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НАУЧНО-ПРАКТИЧЕСКИЙ
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ВОПРОСЫ реконструктивной и пластической ХИРУРГИИ

ISSUES OF RECONSTRUCTIVE AND PLASTIC SURGERY

ТОМ 24 № 1 (76) 2021

Учредители

Автономное некоммерческое объединение «Научно-исследовательский институт микрохирургии» (АНО НИИ микрохирургии)

Единственный в России и один из семи в мире Институт микрохирургии

В институте проводится полный спектр пластических и реконструктивных операций. Врачи Института микрохирургии являются действительными членами Общества пластических, эстетических и реконструктивных хирургов России (ОПРЭХ), обладают необходимыми допусками для проведения пластических операций, а также имеют ученые степени доктора и кандидата медицинских наук. За год специалисты АНО НИИ микрохирургии выполняют более тысячи операций.

Федеральное государственное бюджетное образовательное учреждение высшего образования «Красноярский государственный медицинский университет имени профессора В.Ф. Войно-Ясенецкого» Министерства здравоохранения Российской Федерации (ФГБОУ ВО КрасГМУ Минздрава России)

Миссия КрасГМУ – обучение искусству врачевания и служению людям, основанное на самореализации, академической свободе и профессионализме наставников. Ярким примером наставничества в КрасГМУ стали основатели хирургических школ: знаменитые профессора А.М. Дыхно, М.И. Гульман, Ю.М. Лубенский, Л.Л. Роднянский, Н.С. Дралюк и Б.С. Граков, благодаря трудам которых были заложены основы современной реконструктивной и пластической хирургии.

При участии

Федеральное государственное автономное образовательное учреждение высшего образования «Национальный исследовательский Томский государственный университет» (НИТГУ)

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Областное государственное автономное учреждение здравоохранения «Томский областной онкологический диспансер» (ОГАУЗ ТООД)

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Все операции проводятся с использованием самого современного оборудования, активно используются малоинвазивные методы лечения (лапароскопия, торакоскопия).

Журнал является официальным печатным органом Российского общества кистевых хирургов – Российская кистевая группа

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Вопросы реконструктивной и пластической хирургии

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ОГАУЗ «Томский областной онкологический диспансер» (г. Томск)

Распространение знаний – это распространение благополучия.
Альфред Бернхард Нобель (1833–1896)

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Dissemination of knowledge – is a spread of prosperity
Alfred Bernhard Nobel (1833–1896)

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СОДЕРЖАНИЕ

CONTENT

DEAR READERS, AUTHORS, AND FRIENDS!

ДОРОГИЕ ЧИТАТЕЛИ, АВТОРЫ И ДРУЗЬЯ!

Журнал «Вопросы реконструктивной и пластической хирургии» был учрежден в 2001 г. ЗАО «Сибирская микрохирургии». Главным редактором нового журнала стал генеральный директор ЗАО «Сибирская микрохирургия», организатор и учредитель единственного в России и странах Содружества Независимых Государств полноформатного Института микрохирургии (основан 30.09.1994) профессор В.Ф. Байтингер. В сентябре 2001 г. вышел в свет первый номер журнала. В декабре 2020 г. – номер 75.

Журнал широко известен в профессиональном сообществе пластических хирургов России и Содружества Независимых Государств, образованного на территории ликвидированного в декабре 1991 г. СССР, а также в странах дальнего зарубежья.

Идея издания специализированного номера журнала, посвященного обучению основам микрохирургии, возникла после проведения Первого микрохирургического саммита в Сибири (Томск, 28–29 октября 2019 г.) в Национальном исследовательском Томском государственном университете. В саммите приняли участие около 120 врачей из 13 стран мира. В рамках саммита, в Новоанатомический корпусе Сибирского государственного медицинского университета, компанией ООО «Карл Цейсс» (Россия) была развернута лаборатория (12 техноскопов) для проведения обучающего курса по основам микрохирургии для молодых врачей из России и Австрии.

Непосредственными организаторами и тренерами курса были сотрудник Колумбийского университета (США) Е. Акелина и врачи Института микрохирургии К.В. Селянинов и О.С. Курочкина (Томск, Россия). Елена Акелина широко известна в мире своей работой по обучению резидентов и врачей из многих стран, как на базе Лаборатории микрохирургии Департамента ортопедии Колумбийского университета (Нью-Йорк, США), так и на выезде в страны Северной и Южной Америки. В период пандемии коронавирусной инфекции (COVID-19) она впервые начала проводить обучение основам микрохирургии online (виртуальная микрохирургия). Мое предложение Е. Акелиной о совместном проекте по изданию специализированного номера журнала, посвященного вопросам обучения основам микрохирургии в разных странах мира, было встречено ей с энтузиазмом.

The journal “Issues of Reconstructive and Plastic Surgery” was founded in 2001 by Closed Joint Stock Company (CJSC) “Siberian Microsurgery”. Editor-in-chief of the “Issues of Reconstructive and Plastic Surgery” is Professor V.F. Baytinger, the General Director of CJSC “Siberian Microsurgery”, the organizer and founder of the only full-format Institute of Microsurgery (was founded on September 30, 1994) in Russia and the Commonwealth of Independent States. In September 2001 the first issue of the journal was published. In December 2020 – issue 75.

The journal is widely known in the professional community of plastic surgeons in Russia and the Commonwealth of Independent States, which was formed on the territory of the USSR liquidated in December 1991. The journal is also known abroad.

The idea of publishing a specialized issue of the journal devoted to teaching the basics of microsurgery arose after the First Microsurgical Summit in Siberia (Tomsk, October 28–29, 2019) at the National Research Tomsk State University (Tomsk, Russia). About 120 doctors from 13 countries of the World were attended the Microsurgical Summit. Within the framework of the Summit, a laboratory (12 technoscopes) was deployed in the New Anatomical Building of the Siberian State Medical University (Tomsk, Russia) by Carl Zeiss LLC (Russia) to conduct a training course on the basics of Microsurgery for young doctors from the Russia and Austria.

The direct organizers and trainers of the course were Ye. Akelina, an employee of Columbia University (USA), and K. Selianinov and O. Kurochkina (Tomsk, Russia). Yelena Akelina is widely known in the World for her work on training residents and doctors from many countries both on the basis of the Microsurgery Laboratory of the Department of Orthopedics of Columbia University (New York, USA), and on the road to the countries of North and South America. During the coronavirus infection (COVID-19) pandemic, she first began to teach the basics of microsurgery online (virtual microsurgery). My proposal to Ye. Akelina on a joint project to publish a specialized issue of the journal devoted to teaching the basics of microsurgery in different countries of the World was met with enthusiasm.

The idea to begin papers in a special issue of the journal with historical background was borrowed

Идея начинать статьи в специальном номере журнала с исторической справки была заимствована мною из «Hand Surgery Worldwide» (Ed. James R. Urbaniak, Coed. L. Scott Levin, Goo Hyun Baek, Panayois M. Soucacos: Konstantaras Med. Pub., 2011). Огромную работу в подготовке этого номера журнала выполнила Елена Акелина. Мы, редакционный совет журнала, безмерно благодарны ей за это! Также мы благодарим компанию ООО «Карл Цейсс» в лице Светланы Деменко за финансовую поддержку данного проекта. Обращаю внимание наших читателей с многолетним стажем, что для этого номера журнала дизайнеры сделали ребрендинг обложки.

Что из этого получилось, дорогой читатель, Вы оцените после прочтения статей в этом юбилейном номере журнала, издаваемом Институтом микрохирургии (Томск) и Красноярским государственным медицинским университетом имени проф. В.Ф. Войно-Ясенецкого (Красноярск).

from Hand Surgery Worldwide (eds. James R. Urbaniak, Coed. L. Scott Levin, Goo Hyun Baek, Panayois M. Soucacos: Konstantaras Med. Pub., 2011). Yelena Akelina did a great job in preparing this issue of the Issues of Reconstructive and Plastic Surgery. We, the Editorial Board of the journal, are immensely grateful to her for this! We also thank Carl Zeiss LLC represented by Svetlana Demenko for financial support of this project. I would like to take a note of our readers with many years of experience that for this issue of the journal, the designers have re-branded the cover.

What came of this, dear reader, you will appreciate after reading the papers in this anniversary issue of the journal published by the Institute of Microsurgery (Tomsk, Russia) and Krasnoyarsk State Medical University named after Prof. V.F. Voyno-Yasenetsky (Krasnoyarsk, Russia).

С уважением, главный редактор, профессор ***В.Ф. Байтингер*** *(Россия, Томск)*
Respectfully yours, editor-in-chief, Professor ***Vladimir Bayitinger*** *(Russia, Tomsk)*

It is my great honor and pleasure to be named co-editor-in-chief for this special edition of the journal, *Issues of Reconstructive and Plastic Surgery*. I would like to express my deepest gratitude to my esteemed friend and colleague, Dr. Vladimir Fedorovich Baytinger for conceiving this important idea to help promote microsurgical education and for inviting me to lead this project.

Both Dr. Baytinger and I are big enthusiasts of microsurgery education because we both believe it is our future.

I have dedicated my career to raising a new generation of microsurgeon. I share my expertise and skills with them with the twin goals of making existing surgeons better technically and new imparting new surgeons with the cutting-edge advantage they are going to need in their practices. Again, these are the cornerstones of my work as a microsurgery instructor for the last 25 years.

Для меня большая честь и удовольствие быть соредактором специального выпуска журнала «Вопросы реконструктивной и пластической хирургии». Я хотела бы выразить свою глубочайшую благодарность моему уважаемому другу и коллеге Владимиру Фёдоровичу Байтингеру за то, что он стал автором этой важной идеи, способствующей развитию микрохирургического образования, и за приглашение возглавить этот проект.

И доктор Байтингер, и я – большие энтузиасты образования в области микрохирургии, так как мы оба верим, что это наше будущее.

Я посвятила свою карьеру воспитанию нового поколения микрохирургов. Я делюсь с ними своим опытом, преследуя двойную цель – улучшить технические навыки уже практикующих хирургов и поделиться с молодыми хирургами передовыми знаниями, которые им понадобятся в их будущей практике. Опять же, это краеугольные камни моей работы в качестве инструктора по микрохирургии за последние 25 лет.

За время моего профессионального пути я встретила большое количество замечательных, талантливых и полных энтузиазма микрохирургов со всего мира. Они делились со мной своим педагогическим и профессиональным опытом. И когда доктор Байтингер предложил замечательную идею создания международного образовательного выпуска журнала, посвященного прошлому, настоящему и будущему микрохирургического образования, я подумала о многих

During my professional journey, I have met scores of wonderful, talented, and very enthusiastic microsurgeons from around the World. They have shared this pedagogical and professional maxim with me. So, when Dr. Baytinger proposed this wonderful idea of creating this international educational issue of the journal outlining the past, present and future of microsurgical education, I thought of many friends and colleagues I could ask to contribute. I was honored and fortunate that many of them agreed to participate in the project. They sent us their work in a wide range of formats from around the globe.

For the readers who do not know me, let me quickly introduce myself. I am a Research Scientist and a Director and Instructor in Clinical Microsurgery in the Microsurgery Training and Research Laboratory at the Department of Orthopedic Surgery at Columbia University in New York.

I am a Russian-American. I was brought up in Moscow and immigrated in U.S. in 1992. In Russia, I studied to be a veterinarian at the Moscow Veterinary Academy in 1987. There, I obtained a Master of Science in Toxicology in 1991.

I started working in Microsurgery lab in 1996 as a college intern, quickly earning my veterinary license as a foreign graduate. At the end of my internship Dr. Harold M. Dick, the Department Chair at the time and founder of the lab, offered me a staff position. I took it, never looked back. It seemed a matter of fate, because instead of a licensed veterinarian in just a few years I became one of the most prominent instructors of microsurgery. I worked very hard to learn the new and very difficult skills of microsurgery "on the job", mostly by practicing "trial and error." Rather than seeking a mentor, I observed the students, carefully and learned from their mistakes. I have also been lucky enough to visit and learn from renowned experts like Dr. Robert Acland from Louisville and, Dr. Brian Cooley, Milwaukee.

Over nearly 25 years, I have taught roughly 4,000 surgeons and other medical personnel from all over U.S. and from more than from 70 countries.

We developed a very intense and comprehensive training program in microsurgery that has now become one of the key models in many courses around the World. The main goal of our training program is to teach surgeons to use microscopes to perform surgery on vessels and nerves as small as 1 mm in diameter. Taking this training with them, they then perform similar surgery on people in the home hospitals. That has helped countless patients.

My philosophy of teaching microsurgery is that by taking courses like microsurgery skills any surgeon would become a much better technically and can perform different practical procedures with more gentleness, precision and self-control. And

друзьях и коллегах, которых я могла бы попросить внести свой посильный вклад в реализацию этого проекта. Для меня было честью и удачей, что многие из них согласились участвовать в проекте. Они прислали нам свои работы со всего мира.

Для читателей, которые меня не знают, позвольте мне представиться. Я научный сотрудник, директор и инструктор по клинической микрохирургии в учебно-исследовательской лаборатории микрохирургии при Департаменте ортопедической хирургии Колумбийского университета (г. Нью-Йорк, США).

Я американка русского происхождения. Выросла в Москве. Училась на ветеринара в Московской ветеринарной академии с 1987 г. Получила степень магистра токсикологии в 1991 г. В 1992 г. иммигрировала в США

Я начала работать в лаборатории микрохирургии в 1996 г. в качестве стажера колледжа, вскоре получив ветеринарную лицензию как выпускник иностранного вуза. В конце моей стажировки доктор Гарольд М. Дик, в то время заведующий кафедрой и основатель лаборатории, предложил мне должность сотрудника. Я, не раздумывая, приняла предложение. Волей судьбы, из дипломированного ветеринара всего за несколько лет я стала одним из ведущих инструкторов по микрохирургии. Я очень много работала, чтобы освоить новые и очень сложные навыки микрохирургии «на рабочем месте», в основном практикуясь методом «проб и ошибок». Вместо того, чтобы искать наставника, я внимательно наблюдала за студентами и училась на их ошибках. Мне также посчастливилось побывать у таких известных экспертов, как доктор Роберт Акланд из Луисвилля и доктор Брайан Кули из Милуоки и поучиться у них.

За почти 25 лет работы я обучила около 4 тыс. хирургов и другого медицинского персонала из США и из более чем 70 стран мира.

Мы разработали очень интенсивную и всестороннюю программу обучения по микрохирургии, которая стала одной из ключевых моделей многих курсов по всему миру. Основная цель нашей учебной программы – научить хирургов использовать микроскопы для операций на сосудах и нервах диаметром от 1 мм. Пройдя такое обучение, они могут выполнять аналогичные операции в своей клинической практике, что поможет бесчисленному количеству пациентов в их выздоровлении.

Моя философия преподавания микрохирургии заключается в том, что, пройдя курсы, любой хирург станет намного более технически подготовленным и сможет выполнять различные практические процедуры с большей точностью и самоконтролем. И многие авторы, чьи статьи вы many of the authors whose papers that you will read here are sharing this idea!

I am very happy to introduce you this special edition of the *Issues of Reconstructive and Plastic Surgery*. Within these pages, you with learn about the history, the current state, and future paths of microsurgical education through articles submitted from a diverse group of international experts.

I would like to express one more time my deepest gratitude to the publishers, the editor, Dr. Baytinger, and to all my friends and colleagues who took time out of their busy schedules to participate in this wonderful project.

прочитаете здесь, разделяют эту идею!

Я очень рада представить вам этот специальный выпуск журнала «Вопросы реконструктивной и пластической хирургии», из которого вы узнаете об истории, текущем состоянии и будущих путях микрохирургического образования, прочитав статьи, представленные различными группами международных экспертов.

Ещё раз я хотела бы выразить глубочайшую благодарность издателям, редактору, доктору Байтингеру, а также всем моим друзьям и коллегам, которые нашли время в своем плотном графике для участия в этом замечательном проекте.

Hope you will enjoy reading!
Best, ***Yelena Akelina,*** *DVM, MS*
Приятного чтения!
С наилучшими пожеланиями, ***Елена Акелина,*** *DVM, MS*

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MICROSURGICAL EDUCATION IN THE USA: PAST, PRESENT AND FUTURE

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Microsurgery is a demanding surgical skillset which requires attention to detail and repeated practice to succeed. Microsurgery courses around the globe allow students to learn through performing a variety of technical exercises. Microsurgery education dates back to the late 1960s with notable instructors, Harry J. Buncke and Robert Acland. Currently, many microsurgery courses are available that share commonalities, and some important structural differences have been demonstrated to differentially affect student progression and competence. Multiple available training programs as well as the advancement of supermicrosurgery training is listed and described.

The microsurgery training course at Columbia University's New York Presbyterian Irving Medical Center led by Drs. Ronsenwasser, Strauch and Akelina provides students with expert instruction through a punctilious training curriculum. By imparting these techniques to the students, trainees's progression markedly improves relative to alternative microsurgery courses that do not incorporate expert instruction. The Covid-19 pandemic, has resulted in the development of a virtual microsurgery training program at the lab which focuses on building the foundation of basic skills for trainees unable to travel or receive adequate education.

Keywords: *microsurgery, microsurgical training, virtual training, anastomosis, microvascular surgery, microsurgery education.*

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МИКРОХИРУРГИЧЕСКОЕ ОБРАЗОВАНИЕ В США: ПРОШЛОЕ, НАСТОЯЩЕЕ, БУДУЩЕЕ

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Микрохирургия – это сложный набор хирургических навыков, который требует пристального внимания к деталям и многократной практики для достижения успеха. Образование в области микрохирургии берет свое начало с конца 1960-х гг., ее основоположниками являются известные хирурги Гарри Дж. Банке (Harry J. Buncke) и Роберта Акланда (Robert Acland). Курсы по микрохирургии во всем мире позволяют студентам учиться, выполняя различные технические упражнения. В настоящее время доступно большое количество схожих по содержанию курсов, при этом было продемонстрировано, что некоторые важные структурные различия этих курсов по-разному отражаются на успеваемости и компетентности студентов. Перечислены доступные программы обучения, описано развитие процесса обучения супермикрохирургии.

Учебный курс по микрохирургии в Медицинском центре Ирвинга Колумбийского университета (г. Нью-Йорк, США) под руководством докторов Ронсенвассер, Штраух и Акелиной предоставляет студентам возможность квалифицированного обучения в рамках учебной программы. При этом успеваемость слушателей заметно повышается по сравнению со студентами, проходящими обучение по альтернативным курсам по микрохирургии, которые не включают инструктаж экспертов. Пандемия COVID-19 послужила причиной для разработки виртуальной учебной программы по микрохирургии в лаборатории, направленной на получение базовых навыков для обучающихся и получение ими адекватного образования.

Ключевые слова: *микрохирургия, обучение микрохирургии, виртуальное обучение, анастомоз, микрососудистая хирургия, микрохирургическое образование.*

Конфликт интересов: авторы подтверждают отсутствие конфликта интересов, о котором необходимо сообщить.

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HISTORY OF EDUCATION IN MICROSURGERY

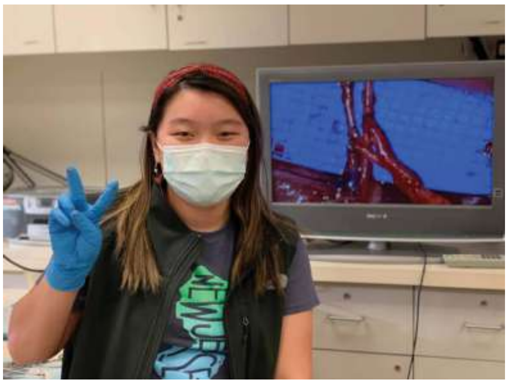
The field of microsurgical education dates back to the 1960s with a series of milestone procedures. These procedures introduced new methods of intraoperative magnification into surgical vascular procedures. First, Julius H Jacobson from University of Vermont and E.L. Suarez's paper titled "Microsurgery in anastomosis of small vessels" is widely recognized as the first microvascular procedure and is based on their completion of an anastomosis of a canine carotid artery in 1960 [1]. It had described that the operating microscope opened horizons for one-millimeter vessel repairs, of which Jacobson termed "microsurgery." Jacobson's pioneering procedure spawned many follow-on studies and procedures globally, highlighted by several of Harry J. Buncke's accomplishments such as his digit replantation procedure [2].

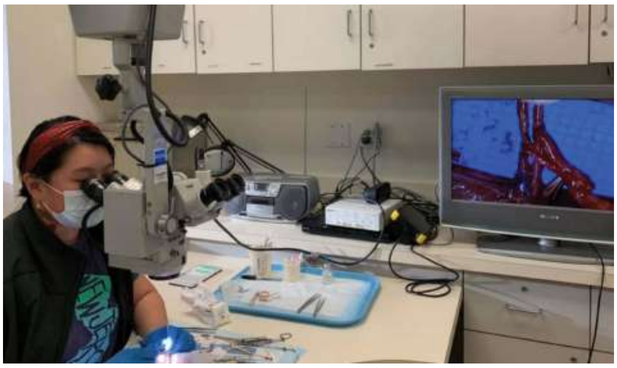
Encouraged by the possibilities of using the operating microscope, Bunke went on to perform his now well-known experiments of tissue transplantation in animal models – starting with the replantation of amputated rabbit ears. In 1967, along with other microsurgical pioneers of the 1960s, Bunke held the United States' first microsurgical panel at the Annual Meeting of the American Society of Plastic and Reconstructive Surgeons in New York

City which denoted the first in-person exchange of microsurgical findings and methods. Following the achievement of this gathering, the International Microsurgical Society was established in 1970. Buncke developed many central standards of microsurgery and is even considered "the father of microsurgery" for both his contributions to the field as well as his ~20 years of training microsurgeons all over the world [3, 4].

On the other hand, Robert Acland is noted as one of the world's greatest microsurgery instructors. After accepting an invitation to establish a microsurgery training laboratory at the Kleinert-Kutz Hand Center in Louisville, Kentucky [5], Acland would go on to teach over 3000 individuals in the Louisville lab. While there, Dr. Acland developed instructional videos and manuals for successful microvascular surgery, many of which are still widely used to this day [2].

The Microsurgery Training & Research Laboratory at New York-Presbyterian/ Columbia University Irving Medical Center was established in 1980 by Harold M. Dick, MD, former Chair of the Department of Orthopedic Surgery. The goal was to make microsurgery an integral part of a surgeon's training. Since its establishment, the laboratory has trained more than 4,000 physicians from 60 US institutions and over 70 countries. With the direction of Dr. Melvin P. Rosenwasser and instruction from Dr. Yelena Akelina, the basic & advanced courses have become internationally recognized.





DIFFERENT TRAINING PROGRAMS IN THE UNITED STATES AND THEIR CURRICULUM

There are a number of microsurgical training programs across the United States and have more recently gained traction in its importance among several surgical specialties that perform microsurgical procedures. Microsurgical procedures are performed in a variety of specialties including but not limited to plastic surgery, maxillofacial surgery, ENT, neurosurgery, orthopaedic surgery, urology, ophthalmology, and many more. Therefore, microsurgical training has been made an essential component in certain residency training programs such as plastic surgery [11] and others where Columbia University Medical Center requires the same of orthopedic surgical residents. Trainees must complete their microsurgical training curriculum and meet certain competency standards in order to successfully graduate the course.

Besides the training programs in the United States that are offered during residency, there are approximately 30 other fellowships in microsurgery offered to surgeons. These fellowships are usually 1 year in length with approximately 1 to 3 open slots per year, and more often than not, solely offered to plastic and reconstructive surgeons.

Microsurgery skill training laboratories will be the main focus in this section, as it is considered the first step into mastering microsurgical techniques before its application into the clinical setting.

Training via microsurgery labs is one of the most common and efficient paths taken by surgeons in the US. These intensive training programs offer surgeons of varying skill levels the ability to develop their microsurgical technique in a controlled environment under the guidance of an experienced microsurgery instructor.

Microsurgical training laboratories typically offer basic and/or advanced levels of practical microsurgery training. This instruction commonly ranges from 15 to 40 hours over the course of a week, depending on program structure and curriculum. Courses may also use different models of both high fidelity, living models (rat) or low fidelity being non-living models such as chicken thigh, chicken wing, and synthetic vessel constructs.

The typical basic microsurgery curriculum will vary slightly across different programs, but will usually cover common topics such as:

1) the use of the operating microscope;

2) basic suturing techniques utilizing a plastic or latex model;

3) learning how to perform end-to end anastomosis of both arteries and veins;

4) learning how to perform end to side anastomosis (ie. end of the femoral artery to the side of the femoral vein);

5) peripheral epineurial repair;

6) free flap reconstruction.

In regards to advanced microsurgery training the student will typically:

1) learn to perform end-to-end and end-to-side bypass anastomoses;

2) learn to perform inter-positional vein grafts;

3) gain more exposure in the usage of free tissue flaps.

Many programs in the United States will also tailor learning to that student's specialty, for example focusing on vasovasostomy for urologists or organ transplants for transplant surgeons.

Towards the end of each course, students are assessed via a practical exam and different assessment objective and subjective tools.

A list and brief overview of microsurgery training programs offered in the United States are included in the Table 1.

Table 1. A list and brief overview of microsurgery training programs offered in the United States

Таблица 1. Список и краткий обзор программ обучения микрохирургии, предлагаемых в США

Training place	Program	Duration	Models	Assessments
Columbia University, New York	Basic Microsurgery Advanced Microsurgery (Super-microsurgery included in advanced course)	5 days (40 hours) 5 days (40 hours)	Non-living (latex glove, synthetic vessels, chicken thigh) and living (rat)	Subjective evaluations, quality control by *transonic auro flo, and a* practical exam with ALI score
Mayo Clinic, Minnesota	Basic Microsurgery Advanced Microsurgery (Super-microsurgery included in advanced course)	5 days (40 hours) 3 days (24 hours)	Living (rodent)	Subjective evaluations and a practical exam
University of Louisville, Kentucky	Basic Microsurgery	5 days (40 hours)	Non-living (rubber glove) and Living (rat)	Subjective evaluations and a practical exam
MOET Institute, California	Basic and Advanced Microsurgery combined into one course	10 days (80 hours)	Non-living (chicken thigh)	Subjective evaluations
Duke, North Carolina	Basic Microsurgery Advanced Microsurgery	5 days (40 hours)	Living (rat)	Subjective evaluations
Cleveland Clinic, Ohio	Basic Microsurgery Advanced Microsurgery	5 days (40 hours)	Non-living (rubber glove) and living (rat)	Subjective evaluations
University of Kentucky, Kentucky	Basic Microsurgery	5 days (15 hours)	Living (rodent)	Subjective evaluations and a practical exam
University of Illinois, Illinois	Basic Microsurgery Advanced Microsurgery	5 days (40 hours)	Living (rat)	Subjective evaluations
Oakland University William Beaumont School of Medicine, Michigan	Basic Microsurgery	5 days (40 hours)	Non-living (rubber glove) and living (rat)	Practical exam

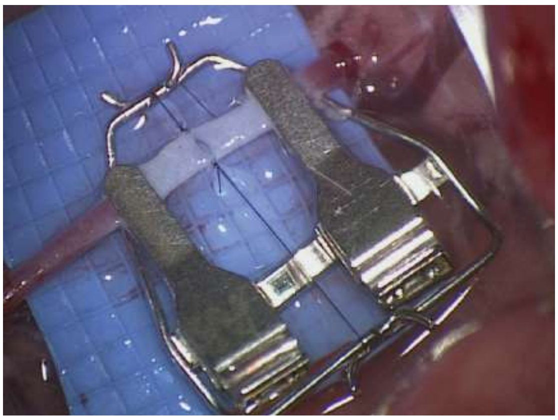
BASIC STEPS FOR END-TO-END AND END-TO-SIDE ANASTOMOSIS

The following instructional passage delineates Dr. Akelina's (from The Microsurgery Training & Research Laboratory at New York-Presbyterian/Columbia University Irving Medical Center) procedural steps for the completion of the end-to-end (ETE), the end-to-end (ETE) "one way up technique," and end-to-side (ETS) anastomosis (arterial-to-venous anastomoses) for the rat femoral vessels (~1 mm diameter). Clinically, these procedures can be applied to re-vascularization during free tissue transfers, organ transplants, arterial-venous (AV) fistula, and venous-arterial (VA) anastomosis for dialysis, among others. Clinical applications for this procedure are far reaching.

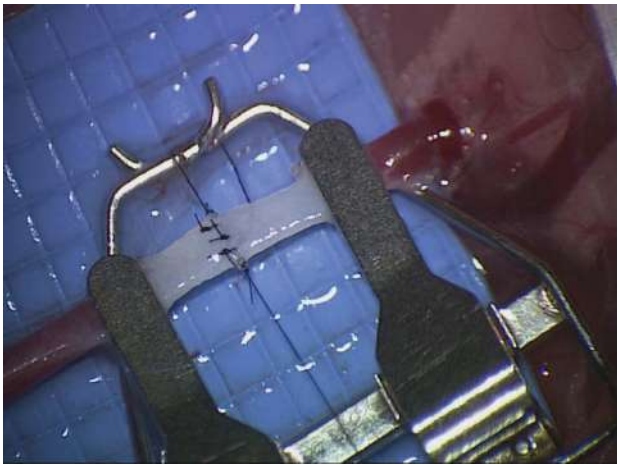
This part of the paper walks through a step-by-step procedure for all three exercises using the femoral artery and vein of the rat (part of the Basic Course). While this procedure can be easily extended to a variety of veins and arteries, the use of two autologous vessels are highlighted due to the similarities in vessel size and anatomical proximity. Although clinically the end-to-side is more commonly performed either artery-to artery or vein-to-vein, we use artery-to-vein and vein-to-artery anastomoses so students learn to perform both arteriotomy and venotomy [9, 10].

End-to-End Anastomosis step-by-step procedure (rat femoral vessel)

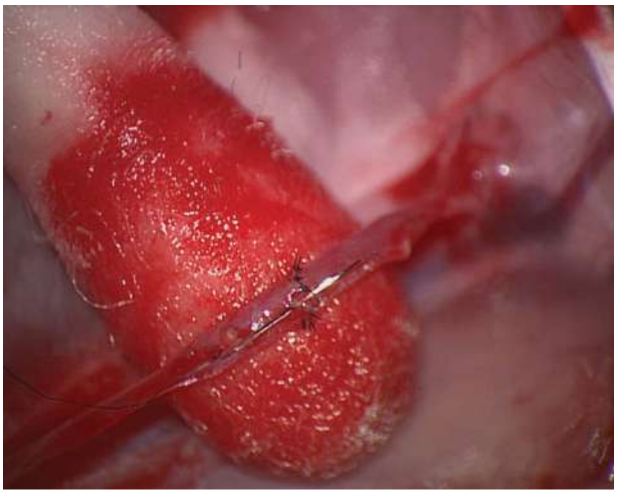
1. Perform blunt dissection of the fat pad to expose femoral vessels in the rat inguinal region.
2. Isolate the femoral artery and ligate and coagulate all muscular branches.
3. Place a double clamp with a frame into a central position on top of a blue background.
4. Divide the vessel in a middle between the double clamps.
5. Prepare the femoral artery edges by trimming adventitia and dilating the edges.
6. Place two interrupted stay sutures at the 12 o'clock and 6 o'clock positions, and fix the ends of each stay suture to the frame as stays.



7. Place three more interrupted sutures starting at 3 o'clock then 1 o'clock and 4 o'clock positions. You might leave the middle stitch longer for handling a wall to avoid catching the back wall.

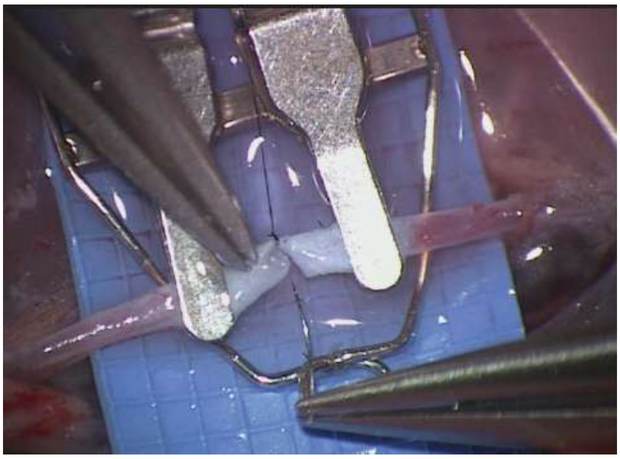


8. Flip the double clamp 180 degrees to expose the posterior wall and complete it the same manner.
9. After completion 8 stitches , release the stays and remove the clamp.
10. Place the fat pad and the gauze over the anastomosis for a few minutes for hemostasis before evaluating patency.
11. If bleeding occurs, repair the anastomosis with additional stitches using the partial occlusion techniques by Dr. Akelina shown below [20].

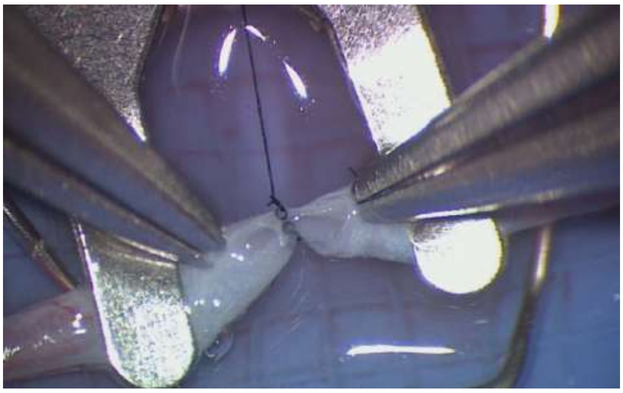


End-to-End Anastomosis utilizing the "One Way Up Technique"

1. Prepare the vessel in the same manner described previously.
2. Place a double clamp with the tips facing toward you. Prepare the vessel in the same manner described above in the normal ETE anastomosis.
3. Place and secure the first stay suture at 12 o'clock position.



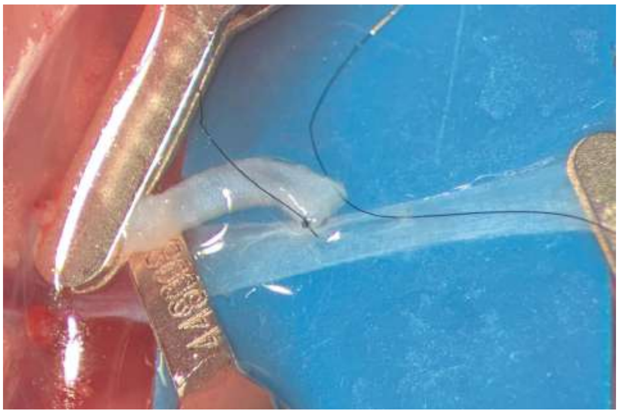
4. For the all [3] posterior wall stitches make the first pass outside-in using a backhand technique and the second pass inside out with the forehand technique described above.



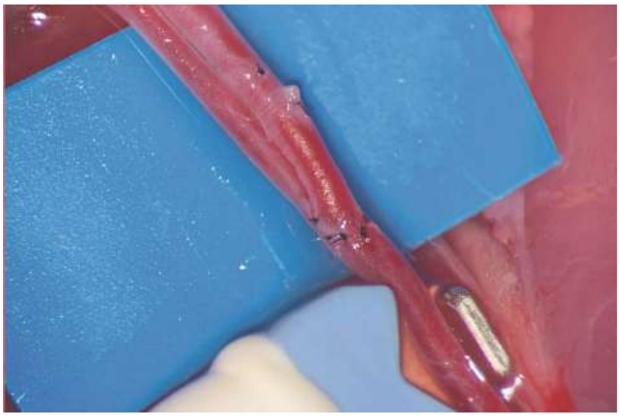
5. Put 6 o'clock stay once you reach the midpoint of the anastomosis
6. Proceed closing the anterior wall in the normal, single pass forehand manner with three more stitches.
7. Upon completion of the vessel sutures, release the stay suture and the vessel clamp.
8. If bleeding occurs, repair the anastomosis with additional stitches using the partial occlusion techniques by Dr. Akelina [20].

Step by step procedure to perform end-to-side anastomosis

1. Dissect the femoral artery and vein by separating the vascular sheath. Use blunt dissection under high magnification. Ligate and coagulate all Murphy's branches.
2. Place a single clamp on the proximal end of the femoral artery and ligate distally towards the epigastric artery.
3. Prepare the edge of the artery by trimming adventitia, and then dilate the vessel edges.
4. Place two single clamps, one on the proximal and one on the distal end of the femoral vein (as shown below).
5. Make a small "v shaped" venotomy and flush the blood with heparinized saline.
6. Dilate the venotomy opening using a vessel dilator (20% larger than diameter of the femoral artery).
7. Connect the end of the artery with the side of the vein with the first stitches at "heel" and "toe" placing both stitches "*outside in, inside out.*"



8. Complete circumferential stitches along the back wall to prevent inadvertent back-wall stitches.
9. Flip the arterial clamp to the opposite side and place a retraction stitch through the adventitia of the Murphy branch before securing it to the nearby muscle.
10. Complete the front wall by keeping the middle stitch open while placing two or more radial stitches.
11. Examine the anastomosis for gaps before releasing the clamps.
12. Place the fat pad over the anastomosis for hemostasis and examine the anastomosis.



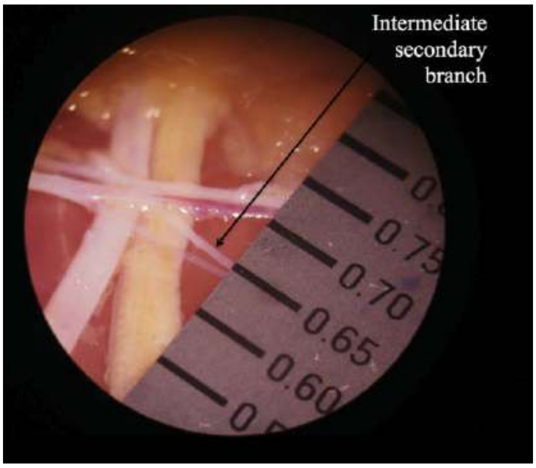
13. If bleeding occurs, repair the anastomosis with additional stitches using the partial occlusion techniques by Dr. Akelina [20].

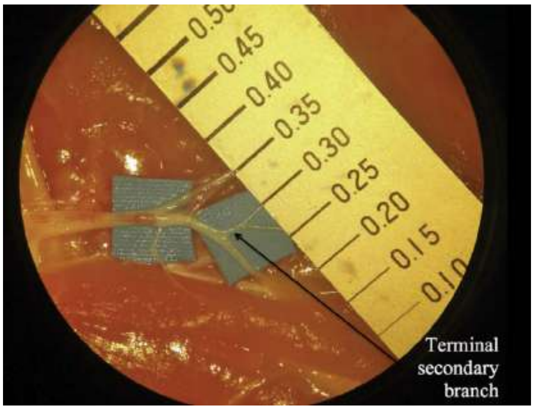
SUPERMICROSURGERY

Supermicrosurgery, a branch of microsurgery, was founded by Professor Isao Koshima, MD, at the University of Tokyo in 2000; it requires a specific set of skills and rigorous training in order to be able to perform successfully.

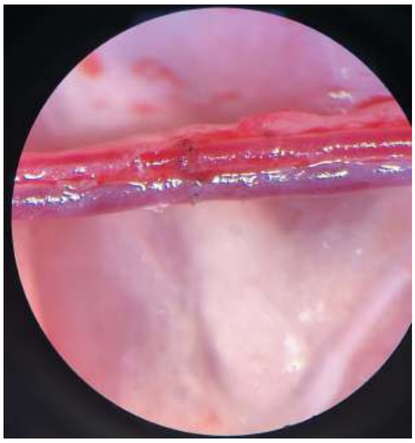
There are a few training centers that instruct trainees in supermicrosurgery in the U.S. Certain fellowships in the U.S. offer supermicrosurgery as part of their training curriculum in microsurgery such as the Cleveland Clinic [12]. Currently two microsurgery training laboratories offer supermicrosurgery training as part of their advanced course, these being Columbia University and Mayo Clinic [13, 14]. They may range from 24 to 40 hours in length over the course of 3 to 5 days. During these training courses, two models are utilized including non-living models such as a chicken thigh, a chicken wing, etc. and a living rat model.

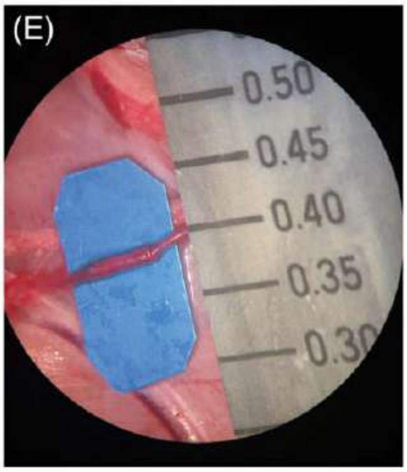
Previous literature noted that the chicken thigh and wing models are much easier to obtain and use [16, 18]. When using a chicken thigh as a model, intermediate and terminal secondary branches of vessels were measured to be from 0.3 to 0.8 mm, making them perfect targets for training specifically in lymphaticovenular anastomosis.

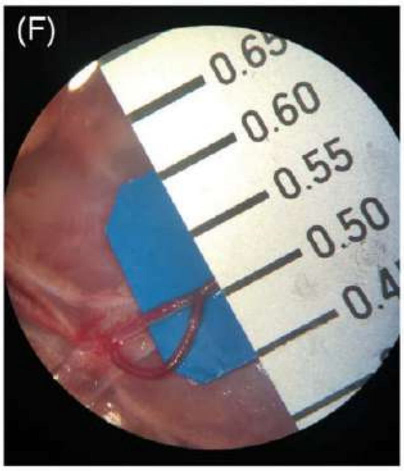




Still, the preferred model for training in terms of clinical practice is the live rat epigastric vessels from 0.3–0.5 mm diameter [17]. During Dr. Yelena Akelina's training, various anastomotic configurations of the live rat superficial inferior epigastric artery (SIEA) and vein (SIEV) are used with the following exercises: interposition SIEV graft between SIEA, end-to-side anastomosis or AV fistula, and SIEA bypass. A bypass graft from the contralateral leg SIEA can be looped to the recipient SIEA with double end-to-side anastomosis. Training with such small vessels fine tune the trainee's skills and increase their experience with supermicrosurgery to be utilized clinically as the diameter of both the SIEA and SIEV capture the character of a human lymphatic vessel or other small vessels [19].







FUTURE IN MICROSURGERY EDUCATION; VIRTUAL TRAINING

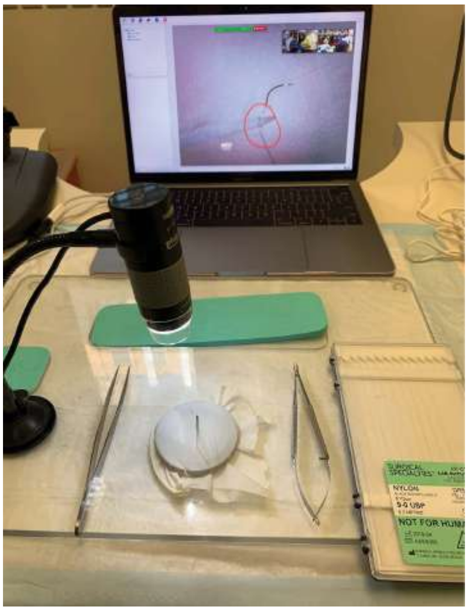
Since the beginning of the Coronavirus/COVID-19 pandemic in February 2020, the United

States has been in a constant state of lockdowns and quarantines. Strict travel limitations, both domestic and internationally, has limited physician access to in-person, live microsurgery training for their future clinical applications. This has caused a rapid state of adaptations of microsurgical education around the evolving restrictions.

Simulated surgical training is one modality microsurgical training labs have turned to. Microvascular surgery training is not new to virtual reality training. In the early 21st century, Stanford University created a system where novice physicians could practice simple microsurgical procedures using virtual reality. Making the operator immersed in this virtual environment makes it a risk-free and repetitive tool. The workstation displays the virtual procedure while real microsurgical instruments are used as input devices [6]. Although this technology is rapidly developing, we believe that it takes away from simulations that offer more hand-on exercises and execution with a physical model.

Virtual training is making its way to the forefront of microsurgical training as it effectively eliminates many of the issues that are faced today. A teleconferencing software is used to connect an expert instructor with a student live. This does allow for all training and communications to happen online yet does not take away expert instruction; it has been previously noted that there are clear benefits in both progress and proficiency to receiving microsurgical training from an expert instructor [7].

Conversely, traditional operating microscopes could be used if available to the student but these have also been seen as a considerable barrier for training as it is not easily accessible.



A “home lab set-up” using either smartphone or digital microscope acquired by the student which is portable, relatively inexpensive and can be easily set up.

The digital microscope is connected to a tablet device and the live capture is broadcast onto the teleconferencing software. This is optimized for training as the instructor could provide immediate feedback. A previous study reported that the use of the digital microscope presented measurable improvements among resident trainees [8].

During a virtual microsurgical training course physicians will be able to learn basic microscope setups, correct body posture and hands positions, basic suturing techniques, and anastomotic procedures. This type of training is currently offered with Dr. Akelina. Thus, within a student's home/lab environments, low fidelity models and live instructions there is a way to familiarize themselves with the appropriate basic techniques in microsurgery.

Although virtual training can never truly replace in-person and live instruction of microsurgery, it is a great starting point in introducing the wide audience of students all over the globe; in hopes that the basics of microsurgery could be taught without the limitations that come with either current events or finances.

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ТЕХНОЛОГИИ ОБУЧЕНИЯ МИКРОХИРУРГИЧЕСКИМ НАВЫКАМ В ИНСТИТУТЕ МИКРОХИРУРГИИ

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В статье описан опыт создания обучающего курса по основам микрохирургии на базе Института микрохирургии (Томск, Россия). Представлена программа курса, разработанная в соответствии с мировыми тенденциями в обучении микрохирургии. Дан перечень основных тенденций в развитии образовательных программ.

Ключевые слова:	*обучение, микрохирургия, программа, опыт.*
Конфликт интересов:	авторы подтверждают отсутствие конфликта интересов, о котором необходимо сообщить.
Прозрачность финансовой деятельности:	никто из авторов не имеет финансовой заинтересованности в представленных материалах или методах.
Для цитирования:	Селянинов К.В., Курочкина О.С., Байтингер В.Ф. Технологии обучения микрохирургическим навыкам в Институте микрохирургии. *Вопросы реконструктивной и пластической хирургии.* 2021;24(1):19–28. doi: 10.52581/1814-1471/76/2

TRAINING TECHNOLOGIES IN MICROSURGICAL SKILLS IN THE INSTITUTE OF MICROSURGERY

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The paper describes the experience of creating a training course on the basics of microsurgery at the Institute of Microsurgery (Tomsk, Russia). The program of the course is provided, developed in accordance with the World trends in teaching microsurgery. The main trends in the development of educational programs are presented.

Keywords:	*training, microsurgery, program, experience.*
Conflict of interest:	the authors declare the absence of obvious and potential conflicts of interest related to the publication of this paper.
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Микрохирургическая технология повсеместно вошла в практику хирургических специальностей, являясь технологией, определяющей качество жизни. В связи с этим чрезвычайно востребованными являются программы по обучению микрохирургии, проводимые на базе различных медицинских центров и университетов [1–3]. Одним из первых целевых циклов, направленных на популяризацию микрохирургической технологии, был двухдневный цикл, организованный академиком РАМН Н.О. Милановым на базе ФГБНУ РНЦХ им. акад. Б.В. Петровского (г. Москва) совместно с фирмами Carl Zeiss и Aesculap (13–14 февраля 2010 г.) (рис. 1). В качестве участников со стороны НИИ микрохирургии (г. Томск) были кандидат медицинских наук К.В. Селянинов и А.В. Байтингер.

По инициативе профессора В.Ф. Байтингера первые программы по обучению микрохирургии в Сибирском регионе проходили на базе Института микрохирургии с 2011 г. Это стало возможным при поддержке одного из мировых лидеров по производству операционных микроскопов и оптических систем – фирмы Carl Zeiss (рис. 2–4). Продолжительность обучения – 1 день (10 ч). В ходе обучения курсанты осваивали навыки по наложению сосудистых анастомозов по типу «конец-в-конец», шва нерва на трупных и живых моделях (белые крысы). Реализация программ в первые годы осуществлялась совместно с кафедрой пластической хирургии с курсом оперативной хирургии и топографической анатомии (зав. – профессор В.Ф. Байтингер) Сибирского государственного медицинского университета (г. Томск).

Microsurgical technology is ubiquitous in the practice of surgical specialties, being a technology that determines the quality of life. In this regard, programs for the training of microsurgery, conducted on the basis of various Medical Centers and Universities, are extremely in demand [1–3]. One of the first targeted cycles aimed at popularizing of microsurgical technology was a two-day cycle organized by Academician of the Russian Academy of Medical Sciences N.O. Milanov on the basis of the Russian Scientific Center for Surgery named after Acad. B.V. Petrovsky (Moscow, Russia) together with Carl Zeiss and Aesculap (February 13-14, 2010) (Fig. 1). The participants from the Research Institute of Microsurgery (Tomsk, Russia) were Cand. Med. sci. K.V. Selianinov and A.V. Baytinger.

On the initiative of Professor V.F. Baytinger, the first microsurgery training programs in the Siberian Region began at the Institute of Microsurgery in 2011. This became possible with the support of Carl Zeiss (Germany), one of the world leaders in the production of operating microscopes and optical systems (Fig. 2–4). Duration of training is 1 day (10 hours). During the training, the cadets mastered the skills of applying end-to-end vascular anastomoses, nerve sutures on cadaveric and live models (white rats). The implementation of the programs in the early years was carried out jointly with the Department of Plastic Surgery with a Course in Operative Surgery and Topographic Anatomy (headed by Professor V.F. Baytinger), the Siberian State Medical University (Tomsk, Russia).

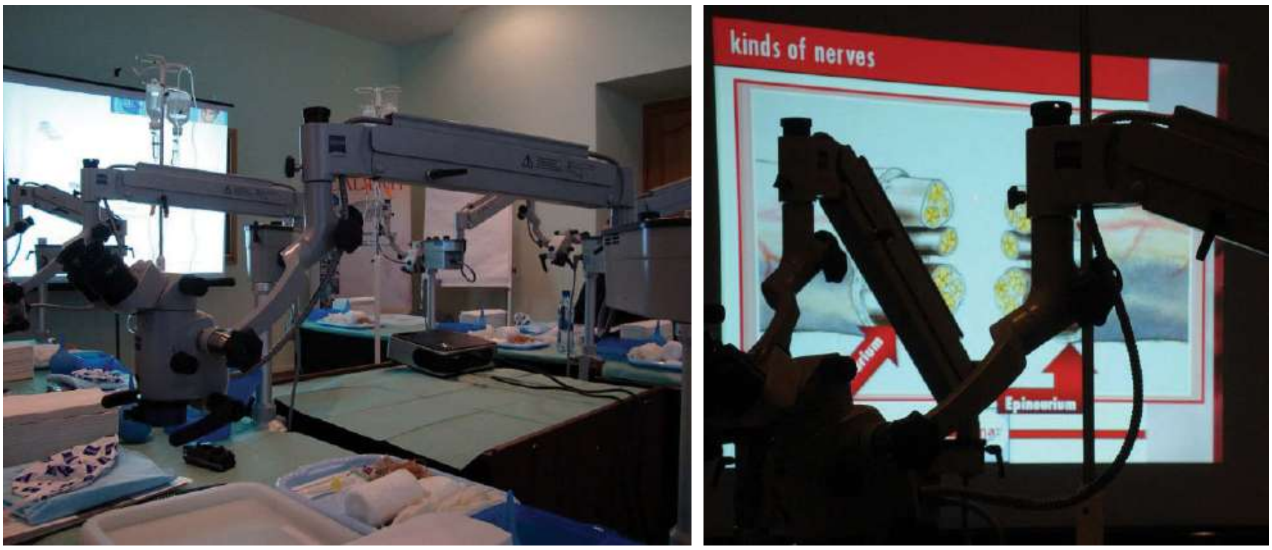

Рис. 1. Обучающий цикл по микрохирургии на базе РНЦХ им. акад. Б.В. Петровского. Москва, 13–14 февраля 2010 г.

Fig. 1. Training cycle on microsurgery on the basis of the Russian Scientific Center for Surgery named after Acad. B.V. Petrovsky. Moscow, February 13–14, 2010

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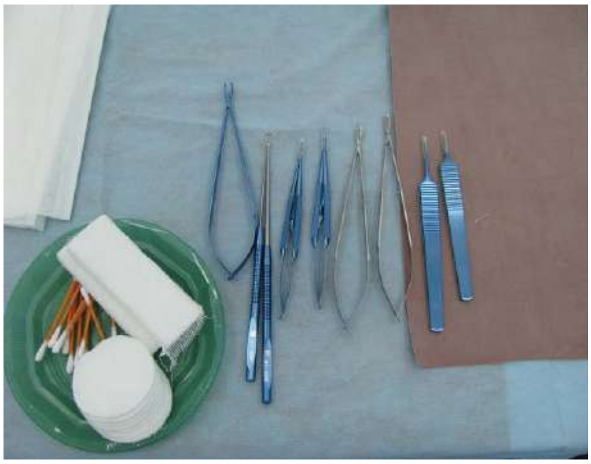

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Рис. 2. Первый обучающий курс «Основы микрохирургии» на базе НИИ микрохирургии (г. Томск, 2011): *а* – вид учебной аудитории с оборудованием фирмы Carl Zeiss; *б, в* – рабочее место участников; *г* – участники курса за отработкой микрохирургических навыков

Fig. 2. First training course "Basis of Microsurgery" on the basis on the Institute of Microsurgery (Tomsk, Russia, 2011): *а* – view of the classroom with the equipment of Carl Zeiss; *б, в* – the workplace of the participants; *г* – course participants for practicing microsurgical skills

Рис. 3. Участники первого обучающего курса «Основы микрохирургии» на базе НИИ микрохирургии (г. Томск, 2011)

Fig. 3. Participants of the first training course "Basis of Microsurgery" at the Institute of Microsurgery (Tomsk, Russia, 2011)

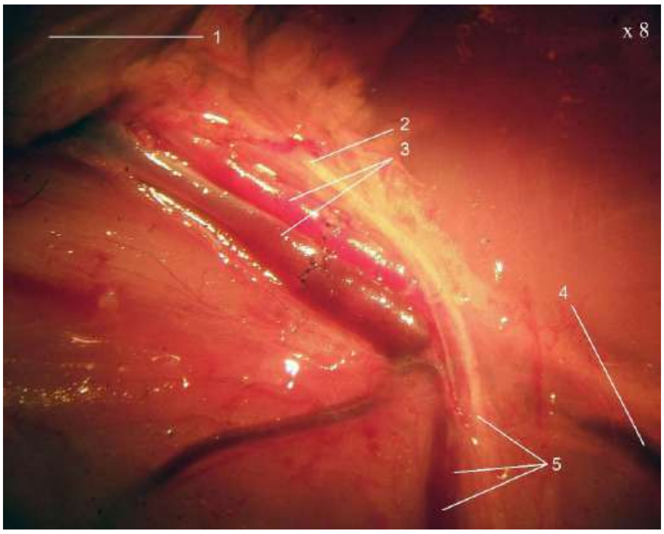

Рис. 4. Микрососудистые швы на бедренном сосудистом пучке (белая крыса): 1 – паховая связка; 2 – бедренный нерв; 3 – зона микрососудистых анастомозов на бедренных сосудах; 4 – подколенный сосудистый пучок (артерия и вена); 5 – сосудистая ножка эпигастрального лоскута. Ув. ×8

Fig. 4. Microvascular sutures on the femoral vascular bundle (white rat): 1 – inguinal ligament; 2 – femoral nerve; 3 – zone of microvascular anastomoses on the femoral vessels; 4 – popliteal vascular bundle (artery and vein); 5 – vascular pedicle of the epigastric flap. Mag. ×8

Естественно, что продолжительность цикла была мала и не удовлетворяла полностью потребностей обучающихся в плане более детального освоения микрохирургических навыков.

7 июля 2009 г. Приказом Минздравсоцразвития России была утверждена специальность «Пластическая хирургия». В связи с этим повысился статус Обучающих центров в плане подготовки медицинских кадров для новой специальности. Программа обучения на базе НИИ микрохирургии была скорректирована в направлении увеличения учебных часов с 10 до 36 (6 дней), проведено лицензирование образовательной деятельности по дополнительному профессиональному образованию (лицензия № 2006 от 24.01.2019) (рис. 5).

The duration of the cycle was very short and did not fully satisfy the needs of students in terms of more detailed mastering of microsurgical skills.

On July 7, 2009, the specialty "Plastic surgery" was approved by the order of the Ministry of Health and Social Development of Russia. In this regard, the status of the Training Centers has increased in terms of training medical personnel for a new specialty. The training program on the basis of the Research Institute of Microsurgery was adjusted in the direction of increasing teaching hours from 10 to 36 (6 days), licensing of educational activities for additional vocational education was carried out (License No. 2006 dated January 24, 2019) (Fig. 5).

Рис. 5. Лицензия на образовательную деятельность НИИ микрохирургии
Fig. 5. License for educational activities of the Institute of Microsurgery

В целях методического сопровождения цикла был разработан и в 2012 г. издан практикум «Введение в микрохирургию» (рис. 6), который активно используется в реализации учебной программы [4]. Также, в дополнение к имеющемуся оборудованию (2 операционных микроскопа фирмы Carl Zeiss) были приобретены 4 учебных микроскопа фирмы «Meiji Techno» (Япония) (рис. 7) и расходные материалы (силиконовые модели сосудов) «Wetlab» (Япония).

В настоящее время обучающая программа состоит их двух разделов – теоретической и практической частей (рис. 8).

Теоретическая часть:

– история развития микрохирургии;

– виды сосудистых швов;

– шовный материал.

Практическая часть:

– знакомство с операционным микроскопом и правила работы на нем;

– знакомство с микрохирургическим инструментарием, отработка навыков наложения швов на перчаточной резине;

– наложение микрохирургического сосудистого шва на искусственной модели кровеносного сосуда (диаметр 1–2 мм), формирование сосудистых анастомозов по типам: «конец-в конец», «конец-в-бок»;

– «живая хирургия» – микрохирургический шов бедренных артерии и вены, сонной артерии, аорты. Модель – белая крыса.

The workshop "Introduction to Microsurgery" (Fig. 6), which is actively used in the implementation of the curriculum, was developed and published in 2012 for the purpose of methodological support of the cycle [4]. In addition to the existing equipment (2 operating microscopes from Carl Zeiss, Germany), 4 educational microscopes from Meiji Techno (Japan) (Fig. 7) and consumables (silicone models of vessels) from Wetlab (Japan) were purchased.

Currently, the training program consists of two sections – theoretical and practical parts (Fig. 8).

Theoretical part:

– history of the development of microsurgery;

– types of vascular sutures;

– suture material.

Practical part:

– acquaintance with the operating microscope and the rules for working;

– acquaintance with microsurgical instruments, practicing the skills of suturing on glove rubber;

– the imposition of a microsurgical vascular suture on an artificial model of a blood vessel (diameter 1–2 mm), the formation of end to end, end to side vascular anastomoses;

– "live surgery" – microsurgical suture of the femoral artery and vein, carotid artery, aorta. The model is a white rat.

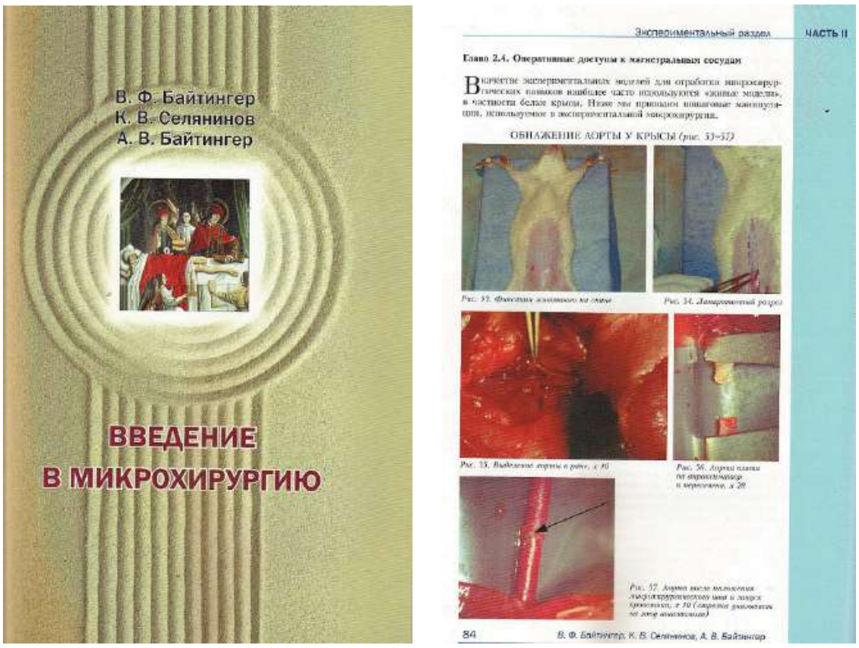

Рис. 6. Практикум «Введение в микрохирургию». Томск, 2012

Fig. 6. Workshop "Introduction to Microsurgery". Tomsk, 2012

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Рис. 7. Обучающий микрохирургический класс НИИ микрохирургии: *а* – общий вид; *б, в* – техноскоп фирмы «Meiji Techno» и индивидуальный бокс «Wetlab» (Япония) для обучения выполнению сосудистого шва

Fig. 7. Educational microsurgical class of the Research Institute of Microsurgery: *а* – general view; *б, в* – technoscope of the company Meiji Techno and an individual box Wetlab (Japan) for training the vascular suture

Код	Наименование разделов дисциплин и тем	Всего часов	В том числе		Форма контроля
			Лекции	Практич. занятия	
1	2	3	4	5	6
1.	Основы микрохирургии				
1.1.	История развития микрохирургии	0,5	0,5	-	
1.2.	Микрохирургическое оборудование и инструментарий	3	1	2	
1.3.	Модели для обучения микрохирургии	10,5	0,5	10	
1.4.	Оперативные доступы к сосудисто-нервным пучкам	1,0	1	-	
1.5.	Сосудистый шов и шов нерва	13	2	11	
1.6.	Реконструкция дефектов нервов	6,5	1	5,5	
	Итоговая аттестация:	1,5	0,5	1	
	Итого:	36	6,5	29,5	Зачет

Рис. 8. Учебный план цикла «Основы микрохирургии» (36 ч)

Fig. 8. Curriculum of the cycle "Fundamentals of Microsurgery" (36 hours)

По окончании цикла выдается удостоверение установленного образца о повышении квалификации. Реализацию программы курса осуществляют: д-р мед. наук, профессор В.Ф. Байтингер, д-р мед. наук К.В. Селянинов, канд. мед. наук О.С. Курочкина.

В период с 2011 по ноябрь 2019 г. на базе Института микрохирургии прошли обучение 74 врача из России, Казахстана, Белоруссии, Австрии (рис. 9). В 2018–2019 гг. отмечалось заметное увеличение количества обучающихся (14 и 24 курсанта соответственно), что связано с популяризацией микрохирургической технологии в России и подготовкой к утверждению профессионального стандарта «Врач пластический хирург» (утвержден приказом Минтруда России 31.07.20 №482-н) (рис. 10).

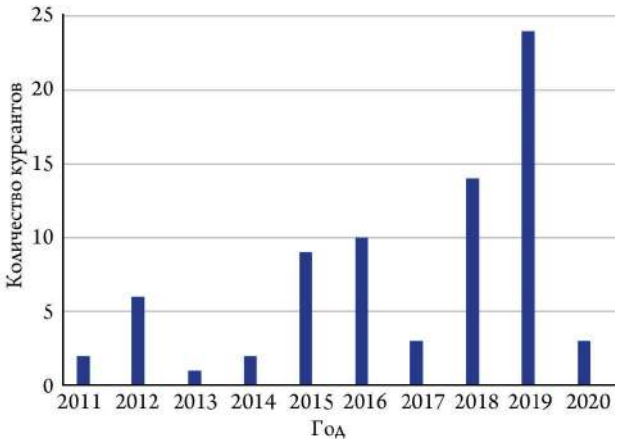

Рис. 9. Количество курсантов, прошедших обучение на базе НИИ микрохирургии, по годам (2011–2020 гг.)

Fig. 9. Number of cadets trained at the Institute of Microsurgery in 2011–2020

At the end of the cycle, a certificate of the established form on advanced training is issued. The implementation of the course program is carried out by: Dr. Med. Sci., Professor V.F. Baytinger, Dr. Med. sci. K.V. Selianinov, Cand. Med. sci. O.S. Kurochkina.

74 doctors from the Russia, Kazakhstan, Belarus, and Austria were trained at the Institute of Microsurgery in the period from 2011 to November 2019 (Fig. 9). There was a noticeable increase in students (14 and 24 cadets, respectively) in 2018–2019, which is associated with the greater popularization of microsurgical technology in Russia and the preparation for the approval of the Professional standard "Doctor-plastic surgeon" (approved by order of the Ministry of Labor of Russia in July 31, 2020, No. 482-n) (Fig. 10).

Рис. 10. Во время обучающего курса «Основы микрохирургии», сентябрь 2020 г. (слева направо: врач-травматолог-ортопед М. Степанов, курсант А. Мордяков (г. Ульяновск), модератор курса О.С. Курочкина)

Fig. 10. Training course "Fundamentals of Microsurgery", September 2020 (from left to right: traumatologist-orthopedist M. Stepanov, cadet A. Mordyakov (Ulyanovsk, Russia), course moderator O.S. Kurochkina)

В последнее десятилетие в обучающую практику студентов и ординаторов медицинских вузов, а также молодых специалистов широко внедряются сетевые программы, позволяющие перенимать опыт ведущих специалистов России и мира в области реконструктивной и пластической хирургии. В 2019 г., в рамках I Микрохирургического саммита в Сибири, Институт микрохирургии совместно с Колумбийским университетом (г. Нью-Йорк, США) провели двухдневный интенсивный курс по основам микрохирургии (рис. 11, 12). Среди участников – врачи травматологи-ортопеды, пластические хирурги из России и стран Европейского Союза. Интенсивный курс был аккредитован в системе Непрерывного медицинского образования.

По окончании каждого цикла обучения проводится анонимное анкетирование участников с целью выяснения их удовлетворенностью качеством обучения в целом, а также пожеланий по совершенствованию учебного процесса. В ходе анонимного анкетирования обучающихся было выявлено, что удовлетворенность от обучения на цикле составила 97,6%. Основными пожеланиями обучающихся являлись: увеличение продолжительности программы, введение дополнительных разделов по микрохирургическому шву нерва, применению аутоневральных вставок, наложению лимфовенулярных анастомозов, а также более активное привлечение курсантов к работе в операционной.

Наличие на постоянной основе на базе клиники Института микрохирургии обучающего класса позволяет хирургам поддерживать микрохирургические навыки на надлежащем уровне, что неоднократно отмечали ведущие микрохирурги России и Европы при посещении института (академик РАН И.В. Решетов (г. Москва), профессор М.А. Волох (г. Санкт-Петербург), профессор М. Нинкович (г. Мюнхен, Германия) и др.) (рис. 13). Профессор М. Нинкович отметил, что именно в НИИ микрохирургии он впервые встретил возможность выполнения тренировки микрохирургических навыков непосредственно перед оперативным вмешательством.

In the last decade, network programs have been widely introduced into the teaching practice of students and residents of Medical Universities, as well as young specialists, allowing them to adopt the experience of leading specialists in Russia and the World in reconstructive and plastic surgery. In 2019, within the framework of the I Microsurgical Summit in Siberia, the Institute of Microsurgery together with Columbia University (New York, USA) are conducted a two-day intensive course on the basics of microsurgery (Fig. 11, 12). There were traumatologists-orthopedists, plastic surgeons from Russia and the countries of the European Union among the participants. The intensive course was accredited in the Continuing Medical Education system.

At the end of each training cycle, an anonymous survey of participants is carried out in order to find out their satisfaction with the quality of training in general, as well as wishes for improving the educational process. It was revealed in the course of an anonymous survey of students, that satisfaction with training in the cycle was 97.6%. The main wishes of the students were: an increase in the duration of the program, the introduction of additional sections on the microsurgical suture of the nerve, the use of autoneural inserts, the imposition of lympho-venular anastomoses, as well as more active involvement of cadets in work in the operating room.

The presence of a training class on the basis of the clinic of the Institute of Microsurgery on a permanent basis allows surgeons to maintain microsurgical skills at an appropriate level. It was repeatedly noted by the leading microsurgeons of Russia and Europe when visiting the Institute (Academician of the Russian Academy of Sciences I.V. Reshetov (Moscow, Russia), Professor M.A. Volokh (St. Petersburg, Russia), Professor M. Ninkovich (Munich, Germany) and others) (Fig. 13). Professor M. Ninkovich noted that it was at the Research Institute of Microsurgery that he first met the opportunity to train microsurgical skills immediately before surgery.

Рис. 11. Занятия на обучающем курсе в рамках I Микрохирургического Саммита в Сибири. Томск, 2019 г.

Fig. 11. Training course within the framework of the I Microsurgical Summit in Siberia. Tomsk, 2019

Рис. 12. Модератор Обучающего курса Елена Акелина (Колумбийский университет, г. Нью-Йорк, США) за техноскопом Carl Zeiss

Fig. 12. Training course moderator Yelena Akelina (Columbia University, New York, USA) at the technoscope Carl Zeiss

а

б

в

Рис. 13. Гости Института микрохирургии за работой в обучающем классе: *а* – академик РАН профессор И.В. Решетов (г. Москва), *б* – профессор М. Нинкович (г. Мюнхен, Германия), *в* – профессор М.А. Волох (г. Санкт-Петербург)

Fig. 13. Guests of the Institute of Microsurgery at work in the training class: *а* – Academician of the Russian Academy of Sciences, Professor I.V. Reshetov (Moscow, Russia), *б* – Professor M. Ninkovic (Munich, Germany), *в* – Professor M.A. Volokh (St. Petersburg, Russia)

ЗАКЛЮЧЕНИЕ

Обучающие программы по микрохирургии позволяют сформировать начальные микрохирургические навыки, которые в дальнейшем становятся базой для профессионального роста. Наставники, участвующие в обучении микрохирургическим навыкам, должны учитывать пожелания курсантов и быть технологически и профессионально готовыми к их реализации. Дальнейшее развитие образовательных программ по микрохирургии мы видим в введении раздела по обучению супермикрохирургии и привлечении роботических и виртуальных систем для отработки практических навыков.

CONCLUSION

Microsurgery training programs allow to form the initial microsurgical skills, which later become the basis for professional growth. Mentors involved in teaching microsurgical skills must take into account the wishes of the cadets and be technologically and professionally prepared to implement them. We see the further development of educational programs in Microsurgery in the introduction of a section on teaching Supermicrosurgery and the involvement of robotic and virtual systems for practicing practical skills.

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СОВРЕМЕННЫЕ АСПЕКТЫ ОБУЧЕНИЯ УКРАИНСКИХ ВРАЧЕЙ РЕКОНСТРУКТИВНОЙ МИКРОХИРУРГИИ

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Современные технологии и навыки специалистов в области реконструктивной микрохирургии позволяют решать проблему восстановления утраченных покровных и костных тканей скелета в один этап с наибольшей эффективностью, а также проводить реплантацию конечностей или их частей. Однако дефицит подобных специалистов является общепризнанным, что приводит к росту инвалидизации и смертности, на которые приходится до 30% глобального бремени национальной службы здравоохранения.

В работе, подготовленной специалистами центров, базирующихся в Днепре и Киеве, рассматривается вопрос освоения навыков по реконструктивной микрохирургии молодыми специалистами. Авторы проводят сравнительный анализ методов обучения на двух базах в Украине и двух базах в странах Евросоюза.

На современном этапе развития международных образовательных программ специализированного онлайн сообщества (International Microsurgery Club) возможно проводить усовершенствование или овладение новыми методиками для хирурга любого уровня базовой подготовки. По критерию цена-качество и географическому расположению лабораторию Pius Branzeu Center (г. Тимишоары, Румыния), в условиях глобализации мировой экономики и интеграции стран Евросоюза, можно считать оптимальным центром обучения базовым навыкам для резидентов и молодых врачей. Однако после приобретения этих навыков микрохирург должен продолжить обучение в реальных клинических условиях существующих центров в Украине для получения опыта работы.

Ключевые слова: *микрохирургия, образовательные программы, international microsurgery, реконструктивная хирургия, пластическая хирургия.*

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CURRENT ASPECTS OF TRAINING UKRAINIAN DOCTORS FOR RECONSTRUCTIVE MICROSURGERY

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Modern technologies and the skills of specialists in reconstructive microsurgery make it possible to solve the problem of restoring the lost cover tissues and bone tissues of the skeleton in one stage with the greatest efficiency, as well as to carry out replantation of limbs or their parts. However, the shortage of such specialists is widely recognized, leading to an increase in disability and death, which account for up to 30% of the global burden of the national health service. In the work, which prepared by specialists from the centres of the cities Dnipro and Kiev, the issue of mastering the skills of reconstructive microsurgery by young specialists is considered. The authors conduct a comparative analysis of teaching methods at two bases in Ukraine and two bases in the European Union.

At the current level of development of international educational programs of a specialized online community (international microsurgery club), it is possible to improve or master new techniques for a surgeon of any level of basic training. According to the price-quality criterion and geographical location, the Pius Branzeu Center laboratory (Romania), in the context of the globalization of the world economy and the integration of the European Union countries, can be considered as optimal centre for teaching basic skills for residents and young doctors. However, after obtaining these skills, the microsurgeon must continue training in the real clinical conditions of existing centres in Ukraine for obtain practical experience.

Keywords: *microsurgery, educational programs, international microsurgery, reconstructive surgery, plastic surgery.*

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Несмотря на то, что лечение ран является одной из древнейших отраслей медицины, оно и сегодня остается актуальной проблемой, особенно в случае возникновения крупных тканевых дефектов [1–3]. В клинической практике хирурги сталкиваются с такими сложными вызовами, когда в результате травм или широких онкологических резекций формируются мягкотканевые дефекты и объемные дефекты костной части скелета. Именно навыки специалистов в реконструктивной микрохирургии позволяют решать проблему восстановления утраченных покровных и костных тканей скелета в один этап с наибольшей эффективностью, а также проводить реплантацию конечностей или их частей [2, 4, 5].

Despite the fact that wound treatment is one of the most ancient branches of medicine, it remains an urgent problem even today, especially in the case of large tissue defects [1–3]. In clinical practice, surgeons face such complex challenges when, as a result of injuries or extensive oncological resections, not only soft tissue defects are formed, but also volumetric defects of the bone part of the skeleton, which provides a support function. It is the skills of specialists in reconstructive microsurgery that make it possible to solve the problem of restoring the lost integumentary and bone tissues of the skeleton in one stage with the greatest efficiency, as well as to carry out replantation of limbs or their parts [2, 4, 5].

Однако дефицит подобных специалистов, способных восстановить микрососуды, нервы и лимфатические коллекторы, является общепризнанным [4, 6]. По данным S. Inchauste и соавт., именно отсутствие такой узкоспециализированной реконструктивной помощи при травмах, ожогах, врожденных аномалиях и других хирургических заболеваниях приводит к росту инвалидизации и смертности, на которую приходится 30% глобального бремени национальной службы здравоохранения. Ряд пациентов отказываются от выполнения жизнесохраняющих онкологических операций из-за опасения приобрести грубые нарушения внешнего облика или функции [6].

В настоящее время во всем мире существует проблема развития реконструктивной микрохирургии. Пластические хирурги зачастую отдают предпочтение эстетической хирургии, что связано с большей прибыльностью этого направления и с тем, что реконструктивная хирургия более сложная в исполнении, более трудоемкая, требует наличия большой обученной команды, а также дорогостоящего оборудования и инструментария [6]. Сложность обучения микрохирургов заключается и в том, что для хорошего владения каждой из техник или методик реконструктивной микрохирургии необходимо большое количество тренировок. Однако на практике это сложно осуществить в рамках одного учебного или клинического центра. К сожалению, даже очень хорошее владение базовыми навыками микрохирургии не дает клинического опыта и умения выполнять комплексное лечение, включающее предоперационную подготовку и планирование реконструкции, послеоперационное ведение и действия в случае возникновения каких-либо проблем с микроциркуляцией пересаженных комплексов тканей [4]. На приобретение специальных знаний уходят долгие годы, иногда десятилетия. В связи с этим в мире уже сформировалась определенная концепция обучения микрохирургов, когда после приобретения базовых навыков микрохирургии, доктора стажируются в разных центрах, специализирующихся на определенном виде реконструкций, где такие операции поставлены на поток. При этом исследователи утверждают, что если в развитых странах существует достаточный выбор специальных курсов, то в странах с развивающейся экономикой имеет место явный дефицит обучающих возможностей [4, 6].

На сегодняшний день в Украине реконструктивная микрохирургия представлена в двух центрах, где хирурги имеют достаточный опыт, и реконструктивные операции поставлены на поток. Вместе с тем, появляется все больше молодых хирургов из других медицинских учреждений, имеющие желание овладеть реконструк-

However, it is generally recognized that there is a shortage of specialists capable of restoring microvessels, nerves and lymphatic collectors [4, 6]. According to S. Inchauste et al., it is the absence of such highly specialized reconstructive care for injuries, burns, congenital anomalies and other surgical diseases that leads to an increase in disability and death, which accounts for 30% of the global burden of the national health service. A number of patients refuse to perform life-saving oncological operations for fear of acquiring gross disturbances in their appearance or function [6].

At present, there is a problem of the development of reconstructive microsurgery all over the World. Plastic surgeons are often give preference to aesthetic surgery, which is associated with the greater profitability of this direction and with the fact that reconstructive surgery is more complex in execution, more laborious, requires a large trained team, as well as expensive equipment and instruments [6]. The complexity of training microsurgeons also lies in the fact that a large amount of training is required for a good mastery of each of the techniques or methods of reconstructive microsurgery. However, it is difficult to accomplish within a single training or clinical center in practice. Unfortunately, even a very good command of basic microsurgery skills does not provide clinical experience and the ability to perform complex treatment, including preoperative preparation and reconstruction planning, postoperative management and actions in case of any problems with microcirculation of transplanted tissue complexes [4]. It takes many years, sometimes decades, to acquire specialized knowledge. In this regard, a certain concept of training microsurgeons has already been formed in the World, when, after acquiring the basic skills of microsurgery, doctors are training in different centers specializing in a certain type of reconstruction, where such operations are put on stream. At the same time, researchers argue that if there is a sufficient selection of special courses in developed countries, then in countries with developing economies there is an obvious shortage of training opportunities [4, 6].

Today in Ukraine, reconstructive microsurgery is presented in two centers, where surgeons have sufficient experience, and reconstructive operations are put on stream. At the same time, there are more and more young surgeons from other medical institutions willing to master reconstructive microsurgery and develop it in their medical centers. This is due to the increased demands of patients for the quality of life and functional rehabilitation after extensive oncological resections, severe industrial injuries and burns, and since 2014, military injuries with critical III degree limb injuries according to Gustilo-Andersen [5–7, 10]. It should be noted тивной микрохирургией и развить ее у себя в медицинских центрах. Это обусловлено возросшими требованиями пациентов к качеству жизни и функциональной реабилитации после перенесенных широких онкологические резекций, тяжелых индустриальных травм и ожогов, а с 2014 г. и военных травм с критическими повреждениями конечностей III степени по Gustilo-Andersen [5–7, 10]. Следует отметить, что реконструктивная пластическая хирургия и микрохирургия, как ее часть, всегда получали импульс развития при военных конфликтах и их последствиях [11–14], когда критически возрастал запрос общества на восстановительные операции.

Методы обучения реконструктивной микрохирургии включают: базовую подготовку по общей и пластической хирургии; теоретический курс тематического усовершенствования по реконструктивной микрохирургии; работу с наставником на симультативных тренажерах, трупном материале, живых тканях и в клинике; работу со специальной литературой и интраоперационным видеоматериалом; мастер-классы, симпозиумы и вебинары [5]. Показали свою эффективность и новые программы самостоятельного онлайн-обучения в сочетании с регулярными практическими занятиями [15]. Использование цифрового увеличения смартфона, как альтернатива дорогим лупам или микроскопу, может помочь молодым хирургам при освоении техники микрохирургического шва [6].

В качестве доступных обучающих баз для украинских врачей можно рассматривать две национальные клинические базы – Национальный институт хирургии и трансплантологии имени А.А. Шалимова НАМН Украины (г. Киев) и Центр термической травмы и пластической хирургии (г. Днепр), а также зарубежные базы: Pius Branzeu Center (PBC, г. Тимишоары, Румыния) и Reconstructive Microsurgery European School (RMES). В мире, разумеется, существуют и другие центры обучения для микрохирургов разного уровня базовой подготовки (Япония, США, Республика Корея), однако географическое расположение делает их менее доступными для поездок на учебу.

В пределах Евросоюза наилучшим вариантом получить хорошее базовое и узкоспециализированное образование и освоить наиболее полный набор практических навыков дает RMES. Прохождение всех курсов программы, которое занимает 2 года, позволяет обрести самые современные знания в области реконструктивной микрохирургии с получением сертификата специалиста. Однако ограничительным фактором выступает стоимость обучения, которая весьма существенна не только для украинских врачей, но и для резидентов ЕС.

that reconstructive plastic surgery and microsurgery, as a part of it, have always received an impetus for development during military conflicts and their consequences [11–14], when the demand of society for reconstructive operations increased critically.

The reconstructive microsurgery teaching methods include: basic training in general and plastic surgery; theoretical course of thematic improvement in reconstructive microsurgery; work with a mentor on simultative simulators, cadaveric material, living tissues and in the clinic; work with special literature and intraoperative video material; master classes, symposia and webinars [5]. New programs of self-directed online learning in combination with regular practical exercises have also shown their effectiveness [15]. Using the digital zoom of a smartphone, as an alternative to expensive loupes or a microscope, can help young surgeons master the technique of microsurgical suture [6].

Two national clinical bases can be considered as available training bases for Ukrainian doctors – the National Institute for Surgery and Transplantology named after A.A. Shalimov, National Academy of Medical Sciences of Ukraine (Kiev) and the Burn and Plastic Surgery Center (Dnipro), as well as foreign bases: Pius Branzeu Center (PBC, Timisoara, Romania) and Reconstructive Microsurgery European School (RMES, Barcelona, Spain). There are other training centers for microsurgeons of different levels of basic training (Japan, USA, Korea) in the World, but their geographical location makes them less accessible for travel to study.

Within the European Union (EU), RMES provides the best option for getting a good basic and highly specialized education and mastering the most complete set of practical skills. Completing all courses of the program, which takes 2 years, allows you to acquire the most modern knowledge in the reconstructive microsurgery with obtaining a specialist certificate. However, the limiting factor is the cost of training, which is very significant not only for Ukrainian doctors, but also for EU residents.

The course at the Pius Branzeu Center is also part of the RMES curriculum as one of the practical basic courses. However, the PBC also conducts independent 2–3-day training cycles in the basic principles of microsurgery, the collection of classical microsurgical flaps, and work with perforator flaps. Training is carried out on living tissues (laboratory rats and pigs), using modern equipment and instruments (Fig. 1). During training, students perform a large number of full-fledged reconstructive operations on living tissues with the opportunity to see the result of the performed reconstructions and assess the state of microcirculation in the formed and displaced flaps. At the same time, the cost of training at PBC is very affordable.

Курс в Pius Branzeu Center также входит в программу обучения RMES, как один из практических базовых курсов. Однако в PBC проводятся и самостоятельные 2–3-дневные циклы обучения базовым принципам микрохирургии, забора классических микрохирургических лоскутов, работы с перфорантными лоскутами. Обучение осуществляется на живых тканях (лабораторные крысы и свиньи), с использованием современного оборудования и инструментария (рис. 1). Во время обучения курсанты выполняют большое количество полноценных реконструктивных операций на живых тканях с возможностью увидеть результат выполненных реконструкций и оценить состояние микроциркуляции в сформированных и перемещенных лоскутах. При этом стоимость обучения в PBC весьма доступна.

а

б

в

Рис. 1. Обучение в Pius Branzeu Center проходит с использованием современного оборудования и инструментария (*а*), включая новые модели микроскопов Zeiss (*б*), на живых тканях (*в*)

Fig. 1. Training at the Pius Branzeu Center is carried out using modern equipment and instruments (*а*), including new models of Zeiss microscopes (*б*), on living tissues (*в*)

Сотрудниками кафедры комбустиологии и пластической хирургии Национальной медицинской академии последипломного образования им. П.Л. Шупика НАМН Украины, на базе Национального института хирургии и трансплантологии имени А.А. Шалимова НАМН Украины (г. Киев) проводится цикл тематического усовершенствования «Основы пластической микрохирургии» продолжительностью 1,5 мес. В этот период курсанты получают широкую теоретическую подготовку, изучая не только технику проведения операций, но и особенности послеоперационного ведения и реабилитации пациентов. Практические навыки отрабатываются на муляжах и на неживом биологическом материале, а также на лабораторных крысах (рис. 2). Обучение проходит как по государственной программе, так и на хозрасчетной основе, поэтому легко доступно с финансовой точки зрения.

The employees of the Department of Combustiology and Plastic Surgery, the National Medical Academy of Postgraduate Education named after P.L. Shupik, National Academy of Medical Sciences of Ukraine are conducts a cycle of thematic improvement "Fundamentals of Plastic Microsurgery" with a duration of 1.5 months on the basis of the National Institute for Surgery and Transplantology named after A.A. Shalimov, National Academy of Medical Sciences of Ukraine (Kiev). During this period, students receive broad theoretical training, studying not only the technique of performing operations, but also the features of postoperative management and rehabilitation of patients. Practical skills are practiced on dummies and inanimate biological material, as well as on laboratory rats (Fig. 2). Training takes place both according to the state program and on a self-supporting basis, therefore it is easily accessible financially.

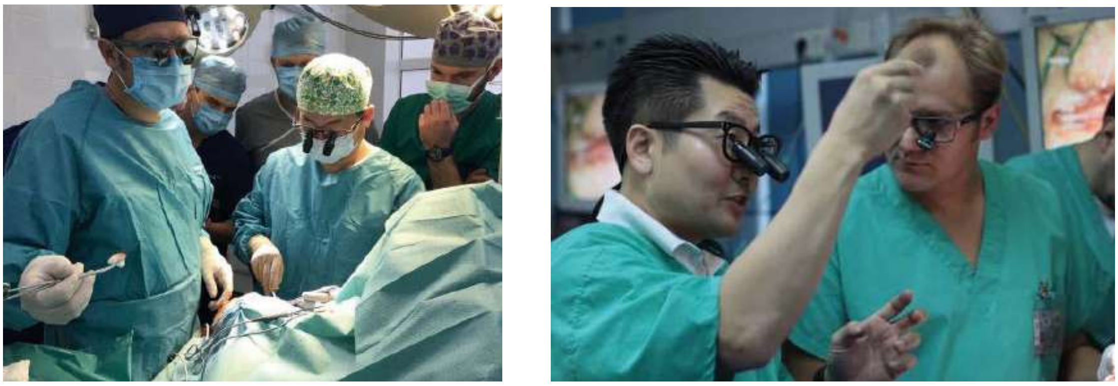
а *б*

Рис. 2. Отработка практических навыков наложения микрососудистого шва (*а*) проводится на лабораторных крысах (*б*) на базе Национального института хирургии и трансплантологии имени А.А. Шалимова» НАМН Украины (г. Киев)

Fig. 2. Practical skills for applying microvascular suture (*a*) are practiced on laboratory rats (*б*) on the basis of the National Institute for Surgery and Transplantology named after A.A. Shalimov, National Academy of Medical Sciences of Ukraine (Kiev)

На базе Центра термической травмы и пластической хирургии медицинской академии (г. Днепр) проходят обучение доктора в рамках индивидуальных программ, где основным методом является работа с наставником на анатомическом материале, на неживом биологическом материале и в клинике. Предоставляется доступ к современной литературе, периодическим изданиям Plastic Reconstructive Surgery и Journal of Reconstructive Microsurgery. Особое внимание уделяется обучению действий врача при нестандартных клинических ситуациях. Новые инновационные методики осваиваются путем проведения мастер-классов для докторов со всей Украины, с привлечением тренеров, занимающих ведущие позиции в мировой реконструктивной микрохирургии. В 2017 г. с участием профессора J.P. Hong из Asan Medical Center (г. Сеул, Республика Корея) был проведен мастер-класс на тему применения ультратонкого SCIP лоскута (рис. 3) [16–18]. В 2019 г. состоялся мастер-класс с участием профессора Bartozs Mankovski из Познанского университета медицинских наук им. Карола Марцинковского (Польша) на тему пересадки малоберцового лоскута с демонстрацией техники на атомическом материале и показательными операциями (рис. 4). Бюджет обучения, который покрывает прямые затраты на участие лекторов и расходные материалы, можно считать вполне доступным для резидентов Украины.

The doctors are trained in the framework of individual programs on the basis of the Burn and Plastic Surgery Center of the Medical Academy (Dnipro, Ukraine), where the main method of training is to work with a mentor on anatomical material, on inanimate biological material and in the clinic. There is access to contemporary literature and the periodicals Plastic Reconstructive Surgery and the Journal of Reconstructive Microsurgery. Particular attention is paid to teaching the doctor's actions in non-standard clinical situations. New innovative techniques are mastered by conducting master classes for doctors from all over Ukraine, with the involvement of trainers holding leading positions of reconstructive microsurgery in the World. In 2017 was conducted a master class on the use of an ultrathin SCIP flap, with the participation of Professor J.P. Hong from Asan Medical Center (Seoul, Republic of Korea) (Fig. 3) [16–18]. In 2019, a master class was held with the participation of Professor Bartozs Mankovski from Poznan University of Medical Sciences named after Karol Marcinkowski (Poland) on the topic of transplantation of a peroneal flap with a demonstration of technique on anatomic material and demonstrative operations (Fig. 4). The training budget, which covers the direct costs of the participation of lecturers and supplies, can be considered quite affordable for residents of Ukraine.



а б

Рис. 3. **Мастер-класс на тему применения ультратонкого SCIP лоскута (*а*) с участием профессора J.P. Hong. Профессор Hong комментирует особенности выделения перфоранта в области пенетрации фасции (*б*)**

Fig. 3. Master class on the use of ultra-thin SCIP flap (*a*) with the participation of Professor J.P. Hong. Professor Hong comments on the peculiarities of perforant extraction in the area of fascia penetration (*б*)

а б

в г

Рис. 4. Мастер-класс на тему пересадки малоберцового лоскута (*а*) с участием профессора B. Mankovski; демонстрация техники на атомическом материале (*б*), разметка дизайна перфорантного лоскута (*в*) и показательная операция (*г*)

Fig. 4. Master class on the transplantation of a peroneal flap (*a*) with the participation of Professor B. Mankovski; a demonstration of the technique on atomic material (*б*), marking the design of a perforating flap (*в*) and demonstrative operations (*г*)

Анализируя преимущества и недостатки основных доступных баз обучения реконструктивной микрохирургии (таблица), можно отметить, что наилучшую теоретическую и техническую подготовку дает прохождение полного курса в

Taking into account the analysis of the advantages and disadvantages of the main available training bases for reconstructive microsurgery (table), it can be noted that the best theoretical and technical training is provided by completing a full course рамках Reconstructive Microsurgery European School, однако важным ограничивающим фактором является стоимость обучения в этом центре. Кроме того, прохождение даже данного курса не дает полного представления о клинических аспектах самостоятельного ведения пациентов с микрохирургическими реконструкциями. После прохождения такого обучения доктора по-прежнему нуждаются в поддержке опытного ментора.

Методы обучения реконструктивной микрохирургии

Вид обучения	Локация прохождения обучения			
	НИХиТ	ЦТТиПХ	PBC	RMES
Вебинары	–	–	–	++
Свободный доступ к специальной литературе	++	++	+–	++
Свободный просмотр видео контента	+	++	+	++
Работа с наставником в клинике (hand on courses)	++	++	–	++
Работа с наставником на трупном материале	–	++	–	++
Работа с наставником на живых тканях	++	–	++	++
Робототехника, работа на симуляторе	–	–	–	+
Обучение супрамикрохирургии, лимфавенозные анастомозы	–	–	++	++
Привлечение к обучению топ-тренеров	–	+	++	++
Программа университета	+	–	+	++
Плата за обучение	+–	+–	+	++

Примечание. НИХиТ – Национальный институт хирургии и трансплантологии имени А.А. Шалимова НАМН Украины (г. Киев); ЦТТиПХ – Центр термической травмы и пластической хирургии (г. Днепр); PBC – Pius Branzeu Center (г. Тимишоары, Румыния); RMES – Reconstructive Microsurgery European School. Интенсивность признака: – отсутствие; + наличие; ++ высокий уровень; +– – существуют варианты признака.

ЗАКЛЮЧЕНИЕ

На современном этапе развития международных образовательных программ в сети Интернет и специализированного онлайн сообщества International Microsurgery Club возможно проводить усовершенствование или овладение новыми методиками для специалиста любого уровня базовой подготовки. Наилучшим методом освоения практических навыков является работа с наставником на живых тканях. Только в этом случае специалист может видеть результат работы в динамике после операции. Содержание лаборатории для работы

within the framework of the Reconstructive Microsurgery European School, however, an important limiting factor is the cost of training in this center. In addition, the passage of this course does not give a complete picture of the clinical aspects of self-management of patients with microsurgical reconstructions. After completing this training, doctors still need the support of an experienced mentor.

Reconstructive microsurgery teaching methods

Type of training	Location of training			
	NIST	BPSC	PBC	RMES
Webinars	–	–	–	++
Free access to the literature	++	++	+–	++
Free viewing of video content	+	++	+	++
Working with a mentor in the clinic (hand on courses)	++	++	–	++
Working with a mentor on cadaver	–	++	–	++
Working with a mentor on live tissue	++	–	++	++
Robotics, working on the simulator	–	–	–	+
Supramicrosurgery training, lymphovenous anastomoses	–	–	++	++
Involvement of top trainers in training	–	+	++	++
University program	+	–	+	++
Paid training	+–	+–	+	++

Note. NIST – National Institute for Surgery and Transplantology named after A.A. Shalimov NAMS Ukraine (Kiev); BPSC – Burn and Plastic Surgery Center (Dnipro); PBC – Pius Branzeu Center (Timisoa, Romania); RMES – Reconstructive Microsurgery European School (Barcelona, Spain). The intensity of the trait: – no; + availability; ++ high level; + – – there are variants of the feature.

CONCLUSION

At the current stage of development of international educational programs on the Internet and the specialized online community of the International Microsurgery Club, it is possible to improve or master new techniques for a specialist of any level of basic training. The best practice is to work with a mentor on living tissue. Only in this case the specialist can see the result of the work in dynamics after operation. The maintenance of a laboratory for working on living tissues requires significant investments, constant updating of equipment and на живых тканях требует значительных инвестиций, постоянного обновления оборудования и инструментария, а также привлечения тренеров мирового уровня. По критерию цена-качество и географическому расположению лабораторию Pius Branzeu Center, в условиях глобализации мировой экономики и интеграции стран Евросоюза, можно считать оптимальным центром обучения базовым навыкам для резидентов и молодых врачей Украины. Однако после получения базовых навыков микрохирург должен продолжить обучение в реальных клинических условиях существующих центров в Украине для получения опыта работы.

instruments, as well as the involvement of world-class trainers. According to the criterion of price-quality and geographical location, the Pius Branzeu Center laboratory can be considered the optimal center for teaching basic skills for residents and young doctors of Ukraine in the context of the globalization of the World economy and the integration of the EU countries. However, after acquiring basic skills, the microsurgeon must continue training in the real clinical conditions of existing centers in Ukraine to gain work experience.

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MICROSURGERY IN THE NETHERLANDS, FROM AN EXPERIMENTAL PHARMACOLOGICAL PERSPECTIVE

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This paper is dedicated to the memory of Hans Rensema (1948–2020), medical artist of Microsurgical Developments Foundation.

The history of training in microsurgical and experimental techniques in the Netherlands goes back to the 1960s. The training was mostly done on an individual basis. Clinical surgeons could benefit from the 'Wet-Lab' training at the Erasmus University of Rotterdam. Experimental microsurgery and techniques training for larger groups of bio-technicians and researchers started at Utrecht University in 1993, and later at Groningen University. The first commercial training was offered at the International Microsurgical Training Centre in Lelystad (IMTC,) in 2002. This paper presents the current state-of-the-art training in the Netherlands and some future perspectives.

Professor Remie studied Pharmacy at the University of Groningen. After completing his studies in 1983, he specialised in pharmacology and did his PhD on the presynaptic modulation of noradrenergic neurotransmission in the freely moving rat portal vein. He joined Solvay Pharmaceuticals as a Group leader in Pharmacology, specialised (1991) in Laboratory Animal Science (Utrecht University), and became Laboratory Animal Scientist and Animal Welfare Officer of Solvay Pharmaceuticals and Fort Dodge Animal Health Holland. He is chairman of the Microsurgical Developments Foundation and several IACUCs. From 1997 until 2012, he was appointed professor with a special chair in Microsurgery and Experimental Technique in Laboratory Animals at the Groningen Centre for Drug Research, Department of Biomonitoring & Sensoring, University Centre for Pharmacy, University of Groningen. He is CEO of 3-R's Training Centre BV, and Director of the René Remie Surgical Skills Centre (www.rrssc.eu).

Irene Cuesta Cobo earned a BSc in Biology and physiotherapy, and an MSc in manual therapy at the University of Jaén (Spain). She worked at the department of physiology at the same university on an *in-vivo* assay with gliomas in rats and subsequently, at the Laboratory of CAR Madrid to analyse top athletes' blood samples. She is a senior instructor at RRSSC.

Edwin Spoelstra earned an MSc in Pharmacy and specialised stereotaxic surgery and microdialysis in the rat. He developed several techniques in mice and spent the last ten years on catheter design and blood-sampling.

Keywords: *experimental techniques, microsurgery training, rats, mice, animal models, 3Rs.*

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МИКРОХИРУРГИЯ В НИДЕРЛАНДАХ С ЭКСПЕРИМЕНТАЛЬНОЙ ФАРМАКОЛОГИЧЕСКОЙ ТОЧКИ ЗРЕНИЯ

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Эта статья посвящена памяти Ганса Ренсема (1948–2020), медицинского художника Фонда разработок в области микрохирургии.

История обучения микрохирургическим и экспериментальным методикам в Нидерландах восходит к 1960-м гг. Обучение в основном проходило индивидуально. Клинические хирурги могли пройти курс обучения «Wet-Lab» в Университете Эразма в Роттердаме. Обучение экспериментальной микрохирургии и методам для больших групп биотехников и исследователей началось в Утрехтском университете в 1993 г., а затем – в Гронингенском университете. Первое обучение на коммерческой основе состоялось в Международном учебном центре микрохирургии (IMTC) в Лелистаде в 2002 г. В настоящей статье представлены современные методы обучения микрохирургии в Нидерландах и некоторые перспективы на будущее.

Профессор Реми изучал фармацию в Гронингенском университете. После завершения учебы в 1983 г. он специализировался на фармакологии и защитил диссертацию на степень PhD по пресинаптической модуляции норадренергической нейротрансмиссии в свободно движущейся воротной вене крысы. Он присоединился к Solvay Pharmaceuticals в качестве руководителя группы по фармакологии, специализировался в области лабораторных животных (Утрехтский университет, 1991) и стал специалистом по лабораторным животным и защите животных в Solvay Pharmaceuticals и Fort Dodge Animal Health Holland. Профессор Реми является председателем Фонда микрохирургических разработок и нескольких Институциональных комитетов по уходу и использованию животных (IACUC). В период с 1997 по 2012 г. Рене Реми являлся профессором специальной кафедры микрохирургии и экспериментальной техники на лабораторных животных в Гронингенском центре исследований лекарственных средств, а также кафедры биомониторинга и сенсорики Университетского центра фармацевтики Гронингенского университета. Он является генеральным директором Учебного центра 3-R's Training Center BV и директором Центра хирургических навыков Рене Реми (www.rrssc.eu).

Ирен Куэста Кобо получила степень бакалавра биологии и физиотерапии, а также магистра мануальной терапии в Университете Хаэн (Испания). Работала на кафедре физиологии в том же университете с глиомами у крыс *in vivo*, а затем в лаборатории CAR Madrid, где занималась анализом образцов крови спортсменов. Является старшим инструктором Центра хирургических навыков Рене Реми.

Эдвин Споэльстра получил степень магистра фармацевтики и специализированной стереотаксической хирургии и микродиализа на крысах. Разработал несколько методов на мышах. Последние 10 лет посвятил разработке дизайна катетеров и исследованиям крови.

Ключевые слова:	*экспериментальные методы, обучение микрохирургии, крысы, мыши, животные модели, 3Rs.*
Конфликт интересов:	авторы подтверждают отсутствие конфликта интересов, о котором необходимо сообщить.
Прозрачность финансовой деятельности:	никто из авторов не имеет финансовой заинтересованности в представленных материалах или методах.
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THE BEGINNING

The introduction of the (operating) microscope and the fundamental techniques of vascular anastomosis were indispensable throughout the history of microsurgery. Implementation of the operating microscope led to a revolution in almost every surgical discipline. Nylén, a clinical assistant in otorhinolaryngology in Karolinska Medical School, first recognised the need for magnification in ear surgery and used a monocular microscope in a few chronic cases of otitis and pseudo-fistula formation in 1921. Holmgren (1923) reported the first microsurgical fenestration for otosclerosis using a binocular operating microscope. Therefore, otorhinolaryngology is considered to be the cradle of microsurgery. Without the operating microscope, it could not have been developed to its present state of perfection. In 1951, Littmann, of the Carl-Zeiss Co., manufactured a prototype of the OpMi-1, a microscope equipped with coaxial illumination for use as a colposcope or otoscope, still used today. It became commercially available in 1953 when it began to be used quite rapidly and increased in the operating room [35].

In 1902, Alexis Carrel first performed end-to-end (ETE) vascular anastomosis by hand using a '3-stay suture technique', a fundamental vascular surgery technique (see R.F. Rickard and D.A. Hudson, 2014 [31] for a historical overview). Jacobson and Suarez (1960) published a brief historical article on microsurgery for 1-mm blood vessel anastomosis. Recognising the difficulty in doing this with the naked eye, they introduced the operating microscope into small vascular surgery.

Work in experimental microsurgery began in the late l950s. Dr Sun Lee (Korean name Sil Heung Lee) the renowned "Father of Microsurgery", was born in Korea and emigrated to the USA in 1950. At that time, rats were seldom used in surgical laboratories, despite a long history of rat usage in allied biological research. Encouraged by Dr Fisher, Dr Lee started his pioneer experiments, performing portacaval shunts in rats in 1957, using end-to-side anastomosis. After many attempts and failures, Lee perfected an end-to-side portacaval shunt in 1958, thus creating the discipline of experimental microsurgery. Microsurgery opened an avenue to conducting allied physiological research and transplantation investigation. In those early years, Lee started to develop kidney and heart-transplantation models in the rat, and in the years that followed, many organs were transplanted between different rat strains. His research raised immunology, then in its infancy, to unknown heights. Today, 95% of organ-transplantation research projects are performed using small rodents. Professor Sun Lee died on October 4, 2015, at the age of 95.

MICROSURGERY IN THE NETHERLANDS

The first International Microsurgical Workshop was held on September 4–5, 1970, organised by Dr van Bekkum in Rijswijk. It was the first meeting of the International Microsurgical Society (IMS), and since then it has continued biennially. In those early days, several groups in the Netherlands were using these new microsurgical technique possibilities. At the Erasmus Medical Centre, Drs Kort and Marquet specialised in small bowel, heart and liver transplantation surgery, and trained students in microsurgery in the 'Wet-Lab'. Simultaneously, Drs Hess and Jerusalem at the Radboud University of Nijmegen developed a heterotopic auxiliary liver-transplantation technique. They later worked on fibrous microvascular polyurethane prosthesis [24, 26]. Dr Wildevuur and colleagues at Groningen University worked on experimental microsurgery and focused, a.o., on lung transplantation in the rat. Teaching was mostly limited to individuals or small groups. Dr Remie and Mr Bartels trained several scientists, technicians, and some dental surgeons at Groningen University in the late 1970s.

However, nonclinical biomedical researchers were slow to discover the additional benefits of using the microscope, along with microsurgical techniques. In the early 1970s, *in vivo* pharmacological research and drug discovery were performed with few exceptions on anaesthetised animals. Freely-moving animal models were rarely seen. Researchers physically restrained the animals, thus circumventing unwanted effects of anaesthetics on the parameters to be measured. Researchers could create freely-moving animal models used for repeated experiments with microsurgery, thus saving many animal lives [28, 29].

Today, a quick search on PubMed shows over 2300 papers published on microsurgical training. Interest in the application of microsurgical techniques was stimulated in the mid-l980s during the revival of the concept of the 3-Rs, originally suggested in 1959 by William M.S. Russell and Rex L. Burch in their book "*The Principles of Humane Experimental Technique*" [32]. Refined surgical techniques in experiments were recommended, leading to an eventual reduction of animal numbers [2, 30]. However, if researchers want to take advantage of microsurgery benefits, they need some tools for learning the proper technique. Hence, we describe the development of several (non-animal) tools for microsurgical training.

MICROSURGICAL DEVELOPMENTS FOUNDATION

In 1982, a group was formed around several equal-minded people interested in furthering training, in microsurgical and experimental techniques. This group organised the first European Society for Parenteral and Enteral Nutrition (ESPEN) workshop in August 1987. In 1990, the group founded the Microsurgical Developments Foundation (MD, www.microdev.nl).

The main objective of this nonprofit organisation is the production of educational tools for life-sciences research. Since the early papers on microsurgical techniques often lacked a clear and detailed description, we compiled the *Manual of Microsurgery on the Laboratory Rat.* Experimental and microsurgical techniques are described and illustrated in great detail [28, 29]. While microsurgery skills can not be mastered purely through books, MD also compiled ten detailed and explicit videotapes of several operations and general techniques used in rats.

When learning microsurgical techniques, it is crucial to develop the ability to concentrate on the visual images seen through the microscope, to use fine instruments, and to coordinate one's movement. At that time, the use of anaesthetised animals was often advocated for training purposes, but it is difficult for students to divide their attention between mastering a technique and taking proper care of the animal. The animals often died untimely, resulting in students feeling disappointed. Due to these and other factors, the number of animals needed in the initial training phase is often remarkably high [3, 16]. Therefore, during these courses, it became apparent that there was a need for a simple device to practice basic techniques.

THE ANASTOMOSIS DEVICE

Many attempts were made to replace animals for (super) microsurgical training purposes [8, 10, 14, 15, 20, 23, 27]. T. Kaufman et al. (1984) were the first to introduce the foliage leaf for microvascular surgery training [17]. A.M. Awwad (1984) introduced the so-called Practi-Card, which contains 16 small compartments consisting of two cardboard pieces with a small rubber piece in between [4]. Freys and Koob (1988) described a training method for increasingly difficult procedures without using live animals [12]. They started with rubber gloves, continued with silicon tubing, a chicken's sciatic nerve, and ended with a coronary arterial vascular anastomosis of a pig's heart. S. Ayoubi (1992) reported using placentas in microvascular exercises [5]. K.E. Korber and B.A. Kraemer (1989) described using small-calibre Gore-Tex grafts as another alternative for microsurgical training [19].

Our MD-anastomosis device is made of PVC; it is smooth, easy to manufacture, and easy to clean. The device consists of three rings. A surgical glove is clamped between two rings, and the third ring is pushed or pinned over it. Students can be trained in hand-eye coordination, instrument handling, needle and suture handling, placing knots, and ergonomics (the primary body and hand positions to avoid tremor and fatigue). In this stage, we break down all movements to specific elements, e.g. knots are tied in 16 separate steps. After mastering these basics, students can establish interrupted and continuous sutures in various directions. The device can also be used to clamp small-diameter silicone or latex tubing to practice suturing and knotting procedures in standard (ETE) and end-to-side (ETS) anastomoses. By turning the device upside down, the students can simulate suturing in deep cavities.

End-to-end anastomosis (termino-terminal anastomosis)

Before starting with the anastomosis, the vessel ends must be free from blood or blood clots, best achieved by intraluminal irrigation, with a diluted heparin solution (5–10 IU/ml) and a blunt 32G needle. The stay- or corner sutures can be placed in several ways. The most straightforward technique is placing the second stay suture at 180° from the first, "the symmetric bi-angulation". John Cobbett in England published a paper on the fundamentals of microvascular surgical techniques in 1967, in which he particularly stressed the importance of "eccentric stay suture at 120 degrees" or "asymmetric bi-angulation." Compared with ordinary stay sutures 180° apart, the needle seldom catches the posterior wall when inserted in the vessel's anterior wall, as the vascular lumen stays open due to the stretching of the stay sutures [9]. However, E. Kim et al. (2016) could not show a significant difference between the bi-angulation and tri-angulation techniques, when done in cryopreserved rat aortas [18]. The tri-angulation was, in fact, a modification of eccentric, asymmetric bi-angulation, as suggested by Alexis Carrel in 1902. The Cobbett technique is used as a standard in our training [1, 7, 25].

Fig. 1 shows the positioning of the first two sutures, which are placed at '10 o'clock' and at '2 o'clock'. By doing this, one can ensure that the vessel's opposite side is not grasped by mistake, thus avoiding a through-stitch. Note that the distance between the needle insertion and the vessel's edge is approximately 0.15–0.25 mm. The bite's size may vary according to the vessel's diameter, the vascular wall's thickness, the suture and needle size. If it is difficult to see the colourless, translucent vessel, place a piece of coloured plastic (blue or yellow) beneath the vessel to better view its fine details. Once the (stay or corner) sutures have been made and tied, some tension must be put at the ends to flatten the vessel wall and expose the anastomosis using small bulldog clamps.

When passing the needle through the vessel wall, do not take the tissue's full thickness between the forceps jaws, as this will cause a great deal of damage. The correct way of passing the needle through is to lift the vessel wall at the adventitia, or place the left-hand forceps on the tissue's underside, and gently push the vessel wall up, which is then easily penetrated.

Subsequently, the needle should pass perpendicularly through the other side of the vessel wall. Again, do not take the entire thickness of the vessel, but take the adventitia, or use the forceps to support the vessel's topside just beyond and beside the place where the needle should emerge. When the needle-holder reaches the tissue, the needle must be released and can be grasped at the other side.

When pulling the needle through the tissues, let it follow its curvature. If one does not do this, the stitch holes will become unnecessarily enlarged. Pull the needle through and let the thread follow the entry-exit line, reducing damage to the tissue by angulating the thread at both the entry and the exit hole. The next suture is placed at 12 o'clock' position (in the middle of the stay sutures) and tied. If the vessel's circumference is divided into equal parts, and the other end of the vessel matches, the edges can be brought together evenly, achieving the optimal result. If not, the anastomosis is destined to be crude and distorted, and stenosis will often make it unsuccessful.

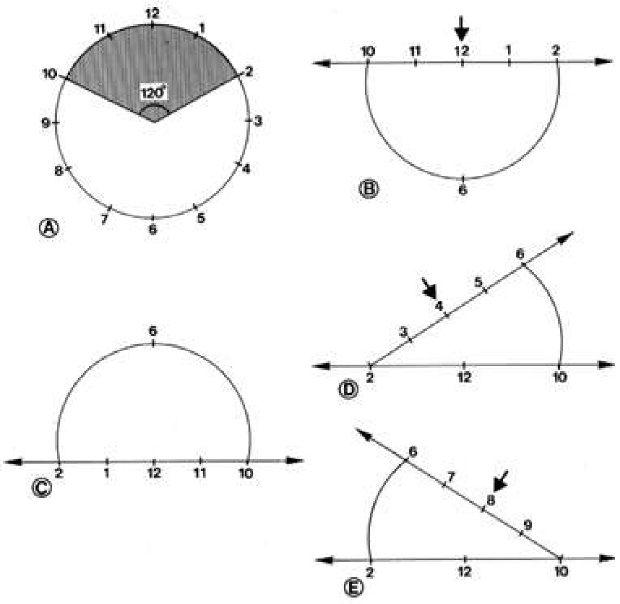

Fig. 1. Schematic drawing of the steps in an ETE anastomosis: A – the corner sutures are placed at 120° ("2 o'clock" and "10 o'clock"); B – light tension is put on the corner sutures, and the next three sutures are placed. The arrow indicates the first suture to be placed; C – the anastomosis is rotated, and the "6 o'clock" suture is placed; D – the "6 o'clock" suture is retracted to the right, and the next three sutures are placed; E – the "6 o'clock" suture is retracted to the left, and the anastomosis is completed

Рис. 1. Схематическое изображение этапов анастомоза ETE: A – угловые швы накладываются под углом 120 ° (в позиции «2 часа» и «10 часов»); Б – угловые швы слегка натягивают и накладывают следующие три шва (стрелкой показан первый шов, который нужно наложить); C – анастомоз поворачивают и накладывают шов «6 часов»; D – шов «6 часов» отводят вправо и накладывают следующие три шва; E – шов «6 часов» отведен влево, анастомоз завершен

After finishing the anterior wall, rotate the vessel, as shown in Fig. 2. There are two ways to do this: rotating the clamps or rotating only the sutures. When possible, clamp rotation is best. Now the anterior wall has become posterior (this was the back wall). Subsequently, place a central suture in the original 6 o'clock position. The next sutures should be placed halfway between 6 o'clock and 2 o'clock, and between 6 o'clock and 10 o'clock, while the 6 o'clock suture is placed under some tension. Depending on the diameter of the vessel, between 6 and 12 sutures should be placed equidistantly. The distance between stitches in a 1-mm artery must be approximately 0.35 to 0.4 mm, meaning that between 6 and 8 stitches are required.

In microsurgery, vessel approximators are frequently used. They are available with and without cleats to hold the stay sutures. A piece of Silastic tubing (1–2 mm in diameter) or latex will ideally serve as a substitute blood vessel as you begin to master the end-to-end anastomosis technique in experimental microsurgery.

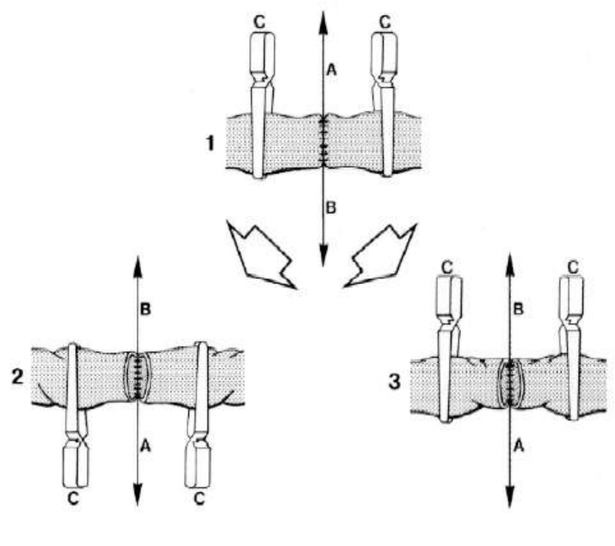

Fig. 2. Rotation of the anastomosis: 1 – the anterior wall has been sutured; 2 – Clamp rotation: the clamps (C) are rotated, and the corner sutures (A and B) are repositioned; 3 – Suture rotation: the corner sutures are repositioned, while the clamps retain their position, resulting in slight torsion of the vessel; A and B – Corner sutures; C – Clamps.

Рис. 2. Ротация анастомоза: 1 – передняя стенка ушита; 2 – вращение зажима: зажимы (C) повернуты, а угловые швы (A и B) перемещены; 3 – ротация швов: угловые швы перемещаются, зажимы сохраняют свое положение, что приводит к небольшому перекручиванию сосуда; А и Б – угловые швы; С – Зажимы.

End-to-side anastomosis (termino-lateral anastomosis)

After making a hole in the main vessel wall, which corresponds to the side vessel's internal diameter used for the anastomosis, one stay sutures should be placed at 9 o'clock and 3 o'clock, then tied. Using a continuous suture technique, leave the suture's standing end (the one without the needle) a little longer than the working strand, and use it to put some tension on the anastomosis. The other end with the needle is used for suturing. If the vessel cannot be turned over for direct visualisation of the posterior wall, the posterior wall should be sutured first from the inside (Fig. 3).

In case the vessel can be turned over, the anterior wall should be sutured first. Then, after turning over the vessel, which allows the anterior wall to become posterior, the posterior wall can be inspected from the inside. Subsequently, the new anterior wall is sutured, completing the anastomosis.

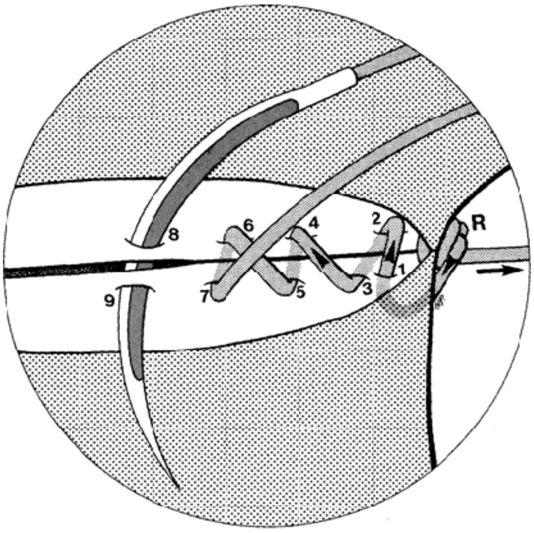

Fig. 3. Detail of the first stitches in the posterior wall: R – Corner suture

Рис. 3. Выполнение первых швов задней стенки: R – угловой шов

The MD PVC-Rat

After some years of experience with the anastomoses device (Fig. 4), we felt a need for a model to simulate a complete surgical technique. Again, the goal was to separate the attention to the technique and the animal. We discussed several options ranging from a stylistic approach to a true-to-life rat model. With a grant from the Platform Alternatives to Animal Use Program (PAD), Ministry of Public Health, Welfare and Sport in the Netherlands, we started developing in 1994, in close cooperation with Solvay Pharmaceuticals, Solvay Plastics, Unilever, and Museum Technical Works Foundation in Groningen.

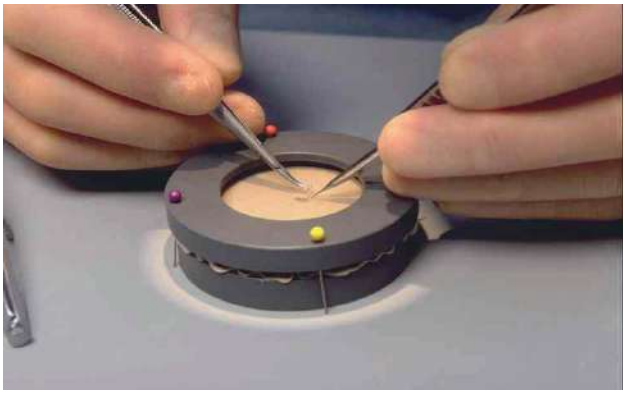

Fig. 4. The anastomoses device in use

Рис. 4. Используемый анастомоз

Several difficulties had to be addressed, such as the most suitable material to make the blood vessels and properly fixate these vessels into the model. We also wanted to produce the MD PVC-Rat in a cost-efficient way to allow as many people as possible to buy the rat at a low cost. The final model is made of PVC, while blood vessels and other structures are made of latex, and the organs made of polyurethane (Fig. 5).

Fig. 5. The MD PVC-Rat

Рис. 5. Анатомическая модель крысы MD PVC-Rat

Both experienced and inexperienced microsurgeons evaluated the model, and we used their comments to improve it. A prototype of the model was presented at the Second World Congress on Alternatives and Animal Use in the Life Sciences, held in Utrecht, in 1996. The final model became available in l999. The MD PVC-Rat can be used in conjunction with the anastomoses device to train students in more than 25 advanced experimental and microsurgical techniques (e.g., catheterisation of portal, renal, and jugular veins, making portacaval shunts using button and suture techniques, and transplantation of blood vessels, kidneys, and hearts). After mastering the technique, students must be trained in perioperative care (patient monitoring). It is essential to understand that unlike physicians or veterinarians, most scientists are not trained in surgery. Therefore, we decided to develop a computer program that would simulate the anaesthetic process and problems that can occur during surgery. The PAD also funded the

REMOTE project when the Product-Group Bio-Simulations of the Van Hall Institute in Leeuwarden designed the software.

Depending on the surgeon's skill, the program will generate problems with parameters such as body temperature, respiratory rate, and heart rate. The student is now forced to concentrate on the animal's welfare, correct the problem, and continue with the technique.

We must also make sure that future scientists, whose research involves surgical intervention in animals, are familiar with the basic principles of aseptic technique. Asepsis is an often-neglected part of the surgery in rats and mice, but it can quickly be learned using the MD PVC-Rat.

After introducing the MD PVC-Rat in our microsurgery courses, we saw further progress in our students' performance. Numerous mistakes that would generally cost animal lives were circumvented, and students felt much more at ease when they perform their first operation on a living animal [2, 30]. We have found that using the model reduced the number of animals used during scientists and animal-technician training by approximately 90%.

MD was also involved in setting up an introductory microsurgery course at the Department of Laboratory Animal Science (LAS), Utrecht University, in 1993. It was a three-day course in microsurgical and experimental techniques. Until 2001, these courses were given three times a year, one of which was in English, and linked to the International Course on LAS. In 2002 International Microsurgical Training Centre (IMTC) was founded. The Centre could accommodate 16 students. The training was extended to five days, with participants practising a model of their choice with experienced instructors' help on the final day. IMTC stopped in 2009, and 3-R's Training Centre took over under the name RRSSC (www.rrssc.eu).

Anatomical knowledge is crucial when performing experimental microsurgical techniques. Unfortunately, there were no suitable rat anatomical models available in the early 1990s. Therefore, MD started to develop a 3-dimensional, four-times life-size anatomical model of the rat (Fig. 6). In this model, hundreds of anatomical structures are shown, and students can learn the optimal approach to the structures of interest.

Today at RRSSC, we start with training on the anastomosis device and continue in the MD PVC-Rat. On day two, we focus on vascular catheterisation, followed by super microsurgery on the rat's femoral artery. We repeat this on the third day and add the end-to-end (ETE) of the abdominal aorta. During the last two days of our clinical Module A, we train end-to-side (ETS) anastomosis (portacaval shunt) free-flap transplantation (superficial epigastric artery and vein), and sciatic-nerve repair. It is a training program similar to the one described by A. Beris et al., 2020 [6].

Fig. 6. The MD 3-D anatomical model of the rat

Рис. 6. 3D-анатомическая модель крысы

In Module B for experimental surgery, we focus on participants' needs, e.g. catheterisation techniques, myocardial infarction, transverse aortic constriction, intrathecal administration, CSF sampling, radio-telemetry implants, and many other techniques.

ASSESSMENT TOOLS

At RRSSC we use the QAPLAS quality assured pedagogy (https://qaplas.net/).

Intended learning outcomes (ILOs), teaching and learning activities (TLAs), assessment criteria (AC) and assessment task/-s (ATs) were identified and described.

In doing so, the course structure was enhanced, specific course obstacles to teaching and learning were identified, and good pedagogy practice versus good laboratory practice and 3R was implemented.

In our courses at the Karolinska Institutet, Stockholm, Sweden, we used a set of assessment tools composed of:

- Instrument choice
- Instrument handling/knowledge
- Suture handling
- Quality of the knot
- Hand position and motion
- Respect for the tissue
- The flow of the operation
- Quality of the final product

We evaluated students during days two and five of the course, to monitor learning. The assessment is best done by an expert who is not involved in the actual training. Several other assessment tools have been developed for clinical microsurgery [36].

ONLINE TRAINING

Like many other businesses, we are affected by our clients' travel restrictions due to the Corona pandemic, and subsequently, the number of course participants being able to follow our training modules has decreased. Although surgical training is best achieved with personal guidance in our dedicated training facilities, we have decided to set up online surgical training for advanced surgeons and expand our training possibilities (Fig. 7).

We have set the highest standard for performing this surgical training online. Both the microscope-vision and overview of the surgical area are provided. Moreover, using a portable digital microscope, we offer the possibility of monitoring students while they perform surgery. This allows us to guide them through procedures and help them perform complicated surgical steps. The online communication using Microsoft Teams enables us to invite other specialists into our network to assist. The training sessions are recorded for future reference.

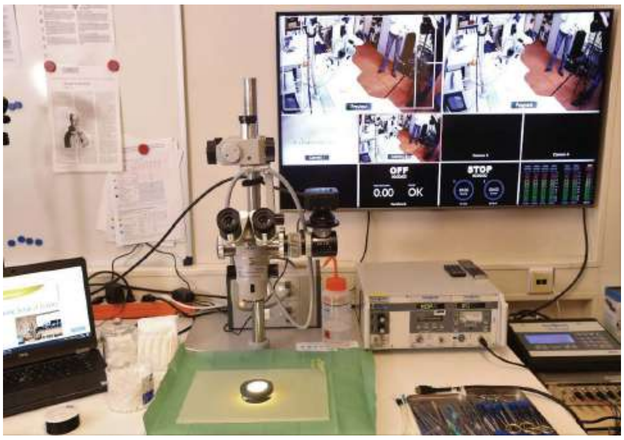

Fig. 7. Online training at RRSSC

Рис. 7. Онлайн-обучение в Центре хирургических навыков Рене Реми

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UK BASED MICROSURGICAL TRAINING

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This describes the UK history of the evolution of microsurgical training. The author has been involved since the start in 1979 and took a sole teaching role in the courses 2 years later. Before teaching microsurgery the necessary skills were obtained by the performance of various organ transplants in mice, rats and rabbits to investigate organ storage and immunosuppression. This experience identified the pitfalls of microsurgery and amplified the then identified need for meticulous microsurgical training. A basic microsurgical program was then instigated to provide step by step exercises of increasing difficulty. This consisted of microscope set-up, correct positioning, instruments, simulated suture exercises, dissection techniques, end to end arterial and venous anastomosis, end to side anastomosis, interpositional vein grafts, nerve anastomosis and groin flaps – all performed on an anaesthetised rat. Latterly we are now running advanced workshops incorporating supramicrosurgical exercises in the chicken (thigh) and the rat. The microsurgical workshops are still running 41 years later!

Keywords: *microsurgery, microsurgical training, Simulation assessment.*

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ОБУЧЕНИЕ МИКРОХИРУРГИИ В СОЕДИНЕННОМ КОРОЛЕВСТВЕ (ВЕЛИКОБРИТАНИИ)

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Представлена история развития обучения микрохирургии в Великобритании, в котором автор принимала участие с момента старта программы в 1979 г., а 2 года спустя стала единственным преподавателем на курсах. Перед началом преподавания микрохирургии она получила необходимые навыки при выполнении различных трансплантаций органов у мышей, крыс и кроликов для исследования органов и иммуносупрессии. Этот опыт выявил подводные камни в микрохирургии и усилил появившуюся тогда потребность в тщательной микрохирургической подготовке. Затем была разработана базовая микрохирургическая программа, в которой предлагались пошаговые упражнения возрастающей сложности, которые включали установку микроскопа, выбор правильного позиционирования, выбор инструментов, имитацию наложения швов, технику рассечения, артериовенозный анастомоз «конец-в-конец», анастомоз «конец-в-бок», анастомоз нервов и паховые лоскуты – все эти процедуры выполнялись на анестезированных крысах. В последнее время мы проводим расширенные семинары, включающие супрамикрохирургические упражнения на курицах (бедро) и крысах. Спустя 41 год после старта обучения микрохирургические семинары по-прежнему успешно работают.

Ключевые слова: *микрохирургия, микрохирургическое обучение, симуляционная оценка.*

Конфликт интересов: автор подтверждает отсутствие конфликта интересов, о котором необходимо сообщить.

Прозрачность финансовой деятельности: автор не имеет финансовой заинтересованности в представленных материалах или методах.

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HISTORY

The first microsurgical course in the UK was setup in 1979 at Northwick Park Hospital, London, some three years after Alain Gilberts' Paris based course.

The need for training was instigated by Prof Colin Green (Medical Research Council (MRC)) who was using microsurgical techniques in his experimental rabbit renal transplantation and by three young like-minded plastic surgeons – Michael Black, Gus McGrowther and Roy Saunders (all now Professors!).

They realised that with the advent of clinical free flaps the microsurgical aspect could not be acquired without some sort of formal training.

I started work for the Medical Research Council (MRC) in 1976 and by 1979 was involved in running the microsurgical workshops having honed my skills on organ transplantation in small animals.

About a year or so later the microsurgical course at Canniesburn, Glasgow, Scotland also started, run by the plastic surgeons working there and to date is still taking place.

TRAINING PROGRAM

The initial course lasted three days and utilised rabbits. It was soon apparent that these were not ideal subjects for training due to anaesthetising en-masse and so the rat was subsequently chosen.

Twelve trainees attended the three day course. Most were plastic surgeons with a few orthopaedics. At that time Zeiss kindly lent us the microscopes (we purchased them in 1986) as the cost in those days for purchasing new machines was exorbitant. Instruments and clamps were expensive but were purchased new from S&T.

Initially topics covered were the microscope set up, femoral vessel dissection and end to end and end to side anastomoses. Lectures on free-flaps were also included. After the first few courses it became apparent that the surgeons were just getting into their stride by day three and that they wanted more hands on time rather than the lectures. From then on the lectures were dropped and the course extended to five days. This meant we could now incorporate vein grafts, nerve anastomosis and a groin flap based on a 0.5 mm epigastric artery and 1 mm vein (now termed supra microsurgery!).

We ran one weekly course per year. As demand soared, by the mid-eighties we were running ten courses a year for up to seventeen participants with a ratio of one lead tutor (Mrs Sandra Shurey) and two trained technicians. By the mid-nineties plastic surgeons were nearly outnumbered by the influx of maxillofacial surgeons and this balance has remained to date. We also had the odd cardiac, vascular, urologist and hand surgeons from the Nordics.

In 1986 we also produced an in house manual of 'Basic Microsurgical Techniques' that we supplied to all our training surgeons and this was updated in 2010. Colin Green also published an article on microsurgical training (1. Green, 1987).

In 1994 the MRC was dissolved and under Prof Green the courses continued under the umbrella of the Northwick Park Institute for Medical Research – NPIMR). From 2019 NPIMR was rebranded as the Griffin Institute.

Around 2012 we also included a five day advanced course that incorporated advanced dissection skills, working at depth, continuous suturing, suturing the posterior wall through the anterior and more microsurgery at supra microsurgical levels both end to end and end to side.

Basic and advanced courses are currently being run at the Griffin Institute (2020).

Due to retirement I have set up a unique home based microsurgical training, running the basic training on a chicken model. For low cost the surgeons can attend a one day refresher or attend a complete five day course. This has proved a popular choice. Information on the UK home based training can be found on my Facebook page (2. Shurey, 2020. MicroShure Microsurgery).

For both Basic and Advanced courses we promoted a step by step learning model with exercises increasing in difficulty as the course progressed.

STEP BY STEP GUIDE TO AN END TO END ARTERIAL ANASTOMOSIS

(5. Shurey, 2020. Module 6: End to End Arterial Anastomosis).

The routine described here is for the Acland vessel approximating clamp (ABB-1), but this can be adapted to other types of double clamp on a slide bar.

The main point of having the two clips on a bar is to allow them to slide toward each other and thus ensure that the divided ends of the vessel are brought close together and are under no tension whatsoever whilst being anastomosed.

Having rinsed the ABB-1 in heparinised saline, it is placed it in the operating field and viewed under low magnification the two clips are slid as far apart on the bar as possible. The clamp is placed over the background material and under the artery until just the clip tips project slightly beyond the vessel with the artery lying in a straight line over the two clips.

Fig. 1. End to end anastomosis of rat femoral artery and vein

Рис. 1. Анастомоз «конец-в-конец» бедренной артерии и вены крысы

With the clamp appliers, the proximal clip is opened, the artery grasped by its adventitia and pulled longitudinally into the open clip before closing. The distal clip is opened and the artery pulled longitudinally toward the centre of the frame, it is slid into the clip and the clamp closed.

This manoeuvre ensures a relaxed length of artery between each clip. Do not twist the vessel and ensure that it is held at the *tip* of the clip, clamping the vessel nearer the clamp bar will lead to vessel slippage when the clamp is pivoted.

With the scissors at a right angle to the vessel wall, the artery should be transected halfway between the two clips with one decisive but controlled movement to achieve a clean cut through the full thickness of the vessel. The divided ends will retract immediately.

Irrigate the vessel with heparinised saline using a 30 gauge Rycroft air cannula attached to a 1 ml syringe.

The clips are now slid gently toward each other until the retracted vessel ends are close together. If ample arterial length has been included between the clamps then they will only need to be pushed together a little, thus leaving plenty of room to do the anastomosis without the clips getting in the way when the needle is being passed.

The chicken artery is non-viable so will not retract once transected so just apply clamps without pulling excess artery between the clamps.

The femoral triangle should now be thoroughly irrigated until it is full of fluid and the divided ends of vessel are floating freely. Only then is it possible to see the loose adventitial tissue. It is important to remove this for 1–2 mm from the anastomosis edge.

The simplest method of doing this is to grasp the tissue with No. D-5a forceps, pull it gently over the vessel-end until a cone or sleeve is formed. Amputate it cleanly in one snip at the level of the underlying stump, the remaining tissue will retract back, leaving the vessel with a clean end.

The chicken artery has very little adventitia so do not overstrip.

Interrupted sutures of 10/0 monofilament polyamide or monofilament polypropylene are used on the rat femoral vessels (8/0 or 9/0 can be used for the chicken artery). The simplest technique is to join these vessels end-to-end using the triangulation method.

The idea of this is to place the first two stay sutures at 120° and then apply horizontal tension. This flattens and stabilises the anterior wall whilst the posterior 240° falls away from the anterior. This helps to prevent catching the posterior wall when suturing the anterior and makes the anastomosis much easier to perform.

If the first two stay sutures are inserted at 180° and tension applied the two vessel walls ‘sandwich’ and the posterior wall could easily be caught in the anterior stitch.

The first stay suture is placed at 2 o'clock around the circumference and secured to the furthest cleat.

The second stay suture is placed on the opposite side of the front wall 120° apart and secured to the other cleat with sufficient traction to stretch the anastomosis line laterally.

The front wall is now sutured using square or reef knots which must lie flat against the anastomosis line.

Under no circumstances must 'granny' knots be made as the ends can easily project through the suture line and into the lumen. Each suture must penetrate the full thickness of the vessel wall and the bite should be about 1.5x the vessel wall thickness.

For intermediate sutures it is easier to pass the needle through both sides of the anastomosis in one movement without releasing the holder.

One suture is placed (the holding suture) equidistant between the two stay sutures and the proximal end left long so that it can be grasped with forceps to raise and stabilise the vessel walls whilst intermediate sutures are placed.

The clamp is turned over *before* tying this suture taking great care that the cleats do not snag or puncture the adjacent vein, and make sure that the back wall has not been picked up. If all is well, return the clamp back again and complete the stitch.

The next suture is placed near the first stay suture, and thereafter they are placed at intervals approximately one needle diameter apart working toward the middle holding stitch.

The other quadrant of the front wall is completed in the same way.

The long uncut end of the middle suture has been used to hold the anastomosis for each of these sutures thus avoiding all handling of the media or intima, and this technique is simpler than picking up the adventitia with forceps.

Having completed the anterior wall, the area is irrigated and the approximating clamp turned 180° so the arterial posterior wall is revealed. The lumen is irrigated with heparinised saline.

If it is necessary nudge each clamp a little closer together to ensure that the suture line is not under tension.

Place the first (holding) suture equidistant between the two stay sutures and, after tying a square knot, leave the proximal end uncut so that this can be grasped to pull the posterior wall away from the anterior and stabilise it whilst the needle is passed for the intermediate sutures.

Remember throughout to use high magnification (10×) to place the sutures and low magnification (4×) whilst tying.

Depending on the size of vessel use ~10 sutures for the complete anastomosis.

After irrigating the field, the clamp is now rotated back to its original position and the artery checked to ensure that it is not adhered to the metal frame.

The stay sutures are divided close to the knots. The distal clip is opened first and the vessel slid out of the clip. Blood should immediately fill the vessel back to the proximal clip having crossed the suture line. Once the anastomosis has stopped oozing, the proximal clip is opened and the artery slid out. Under low magnification, gentle pressure is applied over the suture line with microsurgical swabs until any oozing has stopped.

Pulsatile bleeding must be considered a surgical failure and another suture should be placed after re-clamping and irrigating.

In some clinical circumstances it is not possible to use a double approximating clamp in which case single clamps may be used and the stay sutures attached to the single clamps to hold the stay stitches under tension.

It may also be impossible to use the triangulation technique because vessels cannot be turned over easily (due to lack of access or tension) so it may be necessary to suture the posterior wall first with one suture then gradually work round to the anterior until the anastomosis is completed.

STEP BY STEP GUIDE TO AN END TO SIDE ANASTOMOSIS (RAT FEMORAL ARTERY TO FEMORAL VEIN)

(6. Shurey, 2020. Module 8: End to Side Anastomosis).

In the rat and the chicken the most convenient and simplest model for end-to-side anastomosis is to attach the end of the artery to the side of the vein.

Both vessels are prepared with the backing material placed under *both* vessels and a few drops of 2% procaine applied to prevent spasm.

In the rat, using a single Acland clamp, the artery is occluded as near to the inguinal ligament as possible and the distal end of the artery ligated at the junction with the superficial epigastric origin. The artery is transected straight across close to the tie and adventitial tissue removed by the sleeve technique.

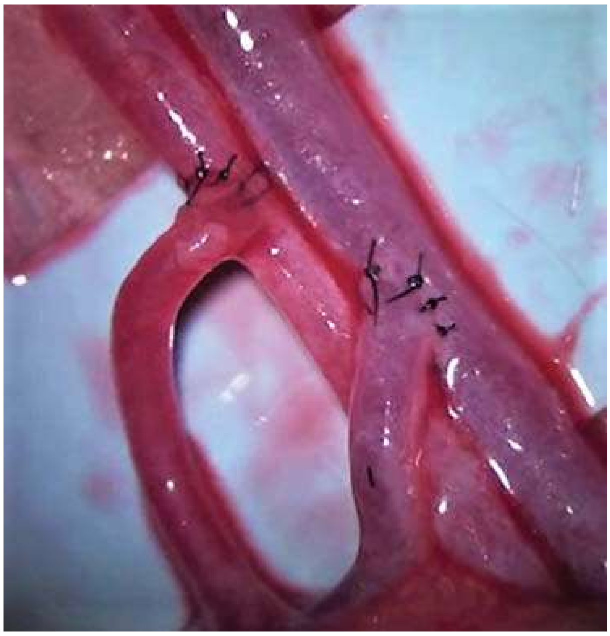

Fig. 2. End to side anastomosis of rat epigastric artery and vein to the femoral artery and vein

Рис. 2. Анастомоз «конец-в-бок» эпигастральной артерии и вены крысы с бедренной артерией и веной

The chicken artery does not have a ‘sleeve’ of adventitia so any obvious adventitial tags are trimmed.

The approximating clamp is then positioned under the femoral vein as close to the inguinal ligament as practicable; it is important to clamp the vein here so that the anastomosis can be performed proximal to the point where the femoral artery has been divided so that no tension is placed on the anastomotic site.

With each clip placed as far apart as possible on the approximating clamp, the vein is slid into the proximal clip first and the distal clip next as this ensures a ballooned vein. This prevents possible damage to the opposite wall when the venotomy is created. The clips of the approximating clamp are slid toward each other to release any tension. The end of the prepared artery is brought alongside the vein so that the artery lies in a gentle curve without tension.

The venotomy is created on the anterior venous wall and is size matched to the outside diameter of the artery and flushed with heparinised saline. The end of the artery is placed alongside the venotomy ready for suturing. For each suture, take normal sized bites out of both artery and vein, avoiding larger bites on the venous side which can cause constriction. Space the sutures as close together as you would in an artery-to-artery anastomosis (one needle thickness apart).

The first suture is placed at the proximal end of the venotomy passing the needle from the outside of the vein to the inside thence from inside the artery to the outside. The suture is pulled through until the edges of the vessels just meet and a surgeon's knot made leaving one end long enough to attach to the furthest cleat of the clamp, but *not* to be attached at this stage.

Place the second suture at the opposite end of the venotomy, this time passing the needle outside of the artery to inside thence inside the vein to outside. Place the third suture in the centre of the anterior wall.

Two additional sutures are placed in the front wall, one in each segment between stay and holding suture. Remember to check each intermediate stitch *before* tying as it is very easy to catch through to the posterior wall. To expose the other side, the long end of the first stay suture is passed under and around the back of the artery. This is used to retract the artery and expose the back wall for anastomosis and is attached to the cleat farthest from the anastomosis.

Take care not to apply to much tension as this can force the arterial and venous wall to lie too close to one another. This stitch is just used to hold the loop of artery gently out of the way.

The back wall is completed in identical fashion to the front. Trim all long ends of knots and cut the stay sutures. Check that there are no obvious gaps when inspected at high magnification and place extra sutures if the gaps look too large.

After each stitch placement gently raise the suture ends before tying to check that the anterior wall has not caught. Additionally keep the vein filled with saline and this too will prevent anterior wall adherence.

Remove the approximating clamp from the vein, proximal clip first, followed by the distal clip. Inspect the posterior wall of the vein to ensure that there are no stitches that have caught through and then remove the single arterial clamp.

Check patency with the milk test.

If the anastomosis is patent, bright red blood should be observed mixing turbulently with venous blood. If the anastomosis is oozing, put gentle pressure over it with a damp swab for a few minutes before re-examining it under magnification. Finally instil a few drops of 2% procaine around the vessels to prevent or reverse any constriction.

NON-LIVING AND LIVING MODELS USED FOR MICROSURGICAL EDUCATION

(7. Shurey, 2020. Module 4: Microsurgical Training Models).

Simulated

Our first exercises are carried out on simulated tissues such as rubber gloves and silicon tubes. The favoured choice for beginners is a glove stapled to card within an envelope, this material is stretchy and more akin to a simulated vessel. The card can also be turned over for stitch inspection. Four 1 cm incisions (horizontal, vertical and two obliques) are made with scissors and the incisions stitched with 8/0.

Penrose Drain Tubing is a rubber tube ideally suited for simulated anastomosis, it is available in varying widths, the 35mm is ideal to start with. Use 6/0 for this as the tubing is quite thick. It can be secured to a cork board with mapping pins in lieu of clamps.

Silastic tubing is soft and easily takes a suture. It is available in many different widths and is suitable for the novice microsurgeon (use 8/0/ & 10/0).

The finest tubes are suitable for practicing at supra microsurgery levels (10/0 & 11/0).

The PVC Rat is a plastic model of a rat in a supine position with exposed major abdominal vessels and organs

This model allows students to practice microsurgical technique before using live animals, an expensive investment but can be re-used many times.

Biological

Japanese noodles are very fine and fragile but good models for practicing supra microsurgery (11/0). Some students like to use earthworms as they have a more ‘vascular’ like structure for practice (8/0). Also umbilical cords offer long lengths of arteries and veins (8/0, 9/0 & 10/0). Cryopreserved rat aortas are also excellent models (use 10/0). Pig or Lambs Heart coronary arteries can be freed and anastomosed (9/0) and Pig or Lambs spleen offers a myriad of vessels for anastomosis (9/0.)

The best non-living model is the chicken thigh and chicken wing (10/0). This involves some macro and micro dissection of the vessels and nerve (8/0 & 10/0) and can also be used to practice supra microsurgical techniques (11/0).

The ultimate practice model is the living rat as it provides immediate feedback on the quality of the vessel preparation and anastomoses,

ASSESSMENTS TOOLS FOR MICROSURGICAL TRAINING

(8. Shurey, 2020. Module 5: Factors Affecting Anastomotic Success).

All participants in our courses were given a certificate of attendance outlining the techniques they had practiced.

Today, the drive is towards the participants being assessed on their performance. There are various scoring mechanisms in the literature describing methods for assessing micro anastomosis but practically they are too detailed to implement in a training environment.

We are currently implementing assessment based on a self- assessment protocol from (9. Ghanem et al, 2016) for end to end anastomosis and for end to side (10. Pafitanis et al, 2017). This was chosen as expert tutor assessment in a microsurgical course can take excessive time and self- assessment over 5 days was proved to be as valid.

They have proved that self-evaluation of an anastomosis using the assessment of skill levels can be compared to that of an experts assessment, each student assesses each anastomotic error and as experience is gained the amount of errors recorded is shown to be reduced.

These two papers contain all the relevant evaluation parameters.

(9. Ghanem A.M. et al. Anastomosis Lapse Index (ALI): A Validated End Product Assessment Tool for Simulation Microsurgery Training).

(10. Pafitanis G., Veljanoski D., Ghanem A.M., Myers S. Intimal Surface Suture Line (End-Product) Assessment of End-to-Side Microvascular Anastomosis).

MODELS AND TECHNIQUES FOR SUPRAMICROSURGERY

Supramicrosurgical exercises can be completed in both the chicken and the rat models.

Rat groin flap

For the purpose of this exercise the groin flap is detached and then anastomosed at the same site to negate the need for any further dissection.

A rectangular area 4 cm x 2 cm is marked out on the depilated skin. An incision using a scalpel is made around the whole flap. The flap is lifted with micro-toothed forceps at the anterior medial corner and then raised, together with its vessel bearing fat pad, by blunt dissection with round-tipped bow scissors.

Great care must be taken when cutting through the inguinal fat pad at the posterior border of the flap as it usually contains vessel branches. These vessels can be contained within the flap if a larger ratio of fat to skin is taken in this area.

It is important that the whole of the flap is freed from any adherent tissue and that it is completely isolated on the superficial epigastric pedicle. If the flap remains attached by any peripheral vessels during the vascular anastomosis it will become congested and fail.

The epigastric vessels (artery ~0.5mm and vein ~1mm) can be used for practicing end to end and end to side anastomoses at supramicrosurgical levels.

(11. Shurey, 2020. Module 10: <1 mm End to End Anastomosis).

(12. Shurey, 2020. Module 11: <1 mm End to Side Anastomosis).

Other models in the rat can include: Interpositional vein graft < 1 mm (Fig. 3) and Femoral Artery to Carotid Loop (Fig. 4).

Fig. 3. Interpositional vein graft <1 mm

Рис. 3. Межпозиционный венозный трансплантат <1 мм

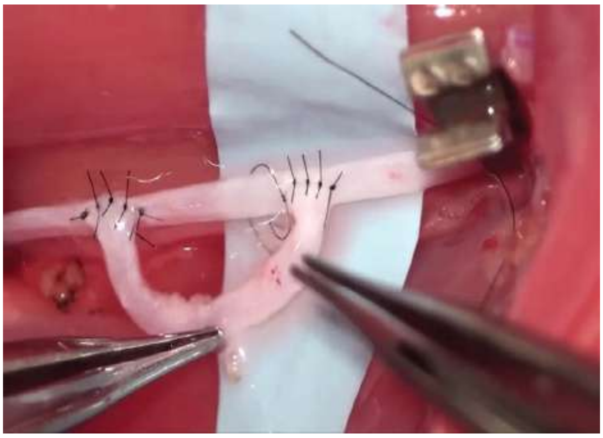

Fig. 4. Femoral artery to carotid loop

Рис. 4. Бедренная артерия к петле сонной артерии

(14. Shurey, 2020. Module 11: Femoral Artery to Carotid Loop).

(15. Shurey, 2020. Module 9a: Interpositional Vein Graft).

To test supramicrosurgical dissection skills the rat renal model can be utilised (Fig. 5).

Fig. 5. Renal Vessel Dissection

Рис. 5. Расслоение почечных сосудов

(16. Shurey, 2020. Module 15: Renal Model with Continuous Suturing)

The chicken tributary vessels can also be used for supramicrosurgical exercises such as <1 mm end to end and end to side anastomosis as well as the interpositional vein graft.

Chicken

For dissection practice the chicken vessels can be raised attached to a flap or alternatively the tributary vessels can just be dissected free, cut and anastomosed.

For details of the chicken flap model see:

(13. Pafitanis G. et al., 2017. The Chicken Thigh Adductor Profundus Free Muscle Flap: A Novel Validated Non-Living Microsurgery Simulation Training Model).

Many of these smaller vessels are very fragile and the smaller veins in particular are good models for mimicking lymphatic anastomoses. The main difference with supramicrosurgical anastomoses is the vessel handling. This must be kept to an absolute minimum and the copious use of fluid helps to 'float' the vessels and the weight of the fluid within the vessel lumen helps to keep the lumen open ready for suturing.

Robotic Microsurgery

At the current time we are not using robots for microsurgical training in the UK. However the Griffin Institute in London now has three Da Vinci robots and three training consoles to help train urologists. We hope to be able to offer microsurgical training with these in the future. Though these robots are now being superseded by robots specifically designed for microsurgery such as the Symani microrobot.

Future in Microsurgery education; virtual

In order to inspire microtraining I have researched the least expensive way to get a home or lab set up (with microscope) and have shared this knowledge on the web, hoping to inspire training in less well-off countries. (3. Shurey, 2020. Home or Lab Set up).

Also, during lockdown due to the Corona-19 virus I have devised 20 e-learning modules for basic microsurgery along with the unedited core videos and placed these on You tube. (4. Shurey, 2020. E-Learning Modules).

Hopefully they will inspire hospitals and labs to set up their own training spaces for their young microsurgeons and in the future, if they can obtain the equipment we can start to encourage virtual training.

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EDUCATION OF MICROSURGICAL TECHNIQUE FOR YOUNG SURGEONS BY INTERNATIONAL SOCIETY FOR EXPERIMENTAL MICROSURGERY WEST JAPAN AND FUTURE PROSPECTS

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The need for microscopic vascular anastomosis has increased in the field of gastrointestinal surgery. Herein we report the activities for microsurgical training by ISEM West Japan.

Since 2015, we have held the Hands-on seminar twice a year using artificial blood vessel. The participants sutured it with 9-0 polypropylene suture under bench microscopes. Competitions for microsurgical arterial anastomosis were held in the seminar, in which we evaluated the anastomosis regarding the leakage and patency.

Totally 208 participants attended the hands-on seminar. No relation was seen between the years of surgical experience and the score. However, there was a relation between the number of participation and the score.

Through our hands-on seminar, young surgeon could improve technique and motivation for the microsurgery.

Keywords: *Microsurgery, Surgical education, Hands-on seminars.*

Conflict of interest: Eiji Kobayashi is a medical advisor of Sunarrow Ltd. The artificial blood vessel made of PVA was developed by Sunarrow Ltd.

Financial disclosure: no author has a financial or property interest in any material or method metioned.

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ОБУЧЕНИЕ МОЛОДЫХ ХИРУРГОВ МИКРОХИРУРГИЧЕСКОЙ ТЕХНИКЕ МЕЖДУНАРОДНЫМ ОБЩЕСТВОМ ЭКСПЕРИМЕНТАЛЬНОЙ МИКРОХИРУРГИИ (ЗАПАДНАЯ ЯПОНИЯ) И ПЕРСПЕКТИВЫ НА БУДУЩЕЕ

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Необходимость микроскопического сосудистого анастомоза в области хирургии желудочно-кишечного тракта не подлежит сомнению. Авторы сообщают о деятельности по обучению микрохирургии в ISEM West Japan.

Начиная с 2015 г., два раза в год, мы проводим практический семинар на тему применения искусственных кровеносных сосудов. Участники семинара тренируются шить их полипропиленовым швом 9-0 под настольными микроскопами. На семинаре проводятся соревнования по выполнению микрохирургических артериальных анастомозов, в ходе которых анастомоз оценивается на прочность и проходимость.

В практическом семинаре приняли участие 208 человек. Никакой связи между количеством лет хирургического опыта и полученной на соревновании оценкой не наблюдалось. Однако имелась связь между числом участников и количеством набранных ими баллов.

Благодаря практическому семинару молодые хирурги могут оттачивать технику и повысить мотивацию к занятиям микрохирургией.

Ключевые слова: *микрохирургия, хирургическое образование, практические семинары.*

Конфликт интересов: Эйдзи Кобаяши – медицинский консультант компании Sunarrow Ltd. Искусственный кровеносный сосуд из PVA был разработан компанией Sunarrow Ltd.

Прозрачность финансовой деятельности: никто из авторов не имеет финансовой заинтересованности в представленных материалах или методах.

Для цитирования: Рёсукэ Габата, Шинтаро Яги, Ёдзи Кобаяши. Обучение молодых хирургов микрохирургической технике Международным обществом экспериментальной микрохирургии (Западная Япония) и перспективы на будущее. *Вопросы реконструктивной и пластической хирургии*. 2021;24(1):56–60. doi: 10.52581/1814-1471/76/6

INTRODUCTION

Microsurgery is used in many clinical fields of surgery including neurosurgery, vascular surgery, plastic surgery, and reconstructive surgery [1], and there are many academic societies for each clinical field, but all of them are vertically divided into different fields [2].

In 1991, the International Society for Experimental Microsurgery (ISEM) (http://www.myisem.org/index.php) was founded by Sun Lee, who had developed many experimental organ transplantation models in rats and had been involved in the dissemination of microsurgery technology throughout the World [3].

The goal of ISEM is to promote the use of microsurgery not only in basic research but also in clinical practice worldwide, and it aims to be a cross-sectional organization involving various fields such as transplantation immunology, pharmacology, and veterinary medicine [4]. In addition, ISEM has been working with the European Society for Surgical Research (ESSR) to propose basic educational methods for experimental microsurgery [5].

On the other hand, in the treatment of liver - diseases, living donor liver transplantation, in which the liver can be regenerated in an appropriate condition after resection and the resected liver can be used as a donor graft, has become a common treatment, and many cases have been experienced [6]. Until now, surgeons dealing with hepatobiliary diseases have not needed microsurgery themselves, but the need for microsurgery has been increasing, especially for arterial reconstruction in living donor liver transplantation [7]. Furthermore, arterial reconstruction is sometimes required in the hilar cholangiocarcinoma and pancreatic cancer surgery. However, on-the-job training is the mainstream for the transmission of this technique, and young surgeons have very few opportunities to be involved, and there is less microsurgical training protocol in Japan.

Accordingly, we set up ISEM West Japan Chapter in order to lead young surgeons to experimental surgical research using microsurgery [4]. We have continuously conducted a microsurgery hands-on seminar organized by the ISEM West Japan Section. Herein we report the activities of the Hands-on seminars we have conducted so far, and then discuss advances in microscopy used in microsurgery and future educational strategies in the era of COVID-19.

HANDS-ON SEMINAR OF MICROSURGERY

In the hands-on seminar, based on the concept of "Not to use living-animals to acquire surgical techniques", we delivered a video of vascular anastomosis to the participants beforehand to give them image training, and then practiced anastomosis of artificial blood vessels using a desktop microscope. Since 2015, we have held the seminar once or twice a year in conjunction with several surgical conferences.

At the beginning of the seminar, the tips and pitfalls of vascular anastomosis under the microscope were explained. Then, assuming the reconstruction of the left hepatic artery in pediatric living-donor liver transplantation, we performed the suture practice of end-to-end anastomosis of a 2 mm artificial vessel (Sunarrow Limited, Niigata, Japan) (Fig. 1) with 9-0 polypropylene thread. Finally, in order to improve the participants' technique in a more scientific manner, we provided feedback on the technique evaluation [4]. And to lift the spirits of the participants, we conducted a contest to evaluate the anastomosis of a 2 mm artificial vessel with 9-0 polypropylene thread (Crownjun, Ichikawa, Japan) in 30 minutes.

Fig. 1. Artificial blood vessel made of PVA for training [4]

Рис. 1. Предназначенные для обучения искусственные кровеносные сосуды, изготовленные из поливинилового спирта [4]

The anastomosis was evaluated by two surgeons performing arterial anastomosis for liver transplantation in a blinded fashion. We evaluated the anastomosis regarding patency, leakage, and the knot from inside and outside. The evaluation methods were as follows: (1) water-proof / leak and patency test (5 points) using an infusion set with an 18G plastic needle connected to their artificial vessels (2). Observation of the anastomosis from the inside and outside (4 points) by making an incision in the long axis direction and pressing the anastomosis with acrylic plates. The total score (9 points in total) (Table 1) was used to award the prize for excellence.

Table 1. The total score used to award the prize for excellence

Таблица 1. Количество присуждаемых баллов за выполнение тестовых заданий

Water-proof test	Patency test	Anastomosis (inner)	Anastomosis (outer)
3 points: No leakage	2 points: Good Patency	2 points: Regular	2 points: Regular
2 points: Little leakage	1 point: Moderate Patency	1 point: Patially irregular	1 point: Patially irregular
1 point: Spout	0 point: No patency	0 point: Irregular	0 point: Irregular
0 point: Not connected	–	–	–

RESULTS

From 2015 to 2018, five hands-on seminars were held in conjunction with relevant conferences on transplantation and general surgery (Kumamoto in October 2015; Osaka in June 2016; Tokyo in November 2016; Kanazawa in July 2017; and Kyoto in December 2017). Of the 208 participants who attended the hands-on seminar, 91% (190 participants) were under 35 years old, including 5 medical and veterinary students. The competition in the Hands-on seminar was held with 77 participants. There was no correlation between the number of years of surgical practice and the scores, but participants who attended the hands-on seminar four or more times (11 participants, median 8 points) scored significantly higher than those who attended the hands-on seminar three or less times (66 participants, median 3 points) ($p = 0.0010$, Kruskal Wallis test). And the individual score of participants, who attended the hands-on seminar multiple times, increased in proportion to the number of times they attended. The participant who got the highest score was the surgeon who attended all our hands-on seminar.

DISCUSSION

Basic education in microsurgery recommends the effective use of non-biomaterials without using living-animals [2, 5] We have also performed hands-on education with artificial blood vessels made from polyvinyl alcohol (PVA) [4]. This PVA has been further improved and can be used for super microsurgery training [9].

We have provided hands-on education for young surgeons at conferences on general surgery, which are not directly related to microsurgery. Owing this biomaterial, we could provide education without contamination at hotel venues. In addition, that many young surgeons could participate in this seminar because the participation fee was reduced by subsidies from the public budget. The contests for the anastomosis of the artificial vessels have been held to motivate the young participants.

On the other hand, Surgical techniques have changed dramatically with the advancement of various medical surgical instruments. In the 1900s, the basis of surgery was "direct" technique, in which the surgeon looked directly with the eyes, but with the development of endoscopes, the technique has changed to "indirect" technique, in which the surgeon looks at the surgical field on an electronic screen and uses forceps to resect or suture the lesion. In other words, "head up surgery", as represented by laparoscopic surgery and robotic surgery, is emerging in the field of digestive surgery, and young surgeons are adapting to "indirect surgery", in which the "direction to look" is different from the "direction to work".

The degree of proficiency is deeply related how soon surgeons start learning same as that of leaning sports. In other words, it is important to experience and practice "indirect" surgery from an early stage. Although microsurgery is originally an “indirect surgery”, the introduction of the video microscope has opened up the possibility of head-up surgery, in which the surgeon, assistant, and observer share the same high-quality screen as in laparoscopic surgery [9].

We have developed a 3D-4K video microscope as part of a medical-engineering collaboration project, and we succeeded in commercializing it under the product name “Hawk Sight”.

This ultra-high-quality image can be transmitted remotely in high-definition such as 5G, eliminating the need for the field to instruct the hands-on and the young doctors participating in the hands-on to gather together.

In the era of COVID-19, it is important to provide education through hands-on webinars via the Internet using these ultra-high images. By using online, the education can be extended not only to Japan but also to the World.

CONCLUSION

Young surgeons in digestive surgery have few opportunities to learn vascular anastomosis techniques under the microscope, and it is difficult for them to master the techniques. However, the practical training in the microsurgery hands-on seminar using artificial vessels and the objective evaluation of anastomosis techniques through a contest improved the motivation and anastomosis skills of the participants.

Development and innovation of devices are also important to increase the number of young surgeons who are interested in microsurgery.

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ОБУЧЕНИЕ МИКРОХИРУРГИИ. ДЛЯ КОГО И КАК?

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Проанализировав достоинства и недостатки существующих курсов обучения микрохирургии, сотрудники кафедры пластической хирургии Сеченовского Университета в 2011 г. организовали трехэтапные микрохирургические курсы по принципу от простого к сложному, интегрировав в практическую подготовку теоретический материал, необходимый для формирования микрохирургического кругозора.

Разделение процесса обучения на краткосрочные этапы, по мнению авторов, позволяет обучающимся постепенно погружаться в микрохирургический мир, при этом самим регулировать периодичность, частоту обучения и необходимость дальнейшего совершенствования навыков. Этапность делает обучение более доступным и позволяет популяризировать микрохирургию как универсальный метод для решения хирургических задач.

Ключевые слова: *обучение микрохирургии, курсы по микрохирургии, микрохирургические навыки.*

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MICROSURGERY TRAINING: FOR WHOM AND HOW?

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In 2011, the staff of the Department of Plastic Surgery, Sechenov University (Moscow, Russia), organized three-stage microsurgical courses. Having analyzed the advantages and disadvantages of the previous practical course, it was created according to the principle “from simple to complex”, integrating theoretical material into the practical preparation for the formation of a microsurgical outlook.

According to the authors, dividing the learning process into short-term stages allows students to gradually immerse themselves in the microsurgical world, while they themselves regulate the frequency of training and the need for further improvement of skills. Due to the phasing, the course becomes more accessible and makes it possible to popularize microsurgery as a universal method for solving surgical problems.

Keywords: *microsurgery training, microsurgical courses, microsurgical skills.*

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Про историю обучения микрохирургии нельзя говорить в отрыве от истории развития самой микрохирургии.

Микрохирургический метод появился как результат прогресса в медицине по мере усложнения задач, которые ставили перед собой хирурги, и стал возможен благодаря совершенствованию технической оснащенности операционной – появлению операционного микроскопа и микрохирургического инструментария.

Первое известное сообщение о шве артериальной стенки датируется 1762 г. [1]. Спустя более века A. Carrel описал технику сосудистого шва [2], за которую вскоре получил Нобелевскую премию, заложив тем самым основу для дальнейшего развития сосудистой хирургии и микрохирургии.

Вторая составляющая развития напрямую связана с именем Carl Zeiss, а точнее с именем одноименной компании, выпустившей в 50х годах прошлого столетия микроскоп. Период экспериментальной хирургии пролетел быстро: от первой успешной реплантации пальца у обезьяны, выполненной G. Bunke в 1965 г. [3], до первой успешной реплантации большого пальца кисти у человека, осуществленной S. Tamai в 1968 г. [4].

В Советском Союзе микрохирургия началась в 1973 г. с создания лаборатории на базе Всесоюзного научно-исследовательского института клинической и экспериментальной хирургии Минздрава СССР под руководством В.С. Крылова [5]. После создания первых обучающих курсов и издания учебников по микрохирургии [6], микрохирургия шагнула в хирургические массы.

Микрохирургия развивалась как новый метод в арсенале хирургов, преимущественно сосудистых, позволяя выполнять микрососудистые анастомозы на структурах малого диаметра. Одновременно с этим лавинообразное расширение возможностей, которые способствовали открытию этого метода, в частности, развитие последовательно двух направлений – реплантации и микрохирургической аутотрансплантации тканей – позволило начать разговор о микрохирургии как отдельной специальности. Однако время показало, что отношение к микрохирургии именно как методу более концептуально и позволяет не замыкать его в рамках одной специальности. Се-

One cannot speak about the history of microsurgery training in isolation from the history of the development of microsurgery itself.

The microsurgical method appeared as a result of progress in medicine as the tasks set by surgeons became more complicated. It is became possible due to the improvement of the technical equipment of the operating room – the emergence of an operating microscope and microsurgical instrumentation.

The first report for the arterial wall suture dates back to 1762 [1]. More than 100 years later, A. Carrel described the technique of vascular suture [2]. He received soon the Nobel Prize for this discovery, thereby laying the basis for the further development of vascular surgery and microsurgery.

The second component of development is directly related to the name of Carl Zeiss, or rather to the name of the company of the same name, which released the microscope in the 1950s. Experimental Surgery period passed quickly: from the first successful replantation of a finger in a monkey, performed by G. Bunke in 1965 [3], to the first successful replantation of the thumb in humans, performed by S. Tamai in 1968 [4].

Microsurgery began in the Soviet Union with the creation of a laboratory on the basis of All-Union Research Institute for Clinical and Experimental Surgery, the USSR Ministry of Health, under the leadership of V.S. Krylov in 1973 [5]. Microsurgery stepped into the surgical masses after the creation of the first training courses and the publication of textbooks for microsurgery [6].

Microsurgery made it possible to perform microvascular anastomoses on small-diameter structures, therefore, it developed as a new method in the arsenal of surgeons, mainly in vascular ones. At the same time, the range of possibilitieswith the help of microsurgery was expanded in two more successive directions replantation and microsurgical tissue auto transplantation. This progress made it possible to start talking about microsurgery as a separate specialty. However, time has shown that the attitude to microsurgery as a method is more conceptual and allows it not to be left within the годня микрохирургия – это хирургический метод, который в своей основе имеет: оперирование под оптическим увеличением, обеспечиваемое хирургическим микроскопом, специальный микрохирургический инструментарий и шовный материал и специальные микрохирургические навыки.

Именно так микрохирургия воспринимается в большинстве стран. Поэтому за рубежом получили распространение базовые курсы, на которых учат только навыку наложения микрососудистого анастомоза, не затрагивая клинические вопросы [7].

Такие курсы длятся в среднем около 5 дней (40 ч) и сосредоточены на работе на живых моделях. Дальнейшее совершенствование микрохирургических навыков возможно через прохождение продвинутых курсов, также длящихся 5 дней (40 ч).

До недавнего времени самые популярные курсы в нашей стране (на базе кафедры косметологии и реконструктивно-восстановительной хирургии РМАПО, в настоящее время – кафедра пластической и челюстно-лицевой хирургии ФГБОУ ДПО РМАНПО Минздрава России)), длительностью 144 ч, помимо освоения навыка наложения микрососудистого анастомоза на фиксированных моделях, включали в себя объемный лекционный материал, диссекции популярных на тот момент кровоснабжаемых лоскутов.

До недавнего времени курсов для дальнейшего совершенствования микрохирургических навыков в России не было, и врачи были вынуждены заниматься самообразованием.

Каждый из этих вариантов обучения имеет свои достоинства и недостатки (табл. 1). Основными преимуществами зарубежных курсов являются гарантированное получение микрохирургических навыков высокого уровня, который позволит применять их сразу в клинической практике, и продолжительность курсов – всего 5 дней. Но имеются и недостатки, например, высокая стоимость курса, к которой необходимо добавить еще оплату перелета и проживания.

Данный формат курсов больше подходит для профессионального сообщества, в котором владение микрохирургическими навыками является обязательными для врачей определенных специальностей. Другими словами, данные курсы были созданы для специалистов, которые хорошо понимают, где и как они будут применять полученные микрохирургические навыки, а также которым необходимо получить максимальный результат за минимальное время, и готовых мириться с высокой стоимостью обучения.

В противоположность зарубежным курсам, отечественный аналог стоил дешевле и даже мог быть обеспечен средствами ГБУ для своих сотруд-

framework of one specialty. Today, microsurgery is a surgical method based on: operation under optical magnification provided by a surgical microscope, special microsurgical instruments, suture material and special skills.

This is how microsurgery is perceived in most countries of the World. That is why basic courses have become widespread abroad, in which they teach only the skill of applying microvascular anastomosis, without touching on clinical issues [7].

These courses last on average about 5 days (40 hours) and focus on working on live models. Further improvement of microsurgical skills is possible through the passage of advanced courses, also lasting 5 days.

Until recently, the most popular courses in Russia were 144 hours. They were held on the basis of the Department of Cosmetology and Reconstructive Surgery of the RMANPO, now – the Department of Plastic and Maxillofacial Surgery, Russian Medical Academy of Continuous Professional Education, the Ministry of Health of the Russian Federation. In addition to mastering the skill of applying microvascular anastomosis on fixed models, the courses included voluminous lecture material, dissection of blood-supplied flaps, which were popular at that time.

Until recently, there were no courses in Russia to further improve microsurgical skills. Consequently, the doctors were forced to educate themselves.

Each of these options has its own advantages and disadvantages (Table 1). The main advantages of foreign courses are the guaranteed acquisition of high-level skills (in just 5 days), which will allow you to immediately apply them in practice, and duration of the course – only 5 days. But there is also a drawback – the high price, as well as payment for flight and accommodation.

This format of courses is more suitable for the professional community, in which mastery of microsurgical skills is mandatory for doctors of certain specialties. In other words, these courses were created for professionals who have a good understanding of how and where they will apply the acquired skills. And also, who need to get the maximum result in the minimum time and are ready to pay a high price.

The domestic analogue was cheaper and could even be provided with funds of the State Budgetary Institution for its employees. And also, it was lasted longer and allowed to master the technique of allocating blood-supplied flaps; at the expense of the lecture material gave an idea of the possibilities of using microsurgery in clinical practice. Then the

Таблица 1. Сравнительная характеристика отечественных и зарубежных курсов

Показатель	Зарубежные курсы	Отечественные курсы
Цели курса	Получение базовых микрохирургических навыков	Получение базовых микрохирургических навыков. Развитие микрохирургического кругозора
Стоимость	1200–1500 $	500 $
Продолжительность обучения	5 дней	20 дней
Тренировочные модели	Биологические (*in vivo*)	Фиксированные (*ex vivo*)
Микрохирургические навыки, баллы	5	2,5–3
Развитие хирургического кругозора, баллы	0	2
Микрохирургическая социализация, баллы	0	2

Table 1. Comparative characteristics of domestic and foreign courses

Indicator	Foreign courses	Domestic courses
Goals of course	Obtaining basic microsurgical skills	Obtaining basic microsurgical skills. Development of a microsurgical outlook
Price	1200–1500 $	500 $
Duration of training	5 days	20 days
Training models	Biological (*in vivo*)	Fixed (*ex vivo*)
Microsurgical skills, points	5	2,5–3
Development of a microsurgical outlook, points	0	2
Microsurgical socialization, points	0	2

ников, длился дольше, но позволял освоить технику выделения кровоснабжаемых лоскутов, а также за счёт лекционного материала давал представление о возможностях применения микрохирургии в клинической практике, в основном в травматологии и ортопедии, что было не очень интересно представителям других специальностей.

На наш взгляд, оба эти варианта обучения имели одинаковый недостаток. Они оказались слишком объемными для тех, кто делал первые шаги в микрохирургии и не был уверен, что будет использовать микрохирургию в своей профессиональной деятельности. Попав на курсы, обучающийся обречен пройти их до конца, даже осознав, что микрохирургия ему не подходит, и дальнейшее обучение становится в тягость.

Проанализировав потребности хирургов в обучении микрохирургии, достоинства и недостатки уже имеющихся курсов, на базе кафедры пластической хирургии Первого МГМУ им. Н.И. Сеченова было принято решение разделить стандартный в международной практике пятидневный базовый курс на два. В результате курсы стали более короткими, что сделало их более доступными для большинства специалистов. Таким образом, в 2011 г. сотрудники кафедры под патронажем академика РАМН Н.О. Миланова и при участии австрийских коллег организовали и провели новые для нашей страны курсы микрохирургии. За основу была взята австрийская модель, которую дополнили привлечением предста-

application was limited to traumatology and orthopedics.

In our opinion, both courses had one common drawback. For those who were just taking their first steps in microsurgery and were not sure that they would use the technique in their practice, the course was too long. The student must complete the course to the end, even realizing that microsurgery is not suitable for him. Further training becomes a burden.

Having analyzed the needs of surgeons, having studied the advantages and disadvantages of the existing courses, it was decided to make the course shorter, which makes it more accessible. It was decided to divide the standard in international practice 5-day course into two on the basis of the Department of Plastic Surgery of Sechenov University. Thus, in 2011, the staff of the Department of Plastic Surgery under the leadership of Academician of Russian Academy of Medical Sciences N.O. Milanov and with the participation of Austrian colleagues organized and conducted courses for microsurgery. They took the Austrian model as a basis, then supplemented it with the involvement of various specialties (plastic surgeons, oncologists, maxillofacial surgeons, traumatologists and orthopedists, neurosurgeons) as teachers. this is an opportunity to greatly expand the horizons of students.

вителей разных специальностей (пластических хирургов, онкологов, челюстно-лицевых хирургов, травматологов, ортопедов, нейрохирургов) в качестве преподавателей, что позволило сильно расширить медицинскую географию курсантов.

Миссия созданных курсов по микрохирургии: популяризация микрохирургии среди врачей для повышения качества хирургической помощи и эффективности лечения пациентов. Проект был создан для организации обучения микрохирургии студентов медицинских вузов, ординаторов и врачей хирургических специальностей, т.е. задачей курсов стало поэтапное доступное для всех приобретение микрохирургических навыков.

Обучение было разделено на три последовательных этапа, позволяющих, двигаясь последовательно от простого к сложному, получить микрохирургические навыки, теоретические и прикладные знания, необходимые для клинической практики:

– первая ступень – базовый курс «Введение в микрохирургию»;

– вторая ступень – «Микрохирургия. Продвинутый курс»;

– третья ступень – «Микрохирургия. Клинический курс».

Каждая ступень также построена по принципу от простого к сложному, состоит из практических упражнений и теории.

Весь обучающий процесс был распределен на этапы (табл. 2), что позволило разделить глобальную цель «обучение микрохирургии» на несколько мелких, но более легко достижимых целей.

Базовый курс (первая ступень) направлен на знакомство курсантов с микрохирургией. На этом этапе курсанты работают под оптическим увеличением (OPMI Pico Techno, Carl Zeiss, Германия) сначала на пластиковых моделях сосудов, затем с биологическими фиксированными моделями с разными по диаметру сосудами, начиная с коронарной артерии препарата бараньего сердца (диаметр 2–3 мм), затем сосуды и нервы препарата куриного бедра (диаметр 1,0–1,5 мм).

Отдельное внимание уделяется диссекции сосудов и нервов, это дает возможность курсанту отточить хирургические навыки, позволяющие сделать свою хирургическую технику менее травматичной, что благоприятно сказывается на результатах операций в реальной клинической практике.

Продолжительность курса составляет 16 ч, т.е. два полноценных рабочих дня, что, на наш взгляд, вполне достаточно для получения обучающимися собственных впечатлений, не позволяющих при этом устать от микрохирургии.

Преподавателями курса являются практикующие микрохирурги, представляющие различные медицинские специальности (пластическая

The mission of creating microsurgery courses is to popularize microsurgery among doctors to improve the quality of surgical care and the effectiveness of patient treatment. This project was created to organize training, that is, the goal of the courses is a step-by-step acquisition of microsurgical skills available to all (doctors, students, residents).

Therefore, the training was divided into three sequential stages, allowing to move sequentially from simple to complex, to obtain misrosirgical skills, theoretical and applied knowledge, which are necessary for clinical practice:

– the first step – basic course "Introduction to Microsurgery";

– the second step – "Microsurgery. Advanced course";

– the third step – "Microsurgery. Clinical course".

Each step consists of practical exercises and theory, and is also structured from simple to complex.

The entire training process was divided into stages (Table 2), which made it possible to divide the global goal of "microsurgery training" into several small, but more easily achievable goals.

The basic course (first stage) is aimed at acquainting students with microsurgery: work under optical magnification (OPMI Pico Techno, Carl Zeiss, Germany) on plastic models of blood vessels, then with fixed biological models. The vessels are provided with different diameters. First, the coronary artery of the ram heart preparation (diameter 2–3 mm), then the vessels and nerves of the chicken thigh (diameter 1.0–1.5 mm).

In order for students to hone their surgical skills, we pay special attention to the dissection of blood vessels and nerves. This helps to make your surgical technique less traumatic and has a beneficial effect on the results of operations.

In our opinion, the duration of the course should take 2 full days (16 hours), which is enough to gain experience and impressions.

The course is taught by practicing microsurgeons from different specialties (plastic surgery, traumatology and orthopedics, maxillofacial surgery, oncosurgery).

We have added lectures to the program to expand the horizons, in which teachers share their experiences and explain the clinical tasks of microsurgery. It is important to discuss the prospects for the further development of microsurgery. The lecture material allows you to break away from the microscope and rest.

Таблица 2. Характеристика этапов обучения микрохирургии

Показатель	Первая ступень «Введение в микрохирургию»	Вторая ступень «Микрохирургия. Продвинутый курс»	Третья ступень «Микрохирургия. Клинический курс»
Цели курса	Знакомство курсантов с микрохирургией. Получение базовых микрохирургических навыков. Развитие микрохирургического кругозора	Совершенствование базовых микрохирургических навыков. Развитие клинического микрохирургического кругозора	Совершенствование микрохирургических навыков в условиях клиники. Работа в специализированной микрохирургической бригаде. Углубленные теоретические знания в соответствии с выбранной специальностью
Стоимость	400 $	530 $	700 $
Продолжительность обучения	2 дня	2 дня	5 дней
Тренировочные модели	Фиксированные (*ex vivo*)	Биологические (*in vivo*)	Биологические (*in vivo*)
Микрохирургические навыки, баллы	2,5–3	5	5
Развитие хирургического кругозора, баллы	5	5	5
Микрохирургическая социализация, баллы	5	5	5

Table 2. Characteristics of the stages of training in microsurgery

Indicator	First step “Introduction to Microsurgery”	Second step “Microsurgery. Advanced course”	Third step “Microsurgery. Clinical course”
Goals of course	Introduction of microsurgical technique. Basic microsurgical skills training. Development of a microsurgical outlook	Improving basic microsurgical skills. Development of a clinic microsurgical outlook	Improving basic microsurgical skills in rehab. Work in a specialized microsurgery team. In-depth theoretical knowledge in accordance with the chosen specialty
Price	400 $	530 $	700 $
Duration of training	2 days	2 days	5 days
Training models	Fixed (*ex vivo*)	Biological (*in vivo*)	Biological (*in vivo*)
Microsurgical skills, points	2,5–3	5	5
Development of a microsurgical outlook, points	5	5	5
Microsurgical socialization, points	5	5	5

хирургия, травматология и ортопедия, челюстно-лицевая хирургия, онкохирургия).

С целью расширения микрохирургического кругозора в программу курса включены лекции, в которых преподаватели делятся своим опытом, рассказывают о том, какие клинические задачи по-

Specialists of the same profile are easier to establish contact with each other, for example, traumatologists. It is easier for trauma students to exchange information with a trauma lecturer. Often this contact develops into mentoring and further friendship outside the course.

зволяет решить микрохирургия в каждой из медицинских специальностей, а также обсуждают перспективы дальнейшего развития микрохирургии.

Также следует отметить, что курсанты травматологии более легко налаживают контакт с преподавателем травматологом, так и курсанты других специальностей более легко находят контакт с преподавателем своей специальности. Зачастую этот контакт вырастает в менторство и дальнейшую дружбу уже за пределами курса.

Важным этапом первой ступени обучения «Введение в микрохирургию» (табл. 3) является оценка полученных навыков. Для этого организаторы курса проводят микрохирургический чемпионат в конце второго дня. Курсантам предлагается выполнить три контрольных упражнения: наложение анастомозов «конец-в-конец» на бедренные артерию и вену, эпиневральный шов бедренного нерва тренировочной биологической модели № 2 (бедро курицы). На выполнение всех упражнений отводится 2 ч. По истечении этого времени преподаватели оценивают результаты работы каждого курсанта.

Оценка производится по пятибалльной шкале по двум критериям: качество и скорость выполнения упражнений. По сумме двух оценок определяется окончательный результат, на основании которого подводятся итоги чемпионата. Курсанты, занявшие первые три места поощряются материальными призами.

Такая проверка первичных практических навыков не только позволяет преподавателям определить эффективность освоения материала и необходимые изменения в подаче материала для лучшего понимания, но и дает возможность курсантам самостоятельно оценить свои достижения и принять внутреннее решение о необходимости дальнейшего совершенствования в микрохирургии.

Пройдя базовый курс и осознав, что они хотят заниматься микрохирургией и нуждаются в совершенствовании своих микрохирургических навыков, курсанты получают возможность попасть на вторую ступень обучения «Микрохирургия. Продвинутый курс» (см. табл. 3). Этой возможностью пользуются далеко не все выпускники первой ступени, что подтверждает правильность разделения процесса обучения микрохирургии на этапы. В связи с этим на два курса первой ступени в среднем проводится один курс второй ступени.

Главная цель второй ступени – довести микрохирургические навыки обучающихся до уровня, позволяющего уверенно накладывать анастомозы на сосуды диаметром 1,0–1,5 мм и менее.

Вторая ступень, как и первая, длится 16 ч (два рабочих дня) и начинается с упражнения, которым заканчивается базовый курс (диссекция и наложение анастомозов на сосуды тренировочной модели «Бедро курицы»). Это особенно не-

Assessment of the acquired skills is an important stage of the first stage of training “Introduction to microsurgery” (Table 3). The course organizers hold a microsurgical championship at the end of the second day. Students are encouraged to complete three control exercises: end-to-end anastomosis of the femoral artery and vein, then the epineural suture of the femoral nerve in training biological model No. 2 (chicken thigh). Two hours are devoted to all three exercises. Teachers assess the results of the work of each student after this time.

The assessment is made on a five-point scale according to two criteria: the quality and speed of the exercise. The final result is determined by the sum of the two ratings. The one with the most points wins. Students who take the first three places are encouraged by material prizes.

There are many advantages to this technique: the ability to assess the effectiveness of mastering the material, determining the necessary changes in the presentation of the material to improve its understanding, and students can independently assess their achievements and understand whether they want to connect their lives with microsurgery.

After the basic course, students have the opportunity to get to the second stage of training “Microsurgery. Advanced course” (Table 3), if they have a desire to work in this direction. Not all first-degree graduates use this opportunity. This choice confirms the correctness of dividing the process of teaching microsurgery into stages. For one course of the second stage, two basic courses are held.

The main goal of the second stage is to confidently apply anastamosis to a vessel with a diameter of less than 1.0–1.5 mm.

The second stage also lasts 16 hours (2 days). It started with the last exercise of the basic course (dissection and anastomosis of the vessels of the “Chicken Thigh” training model). This exercise is especially useful for students who have not used this skill after the course in their practice (Table 3).All the work is done under optical zoom (OPMI Pico Techno, Carl Zeiss, Germany). After successfully completing Exercise No.1 on a fixed model, students move on to performing exercises on the “Wistar Rat” biological model.

End-to-end anastomosis on the abdominal aorta of a rat is the first task in a biological model. Assessment of the quality of the anastomosis is carried out immediately after the imposition of the course by the teachers. And also, when revising the anastomosis the next day.

The second day begins with exercises on the rat's femoral vessels, placing end-to-end anastomoses

Таблица 3

Базовый курс «Введение в микрохирургию»	Продвинутый курс
1-й день	
Лекция «Навыки работы под оптическим увеличением микрохирургический инструмент и шовный материал»	Лекция «История микрохирургии»
Лекция «Микрохирургия в пластической и реконструктивной хирургии»	Представление тренировочной модели № 1 «Куриное бедро»
Презентация первой тренировочной модели – латексная пленка	Практическая часть «Работа под микроскопом на тренировочной модели № 1, упражнение № 1: диссекция сосудистого пучка. Наложение анастомоза: артерия, вена, шов нерва
Практическая часть «Работа под микроскопом: Отработка навыков наложения швов»	Лекция «Микрохирургическая реконструкция молочной железы»
Лекция «Микрохирургия в травматологии и ортопедии»	Презентация тренировочной модели № 2 (крыса линии Wistar), упражнение 2. Наложение анастомоза «конец-в-конец», брюшная часть аорты крысы.
Презентация тренировочной биологической модели № 1 (баранье сердце): «Выделение и подготовка к анастомозированию артерии. Наложение микрососудистого анастомоза «конец-в-конец»	Практическая часть «Работа под микроскопом на тренировочной модели № 2 (крыса линии Wistar), упражнение № 2: диссекция брюшной аорты, шов артерии «конец-в-конец»
Практическая часть «Отработка представленных навыков на тренировочной биологической модели».	Лекция «Профилактика осложнений микрохирургических операций»
Лекция «Микрохирургия в челюстно-лицевой хирургии»	
2-й день	
Лекция «Реконструктивная микрохирургия детского возраста»	Лекция «Ангиосомы: как это работает»
Презентация тренировочной биологической модели № 2 (бедро курицы). «Анатомия, выделение артерии, вены и нерва».	Презентация тренировочной модели № 2 (крыса линии Wistar), упражнение № 3. «Бедренный сосудисто-нервный пучок»
Практическая часть «Отработка представленных навыков на тренировочной биологической модели № 2, шов конец-в-конец: – артерии	Практическая часть «Работа под микроскопом, модель № 2 (крыса линии Wistar), упражнение № 3: диссекция бедренного сосудистого пучка, наложение анастомозов «конец-в-конец»: – артерия; – вена; – шов нерва (по желанию)
Лекция «Микрохирургия в онкохирургии»	Лекция «Микрохирургическая реконструкция периферических нервов»
Практическая часть «Отработка представленных навыков на тренировочной биологической модели № 2, шов «конец-в-конец»: – вены	Практическая часть «Работа под микроскопом на модели № 2 (крыса линии Wistar), упражнение № 4: наложение анастомоза «конец-в-бок» бедренных артерии и вены
Лекция «Реплантации»	Лекция «Будущее микрохирургии»
Практическая часть «Отработка навыков на тренировочной биологической модели № 2, шов «конец-в-конец»: – нерва	Презентация тренировочной модели № 2 (крыса линии Wistar), упражнение № 5. Шов артерии хвоста
Микрохирургический чемпионат	Практическая часть «Работа под микроскопом на модели № 2, упражнение № 5: диссекция и шов артерии хвоста крысы «конец-в-конец»

Table 3.

Basic course "Introduction to Microsurgery"	Advanced course
First day	
Lecture "Skills of working with optical zoom. Microsurgical instrument. Suture material"	Lecture "History of medicine"
Lecture «Microsurgery in plastic and reconstructive surgery"	Presentation of training model No. 1 "Chicken Thigh"
Presentation of the first training model – latex film	Practical part "Working under a microscope on training model No. 1, exercise No. 1: dissection of the vascular bundle. Anastomosis: artery, vein, nerve suture
Practical part "Working under a microscope: practicing suturing skills"	Lecture "Microsurgical Breast Reconstruction"
Lecture "Microsurgery in Traumatology and Orthopedics"	Presentation of Training Model No. 2 (Wistar Rat) Exercise 2. End-to-end anastomosis, rat aorta abdomen
Presentation training biological model No. 1 (lamb heart): "Isolation and preparation for artery anastomosis. End-to-end microvascular anastomosis	Practical part "Working under a microscope on training model No. 2 (Wistar Rat), exercise No. 2: dissection of the abdominal aorta, end-to-end suture of the artery
Practical part "Development of the presented skills on a training biological model"	Lecture "Prevention of complications of microsurgical operations"
Lecture "Microsurgery in Maxillofacial Surgery"	
Second day	
Lecture "Pediatric Reconstructive Microsurgery"	Lecture "Angiosomes, how it works"
Presentation of training biological model No. 2 (chicken thigh). "Anatomy, isolation of an artery, vein and nerve"	Presentation of training model No. 2 (Wistar rat), exercise No.3. Femoral neurovascular bundle
Practical part "Working out the presented skills on the training biological model No. 2, end-to-end seam: arteries	Practical part "Working under the microscope model No. 2 (Wistar rat), exercise No. 3: dissection of the femoral vascular bundle, application of end-to-end anastomoses: – artery – vein – nerve suture (optional)
Lecture "Microsurgery in Oncosurgery"	Lecture "Microsurgical reconstruction of peripheral nerves"
Practical part "Working out the presented skills on the training biological model No. 2, end-to-end seam: veins	Practical part "Working under the microscope on model No. 2 (Wistar Rat), exercise No. 4: end-to-side anastomosis of the femoral artery and vein
Lecture "Replantation"	Lecture "The Future of Microsurgery"
Practical part "Working out the presented skills on the training biological model No. 2, end-to-end seam: nerve	Training model presentation No. 2 (Wistar rat), exercise No. 5. Tail artery suture.
Microsurgical Championship	Practical part "Working under the microscope on model No. 2, exercise No. 5: dissection and suture of the end-to-end rat tail artery

обходимо для тех обучающихся, у которых, с момента прохождения базового курса, не было возможности самостоятельно накладывать микрохирургические анастомозы (см. табл. 3).

Вся работа на курсе проводится под оптическим увеличением (OPMI Pico Techno, Carl Zeiss). После успешного выполнения Упражнения № 1 на фиксированной модели курсанты

on the artery and vein and end-to-side anastomoses between the femoral artery and vein. The final exercise of the course is the application of an end-to-end anastomosis to the tail artery of a Wistar rat (diameter 0.5–0.7 mm). The course program also includes lectures on specific issues of microsurgery.

переходят к выполнению упражнений на биологической модели «крыса линии Wistar».

Первым заданием на биологической модели является наложение анастомоза «конец-в-конец» на брюшном отделе аорты крысы. Качество наложенного анастомоза оценивают преподаватели курса сразу после его выполнения, а также при ревизии анастомоза на следующий день.

Второй день начинается с выполнения упражнений на бедренных сосудах крысы, наложения анастомозов «конец-в-конец» на артерию и вену и «конец-в-бок» между бедренными артерией и веной. Финальным упражнением курса является наложение анастомоза «конец-в-конец» на артерию хвоста крысы линии Wistar (диаметр 0,5–0,7 мм). В программу курса также включены лекции, посвященные частным вопросам микрохирургии.

Следующим этапом развития для прошедших первую и вторую ступени являются Мастер-курсы, которые могут быть направлены как на освещение клинических вопросов и представлять из себя стажировку в клинике с одним из преподавателей курсов «Микрохирургия. Клинический курс», так и на получение новых микрохирургических навыков (сосудистые вставки, артерии-венозные шунты, bypass, супермикрохирургия) в микрохирургическом классе на живых биологических моделях.

По всему миру существует множество обучающих микрохирургических курсов, отличающихся по продолжительности, структуре, использованию различных тренировочных моделей, стоимости. У каждого варианта есть свои преимущества и недостатки. Группа авторов опубликовали в 2013 г. результаты анализа 24 курсов по микрохирургии практически со всех частей света (Северная и Южная Америка, Африка, Австралия, Европа и Азия) [7]. К сожалению, мы не обнаружили в их статье упоминаний ни об одном из курсов, проводимых на постсоветском пространстве.

Следствием данного анализа различных курсов является идея о систематизации процесса обучения микрохирургии, унификации структуры курсов и системы оценки результатов обучения, посредствам контроля за процессом одним из профессиональных микрохирургических сообществ.

Положительной стороной такой унификации является достижение гарантированного результата для курсантов различных медицинских специальностей. Однако из-за высокой стоимости обучения данный путь доступен только для развитых стран с высоким уровнем жизни. Не все врачи живут в одинаковых экономических и социальных условиях, что влияет на доступность обучающих программ и курсов для широкого круга специалистов: обучение ведется за собственный счет обучаемого, по месту работы не

The next stage of development for those who have passed the first and second stages are Master courses. They can be aimed at covering clinical issues and represent an internship in a clinic with one of the instructors of the courses “Microsurgery. Clinical course” and to acquire new microsurgical skills (vascular inserts artery-venous shunts, bypass, Supermicrosurgery) in the microsurgical class on living biological models.

There are many microsurgical training courses around the World, that differ in duration, structure, use of various training models, and price. Each option has its own advantages and disadvantages. In 2013, a group of the authors published the results of an analysis of 24 courses on microsurgery from almost all parts of the World (North and South America, Africa, Australia, Europe and Asia) [7]. Unfortunately, we did not find in their article mentions of any of the courses from the post-Soviet space.

The consequence of this analysis of various courses is the idea of systematizing the process of microsurgery training, unifying the structure of courses and a system for assessing learning outcomes, by monitoring the process by one of the professional microsurgical communities.

The positive side of such unification is the achievement of a guaranteed result for cadets of various medical specialties. However, due to the high price of training, this path is available only for developed countries with a high standard of living. Not all doctors live in the same economic and social realities; this affects the availability of training programs and courses for a wide range of specialists. Their training takes place at the student's own expense, educational leave is not issued at the place of work, and doctors are forced to spend precious days from their vacation on their training. And also the issuance of a state-recognized certificate requires that the course lasts a strictly defined and significant number of hours. Not all doctors have the opportunity to experience microsurgery in their hospitals. Whereas in some specialties microsurgery is simply necessary for further professional growth.

Stepwise training in microsurgery allows students to gradually immerse themselves in the microsurgical world, adjusting the frequency, frequency of training and the need for further improvement of skills.

This training structure is similar to the structure of training programs of the AO Foundation (Arbeitsgemeinschaft für Osteosynthesefragen), recognized as the best in the World and the most massive project of postgraduate medical education [8].

It is important to note that training in microsurgery is not only the development of оформляется учебный отпуск, и врачи вынуждены тратить на своё обучение драгоценные дни из отпуска; выдача сертификата государственного образца требует, чтобы курс длился строго определенное и весьма значительное количество часов; далеко не все врачи имеют возможность прикоснуться к микрохирургии в своих лечебных учреждениях, но следя за отечественными и иностранными коллегами, они понимают, что в некоторых специальностях для дальнейшего профессионального роста микрохирургия просто необходима.

Этапное обучение микрохирургии позволяет обучающимся постепенно погружаться в микрохирургический мир и при этом самим регулировать периодичность, частоту обучения и необходимость дальнейшего совершенствования навыков.

Данная структура обучения схожа со структурой обучающих программ AO Foundation (Arbeitsgemeinschaft für Osteosynthesefragen), признанной лучшим в мире и самым массовым проектом последипломного медицинского образования [8].

Важно отметить, что обучение микрохирургии – это не только развитие микрохирургических навыков, открывающих возможности выполнения реплантации и микрохирургической аутотрансплантации тканей, но и обучение прецизионной стратегии оперирования, лежащей в основе философии не только реконструктивной, но и эстетической хирургии.

microsurgical skills that open up the possibilities of replantation and microsurgical autotransplantation of tissues, but also training in a precision operating strategy that underlies the philosophy of reconstructive and aesthetic surgery.

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CONSIDERATIONS ABOUT THE EXPERIENCE IN EXPERIMENTAL MICROSURGERY IN CATANIA UNIVERSITY

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In the 1980s and 1990s Microsurgery has had a great diffusion in Italy. Our group, who worked in University of Catania, Sicily, got in touch with Sun Lee, the father of Experimental Microsurgery, and applied actively the microsurgical techniques both in the experimental and clinical field.

Several Courses have been organized in Catania to involve young doctors who have been charmed by this new surgical branch.

It is our opinion that in the present time Microsurgery could play an important role in the training of the general surgery residents. An experimental microsurgical training, together with simulators, could guarantee a more complete training of the residents, helping them to be familiar with surgical instruments and suture materials, improving their skill in performing microvascular anastomoses (carotid and femoral arteries) and more complex surgical operations (portocaval shunt) and leading them to a valid research activity.

Keywords: *Microsurgery, training, General Surgery.*

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ОПЫТ ЭКСПЕРИМЕНТАЛЬНОЙ МИКРОХИРУРГИИ В КАТАНИЙСКОМ УНИВЕРСИТЕТЕ

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В 1980–1990-х гг. микрохирургия получила в Италии широкое распространение. Наша группа, работавшая в Университете Катании на Сицилии, связалась с Сун Ли, отцом экспериментальной микрохирургии, и активно начала применять микрохирургические методы как в экспериментальной, так и в клинической работе.

В Катании было организовано несколько курсов для молодых врачей, интересующихся этим новым направлением в хирургии.

По нашему мнению, в настоящее время микрохирургия может играть важную роль в обучении молодых врачей, специализирующихся по общей хирургии. Экспериментальная микрохирургическая подготовка с использованием симуляторов может гарантировать более полное обучение ординаторов, помогая им ознакомиться с хирургическими инструментами и шовными материалами, совершенствуя их навыки в выполнении микрососудистых анастомозов (сонная и бедренная артерии) и более сложных хирургических операций (портокавальный шунт) и способствует их к полноценной исследовательской деятельности.

Ключевые слова: *микрохирургия, обучение, общая хирургия.*

Конфликт интересов: авторы подтверждают отсутствие конфликта интересов, о котором необходимо сообщить.

Прозрачность финансовой деятельности: никто из авторов не имеет финансовой заинтересованности в представленных материалах или методах.

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Professor Sun Lee is universally known as the father of Experimental Microsurgery and through his tireless activity all around the world has greatly helped in spreading it. Even though microsurgical techniques are nowadays not frequently adopted in the field of General Surgery, Microsurgery has had a great role in the surgical achievements of the last century, especially in Transplantation, Immunology and Vascular Surgery. The end-to-side portocaval shunt performed for the first time by Lee in 1957 became a milestone and opened the way to transplantation models in rats [1]. The experimental models created by him have been the basis to study important topics: ischemia-reperfusion effect, rejection, immunosuppression agents. Sun Lee has been very able to draw the attention of the young doctors and fascinate them through his incomparable skill.

In Italy many surgeons approached Microsurgery and carried out several teams and each of them dedicated itself to a specific field. Brunelli in Brescia worked especially on central and peripheral nerves, Fox in Milano studied the pathophysiology of varicocele and to treat it realized the microsurgical anastomosis between the spermatic vein and the saphenous vein [2]. In Genova Campisi carried on the experience of his mentor Tosatti in the surgery of lymphatics and realized many microsurgical techniques to solve the problems linked to primitive and secondary lymphedema [3]. In Rome Gaspari and mostly Ortensi tried to apply microsurgical techniques in the clinical field (repair of lesion of laryngeal nerve after thyroidectomy, etc.). These surgeons not only applied the microsurgical techniques to selected fields, but at the same time organized many microsurgical courses to involve young doctors who, almost always, were charmed by this new surgical branch, so that in Italy a diffuse interest in Microsurgery rose and developed, culminating in many crowded scientific meetings of the Italian Society of Microsurgery, where interesting papers have been presented.

In University of Catania, Sicily, Professor Rodolico realized the potential importance of the role played by Microsurgery in the hands of the general surgeon and induced many of his pupils (Puleo, Di Cataldo, Li Destri, Trombatore) to learn the microsurgical techniques. For many years a tight collaboration between Catania and Lee has been set up and one of us (A.D.) attended for four months the Microsurgical Laboratory of San Diego, California, where Lee welcomed surgeons coming from every part of the world and teached them with great passion and enthusiasm. In our department, guided by the supporting approval of our mentor, between 1983 and 1986 we did three Microsurgical Courses to allow young doctors to acquire a basic microsurgical knowledge [4].

The Courses in Catania have been organized according to the model used by Lee in San Diego.

For one week, Monday through Friday, after a short oral introduction, each student received one operating microscope with a viewer binocular apparatus, so that the instructor was able to observe his/her performance and correct him/her. At first, the student used a practice disc to do suturing incision on a thin rubber shit and working on simulated blood vessels. After this preliminary stage, the students were instructed to perform in the rat end-to-end and end-to-side carotid anastomosis, then femoral artery and femoral vein anastomosis. Other exercises were vasovasostomy and sciatic nerve suture. The last day end-to-side portocaval shunt was shown, and we noted that this experimental exercise was the preferred one by residents in general surgery.

This intense microsurgical activity leaded us to use microsurgical techniques both in the experimental and clinical field.

In the experimental field among the topics that have been deeply studied we would like to remember the pathophysiological alterations after portocaval shunt, both end-to-side and side-to-side [5–7], some technical aspects of pancreas transplantation in the rat [8] and the importance of Microsurgery in the training of the general surgeon [9].

In the clinical field the microsurgical techniques have been used by us especially in the treatment of infertility caused by varicocele: in our department many patients have been treated by microsurgical anastomosis between spermatic vein and saphenous or epigastric vein and their results have been published [10]. Other clinical applications performed by our team have been testicle auto-transplantation in high undescended testis and microsurgical duct-to-mucosa pancreatico-jejunostomy after pancreaticoduodenal resection.

The International Society for Experimental Microsurgery has been founded in 1992 in Rome and our Department joined actively its Meetings that have been held regularly every two years. It has been a good chance to follow the microsurgical experimental studies performed all around the World and to exchange the obtained promising results. We think that the actual problems in this Society is to guarantee the replacement of the old members through the acquirement of young doctors. It will be our task to mold these young doctors and to induce them to the fantastic world of Microsurgery.

With this didactic perspective and in the possibility to use a modern laboratory of preclinical *in vivo* research realized in our University, we organized in Catania University a short but intensive experimental microsurgical course in October 9–11, 2018.

In order to obtain a high-quality course, we asked for the collaboration of the ISEM President elected Professor Mihai Oltean, Associate Professor at Gothenburg University, and Professor Mats Hellstrom, both working at the laboratory for transplantation and regenerative medicine at Sahlgrenska University Hospital, attended also by some of our students. They presented interesting lectures and together with some teachers of our University contributed as instructors to the practical stage of the course.

The course took place with three theoretical sessions in the morning, open to all students and postgraduates, during which various topics were covered such as the instrumental set for basic microsurgery, suturing materials and the principles and techniques in microvascular anastomosis, anatomy and physiology in rats and mice, anesthesia, analgesia and perioperative care in small animals, experimental models, etc.

In the afternoon of the three days, a small number of doctors were guided by the guest and local tutors in a practical training on microscope set-up, suturing and knotting in non-living models, dissection of various vessels in rats, anastomosis on femoral vessels, abdominal surgical anatomy, dissection of inferior cava vein and aorta, microvascular aorta anastomosis etc.

The enthusiasm and the convinced participation shown by all the students has been the best reward for our organizational efforts, in the awareness of having offered them, as our duty, the opportunity to broaden their knowledge and stimulate their interest in research and Microsurgery (Illustration).

Dr. G. La Greca, S. Puleo, A. Di Cataldo, M. Oltean and the residents who attended the Course

Доктора Дж. Ла Грека, С. Пулео, А. Ди Катальдо и М. Олтин с резидентами курса

Realistically we cannot think that experimental microsurgery and its subsequent clinical applications could have a future without the involvement of the younger generations who will, gradually, must replace those of us in the past believed in the value of the role of the experimental research and microsurgery in the training of a surgeon.

What it could be the actual role of Microsurgery in the activity of the general surgeons? In the modern view of General Surgery, we think that Microsurgery could play an important role in the training of the young residents. It has been demonstrated that different factors do not guarantee an adequate training for residents in General Surgery: limitation of working hours, the demand for increased operating room efficiency and medico-legal problems [11]. We agree that the use of simulators could limit the unfavorable effects of these factors and improve the quality of the training, but we think that an experimental microsurgical training could be also very useful to further better the technical skill of the residents.

Through a basic microsurgical Course [12] the resident learns how to perform many surgical procedures: arterial and venous micro anastomoses, portocaval shunt (end-to-side and side-to-side) [13]. After this initial stage he/she can repeat many times the same surgical exercise and after a relatively short period of time gain an undeniable mastery of the technique. This microsurgical experience is valid not only from the technical point of view to increase the skill, but it also could be very important to have the opportunity to perform interesting pathophysiological studies that can be used in a research activity [14].

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MICROSURGERY TRAINING IN FRANCE

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Ecole de chirurgie (AGEPS) – AP-HP, Paris, France

The Microsurgery began in France in 1972. Since the beginning of many training centers have been created, today we identify 19 places of education throughout the territory. Each training center organizes its own program so we will present here the experience of microsurgery teaching as it is carried out at the «Ecole de chirurgie de l'assistance Publique Hôpitaux de Paris». The microsurgery lab has 44 years experience in microsurgery education and the author has helped set up the programs and their organization and she has been involved in education for over 40 years.

Keywords: *Microsurgery, education, France.*

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ОБУЧЕНИЕ МИКРОХИРУРГИИ ВО ФРАНЦИИ

Ж. Леганье

Школа хирургии (AGEPS) – AP-HP, г. Париж, Франция

Микрохирургия во Франции появилась в 1972 г. В то время было создано множество учебных центров. Сегодня мы выделяем 19 центров обучения по всей территории страны. Каждый учебный центр имеет собственную программу. В настоящей статье мы представим опыт преподавания микрохирургии в «Ecole de chirurgie de l'assistance Publique Hôpitaux de Paris». Лаборатория микрохирургии имеет 44-летний опыт обучения в области микрохирургии. Автор принимала участие в создании программ и их организации, в работе центра она участвует более 40 лет.

Ключевые слова: *микрохирургия, образование, Франция.*

Конфликт интересов: авторы подтверждают отсутствие конфликта интересов, о котором необходимо сообщить.

Прозрачность финансовой деятельности: никто из авторов не имеет финансовой заинтересованности в представленных материалах или методах.

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HISTORY OF EDUCATION IN MICROSURGERY IN FRANCE

The Microsurgery began in France date from 1972–1974. In 1976, surgeons from several surgical disciplines decided to share their experiences and develop Microsurgery by creating the Group "GAM" (Group for the Advancement of Microsurgery) whose 1st President was Professor Jacques Baudet. In 2020, GAM was to organize its 42nd Congress.

The first training in Microsurgery appeared in 1972. Between 1972 and 1983, 11 training centers had been created. Today we have 19 training locations across the whole of France.

Despite some attempts, notably through the GAM, to seek to standardize training at the national level, this has never succeeded and 48 years after the opening of the first centers, there is still no standard concerning the organization. formations.

Despite the lack of standardization, there are generally, as at the international level, two levels of training:

– 1 basic course which lasts between 3 and 5 days depending on the centers.

– 1 advanced course lasting between 40 to 120 hours of practical work. Advanced courses are mainly in the form of a University Diploma.

TRAINING PROGRAM IN FRANCE

The example of the Paris School of Surgery

The School of Surgery (Fig. 1) has a Microsurgery laboratory specially dedicated to training. This laboratory has been in existence since 1976. There are 11 operating microscopes. At the head of this laboratory have succeeded 3 orthopedic surgeons: Professor A. Gilbert, Professor A.C. Masquelet and now Professor Fr. Fitoussi. Technical supervision is provided by 1 engineer and 2 laboratory technicians.

Fig. 1. In the School of Surgery

Рис. 1. В Школе хирургии

We organize 2 courses: a basic course and an advanced course (University Diploma).

The training courses are open to all surgeons of any specialty and of any origin (more than 70 nationalities to date). Since its opening, around 2,450 students have followed the initial training and 1,550 the University Diploma. The trainees are mainly surgical residents from Paris.

Currently, we welcome above 60 people per year for basic training and also above 60 trainees of the University Diploma.

Organization and program of basic course

The 3-day initiation program for microsurgery is as follows:

– how to use a microscope and the instruments;

– knots on compress and on silicone tube;

– dissection and anastomosis of the rat abdominal aorta;

– dissection and anastomosis of the carotid artery and the external jugular vein;

– dissection and anastomosis of the femoral artery and vein;

– bypass of the aorta through the external jugular vein.

Organization and Program of the University Diploma (Fig. 2)

The practical teaching of the University Diploma takes place over 9 months. Each student comes to train for half a day a week, for a total of 30 four-hour sessions.

Program :

Students have a training about twenty techniques on the rat. Several end to end anastomosis, grafts, bypass, kidney transplantation, groin flap transfer at the opposite side or on the neck.

Our teaching method is the formation by increasing difficulties – during the first 15 sessions the students never do the same technique but they practice techniques which are more and more difficult. We think that it's good method for doing progress.

STEP-BY-STEP TECHNIQUES OF END-TO-END AND END-TO-SIDE ANASTOMOSES

All anastomoses are performed at separate points and using the symmetrical biangulation technique.

DIFFERENT MODELS USED FOR THE EDUCATION; NON-LIVING AND LIVING

For the first steps in learning microsurgery, we use compresses to learn how to tie knots and silicone tubes to learn how to make anastomoses. These two exercises are done over a whole day.

Then we offer two practice sessions on the chicken thigh before performing all the other exercises in the anesthetized rat.

FACULTE DE MEDECINE - SORBONNE UNIVERSITE

DIPLÔME UNIVERSITAIRE DE TECHNIQUES MICROCHIRURGICALES
Année universitaire 2020 – 2021

Directeur d'enseignement : Professeur F. FITOUSSI
L'enseignement comprend 25 heures de cours théoriques et 120 heures de travaux pratiques.

PROGRAMME DES COURS THEORIQUES

Lundi 30 Novembre 2020		
14 h 00	Introduction à l'enseignement..................	F. FITOUSSI
15 h 00	Principes, difficultés, complications de la suture vasculaire..................	J. LEGAGNEUX, J.-L. VIGNES
16 h 00	Principes, réalisation et surveillance des lambeaux libres............	F. FITOUSSI
17 h 00	Etudes anatomiques par méthode d'injection..................	L. BOURCHEIX
Lundi 4 janvier 2021		
14 h 00	Sutures et greffes nerveuses : facteurs influençant la suture nerveuse Techniques et résultats	M. MERLE
15 h 00	Diagnostics, indications et résultats de la chirurgie du plexus brachial....	M. MERLE
16 h 00	Microchirurgie et reconstruction faciale	R. BOSC
17 h 00	Chirurgie réparatrice de la face et du thorax..................	L. LANTIERI
Lundi 25 Janvier 2021		
14 h 00	Réimplantations digitales..................	E. MASMEJEAN
15 h 00	Transferts musculaires libres fonctionnels	A. CAMBON-BINDER
16 h 00	Allogreffes fonctionnelles vascularisées face et main..................	L. LANTIERI
17 h 00	Microchirurgie en ORL..................	D. SALVAN
Lundi 8 Mars 2021		
14 h 00	Techniques de reconstruction osseuse..................	F. FITOUSSI
15 h 00	Anatomie chirurgicale des transferts osseux vascularisés..................	L. BOURCHEIX
16 h 00	Application clinique des transferts osseux vascularisés..................	M. GERMAIN
17 h 00	Sites donneurs de lambeaux libres de réparation des parties molles	A.C. MASQUELET
Lundi 12 Avril 2021		
14 h 00	Microchirurgie gynécologique..................	M. CARBONNEL
15 h 00	Lambeaux perforants	M. ATLAN
16 h 00	Reconstruction mammaire..................	M. ATLAN
17 h 00	Microchirurgie digestive et transfert d'épiploon..................	M. GERMAIN
Lundi 10 mai 2021		
15 h 00	Replantation de segments de membres : Membre supérieur et Membre inférieur. (Doigts exceptés)..................	J.N. GOUBIER
16 h 00	Microchirurgie en neurochirurgie..................	F. PROUST
17 h 00	Préparation à l'examen..................	J.-L. VIGNES - N. POITEVIN

TRAVAUX PRATIQUES

Les candidats devront s'entraîner pendant toute l'année universitaire, soit au laboratoire de l'Ecole de chirurgie, soit dans leur laboratoire d'accueil, sur une vingtaine de techniques microchirurgicales expérimentales dont la liste leur sera communiquée lors de l'inscription. En plus de l'apprentissage des techniques données, les candidats devront réaliser un protocole expérimental qui fera l'objet d'un mémoire à présenter lors de l'examen et à remettre au secrétariat le 3 juin 2021, délai de rigueur.

DEROULEMENT DE L'EXAMEN

A la fin de l'année universitaire, les candidats devront satisfaire à un examen dont la date sera communiquée ultérieurement. L'examen, qui se déroule à l'Ecole de chirurgie, comporte :
• une épreuve écrite d'une heure sur le programme théorique,
• une épreuve pratique de six heures (pendant cette épreuve les candidats devront réaliser 3 techniques du programme),
•une épreuve orale où ils présenteront leur mémoire.
Les cours théoriques sont **obligatoires**, au-delà de 2 absences, l'étudiant ne pourra pas passer l'examen.

CONDITIONS D'ADMISSION

Le diplôme s'adresse aux personnes ayant déjà reçu une formation élémentaire en microchirurgie vasculaire (un justificatif sera demandé lors de la préinscription).
Sont admis à s'inscrire :
• Les Docteurs en médecine titulaires du D.E.S ou du D.E.S.C de la discipline Chirurgicale délivré par la Commission de qualification de l'Ordre des Médecins.
Les Docteurs en médecine titulaires d'un D.E.S. ou du D.E.S.C de spécialité chirurgicale, ou gynécologique obstétrique, tête et cou, , maxillo-faciale ayant reçu la qualification de l'Ordre des Médecins
• Les étrangers titulaires d'un diplôme permettant d'exercer la Médecine dans leur pays.
• Les internes ayant validé trois semestres de Chirurgie et les étudiants du D.F.M.S. et D.F.M.S.A. ayant validé trois semestres de spécialités chirurgicales.
• Les docteurs Vétérinaires.

INSCRIPTIONS

Une autorisation d'inscription devra être demandée, elle sera exigée lors de l'inscription à la faculté.

S'adresser au Secrétariat de l'Ecole : 7, rue du Fer Moulin- 75005 PARIS du lundi au vendredi, du **1er septembre 2020 au 23 octobre 2020** inclus (Tél.: 01.46.69.15.62 ou 15.60).

Les étudiants ayant reçu l'autorisation d'inscription devront retirer un dossier administratif à la Faculté de Médecine Sorbonne Université – «Les Cordeliers» 15, rue de l'Ecole de Médecine scolarité III – Esc. H – RDC- 75006 PARIS Tél : 01. 44. 27. 45.75 ou 45.82 /45.94. /45.76 – Fax : 01. 44. 27.45. 97.

Les inscriptions à la Faculté se feront du
10 novembre 2020 au 21 décembre 2020 inclus.
Droits d'enseignements : Formation Initiale :
Etudiants DES + FFI +
CCA inscrit en D.E.S.C. : 1.000 €
F.C. Individuelle : 2.000€ -
F.C. Employeur : 2.000 €.
Droits de scolarité : 243 €

Le Doyen de la FMSU
Pr Bruno RIOU
Le Directeur de l'Enseignement
Pr. F. FITOUSSI

Le Président de la Sorbonne Université
Pr. Jean CHAMBAZ
Le Directeur Scientifique de l'Ecole de Chirurgie
Pr. P. FRILEUX

Fig. 2. Organization and Program of the University Diploma

DIFFERENT ASSESSMENTS TOOLS TO DETERMINE QUALITY OF TRAINING

At the end of each exercise, the trainer checks the quality of the technique and opens the anastomoses to check the regularity of the passage of the points.

The student also learns to self-criticize, he learns to analyze his mistakes.

In June, at the end of the academic year, students have an exam. This exam consists of a theoretical test, and – an oral examination in connection with a small experimental work they made during the year and – the most important part is the practical test – the test is composed of three techniques – Students have to do three techniques in six hours and they must pass two of the three techniques.

MODELS AND CURRICULUM IN SUPER MICROSURGERY, TECHNIQUES IN COMPLETING SUPER MICROANASTOMOSIS

In the University Diploma program, students perform anastomoses of small diameters (grafting the femoral artery through the epigastric vein for example) but for us "super microsurgery" is a subjective term that has no real meaning. We use a microscope so we do microsurgery, but what does the word "super microsurgery" really mean?

ROBOTIC MICROSURGERY AND ITS TRAINING

We do not have any experience in robotic microsurgery at the school of surgery. Currently we do not have a robot dedicated to microsurgery, nor an electronic simulator.

FUTURE IN MICROSURGERY EDUCATION; VIRTUAL TRAINING

In the near future, we plan to reduce the number of exercises using rats and replace them with exercises on inert tissues (chicken thighs for example) in order to respect the 3R rule. Mental imagery is also a learning support tool that we will develop. A study on the modeling of anastomosis is also underway.

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THE NEW PARADIGM ON MICROSURGICAL EDUCATION: THE INTERNATIONAL MASTER DEGREE ON RECONSTRUCTIVE MICROSURGERY

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Microsurgery (MS) is a discipline addressed by many specialties and it is our interest to be able to carry out a pedagogical assessment of the Master Degree in Reconstructive Microsurgery (MRM) as a training program in MS.

The MRM is a hybrid, blended program (virtual and face-to-face), developed in 12 modules, over a 2-year duration, which completes 2625 hours. This program is directed by recognized professors in the discipline from different parts of the World and enrolls 35 students per edition.

The program reserves 35% of the places for students from emerging countries. Once each of the modules has been received and the exams passed, the students will undergo a period of clinical immersion in the reference centers around the world and after defending the research project they will be able to receive the distinction of the Master granted by the Autonomous University of Barcelona (UAB).

There have been 11 editions of MRM since 2009 without interruption, with an enrollment of 400 students, 83% received the MRM degree. 65% work as Microsurgeons. 60% were Men and 40%, Women. 32% have become MS leaders in each region.

We consider that the MRM is a solid, reproducible and adaptable program that guarantees each one of the pedagogical aspects. The program is unique and brings together all the qualities so that students have the necessary tools and thus make a safe start in MS.

Keywords: *education, program, Microsurgery.*

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НОВАЯ ПАРАДИГМА МИКРОХИРУРГИЧЕСКОГО ОБРАЗОВАНИЯ: МЕЖДУНАРОДНАЯ СТЕПЕНЬ МАГИСТРА ПО РЕКОНСТРУКТИВНОЙ МИКРОХИРУРГИИ

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Микрохирургия – дисциплина, которой занимаются многие специальности, и мы заинтересованы в том, чтобы иметь возможность провести педагогическую оценку степени магистра реконструктивной микрохирургии (МРМ) в качестве учебной программы в микрохирургии.

МРМ – это смешанная программа (виртуальная и очная), состоящая из 12 модулей, рассчитанная на 2 года обучения и включающая 2625 ч. Программой руководят признанные профессора из разных стран мира. На каждый выпуск зачисляются по 35 студентов, 35% мест резервируется для студентов из развивающихся стран. После завершения каждого модуля и сдачи экзаменов, студенты проходят «клиническое погружение» в справочные центры по всему миру, и после защиты исследовательского проекта они могут получить степень магистра, присуждаемую Автономным университетом Барселоны (UAB).

В период с 2009 г. было осуществлено 11 выпусков МРМ, в которых обучались 400 студентов, 83% из них получили степень МРМ. Микрохирургами работают 65% выпускников, 32% стали лидерами микрохирургии в своем регионе. Среди получивших степень МРМ 60% – мужчины, 40% – женщины.

По нашему мнению, МРМ – это воспроизводимая и адаптируемая программа, которая гарантирует каждый из педагогических аспектов. Программа уникальна, она сочетает в себе качества для того, чтобы студенты имели необходимые инструменты и могли начать изучение микрохирургии.

Ключевые слова: *образование, программа, микрохирургия.*

Конфликт интересов: авторы подтверждают отсутствие конфликта интересов, о котором необходимо сообщить.

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INTRODUCTION

Microsurgery (MS) is a transversal discipline which has been applied since its beginning and throughout history by many medical specialties such as Trauma and Orthopedics, Otolaryngology, Head and Neck Surgery, Plastic Surgery, Cardio-Vascular Surgery and General Surgery, among others.

In order to understand the importance of an educational program in MS, we deem important to begin with a brief summary of the historical evolution of this challenging surgical practice and also to analyze its development over the years, covering a need arising from the high demand of functional reconstructive procedures with the least possible morbidity.

Towards the end of the 19th century, the only possibility of solving a vascular problem was the ligation of the affected vessel. From the 20th century on, experiments began to be performed and results were seen in the repair of blood vessels. Since then, works such as those of Alexis Carrel, with additional modifications made by Dörfler, have shown the ability to perform reproducible vascular anastomoses successfully and consistently. For this work, Alexis Carrel was awarded the Nobel Prize in Medicine and Physiology in 1912 [1].

Carrel's experimental work on anastomosis laid the foundation that allowed Joseph Murray to perform the first human organ (kidney) transplant in 1954, with long-term success. This historic advance in medicine allowed Murray to be awarded the Nobel Prize in Medicine as well [2].

Natural evolution and the discovery of technology applied to medical practices made it possible to reproduce these techniques in small models and thus in 1960, magnification began to be used for ENT and ophthalmic surgery. But it was Jacobson, who one year later (1961), together with Litmann from the Carl Zeiss company, developed the first binocular microscope, called a diploscope [3].

In this way, the introduction of magnification in surgery, together with the development of smaller sutures (called microsutures) and appropriate instruments, made it possible to reproduce the anastomoses in smaller-caliber vessels. These were the keys which opened the doors to the world of Microsurgery [4].

The clinical application of MS was not long in coming; and on July 27, 1965, in the city of Nara, Japan, the first digital reimplantation was successfully performed, after a complete amputation. The intervention was carried out by Doctors Komatsu and Tamai [5].

Although in 1958, Seidenberg et al. published the first jejunum transplant [6], it was in 1971, when Donald McLean and Harry Buncke Junior published the first organ autotransplantation by means of microsurgery technique. In this case, a free omentum flap was performed for a scalp in a 29-year-old patient.

After that, the usefulness of MS started to be seen beyond the micro-anastomosis technique. And its main advantage was discovered in tissue transfer, which played a very important role within surgical practice, dissection techniques. Starting in the 1970s, the focus began to be set on flap dissection, and the concept of muscle transposition was published, introduced by R. Ger (1971) [7] and the design of fasciocutaneous flaps by B. Pontén (1981) [8]. As a result, attention shifted to the tissues to be transferred. Lamberty and Cormack (1990) published their work on the anatomical concepts of the fasciocutaneous flaps [9] and, around the same time, Isao Koshima and Soeda (1989) published a case on tissue transfer based on the deep inferior epigastric system, without the need to transfer muscle [10].

This was another historical fact in microsurgery, because with this, the era of perforators was born, highlighting the work of Ian Taylor on the physiology of these perforator flaps and the concepts of Angiosomes [11].

The 20th century ended with the classification by Mathes and Nahai (1997), anatomically describing the different flap variants, including perforator flaps [12]. The advancement of this tissue anatomical and physiological knowledge made the practice reproducible.

The 21st century begun with a wave of technological advances, especially with the evaluation of complementary studies, highlighting the introduction of the Doppler ultrasound, as a very important tool in practice, allowing to perform free style flaps [13] and the use of CT angiography, For surgical planning, it was another aspect that led to the transformation of microsurgery into an increa-singly safer technique [14], with the main Centers reporting success rates greater than 98% [15, 16].

In recent years, it was due to the introduction of Indocyanine green lymphography [17, 18] for the diagnosis of conditions in the lymphatic system and supermicrosurgery as a surgical technique, added to the understanding of the pathophysiology of the lymphatic system, that microsurgery went one step further, becoming an option for the treatment of diseases such as lymphedema [19].

Supermicrosurgery is an evolution of MS, which allows expanding the range of applications, not only including the treatment of lymphedema, but also nerve reconstructions, distal amputation of fingers and new possibilities of transporting free tissues, performing anastomosis of 0.3 to 0.8 mm (perforator to perforator approach) [20, 21]. This constant evolution transforms it into an innovative practice that, today, forces us to constantly train to achieve the highest standards.

Microsurgery was in constant growth within the medical practice in an evolutionary way until it had an exponential growth in the late 1990s and early 2000s. This can be verified by the large number of publications that begun to appear in libraries such as Pubmed.

This increase in the number of microsurgical procedures is accompanied by a demand from patients, attracted by oncological surgeries requiring more morphological and functional reconstructions, which allows offering patients a better quality of life [16].

As an example of the growth of the specialty, we can cite the increase in Microsurgery Units in developed countries such as Spain, where at the end of the 1990s there were less than 10 Microsurgery Units and currently there are over 30.

In addition to reconstructions after cancer surgeries, microsurgery has various applications and offers a great response to sequelae from high-impact trauma, limb reimplantation, peripheral nervous system disorders and, currently, the lymphatic system.

In order to carry out these procedures, an attitude, knowledge and skills and a long and demanding learning curve are required [22]. Another important aspect to develop this evolved discipline is knowing how to acquire this knowledge, since there is a deficiency in training, due to the scarcity of Fellows programs and other programs lacking contents such as microvascular suture courses (courses of 3–4 days).

These are the most important reasons which led us to understand the need for a continuing education and research training program, with the utmost rigor that addresses each aspect of this discipline, carried out by outstanding professionals in each area, and that complies with each and every necessary pedagogical process.

MATERIAL

With the introduction of perforator flaps, microsurgery becomes an even more demanding practice as it requires more precise and meticulous dissection techniques, thus allowing specific reconstructions with minimal morbidity. This, added to the lack of training, raises the interest in being able to offer a comprehensive educational program that addresses the anatomy and physiology for the functioning of perforator flaps and that focuses on skills in precise dissection techniques, micro-anastomosis, and the methodology for its application.

Although this program began to take shape a few years earlier (2003), it was launched for the first time in France (2006), offering a Masterclass in perforator flap dissection at the TYCO Heathcare Surgical Training Center in Elancourt, France.

With the experience gained and the successful results achieved in the Perforator Flap Dissection Masterclass, a decision was made to implement a more ambitious and comprehensive program that offered training in all areas of reconstructive microsurgery, with an international accreditation issued by a European University; this gave rise to the International Master's Degree Program in Reconstructive Microsurgery (MRM) developed by the European School of Reconstructive Microsurgery.

A dynamic and comprehensive program, which bears the accreditation of one of the most prestigious universities in Europe, the Autonomous University of Barcelona (UAB), which ensures a high educational quality for its students. In turn, the program features as participants prestigious European Institutions such as the Saint Thomas Hospital, the European Institute of Oncology, the Queen Victoria Hospital, the Hospital de la Santa Creu i Sant Pau, Helsinki University Central Hospital and others outside Europe, engaging more than 50 microsurgeon experts around the world and 22 University Hospitals (Fig. 1).

The MRM is a blended learning program, with an individual itinerary for each student of 2 years duration that offers 105 (ECTS: European transferable credit system / 1ECTS-25 hours in study), for a total of 2625 hours, in 12 theoretical-hands-on modules directed and tutored by celebrated physicians from different parts of the World from the most renowned centers (Table 1).

Fig. 1. Clinical immersion centers around the World
Рис. 1. Центры клинического погружения в мире

Table 1. MRM Modules
Таблица 1. Модули МРМ

M1: Essential concepts in clinical microsurgery + Cadaver workshop
M2: Workshop. Microvascular surgery training using a small animal model (rat)
M3: Workshop. Dissection techniques of perforator flaps and supermicrosurgery using a live animal model (pig)
M4: Clinical training in head and neck microsurgical reconstruction
M5. Clinical training in breast microsurgical reconstruction
M6. Clinical training in microsurgical reconstruction of the lower limb
M7. Clinical training in microsurgical reconstruction of the upper limb
M8. Clinical training in genitourinary reconstruction
M9. Clinical training in supermicrosurgery
M10 + M11. Clinical immersion program
M12. Introductory course on the methodology of clinical research. Master Final Thesis / Research Work

It enrolls, under a rigorous selection system, a maximum of 35 students per edition.

The program is developed in face-to-face modules and some virtual ones, accompanied by a virtual campus where all the updated information can be found. The campus platform offers a library with recommended articles and books with high methodological quality. Within it, students can access virtual courses, such as suggested videos. The possibility of uploading case reports is also offered to discuss and interact with other students and teachers. Theoretical modules are carried out online and are assessed through a multiple-choice exam, while the practical skill modules are carried out and evaluated *in vivo* (Fig. 2).

The methodology of this program emphasizes the practical skills of microsurgical techniques, but includes diagnoses, therapeutic options, shared decisions regarding the techniques, and the recognition and management of the risks of complications. Promoting critical and scientific reasoning in a bidirectional and interactive way (Fig. 3).

Fig. 2. Campus On-Line Platform
Рис. 2. Онлайн-платформа кампуса

Fig. 3. Animal Dissection Training Center

Рис. 3. Обучение на животных в Учебном центре

The MRM is organized in different pedagogical areas:

• Theoretical-hands-on workshops with courses where skills and abilities are acquired in training centers (cadaveric flap dissection, microanastomosis and super-microanastomosis in different models) (Fig. 4).

• Clinical modules, where through live surgeries, students acquire the knowledge for the reasoning of microsurgery applied to each of the areas (Head and neck, Breast, Limb and extremities and Genitourinary).

• Clinical immersion program, where the student as a fellow travels the most prestigious Institutions in the world coordinated by Professors with high pedagogical quality outstanding in CM.

• On-Line Campus with updated educational content (Library with the latest selected outstanding works, Videos of Talks, Live Surgeries, Recorded courses, presentation of problem cases and all the necessary methodological aspects available).

• Research work: The students, together with their Tutor-Teacher, develop their ideas within the framework of the research methodology that allows them to carry out the projects to complete their final theses.

The main objectives of the MRM are focused on:

• Providing an environment in which a qualified and motivated student can obtain advanced training in reconstructive microsurgery.

• Mastering and applying suture techniques in microvascular surgery, neuroraphy and lymphatic anastomosis.

• Promoting scientific and critical thinking.

• Preoperative planning of all types of microsurgical flaps: myocutaneous, muscular, bone, axial-skin and perforator flaps.

• Training in microsurgical techniques in all major fields: breast reconstruction, head and neck surgery, limb rescue, lymphedema surgery, genitourinary reconstruction and super microsurgery.

• Analyzing and determining the most appropriate microsurgical technique for each particular case.

• Performing postoperative follow-up of microsurgical flaps: monitoring techniques.

• Approaching and performing microsurgical flap rescue techniques.

• Avoiding complications and sequelae of reconstructive procedures.

• Planning and performing limb reimplantation procedures.

• Learning and implementing super microsurgery techniques.

Fig. 4. Microsurgical Skill Center

Рис. 4. Центр микрохирургических навыков

Fig. 5. Cadaveric dissection training center (Students and Teachers)

Рис. 5. Студенты и преподаватели в Учебном центре по вскрытию трупов

• Analyzing transplant needs and indications.

• Developing the scientific method and start research.

Each and every one of these objectives is achieved in a conducive environment, where the interaction and connection achieved between classmates and teachers stands out, generating firm ties with each of them, allowing interaction and thus awakening interests and ideas. This interconnection creates opportunities for the training and acquisition of knowledge that exceed MS education and reaches social and cultural aspects, among others (Fig. 5).

The program reaches its final objective, in the training of professionals with a solid education in MS and other aspects of life, giving them the necessary tools to generate opinion leaders, who can reproduce their experience in each of the places where they develop.

Another highlight is that the MRM reserves 35% of the places for students from emerging countries, with difficulties in accessing education, making it an inclusive program, allowing equalization of knowledge opportunities (Table 2).

Table 2. Countries of origin, residence or nationality of participants to date

Таблица 2. Страны происхождения, проживания или гражданства обучающихся на сегодняшний день

Argentina	Egypt	Italy	Portugal	Venezuela
Australia	Finland	Libya	Russia	
Austria	France	Mexico	Saudi Arabia	
Brazil	Germany	Netherlands	South Korea	
Canada	India	Norway	Spain	
Chile	Indonesia	Kuwait	Sweeden	
Colombia	Iraq	Paraguay	UK	
Cyprus	Ireland	Peru	USA	

In order to access the MRM degree, participants must receive each module, pass the exams, take the corresponding immersion periods, deliver and defend the corresponding research project; in this way the student will be able to receive the distinction of the MRM diploma issued by the UAB (Fig. 6).

Fig. 6. MRM Degree

Рис. 6. Диплом о присуждении степени MRM

RESULTS

The results obtained from the program's database indicate that 11 editions of the MRM have been carried out, from 2009 to the present without interruption, with 400 students enrolled during the course of these years. Of the total number of students, 83% (332) approved each and every one of the contents of the Master, receiving the corresponding degree. Of these 332 students, 65% (216) are currently Microsurgeons, and use the acquired knowledge on a daily basis.

One thing to take into account is the proportion observed in terms of gender, since the reports collected show a proportion of 60% of men and 40% of women, with an exponential increase in recent years in women; thus balancing the learning opportunities in microsurgery between both genders.

33% (72) of these microsurgeons have become leaders within Microsurgery in each of their respective regions, raising the level and quality of care.

Nowadays, these leaders share their knowledge and values received in their work environments, thus achieving one of the maximum premises of teaching regarding the transfer of knowledge, completing the virtuous circle of teaching, proclaimed by the pedagogical ideals of the MRM.

DISCUSSION

The importance of Microsurgery as a specialty is based on advanced skills, transforming it into a particular discipline. Although there is no universal system to assess types of skills, we can consider 3 broad categories: cognitive / clinical skills, technical skills and social / interactive skills [23].

The development and training of each of these categories are essential to be able to achieve the necessary knowledge and to be able to apply it in practice.

The clinical / cognitive skills are of utmost importance in the assessment, planning and distinction of the cases to be treated in order to offer patients the best treatment possible.

The technical skills require surgical development to perform each of these surgeries, taking into account aspects that are only achieved with the training of skills acquired during specific days, in spaces that guarantee the appropriate environment to acquire this knowledge.

The social and interactive aspect is one of the most important categories, since in order to perform a MS it is essential to maintain team and interdisciplinary discussions for each case in particular and to be especially supervised by more experienced professionals in order to guarantee better results [24].

It seems very important to cite a study published by Gawande, where he reported significantly important data regarding errors in surgery, considering that 53% occur due to inexperience or lack of competence in the area, 43% occur due to lack of communication and 33 % of these errors are attributed to fatigue and high workload [25]. For this reason, we consider it an essential requirement to acquire adequate training in MS, so that professionals are prepared before putting it into practice and thus minimize any risk of error when acting.

Another aspect to take into account is that in many countries, such as the United States, the minimum required for a certification in Microsurgery is 40 hours, but these are not true comprehensive training programs in MS, they are only courses on microvascular sutures, which raises the question, whether these types of courses are sufficient to achieve adequate performance in the operating room [26].

MS is not limited only to performing sutures in small diameter vessels, the concept of MS is much broader, since its implementation requires an understanding of tissue disorders, analysis of complex defects, understanding of tissue regeneration, discernment of the techniques to carry it out and even more knowing how to anticipate to avoid problems.

The concepts about MS recently exposed clear the doubts about the idea that it could be carried out only by a course of vascular sutures, this learning would be insufficient to understand each and every aspect of this challenging discipline that requires a holistic approach. For all this, we consider it extremely important to be able to offer an integrative, inclusive and complete program addressing each of the categories of skills necessary to guarantee their learning.

Knowledge is the base of the pyramid so that students can access a higher step that allows them to know how to discern this acquired knowledge. After this stage of discernment, they will have the necessary tools to go to a higher stage and thus be able to demonstrate what they have learned. Once at the top of the pyramid, in the last stage, the students will have all the necessary elements to be able to take action, applying every aspect of the knowledge acquired by training. Of course, the MRM students will require the necessary time to demonstrate all the knowledge, skills and attitudes that will transform them into true experts [27].

What deserves a separate paragraph in this discussion is educational continuity in the face of global social distancing restrictions, forced by the Sars COVID 2 (coronavirus) pandemic. As it is beginning to be seen in some publications, the educational offer was not only not affected; rather, it raises the question that the novel virtual methodology can be an interesting alternative to traditional methods [28]. The MRM has been developing this methodology, through its innovative online platform, since its inception and demonstrated that despite the restrictions caused by the pandemic, its educational quality has not been modified.

In this way and for more than 12 years, the MRM has trained more than 300 microsurgeons of different specialties, giving them the necessary tools, not only to develop an excellent service, but also to be able to replicate the knowledge acquired to future generations, stimulating them to continue the path of innovation and personal improvement.

CONCLUSION

MS is a discipline in constant evolution, driven by a great desire for improvement of the professionals who carry it out, and which as of today has found no limits to its growth.

We consider MS to be a practice that goes far beyond performing vascular microanastomoses, understanding it instead as a complex discipline that addresses different aspects and requires complete and demanding learning to achieve success in treatments.

The MRM is a solid, reproducible and adaptable program that safely offers the beginning of MS, providing the necessary skills in each of its categories (cognitive / clinical, technical and social / interactive) and in this way addressing both the surgical and non-surgical aspects.

This holistic approach transmits to students the knowledge necessary to know how to evaluate, discern and make decisions about problems, learn anatomical dissection techniques for tissue transfer, understanding the anatomy and physiology of these, know and understand the aspects of cell regeneration, acquire technical skills of sutures for vascular and nerve anastomoses and finally know the necessary care to take into account to guarantee the work carried out.

This program has a dynamic of continuous updating that allows to acquire all the necessary knowledge in CM to avoid possible complications and have the ability to anticipate them, as well as offering students each and every tool necessary for a comprehensive and safe learning.

It contemplates 3 aspects that make it a program of great interest:

1. Training of professionals in a transversal discipline and standardized knowledge environment.
2. It offers up-to-date training, which allows the training of young professionals, as well as the "recycling" of those who have been in the specialty for years.
3. Presents an opportunity to level knowledge, especially in emerging countries that do not have a standardized educational system.

The MS training carried out in this way, reaches the highest standards of pedagogical quality, in order to guarantee the expected results, with a success rate close to 98%, similar to those reported by the main specialized centers around the World.

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INNOVATIONS IN MICROSURGERY TRAINING FROM CHILE

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Ignacio Cifuentes, MD, is a young plastic surgeon from Chile with high interest in microsurgical simulation and training. This paper summarizes some of the work in which the author has collaborated during his plastic surgery residency under the supervision of Bruno Dagnino, MD, as well as some interesting articles regarding microsurgical education in Chile. Francisca Leon, MD, is a microsurgeon and plastic surgeon from Chile with great interest in lower limb reconstruction who collaborated with the development of this review.

Keywords: *Microsurgery, education, innovation.*

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ИННОВАЦИИ В ОБУЧЕНИИ МИКРОХИРУРГИИ ИЗ ЧИЛИ

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Игнасио Сифуэнтес, MD, молодой пластический хирург из Чили, проявляющий большой интерес к моделированию и обучению микрохирургии. В статье приводятся некоторые работы, написанные им в соавторстве во время резидентуры по пластической хирургии под руководством доктора медицины Бруно Дагнино, а также некоторые интересные статьи о микрохирургическом образовании в Чили. В подготовке этого обзора участвовала также Франческа Леон, MD, микрохирург и пластический хирург из Чили, проявляющая большой интерес к реконструкции нижних конечностей.

Ключевые слова: *микрохирургия, образование, инновации.*

Конфликт интересов: авторы подтверждают отсутствие конфликта интересов, о котором необходимо сообщить.

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INTRODUCTION

Microsurgery is an essential technique as part of the armamentarium of the reconstructive surgeon. Common to many surgical subspecialties, this technique requires a magnification device in order to dissect and anastomose vascular and nerve structures.

Due to its steep learning curve, assistance to training courses have had an important growth in the last decade, being nowadays part of the plastic surgery curriculum. Creation and validation of multiple simulation models and the use of objective evaluation methods have allowed the microsurgical skill acquisition in the laboratory. These objective evaluation methods have allowed a transition from a non-structured training in which the expert evaluated the performance of the student according to his experience to a training where the skill acquisition can be quantified with validated learning scales and even some more sophisticated methods like hand movement analysis.

While medical knowledge can be obtained from books, webinars or journals, skills require a lot of training. Every skill has a learning curve and microsurgical proficiency is not the exception. The microsurgical learning curve is steep, which is why simulation by training in different living and non-living models seems to be a great the solution for this problem.

According to Malcolm Gladwell [1] you need 10,000 hours to master any skill. However, this has been challenged by Ericsson [2] exposing that repeating an activity several times doesn't create an expert, while deliberate practice does. It is necessary to acknowledge your mistakes and consciously correct them to improve and master a skill.

Since 2012, there has been a continuous growth of microsurgical training courses in Latin America. In 2016 we performed a simple narrative review of the literature by searching in PubMed the Mesh terms "Microsurgery" and "Training" from 2012 to 2016, completing our search strategy with letter sent to South American presidents of plastic surgery societies. From this review we identified 11 new training courses, which is in concordance with the need for microsurgical training in this region [3].

CHILEAN INNOVATIONS IN MICROSURGICAL TRAINING

The beginnings

We were late in the microsurgical timeline compared to the rest of the World. The first microsurgical case in Chile was done in 1979 by a surgical resident, who later published his first 4 cases [4]. He heavily prepared before in the laboratory, publishing a "New experimental model for microanastomosis between vessels of different diameter" in a rat model and a cervical esophagus reconstruction with small bowel in a dog model [5, 6].

In 2005, Andrades et al. published the first Chilean manuscript regarding how to set up a microsurgical training facility and compared different models going from the simple latex model to some non-living models like the chicken, swine limb, cow heart, human placenta and human epigastric vessels embedded in discarded abdominoplasty tissue [7]. He then concluded that the "microsurgical route" should be a progressive difficulty approach going from the latex model to the living rat.

Using learning theory and non-living models

Until 2016, microsurgical training was done mainly with rat models and without a structured form of evaluation of the microsurgical skill acquisition. The "Halstedian" concept of see one, do one, teach one, combined by a non-structured evaluation of the expert was challenged [8].

Some years earlier, a lot of importance was given on how to objectively assess the microsurgical skill acquisition and many OSATS (Objective Structured Assessment of Technical Skills) were developed and validated [9, 10].

More even, a hand motion analysis system, the imperial college surgical assessment device (ICSAD) had been validated as a method of objectively assess the microsurgical skill [11].

With these assessment tools, the microsurgical learning curve could be mapped [12].

Rodriguez et al. [13] redefined the way microsurgery was been taught in Chile and adapted a progressive difficulty curriculum involving simple knots in latex and vinyl models, moving on to dissection and anastomoses of 2 mm diameter arteries and veins in the chicken tight and finally reaching 1 mm diameter dissection and anastomosis of vessels in the chicken wing. After each training session, effective feedback was given by the experts using validated OSATS scales. This method was designed the same way as a workout sheet in the gym. The students could go whenever they had free time to the laboratory and practice, but in a structured fashion. He also compared how the students performed when doing their first artery anastomosis in a rat living model, and couldn't find any difference with the experts, concluding that the initial steps of the learning curve could be done in non-living models with spaced but constant training, and potentially reducing the number of rats needed.

Creating new assessments, models and going super micro

In the previously mentioned paper, the ICSAD was also used to track the learning curve by analyzing the number of movements and the total length path of both hands while doing the anastomosis. One caveat of this device is that it wasn't designed for small movements and the sensors placed in the fingertips where the size of the distal phalange making more difficult to do a microanastomosis. Cifuentes et al. [14] designed a low cost and more comfortable method of tracking the hand movement while training microsurgery by using colored rubbers in the fingertips and tracking them with a camera. This research concluded that experts made less number of movements and less length distance than non-experts, and correlated well with the level of expertise of the student assessed by the OSATS.

Flap design and dissection is also a key step while learning microsurgery. For this purpose, living rat and pig models had been described. However, there wasn't a non-living model, where one could easily train the pedicle dissection. Cifuentes et al. [15] described the first perforator flap in a chicken model using the chicken leg and studying a big and constant perforator with a long intramuscular path. This same model was later described to train supermicrosurgery, given the different diameters found in the pedicle. Arteries and veins of 0.7, 0.5 and down to 0.3 were anastomosed [16] (Fig. 1).

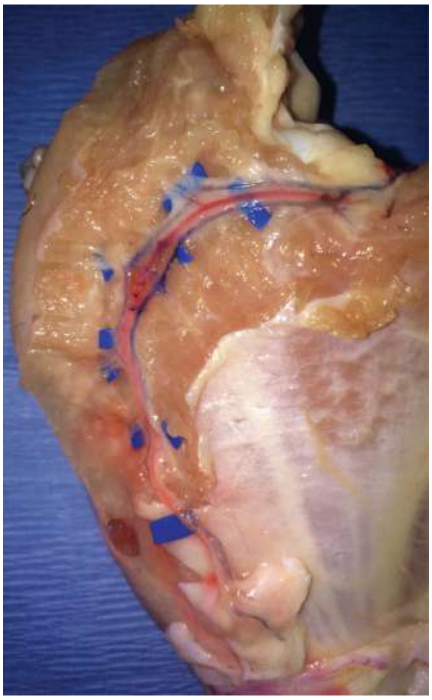

Fig. 1. Intramuscular path of the chicken leg perforator

Рис. 1. Внутримышечный путь перфоратора куриной ножки

Navia et al. [17] carefully dissected the chicken wing, updated the anatomy nomenclature and described smaller vessels. Later Rodríguez et al. [18] described the ulnar artery concomitant veins of the chicken wing for advanced supermicrosurgery training, taking advantage of the resemblance of the veins with the lymphatic vessels.

The swine leg has been described as a lymphatic vein anastomosis training model [19]. By injecting blue dye in the swine foot, the lymphatic vessels can be visualized in the medial aspect of the leg. Interestingly, there is no need for the animal to be alive, which means it can be recycled from other studies. After identifying the lymphatic vessel, a surrounding vein has to be identified in the subcutaneous tissue to perform the lymphatic venous anastomosis, which is not always easy after defrosting the leg. We have proposed an easier way to recycle the limb by taking only the subcutaneous tissue of the leg after the dye injection and harvesting at the same time an inguinal lymph node. The lymph node has veins of multiple diameters, which can be anastomosed to the previously identified lymph vessels in any configuration desired (Fig. 2).

Fig. 2. Subcutaneous tissue of the swine leg with the lymph node and lymphatic vessels

Рис. 2. Подкожная клетчатка ноги свиньи с лимфатическим узлом и лимфатическими сосудами

Moving along with the times

Contemporary microsurgical education supposes the physical presence of an instructor or expert in the laboratory, giving effective feedback after each training exercise. That is to say, correcting the student's errors immediately.

Because of this, the majority of the courses are limited by a maximum number of students per instructor, geographic accessibility due to the lack of experts in the area and the difficulties that suppose their presence in every training.

The distance-based learning or e-learning in the surgical education has been growing in the last decade and potentially allowing students to acquire skills without the physical presence of an instructor.

Cifuentes I.J. et al. [20] described the feasibility of microsurgical skill acquisition using an online platform. The students were exposed to a webpage where progressive difficulty training sessions where explained, starting from basic latex models to the chicken wing. Feedback was done asynchronously by the expert after each session analyzing a video recorded by the student using a camera connected to the microscope and creating a second video in which errors and pitfalls where discussed (Fig. 3 and 4). By the end of training, most students were able to do a 1mm artery anastomosis. Over a one-month period, 6 medical students without any surgical experience, were trained by just one instructor, who employed 6.7 hours in total in doing feedback. In this way, a greater instructor to student ratio could be achieved, optimizing the paucity of teachers in our geographic area and making over the sea instruction possible.

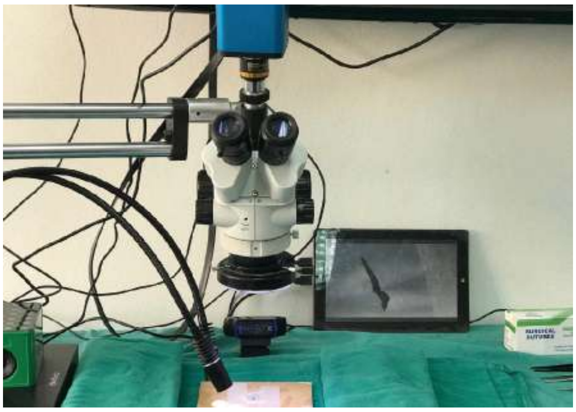

Fig. 3. E-learning Laboratory set up. Microscope with cameras

Рис. 3. Создание лаборатории электронного обучения. Микроскоп с камерами

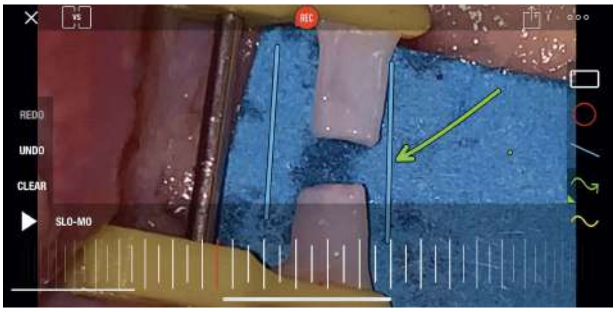

Fig. 4. Snapshot of a video feedback assessing a microvascular anastomosis

Рис. 4. Снимок видео обратной связи, оценивающий микрососудистый анастомоз

Even more, because of the COVID-19 pandemic there has been a shift towards a home-office environment. In the same manner, a modification of the previous model has been suggested in collaboration with Dr. Yelena Akelina, a prestigious international microsurgical instructor from the Columbia University, where a home-based approach using loupes as magnification and the smartphone as the recording device could be employed. Feedback could be done asynchronously with video recordings or synchronously using online platforms as Zoom (Fig. 5).

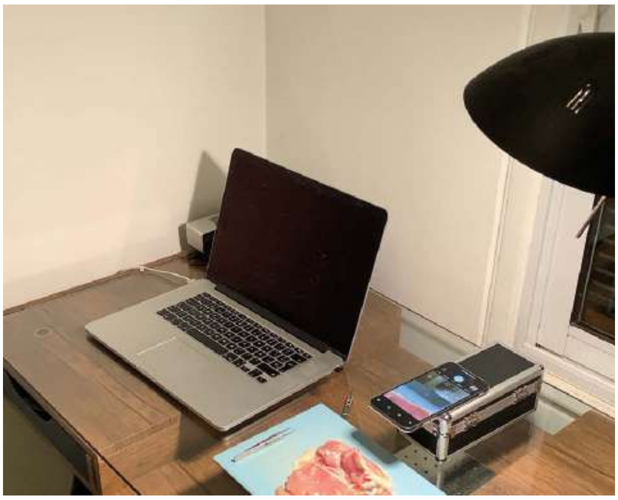

Fig. 5. Home setup for microsurgery training

Рис. 5. Домашняя установка для обучения микрохирургии

In the future, we expect that these technologies could make microsurgical training more accessible to everyone, eliminating geographical barriers and improving patient care all over the globe.

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MICROSURGERY EDUCATION IN SPAIN

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Prior to microsurgery practice on patients, microsurgical skills should be learned in a simulated and controlled environment to increase success rates and reduce surgical complications. These favorable environments have historically been the microsurgery laboratories. The use of the experimental animals has allowed surgical trainees to interact with anatomical structures and physiological processes that a microsurgeon has to face in daily clinical scenarios. In recent decades, there has been an increase in simulation methods to reduce the number of animals used for training purposes and thus meet animal welfare criteria.

Spain has a long history in the practice and teaching of microsurgery, this manuscript aims to highlight the importance of first educators, as well as to evaluate the current situation and future perspectives.

Keywords: *Microsurgery, training, education, Spain, simulation, anastomosis, assessment.*

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ОБРАЗОВАНИЕ В ОБЛАСТИ МИКРОХИРУРГИИ В ИСПАНИИ

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Прежде чем приступить к микрохирургической практике на пациентах, хирургу необходимо получить микрохирургические навыки в смоделированной и контролируемой среде, чтобы повысить вероятность успеха оперативного лечения и снизить риск хирургических осложнений. Благоприятные условия для этого исторически формировались в лабораториях микрохирургии. Использование экспериментальных животных позволило хирургам-стажерам изучать анатомические структуры и физиологические процессы, с которыми микрохирург сталкивается в повседневной клинической практике. В последние десятилетия увеличилось количество методов моделирования, что позволило сократить количество используемых в учебных целях животных.

Испания имеет долгую историю практики и преподавания микрохирургии. Данная статья призвана подчеркнуть роль первых преподавателей микрохирургии, а также оценить текущую ситуацию в этой сфере и ее перспективы.

Ключевые слова: *микрохирургия, обучение, образование, Испания, моделирование, анастомоз, оценка.*

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INTRODUCTION

The downing of microsurgery era is preceded by several events historically located in the first half of the 20th century. In 1902 Alexis Carrel was able to perfor end-to-end vascular anastomosis using his triangulation method [1]. This would be a great advance for vascular surgery as well as for organ transplantation. Thanks to this advance, he was awarded the Nobel Prize in 1912. In 1921, the otolaryngologist Nylen introduced the microscope for the first time in the surgical field, using it in a chronic otitis media surgery procedure [2]. These advances, together with the isolation of heparin and its clinical use as an anticoagulant (Jay McLean and Henry Howell) [3], would lay the necessary foundations for Julius H. Jacobson and Ernesto L. Suárez to perform the first vascular anastomoses with the use of a surgical microscope in vessels with a diameter of 1 mm [4].

The beginning of vascular microsurgery opened up new horizons in reconstructive surgery by enabling the practice of free microvascularized transfer of different tissues. A significant number of surgeons began to develop techniques that would allow the first successes in reimplantation of amputated limbs [5]. During this period, Harry J. Buncke, one of the fathers of microsurgery, conducted innovative studies on replantation and tissue transplantation in animals and developed many of the principles of this discipline [6].

Since then until today, a multitude of techniques have been described and are used in countless procedures (replantation, neurosurgery, limb reconstruction, head and neck surgery, breast reconstruction, peripheral nerve surgery, lymphedema, transplantation, etc.). Microsurgery has ostensibly improved the treatment of patients affected by a wide range of defects and pathologies.

HISTORY OF MICROSURGERY IN SPAIN

In Spain, microsurgical techniques began to be performed in the 1950s by the ophthalmologist Dr. Ignacio Barraquer in Barcelona and by Dr. Antolí Candela in Madrid in the field of ear, nose, and throat surgery.

Following in the footsteps of great names such as Julius H. Jacobson or Harry Buncke, reconstructive microsurgery began in Spain in the 1970s. The peripheral nerve unit of Dr. Santos Palazzi was created in Barcelona, where in 1972 was performed the first surgery of an adult brachial plexus in Spain, and later in 1979 the first brachial plexus in a child. In 1978 Dr. Carmen Pena, in Oviedo, performed the first digital replantation in a girl, and in 1979 the first hand replantation in an adult man. In the same year, the first free flaps were performed by Dr. Nava Pechero, as well as by Dr. Serra and Dr. Ramón Vila. In 1981, the first toe-to-hand transfers were operated by Dr. Vila Rovira. And in 1982 the first vascularized fibular flap by Dr. González del Pino.

The first microsurgery course was carried out at the University of Navarra by doctors J.M. Cañadell, H. Ayala, and H. Millesi.

In the 70s and 80s in Barcelona, thanks to Santos Palazzi, microsurgery was taught with the essential collaboration of big professors such as Gilbert, Narakas, Merle, Morelli and Raimondi among others. In those same decades, in Madrid, Professors Scheker, Chen Zon Wuein and Kleinert were some of the foreign professors who collaborate with national surgeons such as Dr. Monereo Alonso and Dr. Diaz Pardo.

Dr. Eduardo Nava Pechero was possibly the most important figure in the field of experimental microsurgery teaching in Spain. Nava Pechero trained an important group of surgeons who would lead these techniques in different regions of the country in the following years.

Dr. Eduardo Nava Pechero, pioneer in the teaching of experimental Microsurgery in Spain

Доктор Эдуардо Нава Печеро, пионер преподавания экспериментальной микрохирургии в Испании

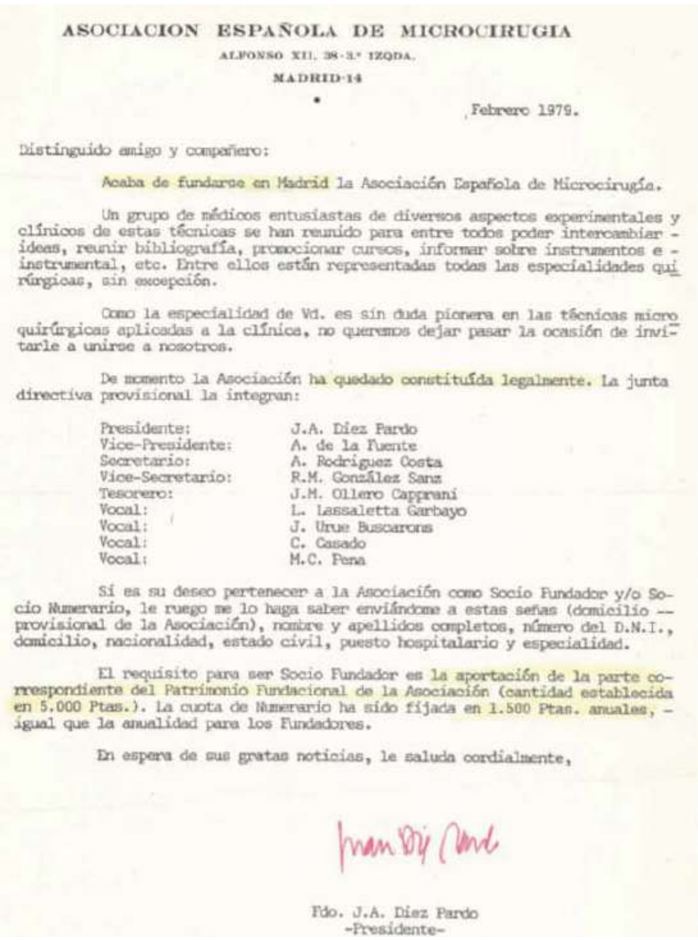
The training was given at the Virgen de la Luz Hospital in Cuenca, but also at a nearby rural location called "El Terminillo". There, with few technical resources, Dr. Nava Pechero taught vascular microsurgery and limb replantation techniques in rats, rabbits and dogs. Today the quality standards for teaching are higher and the legislation to be followed in terms of animal welfare is much more restrictive and necessary, but at that time it was a primary push for the teaching of the main surgical techniques with the use of microscopy.

It is important to highlight the efforts of some illustrious surgeons and reference centers that were essential in the early days of microsurgery teaching in Spain: Dr. Joan Pi Folguera, Sabadell; Dr. Gracía Julve and Dr. Pedro Marquina, MAZ Hospital, Zaragoza; Mrs. Marisa Sanz, Experimental Surgery, Gregorio Marañón Hospital; Dr. César Casado, Burgos; Dr. Carlos Vaquero, Valladolid; the group of Dr. Jesús Usón, Veterinary Medicine, Extremadura University, Cáceres; Dr. Gutiérrez de la Cámara, A Coruña; Dr. Carlos Irisarri and Dr. José Luis Haro, Madrid; etc.

SPANISH ASSOCIATION FOR MICROSURGERY (AEM)

In February 1979, the "Asociación Española de Microcirugía" (AEM, Spanish Association for Microsurgery) was founded. The association was constituted by the following surgeons: Juan Antonio Díaz Pardo (President), Antonio De la Fuente (Vice President), Antonio Rodríguez Costa (Secretary), R.M. González Sanz (Vice Secretary), J.M. Ollero Caproni (Treasurer) and as board members doctors Lasaleta Garbayo, Urueta Buscaons, César Casado and Carmen Pena.

The presidents of the AEM society to date have been the following: Juan Díaz Pardo, Antonio de la Fuente González, Santos Palazzi Coll, Enrique Jáureguizar Monereo, Higinio Ayala, J. A. Gutiérrez Díez, Gustavo García Julve, Juan Gonzalez del Pino, José María Serra Renom, María Luisa Sanz, Joan Pi Folguera, Miguel Cuadros Romero, Pedro Marquina Solá, Salvador Fernandez, Javier López de Alaya, Gabino de Diego Aranda, Carlos Puente, J. M. Rodríguez Vegas, Daniel Camporro, Miguel Ángel Toledo and currently José María Lasso Vázquez.



ASOCIACION ESPAÑOLA DE MICROCIRUGIA
ALFONSO XII, 38-3.° IZQDA.
MADRID-14

Febrero 1979.

Distinguido amigo y compañero:

Acaba de fundarse en Madrid la Asociación Española de Microcirugía.

Un grupo de médicos entusiastas de diversos aspectos experimentales y clínicos de estas técnicas se han reunido para entre todos poder intercambiar ideas, reunir bibliografía, promocionar cursos, informar sobre instrumentos e instrumental, etc. Entre ellos están representadas todas las especialidades quirúrgicas, sin excepción.

Como la especialidad de Vd. es sin duda pionera en las técnicas micro quirúrgicas aplicadas a la clínica, no queremos dejar pasar la ocasión de invitarle a unirse a nosotros.

De momento la Asociación ha quedado constituída legalmente. La junta directiva provisional la integran:

Presidente:	J.A. Diez Pardo
Vice-Presidente:	A. de la Fuente
Secretario:	A. Rodriguez Costa
Vice-Secretario:	R.M. González Sanz
Tesorero:	J.M. Ollero Capprani
Vocal:	L. Lassaletta Garbayo
Vocal:	J. Urue Buscarons
Vocal:	C. Casado
Vocal:	M.C. Pena

Si es su deseo pertenecer a la Asociación como Socio Fundador y/o Socio Numerario, le ruego me lo haga saber enviándome a estas señas (domicilio provisional de la Asociación), nombre y apellidos completos, número del D.N.I., domicilio, nacionalidad, estado civil, puesto hospitalario y especialidad.

El requisito para ser Socio Fundador es la aportación de la parte correspondiente del Patrimonio Fundacional de la Asociación (cantidad establecida en 5.000 Ptas.). La cuota de Numerario ha sido fijada en 1.500 Ptas. anuales, igual que la anualidad para los Fundadores.

En espera de sus gratas noticias, le saluda cordialmente,

Fdo. J.A. Diez Pardo
-Presidente-

Historical foundation record of the Spanish Association for Microsurgery (Asociación Española de Microcirugía) (left). Logo of the Spanish Association for Microsurgery (right).

Документ об организации (слева) и логотип (справа) Испанской ассоциации микрохирургии (Asociación Española de Microcirugía)

TRAINING PROGRAMS AND METHODS

During last decades, the demand for microsurgical training has increased, as well as the centers that carry out this training in Spain: Jesús Usón Minimally Invasive Surgery Center (Cáceres), Francisco de Vitoria University (Madrid), La Paz University Hospital (Madrid), Clinical University Hospital (Zaragoza), University of León (León), Technological Training Center (A Coruña), Burgos University Hospital (Burgos), IAVANTE (Granada), Parc Taulí Hospital (Sabadell), Experimentation and Simulation Center (Orense), University Hospital of Asturias (Oviedo), Antequera Hospital Center - IACE (Málaga), Germans Trias i Pujol University Hospital (Badalona), etc.

Some of the educational programs led from Spain are today international references in microsurgical training. The "Reconstructive Microsurgery European School", an initiative from Sant Pau Hospital (Barcelona), has a global impact since hundreds of microsurgeons worldwide have been trained in these courses, which several of them have been organized at the Jesús Usón Minimally Invasive Surgery Center in Cáceres, a state-of-the-art training facility.

Educational programs differ among institutions. Most of them use the rat as the experimental animal for training. However, there are many courses that start with exercises in synthetic tissues like cardboard sheets [7] or synthetic tubes [8], or with the use of inert organic materials such as chicken tight or chicken wing [9].

Courses differ on teaching methods but also in microscopy and instruments, as well as the ratio between teachers and students. There was a need to standardize this courses and to set the minimum requirements for training. In this sense, the International Microsurgery Simulation Society (IMSS) was created and has connected together the main international specialists and educators worldwide in microsurgery education. The IMSS has recently published a consensus article where it sets main recommendations for organizing microsurgery courses [10] which may help to refine the methodologies of these teaching courses.

MICROSURGICAL TECHNIQUES ASSESSMENT

The objective evaluation of microsurgical techniques is gaining increasing interest in recent years. Objective assessment of procedures and surgical skills are obtaining relevance in accreditation processes and in training curriculums. Practicing in a controlled and validated environment can improve and advance the microsurgical learning curve [11]. Different methods have been described to evaluate procedures and skills such as specific Global Rating Scales for microsurgery [12, 13]. But also the use of technologies is important. Transit-time ultrasound allow nowadays to quantify and predict the results of microsurgical procedures, if a set of recommended minimum thresholds related to blood flowmetry are followed [14].

SUPERMICROSURGERY AND ROBOTIC MICROSURGERY

The exponential increase of microsurgery practice has led to the improvement of microscopes, the refinement of instruments, the development of smaller suture materials, as well as the creation of needles of 30 microns, to facilitate precise supermicrosurgical procedures [15]. Supermicrosurgery is the surgical technique that allows the performance of microneurovascular anastomoses of submillimetric vessels and nerves, between 0.3 and 0.8 mm diameter [16]. These techniques have revolutionized the treatment of lymphedema, but also have allowed the performance of more distal digital replantations, and have facilitated the design of perforator-to-perforator flaps expanding the possibilities of the microsurgical armamentarium [17].

Therefore, the industry has focused its efforts on reducing surgeon tremor and improving surgical precision. Europe is currently leading the research and development of the main surgical robots in the field of reconstructive microsurgery with two different systems: MUSA (MicroSure, Eindhoven, The Netherlands) and Symani Surgical System (MMI, Italy). Part of the preclinical studies performed for MMI's Symani development have been carried out at the Jesús Usón Minimally Invasive Surgery Center (Cáceres, Spain). This robotic system offers the surgeon wrist microinstruments and provides movement scaling and tremor reduction to perform precise supermicro-movements.

In relation to robotic microsurgery teaching, new simulators and specific models are being developed for training. But some of the models already described for reconstructive microsurgery training and research [18–22] are also useful, especially those based on the rat epigastric skin free flap (groin flap) in rats. This flap is perfused by the caudal epigastric artery (0.35 mm diameter) and the caudal epigastric vein (0.70 mm diameter), thus, it is a good model in which to perform suprermicrosurgical anastomoses with 11/0 and 12/0 sutures.

FUTURE IN MICROSURGERY EDUCATION

Microsurgery as well as surgery training is undergoing a rapid transformation due to several factors. The main change is related to the training models used. The increasing requirements for the use of animals are reducing *in vivo* training methods in many countries, while in some it is not even possible anymore. Furthermore, the emergence of new simulators and improving virtual technologies may represent an easy, cost-effective and portable way of learning microsurgery. And in addition, the current COVID-19 pandemic has accentuated the needs for distance training.

This already changing landscape of microsurgical training will bring new opportunities to young surgeons who will benefit from optimized educational curriculums through accurate objective assessment of skills and new simulator set-ups for rapid and effective learning of microsurgical and supermicrosurgical techniques.

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MICROSURGICAL TRAINING: THE ITALIAN EXPERIENCE

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The Italian Society for Microsurgery (SIM, Società Italiana di Microchirurgia) developed a 5 steps training program for surgeons from different specialties who want to learn microsurgery as part of their practice. This 5 steps program has been established in 2013 and each course has a unique program and its own logo.

Presently, there are 10 basic courses in Italy recognized by the SIM in Italy. The basic courses have a theoretical part and a practice of at least 20 hours each, performed on an *ex-vivo* model. There are minimum requirements for each step must be competed to be able to move to the consequent exercise. At the end of the course, each student is evaluated following an extract of the GRS score.

The advanced course is exclusive, it opens to only 20 students each year and involve 35 self-funded tutors.

The program stated by the Italian Society for Microsurgery is very comprehensive and gives the opportunity to young surgeons to learn many aspects of the microsurgical reconstruction.

Keywords: *Microsurgical training, training program, steps of the Italian program.*

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МИКРОХИРУРГИЧЕСКОЕ ОБУЧЕНИЕ: ИТАЛЬЯНСКИЙ ОПЫТ

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В 2013 г. Итальянское общество микрохирургии (ИОМ, Società Italiana di Microchirurgia) разработало программу обучения в 5 этапов для хирургов разных специальностей, которые хотят изучать микрохирургию в рамках своей практики. Каждый курс имеет уникальную программу и свой логотип.

В настоящее время в Италии действуют 10 базовых курсов, признанных ИОМ. Базовые курсы имеют теоретическую и практическую части продолжительностью не менее 20 ч каждая. Обучение проходит на модели *ex-vivo*. Существуют минимальные требования к каждому этапу. Переход к последующему этапу возможен только при условии прохождения предыдущего этапа. В конце курса каждый студент оценивается по выписке из GRS.

Продвинутый курс является эксклюзивным, набор составляет 20 студентов год.

Программа, заявленная ИОМ, является всеобъемлющей и дает возможность молодым хирургам изучить многие аспекты микрохирургической реконструкции.

Ключевые слова: *микрохирургическое обучение, программа обучения, этапы итальянской программы.*

Конфликт интересов: авторы подтверждают отсутствие конфликта интересов, о котором необходимо сообщить.

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INTRODUCTION

The Italian Society for Microsurgery (SIM, Società Italiana di Microchirurgia) was established 10 years ago. SIM developed a five steps training program for surgeons from different specialties who want to learn microsurgery as part of their practice.

There are basic and more advance steps. In basic steps students learn the approach to the microscope and microsurgical sutures performed mostly on synthetic material and nonliving animal model. In more advanced steps students perform the dissection courses on cadaver, the flap raising courses on living animal model and finally, for more motivated students, the clinical fellowship.

This five steps program has been established in 2013 and each course has a unique program and its own logo (Fig. 1).

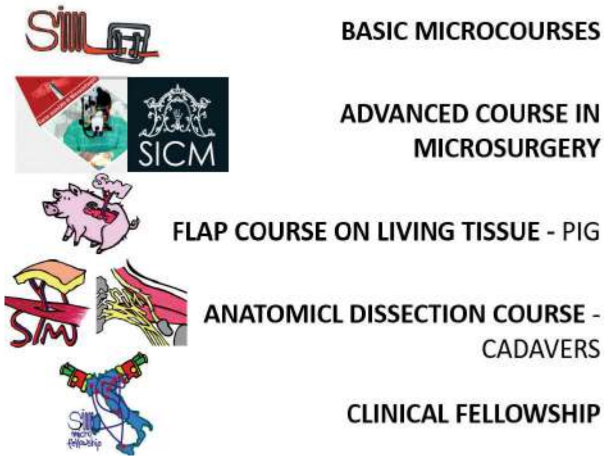

Fig 1. The different steps of the Italian program

Рис. 1. Различные этапы итальянской программы

BASIC COURSES

Presently, there are 10 basic courses in Italy recognized by the SIM in Italy.

Six of those courses were used to standardize the training path and help with accreditation the rest of the courses in different locations.

It is the belief of the SIM training committee that working on living models must be tackled after sufficient practice of the microsurgery techniques and getting sufficient expertise on non-living models to minimize the impact on the animal (complying with 3Rs).

Almost all the basic courses have a theoretical part and a practice of at least 20 hours each, performed on an *ex-vivo* model [1]. These skills are reached after at least 40 hours of practice, at some courses up to 80 hours before the starting the advanced course.

Some training centers that have availability to work with live animal models for the basic course, have the requirements of only 10 hr of practice on *ex-vivo* models prior moving to living ones for another 10 hrs, which are maintained equal to 20 hrs of the courses on *ex vivo* model.

Based on IMSS consensus of 2020 [2] each student has the same equipment: a jeweler's forceps, a micro scissors; a microsurgical clamp, micro needle holder, and 8/0–9/0 sutures.

There is 1 tutor for every 3 students.

The principles of teaching and evaluation of the course are derived from Acland principles and based on the 6 points of the GRS score devised by the Queen Mary University Hospital (Table 1) [3–5]. In their turn they are subdivided in 20 points that the student must consider during the exercise, and on which he will be evaluated.

Courses structure

Macro skills

Before going to the microscope there is a "macro" exercise where the student uses, without magnification, the microsurgical instruments and learns how to do the square/flat knot, how to manage the needle and suture and how to pass the needle under the direct vision of the tutor, which can correct any technical errors.

Micro skills

Then, we pass to the microscope: concepts of optics and setting up the microscope (initial single vision, then binocular focus, maximum magnification, the eyes are always on the operating field, etc) before starting sutures.

These are first work with the micro instruments on the gauze, then on practice card (Fig. 2), finally on the 3D model of the silicone tube. After the 2–3 sutures performed correctly on silicone tube students move to the chicken leg. The model of the silicone tube allows to practice in the positioning of the approximator and in the techniques of affixing points (polar, triangulated).

There are minimum requirements for each step must be competed to be able to move to the consequent exercise.

The chicken tight is known to be an excellent exercise model both for the size of the structures and for the similarity between the tissues of the model and the human ones [1].

Table 1. Queen Mary Global Rating Score to teach and evaluate the students [3]

Таблица 1. Глобальный рейтинг Queen Mary для обучения и оценки знаний студентов [3]

Queen Mary University London Microsurgery Global Rating Scale QMUL Micro GRS

Name/ID: **Setting** Clinical/Experimental Institution: **Model** Simulation Rat Other (Specify)

	Component	Procedure	Error List(please score '0' if there are any of the following errors observed during the procedure	1		3		5	Score
Preparation of operative field	S1	Preparation of operative field	Proceeds despite that operative field not ready for procedure, obstructed or blurred view with no background	loss of central view, inappropriately placed background		Op field prepared for procedure, uses background but fails to re-organize operative field through procedure (eg do not clear cut pieces of sutrue)		continuous organization and optimization of operative field	
Dexterity / Instrument Handling	S2	Instrument holding and hand tremor	Persisitent Tremor	Correct use of instruments, but frequent tremor		Correct holding of instruments but unsteady hands with occasional tremor		Correct and steady holding of instruments with No tremor	
	S3	Number of attempts to pick up the needle	Chases needle in field and unable to pick up needle after > 5 attempts	5 attempts		2 - 4 attempts		1st attempt	
	S4	Technique to pick up and mount needle	picks needle up with fingers OR handles needle with two instruments at the same time	Chases needle in field attempting to pick it up directly or takes >5 attempts to pick and mount needle		Manages to pick up the needle from suture and mounts it in dominant hand instrument in 2-5 attempts		Picks needle up indirectly with suture using non dominant hand then mounts it in the dominant hand instrument in 1 attempt	
	S5	Needle to Needle holder angle (Vertical Plance)	incorrect positioning of needle with needle pointing downwards to line of intended travel	Unable to position needle correctly (Too close to either tip or tail), or in correct position in >5 attempts		Positions needle correctly in 2 - 4 attempts OR needle pointing upwards to line of intended travel		Position needle in middle third in 1st attempt with needle pointing horizontally in line of intended travel	
	S6	Needle to Needle holder angle (Horizontal plane)	Unable to position needle correctly or in >5 attempts (angle too acute or too obtuse)	positions needle correctly after 5 attempts		Positions needle correctly in 2 - 4 attempts		Needle lies comfortably at right angles to the jaw of the needle holders in 1 attempt.	
Needle Handling	S7	Angle of needle to tissue	Unable to maintain angle, drops needle or pushes abruptly through vessel wall	Frequently too acute or too flat		Occasionally too acute or too flat		Always passes needle perpendicularly through the vessel wall	
	S8	Driving needle through vessel wall	Attempts carried out without use of counter pressure	5 or more attempts / occasional use of counter pressure		2- 4 attempts / appropriate use of counter pressure		1st attempt with appropriate use of counter pressure	
	S9	Guiding needle through vessel wall	Cuts through vessel wall	Pulls need through in a straight line not following curvature OR pulls suture perpendicularly upwards		Follows needle curvature BUT pulls suture through without use of pulley/counter pressure		Follows needle curvature AND pulls suture parallel to vessel wall while using the other hand instrument as a pulley/counter pressure	
	S10	Needle damage	Breaks tip or needle	Grasps needle tip		needle bent or flattened		No damage AND no grasp of needle tip	
Tissue Handling	S11	Handling of Vessel	Tears vessel wall during suturing or stripping adventitia*	Attempts to handle tissue with care BUT grasps vessel edges		Fails to clear adventitia OR strip adventitia beyond 3x needle thickness		Does not grasp vessel edge at all, only handle edge from lumen, stay stitch or vessel adventitia	
	S12	Tissue bite	Vessel distortion as a result of unequal tissue bites on opposing edges AND between knots	Unequal tissue bites on opposing edges AND between knots without vessel distortion		Occasionally takes too wide or too small a bite on opposing edges OR unequal spaces between knots		Perfect bites: 2 - 3 times of the needle thickness on both opposing edges WITH even spaces between knots	
Suture Handling	S13	Suture damage	Breaks suture	Bent suture		Thinned points or spiraling of suture ends		No damage	
	S14	Make a loop in 4 steps: "Pick, loop, pick, tighten"	Does not clear field of access suture loops, recurrent slipping of loop off tip of instrument	Loop or free edge are too long OR too short for optimum knot tying OR entangled and struggling with surface tension		Starts from a prepared field with optimum suture position but fails to make a loop in 4 slick moves		Clear field, optimum position, successful loop in 4 slick moves.	
	S15	Knots tention and squaring	NEVER squares knots	Frequently Does not square knots OR knots too loose or too tight		Squares knots BUT pulls upwards perpendicular to vessel direction		All knots squared, pulls suture flat in perfect tension with approximated edges	
operative Flow	S16	Use of magnification	Does not use different magnification	Occasionally uses different magnification		Uses variable magnification inconsistently OR tends to persevere in one magnification power for both needle insertion and knot tying		Always uses higher magnification for needle and tissue handling and lower magnification to handle suture and make knots	
	S17	Operative Flow	Unable to complete task OR has long pauses between steps with hesitant movements OR no check for back wall catching	Completes procedure but very slowly		Does not stop AND checks for back wall catching BUT proceed in either rushed steps or slower than ideal pace		Does not stop, clearly familiar with steps AND always check of back wall catching	
	S18	Time Taken for anastomosis (up to 10 stitches)	>60 min	40-60 mins		21 - 39 min		≤ 20 min	
Quality of end product	S19	**Quality of anastomosis	Unacceptable: sutures are too lose, coming apart OR obvious tears and tissue damage OR significant vessel distortion	Poor: Unevenly spaced untidy stitches but no vessel distortion		Acceptable: stitches are spaced evenly BUT are untidy (cut edges are not parallel to vessel or stick through lumen)		Superior: stitches are equally spaced with ends cut flat and at appropriate length, vessel edges perfectly opposed with no distortion	
	S20	Patency	Not patent OR catches back wall OR Clots*					Patent	
	** the marks for S10 is dependent on S20. If the vessel is not pattent, both S19 and S20 1ill be automatically '0'								
	* Biological models							Total Score	

Fig. 2. Practical card – adapted from Jesus Usón Minimally Invasive Surgery Centre (JUMISC) in Caceres – Spain

Рис. 2. Практическая карта, адаптированная Центром мини-инвазивной хирургии им. Хесуса Усона (JUMISC) (г. Касерес, Испания)

The students learn to recognize the structures, to handle the vessels and their different layers. End-to-end and end-to-side anastomoses, neurorhaphy, vascular grafts can be performed. If the pupils succeed quickly, they can practice on the smaller vessels using the chicken wings. This phase lasts about 10–12 hours. At this point, the transition to the living model is allowed at the courses that use live models.

At the end of the course, each student is evaluated following an extract of the GRS score (Table 2). To assess the quality of anastomosis on an *ex vivo* model, the flow generated with a colored physiological solution and the suture quality using the ALI (Anastomosis Lapse Index) score [6] (Fig. 3) shall be considered.

Table 2. Short GRS to evaluate exercises at the end of the course – the 6th point (patency) in nonliving models is substituted by the ALI score (Fig. 3)

Таблица 2. Краткая оценка GRS для упражнений в конце курса – 6-й балл (проходимость) в неживых моделях заменяется баллом ALI (рис. 3).

	1	2	3	4	5
Time & motion	Many unnecessary moves		Efficient time/motion, but some unnecessary moves		Economy of movement and maximum efficiency
Instrument handling	Repeatedly makes tentative or awkward moves with instruments through inappropriate use		Competent use of instruments but occasionally appeared stiff or awkward		Fluid movement with instruments
Suture handling	Frequently damaged, broke or lost sutures		Occasionally damaged, broke or lost sutures		Sutures were consistently handled delicately under the control of operator
Tissue handling	Frequently used unnecessary force on tissue, caused damage inappropriate use of instruments		Careful handling of tissue, but occasionally caused inadvertent damage		Consistently handled tissue appropriately with minimal damage
Technical skill (anastomosis)	Poorly placed sutures and poor use of irrigation		Fair placement of suture and use of inappropriate use of irrigation		Well-placed sutures and appropriate use of irrigation
Flow of operation	Frequently stopped operating and seemed unsure of the next move		Demonstrated some forward planning, with reasonable progression of procedure		Obviously planned course of operation with effortless flow from one move to the next
Outcome (Patency)	Poor		Moderate, reduced flow		Excellent. Unimpeded flow

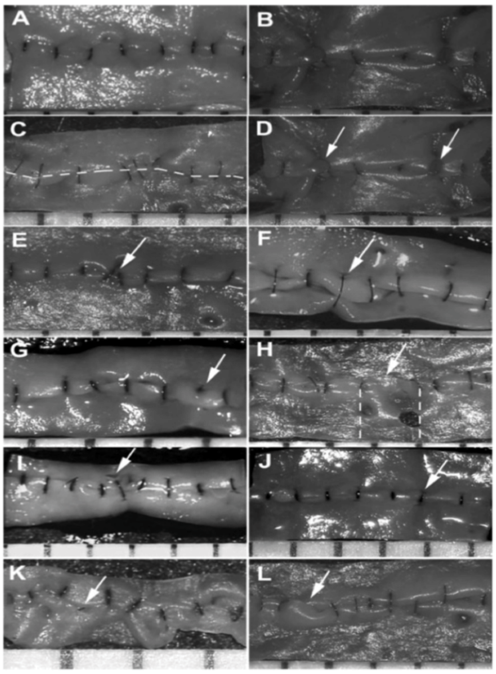

Fig. 3. The ALI (Anastomosis Lapse Index) score (A) Image demonstrating an error free anastomosis. (B) An anastomosis with multiple errors, (C–L) different errors frequently seen among students

Рис. 3. Показатель ALI (индекс разрыва анастомоза). A – изображение демонстрирует безошибочный анастомоз; B – анастомоз с множественными ошибками; C–L – различные ошибки, часто встречающиеся у студентов

ADVANCED COURSE

The advanced course is exclusive, it opens to only 20 students each year and involve 35 self-funded tutors (Fig. 4). It entails performing 16 different exercises during 120 hours of practice on the rats. These are preceded by theoretical lessons where videos of technique are shown, or tutors give the lectures about their experience in such procedures. In addition, students are advised to study the manual of Microsurgery available in free access on the website of the SIM before participating in the course (Fig. 5). This manual was created from the efforts of several tutors and teachers of the various courses. The program is divided into 3 weeks distributed over a calendar year.

Majority of students come from those three macro-areas of most frequent application of microsurgery techniques: hand surgery; head and neck reconstruction; reconstructive breast surgery.

The tutor-students ratio is 1:3/1:4.

Fig. 4. Advanced Course – Naples
Рис. 4. Продвинутый курс (Неаполь)

Fig. 5. The textbook of the Italian Society for Microsurgery for basic and advanced course: a text with progression and exercises has been written by all Italian teachers and tutors in 2015

Рис. 5. Учебник Итальянского общества микрохирургии для базового и продвинутого курса: текст с прогрессией и упражнениями был написан итальянскими преподавателями и наставниками в 2015 г.

Evaluation and Assessments

The student is asked and advised to write down a series of parameters on a self-evaluation sheet that includes annotations regarding technique (dissection time and anastomosis, patency, etc.), physical state, use of tools. The tutor has at his disposal a daily evaluation sheet, which allows him to follow the progress of his students.

Diploma

At the end of the course, to obtain the diploma, in addition to the practical test the student will have to take a written exam on the topics of the macro-area chosen and the discussion of a thesis on their own clinical experience.

The practical test involves the execution of 2 exercises in 5 hours. Within the final evaluation are awarded up to 20/80 points for the path taken by the student, considering its progression.

DISSECTION AND FLAP RAISING COURSES ON CADAVERS

Two courses are present in the program.

The *dissection course on perforator flaps* on cadavers takes place for 3 days every year in Nice and covers in its program the most frequently used free tissue flaps. It also provides a part of free dissection where the student can, for example, dissect the receiving vessels of the main anatomical areas. 2 students per one cadaver, and the tutors are in 1:4 ratio.

The *nerve course* is organized every 2 years and is held in Alicante (Spain). Is an International Course and covers all nerve pathology and palliative surgery of limbs; 2 participants per cadaver and an international faculty is present.

DISSECTION COURSE ON LIVE ANIMAL

The dissection course on perforator flaps utilizing the live animal model (pig) has the duration of two days. The dissection is limited, of course, to the flaps that can be reproduced on the animal model.

There is one pig per every 2 students available.

CLINICAL FELLOWSHIP

Every year the 2 most eligible students accepted to the microsurgery fellowship. This includes the attendance all the activities of 5 training centers of his choice for 2 weeks each to observe the different clinical applications of microsurgery. The fellowship must be completed within 2 years. Each fellow has a bourse of 2000 € to spent during the fellowship.

CONCLUSION

We think that the program stated by the Italian Society for Microsurgery is very comprehensive and gives the opportunity to young surgeons to learn many aspects of the microsurgical reconstruction. We are proud of our teaching program that we think is "unique" compared to other nations.

This accomplishment has been made possible by the determination of many Presidents of our Society and by the passion of all tutors around the countr: plastic, orthopedic and head and neck surgeons.

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MICROSURGICAL EDUCATION IN GREECE: PAST, PRESENT, AND FUTURE

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The aim of this paper is to provide a brief overview of the history of microsurgery in Greece and how it evolved throughout the years. It is based on published literature as well as anecdotal evidence. It is by no means an exhaustive list of available resources and contributions. Microsurgery in Greece begins with Prof Soucacos who acquired his microsurgical skills in the USA (1970–1974), where he worked as a clinical and research fellow. After gaining invaluable experience, he returned to his home country, Greece, to establish a microsurgery replantation team in 1975. His team gained national recognition soon thereafter thanks to the many successes and innovations they achieved. The tradition is continued with contemporary microsurgical courses in Greece from expert faculty and a busy microsurgical practice in several centers across the country. The experimental educational program in microsurgery includes a blend of synthetic and live animal models, such as rats and rabbits. They include a complete exposure to basic and advanced practical exercises through several days. The simulation training models slowly but surely steadily advance to meet the training standards.

Keywords: *Microsurgery, training, history, Greece, simulation, anastomosis, expert instruction.*

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МИКРОХИРУРГИЧЕСКОЕ ОБРАЗОВАНИЕ В ГРЕЦИИ: ПРОШЛОЕ, НАСТОЯЩЕЕ, БУДУЩЕЕ

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Цель статьи – дать краткий обзор истории микрохирургии в Греции и ее развития на протяжении многих лет. Обзор основан на опубликованной литературе, а также на свидетельствах. Приведен ни в коем случае не исчерпывающий список доступных ресурсов. Становление микрохирургии в Греции началось с профессора Сукакоса, который приобрел свои навыки в области микрохирургии в США (1970–1974), работая клиническим и научным сотрудником. Получив бесценный опыт, он вернулся в Грецию, чтобы в 1975 г. создать команду по микрохирургической реплантации. Вскоре его команда получила признание благодаря многочисленным достигнутым успехам и инновациям. Традиция продолжается современными курсами по микрохирургии в Греции под руководством опытных преподавателей, а также интенсивной микрохирургической практикой в нескольких центрах, расположенных по всей стране. Экспериментальная образовательная программа по микрохирургии включает в себя сочетание синтетических и живых моделей животных (крысы и кролики), а также полное ознакомление с базовыми и передовыми практическими упражнениями в течение нескольких дней. Модели имитационного обучения медленно, но неуклонно развиваются, чтобы соответствовать мировым стандартам обучения.

Ключевые слова: *микрохирургия, обучение, история, Греция, моделирование, анастомоз, инструктаж специалиста.*

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Прозрачность финансовой деятельности: никто из авторов не имеет финансовой заинтересованности в представленных материалах или методах.

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OVERVIEW OF HISTORY OF MICROSURGERY IN GREECE

The history of microsurgery in Greece began with Professor Panayiotis N Soucacos who established microsurgical training in Greece. He acquired his microsurgical skills at the Duke University Medical Center in Durham, North Carolina (1970–1974) where he worked as a clinical and research fellow under his mentor, Dr. James Urbaniak. After gaining invaluable experience, he returned to his home country, Greece, to establish a microsurgery replantation team in 1975. Until then, several failed replantation attempts had been performed in Greece by various centers (Hippocration Hospital, Diamandis Cassioumis; Laiko Hospital, Panayotis Balas and Anastasios Giannikas; "KAT" Hospital, Athanasios Trabaklos). These failures were attributed to the fact that there was not a dedicated expert microsurgical team to perform these challenging cases [1].

In 1967, Prof Panayiotis Balas, a vascular surgeon, and Anastasios Giannikas, an orthopaedic surgeon, performed the first successful replantation of a total arm amputation at Laiko Hospital, Athens, Greece [2, 3]. Nowadays, Prof Balas is considered the father of vascular surgery in Greece. In 1976, he successfully replanted an incomplete non-viable amputation of the distal third of the forearm.

In 1979, Prof Soucacos with the assistance of his resident Stathis Anastasiou, performed the first successful multi-digit replantation in Greece by. In 1984, he established the first microsurgical workshop for orthopaedic and plastic surgeons joined by an internationally renowned faculty, Dr. Julia Terzis (President of the International Microsurgery Society at that time) and his mentor, Dr. Urbaniak from Duke University [1].

In 1989, Prof Soucacos and his team performed the first vascularized free fibula flap in a case of a patient with a type IIIb open tibial fracture. In 1990, the Hellenic Society of Reconstructive Microsurgery was founded. In 1994, the first successful thumb replantation was performed in Greece by Prof Soucacos and his team, including Prof Beris, a resident at the time.

Through members' contributions and international collaborations, they managed to expand their clinical work and educational activities, including seminars, workshops, symposia, and meetings [1, 4–14]. Dr. Julia Terzis is a renowned worldwide Greek Plastic Surgeon specializing in facial paralysis, and she has trained many Greek surgeons in this niche field.

In 1986, the Hand Surgery, Upper extremity and Microsurgery Unit of the "KAT" Hospital in Athens, Greece, was established with Dr. Nikolaos Daoutis as Director and Dr. Nikolaos Gerostathopoulos as Attending surgeon, joined thereafter by many other important microsurgeons. "KAT" hospital remains today a busy trauma center, and major microsurgical and hand trauma cases are being managed. It has a long tradition of teaching microsurgery courses for almost thirty years and spread the significance of microsurgery in various surgical specialties.

At the General State Hospital of Athens "G. Gennimatas", Prof. Ioannovits established the Department of Microsurgery under the direction of Dr. Stamatopoulos. One of the first clinical cases of the Department was the successful toe-to-hand transfer in 1990 (Dr. K. Stamatopoulos and A. Kepenekidis). This was a benchmark in the evolution of microsurgery with significant contributions in the introduction of the working microscope and flaps for the reconstruction of severe and complex trauma cases. As a result, the field of microsurgery was expanded further across many surgical subspecialties.

The oncological hospital "Agios Savvas" and the Military Hospital of Athens significantly contributed to the development of microsurgery even more. As such Plastic Surgery in Greece was established as the main specialty that applied microsurgery for the management of complex reconstructive cases in relation to other specialties (e.g., ENT, Neurosurgery, Maxillofacial surgery).

Other centers include the "Thriasio General Hospital of Elefsina", St Andreas Hospital of Patra, and University Hospital of Larisa with invaluable contribution in this field. In 1998, with the election of Prof. Malizos as Head of the University Orthopaedic Clinic at the University of Larissa, another center for Microsurgery was established (co-workers Drs Z. Dailiana and S. Varytimidis). Prof. Malizos coming from Prof. Soucacos' "school", having also been trained in the USA close to Prof. Urbaniak has placed his own contribution in the evolution of microsurgery in Greece with clinical, editorial and educational work. In Patra Prof. Elias Lampiris established a Department for surgery of the hand and microsurgery with Drs. M. Tyllianaki and D. Giannika.

The first microsurgery cases in the armed forces were performed at the Athens Veterans' Hospital (417 NIMTS) since 2000 (Dr. P. Spyriounis, Dr. D. Tentis; resident) and later at 401 General Army Hospital in 2010. Dr Tentis, after returning from his microsurgery fellowship in Canada, and with all the other colleagues' contribution and collaboration, a clinical microsurgery practice to be proud of was established.

Ever since, there has been an exponential growth of the field of microsurgery in Greece with novel techniques being introduced in the current clinical practice, such as replantations, revascularization, free tissue transfer, toe-to-hand transfers, nerve grafts, and so forth. Numerous international peer-reviewed papers have been published in reputable Journals [15–17].

CURRENT STATUS OF MICROSURGICAL TRAINING IN GREECE

Nowadays, thanks to Prof Soucacos initial efforts to establish standardized training microsurgical centers around Greece, there is a variety of educational courses and opportunities. The nationally recognized state-of-the-art Experimental Research and Training Center at "ELPEN", Athens, Greece is a pioneering Institute. The first basic and advanced microsurgical course for plastic surgeons took place at the "ELPEN" training center organized by the Hellenic Society of Plastic, Reconstructive and Aesthetic Surgeons (HESPRAS) in 2002 and 2003, respectively. Until now, 17 basic and 10 advanced courses have been organized by scientific faculty, namely, Dr. Achilleas Kepenekidis, Dr. Dimitrios Michelakis, and more recently by Dr. Christos Assimomitis (in advancing chronological order).

At the ELPEN center, several hands-on microsurgical – both basic and advanced – workshops occur annually until recent unprecedented restrictions due to COVID-19 pandemic. Through expert faculty one-on-one instruction on practical exercises and lectures, participants complete a series of microsurgical exercises with an increasing difficulty. The basic and advanced experimental model is the live wistar rat and rabbit, respectively, which both offer an unparalleled experience for trainees. A veterinary anesthesiologist with his designated crew of assistants provides sedation and analgesia for the animals. The participants of the course practice their skills through a series of practical exercises with increasing difficulty after having been introduced to fundamental concepts through video-based lectures. Step-by-step techniques are being taught, such as end-to-end, end-to-side anastomoses of femoral vessels, neurorrhaphy, interposition vein graft, bypass graft, free groin flap, aorta dissection, and auricular replantation [18] (Fig. 1–3).

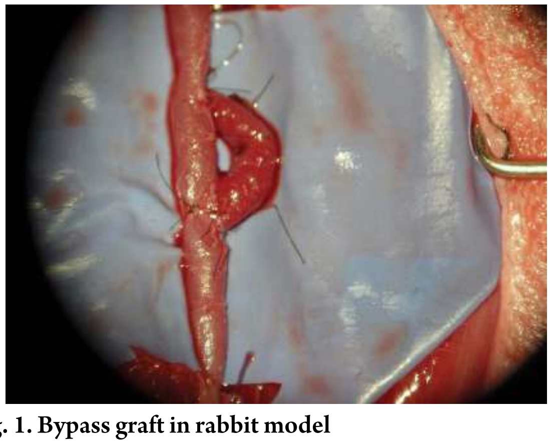

Fig. 1. Bypass graft in rabbit model

Рис. 1. Обходной трансплантат на модели кролика

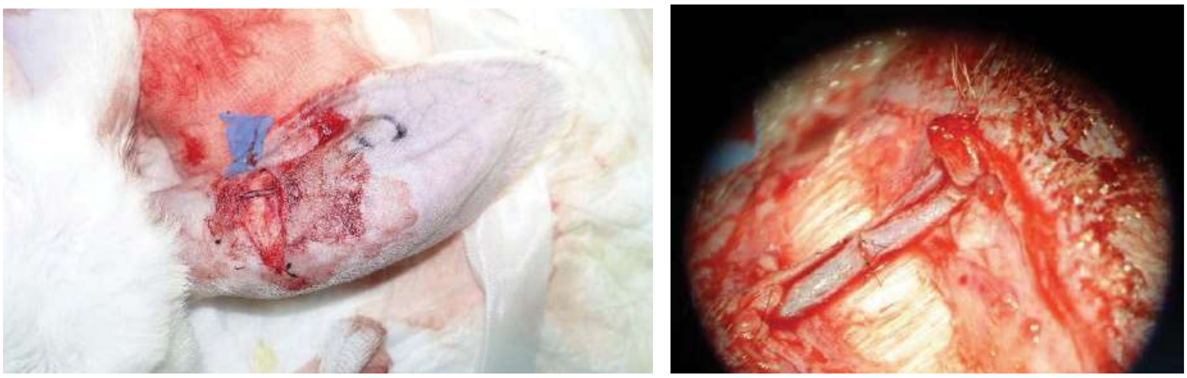

Fig. 2. Auricular replantation in rabbit model

Рис. 2. Реплантация ушной раковины на модели кролика

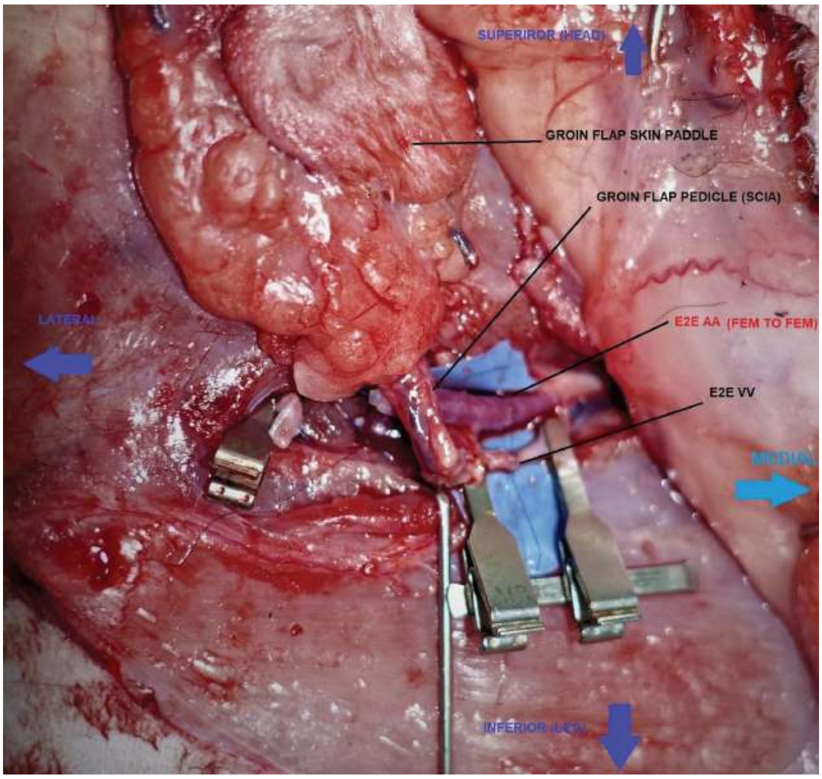

Fig. 3. Free groin flap elevated and inset ready for microvascular anastomoses with femoral vessels in rabbit model. (E2E, end to end; AA, artery to artery; fem, femoral; SCIA, superficial circumflex iliac artery)

Рис. 3. Свободный паховый лоскут приподнят и вставлен для микрососудистого анастомоза с бедренными сосудами на модели кролика (E2E, конец в конец; AA, от артерии к артерии; бедренная, бедренная; SCIA, поверхностная огибающая подвздошная артерия)

In 1988 Dr. Aikaterini (Catherine) Vlastou, a plastic and reconstructive surgeon, returned to Greece from the USA after having trained and worked for 16 years in Cleveland, Ohio, with vast experience in microsurgery. Evers since, she is one of the leading microsurgeons in Greece with crucial clinical, educational and scientific contributions to the field, and one of the constitutional members of the Hellenic Society for Reconstructive Microsurgery, established in early 1990s.

Several research projects and courses in microsurgery are conducted in many Institutions, including the Department of Clinical Sciences, Faculty of Veterinary Medicine, Aristotle University of Thessaloniki, Thessaloniki, Greece. Last but certainly not least, the department of Plastic and Reconstructive Surgery at "Papageorgiou" General Hospital in Thessaloniki, Greece is a leading academic institute in laboratory research and clinical micro- and super-microsurgical innovative reconstructive techniques with a vast diversity of patient caseload. Other courses are listed below:

- Annual International Flap Course on living tissues at the "Center for Orthopaedic Research and Education" (O.R.E.C) established by Prof. Soucacos and ran at Attiko University Hospital, Athens
- Course on hand surgery with practical exercise and live surgery demonstration organized since

2007 by the "Iatriko Athinon" Hospital (organizing faculty Drs. D. Misitzis, P. Giannakopoulos, S. Anagnostou, N. Skouras)

Course on problems of the hand organized in Thessaloniki since 2008 (Prof. Ch. Dimitriou).

• Joint annual symposium co-organized by the Hellenic Society for Reconstructive Microsurgery and the Hellenic Society for Surgery of the Hand, held in Thessaloniki. There are training sessions incorporated in the symposium program with lectures on surgical anatomy, flap anatomy and dissection techniques.

Yearly course in microsurgery organized by the Orthopaedic Clinic of University of Ioannina since 1984.

• 3-month practical training in microsurgery organized at the research center "Th. Garofalidis" at KAT hospital since 1989 with co-direction by the Hand and Microsurgery Clinic, the Research Center and the University Orthopaedic Clinic of KAT.

• Microsurgery week organized by the University Orthopaedic Clinic of Ioannina University since 1989 (Professors Beris, Korompilias and Vekris).

• Course for flap dissection on living tissues (rabbits-pigs): organized by the Dept. of Plastic Reconstructive and Aesthetic Surgery of "YGEIA" Hospital (chief scientific organizing faculty member Dr. Aikaterini Vlastou) and the Dept. of Plastic Surgery and Burns Center of Ioannina University (Dept. Head and co-organizing faculty member Prof. Efstathios Lycoudis).

• Microsurgery training organized by the Plastic Surgery Clinic of Evangelismos Hospital (scientific organising faculty member Dr. George Charkiolakis).

Until today, orthopaedic and plastic surgery residents rotate through several major teaching public hospitals across the country to further gain exposure to hand trauma and microsurgical training alongside experienced faculty. Notably, microsurgery is also being performed in private sector hospitals in major cities in Greece.

OBJECTIVE ASSESSMENT TOOLS FOR MICROSURGICAL TRAINING

Different objective assessments tools and scoring systems to determine the quality of the training provided to trainees. International consensuses on minimum standards for microsurgical courses [19, 20], minimum microsurgery case requirements [21] and several validated training models with objective structured assessment of technical skills (OSATS) have been devised to evaluate the trainers' performance in microsurgery [22–25].

The development of assessment tools for Robot-Assisted Microsurgery (RAMS) skills is still in progress [26–29]. All of these innovative grading tools are comprehensive and reliable for assessing the students' progress throughout a microsurgical course [30, 31]. However, they focus solely on the technical aspects [32], such as manual dexterity, hand-eye coordination, meticulous suture placement [33, 34], speed, operative flow, motion 35, and patency of the anastomosis based on task-specific checklists [36–40]. On the other hand, non-technical skills (NTS) are equally important. Non-technical skills include five broad categories: leadership, situation awareness, decision-making, communication, and teamwork. The integration of these skills in the microsurgical curricula is a work in progress [41]. Last but not least, studies show that expert instruction is pivotal in achieving timely and significant progress in microsurgical courses compared to courses which do not have a designated instructor [42].

The educational ethic of spreading the knowledge for the development of new microsurgeons is reflected today in current microsurgical training; innovative methods are being employed by faculty for residents to be able to expand their technical skills with the elevation of anterolateral thigh flaps under Attending supervision [43]. Contemporary experimental microsurgical research is being conducted in several fields, such as nerve regeneration with an epineurial flap can be used to bridge a nerve defect [44].

Some drawbacks in the microsurgical training are the short residency period of four years and the lack of a robust official rotational training in head and neck, craniofacial, breast, upper and lower limb subspecialties during residency.

FUTURE PERSPECTIVES

Due to COVID-19, the face and shape of the microsurgical training has shifted towards virtual training worldwide. In order to abide by the new regulations, researchers and policy creators have begun to recognize and started to turn to alternative educational modalities, such as nonliving models, virtual/augmented reality (VR/AR) and three-dimensional tools for microvascular anastomosis training [45]. A myriad of novel synthetic [46] (e.g., silicone) and biological training models have been devised over the years. As a result, select microsurgery courses at the University of Ioannina School of Medicine, Greece, have proposed modernized curricula consisting of a blend of both live and virtual learning experiences, and advocated the evaluation of the trainee should be added in the training programs [47].

In conclusion, the history of microsurgery in Greece reflects the long tradition in this field with ongoing contribution from contemporary passionate researchers and physicians.

Note: This concise article is not meant to offer an exhaustive list of "pioneers" in microsurgery in Greece but rather a brief overview based on bibliographical published literature as well as anecdotal evidence. Since no official consensus currently exists in Greece, the authors attempted to highlight the most important facts on the evolution of microsurgical in Greece throughout the years.

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ABSTRACT
TOPICS:
1. Microsurgery in the reconstruction of the upper limb, traumatology and orthopedics
2. Microsurgery in maxillofacial surgery
3. Microsurgery in oncology
4. Microsurgery of peripheral nerves
5. Microsurgery of the lymphatic system
6. Teaching Microsurgery
7. Microsurgery in pediatric surgery
8. Flaps and replantations: complications, prevention and problem solving
9. Competition of complex clinical cases

НИИ МИКРОХИРУРГИИ
ВЫСОКИЕ ТЕХНОЛОГИИ В ХИРУРГИИ