SPINAL
ARTERIOVENOUS
MALFORMATION

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**Case History**
This 37-year-old male presented with progressive paraparesis together with impaired bladder control and sexual function. A 0.8 cm³ spinal arteriovenous malformation (AVM) was diagnosed at the T10-T11 vertebral levels. Three attempts at embolization were made without success. The patient suffered two bleeding episodes, one as a complication following embolization. In each case, the patient’s symptoms worsened leading to paraplegia and partial recovery in one case.

**CyberKnife® Treatment Rationale**
The patient was considered to be inoperable, and was referred by the neurosurgeon for radiosurgery using the CyberKnife® Robotic Radiosurgery System. Treatment of intracranial AVMs was one of the original radiosurgical applications, and radiosurgery has proven an effective modality in this field. Until recently, treatment of spinal AVMs has been impossible because of the limitations of rigid frame-based systems. By providing frameless stereotactic alignment, the CyberKnife System makes it possible to extend radiosurgery to extracranial targets, and its application to spine lesions has been previously reported.1,2,3 Patients are usually referred on the basis of unsuitability for conventional surgery, or when conventional surgery is refused, and in some cases (as in the present one) embolization will have been attempted prior to radiosurgery.
Treatment Planning and Delivery

Four fiducials were implanted in the vertebral bodies above and below the nidus without complication. One week later pre-treatment images were acquired including 3D rotational angiography (3DRA), MR angiography, and contrast-enhanced CT scanning. These image-sets were registered using a normalized mutual information algorithm, and the target volume was defined using the 3DRA images. The patient was positioned supine in a standard vacuum conformed immobilization device. The supine position is preferred over prone because this minimizes the uncertainty due to respiratory motion. Inverse planning was used to generate a plan of 130 beams. A dose of 18.2 Gy was prescribed to the 70% isodose and delivered in 4 daily fractions using a 5-mm collimator. Fiducial tracking was used, and each outpatient session lasted 40 minutes including setup.

<table>
<thead>
<tr>
<th>TREATMENT DETAILS</th>
<th>Fractions / Treatment Time: 4 / 40 minutes average</th>
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</thead>
<tbody>
<tr>
<td>Tumor Volume:</td>
<td>CT, 3DRA, MR Angiography</td>
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<tr>
<td>Imaging Technique(s):</td>
<td>18.2 Gy to 70%</td>
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<tr>
<td>Rx Dose &amp; Isodose:</td>
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<tr>
<td>Conformality Index:</td>
<td>1.56</td>
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<tr>
<td>Number of Beams:</td>
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<tr>
<td>Path Template:</td>
<td>3 path 900_1000 mm</td>
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<tr>
<td>Tracking Method:</td>
<td>Fiducial tracking</td>
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<tr>
<td>Collimator(s):</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

Isodose lines superimposed on multiplanar 3DRA fused images. Note contrast enhancement within the nidus.

3D reconstruction of the CT dataset showing the non-isocentric, non-coplanar beam arrangement.
Outcome and Follow-Up
Follow-up MR angiography was performed at 6 and 12 months post-treatment. Progression of neurological symptoms was apparent for the first six months but then stabilized at 12 months post-treatment.

Twelve months post-treatment the AVM nidus volume had decreased in size. MR angiography was repeated at 24 months, and showed further reduction in the nidus volume. The patient has remained clinically stable with no bleeding episodes throughout this follow-up period, and there was no chronic treatment-related toxicity.

At 36 months MR angiography indicated complete obliteration and this was confirmed by selective digital subtraction angiography (DSA). The patient's symptoms had also improved with reappearance of normal knee reflexes and he can walk with a cane.

Conclusion and CyberKnife® Advantages
CyberKnife® radiosurgery was successfully applied to obliterate this intramedullary spinal AVM. 3DRA images were used to accurately define the AVM. Highly conformal dose delivery with steep falloff avoided radiation-induced neuropathy despite the location of the nidus within the spinal cord. The CyberKnife System allowed delivery of a non-invasive, painless treatment which resulted in hemorrhage-free follow-up period and ultimately in complete nidus obliteration within 36 months.

References