The Evolution of Training in Brain Stereotactic Radiosurgery: A Growing Part of Intracranial Neurosurgery

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■ OBJECTIVE: **Stereotactic radiosurgery (SRS) has evolved to become an established, well-studied treatment modality for intracranial pathologies traditionally treated with more invasive neurosurgical management. As the field expands, among neurosurgeons and across multiple disciplines, resident training will become increasingly crucial.**

■ METHODS: **In this review, we reflect on 25 years of SRS at the University of Pittsburgh Medical Center and the development of formal training in this area at our institution. We describe the formal resident rotation, fellowship opportunities, and training courses for multidisciplinary physician teams and allied health professionals.**

■ RESULTS: **The number of SRS cases performed annually has significantly increased in recent years and indeed surpassed caseloads for certain more traditional surgeries. Residents report high rates of expectation for including SRS in future practice, yet participate in only a small fraction of annual cases. The formal postgraduate year 3 rotation established at the University of Pittsburgh Medical Center provides a way to expose and educate residents in this growing subspecialty within the confines of duty hour regulations. In combination with extended clinical elective opportunities and postresidency fellowships, this rotation prepares residents at our institution for the use of SRS in future clinical practice.**

■ CONCLUSIONS: **SRS is a rapidly expanding field that requires a unique skill set and current neurosurgical resident training often does not fully prepare trainees for its use in clinical practice. Focused resident training is necessary to ensure trainees are proficient in this specialty and well equipped to become leaders in the field.**

Initially conceived in the 1950s for the noninvasive management of medically refractory movement and psychiatric disorders (7), stereotactic radiosurgery (SRS) combines externally applied intracranial guidance technology with radiation delivered with pinpoint precision. It has evolved from an "investigational" or alternative therapy to become a well-established, mainstream option with a wide variety of applications in the management of brain tumors and vascular malformations. First described by the pioneering Swedish neurosurgeon, Lars Leksell, in 1951, the field of radiosurgery had humble beginnings: first, an orthovoltage x-ray generator was combined with a stereotactic head frame. Leksell and his colleague, radiobiologist Borje Larsson, then used cross-fired proton beams generated by a synchrocyclotron at the University of Uppsala; further collaboration led to the development of the first Gamma Knife prototype in 1967 (2, 8). As a less-expensive, simpler alternative to proton beam radiosurgery, the Leksell Gamma Knife used photon beams generated by 192–201 cobalt-60 sources, which was a technology that could be readily installed in a routine hospital environment. Thus, Gamma Knife radiosurgery (GKRS) was born and during the subsequent 40 years, more than a million patients worldwide have undergone GKRS for an ever-increasing number of indications.

Dating back more than 25 years, SRS via use of the Gamma Knife at the University of Pittsburgh Medical Center (UPMC) has become an integral part of our patient care armamentarium. The history of GKRS at UPMC began in 1980, when, Dr. L. Dade Lunsford went to Stockholm, Sweden, to embark upon a van Wagenen fellowship in stereotactic and functional neurosurgery.

Key words
- Education
- Gamma Knife radiosurgery
- Medical residency
- Radiosurgery

Abbreviations and Acronyms
AANS/CNS: American Association of Neurological Surgeons/Congress of Neurological Surgeons
CPT: Current Procedural Terminology
GKRS: Gamma Knife radiosurgery
PGY: Postgraduate year
SRS: Stereotactic radiosurgery
UPMC: University of Pittsburgh Medical Center

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Under the guidance of Professors Lars Leksell and Eric Olof-Backlund at the Karolinska Institute, Dr. Lunsford gained first-hand experience in GKRS technology and realized its utility as an effective, minimally invasive modality that could achieve excellent outcomes for a wide variety of complex clinical neurosurgical problems.

After returning to the United States, Dr. Lunsford was determined to bring the Gamma Knife to Pittsburgh; however, success would require more than 4 arduous years of effort before establishing UPMC as the first site in North America to offer patients this form of brain surgery. Facing resistance to this so-called "disruptive technology," on many fronts, Lunsford et al. advocated this innovative therapy with fellow neurosurgeons who, like many industry leaders before them, found it difficult to accept the interference of their own areas of expertise with a potentially game-changing disruption of the status quo (12). After tackling the obstacles in local approval and funding, as well as numerous regulatory bodies (10), Lunsford's efforts were effective, and he established The Center for Image-Guided Neurosurgery at UPMC. The first North American Gamma Knife unit entered operation in August 1987. More than 25 years and several new models later, more than 12,000 patients have undergone GKRS at the UPMC.

The exponential growth in the field of stereotactic neurosurgery and its firm establishment as a standard treatment modality for a wide range of pathologies is underscored by Sheehan's observation that "radiosurgery has transcended the American Association of Neurological Surgeons/Congress of Neurological Surgeons (AANS/CNS) neurosurgical sections of tumors, pediatrics, vascular, and stereotactic and functional neurosurgery" (13). Indeed, radiosurgery has transcended the specialty of neurosurgery itself and in the United States is based on professional collaborations between neurosurgeons, radiation oncologists, and medical physicists (5). Furthermore, thousands of articles describing long-term outcomes analyses, complications, and limitations for a range of pathologies across multiple disciplines have been published.

Given this widespread diffusion of a technology that was once considered "controversial," reevaluation of training priorities for residents and ongoing education for faculty must occur to ensure that training reflects the evolving nature of the field. Interestingly, during the process of evaluating the impact of SRS on neurosurgical training, Katie Orrico, JD, from the AANS/CNS Washington Committee, was able to compare the number of Current Procedural Terminology (CPT) codes submitted to the Center for Medicaid and Medicare Services for radiosurgery with the number submitted for craniotomy for nonmeningioma tumors in the same time period (1993–2011). As shown in **Figure 1A**, originally presented in an editorial calling for increased SRS training (9), the number of CPT codes submitted for radiosurgery increased exponentially to greater than 8000 codes billed per year after 2004. In contrast, the number of craniotomies remained in the range of 5–7000 codes billed and was surpassed in number by radiosurgery in 2003 (9). Despite the number of cases performed, U.S. neurosurgical residents participate in less than 5% of radiosurgical cases (9).

At UPMC, our long history of GKRS and extensive caseload spurred early incorporation of SRS education into residency and continuing education programs. Herein, we reflect on the trends and evolution of our radiosurgical program and training after more than 25 years of clinical experience in GKRS.

RADIOSURGICAL TRAINING FOR RESIDENTS, FELLOWS, AND HEALTH PROFESSIONALS

A survey of residents in postgraduate year (PGY)-3 and beyond performed in 2009 found that two thirds of U.S. neurosurgery residents did not have formal rotations in radiosurgery incorporated in their program, even though 79% believed that it would be part of their future practice (13). Similarly, a survey performed by the Council of State Neurosurgical Societies found that SRS was one of 6 skill-technique areas reported to be inadequately addressed during residency (11).

At UPMC, graduate medical training involves a fundamental commitment to the education of residents and fellows. To this end, a 3- or 4-month rotation (depending on the number of residents in the program year) in image-guided neurosurgery has been integrated into the residency program within the Department of Neurosurgery at the University of Pittsburgh. This rotation allows PGY-3 residents to become familiar with SRS and concomitantly stimulates the development of experience in clinical outcomes research within this neurosurgical domain.

In addition, should they choose to pursue further training in this subspecialty, residents may do an extended clinical elective in their PGY-5 or PGY-6 years. After residency, recent graduates also may choose to pursue a fellowship in stereotactic surgery, functional surgery, and radiosurgery, ranging in length from 6 months to 2 years. These longitudinal training opportunities have led multiple University of Pittsburgh graduates to include SRS as a major part of their subsequent professional careers. Post-residency fellowship opportunities also have attracted an additional 58 clinical/research fellows from 21 nations in the last 23 years.

The Weekly Program

The rotation on this service is designed to provide trainees with a full-spectrum experience in the evaluation, care, and follow-up of radiosurgical patients. Outpatients are seen twice per week, at which time trainees evaluate patients' history and clinical findings. These are correlated with pertinent imaging studies, and options are explored that are compatible with patient and referring physician goals, as well as patient risk factors and expected outcomes. Because radiosurgery often is applied to patients who are elderly or who have significant comorbidities that make traditional surgery greater risk, decision-making is often complex. The trainee is expected to assess the options and make a recommendation to the attending physician. If radiosurgery is selected, the trainee prepares the patient and accompanying family for the procedure, describes the risks and benefits, and completes the preoperative workup. Final instructions are provided by a trained nurse who assists the patient and surgical team during the procedure, which is often performed the following day. Almost all procedures are performed as an outpatient.

One day per week the trainee prepares a formal review conference to assess newly referred patients. After completion of the daily procedures, the trainee also confers with the responsible attending physician regarding consults received by mail, phone, Internet, or in person that day.