Use of a microvascular Doppler probe to avoid basilar artery injury during endoscopic third ventriculostomy

Technical note

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Basilar artery (BA) injury has been reported in a number of cases as a major complication of third ventriculostomy for hydrocephalus. This report describes the deployment of a pulsed-wave microvascular Doppler probe through the endoscope to locate the BA complex and subsequently to select a safe zone for perforation of the third ventricular floor. This procedure is quick and easily learned, and it is hoped that it can decrease the risk of vascular injury during third ventriculostomy.

KEY WORDS • microvascular Doppler probe • basilar artery • third ventriculostomy • hydrocephalus • endoscopy

THIRD ventriculostomy has become a valuable and increasingly routine technique for the management of certain patients with hydrocephalus. In properly selected patients, the long-term success rate is between 50% and 80%, and the complication rate is quite low. However, one of the most serious potential complications of the procedure is injury of the distal basilar artery (BA) complex. This complication was recently described in a report by McLaughlin, et al.,12 whose patient developed massive intraventricular and subarachnoid hemorrhage and subsequently formed a traumatic aneurysm that required surgical clipping. Although the true incidence of this complication is presently unknown, there are unpublished reports of BA injury occurring at least 12 times in the last few years, with a substantial mortality rate (ML Walker and ML Dailey, personal communication). Several other authors have also described incidents of vascular injury. Grant and McLone4 recorded major vascular hemorrhage in one of their 50 endoscopically treated patients, and Sayers and Kosnik17 reported death from posterior cerebral artery (PCA) injury in one of 46 patients whom they treated using a nonendoscopic technique. Injury to perforating vessels arising from the BA apex may also help explain cases of postoperative hemiparesis and midbrain damage encountered by Jones et al.,7 as reported in their series.

Vascular injury that occurs during third ventriculostomy is related to the proximity of the BA apex and proximal PCAs to the floor of the third ventricle, where they could be damaged by either direct penetration or traction-related avulsion.

The key to avoiding this complication is to understand the precise relationship of the BA complex to the floor of the third ventricle before making the ventriculostomy. Grant and McLone4 have suggested that ventricular perforation should not be performed unless the floor of the ventricle is transparent enough to permit visualization of the BA complex. Goodman3 has suggested that endoscopic ventriculostomy be combined with magnetic resonance (MR) imaging stereotactic localization of the BA. In this report, we present a novel approach to this problem. Our technique relies on using a pulsed-wave microvascular Doppler probe directed through the endoscope to map out the location of the BA complex. The technique and equip-
ment will be described in detail. It is our hope that this technique can substantially reduce the risk of BA injury during endoscopic third ventriculostomy.

Description of Equipment

The endoscopy equipment consisted of a model 2233-005 channel neuroendoscope (Clarus Medical Systems, Inc., Minneapolis, MN). This neuroendoscope has a 4.2-mm external diameter and a 2.15-mm-diameter working channel with a straight-through trajectory that facilitates acceptance of the microvascular Doppler probe (Fig. 1). Other neuroendoscopes with similar characteristics would be equally suitable for this procedure. The endoscope is connected to a light source and a camera that provides high-resolution television display and video recording. We have found it beneficial to use a video system with picture-in-picture capability to enable display of the microvascular Doppler data simultaneously with the endoscopic picture.

The microvascular Doppler equipment consisted of a Multi-Dop P in conjunction with a 2-mm-diameter, 16-MHz pulsed-wave Doppler probe (DWL Elektronische Systeme GmbH, Sipplingen, Germany). The Multi-Dop P provides audible feedback of vascular flow as well as a graphic display of flow amplitude and direction (Fig. 2). The Doppler probe can record vascular flow at depths ranging from 0.5 mm to 17.2 mm in sampling windows ranging from 0.44 to 1.38 mm thick. The Doppler probe was set for a 0° angle of insonation. The Doppler settings (depth, sample volume, scale) can be controlled via a remote keypad wrapped in a sterile bag and placed on the operative field. The video output from the Doppler unit is relayed into the endoscope video monitor via a PC-to-TV video converter (TView Silver; Focus Enhancements, Inc., Sudbury, MA).

Technique

The endoscope is introduced into the third ventricle in the usual fashion via a coronal burr hole through a No. 14 French peel-away sheath traversing the cortex. The third ventricular floor is inspected and the key features of the mammillary bodies, the infundibular recess, and the midline are identified. The 16-MHz pulsed-wave Doppler probe is then introduced through the working channel, and with visual control through the endoscope it is gently positioned on the floor of the third ventricle. Using an initial depth setting of 5 mm and the maximum sampling volume of 1.38 mm, a systematic search is begun by sweeping the probe in an anteroposterior and mediolateral grid along the floor for signals from the BA complex. The sampling depth may be adjusted upward or downward as required to pick up and follow vascular signals. Bearing in mind the anatomy of the BA and bifurcation, flow can be expected to occur toward the Doppler probe when sampling from the BA trunk, and the flow may become multidirectional when recording from the region of the bifurcation. Most commonly, the BA is encountered in the posterior third of the interval between the infundibular recess and the mammillary bodies. Once a vascular signal is detected, the surgeon should attempt to follow this in three-dimensional space, mentally constructing an outline of the vascular anatomy. Based on this information, a presumptive location for safe third ventriculostomy is selected. With the Doppler probe positioned over this site, the full range of sampling depth is scanned to confirm the absence of any underlying vessels. The Doppler probe is then withdrawn and third ventriculostomy is performed using the standard technique. We use a 1-mm-diameter rigid blunt probe to perforate the ventricle and then dilate the opening with a No. 2 French Fogerty balloon catheter.

Case Reports

Case 1

This 33-year-old woman presented with a 1-month history of increasingly severe headaches, short-term memory disturbance, and lethargy. She exhibited an enlarged orbitofrontal circumference, and MR imaging showed aqueductal stenosis with marked hydrocephalus. At surgery,
the third ventricular floor was noted to be opaque. The microvascular Doppler probe allowed us to localize the BA complex just anterior to the mammillary bodies, and the anterior two-thirds of the third ventricular floor was noted to be free of underlying vascular signal. Third ventriculostomy was performed without incident at the junction between the anterior and middle third of the ventricle floor at midline, and no vessels were visualized beneath the ventriculostomy. The patient made an uneventful recovery, with resolution of her symptoms.

Case 2

This 41-year-old man presented with a 2-month history of increasingly severe headache and recent onset of two or three brief episodes of loss of consciousness. He had undergone a right frontoparietal craniotomy at the age of 3 weeks for unknown reasons, but otherwise he had no history of medical problems. His orbitofrontal circumference was enlarged, and he had prominent bifrontal bossing. Magnetic resonance imaging showed aqueductal stenosis with very marked ventriculomegaly. He also had an area of encephalomalacia in the posterofrontal and parietal hemispheric white matter on the right side. At surgery, the foramen of Monro and third ventricle were noted to be markedly dilated. The floor of the third ventricle was opaque. Using the microvascular Doppler probe, the vascular signal was picked up just anterior to the mammillary bodies and just to the left of midline. This could be traced anteriorly over the entire length of the third ventricular floor at a depth of 3 to 6 mm. The right PCA could be traced lying just in front of the right mammillary body and extending laterally. A ventriculostomy was made to the right of midline in the anterior third of the third ventricle floor. The BA was visualized through the ventricular fenestration, running in an anteroposterior direction just under the third ventricle floor and just to the left of midline, corroborating the Doppler probe findings. The patient made an uneventful recovery, with resolution of his symptoms. His preoperative MR image showed no anomalies of the distal BA complex.

Discussion

A variety of technical and anatomical factors undoubtedly contribute to the problem of BA injury during third ventriculostomy. In the case reported by McLaughlin, et al., arterial injury occurred when a fenestration was made just behind the infundibular recess by using a potassium titanylphosphate laser. In the case encountered by Walker (ML Walker, personal communication), the proximal segment of the right PCA was injured when a blunt penetration was made with the endoscope through the anterior third of the third ventricular floor. The vessel apparently had become pinned between the endoscope and the clivus. In both cases, the ventricular floor was opaque and the arterial complex was located in an unexpectedly anterior location along the floor. We are unaware of any studies of endoscopic anatomy that specifically detail the relationship of the BA complex to the third ventricle in patients with hydrocephalus. In our experience, the BA complex is most commonly located just anterior to the mammillary bodies, as in our Case 1; less frequently, more anterior locations are encountered, as in our Case 2. We thus believe that more precise understanding of the vascular anatomy in individual patients is required for the performance of safe third ventriculostomy. With the aid of the microvascular Doppler probe we have been able to obtain this information in both of our patients. In a careful retrospective review of the MR images obtained in the patient in Case 2, we were unable to detect any apparent anomalies of the BA complex or any indication that it would be lying at the anterior end of the third ventricular floor. We believe that the Doppler information is more precise than that gained from preoperative imaging, and this technique also provides an immediate, real-time view within the surgical perspective. With this device we have been able to locate the main BA trunk and the proximal PCAs. We have not attempted to locate the superior cerebellar arteries specifically, and it is unlikely that the device could be used to detect individual perforating vessels. Because the perforating vessels arise from the BA bifurcation and sweep posterosuperiorly, we anticipate that injury to these vessels can be avoided by keeping the ventricular penetration anterior to the BA bifurcation.

This procedure is simple and easily learned. The equipment described in this report costs approximately $16,000, but it also is useful in many vascular neurosurgical cases. The capacity of the equipment to insonate narrow sample volumes at defined depths with a graphic display of flow characteristics greatly facilitates an understanding of the vascular anatomy. This procedure adds only a few minutes to the overall operation, and there is no need for any additional preoperative imaging or preparation. We recommend that positive identification of the BA complex be made in every case to guard against the possibility of false-negative results resulting from either equipment malfunction or technical factors.

Because BA injury during third ventriculostomy is relatively uncommon, it will require extensive experience with this technique to determine if the risk of arterial injury can indeed be reduced. Because BA injury can be so devastating, we believe that the microvascular Doppler technique warrants more extensive investigation.

Conclusions

Using a microvascular Doppler probe directed through the endoscope permits accurate localization of the BA complex prior to performing a third ventriculostomy. This information should help decrease the risk of arterial injury.

Disclosure

The author has no financial relationship with any of the companies whose products are mentioned in this report.

References

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