Introducing flexibility and precision

The introduction of Gamma Knife® radiosurgery at Bristol Gamma Knife Centre has opened up new treatment possibilities in intracranial stereotactic radiosurgery (SRS). Bristol’s SRS treatment portfolio started with linac-based radiosurgery and was later expanded with Leksell Gamma Knife® Perfexion™. Recently the Centre upgraded to the latest generation of the platform, Leksell Gamma Knife Icon.

With the introduction of Leksell Gamma Knife Icon, the Centre has been able to efficiently increase the number of patients treated per day. With stereotactic imaging, online Adaptive DoseControl™, ultra-precise dose delivery and the availability of frameless treatments, Leksell Gamma Knife Icon is capable of treating virtually any target in the brain, regardless of type, location or volume. In July 2015, physicians at Bristol Gamma Knife Centre began using Icon clinically in frame-based treatments. Mask-based treatments began a month later.
Bristol Gamma Knife Centre

Expanding treatment possibilities

Presently at the centre, single-session, mask-based Icon radiosurgery is the standard of care. Of the 23 patients who have had treatment with the mask, 17 had single-session radiosurgery. Among them was a 58-year-old male with four metastases (see figure 1) who Dr. Cameron suspected might have had progression of his disease (additional metastases) since his last MRI and therefore might not even be eligible for Gamma Knife radiosurgery. The original intent had been radiosurgery with the traditional frame and the protocol was to conduct the pre-treatment MRI with the frame attached, something Dr. Cameron was reluctant to do.

“The worst thing you can do is put the frame on a patient, then do the MRI and find out the disease had progressed so much that it’s not worth doing,” she explains. “He was scanned without the frame and we discovered his disease hadn’t progressed. Moreover, none of his metastases were anywhere near a significant organ-at-risk, which meant we wouldn’t need the extreme accuracy of the traditional frame. The accuracy of the mask is very nearly as good, so we made a mask and delivered the single treatment to the four mets in one hour and 53 minutes.”

Dr. Alison Cameron, Consultant Clinical Oncologist and Lead Clinician for the Bristol Gamma Knife Centre
She adds that the treatment went so smoothly that the patient fell asleep and did not wake until the last 15 minutes. The Icon system’s infrared high-definition motion management (HDMM) system alerted doctors that the patient had awoken by detecting a tiny movement of his nose (0.5 mm), which was not enough to interrupt treatment.

Dr. Cameron has found that mask immobilization has been more secure than she expected, based on this case and subsequent ones. The HDMM system, which tracks a marker on the tip of the patient’s nose continuously and in real time during the fraction, will trigger the cessation of beam delivery if motion exceeds a preset threshold. Generally at Bristol it is set at 1.5 mm for automatic stop, even if there is a brief movement spike (see figure 2). However, if the patient consistently drifts to greater than 0.7 mm from baseline, the team manually pauses the treatment and if the patient does not settle back, resets the patient with a new stereotactic cone beam CT (CBCT).

“I’ve been exceptionally impressed,” she says. “I thought that patients were going to constantly ‘trip out,’ but that has not been the case, even for patients who have long treatments. In only a minority of cases have we been required to do a second CBCT to recalculate the plan as a result of patient motion over the threshold. The key is getting the patient snugly in the mask and waiting

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Figure 1: Male 58 year old patient (second image) with 4 metastases; mask based treatment using the Gamma Knife Icon.
Metastasis 1: 22Gy to 52% - 0.174cc
Metastasis 2: 22Gy to 49% - 0.427cc
Metastasis 3: 16Gy to 77% - 0.026cc (abuts brainstem)
Metastasis 4: 18Gy to 50% - 4.948cc
Image courtesy of Dr. Cameron, University Hospitals Bristol, UK
for them to settle comfortably before the first CBCT. The intrafraction monitoring has been hugely reassuring for me, to know that the patients aren’t moving during beam delivery.”

**Fractionation provides protection for the sensitive brain anatomy**

To protect sensitive brain anatomy, Icon enables all fractionation protocols, from radiosurgery, to hypofractionation, to conventional 1.8-2 Gy per fraction schedule: regimes that the centre’s clinicians had used for years in the linear accelerated based intra-cranial radiosurgery/radiotherapy program.

“We are the world’s first centre to have treated patients with completely ‘fractionated out,’ Gamma Knife treatment,” notes Dr. Cameron.

Patients selected for fractionated mask-based treatments are those with lesions too close to critical structures to allow single-session frame-based SRS, such as a growing pituitary adenoma in close proximity to optical pathways.

“If the lesion is less than two millimeters from the optic apparatus, the use of single-session frame-based radiosurgery would incur a dose of greater than 8 or 10 Gray to this anatomy, risking optic neuropathy,” she reports. “Conceivably, you could drop the dose to the top of the tumor, but then you’re risking relapse. Neither of these options is good. We know that 25 fractions at 1.8 Gy each is very safe for the optic apparatus and achieves a very high control rate.”

Dr. Cameron adds that the advantage of fractionated Gamma Knife radiosurgery with Icon over linac-based radiotherapy for this and other indications is in the amount of brain receiving radiation. With volumetric arc therapy (VMAT) or intensity-modulated radiation therapy (IMRT), large areas of the temporal lobe and hippocampus will receive a significant dose of radiation, potentially increasing the risk of stroke, neurocognitive effects and secondary malignancy.

“I can’t prove these side effects will happen but you’re definitely treating more healthy brain when treating the same patient using a linac,” she adds. “The patients we treated with Icon had only minor side effects. They tolerated the treatment really well and the treatment plans were enormously better in comparison to linac plans.”
Patient choice is a priority

Dr. Cameron is confident enough in the mask-based head fixation, motion management and CBCT imaging capabilities of Icon that she has had the opportunity to approve patient requests for the mask.

“One of our patients scheduled for Gamma Knife radiosurgery called to say he had seen the BBC TV spot on our Icon and said he wanted the mask,” she recalls. “I looked at his scan and told him I was confident we could achieve the required accuracy with Icon. We are happy to accommodate patients who proactively choose the mask if the target’s position allows for it. And of course the stereotactic headframe continues to be used, certainly in those cases where the target is close to organs at risk.”

To date, Bristol Gamma Knife Centre has treated a total of 75 patients with Icon frame-based and mask-based radiosurgery.

A move to Gamma Knife treatments

Since 2002, the Bristol Haematology and Oncology Centre, University Hospitals Bristol NHS Foundation Trust had performed linac-based SRS and stereotactic radiation therapy (SRT) to treat intracranial indications, employing both fixed and relocatable frames. Half of these treatments were fractionated and the other half were delivered in a single fraction, with a maximum of two lesions treated at a time. By 2012 the center was treating approximately 100 patients per year.

In 2012, when it came time to replace this linear accelerator, several criteria were assessed for cranial SRS/SRT, including: dose conformity and steep dose drop, the ability to treat multiple lesions, precision, and ease of use.

Three options were considered: a linear accelerator, Cyberknife® and Leksell Gamma Knife Perfexion. Unlike the first two options – which deliver a single 6MV photon beam to sites anywhere in the body – Gamma Knife is a dedicated system for intracranial SRS, delivering multiple, narrow low energy beams from 192 cobalt-60 sources.

“The source focus distance with Gamma Knife is closer, which offers physical benefits.”

“The source focus distance with Gamma Knife is closer, which offers physical benefits,” Dr. Cameron notes. “It can only be used for intracranial treatments but, as a neuro-oncologist, I didn’t consider this a disadvantage. All three systems have different applications on which they focus, but we believed for brain treatments there were gains in several key areas with Gamma Knife. In particular, the beam penumbra is around half that of a photon beam, which spares healthy brain tissue, and the shielding of the Gamma Knife gives much better protection to the patient’s body. This is very important when we treat younger patients, or patients who may be pregnant. In the end I asked myself, ‘Which machine would I want to be treated on?’ That is what I would want for my patients.”

Conclusion: the confidence to switch

The Gamma Knife helped the centre to achieve its main objectives for intracranial SRS, including:

Dose conformity and steep dose drop off

In recent comparative dosimetric studies, Gamma Knife offered greater conformity and
steeper dose drop off than the other options. According to Dr. Cameron, the percentage of normal tissue to receive 12 Gy is much higher (180-290%) with alternative machines. The greater the volume of normal brain tissue to receive 12 Gy or more, the higher the risk of radionecrosis, which can lead to significant complications.

“Dose conformity is extremely important, ensuring that the high dose area maps closely to the tumor,” Dr. Cameron says. “This is particularly important for irregularly shaped lesions or where a tumor wraps around an organ-at-risk. We aim for a Paddick’s conformity index of 0.85 or more. The steepness of dose drop off is also important for avoiding critical structures such as the optic chiasm or the optic nerve, minimizing dose to these areas and reducing neurotoxicity and side effects.”

Ability to treat multiple lesions in a treatment

With Leksell Gamma Knife Perfexion and now Gamma Knife Icon, centre clinicians can now treat multiple brain metastases with ease (see example in figure 3). “With Gamma Knife, we have treated 14 lesions at a time – and could treat more,” Dr. Cameron reports.

Outstanding precision

Dr. Cameron notes that clinicians can treat small lesions confidently, with a set up accuracy of less than 1 mm. This has enabled the centre to expand its program to treat functional indications, which has fostered closer relationships between team members and their neurosurgical colleagues. Unlike other technologies, the unique Gamma Knife technology also provides the centre with a guaranteed precision, which significantly saves on QA time and improves treatment safety.

Figure 3: Leksell GammaPlan image showing treatment plan for patient with multiple metastases. Image courtesy of Dr. Cameron, University Hospitals Bristol, UK.
Efficiency increases patient numbers

“Gamma Knife technology has helped us offer a very efficient service,” observes the doctor. “We have gone from treating one patient per day to treating up to 4 single fraction and 3 fractionated patients per day. Also, since Gamma Knife is a standalone machine for cranial stereotaxy, we are not competing for space on a linear accelerator, which improves accessibility for neurosurgical cases and frees up the linear accelerators for other treatments.”

Low body dose

Dr. Cameron points out that the dose wash within the body is significantly lower with Gamma Knife than with alternative systems. “The low dose wash within the body is significantly lower with Gamma Knife than with alternative systems,” Dr. Cameron says (see figure 4). “Within the brain, this may impact on vascular and cognitive side effects and, within the body, it should result in a lower secondary cancer risk.”

Straight forward Installation

“The Bristol Gamma Knife Centre was remarkably quick and straightforward to set up,” she recalls. “The business case was accepted by the Trust in November 2012 and we treated our first patient within the year on October 15, 2013. A year later we had treated 200 patients using Leksell Gamma Knife Perfexion.” Mid-2015, the Gamma Knife Centre upgraded to Leksell Gamma Knife Icon, a 1 week upgrade.

Data Comparison Chart

Figure 4: Comparison of extracranial dose rates based on data from a number of different radiosurgery units obtained by either in vivo patient measurements or the use of anthropomorphic Rando phantom. Image courtesy of Lindquist and Paddick2
References


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This customer perspective is based on the experience and application of medical experts, and is intended as an illustration of an innovative use of Elekta solutions. It is not intended to promote or exclude any particular treatment approach to the management of a condition. Any such approach should be determined by a qualified medical practitioner.
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