdominal vessels with the aid of two wet gauzes (*Video N°9*).

Microscopic dissection

This is probably the most complicated stage of this technique, or at least the most dangerous. Dissection of the aorta is complex because of its closeness to the vena cava. This has very thin walls and rough handling will be enough to cause vein damage, which could be rapidly fatal due to its high flow. As explained in dissection of femoral vessels, it is advisable to perform dissection always in the same direction. We suggest from distal to proximal, starting at the aortic bifurcation. The aorta has varying in number collateral branches that will have to be ligated as needed. These collateral branches also have their accompanying vein, tributary to the vena cava. Special care should be taken with branches arising from the posterior wall of the aorta, which are difficult to identify but must be dissected and ligated. Dissection finishes when reaching the left renal artery, collateral of the aorta. Once fully dissected, use a contrasting background under the artery that will also serve to protect the fragile vena cava (*Video N°10*).

Video Nº10: Microscopic dissection of the aortic artery

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Clamping and anastomosis

This is done in the same way as described in clamping of the femoral artery. Simply remember that aortic pressure is greater than femoral so the clamp must be adapted to said pressure to prevent persistent flow in the artery. The anastomosis technique used is symmetrical bi-angulation. Make between 8-12 stitches with 10/0 thread. If you get a good distribution, fewer stitches will be required (*video* N°11). Clamp removal and permeability test are performed in the same way as described for end-to-end anastomosis of the femoral artery. (*video* N°7).

Video Nº11: Clamping and anastomosis of the aorta



End-to-end carotid artery and jugular vein anastomosis

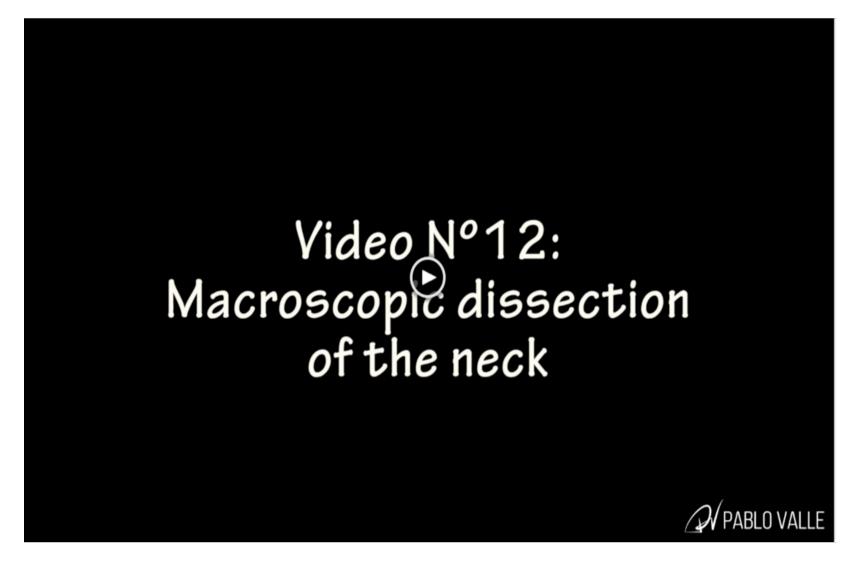
In this technique will perform end-to-end anastomosis of the carotid artery and the right external jugular vein.

Setting of the rat

Position the animal on its back with the head towards the left of the operator. As described above, we can secure the forelegs with more traction to clearly expose the neck (*figure* $N^{\circ}12$).

Macroscopic Dissection

Do a transverse incision at neck level, between the shoulders. The incision should be wide. Be careful not to damage the external jugular vein at the time of skin incision, as this vessel is superficial. We then perform blunt dissection with scissors. What we first identify are the external jugular veins, both right and left. Then identify salivary glands and place a retractor to move them to cephalic. We will objectify sternocleidomastoid muscles, sternohyoid muscle and behind these, the trachea (*video* $N^{\circ}12$).

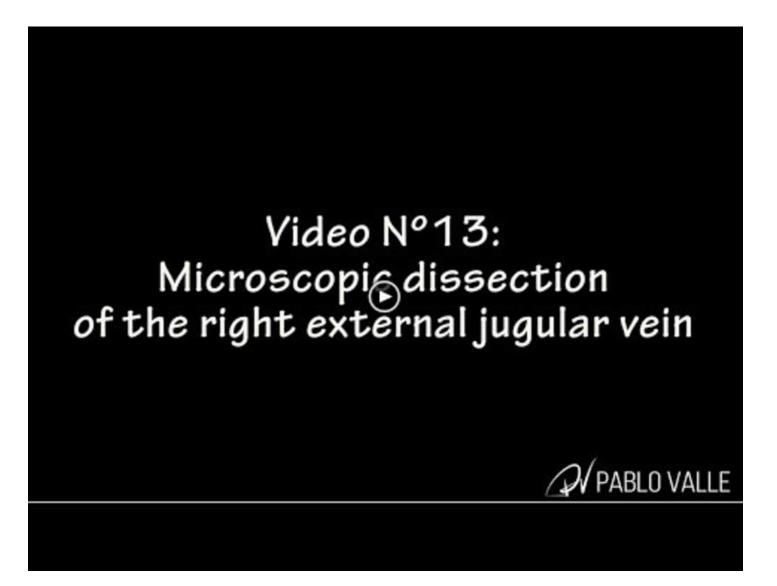


Microscopic dissection

We suggest starting with dissection of the right external jugular vein which is easily exposed in macroscopic dissection. In specimens with more weight and more fat tissue, dissecting it may be more difficult. We suggest starting microscopic dissection from caudal to cephalic, as usual, starting at pectoralis major and paying special attention to the numerous collateral branches.

To achieve a wide dissection and therefore get a broader working site, continue dissection towards cephalic following the facial vein which joins to two other smaller size tributaries to form the external jugular vein. Dissection of the jugular vein is enough to perform end-toend anastomosis, but if we need to grasp the vein to do a by-pass, for example, dissection of the deep tributary along with the jugular may be necessary. Once dissection is finished, place contrasting background and protection so as not to damage the vein while performing carotid dissection, as the retractor can compress it (*video* $N^{\circ}13$).

Microscopic dissection of the right carotid artery is considered one of the simplest dissections. Start with proximal blunt dissection between the sternomastoid muscles, separating it from its contralateral. Then separate to the right the sternohyoideus and notice in the deep the carotid artery with its pulsations. The carotid does not have branches at this level, which simplifies its dissection. On the contrary, it has a fascia that covers it and which is usually well vascularized so when dissecting it may bleed. These vessels generally need not be ligated or



coagulated; in case of bleeding, slight compression with gauze for a few minutes is usually enough to stop it.

The main risk of dissection of the carotid artery is the vagus nerve; its manipulation should be avoided to the fullest since damage or rough handling of the nerve is life threatening for our animal. Once you separated the artery from the nerve, place the plastic contrasting background. At this moment we can remove the retractor. The artery will remain visible due to the plastic contrasting background placed. Said background will bring the artery to surface. (*video* $N^{\circ}14$).

Clamping and anastomosis

The suture technique employed is symmetric bi-angulation. Go over *videos*

N°7 and N°11 which show femoral and aortic artery anastomoses respectively. The thread used is 10/0 or 11/0 when we achieve good handling of the 10/0 thread. Between 6-8 stitches should be made. Then, carry out permeability test.

The vein tends to have a larger diameter so more stitches may be necessary. It is preferable to suture with 11/0 thread paying attention not to tie knots too tight and to irrigate the site with saline solution which will help us see the vessel lumen. Permeability test is identical; simply remember that flow direction is reverse to the artery. The end to end suture technique is identical to the one used for the anastomosis the femoral vein shown in *Video* N°8.



End-to-end caudal artery anastomosis

This technique can be performed in 30 minutes or less once we have acquired microsurgical habit. It is rather quickly as dissection is relatively easy. The artery has a small size so four stitches are usually enough for its anastomosis.

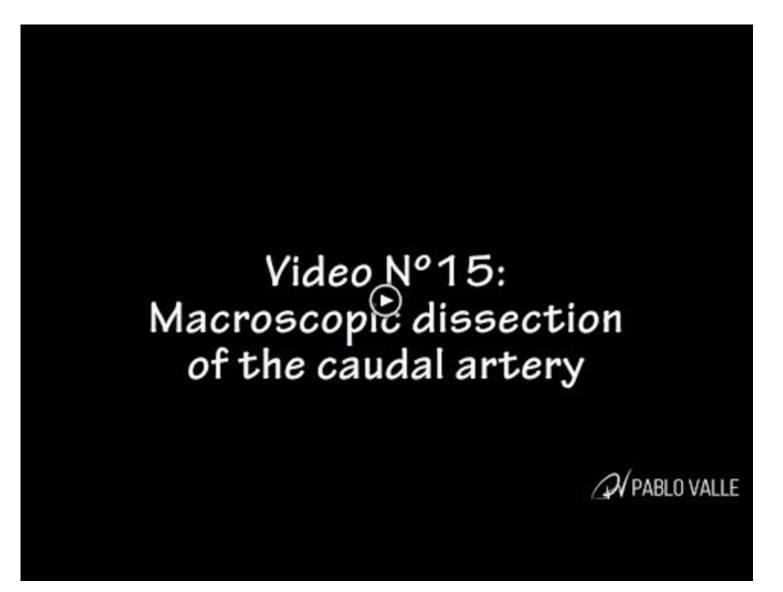
Setting of the rat

Position the animal on its back with the head towards the left of the operator, as already described (*Figure N°12*). It is also

important in this case to secure the tail of the animal.

Macroscopic dissection

With a scalpel create a flap of about 2cm. You should start 2 or 3 cm away from the beginning of the tail because if we do it very distal the artery's diameter will be very small. Move the flap to the left of the animal. Be careful not to damage the artery that lies just below the skin-fibrous plane when doing transverse incisions to the flap (*video* $N^{\circ}15$).



Video Nº16: Microsurgical dissection of the caudal artery

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Microscopic dissection

Microscopic dissection is usually simple. The central artery of the tail lies within a fibrous sheath between two side lines of tendons. When opening the sheath with the scissors, the artery is fully exhibited. We should pay special attention to the deep collateral branches of the artery, which are fragile and difficult to find. They should be ligated as needed. A plastic contrasting background must be placed once the micro surgical dissection moment is over (*video* $N^{\circ}16$).

Clamping and anastomosis

It is performed as already described for end-to-end anastomosis with the symmetrical bi-angulation technique. Four 10/0 stitches tend to be enough if perfectly distributed. If the distribution is not correct, some more stitches may be necessary. After releasing the clamp carry out permeability test and close with separate stitches (*video* $N^{\circ}17$).

Video Nº17: Clamping and anastomosis of the caudal artery

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Carotid artery with jugular vein bypass

In this case we will carry out end-to-side anastomosis. In this technique the main difficulty is not probably performing the anastomosis itself but grasping the vein graft and manipulating it.

Setting of the rat

Position the animal on its back with the head towards the left of the operator (*figure* $N^{\circ}12$).

Macroscopic dissection

Neck dissection as described on *video N°12*.

Microscopic dissection

Microscopic dissection was also developed (*videos* $N^{\circ}13$ *y* $N^{\circ}14$). In this technique it is of special interest dissection of the deep tributary of the jugular vein (facial vein) because its diameter is smaller and therefore it is more appropriate for the carotid artery bypass. However, in the video we do said bypass with the jugular vein to show how useful end-to-side suture of different size vessels anastomosis is as well.

Clamping and right carotid arteriotomies

This is a very important and delicate stage. Clamping is, as usual, with the double clamp as open as possible to have a large working site. This is critical in the technique. The arteriotomies should be performed with scissors. A small transverse incision with the scissors at the level of the artery will result in the round hole we wish for suture. It is preferable to perform a small arteriotomy and then stretch it with forceps to performing a too large arteriotomy (problem with difficult solution). Before starting, think of the best site for the arteriotomies and the distance between them. Ideally, midway between the clamps with a distance of less than a microsurgical forceps N°3 or N°5 opening. After the arteriotomies, the vessel should be thoroughly irrigated as explained in previous techniques (video N°18).

Video Nº 18: Clamping and arteriotomies of the carotid artery

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Graft grasping: right jugular vein

This is a key stage of the technique together with artery preparation. A proximal and a distal ligation to our dissection are performed. Section an end of the vein with the scissors. Thoroughly irrigate it. Then, section the other end. The graft should be reversed 180°. Remember that flow direction in the vein is reverse to flow direction in the artery and that the vein may have valves that prevent backflow. So, the cephalic end of the vein will be anastomosed to the carotid artery caudal arteriotomy and the caudal end of the vein will be anastomosed to the cephalic arteriotomy (*video* $N^{\circ}19$).

Video Nº19: Grasping_©f Jugular vein for graft

Anastomosis

The technique used here is symmetric biangulation, but there are some details to point out as this is end-to-side. The first stitch will be at 3 o'clock, starting from caudal anastomosis. Attention should be paid to pass the stitch in such a way that the knot does not stay in the lumen; this may seem obvious, but it is a common error when starting with end-to-side sutures. The second stitch will be at 9 o'clock in the same arteriotomy. Once these stitches are made and our vein graft is secured, irrigate again with a small pointless needle syringe (this is essential to prevent the graft from having twists). The third stitch is also at 3 o'clock but at the level of distal anastomosis. The fourth stitch will be at 9 o'clock in the cephalic or distal anastomosis. These first four stitches

are of utmost importance, so we must pay special attention when making them. After that, make the remaining stitches of the right side of both anastomoses. Next, place the graft to the right to expose the left side of the anastomoses. Check the suture on the right side and finish the anastomoses by making the sutures on the left side (*figure* $N^{\circ}13$). The number of stitches varies depending mostly on the diameter of the vein, but it is usually between 8 and 10 stitches. Anastomosis can be made with 10/0 or 11/0 thread. When finishing it, perform ligation of the carotid artery at bypass level with 9/0 or 8/0 thread.

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Release the clamp, as already explained, towards flow; first cephalic and then caudal. Perform permeability test distal to the bypass (*video N°20*).

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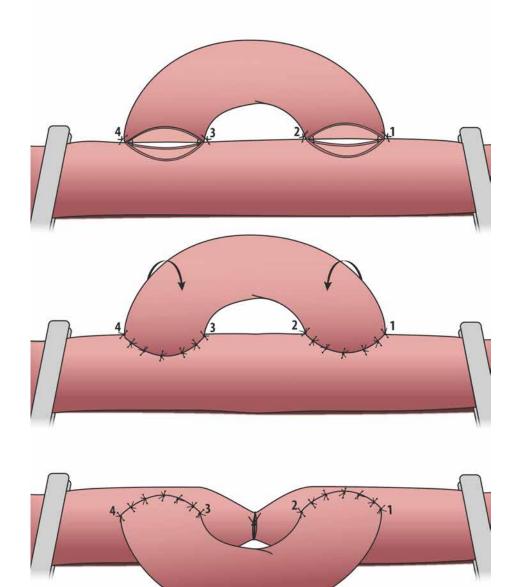


Figure Nº 13: Bypass model

Video Nº20: Carotid artery-external jugular vein Dpass. End-to-side anastomosis.



Carotid artery - jugular vein fistula

In this case we will make end-to-side suture between a vein and an artery. Symmetric bi-angulation as suture technique cannot be used so end-to-side anastomosis stitch by stitch is performed.

Setting of the rat

Position the animal on its back with the head towards our left (*figure* $N^{\circ}12$).

Macroscopic dissection

As formerly described in carotid artery and jugular vein end-to-end suture (*video* N° 12).

Microscopic dissection

Right external jugular vein dissection is performed as described above in End-toend jugular vein suture technique (*video N°13*).

On the contrary, for carotid artery dissection minor modifications must be made. Section of sternohyoid and sternomastoid to allow passage of the carotid artery to the jugular is important. Ligate carotid artery at its distal or cephalic end (*video N°21*).

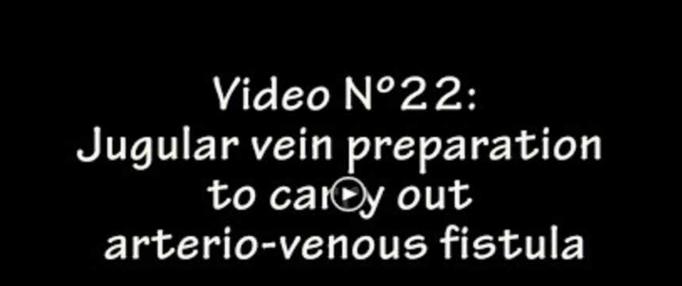


Preparation of the jugular vein

Place a double clamp on the jugular vein as proximal as possible so that the carotid artery can be anastomosed without tension. Perform venotomy with scissors, just as described above for the artery. It is advisable to perform the venotomy as proximal as possible to shorten distance between artery and vein; always with the aim of achieving anastomosis without tension (*video N°22*).

Carotid artery grasping

Place a single clamp at right carotid artery level in a position that allows manipulation and does not hinder anastomosis later on. That is, preferably within the proximal part of carotid dissection. Perform section of the artery immediately caudal to our ligation to preserve the maximum possible length. Irrigate the artery thoroughly (*video* N° 23).



Video N°23: Carotid artery grasping to cary out arterio-venous fistula

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Anastomosis

Position the artery in front of the venotomy. Check there is no excessive tension; if any, enlarge dissection at carotid artery level towards proximal or eventually complete section of the muscular plane that stands between both vessels.

In this case we use a suture technique of proximal stitch to proximal stitch (*figure* $N^{o}14$).

Start suture with a 12 o'clock stitch paying special attention to the knot being outside vessel lumen. Then, make a stitch at each side and continue until completing all of the anastomosis. The thread used is 10/0, the number of stitches required varies, generally between 6 and 10

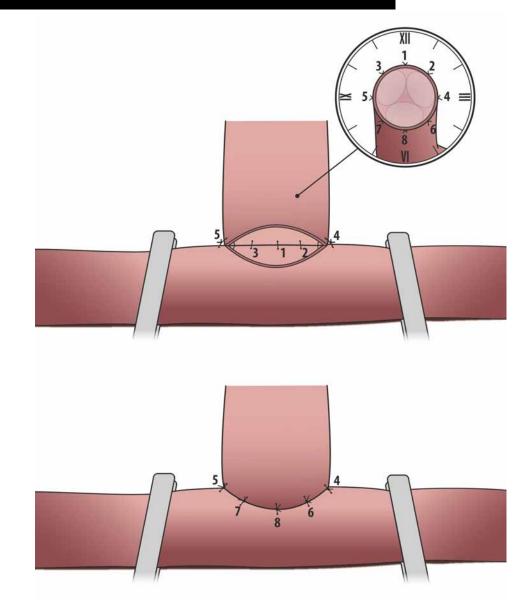


Figure N° 14: End-to-side stitch by stitch anastomosis model

depending on the distribution of the stitches and vessel diameter. Clearly, in this technique we cannot use symmetric bi-angulation because we cannot make the artery to tilt. This problem may occur in clinical practice, so learning this suture technique can be very useful (*video N°24*).

First, release the clamp at vein level and finally the single clamp at artery level. The vein will fill up quickly. Permeability test is also different in this technique; obstruct the passing of blood through the vein with the forceps at each side of the anastomosis. If the test is positive, the vein will fill up and due to wall elasticity will dilate because the artery has higher pressure (*video* $N^{\circ}25$).

As already mentioned, it is recommended to repeat the test at intervals of 5 and 10 minutes. Then proceed to skin suture with separate stitches.



Video N°25: Realeasing clamp and permeability test of the arterio-venous fistula

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Femoral artery with epigastric vein graft

This technique is probably one of the most difficult ones due to the small diameter of the epigastric vein. The technique involves inserting an epigastric vein graft in the femoral artery. The use of 11/0 thread is recommended.

Setting of the rat

Position the animal on its back with the head facing up or towards the left or right side depending on which side we will perform the technique (*figure* $N^{\circ}11$).

Macroscopic dissection

Macroscopic dissection has been described above in end-to-end anastomosis of the femoral vessels (*video N*°5).

Microscopic dissection

Microscopic dissection of the femoral artery has also been described (*video N*°6).

Microscopic dissection of the epigastric vein must be performed with special care. Avoid grasping the vein with forceps, use the artery as contact point for dissection. Dissect the longest possible. First, make distal ligation in relation to vein flow so that while we prepare the recipient site (femoral artery) we achieve dilation of the epigastric vein which can later help when performing our (*video N°26*).

Preparation of the femoral artery

Place the double clamp on the femoral artery, as explained for end- to-end anastomosis of said vessel. Make a section of it after releasing tension, slightly closing the double clamp. It is not necessary to resect a portion of the artery to insert the vein graft. The elasticity of the vessel allows for inserting the vein graft without this resulting in a vessel with turbulent path. Irrigate the artery thoroughly (*video N°27*).

Graft grasping (epigastric vein)

Perform proximal ligation of the vein, following flow direction. Make a section of the vein at one end, irrigate thoroughly with saline solution and proceed to section the other end; always as close as possible to our ligations to keep the maximum possible length. Grasp the graft and place it in its final position midway the sectioned femoral artery, always paying attention to reversing the vein because flow direction of vein and artery are opposite, as already explained in the carotid artery and jugular vein bypass technique (*video N°28*).

Video N°26: Microscopic dissection of the epigastric vein

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Video N°27: Femoral artery preparation to do epigastric vein graft procedure





Anastomosis

Here we will also use the symmetric biangulation technique. Begin with a 12 o'clock stitch at proximal anastomosis level. Then, inject saline solution into the graft to avoid vein twists. Make a second stitch at 12 o'clock but at distal anastomosis level. The third and fourth stitches will be at 6 o'clock in both anastomoses. These first 4 stitches are the most important ones. After that, complete all stitches of the anterior wall of both anastomoses. Turn over the double clamp for access to the posterior wall and after checking the anterior wall stitches through vessel lumen, finish posterior vessel wall suture in both anastomoses (*figure N°15*).

Remove the clamp first distally and then proximally to flow direction. Permeability test is performed as usual, distal to the graft (*video N°29*).

After carrying our permeability test at 5 and 10 minutes, close the rat with separate stitches.

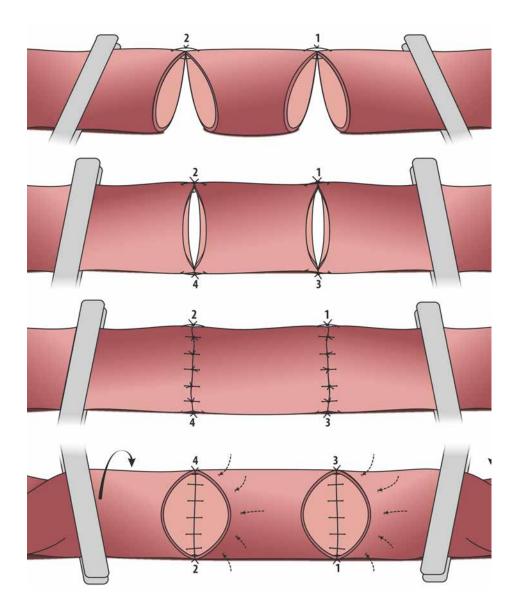


Figure N° 15: Graft performing model

Video N°29: Anastomosis of the femoral artery with epigastric vein graft

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Inguinal flap

This is a very complete technique that requires mastery so as to perform a delicate dissection and to handle the flap properly. It should be pointed out that mishandling of the flap can be catastrophic for its vitality, even when anastomoses are well performed. This technique allows for long term suture permeability control simply by observing the flap.

We will describe three techniques:

- First, Inguinal flap in situ, an important technique as we will learn how to dissect the graft. We will perform endto-end anastomosis of the femoral vessels.
- The second technique is Inguinal flap to the opposite side, i.e. the flap will be moved to perform end-to-side anastomosis on the opposite side with the femoral vessels (end-to-end anastomosis can also be performed).
- The third technique is Inguinal flap to neck in which we will perform end-toside anastomosis of the flap with the carotid and external jugular vein.

Inguinal flap in situ

In this technique we will learn to dissect the inguinal flap. Place the animal with the head up (figure $N^{\circ}11$) or with the head to the left of the operator (figure $N^{\circ}12$). We may dissect the inguinal flap either to the right or to the left of the animal, based on our preferences. It is essential to understand that the flap pedicle is formed by the epigastric and femoral vessels, the latter being the ones we will use for dissection, manipulation, and anastomosis in the different techniques because of their greater diameter. We must avoid manipulation on delicate epigastric vessels so as not to damage them and thereby cause loss of the flap.

Macroscopic dissection

Make a skin incision in the inguinal fold. Dissect with scissors to identify femoral and epigastric vessels. Make a second incision parallel to the midline, 5 mm towards external, from the inguinal fold incision, 4cm towards cephalic. Make a third incision from the cephalic end of the longitudinal incision, parallel to the first incision, until the meeting of dorsal and ventral skin of the animal. At this point you should start raising the flap. The fourth side should be sectioned with direct control from the inside to avoid damaging epigastric vessels (*figure* $N^{\circ}16$). Once raised, the flap should be protected between wet pads, avoiding pedicle traction (*video* $N^{\circ}30$).

Microscopic dissection of the inguinal flap

Microsurgical dissection of femoral vessels has already been described and it is the basis of inguinal flap dissection. Identify femoral vessels distal to epigastric vessels origin and dissect them towards

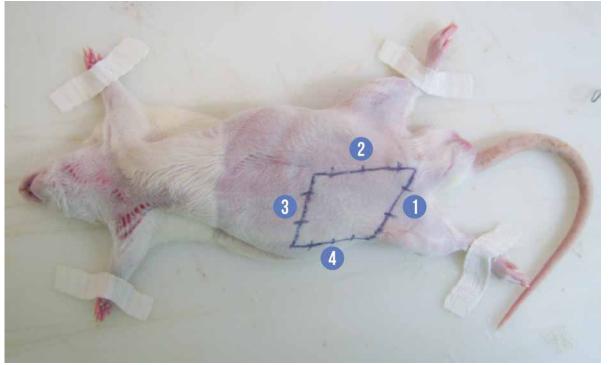


Figure Nº 16: Inguinal flap diagram



proximal up to the inguinal ligament. Ligate collateral branches. Perform a double ligation of femoral vein and artery, distal to the epigastric vessels. At this point the flap must be attached to the animal only by the epigastric and femoral vessels. Place a protective background underneath femoral vessels. Place the double clamp as open as possible to get a good working site. Section artery and vein with scissors. Irrigate the vessels thoroughly (*video N*° *31*).

End-to-end anastomosis of femoral artery and femoral vein

The technique used is, as usual, symmetric bi-angulation. This anastomosis technique has already been explained (*videos* $N^{\circ}7 y N^{\circ}8$).

After carrying out permeability test of the artery and vein, close the skin with separate stitches and keep the animal in a warm environment for flap control. This technique allows for anastomosis control just by monitoring the flap, especially its vitality and color.

Video Nº31: Microscopi©dissection of the inguinal flap



Inguinal flap to the opposite side

In this technique we start manipulating the inguinal flap, moving it to a different recipient site. We will perform side-to-end anastomosis, but end-to-end anastomosis can also be performed sacrificing the flow of the recipient femoral vessels. This has no clinical implications for the animal, however.

Macroscopic dissection of the flap

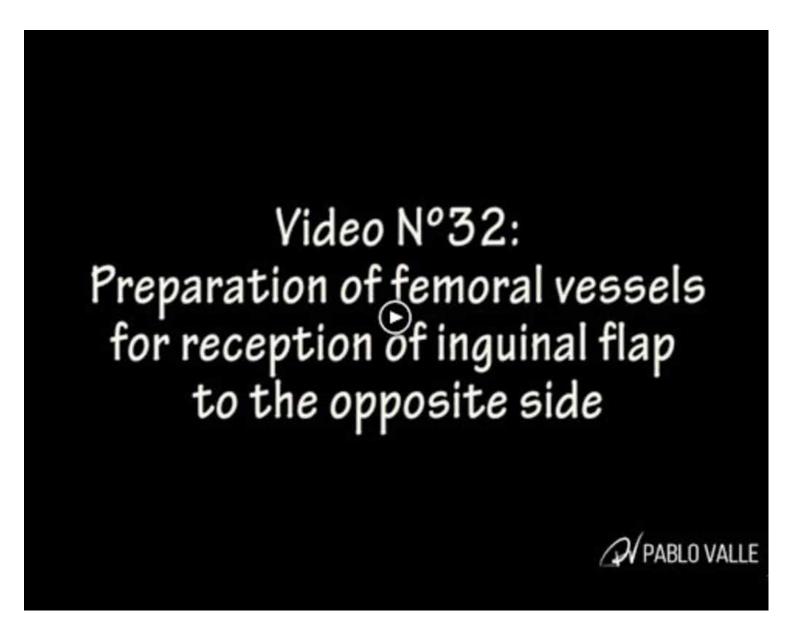
It was formerly described (*video N°30*).

Microscopic dissection of the flap

It was also formerly described. It is exactly the same, except that in this case we will not place the double clamp. The microsurgical dissection of the flap ends with the double anastomosis of the femoral vessels distal to the epigastric vessels (*video N°31*).

Preparation of recipient site, inguinal region

Macroscopic and microscopic dissection are the same as performed for end-to-end suture of the femoral vessels (*videos* $N^{\circ}5 y$ $N^{\circ}6$). Place a double clamp as open as possible. Perform arteriotomy and venotomy with scissors. It is important to perform them apart from each other, i.e. one more proximal and the other one more distal, to be able to perform nonoverlapping anastomoses. Irrigate thoroughly with saline solution (*video* N° *32*).



Flap grasping

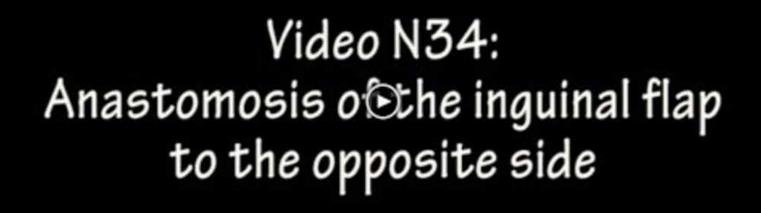
Perform flap grasping only when the recipient site is ready. With 9/0 or 8/0 thread ligate the femoral vessels at inguinal ligament level. It is important to recover the maximum possible length for our pedicle. Place a single clamp on the femoral vessels (not on the epigastric vessels, as they are very fragile). Section femoral vessels at inguinal ligament level. Irrigate the vessels with saline solution. Section the femoral artery and vein distal to the epigastric vessels, within the double ligation made earlier. The flap is now free and can be moved to the opposite side. This must be done carefully to avoid twist at pedicle level. When placed on the opposite side, get the flap on wet pads to achieve tension free and good position suture, avoiding unwanted flap moves while carrying out anastomosis (*video* N° *33*).

Anastomosis

Anastomosis is performed with the symmetric bi-angulation technique for end-to-side sutures with 11/0 or 10/0 thread (*video N°34*).

Carry out permeability Test. Close skin with separate stitches. Control the flap. Donor site is closed by direct suturing. Although this is generally performed under tension, said tension disappears in a few days.





Inguinal flap to the neck

Flap handling is essential in this technique. Good length of the pedicle (femoral vessels) is needed to perform it. The flap will be anastomosed end-to-side to the carotid and external jugular. Position the rat on its back with the head towards the left of the operator (figure N°12). You can begin with the animal on its back with the head up to dissect the flap and later position its head towards the left for neck dissection and flap anastomosis.

Flap macroscopic dissection

Already described (*video N°30*).

Flap microscopic dissection

Already described (*video N°31*).

Preparation of recipient site

Macroscopic dissection of the neck has already been described (*video* N°12), as well as microscopic dissection of the right external jugular vein and right carotid artery (*videos* N°13 y N°14).

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Clamp the carotid artery and perform arteriotomy with scissors (*video N°35*).

Flap grasping

It is performed in the same way as described for the inguinal flap to the opposite side. It is very important to get

Video N°35: Carotid arte y preparation for inguinal flap to the neck

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the longest possible pedicle. Move the flap to the neck area, placing it on the chest of the animal on wet pads to avoid movement and unwanted traction in the pedicle (*video N°32*).

Anastomosis of the inguinal flap to the neck

Start by end-to-side femoral artery anastomosis on the carotid artery with 6-8 stitches using 10/0 thread and the symmetric bi-angulation technique. Free the simple clamp and then the double clamp in the carotid artery, distal to flow at first. Carry out permeability test. There must be venous return at graft pedicle level (femoral vein) (*video* N°36). If permeability test on the femoral artery is good and there is no venous return, this should be addressed. Possible causes may be a twist of the vein or thrombosis. These problems can be solved by bathing the vein with saline solution. If there is damage at flap level itself due to ill or rough handling, vein return will not be enough and the flap will not be viable.

Then, proceed to positioning the double clamp on the external jugular vein, and perform venotomy of it with scissors. Place simple clamp only on the femoral vein. Perform end-to-side femoral vein anastomosis on the external jugular vein. In this case the technique is the same as Video N°36: Arterial anastomosis of the inguinal flap to the neck



for suturing the femoral artery on the carotid, previously described (*video* N° *37*).). If you do not wish to move the flap, a stitch by stitch technique can also be used. Said technique was described for arteriovenous fistula between the carotid artery and jugular vein (*video* $N^{\circ}24$). Remove all clamps, double clamp first and then simple clamp. Carry out permeability

test as explained for carotid-jugular fistula only that in this case the filling in is more subtle due to less vein flow in the case of the flap compared to the pressure of the carotid in the fistula previously described. Close skin with separate stitches. Control flap.

Video N°37: Vein moment of the inguinal flap to the neck procedure



Other Techniques

If you have successfully tried out the preceding techniques, you can move forward and try some others. While working on the procedures mentioned, you have acquired the principles of microsurgery. Once these concepts have been understood you can keep on performing these techniques, try out other techniques or even come up with your own techniques. The idea is to continue with an ongoing training and practice of microsurgery, the only way to achieve good results in this area.

In the following paragraphs, we briefly describe some other techniques you can try out. They will not be developed but simply presented, as we consider that a detailed description is not necessary if you already have the ability to perform the above-mentioned techniques.

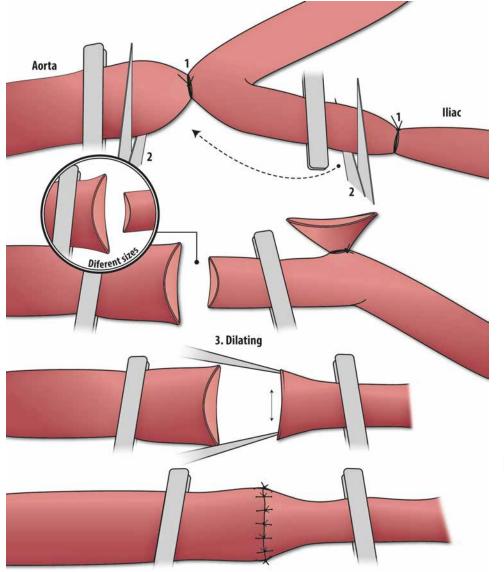
All the gestures included in the techniques presented below have already been described in the handbook.

 End-to-end anastomosis of the epigastric artery and vein. End-to-end suture of very small size vessels. For this technique, 11/0 thread should be used. Dissection was already described. The End-to-end suture is performed with the symmetrical biangulation technique.

- Graft of the aorta with external jugular vein. Technically, it is the same as the femoral artery with the epigastric artery graft. Being larger vessels, the anastomosis is usually easier.
- Graft of the carotid with a tributary of the external jugular vein. Same as above, generally using the facial vein as a graft. Jugular vein may be used as well, although this may make the technique more difficult because of the difference in size between the carotid artery and the external jugular vein.
- Bypass of the aorta with the external jugular vein. Technically, it is the same as the carotid with the external jugular vein bypass.
- Bypass of the femoral artery with the epigastric vein. Similar to the preceding technique.
- End-to-end anastomosis of the iliac artery with the aortic artery. This technique is used to perform anastomosis of different size vessels.
 Dissection of the aorta and its bifurcation should be performed, following the right iliac artery (animal on its back with the head to the left of

the operator). The right iliac artery should be ligated as distal as possible. A ligation of the aorta is done immediately proximal to its bifurcation. Place double clamp in the aorta, as caudal as possible. The iliac artery is sectioned proximal to the ligation so that the end of the iliac artery can be placed in front of the sectioned aorta, turning it 180° (figure N°17). Perform end -to-end anastomosis, after having dilated the iliac artery to suture correctly. Another technique that can be used to compensate for the size difference is oblique section of the iliac artery or sectioning it close to a collateral or bifurcation (figure N°18).

 Renal autotransplantation with end-toend anastomosis of the renal artery and renal vein. It is performed in the left kidney, with the head of the animal



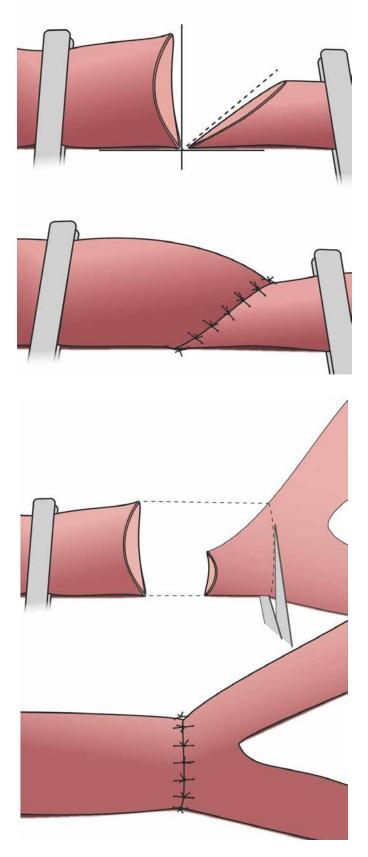


Figure N°17: Model for applicable techniques when there are different sizes

Figure N°18: Model for end-to-end anastomosis of iliac artery with femoral artery placed to the left of the operator. The difficulty of this technique lies in the dissection of the renal pedicle, covered by a fatty tissue difficult to dissect. To do this we recommend the constant injection of saline solution into the fatty tissue. This will create clearer dissection areas, and thus allow us to the pedicle and its collaterals.

- Renal autotransplantation with end-toside anastomosis of renal artery and vein over the aorta and vena cava, respectively. The difficulties in this case are the renal pedicle dissection and the vena cava dissection. In these last two techniques, end-to-end suture of the ureter can also be performed; four stitches on it are usually enough. The ureter has thick walls and a small light. No clamp should be used on the ureter.
- Reimplantation of the leg. It is the complete section of the leg, at the level of the middle of the femur. Longitudinal incision, section of the muscular plane, microscopic dissection of femoral vessels and sciatic nerve, placement of simple clamps at the level of femoral vessels. Section of the vessels and sciatic nerve. Section of the femur and section of the posterior muscular plane. Reimplantation: First carry out osteosynthesis of the femur is with an intramedullary pin, posterior muscular plane suture with 3/0 thread. Suture of sciatic nerve with two 9/0 perineural

stitches. End-to-end anastomosis of the artery and vein with 10/0 or 11/0 thread. Suture of the anterior muscular plane and the skin.

- Sciatic nerve suture and graft. This technique has not been developed as it cannot be assessed objectively. It is a relatively easy or less complex technique compared to vascular suture and can be used to appreciate the consistency of nerve tissue. Video N°38 shows neurorrhaphy in a cadaveric nerve as an example of epi-perineural neurorrhaphy. In the model, the characteristics of this suture can be better seen as it is a larger size nerve. Once you have acquired the ability to perform small vessel vascular anastomosis, performing different types of neurorrhaphy should be relatively simple. There are many more like:
 - Portacaval anastomosis
 - Kidney transplantation
 - Lymphatic-venous sutures, mesenteric region
 - Inguinal flap to the armpit
 - Autograft of the tube and ovary
 - Transplantation of the tube and ovary
 - Heart transplantation
 - Autotransplantation of the leg to dorsal.

Video N°38: Neurorrhaphy on cadaveric model. Chicken drumstick.



Conclusion

The idea of this handbook is to give you tools for your own individual development. Performing different techniques will make the laboratory activity more varied and challenging, thus avoiding monotony that may distance us from the micro surgical practice.

For you to see how long a procedure actually takes *video N*°39 shows an end-to-end anastomosis of the femoral artery; the complete technique, not edited. All the

videos were recorded during my second stage of micro surgical training and if you have acquired the basic principles described herein, when going over the videos you will be able to spot mistakes in my technique. This clearly proves that microsurgery requires ongoing training in a permanent quest for excellence that will lead us to obtaining the best results in our clinical practice.

Video N°39: End-to-end anastomosis of the femoral artery. Non-edited video.

