The Gamma Knife Experience

World Class Facilities

Highest Accuracy in Market

UKM SPECIALIST CENTRE
GAMMA KNIFE
Wholly Owned by UKM Kesihatan Sdn Bhd

Unrivaled Precision

UKMSC

Gamma Knife Centre

Introduction

UKM Specialist Centre (UKMSC) Gamma Knife Centre is the first private-public university partnership allows transfer of knowledge and a continuous learning development for neurosurgeons in government hospitals. The Gamma Knife Centre sits strategically within walking distance to MRI, CT and Angiogram facilities in the hospital.

The UKMSC Gamma Knife Centre also introduces the revolutionized state-of-the art Stereotactic Radiosurgery (SRS) machine, the Leksell Gamma Knife® Icon™. The machine was officially installed on 16th September 2018 (Malaysia Day).

Leksell Gamma Knife® Icon™ features include:-

i) Broader take on precision
ii) Integrated immobilization workflow and imaging technologies
iii) Greater clinical flexibility, enhance everyday efficiency in the clinic. This translates to patients receiving better brain care

The frame-based and frameless immobilization Leksell Stereotactic Radiosurgery (SRS) is designed for patients with cranial disorders.

Our centre offers a full complement of specialists such as neurosurgeons, oncologists, radiotherapists and physicists.

Advantages
of Leksell Gamma Knife® Icon™

Unique Features
- Fully integrated, non-complex system design
- Automatic delivery correction and dose evaluation
- 2-4 times lower dose to healthy brain

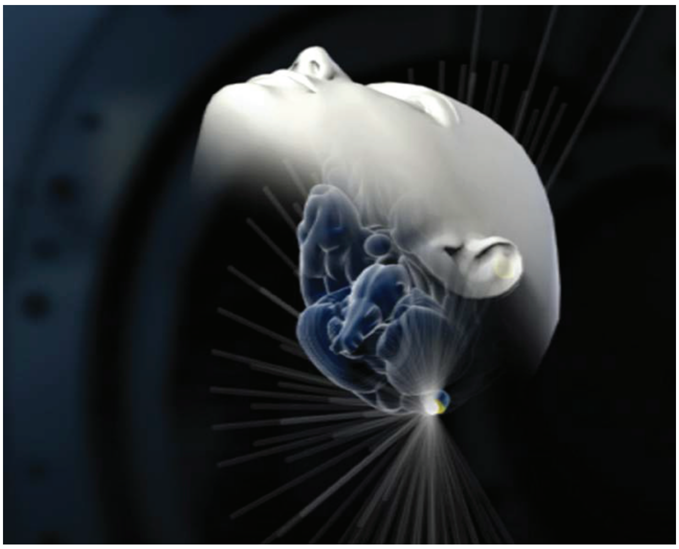
Guaranteed >98% uptime
- Fully integrated system design – with no moving parts during delivery – ensures minimal downtime

Flexible and intuitive workflows
- Well-defined workflows enable fast and intuitive dose planning, even for complex cases

Operational efficiency
- Fully automated treatment delivery allows for small teams and high throughput regardless of treatment volume

System without compromise
- Icon is specifically designed for intracranial radiosurgery and has unique dosimetrical capabilities

Future-safe technology
- Well-defined upgrade paths and proactive support through Elekta Care service



Elekta guarantees the accuracy of Leksell Gamma Knife for its entire lifetime—no other radiosurgery system does the same*

* With a Platinum service contract. The supported lifetime of Icon is 10 years.

Gamma Knife delivers lower dose to healthy tissue than other systems:

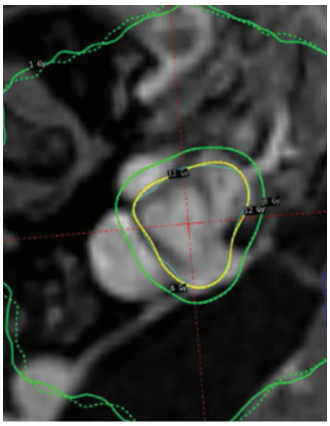
2-4x

lower dose to normal brain

Ma L, Nichol A, Hossain S, et al. Variable dose interplay effects across radiosurgical apparatus in treating multiple brain metastases. Int J CARS. Published online: 20 April 2014. doi: 10.1007/s11548-014-1001-4

Leksell Gamma Knife Icon enables frameless or

frame-based treatments with uncompromising accuracy



Flexible worklows aid efficiency

Frame-based workflow with fiducial based registration

Immobilize → MRI → PLAN → CBCT ⇄ Dose evaluation → Treat

option: QA check only (no correction)

Frame-based workflow with stereotactic CBCT based registration

MRI → Immobilize → CBCT (stereotactic reference) → PLAN: Co-registered MRI → CBCT ⇄ Dose evaluation → Treat

option: QA check only (no correction)

Mask-based workflow with stereotactic CBCT based registration

MRI → Immobilize → CBCT (stereotactic reference) → PLAN: Co-registered MRI → CBCT (patient positioning) ⇄ Dose evaluation → Treat

Correction applied

0.15
mm average accuracy

10
minutes QA

98
percent uptime

2,800
peer reviewed journal articles

>1,000,000
patients treated

UKM news portal

UKM is First Government Agency with Gamma Knife Centre

By Asmahanim Amir
Pictures by Shahiddan Saidi

CHERAS, 23 February 2017 – Hospital Chancellor Tuanku Muhriz, Universiti Kebangsaan Malaysia (UKM) is the first Government Agency to house a Gamma Knife Centre.

The treatment centre, built on the site of the built-up area of 4,000 square feet is valued at about RM25 million and is scheduled to be opened at the end of the year.

FIT FOR LIFE, Sunday 26 November 2017 — Health 5

The virtual scalpel

It's called Gamma Knife surgery, although it is not surgery in the traditional sense. Instead, it is a very precise form of therapeutic radiology.

By Dr HARDIP SINGH GENDEH

IN the last decade, we have seen minimally invasive endoscopic surgery making headway in the treatment of head and neck tumours.

However, like the scalpel blade, surgical telescopes have their limitations.

Multiple small tumours with central locations are difficult to access due to the risk of destroying surrounding structures while making a pathway to approach them.

So, how do we gain access to such tumours?

Therapeutic radiological inventions like Gamma Knife are the answer.

The Gamma Knife

The Gamma Knife was invented in 1967 by professor of neurosurgery Dr Lars Leksell, brain surgeon Dr Ladislau Steiner and radiobiologist Prof Dr Borje Larsson in Stockholm, Sweden.

It was then handed over to the University of California, Los Angeles, United States, in 1979 for clinical trials.

The term "knife" is a misnomer.

The procedure is compared to surgery because it produces similar results, which is to get rid of or destroy a tumour.

A study of 290 patients post-Gamma Knife treatment published by the *American Journal of Clinical Oncology* in 2016 revealed that approximately 87.7% and 87.2% had no tumour progression over a 10- and 20-year period of follow-up respectively.

According to Universiti Kebangsaan Malaysia Medical Centre (UKMMC) consultant brain surgeon Associate Professor Dr Ramesh Kumar, many refer to Gamma Knife as the "miracle knife" as it provides a single, high-dose radiation with pinpoint accuracy and precision to a critical area of the brain. It is often used to address small tumours of the brain with minimal effect to surrounding tissues.

More than 23,500 patients have been treated with Gamma Knife worldwide up to the year 2014.

In Asia, Japan leads with 53 Gamma Knife machines, a ratio of one machine to 2.4 million of its population.

For Malaysia to meet that ratio, we will require 13 Gamma Knife machines nationwide, with an average of one per state.

Stereotactic radiosurgery

Stereotactic radiosurgery allows for calculated doses of gradient concentrations of ionising radiation to the tumour with minimal effect to the surrounding tissue.

UKMMC senior consultant oncologist and Oncology and Radiotherapy Department head Prof Datuk Dr Fuad Ismail shares, "The Gamma Knife is useful in treating brain tumours that are challenging or risky to access with surgery, especially among patients with multiple brain tumours."

Multiple brain tumours may occur due to spread of cancer from other parts of the body, a process termed metastasis.

A study carried out in Sarawak in 2014, and published in the *Malaysian Journal of Medicine*, showed that brain metastasis from other parts of the body are not only a rising in trend in our population, but also doubled in the four years of the study.

UKMMC consultant brain surgeon and Neurosurgical Unit head Assoc Prof Dr Azizi Abdul Bakar shares that the Gamma Knife can also be used in addition to brain surgery, when the tumour is unable to be completely removed due to its close proximity to other vital structures such as major blood vessels and nerves in the brain.

How it works

The Gamma Knife machine consists of a shielded gantry containing cobalt-60 sources arranged in a half circle that shine gamma radiation to the target point in the brain.

Assoc Prof Ramesh likens it to concentrating sunlight with a magnifying glass.

With the Gamma Knife, the cobalt-60 sources act as sunlight and the head protector acts as a magnifying glass to concentrate the light beams onto a small surface area.

Prof Fuad says, "Firstly, a head-frame or custom-made face mask based on the curvature of the individual's head and face is used to lock the patient's head in place.

Radiation beam
Helmet
Area of glioma
Gamma Knife Surgery

The Gamma Knife machine consists of a shielded gantry containing Cobalt-60 sources arranged in a half circle that shine gamma radiation to the target point in the brain. — Wikimedia Commons

"Then, the patient will have to undergo conventional imaging with CT and MRI, to map out the coordinates of the tumour in the brain.

"Thirdly, the patient will be placed at the Gamma Knife machine and targeted gamma rays will be shined upon the marked target."

The face mask or frame is a system to hold the head steady, preventing any unwanted movement that may alter the calibrated direction of the gamma rays to the target.

The process, however, has a multitude of steps involving a multidisciplinary team of brain surgeons (neurosurgeons), cancer physicians (oncologists), imaging doctors (radiologists) and a physics expert (physicist).

Initial CT/MRI findings and the feasibility of the Gamma Knife procedure will have to be evaluated and discussed among the brain surgeons, cancer physicians and imaging doctors.

UKMMC neuroradiologist Assoc Prof Datin Dr Shahizon Azura shares that target areas will be marked by the brain surgeons and radiology doctors.

Computer planning of gamma rays will be performed by the oncologist, neurosurgeon and physicist.

Occasionally, an anaesthetist consult will be required for sedation.

According to Prof Fuad, the Gamma Knife is effective on brain tumours that originate from nerves (neuromas), the pituitary gland (pituitary adenomas), coverings of the brain (meningiomas) and brain tissues (gliomas).

It has also been shown to be effective in treating abnormal blood vessels in the brain and spinal cord, such as arteriovenous malformations (inborn abnormalities of the small vessels of the brain).

Its use is also being explored for functional disorders of the brain such as chronic facial pain caused by the trigeminal nerve (trigeminal neuralgia), epilepsy, depression and obsessive compulsive disorder (OCD).

The use of Gamma Knife in functional disorders is still in its infancy and not widely accepted.

Studies have also highlighted its use in acoustic neuroma, a non-cancerous tumour that originates from the hearing and balance nerves in the brain.

"Stereotactic radiotherapy such as Gamma Knife has a role in acoustic neuromas that are very small and less than 2cm in diameter. It is an option for non-surgical candidates, offering similar tumour control rates," says UKMMC senior consultant Ear, Nose and Throat surgeon and Otorhinolaryngology - Head and Neck Surgery Department head Prof Dr Asma Abdullah.

She adds that the Gamma Knife has been used in Malaysia in selected cases with good outcomes, though it is still a relatively new technology to us.

Various benefits

Gamma Knife treatment is often a day-care procedure whereby patients visit the centre to receive their treatment and are allowed home by the end of the day.

According to Dr Sonia Manocha, "My late father had Gamma Knife treatment and it was painless, which made it bearable."

Assoc Prof Ramesh adds, "The Gamma Knife can be used to treat multiple lesions and most patients only require a single treatment."

Unlike conventional radiotherapy which limits whole grain radiation to once a lifetime, Gamma Knife treatment can be repeatedly if required.

Patients generally have a shorter recovery time and each procedure should take between 20 minutes to three hours depending on the complexity of the case.

Following treatment, the patient will be allowed to return home within the same day and resume their normal activities.

It has less side effects compared to conventional radiotherapy as the gamma rays are concentrated on the targeted tumour, thus resulting in less damage to structures on its approach during shining.

This also enables more patients to be treated in a day. The Gamma Knife treatment does have its downside.

Firstly, it is an expensive technology and cost of treatment will be higher compared to conventional radiotherapy.

The counter argument is that most Gamma Knife patients only require one treatment, while conventional radiotherapy requires multiple courses of treatment depending on the nature of the disease.

According to UKM Faculty of Medicine dean Prof Dr Zaleha Abdullah Mahdy, UKMMC will be the first government-based healthcare agency to equip itself with the Gamma Knife.

The Gamma Knife treatment centre at the university hospital was launched by Health Minister Datuk Seri Dr S. Subramaniam in February and is due to be completed soon.

Dr Hardip Singh Gendeh is a resident medical officer at the UKMMC Department of Otorhinolaryngology – Head & Neck Surgery. For more information, e-mail starhealth@thestar.com.my.

Minister of Health, Datuk S. Subramaniam said the radiosurgery treatment centre will benefit various types of patients, especially those who have abnormal lesions, cancerous and non-cancerous tumour.

Gamma Knife is a non-invasive neurosurgical procedure which uses powerful doses of radiation to target and treat tumours and abnormalities, shrinking them over time or stopping their growth.

"With the centre, patients who have a tumour or brain cancer no longer have to undergo normal surgery, but they just need to do a treatment using Gamma Knife radiation," said Datuk S. Subramaniam.

"This high-tech treatment focuses on specific brain tissue involved without affecting other areas," he explained.

Datuk S Subramaniam said the treatment methods is not only easy, but it can reduce trauma to the brain and the cost of treatment for the long term is also affordable.

At the ceremony, he also launched the Crystal Ward at UKM Specialist Centre.

Also present at the ceremony were Swedish Ambassador to Malaysia, Dag Juhlin Dannfelt and Deputy Vice-Chancellor of Academic and International Affairs, Prof Dato' Ir Dr Riza Atiq Abdullah OK Rahmat.

Left, The Star Sunday, 26 November 2018
"The virtual scalpel"

Indications

- Brain tumors.
- Metastatic brain tumors.
- Benign brain tumors - pituitary tumors, acoustic neuromas, meningiomas, Scwannomas.
- Brain abnormalities, such as arteriovenous malformation (AVM), cavernomas.
- Functional disorders, such as trigeminal neuralgia,tremor, Parkinson’s disease and OCD

What are the benefits of Gamma Knife

- No surgery or general anesthesia required
- Painless
- Day case
- High volume
- Effective alternative treatment for inoperable case
- Can treat mulltiple lesions
- Shorter recovery time
- Less side effects compared to conventional radiotherapy treatment

Quality of life

- The treatment can be done as a single session and as an outpatient procedure
- Less time spend in hospital and more time for treatment of primary disease
- Quick recovery and return to everyday life and work
- Reduced risk of side effects i.e. reduced risk of negative neurocognitive impact, memory loss and dementia, hair loss, skin infection etc.

Gamma Knife® radiosurgery Meningioma

Introduction

Meningiomas are generally slow-growing, intracranial or intraspinal extra-axial tumors that develop from the arachnoid cap cells of the dura mater. Although most tumors grow slowly, some grow quickly and can double in volume within six months to a year. Stereotactic radiosurgery has greatly expanded the management options since patients no longer have to choose simply between resection and observation. Resection is indicated for larger tumors with disabling brain or nerve compression, hydrocephalus, intractable headache or trigeminal neuralgia. Many patients have smaller tumors and do not have severe symptoms. Although the outcomes of surgical removal at centers of excellence have improved markedly over the last two decades, patients increasingly seek lesser invasive options.

Gamma Knife Radiosurgery Technique for Meningiomas

Patients with meningiomas are evaluated with high resolution MRI. For meningioma radiosurgery, a 3-D volume acquisition MRI using a gradient pulse sequence is performed in order to cover the entire lesion and surrounding critical structures. A T2 weighted 3-D volume sequence is performed to visualize the brain parenchyma, any edema, and cranial nerves if appropriate. Planning is performed on narrow slice thickness axial MR images with coronal and sagittal reconstructions. Conformality and selectivity is necessary for brain function preservation. Meningioma planning is usually performed using a combination of small beam diameter (4mm and 8mm) collimators. The treatment isodose, maximum dose, and dose to the margin (edge) are jointly decided by a neurosurgeon, radiation oncologist, and medical physicist. In Gamma Knife® radiosurgery a dose of 11-16Gy is typically prescribed to the 50% (or other) isodose line that conforms to the tumor margin.

Clinical Results

Long-term results of Gamma Knife® radiosurgery for meningiomas have been documented. Recent reports suggest a post-radiosurgery tumor control rate above 90% for grade 1 tumors. In a 2008 report, the University of Pittsburgh group provided further data. The larger patient cohort consisted of 972 patients with 1045 intracranial meningiomas managed during an 18-year period. The overall control rate for patients with benign meningiomas (World Health Organization Grade I) was 93%. Santocroce et al provided results from a large European multi-center study. From 15 participating centers, they reported a retrospective observational analysis of 4,565 consecutive patients harboring 5,300 benign meningiomas. Five- and 10-year progression-free survival rates were 95.2% and 88.6%, respectively. Tumor control was higher for imaging defined tumors vs grade I meningiomas ($P < .001$), for female vs. male patients ($P < .001$), for sporadic vs. multiple meningiomas ($P < .001$), and for skull base vs. convexity tumors ($P < .001$).

Conclusion

Gamma Knife® radiosurgery has become a well documented management option for patients with intracranial meningiomas that is both safe and effective over the long-term. The most data is for grade 1 tumors, either as initial management or for residual or recurrent tumors with known histology. Data past ten years of follow-up are now published, and systematic, serially collected outcomes data are available on patients with for this tumor. Radiosurgery is now a common treatment choice for many patients with smaller volume tumors.

Gamma Knife® radiosurgery Acoustic Neuroma

Introduction

Acoustic Neuromas (vestibular schwannomas) are generally slow-growing, intracranial extra-axial benign tumors that usually develop from the vestibular portion of the eighth nerve. A progressive unilateral hearing decline is the most common symptom that leads to the diagnosis of a vestibular schwannoma.

During the past two decades radiosurgery has emerged as an effective alternative to surgical removal of small to moderate-sized vestibular schwannomas. Long-term results have established Gamma Knife® radiosurgery as an important minimally invasive alternative to resection. Advanced multiisocenter dose planning software, high resolution MRI for targeting, dose optimization, and robotic delivery reflect the evolution of this technology. The goals of vestibular schwannoma radiosurgery are to prevent further tumor growth, preserve neurologic function where possible, to avoid the risks associated with open resection, and in selected patients to improve pre-existing symptoms.

Gamma Knife Radiosurgery Technique

Patients with vestibular schwannomas are evaluated with high resolution MRI and audiological tests that include pure tone average (PTA) and speech discrimination score (SDS) measurements. Dose planning is a critical aspect of radiosurgery, and Leksell GammaPlan® software provides the platform for reliable tumor irradiation. Complete coverage of the tumor and preservation of facial, cochlear and trigeminal nerve function is given priority during dose planning. For large tumors, preservation of brainstem function is also a consideration.

Vestibular schwannoma planning is usually performed using a combination of small beam diameter (4 and 8mm) collimators. A series of 4mm isocenters are used to create a tapered isodose plan to conform to the intracanalicular portion of the tumor. In Gamma Knife® radiosurgery a dose of 12-13Gy is typically prescribed to the 50% isodose line that conforms to the tumor margin.

Clinical Results

Recent reports suggest a tumor control rate of 93–100% after radiosurgery. Kondziolka et al studied 5-10 year outcomes in 162 vestibular schwannoma patients who had long-term 98% tumor control rate was reported. Sixty-two percent of tumors became smaller, 33% remained unchanged, and 6% became slightly larger.

Hearing Preservation

Pre-radiosurgery hearing can now be preserved in 60–90% of patients, with higher preservation rates found for smaller tumors. In a long-term (5–10 year follow-up) study conducted at the University of Pittsburgh, 51% of patients had no change in hearing ability. A recent research has shown that the mean cochlear dose is important for hearing preservation. A dose of <4Gy was associated with better hearing, a finding similar to that of other centers. Age is also important with those under 60 years old faring better. Long-relaxation time (T2) volumetric images are important to identify the cochlea for dose planning.

Conclusion

Gamma Knife® radiosurgery has become a well documented management option for patients with vestibular schwannomas that is both safe and effective over the long-term. Data past ten years of follow-up are now published, and systematic, serially collected outcomes data are available on patients with for this tumor. Radiosurgery may currently be the most common treatment choice for patients.

Gamma Knife® radiosurgery Post-surgical Pituitary Adenomas

Elekta

Introduction

Pituitary adenomas represent one of the most common types of intracranial tumors. While their macroscopic appearance and anatomical location are relatively homogeneous, pituitary tumors have the potential to generate a wide variety of clinical sequelae. Treatment options for pituitary tumors include medical therapy, microscopic or endoscopic surgical resection, radiosurgery, radiation therapy, or observation depending on the biochemical profile and clinical status of the patient

Clinical Results

Nonfunctioning Pituitary Adenomas

In a recent multicenter trial evaluating the role of Gamma Knife® radiosurgery (GKRS) for 512 patients with nonfunctioning pituitary adenomas, the authors observed an overall tumor control rate of 93%. Hypopituitarism following GKRS was noted in 21% of patients.

Cushing's Disease

Invasion of the surrounding dura or neighboring cavernous sinus by many of these tumors decreases the likelihood of cure with surgery alone. Radiosurgery therefore plays a crucial role in the treatment of persistent Cushing's disease refractory to surgical management. Most series demonstrated endocrine remission for the majority of patients after radiosurgery but the reported rates varied widely from 0-100% with a mean of 51.1%.

Acromegaly

Due to the significant resultant morbidities associated with untreated acromegaly, surgical resection is the initial treatment of choice for these patients. Endocrine remission was achieved in 0-82% of patients with a mean of 44.7% whereas post-radiosurgery hypopituitarism occurred in 0-40% of patients with a mean of 16.4%.

Prolactinomas

Prolactinomas are the most common type of secretory pituitary adenomas. However, unlike ACTH- or GH-secreting adenomas, the initial management of prolactinomas is with medical therapy. Endocrine remission off antisecretory medications following radiosurgery ranged from 0-100% with an average of 34.7%.

Complications

Delayed pituitary insufficiency is, by far, the most common adverse effect of radiosurgery for pituitary adenomas, occurring in up to 40% of patients with nonfunctioning lesions and up to nearly 70% of patients with functioning lesions with wide variation across different radiosurgery series. While an ideal radiosurgical dose plan has a steep gradient index which minimizes the dose to normal pituitary tissue and therefore reduces the risk of treatment-induced hypopituitarism, a true 'safe dose' below which the patient is not afflicted with hypopituitarism does not practically exist. The clinical consequences of macroscopic tumor progression or recurrence or persistent hormone hypersecretion far outweigh those of radiosurgery-induced hypopituitarism which is readily managed with medical therapy by neuroendocrinologists.

Conclusion

Radiosurgery and, to a lesser extent, EBRT play important roles in the contemporary management of patients with a pituitary adenoma. Both treatment modalities are typically utilized in patients with substantial residual tumor or recurrence after surgical resection of nonfunctioning adenomas. They are also employed for patients with functioning adenomas that fail to achieve endocrine remission after prior resection. Neurological function after radiosurgery or EBRT is usually preserved or, at times, improved even when the treated adenoma extends into the cavernous sinus. Delayed post-treatment hypopituitarism is the most common complication but is manageable with appropriate hormone replacement. Lifelong neuro-imaging and endocrine follow-up is recommended for pituitary adenoma patients treated with radiosurgery or EBRT.

Gamma Knife® radiosurgery Recurrent Glioblastomas

Elekta

Introduction

Tumor recurrence after initial standard therapy of glioblastoma is virtually inevitable. After standard fractionated radiotherapy, 77-90 % patients relapse within 2 cm of the original glioblastoma within 20-40 weeks. The median survival time after reoperation of recurrent glioblastoma can be estimated with 3.5 – 9 months, provided that the patients are in good preoperative clinical condition.

State of Literature

In 7 studies that reported outcome after stereotactic radiosurgery according to RPA classes, the median survival in RPA class 4 was 15.2 while the historical RTOG series had reported a median survival of 11.1 months for RTOG class 4. In the situation of an almost inevitable glioblastoma recurrence, the treatment is highly complex; as fractionated radiotherapy cannot be repeated and the surgical options may be limited due to the patients' frequently reduced clinical condition. Under these circumstances stereotactic radiosurgery has been proven to be an effective alternative treatment option and patients treated at the time of progression had significantly longer overall survival than those treated on initial presentation.

A recent prospective cohort study demonstrated that stereotactic radiosurgery significantly prolonged survival as a salvage treatment in patients with recurrent glioblastomas (23 months vs. 12 months; P<.0001). When compared to a historical control group from the same institution with patients who had not been treated with radiosurgery for their recurrence and a casecontrol study showed that the combination of salvage Gamma Knife® radiosurgery followed by bevacizumab could add potential survival benefit and could reduce the risk of adverse radiation effects in patients with recurrent glioblastoma (33.2 months vs. 26.7months). The overall survival in this study is surprisingly positive. For patients with recurrent glioblastoma the outcome after use of stereotactic radiosurgery appeared to be at least equivalent to repeated surgical resection.

Conclusion

There is retrospective evidence that radiosurgery offers a minimal invasive approach for the treatment of glioblastoma recurrences when standard treatment has been given and cannot be repeated. A prospective cohort study demonstrated that stereotactic radiosurgery significantly prolonged survival as a salvage treatment in patients with recurrent glioblastomas when compared to a control group who had not been treated with radiosurgery. A case-control study of stereotactic radiosurgery for recurrent glioblastoma showed an outcome that was at least equivalent to repeated surgical resection and a retrospective analysis showed an even improved survival after Gamma Knife® radiosurgery when compared to surgical resection of the recurrent glioblastoma. Hence, the survival after salvage radiosurgery compares favorably to the outcome after reoperation of recurrent glioblastoma, the treatment with temozolomide and the median overall survival on bevacizumab after glioblastoma recurrence.

In the situation of a glioblastoma recurrence, where virtually no other meaningful treatment is available stereotactic radiosurgery in general and Gamma Knife in particular has been shown to offer a safe and effective therapeutic alternative that prolongs the survival. Future prospective studies will further define the ideal clinical criteria to achieve an optimal survival benefit for the radio surgical treatment of glioblastoma recurrences.

Gamma Knife® radiosurgery
Brain Metastases

Elekta

Leksell Gamma Knife® Perfexion™: The Intelligent Choice for Brain Metastases

With the advent of stereotactic radiosurgery, a novel approach to the treatment of brain metastases is emerging. Multiple guidelines and studies have confirmed the role of SRS as an appropriate technique for achieving tumor control while affording quality of life benefits even in the case of multiple metastases[1,2] The number of brain metastases diagnosed each year is growing due to an aging population, ubiquitous imaging and extended survival afforded by systemic therapies. Additionally, the role of SRS in the treatment of cancer is expected to increase as awareness of the negative effects of WBRT grows and ability to select patients that will most benefit from SRS is refined.

The advantages of stereotactic radiosurgery include:

- **Single session treatment, no cessation of systemic treatment required**
- **Avoids complications associated with Whole Brain Radiation Therapy (WBRT) including white matter changes and neurocognitive decline[2-4].**
- **Single session treatment means less burden on patient and caregivers and improved Quality of Life for all.**

Why Leksell Gamma Knife®?

Not all radiosurgery devices are created equal. Designed specifically for and dedicated to the brain, Leksell Gamma Knife® is widely recognized as the gold standard in radio surgery. Leading centers worldwide have adopted Leksell Gamma Knife® as their tool for effective, efficient and patient centric treatment. Over 750,000 patients have been treated worldwide; over 250,000 brain metastases have been treated.

Unique benefits of Leksell Gamma Knife® include:

- Fast treatment delivery and optimized workflow to ensure high patient throughput averaging over 400 cases per year*
- Less dose to normal brain and body compared to other radiosurgery devices due to exquisite conformality and selectivity[5-7]
- Most extensive clinical evidence base with over 2,500 peer-reviewed publications of which over 550 report the results of metastatic tumor treatment including numerous papers describing the utility of Leksell Gamma Knife® for multiple metastases[8-11], targets in challenging anatomic locations[12-14], large tumors[15-17] and radioresistant tumors[18-21]
- Permits physicians to scan, plan and treat in a single session with no technical limitation to number of tumors treated—optimal efficiency at low cost
- Highest uptime with least quality assurance demands minimizes the burden on staff
- Support for every step on the path to a world class SRS program.

* Leksell Gamma Knife Society Survey, 2012

Gamma Knife® radiosurgery Arteriovenous Malformations

Introduction

Over 90,000 intracranial arteriovenous malformations (AVMs) have been treated with Gamma Knife® since it was first used in 1968*. It is increasingly used as a non-invasive adjunct and alternative to more invasive therapies including embolization and microsurgery with approximately 6,500 patients* treated each year.

Obliteration Rate

The goal of Gamma Knife® radiosurgery is complete obliteration of the AVM nidus while avoiding postprocedural adverse radiation effects. The obliteration process is cumulative, with earliest obliterations noted within 2–3 months, 50% of the effect often seen within one year, 80% within two years and 90% within three years.[1-5] If at the end of three years residual AVM is identified by imaging, patients may undergo repeat Gamma Knife® treatment.[6-8] Total obliteration appears to reduce the cumulative residual lifetime risk of hemorrhage to 1% or less. Patients remain at risk for hemorrhage during the latency interval between SRS and obliteration. Whether that risk gradually lessens as that interval increases remains to be fully confirmed.[9]
Dose volume guidelines for Gamma Knife® radiosurgery have been extensively published[10,11] and various grading schemes have been devised[12,14]. There are also over 500 peer reviewed articles elucidating the utility of Leksell Gamma Knife® in specific clinical situations including:

- Anatomical location (e.g., brainstem, basal ganglia and thalamus)[15-22]
- Volume (e.g., large lesions and staged Gamma Knife® radiosurgery)[23-28]
- Pediatric population[29-34]
- Adjunctive use with embolization.[35-38]

Gamma Knife® radiosurgery (GKS) is a safe and effective treatment for AVMs in eloquent, deep-seated areas and other intracranial locations in children and adults. GKS provides high obliteration and cure rates and has low morbidity. Large AVMs and AVMs in eloquent regions that could not be treated three decades ago are now treated quite cost effectively with good clinical outcome.

Why Leksell Gamma Knife®?

Not all radiosurgery devices are created equal. Designed specifically for and dedicated to the brain, Leksell Gamma Knife® is widely recognized as the gold standard in radiosurgery. Leading centers worldwide have adopted Leksell Gamma Knife® as their tool for effective, efficient and patient centric treatment. Over 750,000 patients have been treated worldwide; over 50 percent of cases have been for non-oncologic indications.*

Unique benefits of Leksell Gamma Knife® include:

- Fast treatment delivery and optimized workflow to ensure high patient throughput averaging over 400 cases per year*
- Sharpest dose gradients and lowest dose outside the target minimize the risk of secondary cancer[5-7]
- Wealth of research providing evidence for safe and clinically effective solutions[8-11]
- Highest uptime with least quality assurance demands ensuring ease of use and reliability
- Able to routinely treat broadest spectrum of intracranial disorders in a single session enabling practice expansion beyond typical oncologic diseases
- Support for every step on the path to a world class SRS program.

* Leksell Gamma Knife Society Survey, 2012

Gamma Knife® radiosurgery Trigeminal Neuralgia

Introduction

Trigeminal neuralgia is one of the most severe pain syndromes any person can face. When medical management fails to control the pain of trigeminal neuralgia, patients require surgical intervention. Effective surgical procedures include craniotomy and microvascular decompression, percutaneous ablative procedures, or stereotactic radiosurgery. All surgical procedures have variable but definite rates of risk and pain recurrence.

Unfortunately, many patients with trigeminal neuralgia are poor craniotomy candidates because of advanced age or the presence of medical comorbidities. Stereotactic radiosurgery is the least invasive modality for such patients.

Gamma Knife Radiosurgery Technique for Trigeminal Neuralgia

For trigeminal neuralgia radiosurgery, a 3-D volume acquisition MRI using a gradient pulse sequence (divided into 1 mm thick slices) is performed in order to cover the entire region and surrounding critical structures. A T2 weighted 3-D volume sequence is performed to visualize the cranial nerves and can be helpful in certain patients, particularly after prior microvascular decompression.

In Gamma Knife® radiosurgery a dose of 75-90 Gy is typically prescribed to the 100% (maximum) isodose line. After radiosurgery, patients are followed up with serial clinical assessments which are commonly requested at 3 months and then annually or as needed.

Clinical Results

Most centers report an average latency to pain relief after radiosurgery of approximately 1 to 2 months. A study from University of Pittsburgh demonstrated that 89% of patients responded to treatment at a median of one month. They found that patients with typical trigeminal neuralgia, patients who underwent GKSR as their initial surgical procedure, and patients who underwent earlier GKSR (< 3 years) after pain onset had faster pain relief (grade I to IIIb). The median time to achieve complete pain relief (grade I) was five months. By 12 months after GKSR, 11% of patients still had pain. The experience indicates that the majority of patients experience lasting, satisfactory pain reduction with few complications after GKSR. In this series, 75% of patients achieved or maintained pain control (BNI grade I-IIIb), 59% had pain relief at 3 years, 43% maintained relief at 5 years, and 29% were still controlled with or without medications at 10 years.

Conclusion

Radiosurgical results appear similar, or perhaps less satisfactory than those after a first microvascular decompression. For this reason many clinicians continue to advocate a microvascular decompression for younger patients suitable for invasive surgery. In addition, the benefit of decompression is reduced when performed a second time, or for recurrent trigeminal neuralgia. On the other hand, GKSR is clearly well tolerated, has a better safety profile, and an acceptable degree of benefit that appears consistent amongst centers. Efficacy appears similar to the different rhizotomy surgeries.

Gamma Knife radiosurgery has become a well documented management option for patients with trigeminal neuralgia that is both safe and effective. It is the least invasive surgical option. Reports from centers worldwide show consistent outcomes and longer term data is now available from numerous centers. Outcomes data is consistent because methods of targeting and radiosurgical delivery have been consistent.

Gamma Knife® radiosurgery Medically Refractory Essential Tremor

Elekta

Introduction

Tremor is a common movement disorder that can have disabling effects on daily living, impact employment, and reduce quality of life. Medical management strategies are helpful for some patients, but many patients either become unresponsive to medication or derive no benefit. As the population ages, tremor patients with high surgical risk comor bidities such as long term anticoagulation have been deemed ineligible for invasive surgical procedures. Stereotactic radiosurgical Gamma knife® thalamotomy (GKSRS) is an important option for tremor patients ineligible for other types of thalamic surgery because of advanced age or surgical comorbidities.

Gamma Knife Radiosurgery Technique for Essential Tremor

A contrast-enhanced volume acquisition MRI (with images at 1mm intervals) is performed for stereotactic targeting through the thalamus and midbrain in order to identify the anterior and posterior commissures (AC, PC) and the third ventricle. An axial fast inversion recovery sequence is then obtained to better identify the internal capsule and differentiate gray and white matter structures. The 20% isodose line of the 4mm collimator is kept medial to the internal capsule. A maximum dose of 130–140Gy is the most common dose, delivered with a single 4mm isocenter.

The radiobiological effect of the radiosurgical lesion is unique. The effect consists of a limited central target necrosis (3-4mm in diameter) where the highest dose is delivered. This central zone is surrounded by a non-necrotic peripheral or halo effect that may also provide therapeutic benefit to thalamic cells generating tremor.

Clinical Results

In 70 patients out of 86 from a 2013 series, at least one of the 8 assessed scores was improved following Gamma Knife® Thalamotomy. Of these 70 patients, the median followup time before improvement was demonstrated was 4 months. A recent prospective multicenter study from Japan with 72 patients (PD or MS) found that 81% of patients had excellent or good results. In a University of Pittsburgh series, in each disease subset, GKSRS provided statistically significant improvements in FTM writing, tremor and drinking scores.

Detailed below are specific outcomes (Fahn-Tolosa-Marin clinical tremor rating scale) as recently published by Kooshkabadi et al. Overall, the preoperative mean tremor score was 3.3 ± 0.8 and 1.8 ± 1.2 ($p < 0.00001$) after radio surgery. The mean handwriting score was 2.8 ± 0.8 before GKT and 1.6 ± 1.0 ($p < 0.00001$) afterward. The mean preoperative drinking score was 3.1 ± 0.8 and 1.8 ± 1.1 ($p < 0.00001$) afterward. The clinical benefit of radiosurgery for any indication occurred at an average of two months (range, one week to 8 months).

Conclusion

There are increasing numbers of patients with medically refractory and disabling tremor who are poor candidates for open surgery and require some form of treatment. Gamma Knife® radiosurgical thalamotomy has provided benefit to the majority of patients who underwent the procedure. It has been found to be both safe and effective. The outcomes data has been consistent across centers, both in the United States and Japan. The technique appears to be underutilized given the large number of patients with disabling tremor, especially in an aging population.

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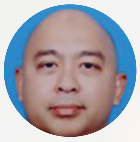

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