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Invited Special Article

Madison Microneurosurgery Initiative: A Tribute to Professor M. Gazi Yaşargil's Legacy in Microvascular Surgery Training. Part II – Principles Applied and Practices Implemented

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ABSTRACT

Building on the historical foundations established by Professor M. Gazi Yaşargil and early microsurgical pioneers, as summarized in Part I, this manuscript focuses on the lessons derived from their early experiences and examines how these lessons were translated into guiding principles and contemporary microsurgical training practices. It then describes how these principles informed structured microsurgical training models and were implemented on a global scale through outreach efforts within the Madison Microneurosurgery Initiative. Through basic and advanced equipment donations, offline, live-streamed, and in-person educational support strategies, and sustained mentorship, microsurgical laboratory training has been established in 86 centers across 45 low- and middle-income countries. Our experience demonstrates that effective microsurgical training can be achieved through thoughtful application of foundational principles rather than reliance on high-cost or technologically sophisticated infrastructure. Together, the integration of historical lessons with contemporary application illustrates how Yaşargil's foundational principles continue to guide sustainable microsurgical training across diverse institutional and resource settings.

KEYWORDS: Global neurosurgery, Laboratory training, Madison Microneurosurgery Initiative, Microvascular surgery, Yaşargil

ABBREVIATIONS: MMCA: Middle cerebral artery, **EC:** Extracranial, **IC:** Intracranial, **BMBTC:** Baskaya Microvascular Bypass Training Curriculum, **MOST:** Madison Objective Self-Assessment Tool, **LMICs:** Low- and middle-income countries, **MMI:** Madison Microneurosurgery Initiative

The pioneering era of microsurgery established not only new operative techniques, but also a disciplined educational framework grounded in systematic laboratory training. While Part I reviewed the historical development of microsurgery through Yaşargil's foundational contributions, the present manuscript shifts focus to the practical lessons derived from those early experiences. This work provides a structured framework for understanding how microsurgical skills should be taught, learned, and sustained, and outlines how these principles were translated into contemporary training models and implemented across diverse institutional and resource settings in low- and middle-income countries within the field of global neurosurgery.

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LESSONS LEARNED

1. Problem-Driven Innovation

A few years apart, both Donaghy and Yaşargil confronted the same clinical problem: middle cerebral artery (MCA) embolectomy. Donaghy, at the age of 50, reframed this challenge as a research question and devoted sustained laboratory effort to the development of microvascular techniques. Yaşargil followed a similar course, stepping away from a demanding clinical and research career at age 40 to commit himself to intensive daily laboratory work in the United States. This disciplined approach led to the acquisition of new operative skills using the operating microscope, which were subsequently applied in clinical practice and ultimately reshaped neurosurgery practice. Their experiences illustrate a core principle: transformative surgical innovation arises when clearly defined clinical problems are addressed through rigorous laboratory experimentation, perseverance, and long-term preparation.

2. Why Microvascular Surgery Training Matters

From October 1965 to November 1966, Yaşargil spent 14 months in Burlington, Vermont, first mastering the existing state of microvascular practice and then advancing it through his own solutions. This extensive laboratory training, combined with his deep anatomical knowledge and prior surgical experience, enabled the systematic introduction of microsurgical techniques across the entire spectrum of neurosurgical practice. Using the operating microscope, bipolar coagulation, and refined microsurgical instrument sets, he applied these techniques routinely in clinical practice.

Yaşargil's experience demonstrates that structured training in microvascular anastomosis is essential not only for vascular procedures, but also as a foundational skill set for a broad range of microsurgical operations. Yaşargil always emphasized the unique role of microvascular training in developing atraumatic microsurgical technique, stating:

> *"Perfection of atraumatic microsurgical technique is best acquired by operating on small-diameter blood vessels (0.8 mm to 1.5 mm) in animals" (29).*

Reflecting on his laboratory experience, he further noted:

> *"The operations I performed on mongrel dogs included re constructions of cortical arteries (patch, graft), operations on the basilar artery via the transclival approach, anastomosis of the carotid to the basilar artery and the lingual artery to the MCA, EC-IC bypass grafts using lengths of femoral artery, and the superficial temporal artery-MCA bypass. They were extremely difficult and tedious operations, but they helped me to develop the necessary skills I needed to apply the technique to humans" (21).*

Following the early clinical implementation of bypass techniques, these methods were widely applied for various indications in the ensuing years, until publication of the Extracranial (EC))–Intracranial (IC) Bypass Cooperative Study in 1985 (3). As the study did not demonstrate efficacy of EC–IC bypass in ischemic stroke prevention, training and routine practice of microvascular anastomosis neglected (29).

3. Microvascular Surgery Training Basics

As the need for microvascular surgery training became clear, key questions emerged regarding training methods, laboratory setup, instructors, trainees, and duration of practice. These issues were extensively addressed in the work of Yaşargil and other microsurgical pioneers, whose publications provide clear guidance for establishing structured microsurgical training programs.

Instrumentation

Instrumentation is critical for successful outcomes; however, it is neither the sole determinant of success nor required to be technologically advanced or costly. In the early years of microsurgery, no instruments were specifically designed for microsurgical use. Julius H. Jacobson addressed this limitation by introducing jeweler's forceps. Even after three decades of practice, he continued to obtain such forceps from jewelry stores in New York at approximately one-twentieth the cost charged by surgical suppliers (9). To assess their suitability for microsurgical use, he devised a simple functional test, stating that *"a useful functional test of a forceps is its ability to pull out a single hair from the back of the hand without the hair slipping or being severed"* (8,10,11).

Donaghy also introduced his own set of microsurgical instruments, which were initially tested in laboratory training and subsequently used in clinical practice (Figure 1) (5,18).

Similarly, Yaşargil relied solely on "jeweler's forceps, a corner broken from a razor blade as a mini-knife, and a sharpened injection needle" during his laboratory experience in Burlington. He also expressed dissatisfaction with the surgical instruments available during the early clinical application of microsurgery and noted that he obtained fine-tipped forceps in six different tip sizes from a watchmaker's shop for only a few dollars (21).

Together, these experiences illustrate that effective microsurgical instrumentation depends less on cost or technological sophistication than on suitability, precision, and thoughtful selection.

Figure 1: Donaghy's original microsurgical instrument set, displayed in front of the R. M. Peardon Donaghy Microvascular and Skull Base Laboratory, Given Building, University of Vermont, illustrating that precise microsurgical technique depends on instrument suitability rather than complexity. Reproduced courtesy of the first author.

Optical Aids and Microscopes

Early in his microvascular anastomosis practice, Jacobson used surgical loupes and simple magnifying devices, which proved inadequate due to limited magnification, illumination, and depth perception. He concluded that precise manipulation of vessels smaller than 3 mm required higher magnification (20×–40×), stereoscopic vision, and coaxial illumination (12,13). These requirements define the fundamental optical principles of microsurgery, all of which were mentioned by Yaşargil and already met by early operative microscopes (23-25,27).

The optical lens quality underlying modern operative microscopes has changed little since the late nineteenth century, when Ernst Abbe, Carl Zeiss, and Otto Schott perfected lens production in Jena, Germany (24,26). These foundational advances enabled the development of early operative microscopes that fulfilled the fundamental optical requirements of microsurgery, and the serial production of the Zeiss OPMI-1 in 1953 therefore marked the beginning of a new era in microsurgery. Subsequent innovations focused primarily on ergonomics, mobility, and functionality rather than fundamental improvements in optical quality.

This principle is exemplified by the continued clinical use of a Yaşargil–Malis prototype free-floating, counterbalanced operative microscope originally developed in 1972 (27). Despite relying on optical principles and lens systems perfected decades earlier by Zeiss engineers, this microscope has supported state-of-the-art microsurgical procedures for decades through ergonomic and functional enhancements alone. It was used clinically by Yaşargil from 1973 to 1993 in Zurich and has remained in active clinical use by Dr. Uğur Türe since 2008 in Istanbul (7,27). During fellowship training at Yeditepe University, the first author directly observed its continued clinical use, allowing first-hand appreciation of the fundamental optical and ergonomic principles of operative microscope design. The microscope was equipped with a mouth switch and ocular heating and was later supplemented with a 4K 3D recording system, which was not available in contemporary commercial microscopes at the time of its introduction.

4. Who Is Qualified to Teach Microvascular Surgery Techniques?

The early history of microsurgery demonstrates that excellence in teaching does not require a medical degree, rather, it demands technical mastery, extensive laboratory training, and sustained dedication. As illustrated by the careers of Esther "Jackie" Roberts, RN, Dr. Donaghy's OR scrub nurse, in Burlington and Rosmarie Frick, Nursing Assistant, in Zurich, effective microsurgical educators emerged through prolonged laboratory training, meticulous technique, and long-term commitment to teaching.

Ms. Roberts learned microvascular anastomosis techniques directly from Drs. Donaghy, Jacobson, and Suarez and played a crucial role in transferring these techniques from the laboratory to the operating room alongside Dr. Donaghy. Over the course of her career, she trained several hundred microsurgeons, including Yaşargil, and nurses in Burlington, many of whom later established microsurgical training centers around the world (18). In recognition of her pivotal contributions, Yaşargil dedicated his first book on microsurgery to her together with the operating room nurses of Zurich (25).

Similarly, Ms. Frick played a central role in microsurgical education in Zurich. Over several decades, she trained thousands of visiting surgeons—including Dr. Uğur Türe—through the Zurich Microsurgery Course and traveled internationally to teach microvascular anastomosis techniques originally developed and refined by Yaşargil (21). Her sustained efforts ensured continuity, standardization, and global dissemination of microsurgical skills across generations and continents. In recognition of her contributions, Dr. Uğur Türe honored her with an honorary doctorate from Yeditepe University in 2017.

It should also be recognized that, at the outset, no established experts existed to teach microsurgical techniques. Early pioneers devoted years to experimentation, failure, and refinement in laboratory settings before applying these methods clinically. We are fortunate that these pioneers shared their experiences through conferences, proceedings, publications, textbooks, and direct instruction, thereby multiplying the impact of their work. As illustrated by Yaşargil's experience, foundational microvascular techniques that took years to master in Burlington, were subsequently learned and applied by others within weeks under structured guidance.

5. Who Is Qualified to Practice Microvascular Surgery?

Historical experience, as demonstrated by the cases of Ms. Roberts and Ms. Frick, shows that success in microvascular surgery training depends on dedication, patience, and sustained concentration rather than professional title.

Our own experience further supports this observation. Thomas M. Staniszewski, an undergraduate student, trained using a basic microsurgery kit guided exclusively by offline instructional videos and achieved one of the most significant performance improvements within the Baskaya Microvascular Bypass Training Curriculum (BMBTC) observed in our laboratory (Figure 2A,B). His progress highlights the impact of disciplined practice and structured guidance, even in the absence of a medical background.

A similar observation was made during the Istanbul Yaşargil Microneurosurgery Course in 2023, where a 13-year-old high school student (Beren Erol), with parental consent and approval of the course instructor, participated out of curiosity and interest in exploring a future career path. Following an initial demonstration by Ms. Frick, course instructor, at the main station and continuous supervision and verbal guidance by the first author (Figure 2C), she practiced knot tying using an stereo microscope for the first time (Figure 2D). On the following day, she performed two end-to-end anastomoses on a prepared rat model that had expired during anesthesia (Figure 2E). Through stepwise instruction and continuous verbal guidance, she demonstrated exemplary technical performance notable for her level of experience.

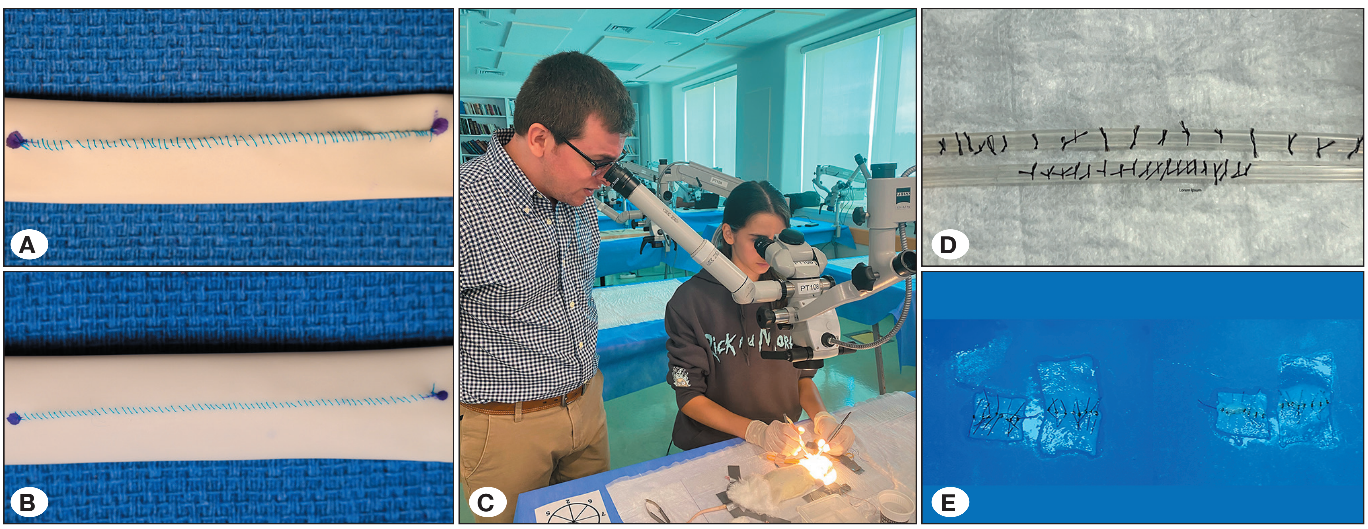

Figure 2: End products from training sessions completed by Thomas M. Staniszewski and Beren Erol **(A)** First practice of continuous suturing on a 6-cm Penrose drain (6-0 suture). **(B)** Tenth practice of continuous suturing on a 6-cm Penrose drain (7-0 suture). **(C)** A 13-year-old high school student (Beren Erol) performs an end-to-end anastomosis on a rat carotid artery under continuous verbal guidance from the first author, who observes the operative field through the assistant observer tube. **(D)** Knot-tying practice demonstrating the first attempt using 6-0 suture (top) and the second attempt using 7-0 suture (bottom). **(E)** End-to-end anastomosis practice on the rat carotid artery (10-0 suture): first (left) and second (right) attempts, with vessels opened to demonstrate the outer surface (top) and inner surface (bottom).

Together, these examples reinforce a consistent lesson drawn from both historical precedent and contemporary practice: the foundational techniques of microsurgery can be taught to individuals of diverse backgrounds when appropriate supervision, structured training, and sufficient dedication are present.

6. How Long Should Laboratory Training Last?

Basic microsurgical training requires sustained practice to convert early procedural familiarity into durable technical skill. Introductory courses provide an essential foundation by teaching the technical steps and principles of microvascular anastomosis, which can often be applied after only a few attempts. However, such courses do not, by themselves, confer true microsurgical skill. The development of refined hand–eye coordination, tissue handling, and consistency requires prolonged, structured laboratory training. Without continued practice, newly acquired microsurgical knowledge and performance may deteriorate within weeks.

Yaşargil consistently emphasized that systematic training in neuroanatomy and microsurgical technique is essential, advising young surgeons to devote at least one year to intensive laboratory training before progressing beyond basic procedures (22). Within this broader educational framework, microvascular anastomosis training constitutes only one component; however, it remains a uniquely demanding and indispensable element of comprehensive microsurgical education.

PRINCIPLES APPLIED

Lessons from the historical development of microsurgery and the experiences of its pioneers define enduring principles that can be deliberately applied to contemporary microsurgical training. When translated into practice, these principles provide a structured framework for teaching, learning, and assessing microsurgical skills across both local and global settings.

The Başkaya Laboratory Fellowship Program

Initiated by Mustafa K. Başkaya in 2006, the Başkaya Laboratory Fellowship Program offers immersive, longitudinal training that integrates microsurgical skill acquisition with neuroanatomy, cadaveric dissection, and clinical observation (15,20). Centered on hands-on laboratory practice, the program combines structured BMBTC training, objective self-assessment, and progressive cadaveric and clinical exposure within a mentorship-driven framework that supports trainees from diverse backgrounds and training levels.

The Başkaya Microvascular Bypass Training Curriculum

The BMBTC was developed to provide a structured, progressive approach to microsuturing and microvascular anastomosis training. Informed by the intensive laboratory training models of early microsurgery—particularly those of Yaşargil and Donaghy—the curriculum emphasizes microsuturing as a fundamental, transferable skill across neurosurgical practice. Introduced by Mustafa K. Başkaya in 2006 and revised in 2021, BMBTC employs a stepwise progression from synthetic models to biological microvascular anastomosis, enabling gradual adaptation to increasing technical complexity, finer sutures, and higher magnification (16,17). This staged design reinforces deliberate practice, standardization, and effective skill transfer from laboratory to clinical microsurgery.

Madison Objective Self-Assessment Tool (MOST)

MOST was developed around foundational principles of surgical education that emphasize self-assessment, systematic training, and professional competence. Max Brödel emphasized that learning is incomplete without self-investigation, requiring the ability to critically evaluate one's own work, while Yaşargil stressed that true competence arises from systematic laboratory training and objective qualification.

Guided by these principles, MOST was created through a focused review of the microsurgical training literature, identifying key qualitative and quantitative performance metrics and integrating them into a structured, user-friendly self-assessment tool (14,16,17). By enabling trainees to objectively evaluate microsurgical end products against standardized reference values, MOST supports deliberate practice, continuous improvement, and responsible skill acquisition, particularly in settings with limited expert supervision.

Basic Microvascular Surgery Training Kit

We developed a basic training kit to apply core principles of microsurgical training using cost-effective, high-quality equipment (Figure 3). Systematic evaluation of surplus tabletop microscopes, light sources, and basic instruments showed that high-quality microvascular training is achievable when essential optical and functional requirements are met. The kit prioritizes magnification, stereoscopic vision, illumination, and instrument suitability, enabling structured practice across diverse training settings (14,17).

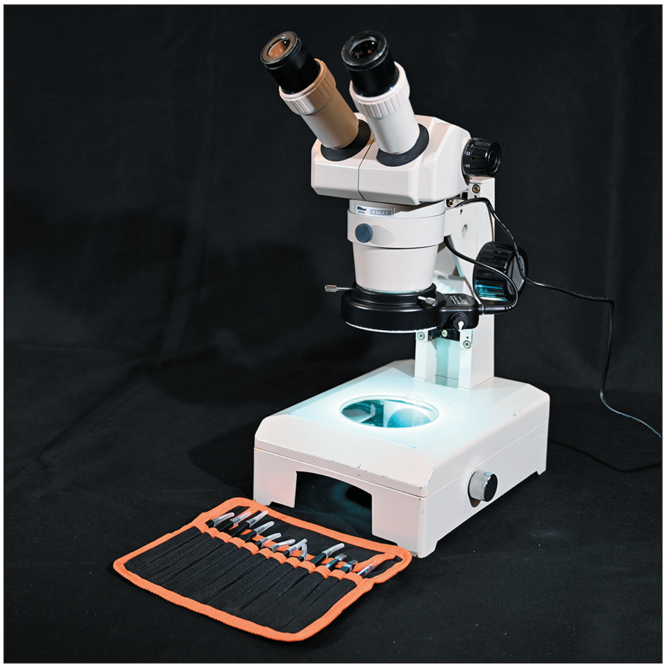

Figure 3: Basic microvascular surgery training kit for microvascular anastomosis practice. Components include a tabletop stereoscopic microscope with high optical quality and magnification (available for as low as $13.50), an LED light source (as low as $25), and basic tweezer set (as low as $10).

PRACTICES IMPLEMENTED

Global Neurosurgery

Neurosurgery has been global since its inception, with knowledge advancing through international training and exchange. Harvey Cushing and Yaşargil exemplified this model, which enabled the dissemination, refinement, and multiplication of microsurgical techniques across generations and centers worldwide (1,21,29).

While the term global neurosurgery has gained prominence only in the past decade, the concept itself is longstanding (19). Since the late 1960s, initiatives such as the Foundation for International Education in Neurosurgery have addressed disparities in neurosurgical care, increasingly emphasizing sustainable capacity building, structured training, and local empowerment over short-term knowledge transfer (3,4).

Although initially less accessible, surgeons from low- and middle-income countries (LMICs) participated in early microsurgical knowledge exchange. The 4th Microneurosurgery Conference, held in Montreal and Burlington, welcomed participants from 23 countries, including Thailand, India, Kenya, South Africa, Chile, and Venezuela, who later contributed to the formative development of microneurosurgery and disseminated these techniques within their home institutions (Figure 4) (2).

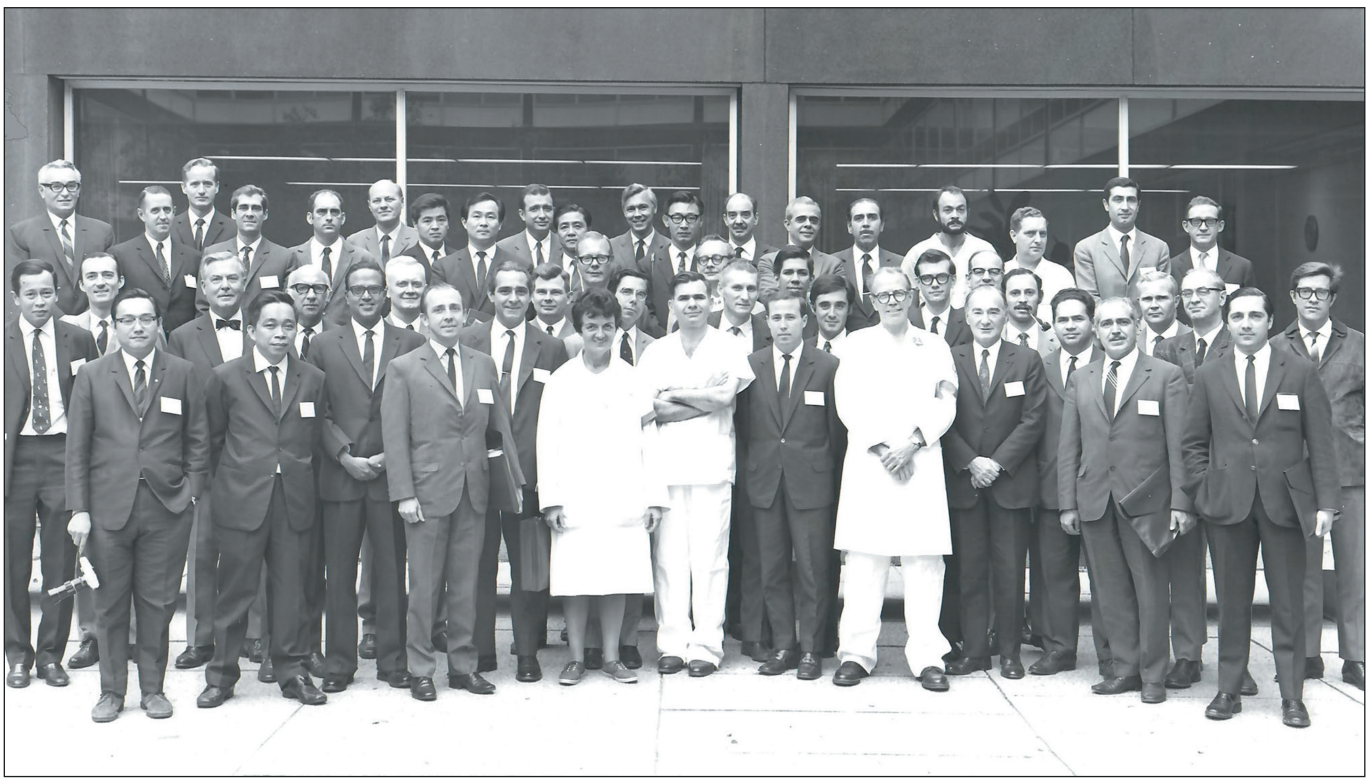

Figure 4: Group photograph of neurosurgeons who attended the 4th Microneurosurgery Conference, taken in Burlington. Fifty neurosurgeons from 23 countries participated in the meeting, held at the University of Montreal (September 29–30, 1969) and the University of Vermont (October 1–3, 1969). Reproduced courtesy of the first author.

Challenges in Global Microsurgical Laboratory Training

Although microsurgical techniques have reshaped neurosurgery for decades, their global adoption remains uneven. Limited laboratory infrastructure and trained personnel—rather than lack of published knowledge—continue to restrict access to hands-on microsurgical training, particularly in LMICs, where microneurosurgery often remains the primary treatment option.

Madison Microneurosurgery Initiative (MMI)

Recognizing the persistent global gap in microsurgical training, M. Gazi Yaşargil articulated a direct call to action during his address at the 2019 World Federation of Neurosurgical Societies Congress. Reflecting on his earlier experiences, he stated:

> *"In the 1990s, I visited Dr. Feng in China and saw their perfection in practicing bypass techniques on mice. I discussed with my colleagues the need to establish an initiative to spread these techniques to all departments. But I didn't have the time and energy to do it." He concluded with a broader appeal to the neurosurgical community: "I hope this congress brings responsible colleagues together to revisit this issue—because time is asking for this" (28)*

Motivated by this call and personal experience in microsurgical training (Figure 5), the MMI was established by the first author under the guidance of Drs. Mustafa K. Başkaya and Robert J. Dempsey to translate Yaşargil's vision into practice through structured, accessible, and sustainable microsurgical training for global dissemination (14-17).

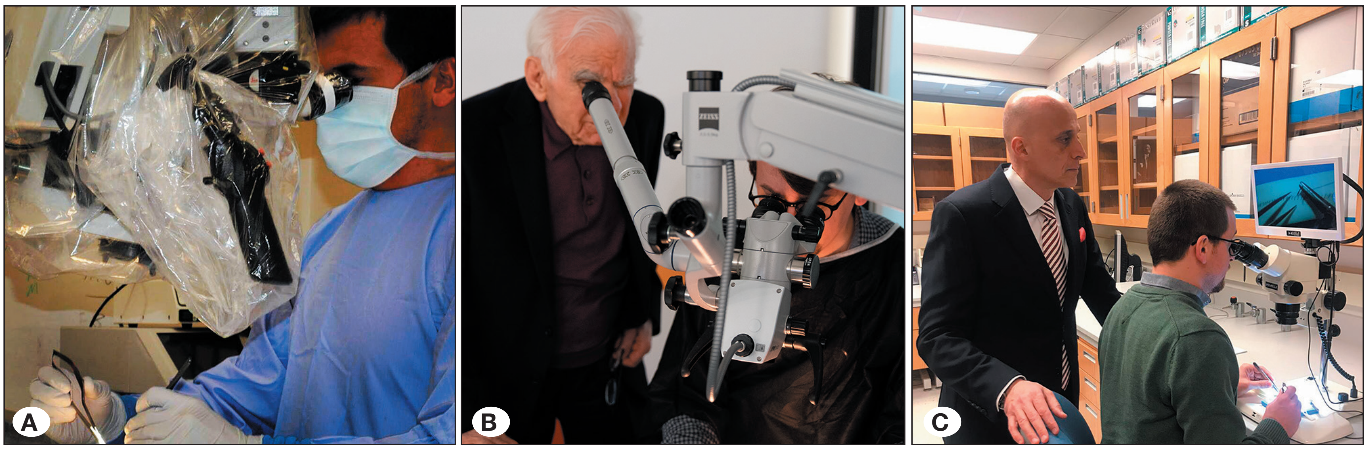

Figure 5: Representative microsurgical laboratory training experiences of the first author. **(A)** Initial microsurgical laboratory training during the summer of 2013, undertaken while the first author was a medical student at Istanbul University during a visiting research period at the Mustafa K. Başkaya Laboratory. Training included arachnoid membrane and vessel dissection and cleaning on more than 20 cerebral hemispheres used for a research study (3) (Madison, Wisconsin). **(B)** Yaşargil observing the first author during microvascular anastomosis training through the observer tube of the operating microscope at the 10th Istanbul Yaşargil Microneurosurgery Course, Part I (Microanastomosis), instructed by Rosmarie Frick at Yeditepe University Koşuyolu Hospital (June 2019, Istanbul, Turkey). **(C)** Continued hands-on microsurgical laboratory training under Mustafa K. Başkaya beginning in October 2019 (photograph from early 2020, Madison, Wisconsin).

The conceptualization and implementation of the MMI were further shaped by the extensive experience of Drs. Mustafa K. Başkaya and Robert J. Dempsey in laboratory-based microsurgical education and global neurosurgery, the department's international fellowship program, and the first author's direct academic interaction with Yaşargil during fellowship training at Yeditepe University. This first-hand exposure to the foundational era of microneurosurgery and its underlying philosophy provided historical continuity and perspective, which have continued to inform the first author's vision and subsequent work. In addition, the first author was exposed on a daily basis to the clinical and laboratory practices of two master microneurosurgeons—spending approximately 2.5 years with Dr. Uğur Türe at Yeditepe University and, since October 2019, with Mustafa K. Başkaya at the University of Wisconsin–Madison—observing the direct translation of sustained laboratory training into contemporary microsurgical practice, an experience that further shaped the first author's vision and subsequent work.

Microsurgery Training Kit Donations

Through the MMI donation program, basic microsurgery training kits were distributed to 86 centers across 45 LMICs in Africa, Asia, Europe, North America, and South America (Figure 6) (14,17). In total, 173 microscopes, including 169 basic stereo microscopes with high-quality optics, three Zeiss OPMI-1 operative microscopes, and one colposcope, together with associated training kits, advanced training and surgical instrument sets, were donated by the end of 2025. All microscopes were initially

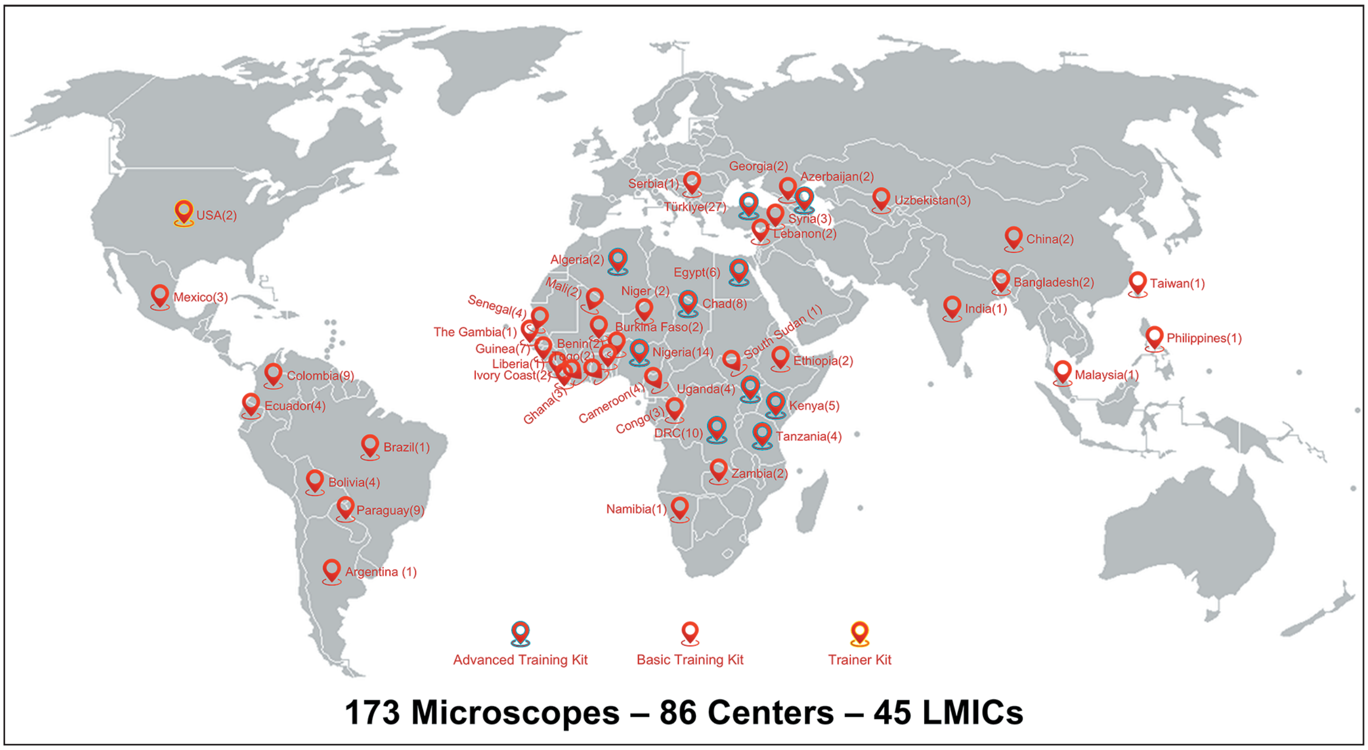

Figure 6: World map illustrating the global distribution of microsurgery training kits donated through the MMI. Each of the 45 LMICs supported is labeled with the corresponding number of microsurgery training kits donated. By the end of 2025, a total of 173 microsurgery training kits had been distributed, highlighting the scale and geographic breadth of global microsurgical capacity-building efforts.

purchased by the first author, with retrospective reimbursement for 22 units provided by one non-governmental organization and one individual donor. Delivery and distribution were accomplished through collaboration with multiple individuals and non-governmental organizations, as well as the direct logistical efforts of the first author. Kit allocation ranged from single units supporting emerging programs to larger distributions at institutional training laboratories, reflecting a capacity-building strategy tailored to local needs.

Offline Training Support

To complement equipment donations, MMI provided participating centers with offline training resources, structured BMBTC and MOST demonstration videos, designed to enable basic microsurgical training and self-assessment without expert supervision (14,16,17). These materials allow trainees to independently acquire foundational techniques and evaluate their results using MOST, without reliance on on-site expertise. The same offline resources have been used routinely in our laboratory for more than three years to support visiting scholars, facilitating independent practice and reinforcing teaching skills required for trainees who will establish and lead microsurgical training programs upon returning to their home institutions. Together, kit donations and offline resources support self-directed practice, objective performance evaluation, and iterative improvement, providing a practical framework for establishing and sustaining local microsurgical training programs.

Live-Streamed Training Support

To extend mentorship beyond physical boundaries and reinforce local training efforts, MMI implemented live-streamed microsurgical training sessions focused on microanastomosis techniques based on the BMBTC and supported by MOST. Following training kit distribution, 12 live-streamed sessions were conducted with faculty and participants from Türkiye, Paraguay, Lebanon, Bangladesh, and Chad, collectively training over a hundred neurosurgeons (14,16,17). These sessions integrated didactic lectures on the historical foundations and contemporary relevance of microsurgical training with real-time demonstrations and interactive discussion. All sessions were recorded and shared with participants, enabling offline review and supporting sustained, independent microsurgical training at participating institutions.

In-Person Training Support

To further support selected partner centers and encourage local microsurgical training initiatives, we developed the Slingshot Program, a mobile, no-cost, hands-on basic microvascular anastomosis training model. The first author traveled with 10–15 microscope workstations to partner institutions or convened participants from multiple LMICs at a single host center (Boston, USA) to deliver intensive in-person training focused on foundational microanastomosis techniques. Through this program, 16 Slingshot courses were conducted across seven countries (Türkiye, Georgia, Azerbaijan, Paraguay, Mexico, the Democratic Republic of Congo, and the United States), training more than 300 participants from multiple surgical specialties, including neurosurgery, general surgery, orthopedics, and plastic surgery. At each site with a residency program, training kits and self-directed educational resources were donated to support continued practice and local capacity building following course completion.

The design and execution of the Slingshot Program deliberately echo the principles underlying the first hands-on microsurgical course organized by Yaşargil in Zurich in 1968. As Yaşargil recalled, that inaugural course was conducted not in a dedicated surgical laboratory but in the pathology department, using borrowed operating microscopes from Zeiss and basic jeweler's instruments (26). Similarly, the Slingshot Program relies on basic yet functionally high optic quality microscopes, portable training setups assembled independently rather than institutionally owned, and nontraditional training spaces, most commonly conference rooms adapted for hands-on practice. In place of some jeweler's forceps, we used our cost-effective tweezer sets for microsurgical training. These shared characteristics reflect a common principle: effective microsurgical education depends not on sophisticated infrastructure, but on thoughtful adaptation of available resources to create focused, hands-on learning environments.

Operative Microscope and Surgical Equipment Donations

Inspired by the pioneering era of microsurgery, we identified and procured high-quality Zeiss operative microscopes (OPMI-1) originally manufactured between the 1950s and 1970s, a period during which such systems were widely used in high-income countries for routine clinical neurosurgical practice. Acquired through surplus sources for $270, $68, and $150, these microscopes were designed for durability, mechanical reliability, and stable optical performance, with minimal reliance on complex electronics and low maintenance requirements. Following cleaning, refurbishment, and basic upgrades to enable video recording, the microscopes were donated to partner centers in Chad, Guinea, and Nigeria.

In the Nigerian example, the recipient fellow completed structured microsurgical laboratory training using the BMBTC and cadaveric dissections covering major cranial approaches in our laboratory before returning to his home institution with the donated microscope (Figure 7,8). To facilitate transport, all microscopes were fully disassembled, and only the optical head and articulated arm were transported in standard suitcases, as the original bases were prohibitively heavy. This limitation necessitated the local design and fabrication of new supporting bases, an adaptation that was successfully implemented in both Chad and Nigeria. In Chad, the donated microscope has already been integrated into routine clinical neurosurgical practice, while similar sustainable clinical implementation is ongoing at the remaining centers under locally adapted conditions.

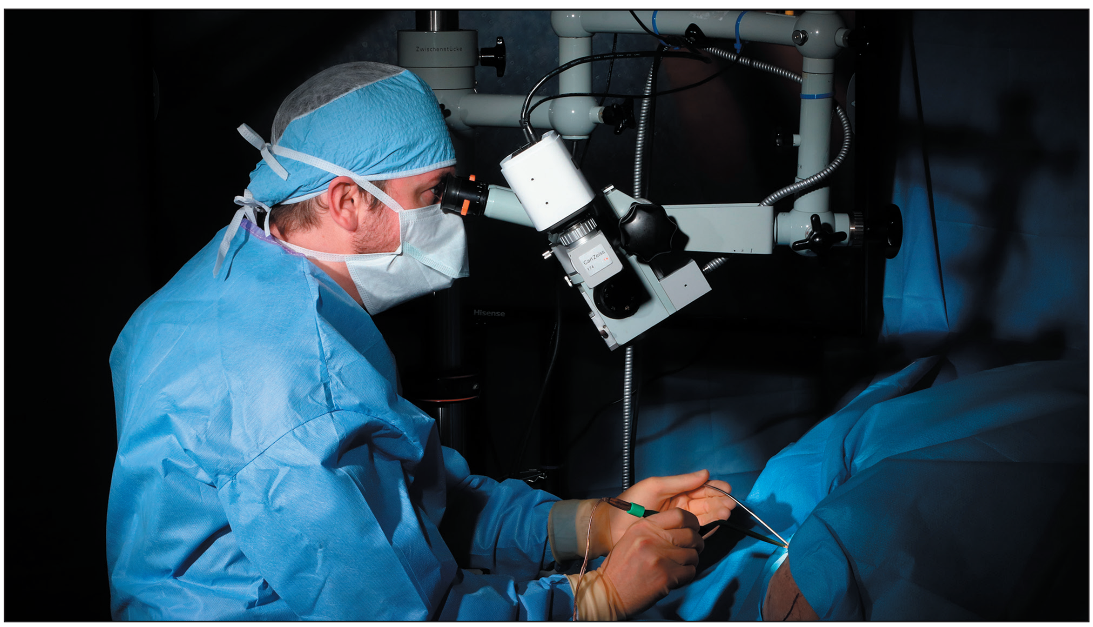

Figure 7: The first author is shown testing the Zeiss OPMI-1 operating microscope on a full-body cadaver prepared in a laboratory setting simulating the operating room environment. A visiting neurosurgeon from Nigeria subsequently completed training in various microsurgical and skull base approaches using this microscope, with procedures recorded through the attached camera system. Upon completion of training and prior to returning to his home institution, the same operative microscope and advanced neurosurgical instrument sets were donated to support his clinical practice in Nigeria.

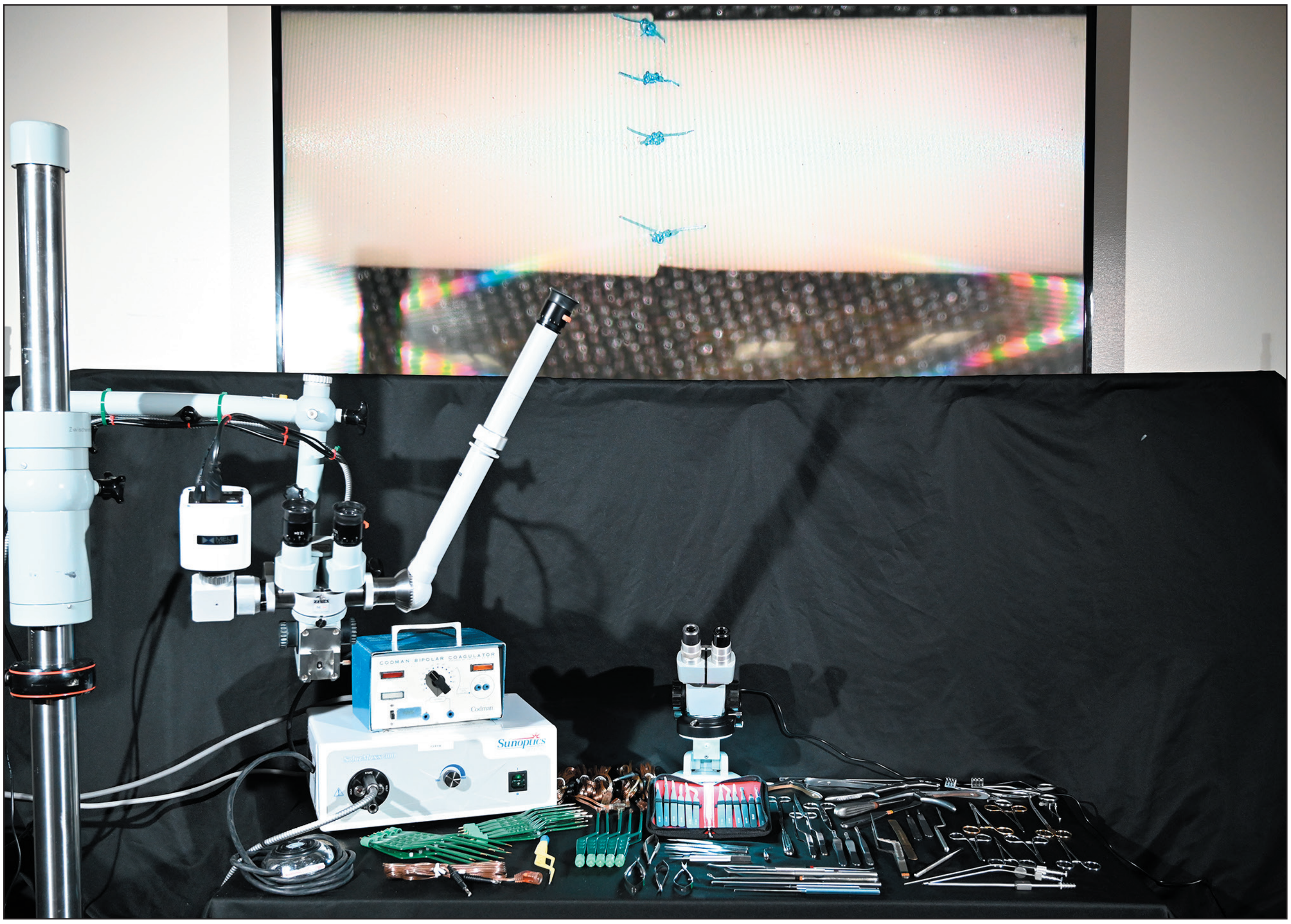

Figure 8: Operative microscope and surgical equipment donated following laboratory-based training. Shown is a Zeiss OPMI-1 operative microscope updated with a recording camera and an external xenon light source, together with a Malis bipolar coagulator and 15 gold-tip bipolar forceps of varying sizes and lengths. The setup also includes a basic microsurgery training kit and advanced neurosurgical instrument sets. On the wall-mounted monitor, a Penrose drain positioned under the operating microscope is visualized and projected in real time via the microscope camera, illustrating integrated microsurgical training and video documentation. This complete setup was used for training in our laboratory and subsequently donated in its entirety to a visiting neurosurgeon from Nigeria.

In parallel with operative microscope donations, extensive sets of high-quality advanced neurosurgical instruments were donated to these and additional partner centers to enable the performance of complex microsurgical procedures using state-of-the-art instrumentation. Compared with the limited instrument sets available during the pioneering era of microsurgery, these comprehensive modern sets substantially enhance operative capability when paired with durable microscopes, reinforcing the translation of laboratory training into contemporary clinical practice.

Advocacy

A core component of the MMI has been sustained advocacy for laboratory-based microsurgical training. This advocacy has taken multiple forms, including peer-reviewed publications, online webinar platforms, and presentations at national and international neurosurgical meetings such as the American Association of Neurological Surgeons, Congress of Neurological Surgeons, World Federation of Neurosurgical Societies, European Association of Neurosurgical Societies, and Continental Association of African Neurosurgical Societies. Through these venues, we have aimed to share practical experience, lower perceived barriers to entry, and reinforce the enduring value of structured laboratory training.

This effort directly echoes the lifelong mission articulated by Yaşargil, who stated:

> *"The quintessence of my 33-year-long mission has been to convince my neurosurgical colleagues (Figs. 15A and 17-22) of the absolute necessity of laboratory training in microtechniques before their application to humans in the operating room" (21).*

Figure 9: Presentation of the 2024 Global Neurosurgery Paper Award at the annual Congress of Neurological Surgeons Meeting on October 12, 2025, in Los Angeles, California. Shown from left to right are Mustafa K. Başkaya, MD, the first author holding the award, and Robert J. Dempsey, MD, following the award presentation.

Even for Yaşargil, advancing this message required decades of persistence. Recognizing these challenges, our advocacy has focused not only on emphasizing the importance of laboratory training, but also on removing practical obstacles by providing accessible training kits, structured curricula, objective assessment tool, and direct instructional support. Our approach emphasizes capacity building rather than short-term intervention, enabling institutions to independently initiate and sustain microsurgical laboratory training.

In summary, the MMI has translated foundational microsurgical principles into practical, scalable training strategies implemented across 86 centers in 45 LMICs. Guided by our direct field experience—and inspired by the pioneering achievements and educational philosophy of Yaşargil, as well as encouraged by his guidance—these efforts demonstrate how microsurgical principles can be effectively applied on a global scale. Through training kit donations, offline and live-streamed training support, in-person hands-on programs, and operative microscope training and donations, we have shown that effective microsurgical education can be achieved through thoughtful adaptation of available resources. Our ultimate goal is to publish, inspire, and guide, enabling colleagues worldwide to draw from our experience and initiate similar programs in their own institutions. This process is already underway, as multiple centers have reached out following our initial publications to adapt and apply these principles within their local contexts.

In reflecting on the broader meaning of our efforts, we are mindful that progress in microsurgery has always been built incrementally, through disciplined training and perseverance across generations. Yaşargil once captured this philosophy metaphorically while describing a climb in the Swiss Alps: *"I accomplished a micro-climb on a well-installed pathway in the Swiss Alps (Stoos, 1600 m). To the younger generation, I wish courage and hard work to pass to higher levels"*. We believe that our work represents another small step forward on this well-installed pathway—as a commitment to his achievements and an effort aimed at enabling future surgeons and institutions worldwide to ascend further through structured training, sustained effort, and shared responsibility. In this context, we consider the selection of our initial publication as the 2024 Global Neurosurgery Paper by the Congress of Neurological Surgeons to reflect the enduring relevance of Yaşargil's legacy rather than individual achievement (Figure 9).

Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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AUTHORSHIP CONTRIBUTION

Study conception and design: AK, MKB
Data collection: AK
Analysis and interpretation of results: AK
Draft manuscript preparation: AK
Critical revision of the article: AK
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