Stereotactic radiosurgery—an organized neurosurgery-sanctioned definition

G. Barnett, M.D.,† Mark E. Linskey, M.D.,‡ John R. Adler, M.D.,¶ Jeffrey W. Cozzens, M.D.,¶ William A. Friedman, M.D.,¶ M. Peter Heilbrun, M.D.,¶ L. Dade Lunsford, M.D.,¶ Michael Schuler, M.D.,§ Andrew E. Sloan, M.D.,‖

THE AMERICAN ASSOCIATION OF NEUROLOGICAL SURGEONS/Congress of Neurological Surgeons WASHINGTON COMMITTEE STEREOTACTIC RADIOSURGERY TASK FORCE

1Brain Tumor Institute and Department of Neurological Surgery, Cleveland Clinic, Cleveland, Ohio; 2Department of Neurological Surgery, University of California Irvine Medical Center, Orange; 3Department of Neurological Surgery, Stanford University Medical Center, Palo Alto; and 4Tiburon, California; 5Department of Neurological Surgery, Evanston Northwestern Healthcare, Evanston, Illinois; 6Department of Neurosurgery, University of Florida, Gainesville; and 7Neuro-oncology Program, Moffitt Cancer Center, Tampa, Florida; 8Department of Neurological Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania; and 9Department of Neurological Surgery, New Jersey Medical School, University of Medicine and Dentistry of New Jersey, Newark, New Jersey

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Change is the law of life. And those who look only to the past or present are certain to miss the future.

JOHN F. KENNEDY

Since its introduction five decades ago, stereotactic radiosurgery (SRS) has evolved from an investigational concept into a mainstream neurosurgical procedure for the management of a wide variety of brain disorders. Contemporary neurosurgeons routinely use radiosurgery either as a definitive or adjuvant treatment modality in the fields of neurooncology and cerebrovascular and functional neurosurgery. Stereotactic radiosurgery offers the surgical neurooncologist a precise and established treatment that, in combination with fractionated radiotherapy, chemotherapy, and conventional surgery, offers additional management options for the treatment of patients with brain tumors.4,5,12 The role of SRS in the management of vascular malformations is also well established. Furthermore, this modality has had a significant impact on the treatment of patients with brain metastases;4,12,26,51 in cases in which SRS is possible, these patients more commonly succumb to their uncontrolled extracranial disease than to their intracranial disease.

Recently there has been a spate of reports attempting to clarify or to (re)define the terms “stereotactic radiosurgery” and “stereotactic radiotherapy” (SRT).1,28,66 It has become increasingly clear that the evolution of radiosurgery and radiotherapeutic techniques demands a reevaluation of the definition of radiosurgery by organized neurosurgery. These factors led the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS) to form the Stereotactic Radiosurgery Task Force under the auspices of the AANS/CNS Washington Committee. Members of the Stereotactic Radiosurgery Task Force were directed to review, clarify, and recommend to their parent organizations a contemporary definition of SRS, which would take into account historical, current, and potential applications of SRS. The purpose of this paper is to express the position of the AANS as well as that of the CNS on the definition of SRS.

Historical Review

“Stereotactic radiosurgery” was defined by the Swedish neurosurgeon Lars Leksell in 1951.57 At that time, Leksell sought to mimic destructive lesions in the brain produced by mechanically invasive stereotactic surgical procedures for movement and pain disorders by delivering a high dose of photon or proton energy to the intended target in a single session, while steep fall-off dose gradients protected the adjacent brain. Early efforts involving stereotactically applied ultrasound, orthovoltage x-ray, and accelerated particles such as protons proved inadequate to create these lesions deep in the brain or were otherwise too cumbersome. To overcome these shortcomings, Leksell, Liden, Larsson, and colleagues developed the Gamma Knife in 1967. This device focuses multiple beams of high-energy gamma rays to a common point directed by frame-based stereotactic guidance.55,58 Contemporaries such as Kjellberg, Winston, Lutz, Loeffler, Fabrikant, and others also developed systems using x-rays or particles to achieve the same ends.52,26,48,73,79

For decades, stereotactic localization was limited to information derived from atlases, plain radiographs, pneumoencephalograms, and angiograms.37,38,42,56,77 Throughout his life, Leksell remained active in advancing the state of the art.
of SRS and was one of several visionaries who developed methods of exploiting the spatial information provided by computed tomography and, later, magnetic resonance (MR) imaging, thereby creating the field of image-guided stereotaxy. Although the radiosurgical treatment of intracranial malignancies became feasible, Leksell believed that SRS was best used for functional neurosurgery or to treat benign tumors and lesions such as arteriovenous malformations and not to treat malignant tumors.

Early neurosurgeons who performed radiosurgery found that collateral damage to adjacent structures occasionally occurred when treating benign disease; several strategies were devised to reduce complications. Stereotactic MR imaging was used to provide better visualization and definition of targets and anatomical structures at risk. Radiation doses directed to the lesion’s margin were gradually reduced while maintaining therapeutic efficacy. Computer-assisted planning systems aided the design of treatment plans that better conformed to the shape of the radiosurgery target, rigid skull fixation, the “gold-standard” for stereotactic accuracy, was supplemented by relocatable frames that allowed radiosurgery to be performed in multiple sessions.

Stereotactic radiosurgery became established and accepted as an important neurosurgical technique in the 1980s and 1990s. Its value transcended the original indications posed by Leksell to include proven efficacy for the most common central nervous system malignancy—metastatic disease. Neurosurgeons wished to extend the reach of this technology beyond the limits of cranial disease. The use of extracranial radiosurgery with the aid of a frame was first reported by Hamilton in 1996. Concurrently, conventional surgical stereotaxy was revolutionized by the neurosurgical development of frameless stereotactic techniques. The notion that radiosurgery could also be delivered without a stereotactic frame was brought to fruition by Adler and others. New linear accelerator (LINAC)–based radiosurgical instruments rely on image-guided stereotactic targeting and advanced beam delivery methods. In one system, radiosurgical delivery is performed by a lightweight LINAC that is robotically positioned and in another, by a LINAC whose output is modulated by computer-controlled multileaf collimators. Today, radiosurgery can and has been performed on virtually any part of the body, and the fewer fixation requirements facilitate the performance of the procedure in multiple sessions.

Recently developed alternative forms of energy include high-intensity focused ultrasound. When delivered stereotactically to destroy or injure tissue, these other forms of energy could be interpreted by some as falling within the umbrella of SRS.

Role of the Neurosurgeon in SRS

These advances notwithstanding, SRS remains a “team” discipline in which the roles of the surgeon, radiation oncologist, and physicist are essential, regardless of the target organ or site of service. As in any surgical procedure involving the brain or spine, the neurological surgeon provides preoperative assessment of the patient and a review of pertinent imaging studies so that therapeutic alternatives can be presented to the patient and informed consent can be obtained. After the procedure, the neurosurgeon provides continued reevaluation and follow-up review at clinically appropriate intervals in order to assess outcomes on a long-term basis. During the radiosurgical procedure itself, the neurosurgeon serves as the primary responsible healthcare provider. Separate tasks of a radiosurgical procedure, including the treatment setup, planning, and delivery that are performed by or directly supervised by the neurosurgeon, comprise the following: delivery of agents for appropriate conscious sedation; application of the stereotactic coordinate frame (when pertinent) based on lesion location; selection and creation of the appropriate imaging data set (for example, computed tomography scans, MR images, angiograms, or positron emission tomography images) necessary for radiosurgical planning; computer-assisted delineation of target volumes and adjacent critical anatomical structures; creation of the 3D volumetric radiosurgical effect assisted by computer planning; setup, confirmation, and delivery of radiation; provision of additional sedation as required; monitoring of the patient’s vital signs during radiation delivery; removal of the stereotactic frame followed by bandaging or other wound care as needed; and standard postradiosurgery 90-day follow-up care. As the primary responsible healthcare provider, the neurosurgeon assumes responsibility for chart completion as required by the patient’s inpatient or ambulatory status after radiosurgery.

Recent Publications on the Role of Radiosurgery Versus SRT

Because new technology now enables radiosurgery to be delivered in more than one session and because “radiation therapy” is sometimes administered with the aid of stereotactic localization, there have been several attempts in the neurological literature during the past few years to define, redefine, or clarify the term SRS. At present there are “purists” who prefer the original definition of SRS offered by Lars Leksell some 50 years ago, while others subscribe to the concept of a procedure that has evolved with the emergence of new technology.

The Traditional Perspective

The principal argument made by authors espousing the traditional perspective is that the term radiosurgery must be restricted to a high dose of ionizing radiation delivered to a defined target in a single session. Stereotactic radiosurgery derives its safety by its high degree of conformity and high selectivity (shown by the steep dose falloff in the adjacent normal tissue), such that dose homogeneity within the target area is irrelevant. On the other hand, these authors contend that the delivery of fractionated radiation delivered in multiple sessions by daily application of a non–skeleton-attached guiding device (SRT) is usually less conformal and precise than conventional frame-based SRS. This presumably makes dose homogeneity desirable. This group also maintains that the rationale for SRT is primarily an attempt to reduce the risks of radiation damage to the surrounding normal tissue. Finally, they state that the term “(hypo-)fractionated stereotactic radiosurgery” is an oxymoron.

Alternative Perspectives

All will agree that a high dose of ionizing radiation deliv-
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erated to a stereotactically defined target in a single session is
(a form of) SRS. Contemporary controversies focus on two
areas: can “radiosurgery” be delivered in more than one ses-
session, and, if so, where does SRS delivered in multiple ses-
ions end and SRT begin?

The historical review presented earlier demonstrates the evolut-
io process of thought and practice in SRS throughout the past five decades. We believe that a reason-
able person will recognize that this evolution includes radio-
surgery delivered in more than one session. In his original
description of SRS in 1951, Lars Leksell did not specifically
state that the procedure needed be performed in a single ses-
ion. In 1983, Leksell described SRS as “a technique for
the non-invasive destruction of intracranial tissues or lesions . . . [in which] the open stereotactic method provides the
basis, . . .”58—again without explicitly restricting its use to a
single session. Statements limiting SRS to a single session
arose years later, in describing the state of practice at that
time.6,7,20,55 Today, the American Medical Association recog-
nizes that SRS may be undertaken in one or more sessions
according to Current Procedural Terminology,3 as does the
Centers for Medicare and Medicaid Services.14

Ionizing radiation has been used for longer than a centu-
ry in medical therapy. Much has been made of the differ-
tential radiobiology of SRS and fractionated radiotherapy—
the “Four Rs” of reoxygenation, reassortment, repopulation,
and repair,36—to distinguish SRS from SRT. In truth, little
is known about the true radiobiology of radiosurgery and
these arguments are theoretical at best.59,54

What is known is the intent of the treatment. Radiosur-
gery aims to injure or destroy tissue at the target and pre-
serve adjacent critical tissue, primarily due to steep dose
gradients. Homogeneity within the lesion is generally not
considered important and can be a disadvantage for achiev-
ing tumor shrinkage when treating lesions that do not
contain normal tissue or for treating internal tumor areas of
necrosis or hypoxemia. Tumors that may be resistant to
fractionated radiotherapy may respond well to radiosurgery.
Multiple sessions may be used to further reduce injury to
adjacent normal tissue while maintaining the efficacy of ra-
diosurgery. In fractionated radiotherapy abnormal tissue is
differentiated from normal tissue within the target site by the
differential sensitivity of these tissues to fractionated
ionizing radiation.21 Dose homogeneity is desirable when
the treatment volume contains sensitive normal tissue (ei-
ther in the tumor or closely adjacent). Deleterious effects
outside the treatment area may be further reduced by en-
hancing treatment conformity and by increasing the dose
gradient. Either technique may be directed stereotactically
(SRS and SRT).

Few would disagree that the precise stereotactic delivery
of a high dose of radiation for the purpose of tissue inacti-
vation or destruction in a single session is within the scope
of SRS, and that the precise stereotactic delivery of radia-
tion in 30 sessions is not SRS but is better described as SRT.
Conversely, such a single-session delivery should fall out-
side the scope of SRT. Between these extremes, however,
are cases of potential overlap between the techniques. We
believe that these are best differentiated by the intended
mechanism of action and that data in the literature, federal
policy, and contemporary practice indicate that the upper
limit of sessions in which SRS may be delivered is five.14

After considerable debate and discussions, on June 29,
2005, the members of the AANS/CNS Stereotactic Ra-
diosurgery Task Force (Appendix A) met in Chicago and
arrived at a contemporary definition of SRS, which has
subsequently been approved by both parent organiza-
tions. Thereafter, on March 20, 2006, representatives of the
AANS/CNS met with the corresponding body of the Amer-
ican Society for Therapeutic Radiology and Oncology (AS-
TRO; Appendix B) and refined this definition of radiosur-
gery, subsequently sanctioned by the AANS, CNS, and
ASTRO:

Stereotactic Radiosurgery is a distinct discipline that utilizes
externally generated ionizing radiation in certain cases to inacti-
ivate or eradicate (a) defined target(s) in the head or spine with-
out the need to make an incision. The target is defined by high-
resolution stereotactic imaging. To assure quality of patient
care the procedure involves a multidisciplinary team consisting
of a neurosurgeon, radiation oncologist, and medical physicist.

Stereotactic Radiosurgery (SRS) typically is performed in a
single session, using a rigidly attached stereotactic guiding
device, other immobilization technology and/or a stereotactic
image-guidance system, but can be performed in a limited
number of sessions, up to a maximum of five.

Technologies that are used to perform SRS include linear
accelerators, particle beam accelerators and multisource Cobalt
60 units. In order to enhance precision, various devices may
incorporate robotics and real time imaging.

Appendix A

Members of the AANS/CNS Washington Committee Stereotactic
Radiosurgery Task Force

Gene H. Barnett, M.D., Chair
Mark E. Linskey, M.D., Vice-Chair
John R. Adler, M.D.
Jeffrey W. Cozzens, M.D.
William A. Friedman, M.D.
M. Peter Heilbrun, M.D.
L. Dade Lunsford, M.D.
Michael Schulsder, M.D.
Andrew E. Sloan, M.D.

Appendix B

Representatives at the March 20, 2006 Meeting of the AANS/CNS
and the ASTRO

AANS/CNS
Gene Barnett, M.D., Chair, AANS/CNS Stereotactic Radiosurgery
Task Force; Chair, AANS Representative Board of Directors
Mark Linskey, M.D., Vice-Chair, AANS/CNS Stereotactic Radi-
osurgery Task Force; Co-Chair, CNS Representative Executive
Committee
Greg Przybylski, M.D., Chair AANS/CNS Coding and Reimburse-
ment Committee; Member, AANS Relative Value Update Commis-
tee
Jeff Cozzens, M.D., Member, AANS/CNS Coding and Reimburse-
ment Committee; Advisor, AANS Current Procedural Termin-
ology
Troy Tippett, M.D., Chair, AANS/CNS Washington Committee;
Member, AANS Board of Directors
Cathy Hill, Senior Manager for Regulatory Affairs, AANS/CNS
Katie Orrico, Director, AANS/CNS Washington Office

ASTRO
K. Kian Ang, M.D., Ph.D., President, ASTRO
Michael Steinberg, M.D., Member, ASTRO Board of Directors;
Chair, Health Policy Council; Advisor, Current Procedural Ter-
minology
Louis Potters, M.D., Member, ASTRO Board of Directors; Vice-

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