Journal of Clinical Neuroscience 22 (2015) 1025–1029

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Technical Note

# Endoport-assisted microsurgical resection of cerebral cavernous malformations

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ARTICLE INFO

*Article history:*
Received 7 January 2015
Accepted 10 January 2015

*Keywords:*
Cerebral cavernous malformations
Endoport-assisted microsurgical resection
Intracranial hemorrhages
Microsurgery
Minimally invasive
Stroke

ABSTRACT

The aim of this case series is to describe the surgical technique and postoperative outcomes for endoport-assisted microsurgical resection (EAMR) of cerebral cavernous malformations (CCM). Significant manipulation of subcortical white matter tracts may be necessary for the successful resection of CCM located in deep brain regions. Minimally invasive neurosurgical devices such as endoport systems can decrease disruption of the cortex and white matter tracts overlying deep-seated CCM through small cranial and dural openings. The role of endoport technology in modern CCM surgery is incompletely understood. Three patients with symptomatic CCM underwent EAMR at our institution using the BrainPath endoport system (NICO Corporation, Indianapolis, IN, USA). Complete resection was achieved in two patients. One patient with a large 4.5 cm callosal CCM was left with a small residual lesion. There were no postoperative complications and all patients were functionally independent (modified Rankin Scale score 2 or less) at follow-up. Based on our initial experience with EAMR for CCM we believe the endoport can be an effective alternative to traditional retractor systems. Due to the nature of the small craniotomy and durotomy performed for endoport placement EAMR has the potential to improve surgical outcomes by reducing postoperative pain, analgesic requirements and hospital stays. Therefore, EAMR may be considered for appropriately selected CCM patients, although additional experience is necessary to improve our understanding of its role in CCM management.



## 1. Introduction

Cerebral cavernous malformations (CCM) are frequently located beneath the cortical surface, thus, requiring considerable dissection and retraction of subcortical white matter tracts in order to approach the lesion [1]. Prolonged cerebral retraction during surgical resection of subcortical CCM may predispose patients to postoperative complications such as seizures, cerebral edema and venous infarction. The development of minimally invasive neurosurgical technologies such endoport systems has allowed access to deep-seated lesions using small craniotomies and dural openings with reduced disruption of the overlying cortex and white matter tracts compared to conventional approaches [2,3]. However, the role of endoport technology in the management of CCM is poorly defined. Therefore, the aim of this case series is to describe the surgical approach, technical nuances and postoperative outcomes for endoport-assisted microsurgical resection (EAMR) of CCM.

## 2. Technical note

### 2.1. Surgical procedure

Preoperative thin-slice (1 mm) MRI, T1-weighted with contrast and T2-weighted sequences and diffusion tensor imaging (DTI) are obtained for EAMR planning in each CCM case. Specifically, DTI is used to evaluate the anatomy and orientation of the white matter fibers. The surgical approach is planned so that the endoport is placed as parallel to the white matter bundles as possible in order to minimize disruption of the adjacent fibers.

After induction of general anesthesia the patient is placed into three-point cranial fixation using a Mayfield Skull Clamp System (Integra, Plainsboro, NJ, USA). The StealthStation frameless stereotactic neuronavigation system (Medtronic, Minneapolis, MN, USA) is utilized in all cases to determine the optimal trajectory for accessing the lesion. A craniotomy, centered over the planned entry point and measuring approximately 3 cm in diameter, is sufficiently large to accommodate the endoport. A small, cruciate dural opening is made in order to minimize cerebrospinal fluid loss prior to endoport placement. A transulcal trajectory is preferably

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http://dx.doi.org/10.1016/j.jocn.2015.01.004
0967-5868/

taken to the lesion but if this is not possible a small corticotomy is made at the planned entry point of the endoport.

We performed all EAMR cases at our institution using the BrainPath endoport system (NICO Corporation, Indianapolis, IN, USA). Briefly, the endoport system consists of an outer sheath which is left in place to maintain access and an inner obturator which is used to introduce the outer sheath with minimal brain trauma. The outer sheath is 13.5 mm in diameter and 50 mm, 60 mm, or 75 mm in length depending on the depth of the lesion below the cortical surface. The sheath has an arm which allows it to be fixed into place using a Greenberg retractor after the desired position has been obtained. The inner obturator has a blunt, tapered tip which is 15 mm longer than the outer sheath to allow gradual cannulation of the brain. An 8 mm obturator tip is also available, only in conjunction with the 50 mm sheath, for shallow cannulation.

The endoport system is advanced to the target CCM under neuronavigation. After the inner obturator is removed the outer sheath is docked onto the lesion and fixed in placed. The operating microscope is then used to perform the resection. A thin cuff of white matter is resected to expose the CCM capsule after which we proceed with CCM resection using standard, bimanual microsurgical techniques. In the following, the surgical strategy and postoperative outcomes are detailed for the first three CCM patients treated with EAMR at our institution. The baseline patient, CCM characteristics and follow-up data are summarized in Table 1.

### 2.2. Patient 1

A 28-year-old woman presented to an outside hospital after awaking from a syncopal episode with left-sided tongue and arm numbness. Brain CT scan showed an intracranial hemorrhage from a large midline lesion and the woman was transferred to our institution for further evaluation and treatment. MRI showed a ruptured 4.5 cm CCM localized in the anterior body of the corpus callosum with intraventricular extension (Fig. 1a–c). The woman underwent EAMR with electrophysiologic monitoring of motor and somatosensory evoked potentials. A right frontal approach was performed with a 50 mm BrainPath endoport to access the lesion. After puncturing the capsule the CCM was internally debulking in order to allow inward retraction and circumferential dissection of the capsule. An external ventricular drain was left in the right lateral ventricle for 1 day postoperatively. The woman had an uneventful postoperative course and was discharged home on postoperative day 2 without neurological deficits. Postoperative MRI at 2 months showed a small, 8 mm residual CCM (Fig. 1d–f). The woman was asymptomatic at 2 months follow-up.

### 2.3. Patient 2

A 36-year-old woman with a previously ruptured CCM and a history of multiple sclerosis and non-epileptic seizures presented with 1 year of intractable headaches. MRI showed a 7 mm CCM localized in the left inferior frontal lobe posterior to the anatomic Broca's area (Fig. 2a–c). Despite our recommendation for conservative management the woman insisted on surgical intervention. Preoperative functional MRI showed left hemispheric dominant speech-related activity with bilateral activation and secondary activation centers in the prefrontal cortex and frontal eye fields immediately adjacent to the CCM for picture naming. Due to the location of the lesion, the woman underwent EAMR with awake speech mapping. A surgical approach was taken through the left middle frontal gyrus with an oblique, inferiorly oriented trajectory to the CCM in order to avoid damage to Broca's area. The CCM was then completely resected *en bloc*. The woman had an uneventful postoperative course and was discharged home on postoperative day 4 at her neurological baseline. Postoperative MRI at 3 months did not show evidence of residual CCM (Fig. 2d–f). The woman was neurologically stable without significant improvement of her preoperative symptoms at 6 months follow-up.

### 2.4. Patient 3

A 47-year-old woman with a history of pseudotumor cerebri, migraines and fibromyalgia presented with 1 month of intractable headaches. MRI showed a 10 mm CCM localized in the left anterior body of the corpus callosum (Fig. 3a–c). Cerebral angiography did not identify a treatable etiology of the woman's pseudotumor cerebri. Therefore, the patient requested surgical extirpation of the CCM. For the EAMR, a left frontal approach was performed with a 60 mm BrainPath endoport to access the lesion. A complete *en bloc* resection of the CCM was achieved. The woman had an uneventful postoperative course and was discharged home on postoperative day 5 without neurological deficits. Postoperative MRI at 12 months did not show evidence of residual CCM (Fig. 3d–f). The woman remained neurologically intact with persistent, intermittently severe headaches at 12 months follow-up.

## 3. Discussion

CCM are associated with variable natural histories depending on their clinical presentation and anatomic location [4,5]. Asymptomatic or minimally symptomatic CCM can be managed conservatively but CCM resulting in overtly symptomatic or recurrent hemorrhages or in progressive neurological deterioration refractory to medical management should be considered for intervention [6,7]. Unlike arteriovenous malformations, CCM cannot be cured with radiosurgery which remains a controversial therapy for CCM [8–25]. Therefore, when intervention is indicated for symptomatic CCM, surgical resection remains the gold standard of treatment [26]. Endoport technology allows neurosurgeons to access subcortical CCM with less trauma than traditional transcortical approaches, thereby potentially improving surgical outcomes.

**Table 1**
Summary of cerebral cavernous malformation patients treated with endoport-assisted microsurgical resection

| Patient | Age (years), sex | Clinical presentation | mRS at presentation | CCM maximum diameter cm/volume ($cm^3$)* | Location | Complete resection | Complications | Follow-up (months) | mRS score at follow-up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 28, female | Syncope, tongue and arm numbness | 2 | 4.5/41.0 | Corpus callosum | No | None | 2 | 0 |
| 2 | 36, female | Headache | 2 | 0.7/0.17 | Left frontal | Yes | None | 6 | 2 |
| 3 | 47, female | Headache | 2 | 1.0/0.63 | Corpus callosum | Yes | None | 12 | 2 |

CCM = cerebral cavernous malformation, mRS = modified Rankin Scale.
* Volume was calculated by multiplying the axial, transverse and craniocaudal dimensions of the CCM and dividing the product by 2.