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Invited Special Article

Madison Microneurosurgery Initiative: A Tribute to Professor M. Gazi Yaşargil's Legacy in Microvascular Surgery Training. Part I – A Brief History of Microsurgery and Yaşargil's Contributions

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ABSTRACT

In the late 1960s, Professor M. Gazi Yaşargil began to systematically incorporate microsurgery into neurosurgical practice, grounded in anatomical expertise and intensive, systematic laboratory training followed by clinical application. Using the operative microscope, he introduced microsurgical techniques and redefined surgical anatomy that had long existed but remained largely unseen. By exploiting natural cisternal pathways to achieve pure lesionectomy, he reintroduced operability for complex pathologies and established new standards in modern neurosurgery. Yaşargil's early contributions to microvascular training and neurosurgical practice exemplify enduring principles from which neurosurgical professionals at all stages can continue to draw guidance. Our exposure to his work—through lectures, publications, and personal communications—profoundly shaped our own approach to neurosurgery and ultimately informed the philosophy underlying our global neurosurgery efforts, embodied in the Madison Microneurosurgery Initiative. This manuscript reviews the historical foundations of microneurosurgery through Yaşargil's early career, his formative laboratory work in Burlington, Vermont, and the systematic clinical implementation of microsurgery in Zurich, distilling key lessons derived from these pioneering experiences. A companion manuscript (Part II) describes how these principles were translated into structured curricula and implemented through contemporary microsurgical training and our global neurosurgery efforts.

KEYWORDS: Donaghy, History, Jacobson, Laboratory training, Microvascular surgery, Yaşargil

ABBREVIATIONS: MMI: Madison Microneurosurgery Initiative, **AVM:** Arteriovenous malformation, **MCA:** Middle cerebral artery, **UVM:** University of Vermont, **STA:** Superficial temporal artery, **EC:** Extracranial, **IC:** Intracranial

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The better we see, the more we know. The more we know, the better we see (28, 37).

(M. Gazi Yaşargil)

"The better we see, the more we know" reflects the concept that improvements in tools and techniques—whether through the surgical microscope or the development of new approaches—reveal details that were previously unrecognized and, in turn, expand our understanding.

"The more we know, the better we see" completes the cycle: expanding understanding reshapes perception. As knowledge deepens, we better appreciate subtle details, define critical relationships, and perceive anatomical structures with greater clarity; what was once hidden comes into view.

Yaşargil's incorporation of microsurgery into neurosurgical practice exemplifies this reciprocal principle. Through meticulous visualization using the operative microscope, he introduced microsurgical techniques and redefined surgical anatomy that had long existed but remained largely unseen. This advancement allowed neurosurgeons to use natural cisternal pathways to achieve pure lesionectomy with unprecedented precision, re-introducing operability and establishing new standards in modern neurosurgery.

Our exposure to Yaşargil's work—through his lectures, publications, and personal communications—allowed us to gradually appreciate the breadth and depth of his contributions to the field of neurosurgery. As our understanding evolved, it refined our perception, revealing additional layers of insight that continued to shape our approach to the field. This reciprocal process of learning and perception ultimately shaped the philosophy underlying our global neurosurgery outreach efforts, embodied in the Madison Microneurosurgery Initiative (MMI).

A thorough understanding of the lasting influence of Yaşargil's legacy on our approach requires a detailed exploration of his early career, the birth of microsurgery, and his foundational contributions—particularly the innovations that reshaped microsurgical practice and established core principles of microsurgical training.

EARLY CAREER OF YAŞARGIL

Following high school education in Ankara, Turkey, Yaşargil began his medical education at the Friedrich Schiller University in Jena, Germany and completed his medical degree at the University of Basel in Switzerland. Early in his education, he studied anatomy at the renowned Institute of Anatomy at the Friedrich Schiller University (28). In 1945, under the guidance of Professor Adolf Portmann, he performed microscopic transpalatinal exploration and selective removal of the intermediate lobe of the frog hypophysis. This experience marked his first encounter with microsurgery (28).

Additionally, Yaşargil spent three intensive months at the Institute of Anatomy "Vesalianum" in Basel under the mentorship of Dr. Klingler, where he learned the white matter fiber dissection known as Klingler method and examined the internal architecture of the brain. He continued refining his fiber dissection skills and deepen his understanding of internal neuroanatomy over the subsequent three years, using specimens he had borrowed from Basel (28). During these years, he extensively studied Brain and Spinal Cord (26), and the Atlas Cerebri Humani (20). In addition, Yaşargil extensively studied Walter E. Dandy's Surgery of the Brain book German edition before his residency start in Zurich. On January 4, 1953 he began his neurosurgical training under Professor Hugo Krayenbühl in Zurich (28).

In 1957, Yaşargil received training in stereotactic surgery in Freiburg with Professors Th. Riechert, H. Hassler, and Fr. Mundinger, subsequently introducing these techniques in Zurich and performing more than 800 procedures by 1965 (28,30). In 1958, he spent four weeks in Paris training with Professor J. Talairach, where he learned stereotactic approaches to the treatment of epilepsy. He further expanded his physiological understanding of the central nervous system through training with Professor Niels A. Lassen in Copenhagen on local cerebral hemodynamics and with Professor Nils Lundberg in Lund on intracranial pressure monitoring (28).

Driven by his interest in cerebral vascularization, Yaşargil conducted extensive studies on neurovascular anatomy, examining anatomical variations and collateral pathways in 200 injected cadaveric brains (400 hemispheres). He explored the integration of stereotactic and endovascular techniques, including iron particle injection for targeted occlusion of aneurysms and arteriovenous malformations (AVMs), as well as the use of polymerizing substances in saccular aneurysms (28,35). Concurrently, he angiographically analyzed more than 100 orbital lesions, collateral cerebral circulation, and the lenticulostriate arteries (35). Alongside this cranial work, he treated 12 spinal AVMs, developed substantial expertise in spinal disc surgery, and designed a telescopic screw (28).

By 1965, at the age of 40, Yaşargil had devoted 22 years to medicine, including 13 years in neurosurgery, and had performed approximately 3,000 operations. His expertise extended to stereotactic surgery, with experience in more than 900 cases, and to neuroradiology, having conducted roughly 9,000 transcutaneous and stereoscopic angiographic studies of the carotid, vertebral, and orbital vessels. In parallel, together with Professor Hugo Krayenbühl, he had published 82 papers, authored four monographs, and contributed chapters to three additional monographs (35).

THE ADVENT OF MICROSURGERY

The operating microscope was first introduced into clinical surgery in 1921 by the otolaryngologist Carl Olof Nylen in Stockholm (21). Its application was subsequently advanced by pioneers in otolaryngology—including Holmgren, Wullstein, Shambaugh, and House—as well as by ophthalmic surgeons such as Perritt, Harms, and Barraquer, before its adoption in neurosurgery. In 1957, Theodore Kurze became the first to employ the operating microscope in a neurosurgical procedure (19). Subsequent applications included aneurysm surgery and, by the mid-1960s, vestibular schwannoma surgery (2,34-36).

MICROVASCULAR SURGERY IN BURLINGTON, VERMONT

While pioneering microsurgical efforts in the United States initially emerged on the West Coast in the late 1950s, parallel work was underway on the East Coast at the University of Vermont (UVM). Following his appointment as Associate Professor and Director of Surgical Research at the UVM in 1959, Julius H. Jacobson collaborated with W. H. McMillan to study procedures requiring carotid denervation in canine models (12,13). They demonstrated that excision of the carotid artery followed by reanastomosis achieved approximately 70% patency in 3-mm vessels without optical aids—at a time when successful anastomosis of 6-mm arteries was not yet feasible (13). They recognized that the primary obstacle was inadequate visualization, noting that "*the eye not being able to see well enough to guide the hand properly*" (12,13,15). Various optical aids, including magnifying loupes, were subsequently employed, but outcomes remained unsatisfactory (13,16,25). A pivotal moment occurred when Jacobson observed an otolaryngology colleague using an operating microscope in the operating room at Mary Fletcher Hospital—an experience he later recalled from his residency at Presbyterian Hospital in New York (13).

Recognizing the limitations of available surgical instruments, Jacobson purchased fine jewelry forceps from a local jeweler—tools he described as "s*uperior to anything in the surgical armamentarium*" (12). When combined with the operating microscope, these instruments enabled 100% patency in microvascular arterial anastomoses involving vessels ranging from 3.2-mm to 1.4-mm in diameter (12,17,18,35,36). With further refinement, consistent patency was later achieved in vessels as small as 1-mm (14,38).

Meanwhile, in 1959 at the same institution, Dr. R.M. Peardon Donaghy encountered a patient with a middle cerebral artery (MCA) embolus; the case, managed with medical therapy only, ended in frustration because of lack of experience with embolectomy (2,4,6). This event, together with Donaghy's "Orlab Concept," marked the beginning of microneurovascular research in the Neurosurgical Laboratory at the UVM. Shortly thereafter, Jacobson, who had already published his seminal work (18), demonstrated the advantages of the operating microscope to Donaghy and strongly advocated its use in such cases (2,4).

Following intensive experimental laboratory work using an operative microscope, the first microsurgical MCA endarterectomy was performed in Burlington on August 4, 1960, by Donaghy and Jacobson, with limited success (2,7,13,25). Over the following six years, eight additional embolectomies or endarterectomies were performed, with only two achieving technical success (2,35,36). Reflecting on these early efforts in 1967, Donaghy noted: "*we feel in the past seven years since this work was begun we have progressed but little, but have progressed none the less, and hope that knowledge gained from our confreres will lead to even greater progress during the next seven years*" (4).

MICROSURGERY IN ZURICH

The microsurgical work of Drs. House and Kurze was well received in Zurich (28). In late 1963, a Zeiss binocular diploscope was acquired by the Department of Neurosurgery in Zurich and used in a limited number of cases, including facial nerve anastomosis and lumbar spine surgery. However, because of its cumbersome mobility and the absence of structured laboratory training, it could not be effectively adapted for broader surgical applications and was soon abandoned (28,29,30,35). In 1966, it was replaced by the Zeiss OPMI-1 (35).

Yaşargil later recalled his early experience using the operating microscope in spine surgery with Dr. Eric Zander as follows:

> *"Gazi, you are doing the surgery now." I was shocked. "Okay," I started. I started on the left side, opened the paraspinal muscles, and stopped. I said, "Dr. Zander, that's it—this is what I can do. I don't have the moral power. This is too much to start doing everything. I know what I can do, but I do not have experience."*
>
> *In the afternoon, he told Dr. Krayenbühl during a discussion. He said Gazi had a hesitation to operate further. The reaction of Krayenbühl was important for me—for everybody. He said, "This is a good sign. He is going to be a good surgeon, because we should not run in."*
>
> *I said, "We have no training facilities. We never had any laboratory. I didn't have any idea about the spinal musculature and the bones. I just watched it. But watching was not under the microscope at all" (37).*

In late 1963, Ake Senning asked Yaşargil to perform an embolectomy on a 17-year-old girl who had, after open cardiac surgery, developed right-sided hemiplegia due to an embolus occluding the left central sulcus artery (approximately 1–1.5 mm) (28,30,35). Yaşargil later reflected on this encounter as follows:

> *"Professor Senning insisted that I immediately remove the embolus. He was very upset by my hesitant behavior and my explanation of incompetence given my lack of laboratory experience with microvascular surgery" (35).*

From these early experiences, Yaşargil drew a lasting lesson: surgical innovation must be grounded in thorough, intensive laboratory training before application in the clinical practice.

Similar to Donaghy's experience in 1959, the MCA embolectomy case stimulated Yaşargil's growing interest in structured microsurgical laboratory training, ultimately led him to Burlington, Vermont, in 1965 (28,30,35). At the age of 40, Yaşargil left an established clinical and research career in Zurich and arrived in Burlington in October 1965 with his wife and three children. By then, Jacobson had already left Burlington.

YAŞARGIL IN BURLINGTON, VERMONT

When Yaşargil arrived in Burlington, he already had a clear plan to pursue microvascular surgery training. He outlined a structured training program focused on developing microvascular techniques for cortical artery embolectomy; performing extra- and intracranial bypass for internal carotid artery occlusion; establishing middle cerebral artery bypass grafting; and exploring bypass procedures involving the superior sagittal sinus (30).

His extensive experience in anatomy, clinical practice, and research had prepared him for the next stage of his career—a point later underscored by Jacobson, who recalled:

> *One day in 1965, a young Turkish neurosurgeon, M. Gazi Yaşargil, appeared at Mount Sinai. He turned out to be the hardest working man whom I have ever encountered. You may recall that Sir William Osler stated that the magic word of medicine was work which "makes the dull student bright, the bright student brilliant, and the brilliant student steady." By that definition, Leonard Malis and M. Gazi Yaşargil are "steady" (13).*

It is important to note that Yaşargil's visit to Burlington was not limited to learning microvascular techniques. He also served as a visiting professor, sharing his clinical expertise, particularly in vascular malformations, with residents—a contribution often been underrecognized (23).

Yaşargil's early work focused on the patch technique for embolectomy in small vessels; as his experience expanded, he developed techniques of his own that enabled him to perform a wide range of vascular procedures, including multiple forms of anastomosis, vessel duplication and loop formation, vein and synthetic grafting, and patch repair (Figure 1) (3,7,28,29,39).

Figure 1: Building on extensive prior experience and instruction from highly skilled mentors, Yaşargil rapidly mastered the fundamentals of microvascular anastomosis. Yaşargil with his main teacher in microtechniques, Ms. Esther 'Jackie' Roberts, RN in Burlington, Vermont, February 8, 1966. Reproduced courtesy of Fletcher Allen Health Care Records, Special Collections, University of Vermont Library.

On February 2, 1966, Yaşargil attempted a common carotid–MCA bypass using a femoral artery and jugular vein graft. Although the procedure was technically successful, the graft subsequently thrombosed. These early results led him to revise his strategy and adopt the superficial temporal artery (STA) as the donor vessel, thereby avoiding an additional anastomosis (7,35). From March 30 to September 1966, he successfully performed 33 STA-MCA bypass operations in mongrel dogs (30,33,35).

The purchase of a small bipolar coagulator ($120), rather than a new Bovie unit ($500), represented a turning point in his experimental efforts. It enabled precise hemostasis and played a key role in the safe and effective application of microsurgical techniques in neurosurgery (28).

Beyond the technical aspects of microvascular anastomosis, Yaşargil recognized the critical role of regional cerebral blood flow assessment in determining the indication for bypass surgery. He believed that accurate pre- and postoperative assessment of cerebral perfusion as essential for establishing appropriate surgical indications, although such measurements were not technically feasible at the time (32). The results of the Extracranial (EC)–Intracranial (IC) Bypass Study published in 1985 later validated his concerns, demonstrating that bypass surgery should not be performed without proper indications in stroke management (11,28).

After six months of laboratory work, Yaşargil visited major centers across the United States and Canada in the summer of 1966 to share his experience in microvascular surgery and assess contemporary microvascular surgical practice in general, vascular, plastic, and neurosurgery (30,36,39). In those centers, he presented 16-mm color films of his laboratory work in Burlington, footage of 12 spinal AVM surgeries performed without microsurgical aids in Zurich, and angiographic studies from 110 patients with orbital lesions, along with his work on cerebral arterial collateral circulation and the lenticulostriate arteries (28,35,39).

During this tour, Yaşargil recognized the need for a dedicated meeting to unite colleagues working on microvascular surgery techniques. Accordingly, a conference was held in Burlington, Vermont, on October 6–7, 1966, attended by approximately 60 surgeons from four specialties—vascular, plastic, reconstructive, and neurosurgery. The meeting was honored by the presence of Dr. Krayenbühl, who observed Yaşargil's laboratory work firsthand and became convinced that microsurgical techniques and bipolar coagulation should be routinely incorporated into neurosurgical practice (35). The proceedings were subsequently published as a monograph (5).

This initial meeting was followed by a series of neurosurgical conferences, beginning with one held on April 13–15, 1967, at the University of California, Los Angeles. During this meeting, Yaşargil demonstrated the combined use of the operating microscope and bipolar coagulation in a spinal AVM operation in collaboration with Dr. Rand, marking the first clinical application of microtechniques (7,30). The conference proceedings were subsequently published in another monograph (24).

YAŞARGIL BACK IN ZURICH

"Dr. Yaşargil went back to Zurich in 1967 where his work is already legendary" (7). Following 14 months of intensive laboratory work in Burlington, this return marked a decisive transition, as his experimental experience had demonstrated that microsurgical techniques could—and should—be routinely applied in neurosurgical practice. Yaşargil later emphasized that his meticulous laboratory work in Burlington provided the skills necessary for safe application of these techniques in humans (28).

FROM THE MICROSURGICAL LABORATORY TO THE OPERATING THEATRE

The routine clinical application of microtechniques in Zurich began on January 18, 1967, with the removal of a glioma and clipping of an aneurysm in the same session (35,36). These techniques were rapidly adopted across the full spectrum of neurosurgical practice, including reconstruction of occluded intracranial arteries and the treatment of aneurysms, AVMs, cavernomas, extrinsic and intrinsic tumors, as well as spinal lesions (28,36,39). This broad application emphasizes that training in microvascular surgery extends beyond bypass procedures, enhancing outcomes across diverse neurosurgical operations through shared microsurgical skills developed in the laboratory.

On October 30, 1967, Yaşargil performed the first EC–to–IC STA–MCA bypass, one day before Donaghy carried out a same procedure in Burlington (2,7,28,35). Notably, although routine microsurgical practice had already been established in Zurich, Yaşargil waited nearly ten months before applying this technique clinically. He later explained this deliberate decision as follows:

> "*My forbearance was due to the fact that I did not want to discredit the technique of this operation by choosing a case with questionable indications. I thus waited for an ideal case*" (30).

Until 1973, Yaşargil performed 35 STA-MCA bypass procedures with considerable apprehension and hesitation, as indications were not yet well defined (31). The absence of reliable methods to assess cerebral tissue viability and measure cerebral blood flow limited appropriate patient selection, and even by 1999, definitive indications remained incompletely established (28,38). From 1973 onward, younger colleagues—Drs. Yonekawa, Zumstein, and Imhof—performed these operations under his guidance, completing an additional 200 cases through 1993 (30,35).

ZURICH MICROSURGICAL LABORATORY

After returning to Zurich, Yaşargil continued his experimental research in microvascular surgery at the Brain Research Institute, alongside an intensive clinical practice (1,8-10,22,27). In November 1968, the second microneurosurgery conference and the first hands-on microsurgical course were organized in Zurich, an event Yaşargil later recalled as follows:

> *"The third microsurgical conference and first hands-on microsurgical course were held in the pathology department of University Hospital, Zurich, in November 1968. We expected 20–40 participants and had borrowed 10 operating microscopes from the Zeiss Company and bought some jewelers' instruments for the course. To our great surprise, we experienced the arrival of 186 neurosurgeons from Europe, Canada, and the US—a great number of them being chairmen of neurosurgery departments" (35).*

In this initial course, Yaşargil emphasized that hands-on instruction alone was insufficient and that prolonged laboratory practice was essential before applying microsurgical techniques in clinical settings. He later recalled:

> *"In hands-on courses the microtechniques of tissue dissection, bone drilling, bipolar coagulation, and suturing were demonstrated and practiced. Colleagues were encouraged to continue practicing in the laboratory for a long period of time until they achieved competence in the application of microtechniques, before performing surgery on patients" (35).*

Proceedings of this conference were published as another monograph (34).

In 1972, the program moved to a modern animal laboratory equipped with 10 Zeiss OPMI-1 microscopes (28). By 1999, more than 4,000 surgeons from various specialties had been trained in microsurgical techniques in this laboratory and had completed the Zurich Microsurgery Course—initially under Yaşargil's leadership until 1971, subsequently under Drs. Yonekawa and Nishikawa, and over four decades under Rosmarie Frick, Nursing Assistant (28,40). Under her leadership, the Zurich Microsurgery Course was also conducted in some other countries, including Türkiye, where the first author completed the course and observe multiple courses between 2017 and 2019.

In summary, the pioneering work of Yaşargil established microneurosurgery not only as a technical innovation, but as a disciplined educational paradigm grounded in meticulous anatomical study, systematic laboratory training, and judicious clinical application. His experiences demonstrated that sustained, hands-on laboratory practice is essential for the safe and effective adoption of microsurgical techniques. These historical foundations yielded enduring lessons that continue to inform contemporary microsurgical education and practice. Building on these lessons, Part II of this series describes how the principles derived from Yaşargil's legacy were translated into structured training curricula and implemented through contemporary microsurgical training models and global neurosurgery efforts.

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AUTHORSHIP CONTRIBUTION

Study conception and design: AK, MKB
Data collection: AK
Analysis and interpretation of results: AK
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