Preserving hearing: The holy grail of acoustic neuroma care

by Douglas Kondziolka, MD
Hideyuki Kano, MD, PhD
John C. Flickinger, MD
L Dade Lunsford, MD

Acoustic neuromas (AN), also known as vestibular schwannomas, are benign tumors arising from the vestibulocochlear nerve sheath. The most frequent presenting symptoms include tinnitus, hearing loss, gait disturbances, facial numbness, or weakness.

Common hypotheses for the development of hearing loss included direct compression of the cochlear nerve fibers by the adjacent AN, the development of a conduction block followed by degeneration of nerve fibers, compression and/or thrombosis of the internal auditory artery, and/or ischemic injury to the cochlea. Until the last decade, preservation of hearing was a goal thought to be almost unattainable.

Therapeutic options include observation, microsurgical removal, gamma knife radiosurgery (SRS), or stereotactic radiation therapy (SRT). Recently, a number of reports have wondered whether the radiation dose received by the cochlea was important for hearing preservation in those patients who had not already lost it.

Beginning in 2004, we began a protocol that studied tumor anatomy, radiosurgical planning, and the dose received by inner ear structures to define a relationship before radiosurgical technique, tumor extent, hearing function at presentation and later outcome.

Between October 2004 and March 2007, 248 consecutive patients with previously untreated unilateral acoustic neuromas underwent SRS using the Gamma Knife at the University of Pittsburgh. For this series, we excluded patients with neurofibromatosis type II, patients with non-serviceable hearing at the time of SRS, and patients with a radiographic and audiological follow-up less than six months after SRS.

There were 40 males and 37 females with a median age of 52.0 years (range, 22 – 82 years). Audiogram results were evaluated according to the GR classification.

Serviceable hearing (useful hearing) was defined as GR class 1-2, (speech discrimination > 50% and pure tone average < 50 dB). Before SRS, 46 patients had Class 1 (speech discrimination > 70% and pure tone average < 30 dB) and 31 patients had Class 2 (speech discrimination 69-50% and pure tone average 31-50 dB). The median tumor volume was 0.75 cc (0.07-7.7 cc). The median prescription dose delivered to the margins of the tumor was 12.5 Gy (12-13 Gy). Radiosurgical planning was performed with contrast-enhanced volume acquisition images (1mm) and with volumetric T2 images that showed the cochlea and other inner ear structures.

Based on MR images of each radiosurgical plan, the dose to the central cochlea (modiolus), at the vestibule, in the middle of the horizontal semicircular canal and the distance from the end of tumor to the end of the auditory canal were defined (see figure 1 on page 4).

Results

No patient has required any other procedure. Tumor control was attained in 75 (97.4%) of the 77 patients at last follow-up. Two patients had a small tumor expansion (2 mm) of the extracanalicular tumor component on early imaging after SRS.

Hearing Preservation after SRS

The last audiological examination demonstrated that 45 patients (58.4%) remained within the same pre-SRS GR hearing class. Two patients (2.6%) had improved

(continued on page 4)
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Advanced, collaborative techniques critical for success

Neurosurgery work to improve neurologic function. For some patients, improvement may not be a realistic goal, and avoidance of new deficits or disabilities becomes paramount. Whether surgery is performed on the brain, its coverings, the spinal column, spinal cord, or peripheral nerves, surgical judgment and technique together with an understanding of the patient’s own goals are crucial.

In this issue of University of Pittsburgh Neurosurgery News, we focus on techniques to preserve cranial nerve function and the special senses. Tumors and disorders of the skull base can challenge patients with loss of visual acuity, clarity, or visual field, hearing, facial movement or sensation, swallowing or voice.

Advanced skull-based techniques are critical for larger tumors that displace or invade cranial nerves to restore their axonal integrity and blood flow. For smaller tumors, Gamma Knife radiosurgery can achieve results sometimes better than those associated with resection, particularly as they pertain to acoustic neuromas or tumors of the cavernous sinus. Our own experience has been evaluated and published during the past two decades with a critical analysis of techniques and outcomes. Hearing preservation, almost the Holy Grail of acoustic neuroma management just 15-20 years ago, is now common place. A normal face and a normal smile are almost always expected for patients with acoustic neuromas using radiosurgery. In patients with large tumors, a combined resective and radiosurgical approach may be optimal. When possible, surgical resection can be curative for some schwannomas and meningiomas if anatomically feasible. Our goal has not only been to remove or inactivate the mass but to give the patient the best chance for long-term preservation of function and return to full activity.

To achieve such goals, neurosurgeons work closely with other clinicians in otorhinolaryngology, radiation oncology, neuro-radiology, plastic surgery, rehabilitation medicine, and medical physics.

We look forward to the continued privilege of helping with your patients and meeting their personal goals.

Douglas S. Kondziolka, MD
Editor, University of Pittsburgh Neurosurgery News
Peter J. Jannetta Professor of Neurological Surgery
Vice Chairman, Education, Dept. of Neurological Surgery

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Cranial nerve safety using Gamma Knife radiosurgery for petroclival meningiomas

by L. Dade Lunsford, MD
Thomas Flannery, MD, FRCS
Hideyuki Kano, MD, PhD
Ajay Niranjan, MCh, MBA
John Flickinger, MD
Matthew Tormenti, MD
Douglas Kondziolka, MD

Because of their development close to critical cranial nerve brainstem and important skull base vascular structures, petroclival meningiomas remain a management challenge for both patients and their physicians. Often they can affect nerves of ocular motion (III, IV, VI), facial sensation (V), facial movement and hearing (VII and VIII).

In our series, most patients presented with symptoms related to loss of sensation in the face (38%), balance disorders (29%), double vision (28%), or hearing loss and tinnitus (28%). The most common neurological deficits at the time of Gamma Knife were facial sensory loss, facial weakness or hearing dysfunction.

Although continuing advances in cranial base surgery have improved outcomes, microsurgery is still associated with significant morbidity.

Gamma knife radiosurgery has been used for 22 years in the management of such meningiomas. We recently reviewed our experience in 168 patients who underwent Gamma Knife radiosurgery for skull base tumors that occur between the petrous apex and the upper two-thirds of the clivus. Seventy-four percent of patients were female, and the average age was 57 years.

At the time of initial surgery, three patients were found to have atypical meningiomas (World Health Organization Grade II), and two had anaplastic meningiomas (WHO Grade III). Gamma knife radiosurgery was performed as the initial treatment in 97 patients and after subtotal resection in 32 patients. In 39 patients, the Gamma Knife was used for recurrent tumors that developed after initial complete resection.

Radiosurgical Technique

Radiosurgery was performed under local anesthesia after stereotactic head frame application and the usage of mild intravenous sedation. An intraoperative high resolution MRI scan was performed in order to define the target in the skull base. Software computer programs allowed us to treat the tumor by enclosing the irregular tumor borders in a high dose of radiation delivered by one of the three Gamma Knife technologies at our center.

All patients underwent their procedure as an outpatient, and all patients were discharged to home within three to 24 hours and returned to their activities immediately.

Follow-Up

Patients are seen at regular intervals, usually at one, two, four, eight and 12 years after Gamma Knife. At that time, both clinical evaluation and repeat imaging studies are performed. The median follow-up interval was six years, and the longest was 14 years. Twenty-four percent of patients had follow-up for more than ten years after radiosurgery.

Outcomes

After Gamma Knife, neurological symptoms or signs improved in 26% of patients and remained stable in 58% of patients. Due either to tumor progression or development of temporary side effects, 15% of patients had new, usually temporary, symptoms in the follow-up interval. Prevention of further growth was achieved in 90% of patients at an average of five years.

Twenty-four patients required delayed craniotomy and resection, and eight patients had repeat radiosurgery. Four patients underwent subsequent fractionated radiation therapy.

The response rates in our patients treated initially with Gamma Knife and those treated after prior surgery were similar. Larger tumors had a higher chance of subsequent new symptom development over time.

In 31 patients who had follow-up for at least ten years after Gamma Knife, 16 had shrinkage, 14 had stable disease, and one patient required repeat Gamma Knife for delayed tumor progression at 125 months. Side effects after Gamma Knife radiosurgery, defined as the development of new symptoms or signs in the absence of tumor growth on MRI, occurred in 8% of patients.

Recommendations

The natural history of petroclival meningiomas indicates that such tumors will eventually grow under observation. These observations indicate that most petroclival meningioma patients should undergo management, unless the patient has advanced age or other health limiting significant medical risk factors.

Although refinements in microsurgical techniques have improved the outcomes after treatment of petroclival meningiomas, significant morbidity and mortality rates remain. Our results indicate that Gamma Knife radiosurgery leads to long term tumor control and minimal treatment related morbidity. Overall tumor control was confirmed in 91% of patients at five years and 86% of patients at ten years.

Smaller tumors are easier to control and are associated with less risk. The long term goals of Gamma Knife radiosurgery are tumor growth control and risk minimization. Our data indicates that radiosurgery is a safe and effective strategy that should be used for smaller volume, newly diagnosed, or residual petroclival meningiomas. The ten year tumor control rates are similar to those expected after a complete resection of a histologically benign meningioma.*

MR images of a petroclival meningioma following Gamma Knife radiosurgery. Left image depicts a conformal Gamma Knife radiosurgery plan with the inner contour corresponding to the tumor margin. Center image indicates a dose plan for repeat Gamma Knife radiosurgery for delayed tumor progression at nine years. Right image indicates marked tumor regression eleven years after initial radiosurgery.
hearing from GR class 2 to 1. Thirty patients (39.0%) developed some reduction in hearing after SRS. Twenty-three patients had their hearing reduced by one GR class (eight patients reduced their hearing from GR class 1 to 2 and 15 patients from GR class 2 to 3), four patients by two classes (these four patients reduced their hearing from GR class 1 to 3), two patients by three classes (these two patients reduced their hearing from GR class 2 to 5) and one patient by four classes (this patient reduced their hearing from GR class 1 to 5). The audiological status of 22 patients (28.6%) showed deterioration to non-serviceable hearing (GR class 3-5) after SRS. Thus, 55 (71.4%) of 77 patients maintained serviceable hearing (GR class 1-2) after SRS (see table on page 1).

The rate for maintaining the same GR class was 84.0% and 56.5% at one and two years, respectively (see figure 2). The median time for dropping to a lower GR class was 25.0 months (SD; 5.1). The preservation rate for serviceable hearing after SRS was 89.3% and 66.8% at one and two years, respectively. For those whose hearing became unserviceable, the median time was 31.1 months (SD; 3.5).

Relationship Between Age and Hearing Preservation
Eighteen patients (23.4%) were older than 60 years and 59 patients (76.6%) were 60 years or younger. Twelve of 18 (66.7%) older patients exhibited some hearing deterioration (any drop in GR class) compared to only 18 of 59 (30.5%) younger patients. While overall, younger patients had 1- and 2-year maintenance of same GR class of 94.4% and 69.6%, respectively, older patients did not do as well (48.9% and 17.5%, respectively). Thus, patient age less than 60 years was significantly associated with maintenance of GR class (log-rank test; p=0.001, Fisher’s Exact test; p=0.011).

Influence of Radiation to the Cochlea on Hearing Preservation
The mean and median radiation dose to the central cochlea for this series was 4.5 Gy (range, 1.1-8.2). In the entire series, patients who received < 4.2 Gy to the central cochlea had significantly better maintenance of same GR class (Fisher’s Exact test; p=0.022).

In multivariate testing for patients < 60-year-old, factors associated with improved hearing preservation were initial GR class 1 (p=0.014 and p=0.0001, respectively) and central cochlear dose < 4.2 Gy (p=0.028 and p=0.059, respectively).

Best Opportunity for Hearing Preservation
In patients < 60 years old with GR class 1 hearing, only two of 12 (16.7%) who received a central cochlear dose < 4.2 Gy exhibited any GR class deterioration compared to six (27.3%) of 22 patients who received a higher cochlear dose. These patients with the lower cochlear dose had a 93% rate for maintenance of GR class at two years. In addition, all 12 patients < 60 years with a cochlear dose < 4.2 Gy maintained serviceable hearing at two years. Although not enough patients were managed to reach statistical significance, two-year serviceable hearing was maintained in 80% of the 22 patients of younger than 60 years who received a cochlear dose > 4.2 Gy.

Recommendations
The goal of radiosurgery is control of tumor growth with preservation of neurological function. In recent years, preservation of hearing has become a common goal for many patients. This is true when an early diagnosis is made, especially with more frequent use of high-resolution MR imaging to evaluate patients with mild hearing dysfunction or tinnitus. We previously reported a six-year clinical tumor-control rate of 98.1% after GK SRS with a median margin dose of 13 Gy. Facial neuropathy is rare.

In the group of patients less than 60 years old with GR class 1, those with radiation dose to the central cochlea < 4.2 Gy had a two-year maintenance of same GR class of 93%, and serviceable hearing preservation of 100%. Such data are provocative, and may agree for earlier radiosurgical management of younger patients with high-level hearing. Many such patients are currently being observed for imaging-defined tumor growth or hearing deterioration. Thus, we suggest that Gamma Knife radiosurgery be considered for younger patients with smaller acoustic neuromas in an attempt to preserve functional hearing.
**Endoscopic endonasal approaches (EEAs) were largely developed at the University of Pittsburgh Medical Center over the last decade. The key concept driving this approach is the resection of midline tumors through a midline corridor. This allows direct access to the pathology without retraction or manipulation of critical neurovascular structures. Perhaps no such structure is more important when dealing with suprasellar tumors than the optic apparatus.

Traditional craniotomies, with a lateral to medial trajectory, inevitably require some manipulation or blind tumor dissection around the optic nerves or chiasm. Published studies of visual outcomes following craniotomy for meningioma show 11-20% visual decline following surgery.

By contrast, the largest such study for EEA, from UPMC, had no incidents of vision worsening. Rather, all 35 patients had improvement or resolution of their preoperative vision loss.

A similar trend was seen when addressing craniopharyngioma. Again, no patient had visual worsening. 93% had improvement in vision and one remained stable. Many patients with both craniopharyngiomas and meningiomas present with vision loss as a key symptom, making visual outcomes critical to patient satisfaction and long term quality of life. In the end, this is perhaps the best definition of ‘minimally invasive.’ The EEA, while it may avoid a skin incision is even less invasive with respect to parasellar neurovascular structures.

**a patient’s story**

**James ‘Mike’ Galyon**

James “Mike” Galyon had a vision problem that new glasses could not correct. It was 2003 when Mike, a retired Air Force Lieutenant Colonel, now employed as a realtor and college political science professor, complained to the optometric clinic.

“I was convinced there was a problem with my new lenses,” recalled Mike. “I sent the glasses back to the lab multiple times. Eventually the clinic staff lost their patience and suggested I go elsewhere for treatment.”

The next eye doctor referred him to a local neurosurgeon. A subsequent MRI revealed that something impinging on the optic nerve was the likely culprit.

While relieved to finally understand the apparent cause of his declining vision, Mike was hesitant to comply with the recommendation that he undergo a sublabial transseptal surgery. “The sublabial approach involves a large incision below the upper lip, and a long recovery time,” noted Mike with a shudder. He continued his quest for a better treatment option.

Meanwhile, his declining vision began to interfere with his work and recreational activities. “As a college teacher and real estate agent, I rely on my vision extensively. No longer able to bring the fine print into focus, I became frustrated as I struggled to keep up with all the reading that was expected of me. Class preparation, correcting students’ written assignments, reviewing real estate contracts, and background research—poor vision affects them all.”

Then one evening, NBC News broadcast a story of a medical center in Pittsburgh with a neurosurgery team that had removed a pituitary tumor through the nose. The new procedure had yielded excellent results and vastly shorter recovery times.

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IMPROVING VISION: a patient’s story
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“The Expanded Endonasal Approach minimizes the disturbance of surrounding tissues,” explains Paul Gardner, MD, assistant professor of neurosurgery at the University of Pittsburgh, and co-director for the Center for Skull Base Surgery at the University of Pittsburgh. “Without a need for incisions or face disassembly we can deliver our surgical and visualization tools directly to the target via the nostril. This has the potential to reduce the impact on the patient, lessen the morbidity, and reduce the length of stay in many cases.”

Mike called UPMC for more information and quickly learned that he would be a likely candidate for a surgery through the nose. Unfortunately, his insurance provider had not yet approved the new procedure.

In August of 2009 he finally received approval and was able to schedule the treatment and travel to Pittsburgh. In the pre-op exams and consultations, he learned that had he waited another few months for treatment, he might have become blind. Time was running out. The surgery was scheduled immediately, and as is often the case at the University of Pittsburgh, involved surgeons from multiple departments.

Otolaryngologist Carl Snyderman, MD, co-director of the Center for Skull Base Surgery. “Surgery to preserve or restore vision benefits from a collaborative team representing both neurosurgery and otolaryngology. We work closely together at every stage, from initial consultation, through surgery and follow up, to ensure an optimal result for the patient.”

During surgery, the doctors discovered a giant granuloma pressing on the optic nerve. A granuloma is an area of inflammation in tissue due to injury or infection, and can easily be mistaken for a tumor in an x-ray and other imaging. Fortunately, Drs. Gardner and Snyderman were alert to this possibility and were able to resolve the problem.

Mike awoke that evening with a dry mouth but virtually no pain, and an immediate improvement in his vision. “I could not believe how well I could see,” marveled Mike. “For years I had compensated for poor vision, and now in the recovery room I was amazed by the level of detail.”

Mike was discharged from the hospital two days post surgery, and began teaching his fall classes eleven days after treatment.

Department treats 10,000th Gamma Knife patient

On December 21, 2009, University of Pittsburgh Center for Image-Guided Neurosurgery physicians treated their 10,000th Gamma Knife patient. The milestone surgery—the treatment of a metastatic brain tumor in an 81-year-old man—distinguishes the center as a world leader in this advanced minimally invasive radiosurgery procedure.

Gamma Knife radiosurgery represents one of the most advanced means available to treat deep-seated vascular malformations, brain tumors, and other brain disorders once considered inoperable. The treatment is advantageous because it does not require a surgical incision to ‘expose’ the lesion.

“Our involvement in the development of clinical uses for the Gamma Knife has given us the rare opportunity that few clinicians experience to shape the field of radiosurgery,” said L. Dade Lunsford, MD, Lars Leksell and Distinguished Professor of Neurological Surgery and co-director of the Center for Image-Guided Neurosurgery.

In 1987, Dr. Lunsford was responsible for bringing this technology to the United States and the University of Pittsburgh. In the ensuing 22 years, the department has evolved into a world leader in Gamma Knife treatment of brain disorders with patients from around the world coming here for treatment.

Gamma Knife radiosurgery is a multidisciplinary procedure that relies on the talents of radiation oncologists and medical physicists who partner with neurosurgeons in the treatment of often difficult clinical problems.

The lessons learned from over 22 years of clinical care, education and research has allowed department physicians to help guide the development of the technology.

“We have learned from these ten thousand cases that by helping to advance this technology, we are able to deliver optimal management of patients with increasingly complex and often deadly brain tumors and other brain and vein abnormalities,” said Douglas Kondziolka, MD, Peter Jannetta Professor of Neurological Surgery, department vice chair for education and co-director of the center. Thankfully, in most cases, we can extend our patients’ lives and preserve and enhance the quality of their lives.”

Gamma Knife staff and dignitaries mark 10,000th patient milestone: (front, kneeling) L. Dade Lunsford, MD; Charlene Baker; Nasir Awan, MD; Douglas Kondziolka, MD; Cheryl Rodgers; Oren Berkowitz; Jeff Tomkowitz (Elekta); (behind Dr. Lunsford) Wade Yang, MD; Hideyuki Kano, MD; (back row) Mary Ann Vincenzini; Judy Tisdale; Melissa Lukehart; Melissa Sroka; Laurie Colt; Kelly Powell; Ramesh Grandhi, MD; Frank Taormina; Jonet Vacsulka; Andy Lunsford (Elekta); Debbie Jennette; Mubina Quader, MD; Tomas Puusepp (President and CEO, Elekta); Donna Brenlove; John Innocenti (President, UPMC Presbyterian/Shadyside); Don Jeter.
**In the News**

- **Joseph Maroon, MD**, received widespread media attention in the fall of 2009 for his prominent role in helping provide advanced neurological care for athletes suffering concussions. A world-renowned specialist in the treatment of injuries and diseases of the brain and spine—and team neurosurgeon for the Pittsburgh Steelers—Dr. Maroon was quoted or mentioned in numerous Pittsburgh area media outlets plus the *New York Times*, *USA Today*, *Washington Post*, *Philadelphia Inquirer*, *ABC’s Nightline* and *NBC’s Football Night In America* among others.

  Also, in conjunction with his role as an expert in this field, Dr. Maroon—a member of the National Football League’s Mild Traumatic Brain Injury Committee—testified before the U.S. House Judiciary Committee on the diagnosis, treatment and return to play decisions in the NFL regarding players suffering concussions.

- Dr. Maroon was also featured in a November 9 news story on WTOV-TV9 (Steubenville, OH) discussing the latest technological advances in safer football helmets for high school athletes.

**Honored Guest Appearance**

- **Peter Gerszten, MD**, was a guest of honor speaker at the 22nd Annual Meeting of the Columbian Neurosurgical Association in Cali, Colombia, November 13-15.

**New Research Projects**

- “Transforming Traumatic Brain Injury Clinical Care and Research.” **David O. Okonkwo, MD, PhD**, (in partnership with University of California San Francisco; University of Texas, Houston; and Mt. Sinai Medical Center), $5.3 million, NIH.
- “Novel Approaches to Screening for Inflicted Childhood Neurotrauma.” PI: Rachel P. Berger, MD, PhD, Co-Investigator: Elizabeth Tyler-Kabara, MD, PhD, $10,256, NIH.

**Fellowship Available**

The Center for Clinical Neurophysiology is seeking a candidate for a one-year fellowship in intra-operative clinical neurophysiologic monitoring beginning July 2010. For more information, please contact **Miguel Habeych, MD, PhD**, at (412) 648-2570.

**Faculty Presents at 2009 CNS Annual Meeting**

The University of Pittsburgh was well-represented at the 2009 Congress of Neurological Surgeons annual meeting held October 24-29 in New Orleans, LA. For a complete list, please visit our website at neurosurgery.pitt.edu.

**Welcome**

- **Allison Hricik, MS**, neuropsychological outcome coordinator for David O. Okonkwo, MD, PhD; **Terretta Holiday**, clinical secretary for Elizabeth Tyler-Kabara, MD, PhD; **Tammy Brooks**, medical secretary for Adnan Abla, MD, and Daniel Wecht, MD.

**Congratulations**

- **Nestor D. Tomycz, MD**, announced his engagement to Evann Pierre, PA.
- **Adnan A. Abla, MD**, was recognized as a ‘Patient’s Choice’ doctor by MDx Medical, Inc. The honor reflects online feedback received from patients.

**And the ‘Cup’ makes two for department**

Douglas Kondziolka, MD, (right)—Peter Jannetta Professor of Neurological Surgery and team neurosurgeon for the Pittsburgh Penguins—received his Stanley Cup ring from the 2008-09 NHL champions in October. It was the second such recent recognition for a faculty member. This past summer, Joseph Maroon, MD, (left)—Heindl Scholar in Neuroscience and team neurosurgeon for the Pittsburgh Steelers—received his Super Bowl ring from the 2008-09 NFL champions.
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