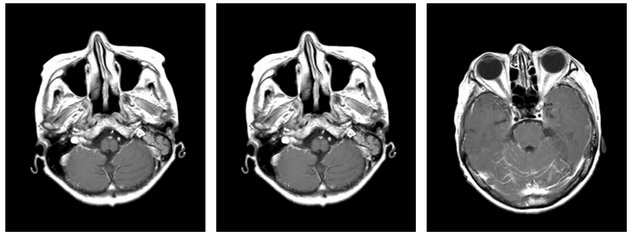

Figure 7. MRI scans at six weeks post SRS

Outcome and follow up

MRI scans were obtained six weeks post treatment (figure 7). There was no evidence of disease at the three sites treated, indicating that a complete clinical response was achieved. There were no significant medium term side effects and the patient was reported to be well at six months post radiotherapy.

Discussion and conclusions

Brain metastases are the most common malignant condition of the brain parenchyma. With improving moderate term outcomes achieved using systemic chemotherapy treatments, it is expected that the incidence of brain metastases will increase and add to end stage care issues.

The blood brain barrier often prevents effective systemic approaches and so there is a noticeable trend towards radiotherapy options, such as whole brain radiotherapy (WBRT) and SRS for the treatment of brain metastases. Management of such patients is dependent on the site of the lesion(s), the number of lesions and the patient's overall medium term prognosis: best supportive care for very ill patients; WBRT for multiple metastatic disease; surgery for solitary lesions which are surgically amenable (provided there are no other significant systemic metastases); radiosurgery (delivered using Leksell Gamma Knife® or a linear accelerator) or local stereotactic radiotherapy for a few lesions.

WBRT requires at least two to three weeks of fractionated radiotherapy and acute toxicity associated with this methodology is significant. Neurocognitive toxicity resulting from WBRT can be debilitating and significant in the moderate term.

Stereotactic radiotherapy options offer a number of advantages, including smaller volumes of healthy brain exposure, shorter fractionation protocols (< 5 days) and significantly less neurotoxicity than WBRT, both acutely and in the longer term post treatment. This approach is considered at this centre for up to six metastases seen on 1.3 mm fine cut MRI, with dimensions of no more than 50 mm.

Shtraus et al (2011) concluded that single isocenter plans can be utilized to deliver conformity equivalent to that of multiple isocenter techniques, with little difference apart from a larger volume of normal brain exposed to low dose. Furthermore, it was noted that treatment time was markedly faster using VMAT.[1]

Huang Chi (2012) also concluded that single-isocenter VMAT is able to achieve comparable dose conformity, target coverage and quality of coverage to conventional dynamic conformal arc (DCAT) and 3D-CRT plans with significantly superior delivery efficiency. Conformity for VMAT plans was equivalent to or better than dynamic conformal arc (DCAT)/3D-CRT plans. VMAT and DCAT/3D-CRT plans had similar target coverage, and VMAT plans had higher quality of coverage. The mean monitor units (MU) decreased by 42% and the mean treatment time decreased by 49% for VMAT plans.[2]

In conclusion, the combination of the Monaco treatment planning system and the rapid leaf speed, accuracy and low transmission of the Agility 160-leaf MLC allowed the successful linac-based SRS treatment of three brain metastases, two of which had close proximity to the brainstem. Using a single isocenter and nine non coplanar VMAT arcs, a total treatment delivery time of just 20 minutes could be achieved. This single isocenter approach has been used frequently at this institution for hypofractionated irradiation of multiple brain metastases and the use of two to three isocenters for greater than ten brain metastases has also been successfully applied.

References

[1] N Shtraus, D Schifter, S Alani, H Tempelhof, D Matceyevsky, E Gez, B Corn, and A Kanner. Stereotactic Treatment of Multiple Targets Using Single Isocenter: Planning, Dosimetric and Delivery Advantages Med. Phys. 38, 3395 (2011)

[2] Huang Chi - Masters Thesis, Duke University 2012

Disclaimer

This case study 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.

It is important to note that radiation treatments, while usually beneficial, may also cause side effects that vary depending on the area being treated along with other medical circumstances. The most frequent side effects are typically temporary and may include, but are not limited to, skin redness and irritation, hair loss, respiratory, digestive, urinary or reproductive system irritation, rib, bone, joint or soft tissue (muscle) pain, fatigue, nausea and vomiting. In some patients, these side effects may be severe. Treatment sessions may also vary in frequency, complexity and duration. Finally, radiation treatments are not appropriate for all cancers, and their use along with the potential benefits and risks should be discussed before treatment.

ABOUT ELEKTA

Elekta's purpose is to invent and develop effective solutions for the treatment of cancer and brain disorders. Our goal is to help our customers deliver the best care for every patient. Our oncology and neurosurgery tools and treatment planning systems are used in more than 6,000 hospitals worldwide. They help treat over 100,000 patients every day. The company was founded in 1974 by Professor Lars Leksell, a physician. Today, with its headquarters in Stockholm, Sweden, Elekta employs around 4,000 people in more than 30 offices across 24 countries. The company is listed on NASDAQ OMX Stockholm.

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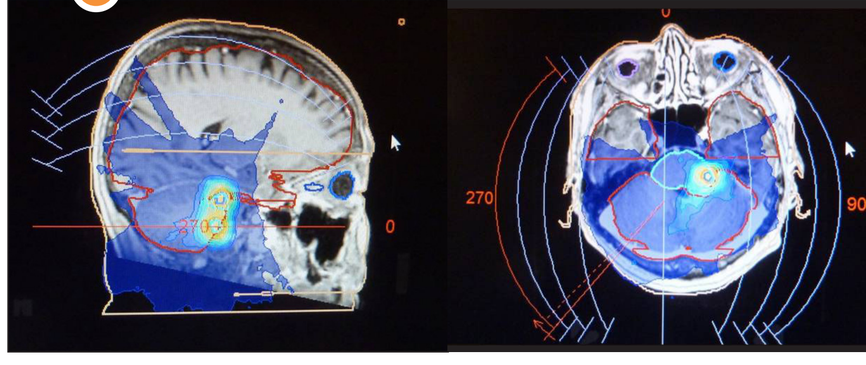
Single isocenter frame-based SRS for multiple brain metastases

The combination of Monaco® treatment planning system and Agility™ MLC for linac-based SRS treatment of multiple brain metastases using a single isocenter

CASE STUDY



Institution:
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Location:
Singapore

Consultant radiation oncologist:
Dr. Yang Tuck Loong

Medical physicist:
Mr. Tay Yak Koon

Gleneagles™ SINGAPORE

Summary

Patient demographics

63-year-old female, treated in 2011 for stage 4 non-small cell lung cancer (NSCLC) with C-spine and sacral metastases, presented with giddiness in December 2012.

Treatment

Multiple target stereotactic radiosurgery (SRS). Prescription – lesion 1: 20 Gy; lesion 2: 16 Gy; lesion 3: 18 Gy delivered in a single fraction using a single isocenter, nine partial VMAT arc plan.

Diagnosis

MRI investigation revealed three brain metastases located in the cerebellum: 10 mm, 7 mm and 8 mm.

Treatment planning and delivery system

- Leksell Stereotactic System® cranial immobilization
- Monaco® treatment planning system
- Elekta Synergy® with Agility™ MLC
- XVI imaging tools

Patient history and diagnosis

A 63-year-old female patient was previously diagnosed with stage 4 NSCLC in July 2011. She received radiation therapy initially to C-spine and sacral metastases (20 Gy delivered in five fractions) with good response. The patient also responded well to systemic chemotherapy and was progression free from December 2011.

In December 2012, the patient presented with giddiness. MRI investigation revealed three brain metastases, with dimensions of 10 mm, 8 mm and 7 mm, in the cerebellum (figure 1). No other sites of involvement in the brain or extra-cranially were detected by PET or CT scans.

The patient was a good candidate for SRS because there was minimal extracranial disease and her moderate term prognosis was good (compared to someone with extensive active disease), which justified our offer of a more radical approach to the treatment of brain metastases in this instance.

It was decided to treat all three brain metastases using multiple target, single isocenter SRS and volumetric modulated arc therapy (VMAT). This is achievable through the combination of Monaco treatment planning system (TPS) and Elekta's Agility 160-leaf multileaf collimator (MLC) with its rapid leaf speed, minimal interleaf leakage and ability to interdigitate, which allows the creation of treatment 'islands'.

The decision to use a single isocenter was based on the fact that there were two lesions sitting near the brainstem and, if separate isocenters had been used, there would have been issues of beam overlap. If this beam overlap was to occur in the area of the brainstem, it could potentially result in inacceptable dose to the brainstem and, therefore, limit the amount of radiation that could be delivered to the targets. Moreover, based on published data, it is likely that treatment times could be at least halved using a single isocenter compared to treating using three separate isocenters.[1,2]

Treatment planning

Leksell Stereotactic System® (figure 2) was used for cranial immobilization during treatment planning and treatment delivery.

Leksell Stereotactic System provides exceptional rigidity and ease of use to ensure very accurate stereotactic radiosurgery. The system uses x, y, z coordinates and the

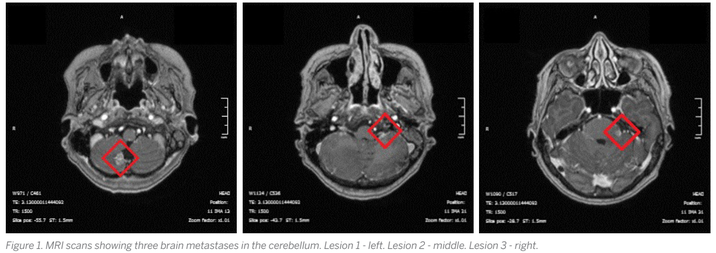

Figure 1. MRI scans showing three brain metastases in the cerebellum. Lesion 1 - left. Lesion 2 - middle. Lesion 3 - right.

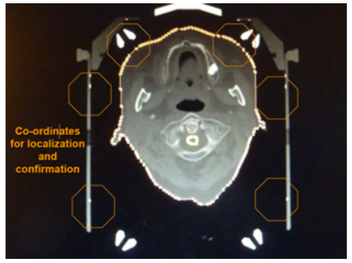

Figure 2. Cranial immobilization was achieved using Leksell Stereotactic System

center-of-arc principle to stereotactically localize treatment targets in 3D space with absolute precision.

A fine cut (1.3 mm) post contrast MRI scan was co-registered with the CT scan (non contrast) for target localization, which provides good resolution and has been standard practice for SRS/SRT at this center since 1997.

A single isocenter, nine partial arc VMAT plan was created on Monaco VMAT as a multiple target solution (figure 3, below). The isocenter was placed as equidistant as possible to all three targets. Margins were limited to 2 - 2.5 mm, especially for the lesions near the brainstem. Nine non coplanar arcs were used to ensure the best achievable conformity and dose homogeneity, and to achieve good fall off dose from the targets.

The Agility MLC was chosen for this treatment because of its ability to interdigitate, which is important for treating multiple targets at the same time, and due to the speed and accuracy of the MLC. Interdigitation allows treatment islets to be formed for the different targets, which keeps the dose low in the area between targets. Furthermore, with the low transmission dose of the Agility MLC, a steeper dose gradient could be achieved.

The dose prescribed for each lesion is shown in table 1.

Lesion	Dimensions	Dose prescribed
lesion 1	10 mm	20 Gy
lesion 2	7 mm	16 Gy
lesion 3	8 mm	18 Gy

Table 1. Dimensions and dose for each brain lesion

Pretreatment planning quality assurance (QA) was carried out using MatriXX (IBA Dosimetry) 2D fluence measurements (figure 4) and point dose measurements (figure 5) with gamma analysis: 3% and ±3 mm dose and position deviation. A gamma analysis of less than 3%/3 mm was achieved.

Treatment delivery

Cone Beam CT (CBCT) verification was performed using Elekta XVI Intuity™ prior to treatment delivery to confirm positioning accuracy (figure 6).

The multiple target, single isocenter SRS VMAT plan (nine non coplanar arcs) was delivered using an Elekta Synergy linear accelerator with the Agility MLC. Due to the rapid leaf speed and accuracy of this MLC, all three brain metastases were treated in a total treatment delivery time of 20 minutes.

The patient tolerated the treatment well, with no acute or subacute reactions of note recorded.

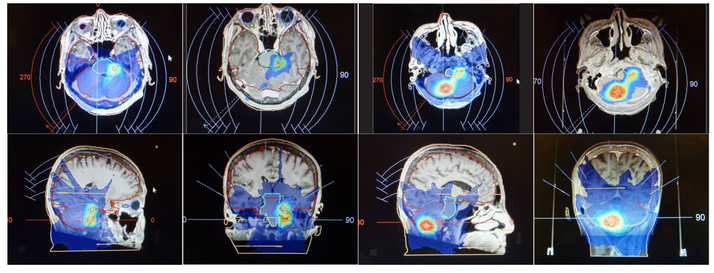

Figure 3. Single isocenter, nine partial arc VMAT SRS plan created using Monaco VMAT

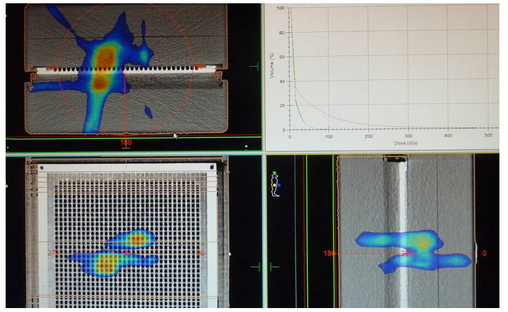

Figure 4. Monaco treatment planning QA using MatriXX 2D fluence measurements

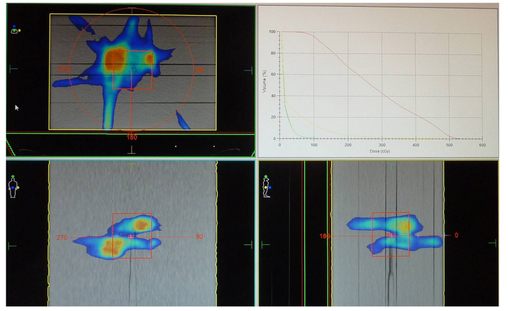

Figure 5. Monaco treatment planning QA using point dose measurements

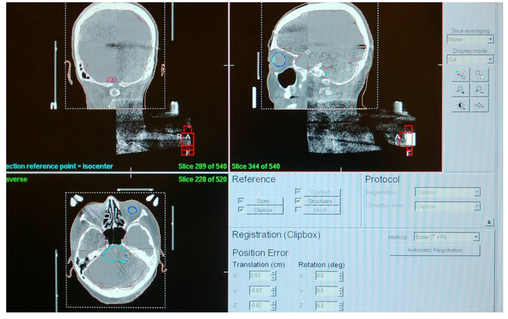

Figure 6. CBCT treatment verification using Elekta XVI