Identification of venous sinus, tumor location, and pial supply during meningioma surgery by transdural indocyanine green videography

Clinical article

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Object. Indocyanine green (ICG) videography is commonly used in the neurosurgical field for minimally invasive neurosurgery. The aim of this study was to evaluate a new intraoperative imaging modality by performing transdural ICG videography during surgery for meningiomas.

Methods. Between March 2011 and April 2012, 10 patients with meningiomas received intravenous injection of 12.5 mg ICG just prior to dural opening. The cases comprised 8 convexity meningiomas and 2 foramen magnum meningiomas. Efficacy of the transdural ICG videography was assessed in terms of the tumor volume, the circulation time from the first appearance of the vessel to the appearance of the venous sinus, the tendency to bleed, and the discrimination of the venous sinus.

Results. The mean tumor volume was 71.6 ± 87.9 ml (the mean is expressed ± SD throughout). The cortical arteries, veins, and the venous sinus were identified by the ICG videography transdurally. The projection of the meningiomas was identified by a shadow (which the authors call the eclipse sign). Total eclipse signs were obtained in 8 cases and partial eclipse signs were obtained in 2 cases; tumor volume in the latter was more than 200 ml. In 5 of 10 cases the adjacent venous sinuses were exposed and were successfully visualized by ICG videography in 5.92 ± 1.05 seconds from the first appearance of the vessel. In 5 of 10 cases the total and the partial eclipse signs were diminished in 3.46 ± 1.31 seconds. The diminishment of the total and the partial eclipse sign was earlier than the visualization of the venous sinus (p = 0.011, t-test), revealing bleeding from the tumor that was observed until coagulation of the feeding arteries from the intracranial arteries.

Conclusions. Prior to opening of the dura mater, transdural ICG videography was used successfully to visualize the dural attachment of meningiomas and the venous sinus, resulting in safe and appropriate dural opening. The diminishment of the total and partial eclipse signs may represent significant feeding from the intracranial arteries and a tendency to bleed during resection.

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Key Words • brain tumor • meningioma • minimally invasive surgery • transdural indocyanine green videography • venous sinus • pial supply • oncology

Indocyanine green videography is commonly used in the neurosurgical field for intraoperative assessment of vascular flow following clipping of cerebral aneurysms and for cortical perfusion measurements in moyamoya disease.1-3,5-7,12-14,16,18 The ICG videography modality is quick, cost-effective, and simple to use with its integration into the surgical microscope and has become well established in the field of vascular neurosurgery. There are few reports of the use of ICG videography for brain tumor surgery, because direct identification of the tumors in relationship to the cortical arteries and veins is frequently difficult due to the various consistencies and locations of the tumors such as gliomas.4,8,15 During surgery for meningiomas, it is important to estimate the tumor projection (which we call the eclipse sign17) before the dura mater is incised, especially in cases in which tumors
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are located adjacent to the venous sinus. To decrease the risk of intra- and postoperative complications such as bleeding from the venous sinuses or CSF fistulas, the dural opening should be minimized as much as possible while still allowing safe removal of the tumor.

The aim of the present study was to evaluate the use of transdural ICG videography to detect the projection of meningioma tumors and the venous sinuses. The tendency to bleed was evaluated retrospectively based on the presence of the eclipse sign.

Methods

Between March 2011 and April 2012, 23 meningiomas were treated surgically at our institute. There were 8 cases of convexity meningiomas, 2 cases of foramen magnum meningiomas, and 13 cases of skull base or deep-seated meningiomas. After routine preoperative workup including MRI and digital subtraction angiography studies, all patients underwent a craniotomy. Written informed consent approved by the institutional review board at the Fukuoka University Hospital was obtained from all patients for use of ICG. Following exposure of the dura, the feeding arteries from the ECA were coagulated completely before the transdural ICG videography was performed. Because the recommended dose of ICG (Pulsion Medical Systems) for videoangiography is 0.2–0.5 mg/kg, we provided a standard dose of 12.5 mg intravenously.

In a darkened operating room, the intravascular dye was visualized using an operating microscope (OPMI Pentero; Carl Zeiss Meditec) equipped with an additional fluorescent light source (wavelength 700–850 nm). The tumor projection and the venous sinus were delineated transdurally by the ICG videography (Fig. 2). A safe and optimal dural incision was facilitated, with no cutting over the venous sinus.

In 8 of 10 cases the total eclipse sign was identified in the early images. However, in the late-phase images, diminishment of the total eclipse sign was observed in 3 cases within 3.46 ± 1.31 seconds (Figs. 1B and 2B; Case 6), which is earlier than the visualization of the venous sinus, a putative normal circulation time (Table 2; p = 0.011, t-test), suggesting the presence of the intracranial feeding arteries. In 2 of 10 cases the eclipse sign was partial, and diminishment of the partial eclipse sign was observed. These phenomena suggest the presence of the intracranial blood supply of the meningioma.

Results

The ICG videography modality was useful in 10 cases of meningiomas (Table 1); however, we obtained no findings in 13 cases of skull base or deep-seated meningioma. The cortical arteries, veins, and the venous sinus were identified transdurally by the ICG videography. The projection of meningiomas was identified as a shadow (the so-called eclipse sign). Total eclipse signs were obtained in 8 cases and partial eclipse signs in 2 cases, both of which were more than 200 ml in volume. Good discrimination between the brain surface and the tumor before dural opening was achieved in cases with a total eclipse sign. In 5 of 10 cases the adjacent venous sinus was exposed and was successfully identified by ICG videography in 5.92 ± 1.05 seconds after the first appearance of the vessels (Table 2). In Case 7, as a representative case, the preoperative MRI study showed that the tumor was adjacent to the transverse sinus (Fig. 1). We could discriminate between the tumor as a shadow and the sinus by using transdural ICG videography (Fig. 2). A safe and optimal dural incision was facilitated, with no cutting over the venous sinus.

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**TABLE 1: Characteristics of 10 patients with meningioma**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Lesion Location</th>
<th>Pathological Findings</th>
<th>Tumor Vol (ml)</th>
<th>ECA Staining</th>
<th>ICA or VA Staining</th>
<th>Eclipse Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53, F</td>
<td>foramen magnum</td>
<td>meningothelial</td>
<td>5.3</td>
<td>none</td>
<td>none</td>
<td>T</td>
</tr>
<tr>
<td>2</td>
<td>64, F</td>
<td>convexity</td>
<td>meningothelial</td>
<td>10.6</td>
<td>slight</td>
<td>none</td>
<td>T</td>
</tr>
<tr>
<td>3</td>
<td>69, F</td>
<td>foramen magnum</td>
<td>meningothelial</td>
<td>14.5</td>
<td>slight</td>
<td>slight</td>
<td>T</td>
</tr>
<tr>
<td>4</td>
<td>68, F</td>
<td>convexity</td>
<td>meningothelial</td>
<td>23.6</td>
<td>slight</td>
<td>none</td>
<td>T</td>
</tr>
<tr>
<td>5</td>
<td>42, F</td>
<td>convexity</td>
<td>meningothelial</td>
<td>24.6</td>
<td>NE</td>
<td>NE</td>
<td>T</td>
</tr>
<tr>
<td>6</td>
<td>50, F</td>
<td>convexity</td>
<td>psammomatous</td>
<td>29.7</td>
<td>strong</td>
<td>none</td>
<td>T</td>
</tr>
<tr>
<td>7</td>
<td>36, F</td>
<td>convexity</td>
<td>fibrous</td>
<td>51.0</td>
<td>slight</td>
<td>none</td>
<td>T</td>
</tr>
<tr>
<td>8</td>
<td>58, F</td>
<td>convexity</td>
<td>meningothelial</td>
<td>98.7</td>
<td>strong</td>
<td>strong</td>
<td>T</td>
</tr>
<tr>
<td>9</td>
<td>49, F</td>
<td>convexity</td>
<td>meningothelial</td>
<td>204.8</td>
<td>strong</td>
<td>strong</td>
<td>P</td>
</tr>
<tr>
<td>10</td>
<td>80, M</td>
<td>convexity</td>
<td>meningothelial</td>
<td>253.4</td>
<td>slight</td>
<td>slight</td>
<td>P</td>
</tr>
</tbody>
</table>

* NE = not examined; P = partial; T = total.
feeding arteries. Indeed the cases with diminishment of the total eclipse sign and the partial eclipse sign tended to bleed until the feeding arteries from the ICA or the VA were coagulated (Figs. 1C and 2C; Case 10).

**Discussion**

In the present study we demonstrated that transdural ICG videography is also useful for examining tumor and sinus location and for the optimization of the dural incision during meningioma surgery. Furthermore, we found that the diminishment of the total and the partial eclipse sign was indicative of the tendency to bleed during tumor resection.

Fluorescein angiography was first used in the study of retinal blood flow, and has since been widely applied in experimental and clinical medicine, including the intraoperative assessment of skin graft perfusion and endoscopic gastric tumor detection. In the clinical setting, ICG videography is a valuable tool for vascular neurosurgery, allowing immediate evaluation of aneurysm clipping or patency after extracranial-intracranial bypass surgery. However, there are few reports on the use of ICG videography in brain tumor surgery.

In our present series we found that the dural incision could be minimized in all cases by using transdural ICG videography, which is desirable because the length of incision is a risk factor for the development of CSF fistulas after surgery. The ICG videography also allowed clear delineation of tumor margins with dural contact, as previously reported. Furthermore, the transdural ICG videography in the cases of intrinsic brain tumors and brain tumors without dural contact, including skull base meningiomas, was negative for clear delineation of tumor margins such as the eclipse sign (data not shown).

We were able to identify the transdural location of the cortical arteries and veins and the venous sinuses exactly, resulting in clear delineation of meningioma margins. The diminishment of the total and partial eclipse signs represented significant feeding from the pial branch of the ICA and the branch of VA, resulting in intraopera-

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**TABLE 2: Duration of sinus visualization and diminishment of the total and partial eclipse signs in 10 patients with meningioma**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Eclipse Sign</th>
<th>ICA or VA Staining</th>
<th>Pial Invasion</th>
<th>Diminishment of Eclipse Sign</th>
<th>Time to Diminishment (sec)</th>
<th>Tendency to Bleed</th>
<th>Adjacent Sinus</th>
<th>Sinus Visualization Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T</td>
<td>none</td>
<td>no</td>
<td>no</td>
<td>ND</td>
<td>no</td>
<td>no</td>
<td>ND</td>
</tr>
<tr>
<td>2</td>
<td>T</td>
<td>none</td>
<td>yes</td>
<td>no</td>
<td>ND</td>
<td>no</td>
<td>SSS</td>
<td>4.52</td>
</tr>
<tr>
<td>3</td>
<td>T</td>
<td>slight</td>
<td>no</td>
<td>yes</td>
<td>4.01</td>
<td>yes</td>
<td>no</td>
<td>ND</td>
</tr>
<tr>
<td>4</td>
<td>T</td>
<td>none</td>
<td>yes</td>
<td>yes</td>
<td>5.05</td>
<td>yes</td>
<td>TSS</td>
<td>6.99</td>
</tr>
<tr>
<td>5</td>
<td>T</td>
<td>NE</td>
<td>no</td>
<td>no</td>
<td>ND</td>
<td>no</td>
<td>no</td>
<td>ND</td>
</tr>
<tr>
<td>6</td>
<td>T</td>
<td>none</td>
<td>yes</td>
<td>yes</td>
<td>1.47</td>
<td>yes</td>
<td>TSS</td>
<td>6.12</td>
</tr>
<tr>
<td>7</td>
<td>T</td>
<td>none</td>
<td>no</td>
<td>no</td>
<td>ND</td>
<td>no</td>
<td>TS</td>
<td>5.20</td>
</tr>
<tr>
<td>8</td>
<td>T</td>
<td>strong</td>
<td>yes</td>
<td>no</td>
<td>ND</td>
<td>yes</td>
<td>TSS</td>
<td>6.79</td>
</tr>
<tr>
<td>9</td>
<td>P</td>
<td>strong</td>
<td>yes</td>
<td>yes</td>
<td>3.51</td>
<td>yes</td>
<td>SSS</td>
<td>6.79</td>
</tr>
<tr>
<td>10</td>
<td>P</td>
<td>slight</td>
<td>yes</td>
<td>yes</td>
<td>3.25</td>
<td>massive</td>
<td>no</td>
<td>ND</td>
</tr>
</tbody>
</table>

* ND = not detected; SSS = superior sagittal sinus; TS = transverse sinus; TSS = transverse-sigmoid sinus.
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Conclusions

Transdural ICG videography integrated into a surgical microscope is easy and quick to apply, cost-effective, and safe. We found that transdural ICG videography could delineate tumor location and venous sinus, thus enabling precise opening of the dura and optimization of the surgical approach. The diminishment of the total and partial eclipse signs could imply significant feeding from the intracranial arteries, resulting in bleeding.

Disclosure

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Author contributions to the study and manuscript preparation include the following. Conception and design: Ueba, Higashi. Acquisition of data: Okawa, Abe, Nonaka. Analysis and interpretation of data: Iwaasa. Drafting the article: Ueba, Takano. Approved the final version of the manuscript on behalf of all authors: Ueba. Study supervision: Inoue.

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