Intraoperative Flow Measurement by Microflow Probe During Spinal Dural Arteriovenous Fistula Surgery

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■ OBJECTIVE: **Flow measurement by microvascular ultrasonic flow probe is an established procedure in intracranial vascular surgery. This study tested the application of this procedure in spinal dural arteriovenous fistula (SDAVF) treatment.**

■ METHODS: **Data from 12 SDAVF patients who consecutively underwent microsurgical resection with the assistance of both microflow probe and indocyanine green videoangiography (ICG-VA) were retrospectively analyzed. Flowmetry was performed on a dilated perimedullary venous plexus at different distances from the fistula point (FP). In addition, measurements were made at different phases of surgery to address specific issues: at the beginning, to identify the fistula; after temporary clipping, to evaluate proper disconnection; and after section, to exclude residual filling.**

■ RESULTS: **Flowmetry was reliable in assessing both the value and direction of flow in all cases, thereby aiding fistula localization and confirming its disconnection. Indeed, fistula localization was helped by detection of increasing flow values approaching the FP (mean flow: 11 mL/min <10 mm vs. 3 mL/min >20 mm), while fistula disconnection was confirmed by a flow value lower than 1 mL/min (0—1 mL/min). Data from microflow probe measurements were concordant with ICG-VA data in all cases. In 3 cases, ICG-VA findings on fistula disconnection uncertain due to residual ICG dye were clarified by flowmetry.**

■ CONCLUSIONS: **With the limits of our small series, multistage intraoperative quantitative flow measurement is a feasible, safe, and reliable adjunct in the surgical treatment of SDAVFs. The procedure provides data helpful in guiding the surgical strategy or clarifying ICG-VA data when necessary.**

INTRODUCTION

Type I spinal arteriovenous malformations (AVMs), also known as spinal dural arteriovenous fistulas (SDAVFs),[1] are the most common type of spinal vascular malformations, accounting for 80% of spinal cord vascular lesions.[2] SDAVF consists of an arteriovenous fistula located in the dura of the nerve root and/or adjacent spinal dura. It is fed by a radicular artery, which drains into a medullary vein and fills the coronal venous plexus of the spinal cord in a retrograde manner. Arterial blood flow through the medullary vein results in a congested and dilated coronal venous plexus.[3] The best treatment is still debated, but recent literature reviews reported a higher initial definitive fistula occlusion rate by surgery than endovascular treatment (96.6 vs. 72.2%).[4-6] A recent meta-analysis on surgical outcome reported that only some patients improve over time, whereas 34% remain unchanged and 11% worsen.[4-6] The intraoperative goals are fistula ligation and disconnection between the artery and vein while minimizing manipulation of the spinal cord. Identification and complete

Key words
- Cerebrovascular surgery
- Flowmetry
- Microflow probe
- Microsurgery
- Spinal dural arteriovenous fistula
- Spinal surgery

Abbreviations and Acronyms
AVM: Arteriovenous malformation
SDAVF: Spinal dural arteriovenous fistula
ICG-VA: Indocyanine green videoangiography
DSA: Digital subtraction angiography
MRI: Magnetic resonance imaging
AL: Aminoff and Logue

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interruption of the fistula are essential but not always obvious during surgical treatment. Indocyanine green videoangiography (ICG-VA) has proven to be a useful tool in the surgical treatment of SDAVFs by helping to localize the fistula and confirm its disconnection.[7-15] Some authors suggest this modality could potentially reduce the need for intraoperative angiography with its inherent risks.[15] Echo Doppler use has been reported in case series of SDAVF surgery,[16-21] but the micro Doppler does not provide quantitative flow data. Flow measurement by microvascular ultrasonic flow probe[22,23] is an established procedure in vascular surgery. To date, its application has been reported in surgery for intracranial[24-26] but not spinal vascular malformations.

MATERIAL AND METHODS

Patients and Spinal Dural Arteriovenous Fistulas

Data from SDAVF patients who underwent surgical closure from October 2012 to November 2014 at our department with the assistance of quantitative flow measurement by microflow probe and ICG-VA were retrospectively analyzed. The application of both techniques is included on the institutional informed consent form because they are common practice in vascular and oncologic surgery in our department. SDAVF features were defined according to preoperative digital subtraction angiography (DSA) and magnetic resonance imaging (MRI). Intraoperative data on flow value and direction were reviewed in all cases. ICG-VA data were then compared with microflow probe data. A preoperative and postoperative (1 week after surgery and last outpatient control) Aminoff Logue (AL) scale[27] was compiled in all cases to assess patient outcomes. A postoperative resection result was assessed by DSA.

Surgical Procedures

A focused laminectomy was performed in all cases. The fistula point (FP) was identified by microflow probe followed by ICG-VA. FP was closed with temporary clipping, and then flowmetry by microflow probe followed by ICG-VA was performed. After removing the temporary clip, the FP was coagulated and sectioned. The final FP exclusion was assessed with flowmetry and ICG-VA. The dura was closed in a watertight fashion. An illustrative surgical **video 1** is available.

Video

Video available at WORLDNEUROSURGERY.org

Intraoperative Flow Measurements

Vascular flow was measured using the microvascular ultrasonic flow probe (Charbel Micro-flow probe; Transonic Systems, Inc., Ithaca, New York, USA).

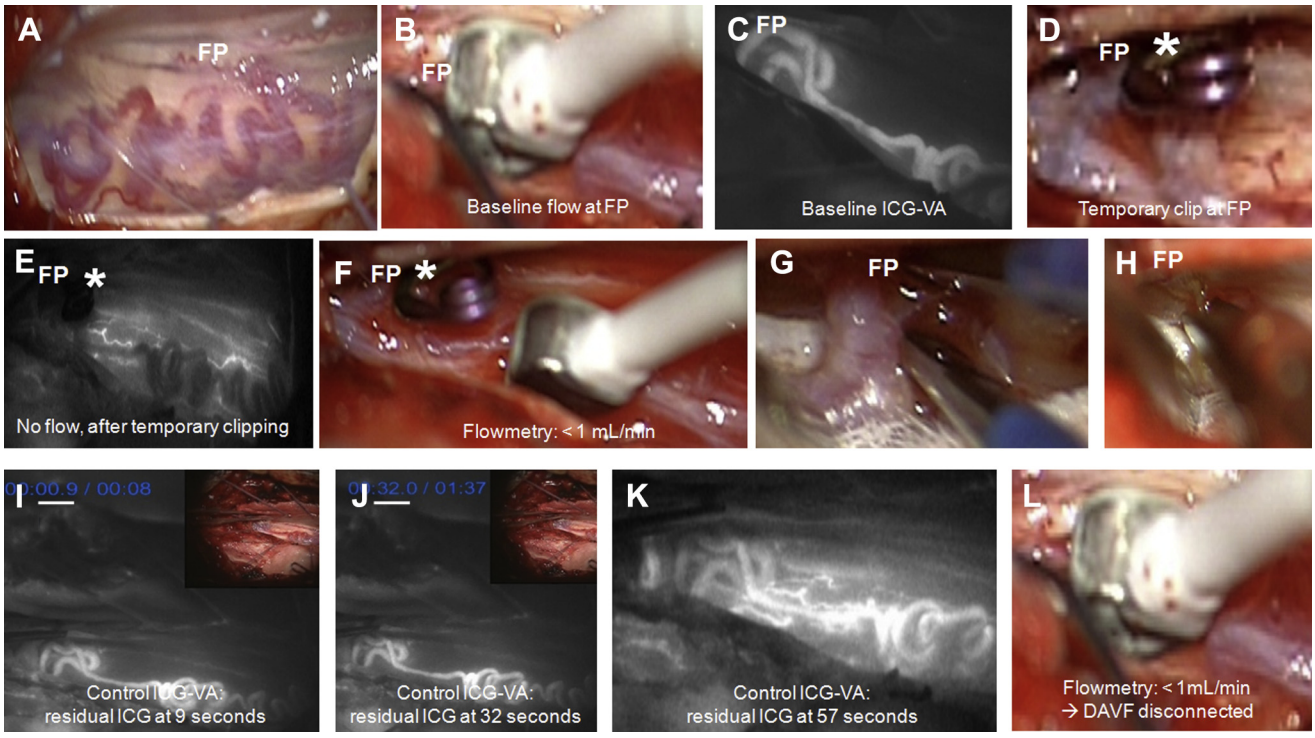

Figure 1. M/56Y: thoracic (D6) SDAVF. (**A-I**) Intraoperative microscopic images. Initial view (**A**), flow assessment with microflow probe of perimedullary venous plexus at fistula point (FP), before fistula closure (**B**), and ICG-VA picture (**C**). Temporary clip (*asterisk*) positioned on the FP (**D**), ICG-VA and flowmetry (**E-F**) after temporary clipping and detection of flow absence; final fistula closure by coagulation (**G**) and section (**H**). ICG-VA after permanent fistula closure (**I**–**K**): Residual ICG at videoangiography made it uncertain whether fistula had been occluded. (See images at 9 [**I**], 32 [**J**], and 57 [**K**] seconds. The seconds are underlined in the figures). At final assessment by microflow probe (**L**), permanent closure flow values were unchanged in comparison with measurements recorded during temporary clipping (flow absence).