Intraoperative indocyanine green angiography for obliteration of a spinal dural arteriovenous fistula

Case report

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Spinal dural arteriovenous fistulas (DAVFs) are the most common type of spinal arteriovenous malformation and are an important, underdiagnosed cause of progressive myelopathy and morbidity in patients with spine disorders. Successful microsurgical management of these lesions is dependent on the surgeon’s ability to identify vessels of the fistula and to confirm its successful obliteration postintervention. Indocyanine green (ICG) fluorescent angiography is an emerging tool for delineating intraoperative vascular anatomy, and it has significant potential utility in the treatment of vascular disease in the spine.

The authors present the case of a 76-year-old man with progressive and debilitating bilateral lower-extremity weakness and numbness on exertion, in whom a left T-8 spinal DAVF was diagnosed based on results of conventional spinal angiography. Unfavorable anatomy based on angiographic findings precluded endovascular embolization of the fistula, and the patient subsequently underwent T7–9 bilateral laminectomies for microsurgical clip occlusion. Intraoperative ICG fluorescent angiography was used before clip placement to identify the arterialized veins of the fistula, and after clip placement to confirm obliteration of the fistulous connection and restoration of normal blood flow.

Intraoperative ICG angiography serves an important role in the microsurgical treatment of DAVF. It can be used to map the anatomy of the fistula in real time during surgery and to verify fistula obliteration rapidly after clip placement. This report adds to the growing body of literature demonstrating the importance of ICG angiography in vascular neurosurgery of the spine. (DOI: 10.3171/2009.6.SPINE09315)

Key Words • spinal dural arteriovenous fistula • indocyanine green • intraoperative angiography • operating microscope

Abbreviations used in this paper: AVM = arteriovenous malformation; DAVF = dural arteriovenous fistula; DS = digital subtraction; ICG = indocyanine green; MEP = motor evoked potential; SSEP = somatosensory evoked potential.
important intraoperative tool for microsurgical management of cerebrovascular lesions. It has been used to assess vessel patency and aneurysm occlusion,\(^5\) \(^8\) \(^9\) \(^10\) to detect residual nidus in cerebral AVMs,\(^5\) and to demonstrate extracranial-intracranial bypass patency.\(^5\) Furthermore, integration of ICG near-infrared video technology into the surgical microscope has greatly facilitated intraoperative use and acceptance of this technique.\(^5\) \(^9\) \(^11\) In this report, we describe the use of ICG fluorescence angiography in the microsurgical treatment of a patient with a symptomatic spinal DAVF. The ICG angiography, a noninvasive technique, facilitated the identification of the exact position of the arteriovenous shunt and confirmed the restoration of normal venous flow in these vessels after microsurgical obliteration of the fistula.

**Case Report**

**History and Examination.** This 76-year-old man presented with a 2-year history of progressive bilateral lower-extremity weakness and numbness, with inability to walk distances. The patient received an initial diagnosis of neurogenic claudication secondary to lumbar stenosis, and underwent lumbar decompressive laminectomies performed by another surgeon. Although his postoperative recovery was uneventful, his baseline symptoms did not improve. He continued to worsen significantly over the next few months, with weakness more pronounced in the left lower extremity. On neurological examination, he had full strength in all muscle groups at rest, decreased sensation to pinprick and light touch below the nipples, with 3/5 reflexes at the knees and ankles. After induced exertion in the clinic (walking with a cane), results of his motor examination deteriorated to between 4/5 and 4+/5 in both lower extremities.

The patient subsequently underwent an extensive workup, which included MR imaging of the thoracic spine that demonstrated generalized increased T2-weighted signal throughout the spinal cord from approximately T-3 to the conus medullaris, with T1-weighted images obtained after addition of contrast material showing diffuse enhancement from T-6 to the conus medullaris (Fig. 1A). Spinal angiography revealed a left-sided DAVF at the T-8 level, as demonstrated by early filling of a mildly tortuous spinal vein draining superiorly and inferiorly and fed by the left T-8 radicular artery, with a direct fistula in the expected position of the nerve root sleeve (Fig. 1B). Endovascular embolization of the DAVF was pursued, but was abandoned due to the presence of a prominent left posterior spinal artery arising from the targeted radiculomedullary artery immediately adjacent to the fistula.

**Operation.** The patient underwent T7–9 bilateral laminectomies for microsurgical clip occlusion of the left T-8 DAVF. An OPMI Pentero microscope adapted with near-infrared ICG video angiography technology (Carl Zeiss) was used. Electrophysiological monitoring of MEPs and SSEPs was performed throughout the operation. The thoracic spinal cord was exposed via a dural opening from T-7 to T-9. Candidate abnormal arterialized veins were initially identified based on location, size, and color (Fig. 2A). Using ICG angiography (10 mg ICG [Akorn, Inc.] diluted in 10 ml sterile water and given as bolus in a peripheral vein), these vessels were confirmed to be arterialized veins when rapid filling in the arterial phase was apparent on imaging (Fig. 2B). Of note, this study conclusively demonstrated that the superiorly located vessel was part of the fistula, thus helping to guide the initial occlusive maneuvers. The arachnoid was then dissected free from the fistulous transition point and temporary clips were applied in this location (Fig. 2C). No changes in MEP or SSEP signals occurred after clipping. Twenty minutes after the first ICG bolus, a second bolus was given to confirm obliteration of the fistulous connection and restoration of normal venous flow in previously arterialized veins (Fig. 2D and E). The temporary clips were then replaced with permanent clips (Fig. 2F).

**Discussion**

Spinal DAVFs are common spinal AVMs that can lead to myelopathy or frank paraplegia if left untreated. Treatment involves endovascular or microsurgical obliteration of the fistula, but such procedures are often com-
Angiography with ICG to aid microsurgery in a case of spinal DAVF

Complicated by uncertainty regarding the exact vascular anatomy. If such uncertainty exists, failure to treat the DAVF adequately may occur, or worse, the dedicated spinal arterial supply may be compromised, leading to spinal cord infarction and patient morbidity. The use of ICG in angiography is a well-known, noninvasive technique used in the treatment of cerebrovascular pathological entities to aid the surgeon in more accurately identifying the fistula.

In this report, we describe the microsurgical occlusion of a thoracic spinal DAVF that was facilitated by the use of intraoperative ICG fluorescence and DS angiography. This patient presented with progressive problems with ambulation and was found to have a thoracic DAVF following lack of improvement after decompressive spine surgery. Intraoperatively, ICG angiography provided visual confirmation of the extent of the fistula, which was not clear with gross and microscopic visualization of the spinal cord. In addition, ICG angiography corroborated obliteration of the lesion once surgical clips were applied. This technique was done in a noninvasive manner involving systemic injection of ICG during two points in the surgery.

Fluorescent angiography performed using fluorescein sodium was first introduced into neurosurgery by Feindel et al.3 to examine the cerebral microcirculation. Although fluorescein has been used by certain groups,1,13,17 ICG has emerged as the preferred dye for microsurgical application because of improved vessel contrast for both primary and repeat dye administration.11 The ICG angiography method is a simple, safe, and accurate way of assessing real-time vascular anatomy and flow dynamics at critical steps during an operation, particularly at clip application.10 Rapid feedback for vascular interventions is important to avoid hypoperfusion and ischemic damage.

The use of ICG angiography for surgical treatment of DAVFs in 2 cases has been reported by Raabe and colleagues.8 They mention the use of ICG in the case of a T11–12 dural vascular malformation and a right parietooccipital dural vascular malformation. Although these authors reported the use of ICG angiography to demonstrate fistula occlusion without residual filling, no specific details of the technique or sample images were presented from either case. In our case, we clearly demonstrate the use of ICG angiography to visualize abnormal arterialized vessels of a spinal DAVF and the subsequent return.

Fig. 2. A: Intraoperative photograph showing the DAVF and its arterialized veins. Arrows identify a superior projecting vessel with questionable fistula involvement. B: Intraoperative ICG angiography study (arterial phase) clearly demonstrating the arterialized veins of the fistula, including involvement of the superior projecting vessel mentioned in A(arrows). C: Intraoperative photograph showing temporary clips applied at the suspected fistula point. D and E: Intraoperative ICG angiography study obtained after clip placement, demonstrating obliteration of the fistula. The abnormal arterialized vessels no longer fill during the arterial phase (D) of the ICG injection, but they do fill during the normal venous phase (E). In panel E, the venous phase is confirmed by ICG signal in the contralateral normal spinal veins (arrows). F: Intraoperative photograph showing permanent clip configuration prior to dural closure.
to normal venous flow patterns after disruption of the connection with the feeding vessels. With this current application of ICG, vascular anatomy can be delineated at any point during the operative procedure, and can provide immediate feedback after vessel manipulation. In addition, ICG use is noninvasive and considered quite safe, so it can be repeated as needed without associated morbidity.

Fluorescence angiography is not without its limitations. The primary limitations of this technique are that only vessels visualized in the surgical field and only those not obstructed by clot, calcification, or atherosclerosis are observed during angiography. For these reasons, ICG angiography is not a replacement for DS angiography, but rather complements it. We used both angiographic methods during treatment in our case to ensure complete fistula obliteration. We anticipate that intraoperative ICG angiography will become a standard adjuvant to simplify and render safer the microsurgical treatment of AVMs in the spinal cord and brain.

Conclusions

We present the case of a patient who presented with progressive myelopathy secondary to a symptomatic thoracic spinal DAVF. This patient underwent an open microsurgical procedure for obliteration of his DAVF by disruption of the fistula transition point. Intraoperative ICG fluorescent angiography was used both before clip placement to delineate the anatomy of the fistula accurately, and after clip placement to confirm its obliteration and restoration of normal arterial and venous flow. The ICG applications were quick, noninvasive, and provided real-time information that was invaluable to intraoperative surgical decision making. This case clearly demonstrates the importance of intraoperative ICG angiography in the microsurgical treatment of spinal DAVFs, and it adds to the growing body of literature supporting the use of ICG angiography during the treatment of vascular lesions of the spine and brain.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References

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