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## GAMMA KNIFE SURGERY

Surgical treatment of pathologies deep in the brain has always been hampered by the morbidity and even mortality of having to cut through normal functioning brain before getting to the abnormality. This was particularly important for multiple abnormalities, like metastatic cancer in the brain. Despite the advances over the last 50 years of microsurgery and image guided navigation within the skull, the side-effects of open surgery stubbornly remained sufficiently high for surgeons to seek an alternative. This was finally provided by the advent of radiosurgery.

This technique combines the principle of three-dimensional coordinate system-based navigation within the skull on one hand and the approach of the target through literally hundreds of individually harmless weak radiation beams. As the inventor, Prof Lars Leksell, a Swedish neurosurgeon, was quoted saying:» In the brain no tool can be too refined«. It could not be more true for radiosurgical tools.

In a recent article in *The Consultant*, Dr Mascott described the advantages of using radiosurgery for a wide range of pathological processes in the brain. As he writes, and despite Linear accelerator technology being a much older technology, the overwhelming majority of patients around the world have received this treatment using the Gamma Knife, the purpose-built machine to treat abnormalities in the brain. The beauty of this equipment is the ingenious way radiation is delivered simultaneously from hundreds of pencil-fine beams, rather than requiring a moving single beam to achieve the focusing effect. This feature ensures precision and speed of treatment: the reason Gamma Knife remains the gold standard tool. There is a lot of debate about the relative merits or demerits of the different technological solution to the radiosurgery problem: how to best deliver the maximum amount of energy to the target, with the least radiation dose to the surrounding normal tissue. Normal tissue dose has been proven to be apparatus-dependent, with Leksell Gamma Knife® Perfexion™ scoring best, while some competitors delivering up to 100 times this unwanted dose.

Since introduction into the neurosurgical and oncological armamentarium, more than 500,000 patients have been treated worldwide with this tool. In Sheffield, where we had the privilege of installing the third Gamma Knife in the world, since 1985 we have treated over 12 thousand patients. The depth of acquired knowledge about Gamma Knife Surgery (as this specific form of radiosurgery has been termed more recently) achieved dramatic changes in management of these patients.

The reports at the recent 16th International Meeting of the Leksell Gamma Knife® Society in March 2012 in Sydney, Australia, show the wide range of pathologies where we can help. Acoustic neuromas (a.k.a. vestibular schwannomas) are now only exceptionally operated and only when they are larger than 3-4 cm. For the elderly this treatment offers a daycase treatment instead of the

risk of months of recovery after a high-risk operation. For the young, it is the more than 75% hearing preservation and almost guaranteed facial nerve preservation that is particularly attractive. Similarly glomus jugulare tumours, these benign but extremely vascular skull base tumours whose removal used to cause life-long suffering of the postoperative lower cranial nerve palsies, is now successfully controlled in more than 90% of cases with Gamma Knife. The recently published European multicentre study reported long term success with 4,500 meningiomas, mainly on the skull base with rare complications and better long term control than expected from microsurgery. The same applies to many other, small and often surgically inaccessible other tumours.

One of the earliest indications to use radiosurgery is cerebral arteriovenous malformations (AVMs), which pose a risk of brain haemorrhage and major neurological disability. These congenital abnormalities are of course operated if the blood clot has to be removed as an emergency. The very large lesions are treated with endovascular embolisation techniques. Most, however, are treated with Gamma Knife. This is successful particularly if the core of the AVM, the so called nidus, is small and compact, without previous embolisation.

The current buzz is around the management of cancer metastases to the brain. The traditional pessimism and the resulting palliative management (whole brain radiotherapy), has given way to successful control with Gamma Knife. Patients with good performance status and intracranial tumours less than 3 cm size are the good candidates. The growing experience shows that the number of deposits in the brain matter much less than size, so even in a patient with 5-7 distinct metastases this treatment offers control of disease in the brain. Importantly, the risk of dementia, the greatest threat after whole brain irradiation, is prevented by using focal treatment. The drawback is that salvage treatment, repeat Gamma Knife surgery, is needed in 3-4 months in some cases. Looking at it another way, this treatment can be repeated several times in cases of later cranial metastases if necessary: unlike the «standard» whole brain treatment.

An exciting new prospect was announced in Sydney: soon the combination of Gamma Knife with cone beam CT will offer the best of both worlds, the precision and efficiency of the Gamma Knife with in-treatment confirmation of position. This will allow a further expansion of indication to the larger tumours in the brain and cervical spine.

Obviously, the dedicated machine for intracranial targets is not suitable to treat in the rest of the body, partly because the targeting frame-based coordinate system is fixed to the skull and partly because the targets would move in the body with respiration. To solve this, several manufacturers have introduced alternative methods, usually combining some form of imaging during treatment with x-ray or CT scanning. Due to the

unavoidable uncertainty introduced by such movement, fractionated treatment is usually prescribed. These machines are linear accelerator based, and found their niche in treatment of cancers in the lung, prostate, liver and spine. Cyberknife, Novalis Tx, TruBeam and Axesse are the front-runner machines in this field.

The economic aspects of the march of radiosurgery are enormous. Converting complex microsurgical procedures, requiring lengthy use of high-tech operating theatre and intensive care facilities and lengthy recovery to an outpatient procedure after which patients can

return to work in days is a major bonus to patients but also to society at large. Admittedly, it is not easy to take the secondary costs to society into account but many healthcare systems are working on making the much needed savings. Minimally invasive neurosurgery in general and Gamma Knife Surgery in particular can contribute to make this happen. The fact that this is achieved while improving patient experience and outcome is the reason why this technique is taking over from traditional surgery and radiotherapy.