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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.

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

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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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