ACCURAY

CASE STUDY

A COLLECTION OF INTRACRANIAL CASES

Precise CyberKnife® Treatments Maximise Success for Patients

Established in October 2007, the Huashan Hopsital CyberKnife Center at Fudan University is one of China's earliest facilities of its kind.

CyberKnife®

Case 1. Recurrent Glioblastoma

Patient History

In January 2019, a 46-year old female, presented with a 1-month history of headaches. Enhanced MRI showed left temporal lobe occupancy. Left temporal lobe tumor resection was performed. Postoperative surgical pathology confirmed left temporal lobe glioblastoma (GBM), WHO grade IV. The STUPP protocol was prescribed consisting of postoperative chemoradiotherapy including 6 cycles of adjuvant temozolomide. Enhanced MRI examination on December 1, 2020 showed the left temporal and occipital lobe were occupied with high signal and edema, indicating the possibility of recurrence.

CyberKnife® Planning Parameters	
Tumor volume	26942.33 mm^3
Prescription dose	25 Gy in 5 sessions to the 65% isodose line
Collimator size	15 mm
Number of beams	240
Tracking method	Synchrony® Skull Tracking™

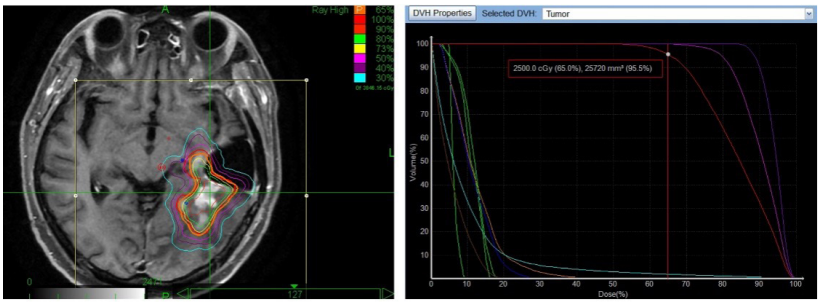


Figure 1. CyberKnife treatment plan and plan DVH

Treatment Outcome and Follow-up

At 4 months post CyberKnife SRS the treatment outcome was optimal. The overall survival (OS) was up to 26 months at last follow up. The whole treatment was tolerated well with only Grade 2 hand-foot syndrome which was relieved with symptomatic dermatologic treatment.

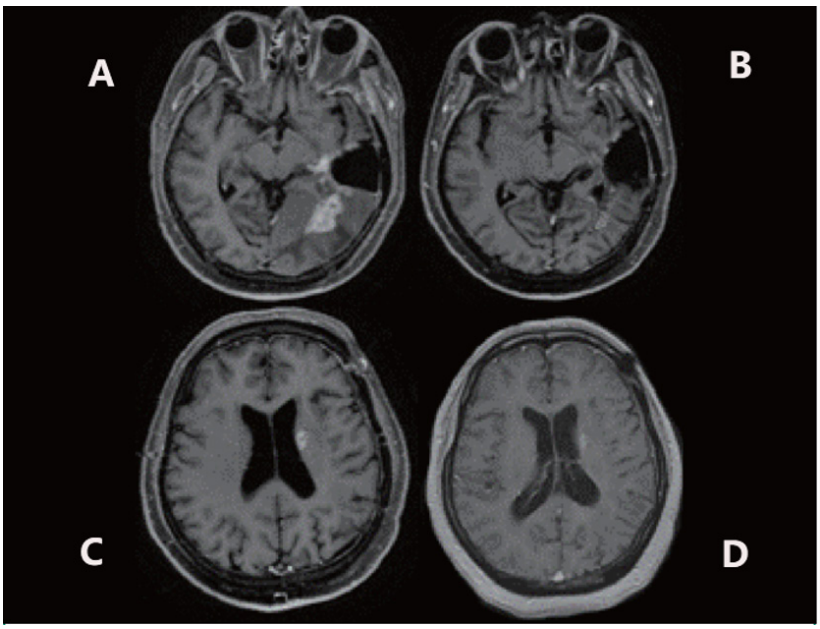


Figure 2. Cyberknife treatment course and follow-up
A: GBM recurrence after surgery and chemoradiotherapy
B: Four months follow-up after CyberKnife SRS
C: Progressive disease at 12 months after SRS, then the 2nd CyberKnife was delivered
D: Four months follow-up after the 2nd CyberKnife SRS and 16 months after the 1st CyberKnife SRS

CyberKnife®

Case 2. Arteriovenous Malformation

Patient History

In February 2016, a 21-year old male presented with intracranial hemorrhage with unconsciousness, left-sided hemiparesis simultaneously and occasional focal epilepsy, without apparent clinical inducement. Digital subtraction angiography (DSA) suggested right frontoparietal arteriovenous malformation (AVM). Diffusion tensor imaging (DTI) confirmed a nerve conduction bundle and administered stereotactic radiation therapy with the CyberKnife System at 23 Gy in two sessions to an isodose curve of 65%.

CyberKnife® Planning Parameters	
Tumor volume	7029.75 mm^3
Prescription dose	23 Gy in 2 sessions to the 65% isodose line
Collimator size	10 mm and 12.5 mm
Number of beams	181
Tracking method	Synchrony® Skull Tracking™

Treatment Outcome and Follow-up

Five-years after treatment, the DSA showed complete obliteration of the lesion. No worsening of limbic disorders or seizures reported.

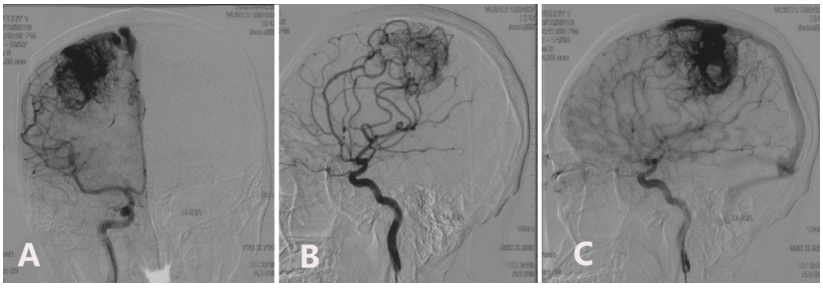


Figure 1. DSA of right frontoparietal AVM before CyberKnife treatment
A: Posterior-anterior view of DSA;
B & C: Lateral view of DSA

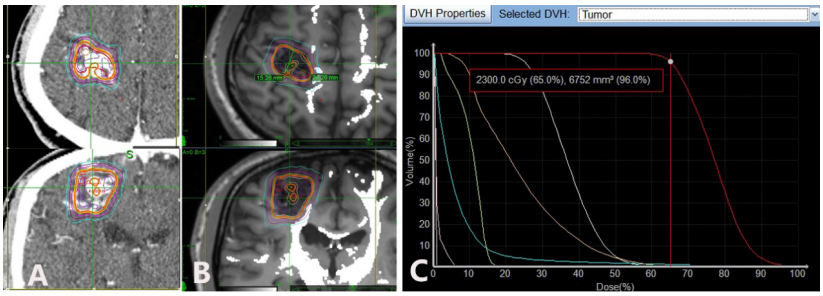


Figure 2. CyberKnife treatment plan
A: CT-Sim;
B: Planning of Diffusion tensor imaging (DTI);
C: Plan DVH

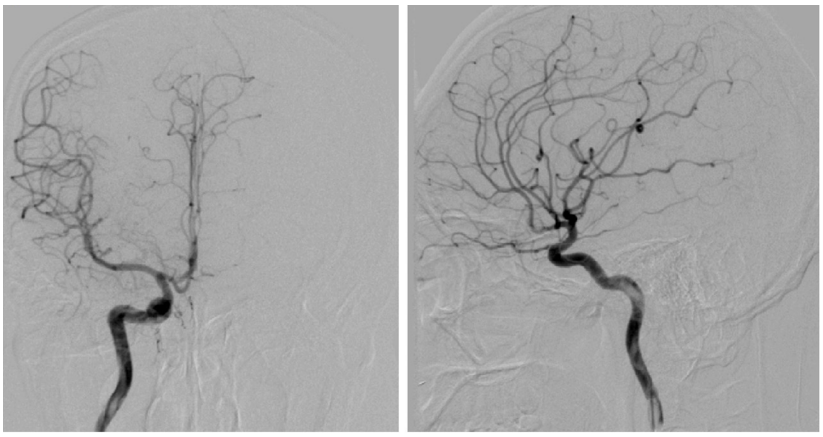


Figure 3. DSA showed complete obliteration of the malformed vessel 5 years after CyberKnife treatment

Case 3. Giant Acoustic Neuroma

Patient History

In May 2010, a 26-year-old female went to the hospital complaining of unstable walking, tinnitus and hearing loss. Upon cranial MRI a huge acoustic neuroma was found. At the Department of Neurosurgery of Huashan Hospital she underwent surgery to remove most of the acoustic neuroma. Postoperative pathological results confirmed acoustic neuroma.

CyberKnife® Planning Parameters	
Tumor volume	6065.24 mm^3
Prescription dose	20.10 Gy in 3 sessions to the 69% isodose line
Collimator size	7.5 mm and 10 mm
Number of beams	179
Tracking method	Synchrony® Skull Tracking™

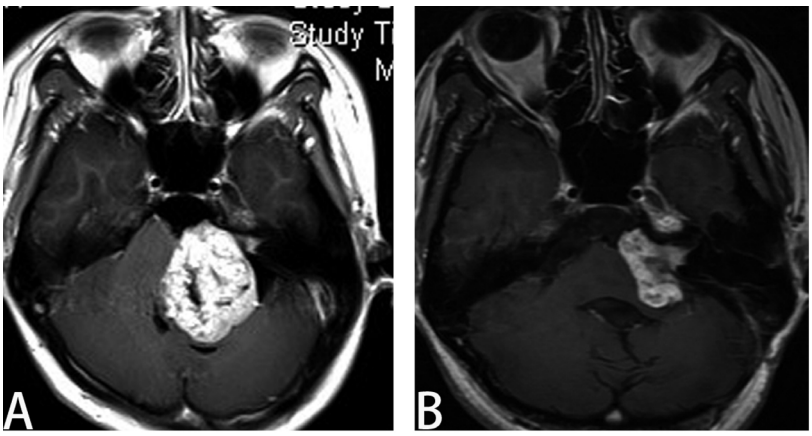


Figure 1. Preoperative and postoperative MR images
A: Preoperative image;
B: Postoperative residual image

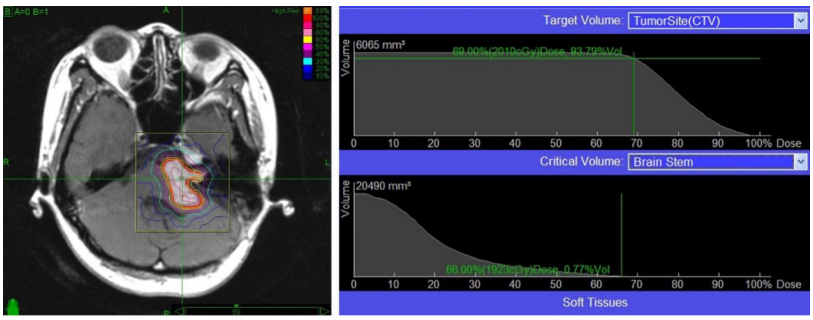


Figure 2. CyberKnife treatment plan and DVH

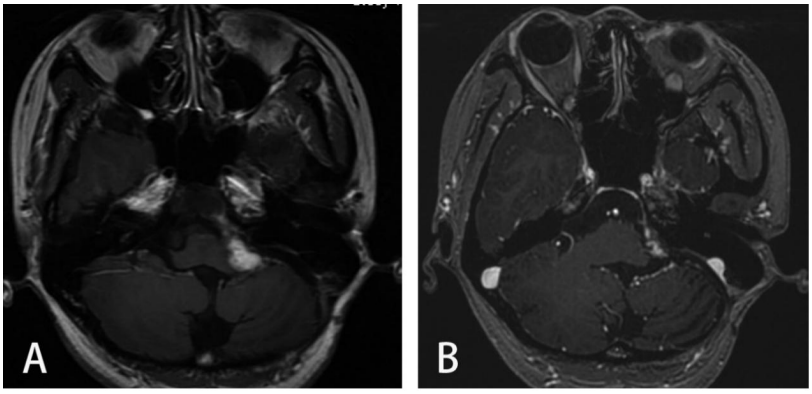


Figure 3. Follow-up image
A: One year after CyberKnife treatment
B: 11 years after the treatment showed that tumor volume gradually decreased, and the brainstem compression was released

Challenges and Solutions

Due to the special location of the acoustic neuroma and the surrounding nerves and blood vessels, the surgery was difficult and could easily lead to facial paralysis and other neurological dysfunctions. There was an additional risk of residual tumor at the resection site. The patient expressed that the facial nerve function be preserved to maintain her normal quality of life after treatment. To meet the patient's requirements for quality of life and to effectively control the growth of the acoustic neuroma CyberKnife was considered. The CyberKnife System had obvious advantages for minimizing dose to the intracranial nerves such as facial, auditory, and trigeminal nerves, which could greatly reduce side effects. The CyberKnife System was used to deliver radiation to a prescribed dose of 20.10 Gy in three sessions to the 69% isodose line.

Outcome and Follow-up

Tumor volume was reduced by more than 50% after CyberKnife stereotactic radiosurgery. The patient had a high quality of life and did not develop facial paralysis. At her 11-year follow-up she had not experienced any recurrence or side effects.

Case 4. Jugular Foramen

Patient History

In July 2009, a 32-year-old patient presented with left facial pain and poor sleep, but no obvious cause was found. Later, the symptoms worsened. The patient underwent a cranial MRI examination and was found to have a tumor in the jugular foramen.

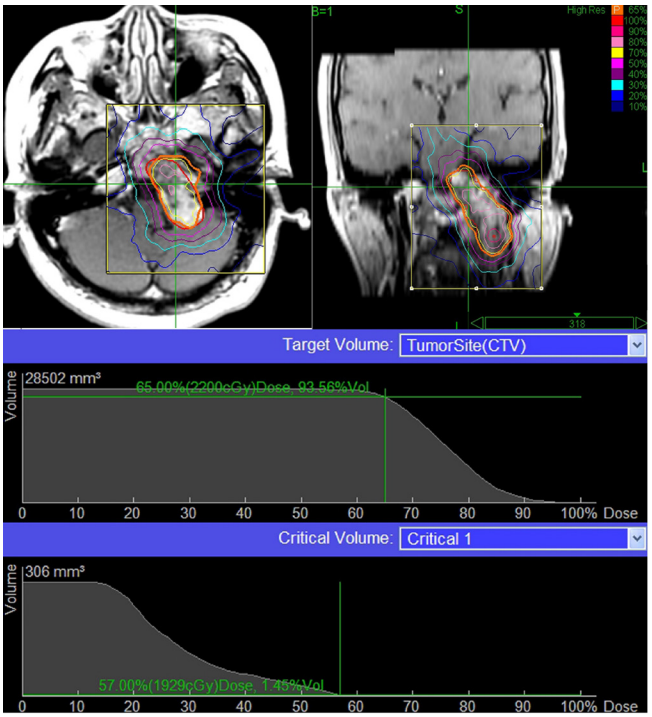


Figure 1. CyberKnife treatment plan and DVH

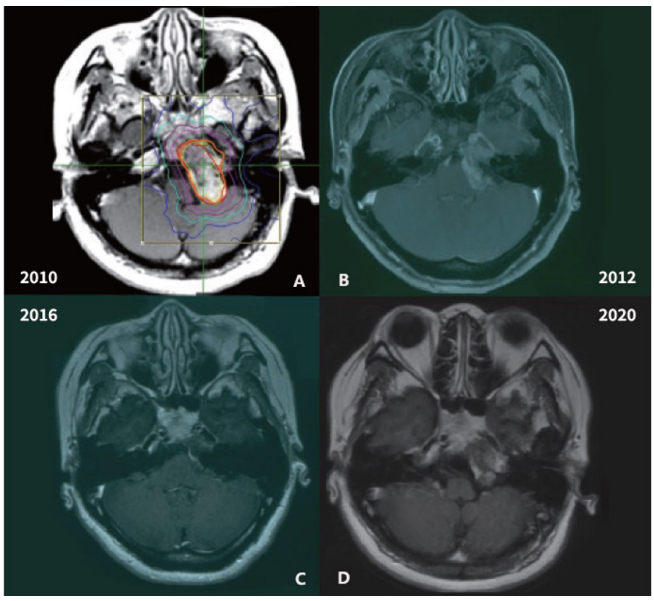


Figure 2. Tumor volume gradually reduced, and brainstem compression released after CyberKnife treatment
A: Treatment plan
B: Results were followed up after 2 years of treatment
C: Results were followed up after 6 years of treatment
D: Results were followed up after 10 years of treatment

CyberKnife® Planning Parameters	
Tumor volume	28502 mm^3
Prescription dose	22 Gy in 3 sessions to the 65% isodose line
Collimator size	15 mm and 20 mm
Number of beams	164
Tracking method	Synchrony® Skull Tracking™

Challenges and Solutions

The jugular foramen area is deep, complex with important blood vessels passing through it, making surgery traumatic and difficult to perform complete excision. Total resection is often associated with cerebrospinal fluid leakage and lower cranial nerve damage. However, CyberKnife radiosurgery can help to effectively control the tumor growth in the jugular foramen area, with a low incidence of neurological damage and significant improvement of patients' postoperative quality of life. The patient was admitted to the outpatient clinic of Shanghai Huashan Hospital where left jugular foramen was confirmed and CyberKnife treatment was delivered.

Outcome and Follow-up

After CyberKnife stereotactic radiosurgery, the tumor gradually reduced in size and the brainstem compression was released. During the 10-year follow-up, no local enlargement or recurrence was observed. The patient did not have any side effects or neurological damage and maintained a good quality of life after the treatment.

Case 5. Multiple Brain Metastases

Patient History

In March 2011, an 81-year-old male presented with chest pain, memory loss, slow reaction times, and abnormal limb movement. PET-CT examination revealed irregular lobulated tissue nodules of about 2.3 cm x 2.8 cm in the apical segment of the right upper lung. Well defined round nodules with clear boundaries were also detected in the left frontal lobe and the right cerebellum.

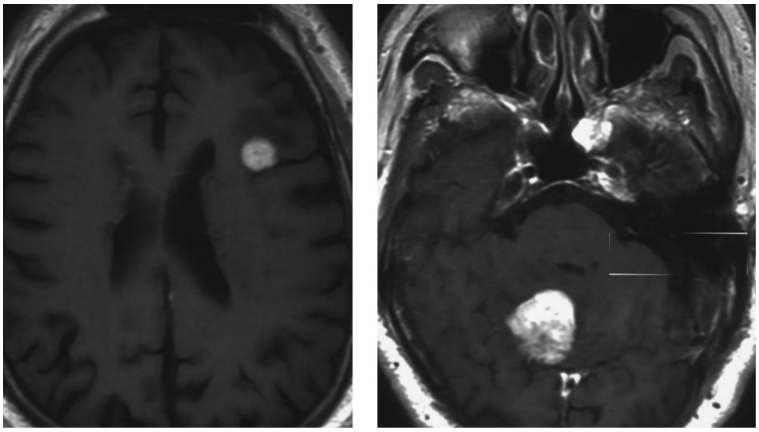


Figure 1. Image before the treatment in 2011

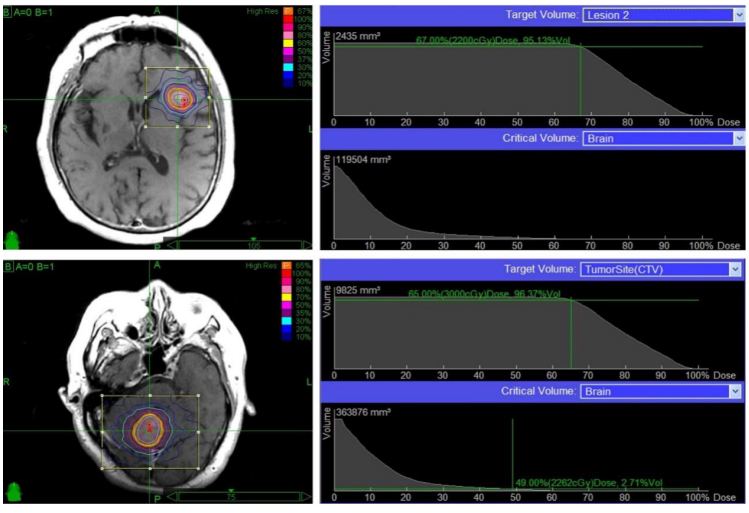


Figure 2. CyberKnife treatment plan

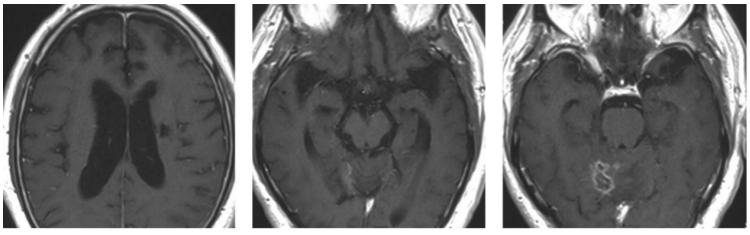


Figure 3. Follow-up of the enhanced-contrast MRI after 3 years of treatment

CyberKnife® Planning Parameters: Right Cerebellar Metastasis	
Tumor volume	9825.48 mm^3
Prescription dose	30Gy in 2 sessions to the 65% isodose line
Collimator size	15 mm
Number of beams	148
Tracking method	Synchrony® Skull Tracking™

CyberKnife Planning Parameters: Left Frontal Lobe Metastasis	
Tumor volume	2434.59 mm^3
Prescription dose	22 Gy in 1 session to the 67% isodose line
Collimator size	10 mm
Number of beams	136
Tracking method	Synchrony® Skull Tracking™

Challenges and Solutions

The largest intracranial mass was about 2.5 cm in diameter. The final diagnosis was confirmed as peripheral right upper apical lung cancer with left frontal lobe and right cerebellar metastases. Both brain metastases were irradiated with CyberKnife at Huashan Hospital. The CyberKnife System enables precise irradiation around the tumor whilst minimizing dose to normal brain tissues, allowing high doses of irradiation to be delivered. The right cerebellar metastasis received 30 Gy in 2 sessions to the 65% isodose line. The left frontal lobe metastasis received 22 Gy in 1 session to the 67% isodose line.

Outcome and Follow-up

At three months post CyberKnife treatment, the tumor had completely disappeared. At 2 years follow-up minimal toxicity was noted without affecting the patient's quality of life.

Case 6. Re-Irradiation of Ventricular Meningioma

Patient History

In May 2007, a 60-year-old male successfully underwent his fourth ventricular tumor resection. Postoperative pathological results suggested a glioma (WHO grade II). In 2008, the patient underwent CyberKnife® treatment. In 2016, no tumor recurrence was seen at MRI. In 2020, a cranial MRI showed right cerebellopontine angle (CPA) occupancy with low T1 signal, high T2 signal, and heterogeneous enhancement, suggesting tumor recurrence. Craniotomy was performed under general anesthesia, and the tumor was removed. Pathological report showed right CPA glioma (WHO grade II) with abundant local cells and a high proliferation index. However upon resection it was found that the tumor had adhered to the brainstem surface making it difficult to remove the tumor, resulting in a high possibility of residual disease in this area. Because of this, the patient returned to the hospital in 2020 for further CyberKnife treatment.

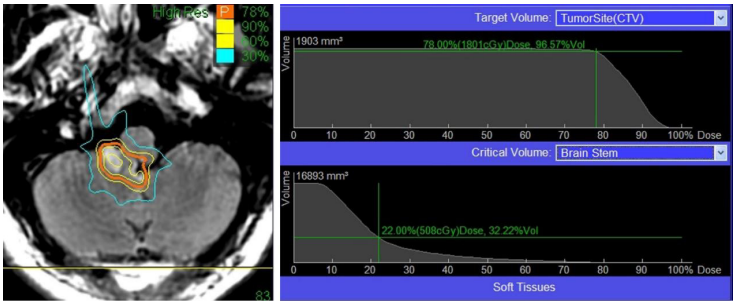


Figure 1. Postoperative residue and treated with CyberKnife (first treatment plan diagram and DVH in 2008)

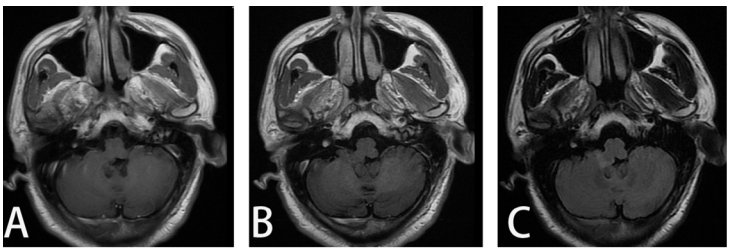


Figure 2. Good tumor control at 4-year follow-up after the first CyberKnife treatment in 2012

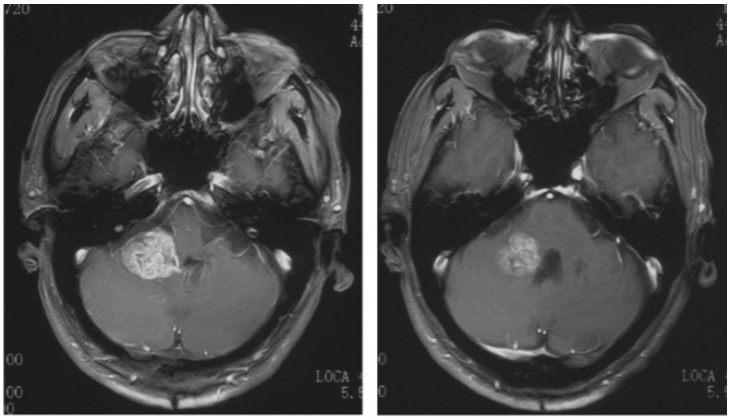


Figure 3. Imaging showed tumor recurrence in 2020

CyberKnife Planning Parameters: 2008	
Tumor volume	1902.69 mm^3
Prescription dose	18 Gy in 3 sessions to the 78% isodose line
Collimator size	10 mm and 15 mm
Number of beams	233
Tracking method	Synchrony® Skull Tracking™

CyberKnife Planning Parameters: 2020	
Tumor volume	2138.00 mm^3
Prescription dose	17 Gy in 2 sessions to the 70% isodose line
Collimator size	10 mm and 15 mm
Number of beams	148
Tracking method	Synchrony® Skull Tracking™

Case 6. Re-Irradiation of Ventricular Meningioma (cont'd.)

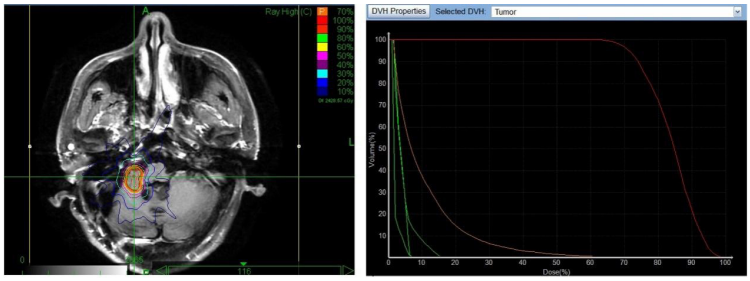


Figure 4. Ten years after first CyberKnife treatment, after surgery, the patient treated with CyberKnife (Second CyberKnife treatment plan diagram and DVH in 2020)

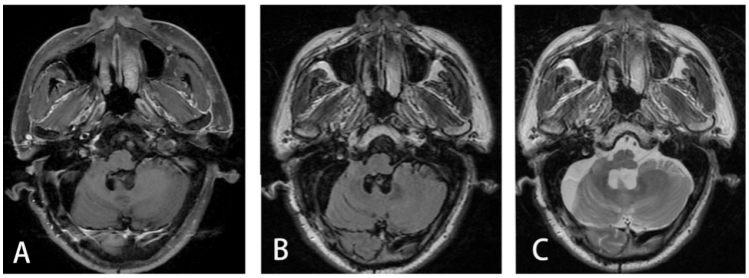


Figure 5. Six-month follow-up after the second CyberKnife treatment in January 2021

Challenges and Solutions

The tumor was located at the base of the fourth ventricle and the dorsal side of the brainstem, therefore it was essential to avoid the critical organs and the nervous system during radiotherapy. The CyberKnife® System was able to treat the postoperative residual lesions precisely whilst minimizing dose to the surrounding brain tissues. The precision of the CyberKnife System also made it possible to re-treat the patient with SRS.

Outcome and Follow-up

More than 1-year post CyberKnife treatment, no tumor recurrence has been observed.

Case 7. Meningioma in Pineal Region

Patient History

In May 1997, a 59-year-old female underwent surgical resection in a neurosurgery department for occupancy in the pineal region. The postoperative pathological results confirmed meningioma. In 2009, a cranial MRI revealed tumor recurrence. The patient was admitted to Huashan Hospital in March 2010 for stereotactic radiation.

CyberKnife® Planning Parameters:	
Tumor volume	8456.35 mm^3
Prescription dose	21 Gy in 3 sessions to the 67% isodose line
Collimator size	10 mm and 15 mm
Number of beams	182
Tracking method	Synchrony® Skull Tracking™

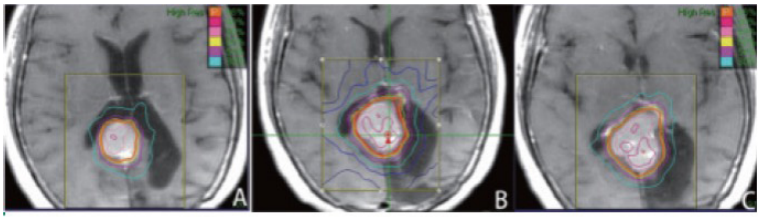


Figure 1. CyberKnife treatment planning diagram

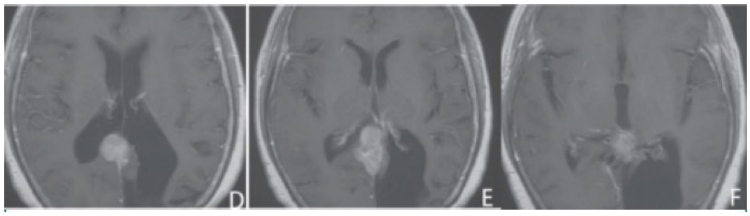


Figure 2. Eight years after CyberKnife treatment, the tumor was reduced progressively and was not seen in the last follow up image

Challenges and Solutions

The tumor was located in the deep pineal region with complicated adjacent neurovascular structures making surgery difficult to perform. The patients age and that the lesion was a recurrence contributed to the decision of prescribing fractionated SRS with CyberKnife to control tumor growth and reduce damage to intracranial nerves. CyberKnife treatment did not require anesthesia or craniotomy and the incidence of neurological dysfunction was relatively low.

Outcome and Follow-up

The tumor gradually decreased in size following treatment. Eight years after the treatment the tumor was significantly smaller than at the beginning of treatment. And no radiotherapy related side effects were reported at last follow-up.

Case 8. Cavernous Sinus Meningioma

Patient History

In June 2007, a 45-year-old female with a history of lactation had stopped bromocriptine medication due to dizziness and discomfort. Cranial MRI showed no pituitary tumor but a right cavernous sinus tumor was detected that revealed a meningioma. In 2008, the patient was prescribed CyberKnife treatment.

CyberKnife® Planning Parameters	
Tumor volume	4942.47 mm^3
Prescription dose	19 Gy in 2 fractions to the 74% isodose line
Collimator size	7.5 mm
Number of beams	128
Tracking method	Synchrony® Skull Tracking™

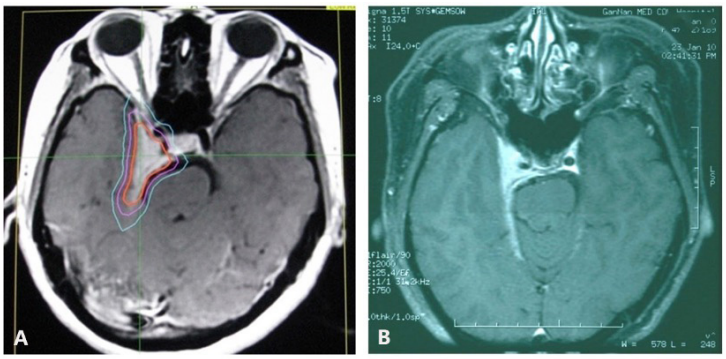


Figure 1. CyberKnife treatment image
A: Plan image
B: Image at 2-year follow-up after CyberKnife treatment

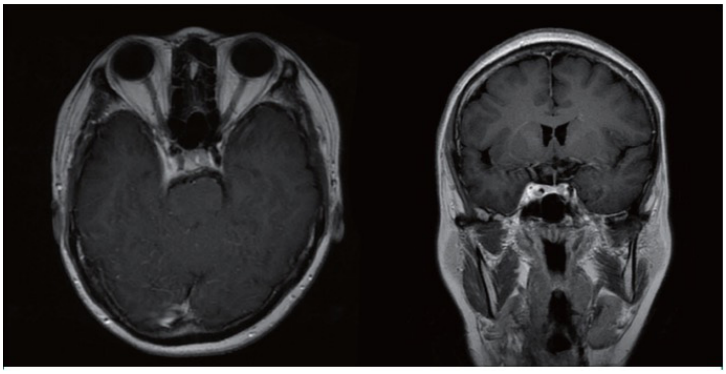


Figure 2. The latest follow-up MR images (in 2021) revealed reduced tumor and no progress

Challenges and Solutions

The cavernous sinus has a complex structure, deep location, rich nerves, and rich vascularity, making complete resection of the tumor challenging, with a risk of neurological dysfunction. CyberKnife offers an effective approach of controlling cavernous sinus meningioma growth.

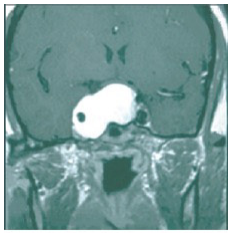
Outcome and Follow-up

After CyberKnife treatment, the patient had occasional numbness on the right side of the face, no trigeminal neuralgia, good eye movement, and was able to work normally. At 2 years after the treatment the tumor, volume was significantly reduced. At 12 years after the treatment, the tumor further decreased in size. CyberKnife radiosurgery can help to effectively improve tumor control, reduce brain damage, and improve patients' quality of life.

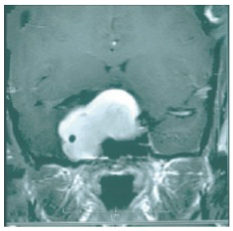
Case 9. Cavernous Hemangioma

Patient History

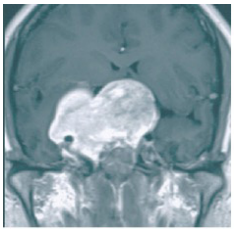
In November 1998, a 43-year-old female visited the clinic with blurred vision. MR suggested a lesion in the right cavernous sinus and saddle area. Surgical resection was unsuccessful due to an intraoperative massive bleed, therefore only a biopsy was performed. Pathology confirmed a cavernous hemangioma of the cavernous sinus. Due to lack of effective treatment at that time, it was decided to proceed with a watch and wait strategy. In 2003, MR indicated that the lesion had increased in size and the patient's vision had deteriorated. In 2010, MR indicated the lesion had largely increased. The patient's visual acuity index was 1 m in both eyes, and visual field was significantly impaired.
In 2011, the patient was treated at Huashan Hospital with CyberKnife at a prescribed dose of 18 Gy in 4 sessions to a 60% isodose curve.



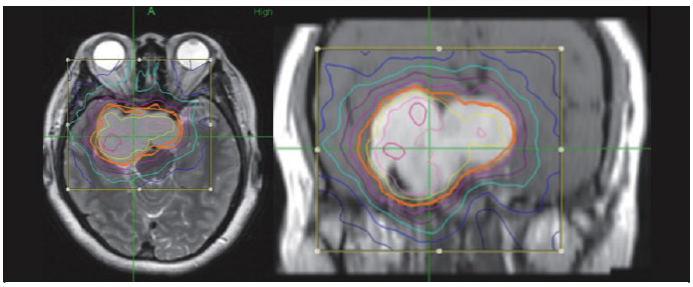
In 1998, tumor volume was 20 cm^3, with blurred vision, confirmed by biopsy



In 2003, the tumor increased in size and vision impaired



In 2010, tumor volume was 76 cm^3, F/C 1m



CyberKnife treatment planning diagram

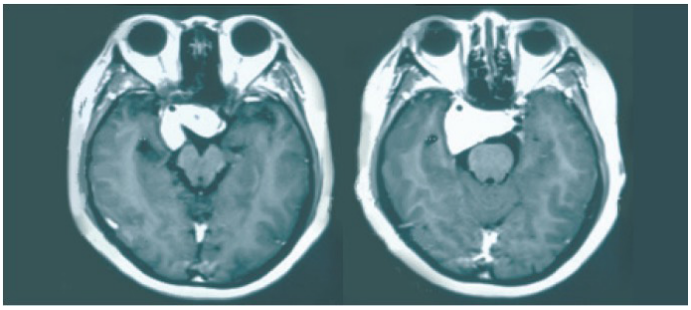
CyberKnife® Planning Parameters:	
Tumor volume	76166.57 mm^3
Prescription dose	18 Gy in 4 sessions to the 60% isodose line
Collimator size	20 mm and 25 mm
Number of beams	215
Tracking method	Synchrony® Skull Tracking™

Challenges and Solutions

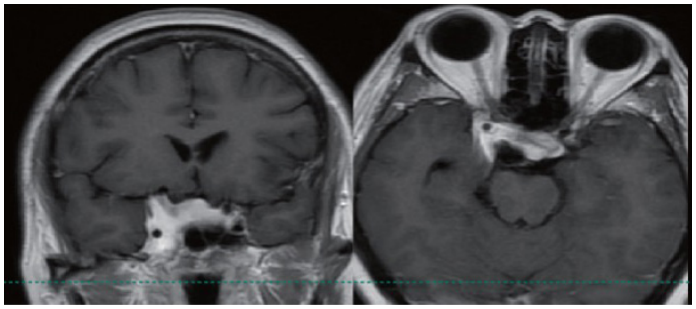
Surgery for cavernous hemangioma of the cavernous sinus is potentially curable but very challenging. The complex neurovascular structure around the cavernous sinus, a low rate of total resection, a high incidence of postoperative cranial nerve injury, and a high intraoperative bleeding rate, contribute to the challenges.

Outcome and Follow-up

At 6 months post CyberKnife treatment, the patient's tumor volume shrank by 80% and visual acuity improved significantly. In July 2014, MRI indicated only a small residual lesion where the 99% of tumor had remised. The patient's bilateral visual acuity recovered to 0.6, the visual field returned to normal and it was now possible for her to go to work and take care of herself completely.



After 6 months of CyberKnife treatment, tumor volume reduced by 80% and the vision improved



Patient's tumor size reduced by 99% after 3.5 years of CyberKnife treatment

Case 10. Malignant Melanoma Brain Metastasis

Patient History

In March 2017, a 42-year-old male visited the hospital for a left frontal lobe occupancy with PET/CT suggestive of a right lower pulmonary nodule. Surgical resection of the left frontal lobe lesion was performed, and the postoperative pathological result suggested malignant melanoma. The right lower pulmonary nodule was resected, and the pathology showed malignant melanoma in the dorsal segment of the right lower lung. Postoperative temozolomide combined with cisplatin adjuvant chemotherapy was administered for 6 courses. Genetic testing suggested a mutant type of exon 3 of the NRAS gene. In 2018, left-sided limb weakness was detected, and cranial MR showed a new metastasis in the right parietal lobe post left frontal lobe melanoma resection. Stereotactic radiosurgery was prescribed to the new intracranial lesion. Maintenance therapy of Pembrolizumab was administered as an ongoing treatment.

CyberKnife® Planning Parameters	
Tumor volume	62834.20 mm^3
Prescription dose	33.20 Gy in 4 sessions to the 65% isodose line
Collimator size	20 mm and 30 mm
Number of beams	184
Tracking method	Synchrony® Skull Tracking™

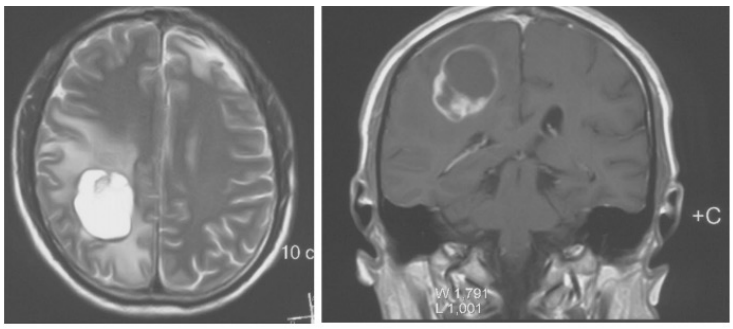


Figure 1. Pre-treatment imaging results

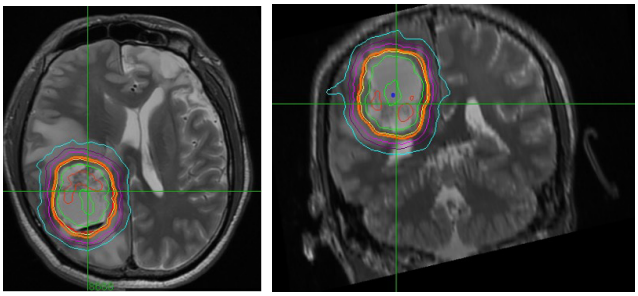


Figure 2. CyberKnife treatment plan with midline displaced brain metastasis

Challenges and Solutions

The primary clinical strategy for large volume brain metastases is surgical resection, depending on symptoms and patient choice. Pre or postoperative adjuvant radiotherapy can be prescribed. Patients unwilling or unable to undergo surgery may also be treated with hypofractionated radiotherapy. A large volume brain metastasis is one of the indications expanded by fractionated SRS technology, which allows higher precision and higher dose, facilitating the killing of less radiation-sensitive tumors. Fractionated radiotherapy is more in line with the 4R theory, indirectly indicating it could be a treatment option for selective large tumors with relatively mild side effects.

Outcome and Follow-up

The patient's tumor size was significantly reduced after CyberKnife treatment, and no adverse effects have been reported since last follow-up.

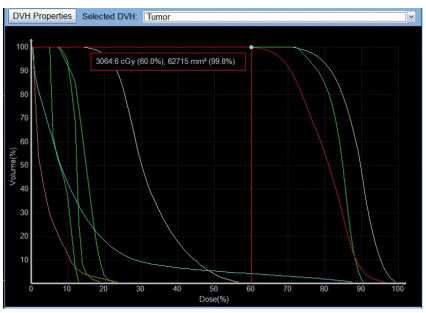


Figure 3. CyberKnife treatment DVH

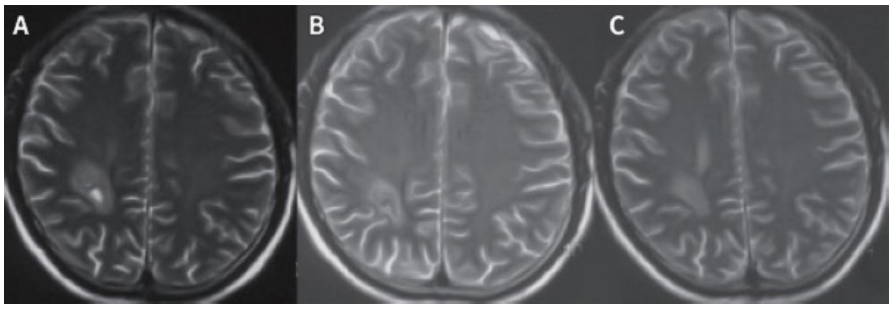


Figure 4. A: After 2 months of treatment, the tumor size was significantly reduced at follow-up
B: Imaging of 8 months post-treatment
C: After 2 years follow-up MR images

ACCURAY

CASE STUDY

CASE STUDIES COURTESY OF HUASHAN HOSPITAL

Huashan Hopsital
CyberKnife Center Team
at Fudan University

Important Safety Information:
Most side effects of radiotherapy, including radiotherapy delivered with Accuray systems, are mild and temporary, often involving fatigue, nausea, and skin irritation. Side effects can be severe, however, leading to pain, alterations in normal body functions (for example, urinary or salivary function), deterioration of quality of life, permanent injury, and even death. Side effects can occur during or shortly after radiation treatment or in the months and years following radiation. The nature and severity of side effects depend on many factors, including the size and location of the treated tumor, the treatment technique (for example, the radiation dose), and the patient's general medical condition, to name a few. For more details about the side effects of your radiation therapy, and to see if treatment with an Accuray product is right for you, ask your doctor. Accuray Incorporated as a medical device manufacturer cannot and does not recommend specific treatment approaches. Individual results may vary.

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