Hanno Millesi: Pioneer of Plastic Surgery and Nerve Surgery (1927–2017)

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Abstract: Recently, plastic surgery lost one of its most prominent surgeons—Dr. Hanno Millesi. His contributions to the field continue to impact the practice of medicine and surgery. As such, it is appropriate to reflect upon his career and recognize his accomplishments in peripheral nerve surgery, hand surgery, and Dupuytren disease.

Key Words: Millesi, Dupuytren disease, microsurgery, plastic surgery, peripheral nerve surgery, hand surgery, interfascicular repair, nerve grafting, interfascicular neurolysis, brachial plexus

(*Ann Plast Surg* 2020;85: 588–591)

Those who knew him well appreciated his easily approachable, generous personality, open to anyone's suggestions or questions. He was at all times an elegant gentleman, as we saw watching him dance to Austrian waltzes—(As remembered by Dr. Wyndell Merritt)

Dr. Hanno Millesi was an innovative plastic surgeon, a trailblazer in the field of peripheral nerve surgery, and a pioneer of hand surgery. Early in his career, Dr. Millesi used animal studies and clinical data to demonstrate that autologous nerve grafting was superior to suturing under tension in the repair of peripheral nerves. In one of his seminal works, he described a novel microsurgical technique of interfascicular nerve grafting, a technique which substantially improved the functional outcome of peripheral nerve repairs.[1–3] These publications were instrumental in changing standard practice in the field of peripheral nerve surgery.[4] Additionally, as a young physician, Dr. Millesi published several landmark papers on Dupuytren disease (DD).[5] This research helped shape the medical community's understanding of the underlying processes of DD and improved surgical therapies used to treat the disease.[6,7] Dr. Millesi remained a prolific academic researcher throughout his life. His contributions to medicine have been recognized by international organizations, academic institutions, and physicians across various specialties.[8] Dr. Millesi is one of the most important plastic surgeons in history; an examination of his scholarly work provides insight into the possibility for innovation in medicine and the evolution and history of microsurgery.

BACKGROUND

Dr. Hanno Millesi was born on March 24, 1927, in Austria. He graduated from University of Innsbruck Medical School in 1952 and then went on to train in internal medicine and pathology at the Wilhelminen Hospital in Vienna. He subsequently specialized in general and plastic surgery at the First Surgical Clinic, University of Vienna Medical School.[9] During his training in plastic surgery, Dr. Millesi worked in Sweden under the mentorship of Dr. Alan Ragnell. In 1967, Dr. Millesi received Habilitation (Professorship) at the University Hospital of Vienna and was appointed Associate Professor of Plastic and Reconstructive Surgery there in 1972.[8] Dr. Millesi incorporated research into his work early on in his career; this early work led to some of his most important publications (Fig. 1).

MICROSURGERY OF PERIPHERAL NERVES

Interfascicular Grafting

Dr. Millesi became renowned for his research on a variety of topics in plastic and reconstructive surgery. He is perhaps best known for his innovative work on microsurgery and, more specifically, peripheral nerve repair. His contribution to the field consisted of studying the effects of tension on regenerating axons, outlining a novel solution to this problem, and then showing the effectiveness of his solution.

In his 1973 article in *Hand*, Dr. Millesi outlined advancements in the field of peripheral nerve surgery and explained his reasoning as to why surgical outcomes still fell short of expectations. For many years, magnifying loupes were used by surgeons in order to improve the precision of their technique.[10] The first major advancement in nerve surgery since the World War II was in 1964 when James W. Smith used a dissection microscope for microsurgery of the peripheral nerves.[11] Use of the dissection microscope led to superior accuracy of dissections and end-to-end nerve repair.[4] However, as Dr. Millesi pointed out in his article, these technological advancements did not address a critical issue: the tension caused across the suture lines of nerve repairs.[10]

As Millesi et al[1] showed in a study published in 1972, tension across suture lines in nerve repairs is inversely correlated with nerve regeneration. They compared methods of repair of the sciatic nerve in several groups of rabbits. In the first group, the sciatic nerve was transected and subsequently repaired by epineural end-to-end suture. In a second group of rabbits, a 5-mm section of the sciatic nerve was excised and the stumps were sutured under moderate tension. In a third group, a 5-mm section of the sciatic nerve was excised, but then regrafted between the stumps as a free graft. In this third group, tension was minimal; however, regenerating axons had to cross 2 suture lines. When compared, the functional results in the third group were equal to those of the first group and far superior to those of the second group. This meant that despite creating two suture lines instead of one, nerve grafting led to superior outcomes than suturing under tension.

Dr. Millesi's 1972 study in rabbits was not the first documented use of nerve grafting as an alternative to suturing under tension of transected peripheral nerves.[12] Nevertheless, before his contributions to the field, autologous nerve grafts were unsuccessful in around 50% of cases and were thus considered a second-line therapy.[10,12,13] At the time, it was also known that the deleterious effect of tension could not be eliminated by immobilizing the joint adjacent to the site of repair in flexion. Immobilization in flexion did not work, because even if axons did regenerate across suture lines, they were shown to be damaged by stretching once the joint was no longer immobilized.[14] Other methods to overcome a nerve gap were used instead when possible. For example, osteotomy was used to shorten the bone and consequently

Received July 30, 2020, and accepted for publication, after revision September 29, 2020.
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Conflicts of interest and sources of funding: none declared.
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ISSN: 0148-7043/20/8506–0588
DOI: 10.1097/SAP.0000000000002600

FIGURE 1. Dr. Hanno Millesi. full color online

shorten the length of an existing nerve gap. Another method used was the mobilization of the nerve and alteration of its course to gain length. For example, the ulnar nerve was transposed to the volar aspect of the elbow joint to minimize the size of an existing defect. However, these 2 methods were limited in their use and did not provide a satisfactory solution.[10]

In another 1972 publication, Millesi et al[2] proposed an innovative solution to the problem outlined above. In this article, Millesi et al suggested leveraging the then-novel dissection microscope and using it to carry out the autologous nerve grafting procedure. The use of the microscope allowed for finer detail of dissection, decreased collateral damage to nerve tissue, and, most importantly, interfascicular bridging of the nerve gap using an autologous graft. Millesi et al. provided a detailed description of the operative technique in the repair of median and ulnar nerves in their article. Under the microscope, the nerve was exposed, the epineurium incised, and a circular strip of epineurium removed (Fig. 2A). Then, using blunt dissection, major fasciculi and groups of minor fasciculi were isolated. Once dissected, the distal and proximal stumps both consisted of 4 to 6 individual fasciculi or groups of minor fasciculi (Fig. 2B). Then, a sketch of the 2 stumps was made to identify corresponding stumps at the distal and proximal ends of the defect (Fig. 3A). This sketch was also used to determine the number of grafts needed for the repair and helped with the selection of the donor nerve.[2] Millesi et al. then described the technique for harvesting the sural nerve. Finally, they emphasized that once the graft is obtained, each piece of the graft bridging corresponding fasciculi must be larger than the defect itself to prevent the occurrence of any tension along the repair (Fig. 2C and Fig. 3B). The novelty of the technique was that individual grafts were placed to bridge corresponding fasciculi, unlike the cable grafts which were used at the time.[2]

Functional results of Millesi et al's innovative procedure were reported in a later publication in more detail and after a longer follow up.[3] Millesi et al reported that of the 38 median nerve repairs evaluated, sensation was restored in all but one of the patients, and motor recovery (grade 3 strength or better) was attained in 82% of the patients. Of the sixteen patients evaluated postradial nerve graft, and the 39 patients evaluated postulnar nerve graft, 77% and 100% of the patients, respectively, gained useful motor function.[2,3] When specimens were examined histologically, it was observed that Schwann cells were able to survive and fibrosis was absent.[15] With these results, Millesi et al. showed that the new interfascicular nerve repair technique they described was not inferior to epineural end-to-end repair performed under ideal conditions. More notably, however, was that this new method was far superior to repairs under tension as well as to cable grafts.[3]

Dr. Millesi's publications transformed peripheral nerve surgery; in light of his research, nerve grafts began to be used more and more frequently.[4] Many surgeons followed Millesi et al[15–17] by adopting interfascicular nerve repair and published confirmatory positive results. Thus, the novel microsurgical technique became widely accepted and used.

Brachial Plexus Repair and Interfascicular Neurolysis

Dr. Millesi continued to conduct research on various topics in the field of peripheral nerve surgery throughout his career. Notably, he described a new classification system for lesions of the brachial plexus. In this system, injuries are described according to their anatomic location: preganglionic, postganglionic, trunk, or cord, and noted as levels I, II, III, or IV, respectively. This classification system, known as the Millesi Classification of Brachial Plexus Injury, was adopted by plastic surgeons, neurosurgeons, and physiotherapists alike. Additionally, Dr. Millesi introduced the use of interfascicular grafts in the repair of these lesions.[18–20] Since the 1970s, there has been a noted surge in the successful surgical repair of these injuries—a phenomenon largely attributed to Dr. Millesi's work.[21]

Another area of peripheral nerve surgery enhanced by Dr. Millesi is microsurgical neurolysis. Through the use of his extraordinary understanding of the intricacies of anatomy and physiology, Dr. Millesi once again used the dissection microscope to refine a surgical procedure and outline a new technique—he described the stepwise epifascicular epineurotomy as well as the indications for internal neurolysis.[15,22] Dr. Millesi's historic contributions the field of peripheral nerve microsurgery throughout his career established his reputation as a prolific surgeon-scientist.[23,24]

DUPUYTREN DISEASE

In addition to his contributions to the field of peripheral nerve surgery, Dr. Millesi also focused much of his clinical work and research on DD and hand surgery. As a young physician, Millesi published a study examining the pathogenesis of DD in 1959. This article demonstrated that the disease may progress aggressively and quickly lead to dislocations of the digital joints, but may also progress at a slower rate, alternating with periods of standstill. Through this research, Dr. Millesi was able to show that the digitopalmar flexion stage of the disease was not inevitable.[25] Because Dr. Millesi showed that many patients may never progress to the stage of contraction, researchers studying the condition proposed that its name be changed from Dupuytren Contracture to DD.[7,26]

In 1965, Dr. Millesi published his habilitation thesis (doctoral dissertation) on the pathogenesis of DD, and in 1967, he received his postdoctoral qualification based on his extensive research of the disease.[9] Dr. Millesi studied the biomechanical properties of the palmar fascia as a functional system. His postdoctoral work outlined the role of the palmar aponeurosis in this functional system and related it to the different distribution of early DD. Additionally, this research helped

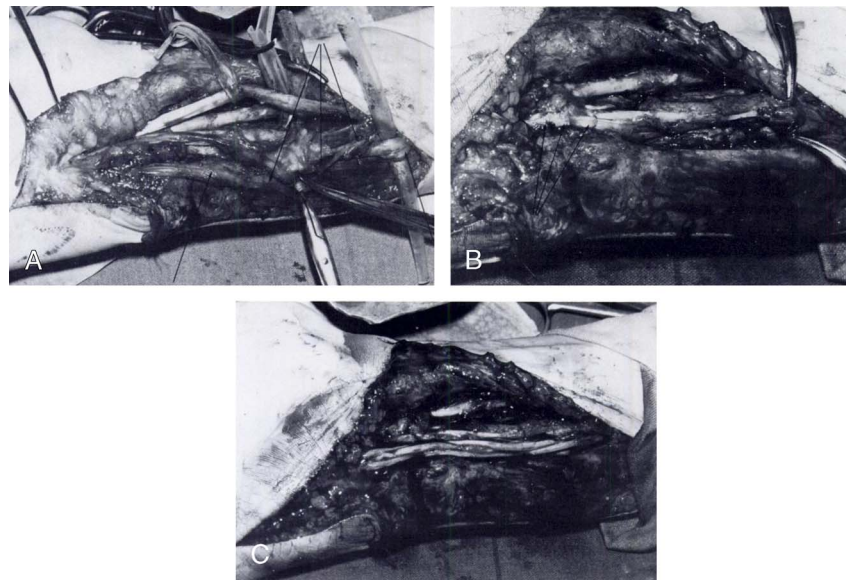

FIGURE 2. A–C, From Millesi et al., (1972) *The Interfascicular Nerve-Grafting of the Median and Ulnar Nerves*.[2] "A fifteen-year-old boy, four months after an injury to the right forearm with transection of the flexor tendons and the ulnar nerve. Primary repair had been carried out elsewhere with no return of nerve function. The boy was operated on again in January 1971, too recently to be included in this study." A, "At re-exploration the proximal stump of the ulnar nerve (arrow, lower right) was found to be sutured to a flexor tendon (arrows, upper right) while the distal stump of the nerve (arrow, lower left) was united to the proximal stump of a severed flexor tendon by scar." B, "After resection of the scarred portions of the nerve ends and dissection of the fasciculi, there was a gap of 6.5 cm in length. Note fasciculi projecting from proximal stump (between hemostats) and the fasciculi in the distal stump which have been dissected out and transected at different levels (arrows)." C,"Completed grafts. Four grafts from a sural nerve are in place. Note absence of tension."

establish Dr. Millesi's view that the pathogenesis of DD begins with the fibrosis of elastic tissues and not with fibromatosis and cellular proliferation.[27] His observations supported the theory that DD was initiated by the failure of elastic fibers to recoil following a triggering stress. According to this view, the failure of elastic fibers to return to their original state triggers collagen production. This is followed by failed cellular proliferation and then the consequent fibrosis seen in DD.[5,27]

Dr. Millesi continued to study DD throughout his career and contributed to the advancement of the understanding of the disease and its treatments through his research. When studying surgical treatments for DD, Dr. Millesi documented lower rates of recurrence and slowed progression in patients who underwent total fasciotomy as opposed to partial fasciotomy.[7] He refined Tubiana's Staging System of the condition by adding the suffixes "F," "L," and "R" to the stage of the disease to note fusion (ankylosis), limitation (flexion deficit), and relapse, respectively. These suffixes helped contextualize the extent of mobility impairment observed by the clinician.[7] Ultimately, Dr. Millesi published numerous studies, authored many book chapters and lectured extensively on DD throughout his life.

FIGURE 3. A and B, From Millesi et al. (1972): *The Interfascicular Nerve-Grafting of the Median and Ulnar Nerves*.[2] A, "Sketch of nerve ends made during operation to define corresponding bundles to be joined by grafts." B, "Diagram showing fasciculi in the 2 nerve ends and a graft being placed between matched fasciculi."

LEGACY

Dr. Millesi's contribution to the scientific community extended far beyond his authorship of over 320 scientific publications as well as numerous books and book chapters. He was a member of 21 scientific societies located across North America, South America, Europe, and Asia. Dr. Millesi was also a founding member and President of the Austrian Society of Plastic Surgery, the International Society of Reconstructive Microsurgery, the German Speaking Study Group on Peripheral Nerves and Vessels, as well as the Austrian Society for Surgery of the Hand. He established the first 24-hour replanting service in Europe in 1974 and in 1998 he was honored as a "Pioneer of Hand Surgery" by the International Federation of Societies for Surgery of the Hand.[8,9]

Dr. Millesi received countless prestigious awards for his groundbreaking research and contributions to the field of peripheral nerve microsurgery and to the study and treatment of DD. He spoke at numerous conferences and meetings and shared his invaluable experience with colleagues in a variety of medical specialties around the world.[8,28] Dr. Millesi also devoted his career to teaching students. Those who knew him well appreciated his easily approachable, generous personality, open to anyone's suggestions or questions. Dr. Millesi was at all times

an elegant gentleman. His agility and finesse were not limited to the operating room—he was also known to gracefully dance to Austrian waltzes. He was a scholar, an innovator, a teacher, and a scientist. Dr. Millesi's pivotal contributions to plastic surgery continue to improve the lives of patients and shape the treatments they receive; his most important legacy may perhaps be quality of life restored to countless patients, even after his death.

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