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ORIGINAL ARTICLE - HISTORY OF NEUROSURGERY

The historical evolution of microvascular decompression for trigeminal neuralgia: from Dandy's discovery to Jannetta's legacy

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Abstract

Although the symptoms of trigeminal neuralgia (TN) have been well described throughout the history of medicine, its etiology was initially not well understood by most surgeons. The standard procedure used to treat TN today, microvascular decompression (MVD), evolved due to the efforts of numerous neurosurgeons throughout the twentieth century. Walter Dandy was the first to utilize the cerebellar (suboccipital) approach to expose the trigeminal nerve for partial sectioning. He made unique observations about the compression of the trigeminal nerve by nearby structures, such as vasculature and tumors, in TN patients. In the 1920s, Dandy unintentionally performed the first MVD of the trigeminal nerve root. In the 1950s, Palle Taarnhøj treated a TN patient by performing the first intentional decompressive procedure on the trigeminal nerve root solely through the removal of a compressive tumor. By the 1960s, W. James Gardner was demonstrating that the removal of offending lesion(s) or decompression of nearby vasculature alleviated pressure on the trigeminal nerve and the pain associated with TN. By the 1990s, Peter Jannetta proved Dandy's original hypothesis; he visualized the compression of the trigeminal nerve at the root entry zone in TN patients using an intraoperative microscope. In this paper, we recount the historical evolution of MVD for the treatment of TN.

Keywords James Gardner · Microvascular decompression · Palle Taarnhøj · Peter Jannetta · Trigeminal neuralgia · Walter Dandy

Introduction

Trigeminal neuralgia (TN) was first described by Nicolas André as "tic douloureux" in 1756 [3]. The disease in its classical form produces intense, lancinating facial pain in an unpredictable, episodic manner. This is typically due to compression of the trigeminal nerve by offending structures, such as vasculature [3]. Today, microvascular decompression (MVD) is the conventional operation used to treat TN due to its high success and minimal recurrence rates [1, 16, 25]. The procedure involves the separation of the trigeminal root from its compressive structure [16]. The efforts of numerous neurosurgeons who explored MVD throughout the twentieth century resulted in the large-scale adoption of the procedure by the neurosurgical community.

We previously published a broad overview of the history of TN and a variety of surgical and percutaneous treatments [20]. Here in this historical review, we focus and elaborate on the historical evolution of the MVD procedure, primarily from the 1920s to the 1990s, from Dandy to Jannetta. We incorporate new information from various sources into the timeline to

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enlighten our understanding of the development of MVD and its acceptance as the ideal procedure for the treatment of TN.

Early revelations, criticisms, and rejection: the microvascular compression theory

Surgical options for TN management have existed since 1858 [3, 26]. By 1928, the Spiller-Frazier technique (Fig. 1a, b), a refinement of the Hartley-Krause (Fig. 1c, d) technique, permitted the exclusive sectioning of affected parts of the dorsal trigeminal root through a middle fossa approach and became the standard approach to treat TN (Fig. 2) [3, 20]. Perturbed by the complications of facial paralysis and anesthesia associated with the Spiller-Frazier technique [20], Walter Dandy (Fig. 3d) eventually developed a route to the posterior fossa that he named the "cerebellar approach," which is essentially similar to the current retromastoid suboccipital approach. With this technique, the sensory root of the trigeminal nerve was exclusively targeted and partially sectioned through a posterior fossa approach (Figs. 3a–c and 4) [20]. Dandy's technique was associated with significantly decreased risks of facial paralysis and anesthesia because it was directed at the portion of the sensory root farthest from the facial nerve, geniculate ganglion, and trigeminal motor root [21]. Using this partial sectioning technique, he was able to preserve some facial sensation and avoid trigeminal motor dysfunction, remarkably without the aid of an operative microscope.

In 1929, after utilizing his technique for some time, Dandy detected a difference:

> "… It was observed that the complications of the old method (Spiller-Frazier) did not appear; there were no corneal disturbances and the motor root was never injured. Moreover … sensation of varying amount was

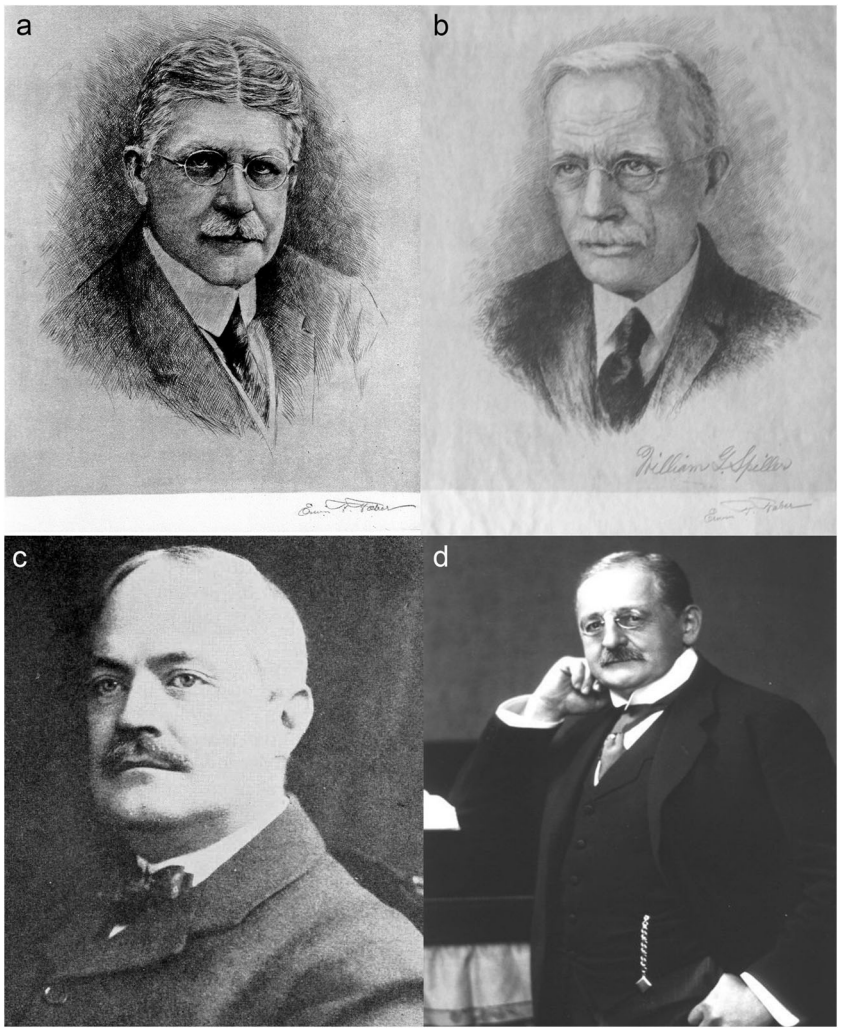

Fig. 1 **a** Etching of neurosurgeon Charles H. Frazier (1870–1936) (Public domain: https://collections.nlm.nih.gov/catalog/nlm:nlmuid-101415402-img). **b** Neuropathologist and neurologist William G. Spiller (1863–1940) (Public domain: https://www.philaprintshop.com/histfig.html). **c** Portrait of surgeon Frank Hartley (Public domain: reprinted from Stookey BP, Ransohoff J (1959) Trigeminal neuralgia: its history and treatment Charles C Thomas Publisher, Springfield). **d** Portrait of surgeon Fedor Krause (Public domain: https://collections.nlm.nih.gov/catalog/nlm:nlmuid-101420883-img). Both described an extradural, subtemporal, middle fossa approach for Gasserian ganglionectomy in 1892

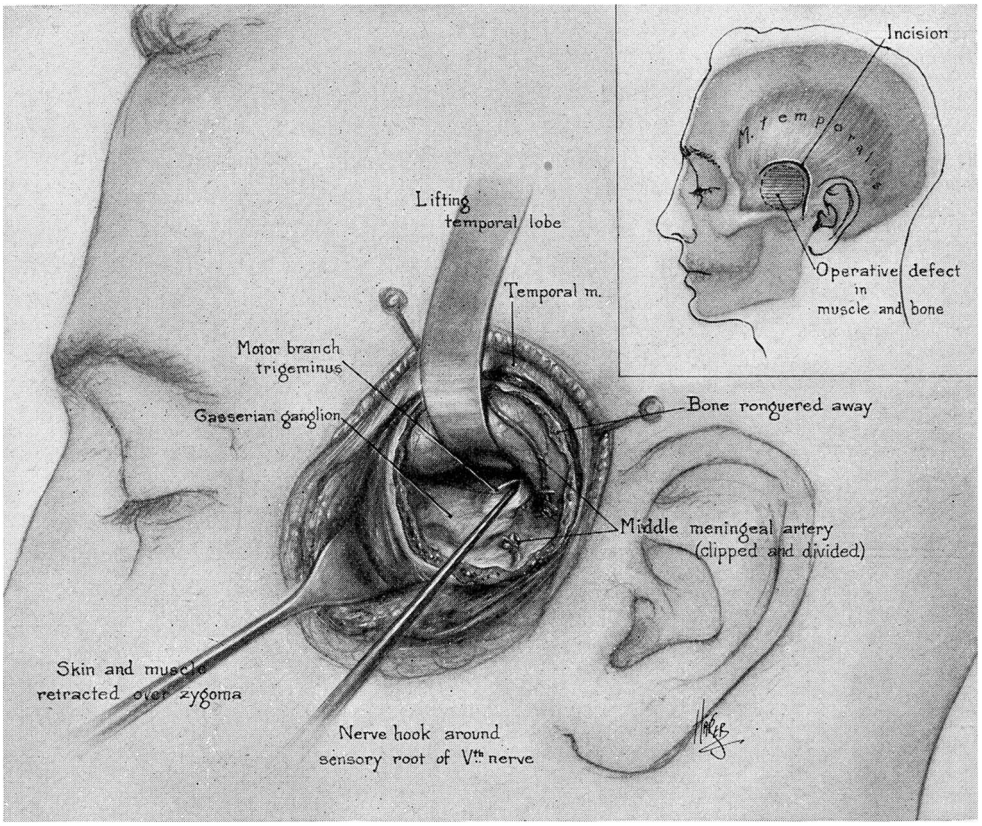

Fig. 2 The modification of the Hartley-Krause subtemporal approach performed by Spiller and Frazier. The temporal lobe is retracted upward and a nerve hook can be seen around the sensory root of the trigeminal nerve. The motor root and Gasserion ganglion can be visualized more medially and anteriorly, respectively (Public domain: reprinted from Dandy WE (1963) The brain. In: Walters W, Ellis FH Jr Lewis-Walters practice of surgery, vol. XII. WF Prior Co, Hagerstown, Maryland, pp 1–671)

usually but not always retained in the face, and without return of the pain" [4].

In 1929, Dandy published his first case series of his technique in *Archives of Surgery* [4]. Visualized by his own naked eyes without an intraoperative microscope, he made remarkable intraoperative observations of neurovascular compression at the trigeminal root which were demonstrated in his operative illustrations. He described arterial loops that interfered with the visibility of the sensory root of the trigeminal ganglion in a few cases [4]. In one of these cases, he unintentionally performed the first MVD of the trigeminal nerve root:

> "Only occasionally does an artery concern the operator, but in two or three instances an arterial loop projects freely in the subarachnoid space and encircles the sensory root. At these times … the part of the artery between the pons and the sensory root is cautiously isolated from the nerve … before its division with the knife. In one instance it was necessary to depress the free arterial loop, and a small wet cotton pack was used to cover and keep it out of reach during the manipulation of the nerve" [4].

In 1932, Dandy presented over 250 cases of TN treated with his technique in a precedent-setting publication in *Annals of Surgery* [5]. In his report, he frequently observed conflict at the trigeminal root usually by neurovascular compression:

> "It is worthy of note in passing that in perhaps one-third of the cases … a gross lesion is disclosed which we think is responsible for the trigeminal neuralgia. Aside from tumors the two common causes are, free arterial loops … and the venous branches which cross the nerve, sometimes dividing it into two parts" [5].

Despite Dandy's significant findings, he was continuously defending his ideas from criticism by his peers. William Van Wagenen criticized Dandy's cerebellar approach as "considerably more hazardous and difficult" [30]. Dandy, in response, stated:

> "It was largely the inferior results with the temporal route that led me to search for a different attack. I think it very unfair to make assertions that this approach is highly dangerous when I have done 150 such operations without a death or undesirable sequelae" [5].

Later, Dandy was criticized at the American Neurological Association meeting by William Spiller, Charles Frazier, and

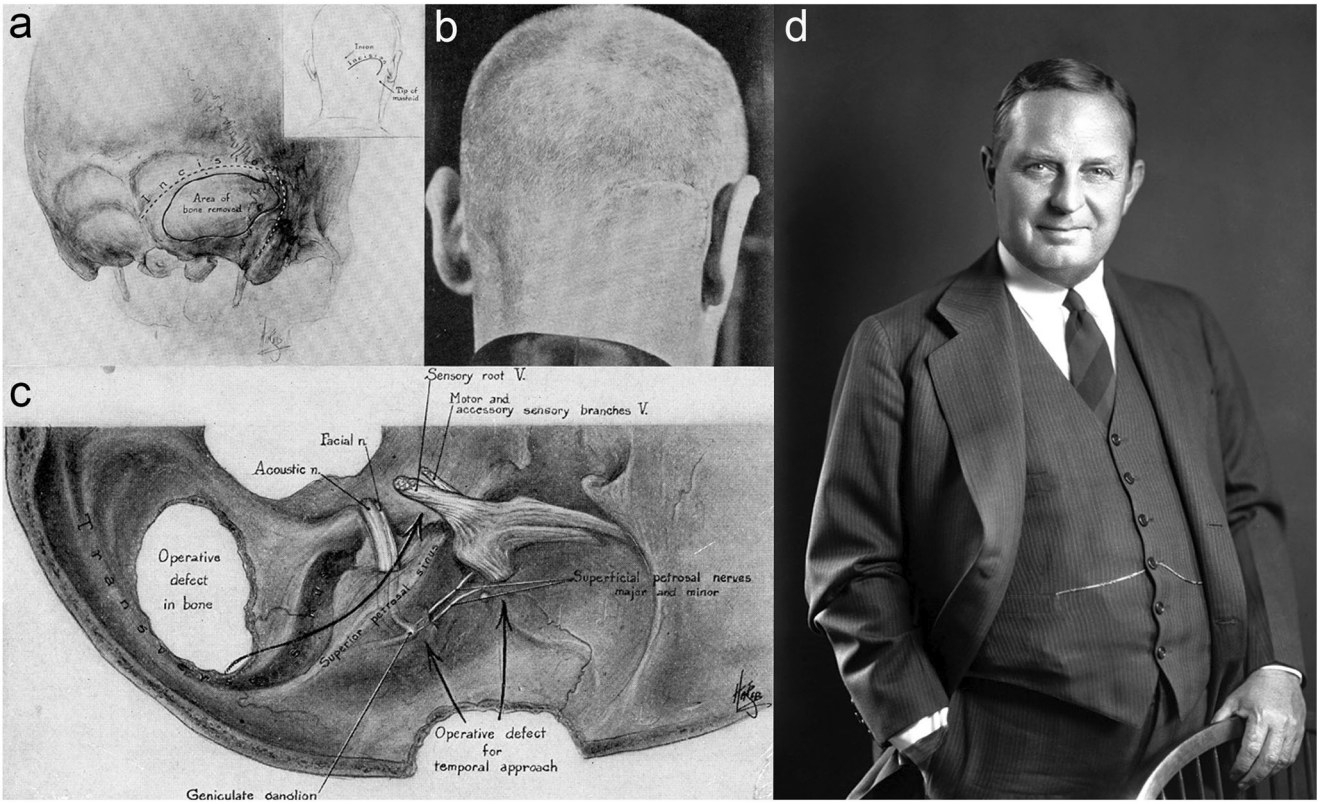

Fig. 3 **a** Drawing portraying the skin incision and craniotomy performed by Dandy in his suboccipital cerebellar technique targeting the trigeminal root. **b** Photograph of a healed skin incision post-surgery involving the suboccipital cerebellar technique. **c** Anatomic drawing comparing the operative defects that resulted from the temporal or middle fossa technique of Frank Hartley and Fedor Krause and the suboccipital or posterior fossa technique of Walter Dandy (Public domain: reprinted from Dandy WE (1963) The brain. In: Walters W, Ellis FH Jr Lewis-Walters practice of surgery, vol. XII. WF Prior Co, Hagerstown, Maryland, pp 1–671). **d** Portrait of neurosurgeon Walter E. Dandy (1886–1946) (Permission: courtesy of Mary Ellen Marmaduke)

others [7]. Dandy wrote to his first resident, Frederick Reichert, that he had been the object of a concerted attack:

> "You should have been to the American Neurological Meeting. There was a well-planned attack by Frazier, Loyal Davis, Stookey and Spiller and I got nothing but very hard words from all of them … [Frazier] is quite rabid on the subject, which, of course, is encouraging for it shows that his back is against the wall" [7].

In 1934, Dandy analyzed 215 of his roughly 500 cases in a publication in *The American Journal of Surgery* [6]. Dandy explicitly commented on his findings of pressure on the trigeminal root caused by various structures (Fig. 5), most commonly the superior cerebellar artery or petrosal vein, in a majority of these cases:

> "… I have been impressed with the frequency of certain anatomical findings which, I believe, must have a bearing upon the production of this pain" [6].

Though his hypothesis would later prove to be correct, Dandy himself did not test his postulations [20]. One reason could have been the apparent resistance that his approach received when compared to the Spiller-Frazier approach. Dandy was the only neurosurgeon utilizing his cerebellar approach at the time (Fig. 6). A second reason could have been the difficulty associated with further experimentation, as a majority of these vascular structures are indiscernible to the naked eye and Dandy's observations were documented without the assistance of a surgical microscope. A third reason could have been a possible prejudice against Dandy that prevented him from pursuing his original observations. In particular, during the period when Dandy's work was coming to fruition, Harvey Cushing was beginning to be referred to as one of the pioneers in neurosurgery:

> "No one would dispute Cushing's skills nor his contributions to the field nor the influence he wielded from his position at the Harvard Medical School. And no one would dispute the fact that he had little regard for Walter Dandy, which had an effect on the acceptance of Dandy's work" [24].

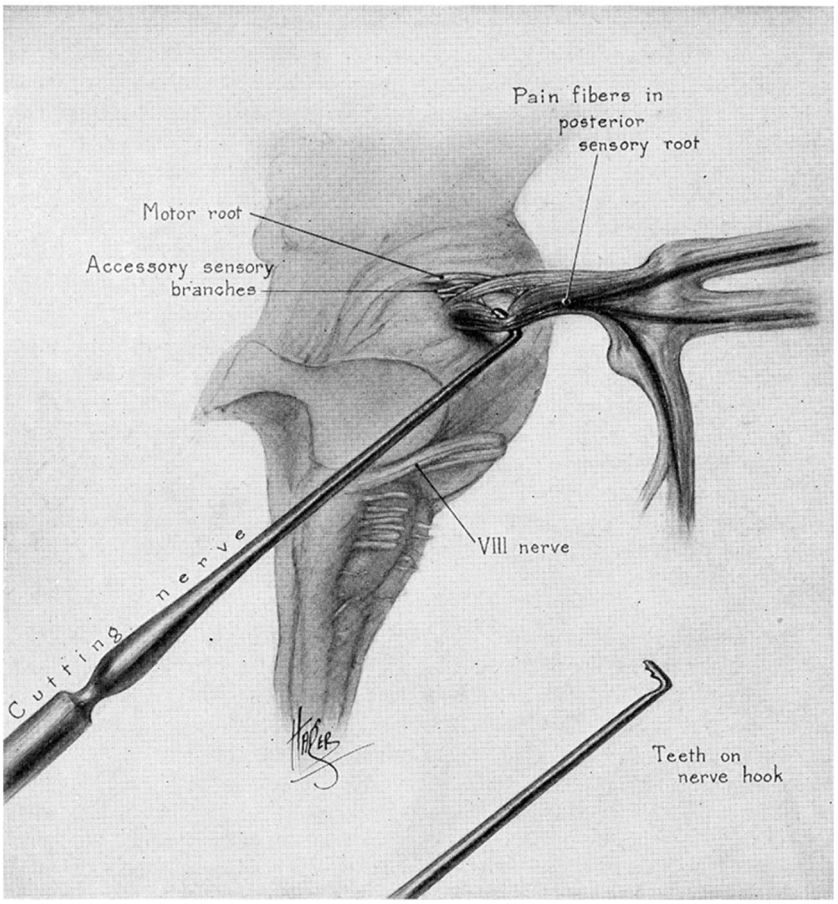

Fig. 4 Diagram depicting partial sectioning of three branches (seen here as dark fibers in the nerve hook) in the posterior part of the sensory root as advocated by Dandy (Public domain: reprinted from Dandy WE (1963) The brain. In: Walters W, Ellis FH Jr Lewis-Walters practice of surgery, vol. XII. WF Prior Co, Hagerstown, Maryland, pp 1–671)

The lack of further publications by Dandy regarding his technique after 1934 would eventually lead to it being temporarily forgotten by the neurosurgical community by the 1940s [24].

Restoration of the suppressed theory: the Copenhagen and Cleveland series

In the early 1950s, Dandy's postulations underwent a revival in Copenhagen, Denmark, primarily due to the efforts of Palle Taarnhøj at Rigshospitalet [20]. In 1951, a 31-year-old male was admitted to his department with classical TN. Taarnhøj recalled a report by his former mentor, Herbert Olivecrona, on cholesteatomas at the cerebellopontine angle that caused TN [19]. Similarly, Taarnhøj attributed the patient's TN to an epidermoid tumor in the right cerebellopontine angle. His suspicion was confirmed during surgery and the epidermoid was removed [27]. However, it was not what Taarnhøj did as much as what he did not do that would lead to his discovery. During surgery, Taarnhøj had felt it was enough to remove the tumor and relieve the pressure on the trigeminal root and posterior part of the ganglion without performing a neurectomy [27]. The patient woke up with complete pain relief and was discharged without symptoms [27]. Taarnhøj had become the first surgeon to intentionally perform a decompressive procedure on the trigeminal root without sectioning. While the majority of Taarnhøj's cases involved dividing the dura over the root, he speculated that some "small changes, either in the dura or adjacent tissues, perhaps of vascular origin, could be assumed to narrow the channel so much that a compression takes place," further suggesting that it could be "possible to treat patients with trigeminal neuralgia by dividing the dura over the root without trigeminotomy" [27]. The Taarnhøj technique, a modified version of the Spiller-Frazier technique, was positively received by the neurosurgical community due to limited recurrence of pain and absence of permanent facial paralysis or anesthesia [28, 29].

Taarnhøj's progress was being followed by W. James Gardner at Cleveland Clinic (Fig. 7) [20]. Gardner's interest in TN began with his residency training in 1926. An unexpected vacancy in Frazier's program at University of Pennsylvania catapulted him to chief resident. By then, Frazier's approach for TN had been well established and Gardner witnessed the results firsthand. Gardner eventually adopted the Taarnhøj technique [10].

By 1962, Gardner was emphasizing the mechanism of sensory root compression as the cause of TN. He believed that removing the offending lesion(s) or performing a

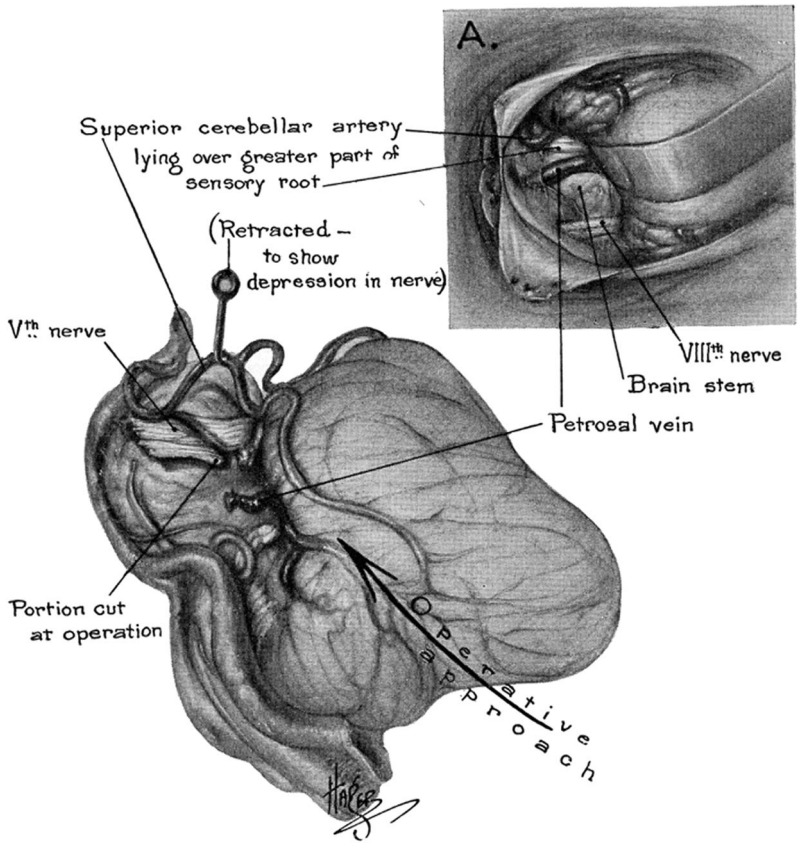

Fig. 5 Drawing depicting compression of the trigeminal nerve root by the superior cerebellar artery (Public domain: reprinted from Dandy WE (1963) The brain. In: Walters W, Ellis FH Jr Lewis-Walters practice of surgery, vol. XII. WF Prior Co, Hagerstown, Maryland, pp 1–671)

vascular decompression without neurectomy alleviated the pain associated with TN [20]. Of Gardner's 100 surviving patients, 67 reported no paroxysms after recovery; of the remainder, only eight reported mild recurrence [9]. Gardner accurately described the vascular compression of not only the trigeminal nerve as the cause of TN but also of the facial nerve as the cause of another related condition, hemifacial spasm (HFS) [8]; he became the first neurosurgeon to perform MVD for HFS [11]. However, similar to Dandy, Gardner was unable to produce evidence for the vascular compression hypothesis due to the unavailability of a surgical microscope at the time [20].

Initial skepticism and eventual acceptance: the rise of microvascular decompression under Jannetta

The classic MVD procedure underwent its last refinements under Peter Jannetta (Fig. 8). In the 1960s, while Gardner was publishing his findings, Jannetta was a research fellow working on the spinal cord projections of the vestibular system in cats. For such detailed research, Jannetta utilized an operating microscope on a daily basis. Solomon Erulkar, his mentor, recalled:

> "Peter was very, very taken with the microscope … Peter perfected the use of the microscope, got used to seeing things under high resolution, which, of course, later was of much importance in his work at UCLA [University of California, Los Angeles]" [15].

Through this experience, Jannetta became confident in the value of the microscope. Jannetta was pleasantly surprised that UCLA neurosurgeon, Robert Rand, was utilizing it when he arrived for his residency. Because Jannetta demonstrated proficiency with the microscope, Rand requested that he dissect the cranial nerves on a closed-circuit television for dental students. According to Jannetta, this small task was "a little job that changed my life" [15]. It was through these dissections that Jannetta was able to develop and perfect his approach for the treatment of TN. His index case arrived when a patient at an affiliate hospital presented with classical right-sided TN. Jannetta was forbidden to operate at the teaching hospital of UCLA. Moreover, he was not allowed to operate using the retromastoid exposure in general. Throwing caution to the wind, Jannetta transported Rand's microscope to the Harbor General Hospital in his 1957 Ford station wagon. Jannetta recalled:

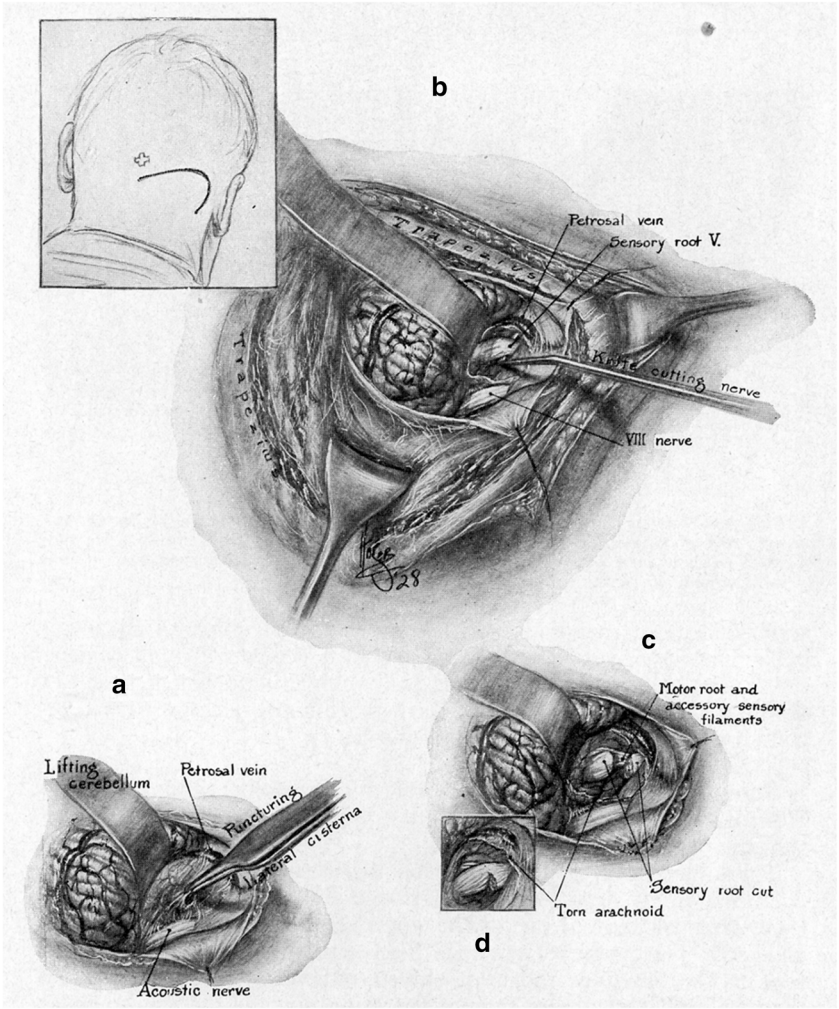

Fig. 6 Drawings outlining Dandy's technique. **a** The release of the cisterna lateralis in order to gain access to the trigeminal nerve. **b** The relationship of the petrosal vein and the auditory nerve to the sensory root of the trigeminal nerve (seen here divided by the nerve hook). **c** The result of partial sectioning of the sensory root with preservation of the motor root of the trigeminal nerve *(*Public domain: reprinted from Dandy WE (1963) The brain. In: Walters W, Ellis FH Jr Lewis-Walters practice of surgery, vol. XII. WF Prior Co, Hagerstown, Maryland, pp 1–671)

> "A magic moment! We exposed the trigeminal nerve through an opening in the tentorium cerebella. An artery, the superior cerebellar artery was cross-compressing the trigeminal nerve. 'That's the cause of the tic,' I said. It was very convincing to me" [15].

Although Jannetta proceeded to perform a selective nerve sectioning, he was motivated to determine if his intuition was correct. Jannetta was utterly convinced that he had discovered the cause of TN but continued to perform the partial sectioning of the root. Furthermore, he was convinced that a vascular etiology was responsible for another related condition, HFS. Jannetta proceeded to perform MVD on a patient with HFS in 1966 [15].

Jannetta later operated on a 41-year-old mechanic with progressive left-sided HFS. Much to his dismay, he discovered that the anterior inferior cerebellar artery was not affecting the seventh nerve. Instead, he made a peculiar observation: a small vein was crossing the facial nerve, directly anterior to the pons. Jannetta divided the vein and coagulated both ends. The patient subsequently woke up with mild HFS, which was fleeting and eventually subsided permanently. Several decades later, Jannetta recounted, "If I had remained interested in the artery and had not seen the vein, I do not know if I ever would have had the temerity to persist with the MVD" [15]. For Jannetta, this case established the legitimacy of the vascular compression theory and the efficacy of the MVD procedure. Soon after, Jannetta operated on five more patients with TN, selectively sectioning the sensory root and finding small arteries compressing the nerve in all cases (Fig. 7a–c) [17]. He published his first case series of MVD for TN in 1967 [12].

More than 40 years after the controversy associated with Dandy, the neurosurgical community still did not welcome the vascular compression theory; Jannetta received both criticism and opposition. In his foreword in the 2005 *Neurosurgical Focus* issue entitled "Trigeminal Neuralgia," Jannetta wrote:

> "The facts in reading about the origins and mechanism of TN were almost incomprehensible to me … Furthermore, when I made my first observations on blood vessels triggering and causing TN, I was

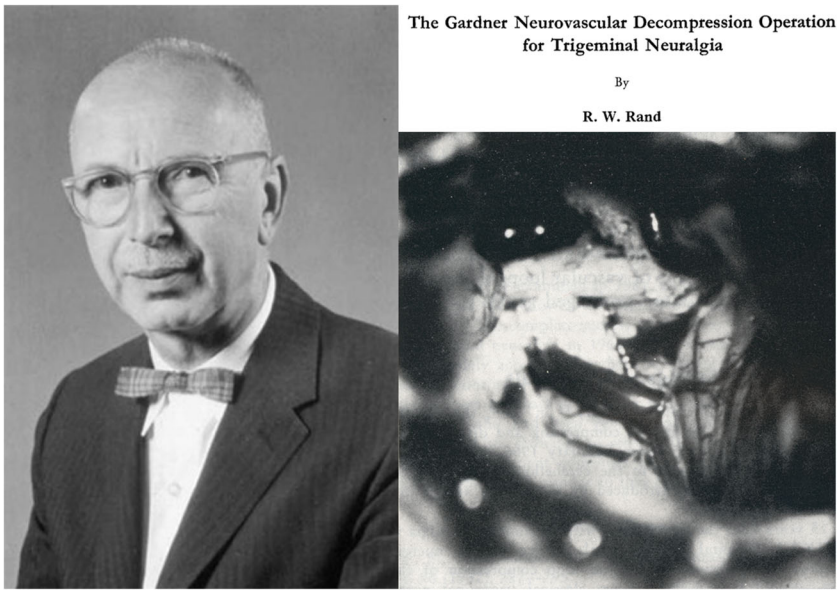

Fig. 7 Left: Portrait of neurosurgeon W. James Gardner (1898–1987) (Permission: reprinted from Dohn DF (1991) W. James Gardner, M.D. Surg Neurol 35:5–7). Right: Cover page of Robert Rand's publication, "The Gardner Neurovascular Decompression Operation for Trigeminal Neuralgia," (Permission: reprinted from Rand RW (1981) The Gardner neurovascular decompression operation for trigeminal neuralgia. Acta Neurochir 58:161–166) and the separation of arteries from the trigeminal nerve via Gardner's technique (Permission: reprinted from Rand RW (1981) Gardner neurovascular decompression of the trigeminal and facial nerves for tic douloureux and hemifacial spasm. Surg Neurol 16:329–332)

unprepared for the 'loyal opposition,' the Tories, so to speak, the resisters to change, the people who wanted to keep things the way they were" [14].

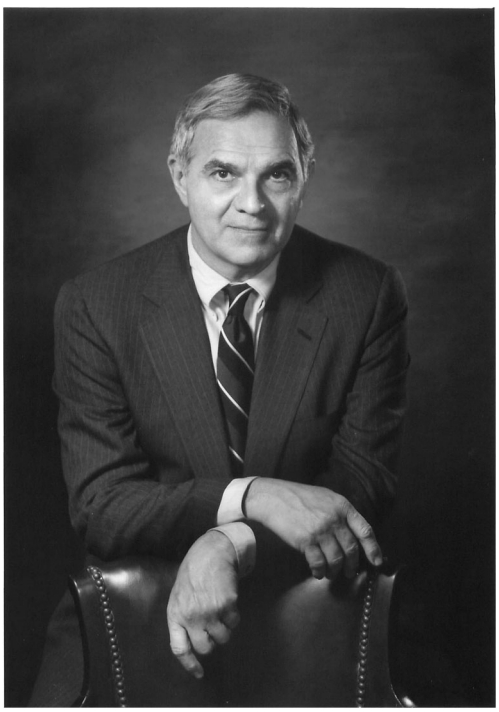

Fig. 8 Portrait of neurosurgeon Peter J. Jannetta (1932–2016) (Permission: c*ourtesy* of Raymond F Sekula, Jr, MD)

In his biography of Jannetta, Mark Shelton wrote:

> "The world of neurosurgery was not particularly ready for Peter Jannetta nor for his brand of revolution, which is one reason … why he has been called a quack and a fake, why some neurosurgeons think and say … that the whole business is an embarrassment and a fraud perpetuated by an arrogant youngster who thinks a tiny blood vessel, in just the right place, causes everything from trigeminal neuralgia to plagues of locusts, or so it seems" [24].

Not only did many neurosurgeons of the day view his ideas as preposterous, but much of the controversy around Jannetta's procedure was that his "novel" decompression surgery had been performed in the past by Dandy and Gardner [2]. In 1981, Rand commented that the MVD procedure is often misnamed as the "Jannetta operation" and, rather, Gardner should receive credit for its conception and development [23]. These strong accusations weighed heavily on Jannetta, as he was always conscious to reference his predecessors and never suggested the invention of the MVD as his original idea.

In 1967, Jannetta moved to Louisiana State University [15]. There, he was finally provided the opportunity to pursue his theory and routinely perform atraumatic MVD (without neurolysis or nerve sectioning) for TN and HFS using a

retromastoid suboccipital approach. By late 1967, he felt that the vascular compression theory was correct and the results from his patients were consistent. He stated:

> "It was progressively more reasonable to assume, as our experience evolved, that TN is due to vascular compression of the trigeminal nerve … compressing vessels were frequently multiple and often distal" [15].

Around this time, MVD for TN was being performed with other approaches by other neurosurgeons. Jules Hardy from Montreal, Canada, was the first neurosurgeon to use the technique via the cerebellopontine approach, publishing his findings in 1970 [22]. In the 1990s, Jannetta successfully convinced the scientific community of his findings. Using a microscope, Jannetta clearly visualized offending arteries and veins. Though Jannetta was initially not familiar with the findings of Dandy and Gardner when he made his first observations of vascular compression of the trigeminal nerve, he eventually incorporated their work in addition to his own findings to successfully promote the utility of MVD. In 1996, nearly three decades after his first MVD, Jannetta published a series of 1185 patients treated with MVD at the Presbyterian University Hospital in Pittsburgh [1]. Jannetta then challenged his peers to test his findings. The initial success rate was 82% for complete relief, 16% for partial relief for a combined rate of 98%. At 10-year follow-up, 68% of patients reported excellent or good relief. While drawing parallels between his own work and Dandy's, Jannetta recalled:

> "Dandy wasn't able to do what he had to do outside the operating room. He was advocating a difficult procedure that was unsafe unless the neurosurgeon had been well trained in the technique. He didn't train … surgeons to do the procedure, which is necessary if something is going to be kept alive. One surgeon, no matter how much he operates, has very little effect. But if [he or she] trains a group of surgeons who go forth and multiply and train others, then the ripple effect is tremendous" [24].

Once Jannetta's ideas were established, MVD became an accepted treatment for TN and other neurovascular compression syndromes [13, 18]. Jannetta's contribution to the advancement of MVD surgery was well encapsulated by Shelton:

> "One person cannot change medicine unless he changes the minds of enough of his peers for word to begin to get around. Only then is the revolution safe" [24].

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

Abbreviations *HFS,* Hemifacial spasm; *MVD,* Microvascular decompression; *TN,* Trigeminal neuralgia; *UCLA,* University of California, Los Angeles

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