Women have historically been poorly represented in neurosurgery. This is especially true in South Asia, considering the added social and cultural expectations for women in this region. Yet, it was in India, with its difficult history of gender relations, that Asia’s first fully qualified female neurosurgeon, Dr. T. S. Kanaka (1932–2018), took root, flourished, and thereafter played an integral role in helping develop stereotactic and functional neurosurgery in the country. While a few biographical accounts of her exist, highlighted here are the lessons from her illustrious life for neurosurgical trainees and educators worldwide, along with the instances that exemplify those lessons, drawn from several hitherto unutilized primary sources. These lessons are consistent with the factors identified in previous systematic reviews to be contributing to gender disparities in neurosurgery. Many of the virtues that ensured her success are attributes that continue to be critical for a neurosurgical career. Additionally, the circumstances that helped Kanaka succeed have been recounted as considerations for those working to promote diversity and inclusion. Finally, her life choices and sacrifices are described, which are underexplored but relevant concerns for women in neurosurgery.

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A Life Devoted to Neurosurgery

Thanjavur Santhanakrishna Kanaka, more widely known as T. S. Kanaka, was born on March 31, 1932, in the city of Madras (currently called Chennai) in South India, to highly educated parents and siblings. Her father was the principal of Teachers’ College of Madras, likely the oldest teacher training institute in India. She entered un-
Undergraduate medical education in the late 1940s, close to the time of Indian independence from colonial rule, when a spirit of defiance was prevalent. The same spirit would later go on to characterize how Kanaka confronted gender discrimination.

The growth of Indian neurosurgery and the life of Asia’s first female neurosurgeon are heavily intertwined. Returning to India after training in North America, Jacob Chandy, the “father of Indian neurosurgery,” had started the first stand-alone neurosurgical department in 1949 at Christian Medical College, Vellore (CMC-V) in Tamil Nadu. The second such department was established as part of the Madras Medical College (MMC) in 1950 by B. Ramamurthi, who would later become Kanaka’s most significant mentor. Both CMC-V and MMC were also the first in India to start neurosurgery residencies. Notably, Madras, in 1951, also served as the birthplace of the Neurological Society of India (NSI), the combined society of neurosurgeons and neurologists, with Ramamurthi as one of the four cofounders. It is against this backdrop that Kanaka’s journey began.

Finishing medical school in 1954, Kanaka pursued, against great hostility, a residency in general surgery. She obtained the degree of MS (Surgery) in 1963. During this period, she spent 2 years under Dr. A. Venugopal, a urologist at MMC, and also served for some time during the Sino-Indian war as an army surgeon in 1962 (Fig. 2).
During this period, stereotactic surgery was developing independently in several centers worldwide. Near the time Kanaka entered medical school, Ernest Spiegel and Henry Wycis in the US had built the first stereotactic frame for clinical use, expanding upon Horsley-Clarke’s concepts, and later had also created the first brain atlas.9 Concomitantly in Asia, Hirotaro Narabayashi had started stereotactic neurosurgery in Japan through building an indigenous instrument and was performing pioneering procedures with Sano, Jinnai, and Matsuomoto.9

By the time Kanaka completed medical school, Spiegel and Wycis had developed the stereoeoncephalotome, while Jean Talairach in France had greatly improved his grid-based coordinate system.10 Stereotactic surgery was being rapidly adopted and innovated upon by eager practitioners around the world by the time Kanaka finished her general surgery residency; key figures included Percival Bailey, George Austin, Arnold Lee, Irving Cooper, Nicholas Zervas, Blaine Nashold, Edwin Todd, and Theodore Roberts, among others.9 By this time, stereotactic surgery had started in Madras after visits by Lawrence Walsh and Denis Williams from the UK and the arrival of Leksel’s frame in 1962.11,12

For Kanaka, the journey ahead became easier, as she then found the teacher she wanted in Ramamurthi for neurosurgical training.8,13 She finished her MS (Neurosurgery) under him in 1968 from MMC and moved on to doctoral studies.3 Her PhD dissertation on “Evaluation of stereotactic surgery in the surgical management of cerebral palsy” was finished in 1972. The same year saw the inauguration of another of Ramamurthi’s endeavors, the Madras Institute of Neurology (MIN), modeled after the Montreal Neurological Institute, where he had trained. MIN was soon to become a center of excellence in clinical neurosciences.11 Kanaka soon became a permanent faculty member there, forging a place for herself at the institution that was making the greatest strides in stereotactic surgery in the country. Thereafter her career flourished, covered in greater detail elsewhere.2–4 She and her colleagues performed the first neurosurgical operations in India for tremors, epilepsy, behavioral disorders, psychiatric disorders, and spasticity, leading MIN to become a center of international repute (Fig. 3).9,11,12 As she recounted, the operations at MIN were conducted using air studies and Schaltenbrand-Bailey’s atlas, as this was before the advent of the CT scanner in Madras.14 While they had to manage in a resource-constrained environment, their contemporaries in the developed world had superior instruments to work with. Notably, Claude Bertrand in Canada, whose group had operated on more than a thousand patients for movement disorders by 1973, had developed and was utilizing electrical stimulation for target localization, similar to Gillingham in Europe. At the Montreal Neurological Institute, Gilles Bertrand and Andre Olivier were leading the way in introducing interfaces for the computer-brain atlas.9

Within 15 years of the arrival of Leksel’s frame at MIN, more than 1700 stereotactic operations had been performed.3 MIN thus became the birthplace and the leader of functional neurosurgery in India.11,12,14 For Kanaka’s pathbreaking work, numerous awards, newspaper profiles, national and international visiting professorships, and guest lecturerships followed.3,13,15–20 Kanaka retired from MIN in 1990, yet ever desirous to serve more, she continued to deliver immense amounts of pro bono work for the community until her last days.13,17 She passed away on November 14, 2018, at the age of 86, and her death was covered worldwide.3,21–23

It is unfortunate, however, that during her lifetime she received far less international recognition compared to her contemporaries in the developed world, with media coverage restricted largely to India.13,15–20 Similarly, little work existed in the neurosurgical literature regarding her contributions until after her demise.2,3

Life Lessons for Modern Neurosurgical Trainees and Educators

Corresponding with Robert Hooke in 1676, Isaac Newton wrote, “If I have seen further it is by standing on the shoulders of giants.”24 In the life of Dr. Kanaka, a true giant of neurosurgery, exist several lessons for neurosurgical trainees and educators worldwide. These lessons correspond well with the eight major factors that were identified in a recently published systematic review to exist behind gender disparities in neurosurgery: discrimination, mentorship, lifestyle, interest in neurosurgical training, conference representation, physical burden, compensation, and presence of a glass ceiling.25

Perseverance and Resilience in the Face of Gender Discrimination

In a systematic review of the factors behind choosing surgical specialties, Peel et al. report on a large body of work performed worldwide detailing how gender discrimination has deterred women from choosing surgery.26 Indeed, India has had a difficult history of gender relations, in both personal and professional domains, including medicine. Despite cultural progress, the country continues...
to have a patriarchal social system, with household work and childcare considered a woman’s responsibility. Stereotypes that females must not go into surgical specialties are widespread, primarily revolving around the exhaustive working hours and the protracted training, coupled with poor maternity policies during residency. This reflects how women in neurosurgery continue to be an exception in India, even today. As of late 2017, the country had only 73 female neurosurgeons, including trainees, a dismal 2.5% of the total workforce. However, nearly half of current Indian medical students are female.

Discrimination by people outside healthcare professions often mirrors those inside. As Thum et al. report from a recently conducted survey of US neurosurgeons, nearly 80% of female respondents have faced microaggressions in their workplace, 95% of which were gender-based. Meanwhile, a survey of Indian female neurosurgeons demonstrated that almost half had faced explicit discouragement from neurosurgeons or other physicians. Approximately 40% had faced gender-based discriminations during training alone. Hence, even today, it is difficult for a female surgical trainee in India to devote herself to her craft. A century ago, the challenges for women in surgery were even more magnified, the hostility even more explicit. Yet, it was in this India that Kanaka had to take root.

Her first major encounter with discrimination was when it prevented her selection to general surgery residency, where the sole selection criterion was the applicant’s rank on a competitive entrance examination. Because the examination’s subjective essay-type pattern allowed for bias in marking the answers, Kanaka, despite being academically excellent, lost several years trying to get in; she recounted, “Women were never admitted to master’s programme (MS) in general surgery… When I applied for the MS programme, I was told I would never be accepted.” Only two other women had previously been admitted, with one later becoming a professor of anatomy and the other leaving surgery altogether.

After several years of writing the examination, Kanaka was finally admitted, the only female among eight residents. Yet, her struggles were far from over, as she narrated: “The moment I entered the ward to do surgery, the chief fellow who was supposed to give me chances to practise, said to me, ‘I’ll see that you don’t become a surgeon.’ He had even given instructions to people that I should not be given a chance.” She went on, “the department chief (fellow) always conspired against me. He never gave me the knife; he made sure that I wasn’t given any emergency cases during admission days.” In the face of such hostility, she persevered. Passing out of MS (General Surgery) was even more challenging: “Every time I took the final exam, the external examiner from Bombay failed me. It was only in the sixth attempt that I qualified,” she recounted.

Thus, Kanaka faced significant challenges. By her own admission, what helped her overcome this hostility were her virtues of perseverance and resilience. She personified grit, i.e., passion and perseverance for long-term and meaningful goals. A survey of 427 US neurosurgery residents recently demonstrated that grit and resilience were inversely correlated with burnout. Grit has also been found to be predictive of future “psychological well-being” among surgical residents, demonstrating its value.

### Mentors Open Several Doors for Their Trainees

Mentorship has been widely reported to have been indispensable for the growth of neurosurgical trainees. Kanaka’s earliest, and greatest, mentor was Ramamurthi. He played a pivotal role in igniting her interest in neurosurgery. During medical school, a relative of Kanaka had developed seizures and consulted Ramamurthi. She loved asking him questions about this disorder, and he would answer patiently. Later, she got the chance to shadow him in the operating room during vacations. Recognizing her passion, he told her, “Finish your MBBS and come; I’ll teach you neurosurgery.” Indeed, he did fulfill his promise. Kanaka also made mentors out of hostile teachers using persistence. Such was the case with Dr. A. Srinivasan, who was famously “known to make female student-doctors cry,” as she described. He later told her, “You have survived me; you can survive any hardship.”

During surgical training, Kanaka’s obstacles eased considerably once she started receiving opportunities to first-assist. This happened under A. Venugopal during 1958–1960. As Kanaka narrated, “In fact, the first day I joined, he welcomed me and asked me to wash up and help him in the operating room. I was surprised as it was major surgery. I told him I was raw and had not done much during my studies. He told me not to worry and that he would help me.” Through Venugopal’s support, Kanaka attained operative skills.

After training under Ramamurthi, she joined him as a colleague. He had returned to India after training abroad under Geoffrey Jefferson, the UK’s first professor of neurosurgery, and Wilder Penfield in Canada, and wanted to make MN equal to their centers. He ensured that she operated with autonomy and opened doors for her, helping her grow professionally. “Whenever foreign visitors came to the department, Dr. Ramamurthi told me to perform the surgery so that they could see how I did my work.” Kanaka once narrated with pride. It helped her greatly to have been mentored by a leader of clinical neurosciences in India. Along with his other endeavors, he strived for more than two decades to establish a national body for neuroscience research, which came to fruition in 2003 as the National Brain Research Centre, Manesar. He also helped establish and helm the organization for standardizing postgraduate medical education in India, known as the National Board of Examinations.

Another mentor-cum-colleague was the neurosurgeon V. Balasubramaniam. Inspired by his PhD work, Kanaka herself completed doctoral studies. Together, they operated and published extensively (Supplemental Table 1).

### Dedication and Personal Sacrifices Take Us From “Good” to “Great”

Kanaka’s dedication to patient care was evident in her sacrifices. She had decided early on to not marry. This choice was later cemented when her brother died during her residency. She herself stated, “I chose to be single so
that I can do my work without any encumbrances. I’d be free to attend to my patients.”

Residency training in India lacked work-hour restrictions in her time, just as it continues to do so now. But Kanaka would already spend nearly all her time in the hospital. She recounted, “I used to come back only two days a week…. There were no specially trained people to look after the patient after an operation and anything could happen…. So I stayed in the hospital and looked after my patients.” Her schedule, even after becoming an attending, remained the same. One of her trainees recounted, “Dr. Kanaka literally lived in the institute. She would stay for several days in a week in her room, which was hardly 6ft by 8ft in the third floor of the Institute of Neurology.”

Kanaka belonged to an era in which sacrificing one’s entire life to medicine was celebrated. It is, however, widely recognized that in this age, such a philosophy is inappropriate, lest burnout or too narrow a focus may develop. But her exacting lifestyle was merely an embodiment of the dedication that has historically characterized the giants of neurosurgery. As Thum et al. conclude, open discussions and correct depictions of life in neurosurgery may decrease the attrition of women from neurosurgical training.

The Enduring Value of Research and Innovation

Medical student research in developing countries is far less than that in developed nations. Among Indian students, unfavorable attitudes toward research exist even today. These were magnified 70 years ago. However, even as an undergraduate medical student, Kanaka participated in several projects, including culturing gonococci, developing leprosy vaccines, and studying biochemical parameters of CSF. These were the early beginnings of an academic surgeon who would go on to have far greater productivity than her compatriots even in other specialties in South Asia, similar to how an early start in research is noted to be an indicator of future academic productivity, including in neurosurgery.

Later, Kanaka’s work would be reflected in numerous publications, a number far higher than most neurosurgeons in India today. This publication record is given in Supplemental Table 1, which has been created after a perusal of historical records along with searches of indexing databases. Some of her works included a new classification of tumours, surgical treatment options for cerebral palsy, multisite combined ablative procedures for spasticity, hypothalamic lesioning for juvenile aggression, cingulotomy for substance abuse disorders, limbic system sectioning for epilepsy, electrophysiology during sedative neurosurgery, and neural stimulation for spinal spasticity, among others. Their role in impacting stereotactic neurosurgery has been described in further detail elsewhere.

Her research would earn her several invitations for guest lectures along with awards from numerous organizations, including the World Federation of Neurosurgical Societies (WFNS) and the Walter Dandy Neurosurgical Society. In an era in which Indian women would not even fly abroad, she would travel alone across continents to present her works. At several conferences, especially in Asia, she would be the only female presenter, a fact consistent with the theme of poor conference representation that has been identified as a factor behind gender disparities in neurosurgery. She continued this late into her life.

Kanaka was devoted to neurosurgical innovation. She was the first in South Asia to perform chronic brain electrode implantation (exteriorized outside scalp), with some of the instruments used having been constructed locally (Fig. 4). She would remain preoccupied with developing low-cost deep brain stimulation systems until the end of her life. “My job is not done until India develops its own kit for cost-effective treatment,” said she at the age of 79.

Working With the Right Team Is Critical

Kanaka greatly benefited from being a member of the team that established stereotactic and functional neurosurgery in India. She was part of a combined department of neurosurgery and neurology, and they helped deliver multidisciplinary care in India at a time in which this concept was unheard of. Each member would go on to serve in critical leadership positions in academic neurology and neurosurgery. Other than Ramamurthi (NSI president, 1958) and Kanaka, these were V. Balasubramaniam (founder-president of Indian Society of Stereotactic and Functional Neurosurgery), S. Kalyanaraman (NSI president, 1987), G. Arjundas (neuroligist and NSI president, 1976), and K. Jaganathan (neuroligist and NSI president, 1980).

A supportive academic atmosphere and overall departmental productivity have been documented to be the most important covariates of neurosurgical trainee productivity. As a part of the MIN, which had significant administrative and academic support relative to other Indian centers, Kanaka found the right atmosphere to excel both inside and outside the operating room. Her works described gratifying outcomes in spasticity and rigidity by combining lesions in the cerebellum, ventral intermediates, and central median nuclei while working with Balasubramaniam (Supplemental Table 1). In contrast, few academic centers worldwide were practicing stereotactic surgery by the mid-1970s, others having stopped due to the advent of levodopa.

Developing a Mindset of Lifelong Learning

An attitude of lifelong learning has been widely noted to be critical for a neurosurgeon, and Dr. Kanaka was a personification of this attitude. After completing residency, she chose to pursue a PhD, completing it at the age of 40 in an era in which women rarely pursued postgraduate education. Even after becoming a faculty member, she chose to undertake a yearlong research stint under the Colombo Plan Fellowship at Avery Laboratories in the US, where she investigated phrenic nerve stimulation, diaphragm pacing, and pain management devices.

Kanaka’s love for learning led her to pursue another degree at the age of 51. As one of her trainees described it, “One day in 1983, she overheard me talking with a colleague about a Diploma in Higher Education (DHEd) program…. I attended a few classes but was unable to spare the time and discontinued. Though 18 years senior to me, she persisted, passed the exam, and was very proud of that academic achievement.”
Training the Next Generation: A Living Legacy

Well renowned for her exacting nature and high expectations, Kanaka ensured her residents were ready to face any challenge in neurosurgery upon graduation. Her trainees, including Dr. K. Ganapathi, would themselves go on to achieve major recognition.3,49 She also supervised several PhD dissertations.

Kanaka would also greatly ease the path of several future female neurosurgeons across Asia. She was a close mentor of Yoko Kato, the first woman to become a professor of neurosurgery in Japan. 21 Together they founded the Asian Women's Neurosurgical Association (AWNA) in 1996 in Calcutta, India, with Kanaka serving as the inaugural president.3 The AWNA soon became a key platform for uniting female neurosurgeons, with Kato serving as its fourth president. The latter would go on to become the first chair of the Women in Neurosurgery forum of the WFNS, along with serving as the current president of the Asian Congress of Neurological Surgeons. She wrote in Kanaka's obituary: “Not only did she dedicate her life for treating masses of suffering patients, she also volunteered to deliver knowledge for young neurosurgeons around the world. On a social platform, she promoted and encouraged many women neurosurgeons to be leaders in their works.”21

Later, under Kanaka’s supervision, the Women in Neurosurgery in India (WINSI) group was formed as part of the NSI’s umbrella at its annual meeting in 2016 (Fig. 5). Nearly all 69 female neurosurgeons in the group agreed that they had been deeply inspired by Kanaka.3 Through this living legacy is embodied her greatest contribution to modern neurosurgery.

Putting Patients Before Profit and Giving Back to the Community

Kanaka was offered but shunned many well-paid offers to practice neurosurgery overseas. She also did not join private practice and continued services at MIN at a meager salary until her retirement.13 Working in India’s two-tiered system of public and private healthcare, she believed that patients in publicly funded hospitals needed her more.50,51 Notably, she had once held the Indian record for the maximum number of blood donations—139 times.

Kanaka also gave consultations, free of charge, at Adyar Cancer Institute, Hindu Mission Hospital, and Tirupathi Tirumala Devasthanam Hospital for economically disadvantaged individuals. This consultation work would continue well into her retirement. A nonprofit collaboration with the Epidemiological Research Centre of the Indian Council of Medical Research resulted in an original article in the Lancet at the age of 71.52

Post-retirement, she used all her savings to establish and run the Santhanakrishna Padmavathi Healthcare and Research Foundation. There, she would provide annual checkups, consultation for common medical problems, and routine investigations for the elderly and the poor for free, setting a powerful example of service for Indian neurosurgeons to follow (Fig. 6). She once noted, “It (center) is like my child. I spend very little on myself because my needs are very few. All that I have I spend on the founda-
tion.”17 She maintained meticulous records of the hundreds of elderly patients who thronged her free clinic. She continued this until her very last days.9,15

Diversity, Equity, and Inclusion Go Together in Society and Neurosurgery

Many powerful happenstances came together to help the early growth of Asia’s first female neurosurgeon, indicating how diversity in neurosurgery will go hand in hand with the progressive values and enabling forces of the society around it, a key consideration for educators and leaders aspiring to make neurosurgery more diverse.25 It so transpired that Kanaka was born and went to medical school in the same city where several cornerstones of Indian neurosurgery were being laid, i.e., Madras in Southern India, while Northern India would remain deprived of neurosurgical training for a few more years. Her mentor, Dr. Ramamurthi, was a deeply progressive leader, who opened several doors for Dr. Kanaka.6 It so happened that the vice-chancellor of Madras University was the one who introduced standardized residency programs in India and mandated minimum operative volumes for trainees, which helped Kanaka in getting similar operative experience as her male colleagues.9 It so transpired that Kanaka was born and went to medical school in the same city where several cornerstones of Indian neurosurgery were being laid, i.e., Madras in Southern India, while Northern India would remain deprived of neurosurgical training for a few more years. Her mentor, Dr. Ramamurthi, was a deeply progressive leader, who opened several doors for Dr. Kanaka.9 It so happened that the vice-chancellor of Madras University was the one who introduced standardized residency programs in India and mandated minimum operative volumes for trainees, which helped Kanaka in getting similar operative experience as her male colleagues.9 Finally, Kanaka belonged to a highly educated family that had reformist attitudes toward gender roles and women’s education, without which her neurosurgical career may not even have existed.27–29

Conclusions

Many lessons are inherent in the life of Dr. T. S. Kanaka, who overcame seemingly insurmountable barriers. Her most valuable traits—perseverance and resilience—enabled her to rise above significant hostility. Her exceptional work ethic, which made her clinically and academically excellent, helped her conduct pioneering research and innovation. Additionally, the value of research and mentorship in neurosurgery cannot be overstated. For mentors, encouraging diversity is often as simple as impartially recognizing a competent and dedicated individual. Finally, it is Kanaka’s absolute dedication toward patient care, teaching, and community service that makes her legacy perpetual.

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**Supplemental Information**

**Online-Only Content**

Supplemental material is available with the online version of the article.

*Supplemental Table 1.* https://thejns.org/doi/suppl/10.3171/2021.3.JNS2193.

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