

The CyberKnife® Advantage: Redefining Treatment of Tumors

Stereotactic radiosurgery (SRS) is a well-established method for the noninvasive treatment of benign and malignant tumors, vascular malformations and other disorders of the brain. Classically, SRS has been limited to treatment of disorders that are localized in the brain. The recent implementation of CyberKnife radiosurgery into clinical practice has completely redefined the way physicians treat cancer throughout the body, including lungs, liver, prostate and spine.

Clinical Advantages

The goal of CyberKnife radiosurgery is not to replace surgery, chemotherapy or traditional external beam radiation for cancer treatment. Instead, it is an important alternative to surgery or an option to treat patients who have exhausted other treatment methods. CyberKnife also offers an attractive option for hypofractionated radiotherapy and delivers radiation not only more safely, but also gives new hope for patients who have already received the maximum amount of radiation through other treatment methods.

The ability to deliver radiation over several *days* as opposed to several *weeks* could be particularly useful in the treatment of large tumors or lesions located near the brainstem, spinal cord, nerves and other sensitive structures. Such staging is not possible with other SRS systems. CyberKnife allows local dose escalation to surgically inaccessible areas, so patients with tumors previously designated as inoperable may now have another option.

All patients who are treated with CyberKnife radiosurgery are evaluated by a team of physicians that includes a neurosurgeon and radiation oncologist as well as a physicist. The actual CyberKnife procedure is performed on an outpatient basis and takes only about an hour. Patients can go home immediately after the procedure.

Technical Advantages

The CyberKnife system represents an entirely new approach to SRS – one that does not require an external frame temporarily affixed to the skull

for targeting (as is necessary for Gamma Knife) and offers superior maneuverability and accuracy, making it appropriate for a wide range of treatment options. CyberKnife has a unique ability to rely on internal reference points in patient anatomy, such as bony landmarks or small embedded markers, to target the radiation.

Designed to address the limitations of older frame-based SRS systems, CyberKnife was further refined to be the most accurate and flexible tool available for aggressive, focused, therapeutic irradiation. The CyberKnife system couples an orthogonal pair of X-ray cameras and a compact, lightweight linear accelerator (LINAC) mounted on a flexible robotic arm. The robotic arm moves the LINAC sequentially to multiple precalculated positions around the patient with submillimetric precision. At each of these positions, the LINAC fires a precise beam of radiation at the tumor or lesion. Preoperative CT images are used to define the spatial relationship between the patient's bone structure and the lesion. Image guidance cameras verify target position and make dynamic adjustments as necessary. Any patient movement during treatment is detected by the system's X-ray cameras in real time. The robotic arm



CyberKnife permits highly precise radiosurgery for the treatment of tumors and arteriovenous malformations, including those previously considered inoperable. CyberKnife's robotic arm delivers precise doses from hundreds of positions... without requiring an invasive frame. This dramatically reduces impact on patients and allows for treatment in the entire body.

then repositions automatically to ensure accurate delivery of each radiation beam. The convergence of all the beams at the tumor or lesion results in a high cumulative dose of radiation strong enough to destroy or stabilize the abnormal cells while minimizing radiation damage to surrounding normal tissue. This exceptional maneuverability of CyberKnife offers the clinician the widest range of treatment options available.

CyberKnife Radiosurgery for Brain Lesions

The role of SRS for the treatment of intracranial lesions including benign and malignant tumors, metastases, arteriovenous malformations (AVMs) and trigeminal neuralgia is well-established, and treatments in the brain can be performed with all existing SRS systems. Superior results in survival and morbidity are generally reported in the medical literature for patients who were treated with SRS compared to surgery and conventional radiotherapy alone.

CyberKnife has the capacity to treat brain lesions that are difficult to reach with frame-based systems, such as meningiomas and multiple metastases located in the low posterior fossa and foramen magnum. The advanced image guidance system used by CyberKnife likewise allows multiple metastases widely dispersed throughout the brain to be more easily treated in a single session. CyberKnife combines computer-controlled robotics with real-time image guidance to provide high treatment conformity without resorting to uncomfortable fixation of the head during treatment, therefore offering an attractive option for hypofractionated treatment usually divided into one to five sessions. The fractionation allows the neurosurgeon to not only safely use higher radiation doses but also may reduce the risk of radionecrosis development.

These are only a few reasons why Boulder Neurosurgical Associates is among the first few centers in the United States to use this technology. We have also been at the forefront of establishing efficacy, long-term safety and optimal radiosurgical

treatment parameters for the various treatments. The safety and effectiveness of CyberKnife radiosurgery for trigeminal neuralgia (TN) treatment was evaluated in a recent multicenter study that was initiated and carried out by BNA physicians. This study was performed in collaboration with Stanford University School of Medicine, Rocky Mountain CyberKnife Center and Besta Neurological Institute in Italy. A total of 95 patients with idiopathic TN that became intolerant or refractory to medications and had contraindications to surgery were treated with CyberKnife. A total of 87 (92%) patients responded to the treatment and 67% had excellent or good long-term pain relief. The mean time to pain relief was 14 days. This study established a clear correlation between efficacy and the length of the trigeminal nerve treated and maximal radiation dose used. We demonstrated that the established optimal radiosurgical treatment parameters helped us to achieve excellent pain relief and avoid complications when these parameters were used for patient treatment. For further information please refer to: *Villavicencio AT, Lim M, Burneikiene S, et al., CyberKnife Radiosurgery for Trigeminal Neuralgia Treatment: A Preliminary Multicenter Experience. Neurosurgery 2008, 62(3); 647-55.*

Despite decades of research investigating new treatment modalities for glioblastoma multiforme (GBM), there have been no significant treatment advances reflected in outcome since the 1980s. Reported median survival times for patients with GBM treated with conventional treatment programs generally range from nine to 19 months. BNA surgeons reviewed and evaluated the efficacy and identified the appropriate timing of CyberKnife radiosurgery in the treatment of glioblastoma multiforme tumors. Survival rates of two groups of patients were evaluated: 20 patients treated with CyberKnife radiosurgery as the primary treatment intent and 26 patients treated at the time of tumor recurrence or progression. Tumors in any location and treatment volume less than 50 cm³ were considered for treatment. This study established that there was no apparent survival advantage in using CyberKnife in initial management of GBM patients and it should be reserved for patients manifesting with local tumor recurrence/progression after conventional therapy. The study received the BrainLab Community Award at the 2008 American Association of Neurological Surgeons meeting and is currently in print for publication in *Neurosurgical Review*.

CyberKnife Radiosurgery for Spinal Lesions

The CyberKnife System is the world's first and only robotic radiosurgery system that combines computer-controlled robotics with real-time imaging guidance to safely treat tumors in the spine. CyberKnife employs the Spine Tracking System, which uses internal anatomy to tract a lesion and thus eliminates the need for frames or implanted radiographical markers.

This innovative tracking capability in addition to sub-millimeter accuracy enables treatment of tumors close to the spinal cord. Prior to the introduction of CyberKnife, patients had few alternatives for tumors that could not be surgically resected.

Radiation dose, fractionation and treatment volume are the main factors that affect probability of local tumor control or complications to the surrounding adjacent normal tissues. This becomes extremely important in the treatment of spine tumors due to their close proximity to the spinal cord. Physicians at Boulder Neurosurgical Associates evaluated the spinal cord radiation tolerance in a study that analyzed 79 patients and 93 spinal tumors treated with CyberKnife radiosurgery. The treated tumor volume varied from 0.02 to 282 cm³. Local tumor control was achieved in all but two patients and there were no radiosurgery related complications observed. A total of 68.7% and 54.5% of patients noted an improvement in their pain score and neurological function, respectively. It was established that hypofractionation (up to three treatment sessions in these cases) allowed safe treatment of patients with very high radiation doses. This was because only a tiny portion of the spinal cord was exposed to significant radiation. These results and conclusions added to further understanding about the capabilities and safety of this new technology. Furthermore, this study addressed treatment of intramedullary tumors and demonstrated that CyberKnife can be effectively used for lesions that are not easily amenable to open surgical procedures.

A Partner in Patient Care

Neurological disorders are very individual challenges that require close focus and unwavering commitment. As a center of excellence, we pride ourselves on being able to offer some of the region's best results by tailoring our care to each patient's unique circumstances.

At Boulder Neurosurgical Associates, we are making positive changes in how neurological and intracranial disorders are resolved. CyberKnife technology has revolutionized SRS. With CyberKnife, we are reducing the risks and complications. Hospitalization and recovery times historically associated with these types of cases are also significantly reduced. We are also eliminating the need for surgery for many tumors and vascular malformations. The combined benefit of these innovative methods is improved results for the patient.

We are committed to serving the needs of physicians looking to give their patients the most effective treatment options available. If you have a question about CyberKnife and how it can benefit your patients or you would like to arrange a consultation or referral, please call us at (303) 938-5700 or visit our website at www.BNAsurg.com.

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ADVANCED, INNOVATIVE CARE FOR:

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- > Vascular malformations of the brain & spine
- > Microvascular nerve-compression disorders
- > Acoustic neuroma
- > Chronic neck & back pain
- > Spine disorders & degenerative conditions
- > Spinal stenosis
- > Herniated disk
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- > Minimally invasive lumbar fusion
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- > Microscopic surgical techniques
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- > Highly effective nonsurgical spine treatments
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BOULDER NEUROSURGICAL ASSOCIATES

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