Historical Vignette

The Krause operations

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Some of Fedor Krause's contributions to operative technique are reviewed and portrayed as fundamental steps in the progress of neurological surgery. The approaches he devised, the "Krause operations," are exposure of the trigeminal ganglion and root, of the cerebellopontine angle, and of the pituitary (transfrontal) and the pineal (supracerebellar) regions. This review recalls the significance of the aggregate body of Krause's work, which has not been fully appreciated except by his compatriots.

Key words • Fedor Krause • neurosurgical history • operative technique

The German surgeon-anatomist Fedor Krause (Fig. 1) was born in 1857 and died in 1937. He advanced neurosurgery by devising practical operative approaches to hitherto inaccessible regions of the brain. Over the years, Krause has been somewhat in the shadow of other neurosurgeons outside Germany,27 but his contributions to clinical and operative neurosurgery cannot be overemphasized. On first looking at the surgical exposures illustrated in his papers and books, one is struck by their familiarity only because they have long since been incorporated into standard neurosurgical technique. This, however, should not blur their origin. Krause did more for the practice of neurosurgery than for its science, where he was surpassed by the surgeon-physiologist Victor Horsley, but he was the first to systematize the clinical and operative neurosurgery of his day.

Published first in Germany from 1908 to 1911, Krause's Surgery of the Brain and Spinal Cord29 was didactic as well as practical, a textbook as well as an atlas. The surgical impact of Cushing's 1908 comprehensive treatise, "Surgery of the head"30 was less by comparison because it did not project neurosurgical techniques as vividly. Krause's book, filled as it is with case histories, with illustrations of the operations and lesions found, and with innumerable observations and technical details based on his personal experience, encompassed all of contemporary neurosurgery. Despite a few archaisms, it reflects the attainments of neurosurgery. As one of those who forced the limits of neurosurgery, an innovator, and a versatile master surgeon, Krause was the forerunner of Walter Dandy.

Behrend's article in Grosse Nervenärzte44 is a resource for material on Krause's career. Krause's teacher was Richard Volkmann, whose experience with trephination and trigeminal neuralgia introduced him to neurosurgery. In a letter dated 1889, the year he died, Volkmann wrote that his first assistant, F. Krause, had been active with him for 6 years, had developed into a finished surgeon capable of performing all operations, had conducted lectures and scientific work, and possessed unusual clinical experience, a humane attitude, and great talent. Krause succeeded Volkmann at Halle until 1892, when he moved to the Hamburg-Altona City Hospital to be director of the surgical clinics. He revered Volkmann all his life and would reminisce about him lovingly while scrubbing with his assistants. Behrend wrote that many today would find Krause's words of respect for his chief "romantic," but their sincerity had to be respected.44

In 1900, Krause became chief at the Augusta Hospital in Berlin, and for the next 30 years he pursued an intensive general surgical and neurosurgical practice. He was the trusted consulting surgeon for the Berlin neurological community, at the head of which was Oppenheim. From his collaboration with Oppenheim came much of the material presented in Surgery of the Brain and Spinal Cord.39 In recognition of his unique contributions, he was appointed Honorary Professor in the Berlin Medical Faculty. He retired from practice in...
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1930, but followed the advances in American neurosurgery with interest.

Krause's neurosurgical "descendants" may be traced through Heymann in Berlin and Koenig, an early transpalatal transsphenoidalist who succeeded him at the Hamburg-Altona City Hospital in 1900. According to Gerlach,2 Koenig was "one of the first general surgeons to propose that neurosurgery should not be undertaken 'between two appendectomies,' but required an exclusive department." He sent his assistant Tönnis to study with Olivecrona; in 1937, Tönnis, the founder of the Zentralblatt für Neurochirurgie, was named to the first chair in neurosurgery in Germany at the University Clinic of Berlin. Gerlach chronicled these and succeeding events.

Geoffrey Jefferson, a recipient of the Krause medalion from the German Society of Neurosurgery, said that Krause must have labored more than he did under the bias "that surgery of the brain was a sad, discouraging undertaking." Behrend paid Krause a knowing tribute when he wrote that, "If one thinks of the successes he obtained without the indispensable aids available today, one must marvel at his achievements." In celebrating Krause's 80th birthday in Berlin in 1937, Ferdinand Sauerbach honored him with these measured words: "As a master of the surgical art you were a pioneer in the difficult field of neurosurgery at the turn of the century. Your enthusiasm for the young specialty, your fundamental work and skilled hands were the prerequisites for its systematic development. You can look back on your work with pride, and rejoice in its future progress and prosperity. Even the notable progress in surgery of the central nervous system in other countries rests to a large extent on your basic work." (italics mine).

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Trigeminal Neuralgia

Krause's involvement in neurosurgery began in 1892 with his operations for trigeminal neuralgia, although an earlier interest is reflected in a dissertation on malignant neuromas in 1887. In the 1890's, the stage was set for an intracranial approach to the trigeminal nerve. Horsley reviewed the prior extracranial operations and then gave a description of his own intradural exposure and avulsion of the trigeminal root in 1891 in a detailed three-part article. From his conclusion, it is clear that Horsley still favored extracranial peripheral operations, and he wrote that as soon as drugs and electricity fail to control the pain, "the branch of nerve affected should be excised." In the United States in August, 1891, Hartley performed an extradural neurectomy of the second and third divisions and introduced it as a new method in the New York Medical Journal of March, 1892. The nerves were divided at their foramina and resected with a portion of the ganglion. In February, 1892, Krause operated in two stages on a patient who had failed resection of the maxillary nerve in the ptergomaxillary space. He resected 0.5 cm of the second division after making a temporal osteoplastic flap and elevating the dura. He had prepared himself for the operation by doing many cadaver dissections. When he researched the literature for his publication in October, 1892, he was unaware of Hartley's recent paper and referred only to the intracranial procedures of Rose (1890) and Horsley (1891). Rose had reached and partly removed the ganglion by drilling up through the foramen ovale from the infratemporal fossa. Krause emphasized the advantage of the extradural approach over Horsley's intradural method, saying that it avoided the direct pressure of elevation of the temporal lobe.

By the following year, 1893, Krause had extended the operation to include resection of the ganglion and the root, giving as his rationale the need to avoid injury to the cavernous sinus when operating for ophthalmic neuralgia. Horsley had already made the point that in resecting the ophthalmic nerve in his anatomical preparations he always entered the cavernous sinus. Krause revised the operation to be done in one stage. It included reflecting a temporal skin flap, performing a craniectomy rather than creating an osteoplastic bone flap, ligation of the middle meningeal artery, elevation of dura (but avoidance of exposure of the ophthalmic nerve), and resection of the maxillary and mandibular...
nerves at their foramina and of the ganglion and root posteriorly. In 1896, his 260-page monograph on trigeminal neuralgia appeared. It included anatomy, physiology, and clinical and surgical experience in 14 cases, with postoperative sensory charts by Nonne. By 1897, he had operated on 30 patients, one of whom died; by 1911, he had performed 70 resections. Horsley had treated only eight cases by 1897, using a modified Hartley-Krause operation. In August, 1899, Cushing, who was 12 years younger than Krause and just starting his neurosurgical career, performed his first operation for trigeminal neuralgia, essentially along the lines of the Hartley-Krause procedure with his own modifications, one being that he did not ligate the middle meningeal artery. Despite his early and profound interest in the operation, Cushing did not meet Krause when he took his working vacation in Europe in 1900 and 1901.

In view of the frequency of trigeminal neuralgia surgery today and its role, not as a last stage but as an early step in treatment, consider the following example of Krause’s foresight and confidence in his operation: “In general, an extirpation of the ganglion should only be considered after less serious operations have failed. Should, however, further experience teach that removal of the gasserian ganglion cures permanently . . . it is probable that the stage will be reached when the operation will be undertaken in the very beginning.”

**Tumors of the Cerebellopontine Angle**

Krause’s approach to tumors of the cerebellopontine angle evolved from an operation on the acoustic nerve. In 1897, he was consulted about a patient with intractable tinnitus, the question being whether the condition was analogous to trigeminal neuralgia and so might be helped by acoustic nerve section. After anatomical study and preparation, Krause operated in July, 1898, with the patient in a sitting position; he used a unilateral suboccipital osteoplastic flap which exposed the transverse and sigmoid sinuses. After the dura was opened, Krause had the assistant who was holding the head tilt it to the opposite side, allowing the hemisphere to fall away. With mild retraction he saw the tentorium, the petrous surface, a vein that he ligated and divided passing from the superior petrosal sinus to the cerebellum, and the nerves entering the porus. An exquisite drawing of the field was made by his medical artist (Fig. 2), and a photographer made stereoscopic views of the exposure which were included in the paper. From previous observations, Krause knew that the acoustic nerve was reached first, that the facial nerve lay in a furrow on its deep surface, and that the acoustic nerve was especially soft (portio mollis), whereas the facial nerve was firm (portio dura). He divided the acoustic nerve, sparing the facial nerve and the internal auditory artery. The patient awoke with mild facial weakness. The tinnitus was gone in 48 hours and she was taking fluids, but she developed pneumonia on Day 5 and died. At autopsy there was minimal posterior fossa blood, no meningitis, and pneumonia.

Krause wrote that the exposure used for that patient is potentially useful for the proportionately large number of benign, encapsulated tumors that occur in the cerebellopontine angle. In that paper, he described the use of ventricular puncture above the transverse sinus in two cases of suspected cerebellar tumor, saying that cerebrospinal fluid drainage made it easier to explore the surfaces of the cerebellum.

A paper by Stewart and Holmes on the symptomatology of cerebellar tumors credits Horsley, in passing, with removing cerebellopontine angle tumors in at least four cases, one of which involved bilateral tumors; however, details are not given. In 1906, Krause described removal of acoustic tumors in two patients using his approach to the eighth nerve. The first patient recovered and improved after total resection; the second died after subtotal removal. Borchardt reviewed the contemporary literature on tumors of the cerebellopontine angle and stated that Krause’s case was the first successful one to be reported. From his own experience with operations in the posterior fossa, Borchardt was clearly aware of the occurrence of foraminal herniation. He described the transverse groove in the tonsils and recommended removal of the arch of the atlas.

In *Tumors of the Nervus Acusticus and the Syndrome of the Cerebellopontine Angle*, Cushing stated that “no matter how modified, all posterior unilateral measures have come to be attached to Krause’s name, with some justification in view of his careful description of the method.” It is clear that, in general, Krause had very detailed and practical knowledge of anatomical exposures, always appreciating the surgical possibilities of his dissections. By 1911, he had operated on 75 posterior fossa lesions, of which 25 were cerebellopontine angle tumors. In a chapter in which he acknowledged Heymann (pp 673–701), Krause gave details of the symptomatology and progression, the focal manifestations (he recognized that the facial nerve withstood the effects of large tumors), the applied anatomy of the operation, the clinical physiology of the cerebellum, and relevant pathology. The section is organized as a
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lesson, and could have served as a neurosurgical text. Some special features of his technique should be mentioned. As early as 1898, he placed his patients in the sitting position for this procedure, an assistant holding the head, or in the lateral position, sometimes with the assistant tilting the head to allow the cerebellum to sag to the dependent side. Krause specifically forbade the popular technique of finger dissection of tumors in the posterior fossa. He wrote, "...to find the line of cleavage between the normal cerebellum and neoplasm...it is best to employ small wipes affixed to slender holders which may be used alternately with a pliable spatula. The tactile finger is not available in this situation as it occupies too much room and may produce dangerous pressure upon the medulla. All manipulations should be executed slowly" (p 137).

Transfrontal Exposure of Pituitary Tumor

In a paper published in 1906, Horsley mentioned attempting a subfrontal approach to the pituitary in 1889. The difficulties, however, prompted him to refer to the approach as "prehistoric" and "not the proper way" when he later shifted to the subtemporal approach. In The Pituitary Body and Its Disorders, Cushing referred to the subfrontal operation as "inconceivably radical." His experience with intracranial pituitary surgery up to 1909, when he began to perform the transsphenoidal operation, was restricted to attempted subtemporal exposure or subtemporal decompression. It is plain that the increased intracranial pressure from large tumors and obstructive hydrocephalus was the factor that made the operation so difficult.

Because Krause came to pituitary surgery fortuitously, he had an entirely different view of the possibilities of the subfrontal exposure. In 1900, Krause removed a bullet from the region of the anterior clinoid process of a man who had been shot in the head 4 years earlier. He described elevation of an osteoplastic flap of the forehead lateral to the frontal sinus and an extradural approach until the dura was opened over the bullet. In opening the dura, he exposed the optic nerve and the carotid artery. As he was not operating on a tumor, it was easy to elevate the relaxed brain, and he was quick to see this as a potential approach to the pituitary. He wrote, "Though the peduncle (infundibulum) of the pituitary arises from the brain behind the chiasm, the hypophysis itself lies in front, beneath its anterior edge" (p 117).

In October, 1900, Krause demonstrated a cadaveric preparation of the exposure at a meeting of the Berlin Medical Association. After extradural elevation of the frontal lobe to the lesser wing of the sphenoid, he incised the dura at that point, exposing the optic nerves, chiasm, and hypophysis. In 1904, he removed a subfrontal sarcoma (meningioma) and, in 1909, exposed and removed a pituitary tumor through that route. Heuer, in his review of the surgical approaches to the pituitary, wrote, "While Krause himself seems to have performed few operations for hypophysial tumor, his operation has served as a model for almost all subsequent frontal operations."

Cushing's paper on his first 95 operations for pituitary tumor, published in 1913, did not mention the transfrontal exposure. He had used only the transsphenoidal approach, subtemporal decompression with or without subtemporal exploration, and subtemporal exploration alone. Not until the following year, when he gave the Weir Mitchell lecture, was he able to describe his beginning experience with the transfrontal operation.

Pineal Tumor

From 1898 onward, Krause used the following order of exploration for tumors of the posterior fossa: 1) the cerebellopontine angles; 2) the cerebellomedullary spaces beneath the tonsils; and 3) the superior surface of the vermis and hemispheres. Not until these explorations were negative did he incise the cerebellum. He said, "I make this an absolute rule" (p 133).

In 1913, he explored the posterior fossa in one of Oppenheim's patients who had papilledema and signs referable to the tectum and cerebellum. Finding nothing abnormal on the right or left, he sat the patient up straighter, flexed the neck, and elevated the tentorium with a retractor. Upon looking into the funnel-like space above the vermis, he saw the yellow-red surface of a tumor, quite distinct from the vermis. Using semi-sharp spoons, he shelled out a hard mass 38 × 40 × 18 mm in size. After controlling bleeding by packing the tumor bed lightly, he could see the internal cerebral veins and both pulvinars. In 1926, Krause wrote on his additional experiences with exposure of the tectum, and mentioned leaving an indwelling cannula in the posterior horn during the operation. It is this second paper that Stein refers to in calling the infratentorial supracerbellar exposure of the pineal region "Krause's approach."

Conclusions

Fedor Krause was an astute surgical anatomist. The logic and practicality of his surgical approaches have given them permanence in modern operative technique. He was alert to the possibility of new surgical exposures whether suggested by chance from other operations or undertaken by intent based on anatomical study, and his large number of referrals enabled him to put them into practice. Krause's papers and books reflect the attainments of neurosurgery in his time and his role in achieving them. The aggregate body of his writings assures him a place in the arch of modern neurological surgery which, Cushing said, is supported on one side by McEwen and on the other by Horsley.

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