The lion’s mane sign: surgical results using the bilateral fronto-orbito-nasal approach in large and giant anterior skull base meningiomas

Clinical article

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Object. Concerns about extreme peritumoral edema and its ensuing surgical and perioperative complications led the authors to use the bilateral fronto-orbito-nasal approach to remove midline anterior skull base meningiomas that were larger than 4 cm. The authors hypothesize that extreme vasogenic edema exemplified by finger-like hyperintensities extending into the bifrontal white matter and external capsule and/or the extreme capsule, coined the lion’s mane sign (LMS), would help identify patients with a challenging postoperative course. They hypothesize that the LMS would better predict symptomatic postoperative cerebral edema than the edema index (EI).

Methods. This is an observational case series of 9 patients. The authors noted the grade, pathology, tumor volume, EI, and the presence or absence of the LMS in all tumors. They used the intensive unit care (ICU) length of stay as a nonspecific measure reflecting postoperative symptomatic cerebral edema. Comparisons of edema-related postoperative complications and the EI were made between patients with and without an LMS.

Results. Bifrontal hyperintensities, extending into at least three-eighths of the length of the external capsules on T2-weighted MRI, seen in 4 of 9 patients, portended a longer postoperative ICU stay. The presence of an LMS better predicted postoperative complications related to cerebral edema than tumor grade, pathology, volume, or EI.

Conclusions. The LMS predicts an increased duration of stay in the ICU after a bilateral fronto-orbito-nasal approach for resection of large and giant anterior skull base meningiomas. Furthermore, the LMS better predicted increased length of stay in the ICU than did the EI.

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Key Words • lion’s mane sign • peritumoral brain edema • edema index • oncology

The lion’s mane sign (LMS) is a previously unreported radiological sign that we have observed in a subset of patients harboring large to giant midline anterior skull base meningiomas (> 4 cm). The LMS is characterized as peritumoral finger-like hyperintensities extending into the bilateral frontal white matter and into at least three-eighths of the total length of the external and/or extreme capsules on T2-weighted MRI, representing extreme capsules on T2-weighted MRI, representing extreme peritumoral brain edema (PTBE). This sign is usually accompanied by flattening of the caudate nucleus on the ipsilateral side. To standardize the observation of this sign, we look for its presence on axial T2-weighted MRI slices, at the foramen of Monro (Fig. 1).

This sign correlates with severity of PTBE, which portends symptomatic brain swelling postoperatively as well as prolonged persistence of white matter edema on imaging, which is not immediately reduced with craniotomy and lesionectomy.

In our prospectively collected homogeneous series of 9 patients harboring large and giant anterior midline skull base meningiomas, we discovered that the edema index (EI = [edema volume + tumor volume]/tumor volume) as reported by Inamura et al.6 did not accurately reflect the severity of postoperative complications due to PTBE in very large tumors. The shortcoming of the EI arises from the difficulty presented by edema patterns that are not spherical. The bifrontal skull bones limit the radial egress of edema fluid. The accumulated excess fluid then irradiates into the external and extreme capsules. Therefore, compared with the EI, the identification of the LMS will better alert the surgeon and the patient to the possibility

Abbreviations used in this paper: EI = edema index; ICU = intensive care unit; LMS = lion’s mane sign; LOS = length of stay; PONES = postoperative nonconvulsive encephalopathic status; PTBE = peritumoral brain edema.
of increased severity of postoperative morbidity as manifested in an increased length of stay (LOS), both in the intensive care unit (ICU) and the hospital.

Methods

Between June 2009 and February 2012, prospective data were collected from 9 consecutive patients at a single institution. Their anterior midline skull base meningiomas were classified as Type III (large) or IV (giant) according to the Mohr classification system. The EI was calculated, and the presence or absence of an LMS was noted. All patients underwent bilateral frontal craniotomy and removal of the bilateral orbital bar (or the extended subfrontal approach) with lumbar drainage, perioperative steroid coverage, broad-spectrum antibiotic coverage, and hyperosmolar therapy as needed. In all cases the anterior sagittal sinus was sacrificed as anteriorly and inferiorly as possible. The falx was split, and the tumor was microsurgically removed with minimal brain retraction by delivering the tumor mass toward the nasal cavity. Skull base reconstruction was performed with layered fascia lata grafts and a vascularized pericranial flap. The orbital bar was replaced at the end of the procedure, but the bifrontal bone flap was left out if an LMS was present. After the CT scans showed reduced and stabilized brain edema, the bilateral frontal bones were replaced. The tumor grade, pathology, and volume; outcomes; operative time; and ICU LOS were noted. The ICU LOS was used as an indirect and nonspecific estimation of the severity of postoperative morbidity due to seizures, slowness to awaken, and temporary new neurological deficits.

Results

Descriptive statistics were used to summarize the sample populations and the postsurgical edema-related complications in Table 1. Nine patients (2 males and 7 females) with a mean age of 51 years (range 36–67 years), of similar socioeconomic status had a mean EI of 5.61 ± 3.92 (SD). Anosmia aside, complications from these surgeries included temporary pneumocephalus, temporary frontal lobe syndrome; slowness to awaken; 2 cases of seizures (1 intraoperative and the other postoperative nonconvulsive encephalopathic status [PONES]); 2 cases of CSF leak and successfully treated meningitis (1 with osteomyelitis and the other with a frontal epidural infection); pneumonia; and 1 case of temporary alopecia with mild cosmetic disfigurement. All patients were able to

**Fig. 1.** Cartoon of the LMS showing division of the length of each external capsule into 4 quarters from the caudate nuclei toward the tritice (left) and superposed on the patient (Case 6), who had the most severe case of vasogenic peritumoral edema (right) with involvement of 8 quarters (that is, 4 quarters on each side) of the external capsules.

**Fig. 2.** Mohr classification of anterior fossa meningiomas according to size and location (olfactory groove and crista galli [a], planum sphenoidale [b], jugum sphenoidale [c], and tuberculum sellae and diaphragma sellae [d]). A new classification system was developed using the tumor size and extent of anterior fossa extension as parameters. Type I (small) tumors (black): localized to 1 segment, size < 2 cm. Type II (moderate) tumors (dark gray): localized to 2 segments, size 2–3.9 cm. Type III (large) tumors (light gray): localized to 3 segments, size 4–5.9 cm. Type IV (giant) tumors (white): localized to 4 segments, size > 6 cm.

**Invasiveness (ethmoid and sphenoid sinuses, cavernous sinuses)**

**TYPE IV : FOUR Segments or Size > 6 cm “GIANT”**

**TYPE III : THREE Segments or Size 4 - 5.9 cm “Large”**

**TYPE II : TWO Segments or Size 2 - 3.9 cm “Moderate”**

**TYPE I : ONE Segment or Size < 2 cm “Small”**
## TABLE 1: Descriptive information and postsurgical complications*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Type†</th>
<th>Pathology</th>
<th>Complications From Cerebral Edema</th>
<th>Result</th>
<th>Tumor Vol (cm³)</th>
<th>OR Time (hrs:mins)</th>
<th>ICU (days)</th>
<th>LOS (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36</td>
<td>IV</td>
<td>transitional</td>
<td>none</td>
<td>returned to work</td>
<td>1.9</td>
<td>63</td>
<td>14:37</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>III</td>
<td>transitional</td>
<td>none</td>
<td>returned to work</td>
<td>5.6</td>
<td>49</td>
<td>10:22</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
<td>IV</td>
<td>transitional</td>
<td>none</td>
<td>retired, KPS score 100</td>
<td>2.6</td>
<td>68</td>
<td>11:45</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>59</td>
<td>III</td>
<td>meningothelial rhabdoid</td>
<td>nonconvulsive status epilepticus, craniectomy for edema</td>
<td>retired preop, postop KPS score 100, returned to work</td>
<td>12</td>
<td>35</td>
<td>4:23</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>III</td>
<td>transitional</td>
<td>cerebral edema preventing attempt to replace bone flap</td>
<td>KPS score 100</td>
<td>3.5</td>
<td>67</td>
<td>21:30</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>53</td>
<td>IV</td>
<td>transitional rhabdoid</td>
<td>frontal lobe syndrome, slowness to awaken</td>
<td>lost to FU, returned abroad</td>
<td>4.8</td>
<td>117</td>
<td>14:07</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>IV</td>
<td>psammomatous meningioma WHO Grade II, invasion of brain</td>
<td>none</td>
<td>returned to work</td>
<td>4.0</td>
<td>61</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>66</td>
<td>III</td>
<td>atypical meningioma, WHO Grade II</td>
<td>none</td>
<td>KPS score 100 until unrelated death due to ruptured aneurysm</td>
<td>3.6</td>
<td>32</td>
<td>5:56</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>41</td>
<td>III</td>
<td>meningothelial WHO Grade I</td>
<td>intraop seizures</td>
<td>KPS score 100</td>
<td>12.5</td>
<td>31</td>
<td>9:59</td>
<td>11</td>
</tr>
</tbody>
</table>

* Patients are listed in consecutive order. Data for those patients with the LMS (hyperintensity of the bilateral frontal and at least three-eighths of the length of the external capsule and/or extreme capsule) are shown in boldface. When the LMS was compared with the EI in predicting edema-related postsurgical morbidity, only the LMS predicted increased postoperative stay in the ICU. Tumor volume did not predict postoperative morbidity (tumor volume = (4/3) × π × radius1 × radius2 × radius3). FU = follow-up; KPS = Karnofsky Performance Scale; OR = operating room.
† Mohr classification. Refer to Fig. 2 for definitions of the types.
function as well as or better than before surgery. Patients who were working preoperatively have returned to work except for 1 patient who is still recovering after a recent cranioplasty. No procedural deaths occurred, and no recurrences have been noted to date.

A positive LMS was seen in patients with symptomatic brain edema after surgery (Fig. 3), and it was not seen in patients without this finding (Fig. 4). The patient in Case 4 who had a positive LMS preoperatively was the only patient in the series who underwent replacement of the bifrontal bone flap at the end of surgery. However, this patient developed PONES, a previously described complication after skull base surgery, and the bifrontal bone flap was removed to facilitate recovery. There was no evidence of sinus thrombosis on vascular MRI. This patient recovered completely, returning to work after a delayed cranioplasty.

A positive LMS was a predictor of longer ICU stays and was used as an indirect measure of increased postsurgical complications due cerebral edema (as reflected by seizures, slowness to awaken, and temporary new neurological deficits). Presence of the LMS was a better prognosticator of extreme postoperative brain edema than the EI. There was no correlation between EI and the ICU LOS. Furthermore, the EI did not reliably and consistently predict symptomatic postoperative brain edema either on the basis of tumor pathology and grade or tumor volume.

**Discussion**

The treatment of large and giant anterior skull base meningiomas remains challenging as evidenced by mortality even in present-day series. While there are technical and surgical factors that portend poor results, one important contributing factor toward mortality and post-

![Fig. 3. Clinically relevant LMSs. Axial T2-weighted MRI slices at the level of the foramen of Monro showing peritumoral finger-like hyperintensities extending into the bilateral frontal white matter and external capsule edema extending from the caudate nucleus toward the trigone. A: Case 4. Four-eighths of the length of the external capsules. B: Case 5. Three-eighths of the length of the external capsules. C: Case 6. Eight-eighths of the length of the external capsules. D: Case 9. Five-eighths of the length of the external capsules.](image)

![Fig. 4. Axial images obtained in patients without the LMS. A: Case 1. Two-eighths of the length of the external capsules. B: Case 2. Two-eighths of the length of the external capsules with insufficient bilateral frontal white matter edema. C: Case 3. Four-eighths of the length of the external capsules with insufficient bilateral frontal white matter edema to meet criteria for the LMS. D: Case 7. One-eighth of the length of the external capsules. E: Case 8. Two-eighths of the length of the external capsules.](image)
operative complications is the presence of preoperative PTBE.3,4,15 Other factors associated with PTBE include histological subtype, increased tumor size, irregular margins, pial cortical blood supply, location at the midline10 or frontal skull base,17 and poor basal venous drainage.11,18,19,21 The physiological basis for meningioma-associated cerebral edema is attributed to blood-brain barrier breakdown. Biological factors such as expression of VEGF, matrix metalloproteinase–9,16 and interleukin-617 trend toward an increase in PTBE. These molecules play an important role in the alteration of vessel permeability and the release of local mediators causing extracellular vasogenic edema.7,14 Since tumor edema propagates by bulk flow,12 the distribution of vasogenic edema is related to the pressure gradient between tissues. White matter is preferentially affected, and the later appearance of vasogenic edema in the external and extreme capsules5 is due to the capsules’ increased resistance4 relative to the long association fibers. However, not all patients with large and giant tumors will suffer the consequences of extreme cerebral edema postoperatively. Therefore, the identification of a preoperative sign for severe PTBE will assist clinicians in recognizing susceptible patients and allow them to take appropriate measures.

Inamura et al.8 first described the EI using MRI. Others11,17,21,22 have also recognized the importance and clinical relevance of PTBE and have continued to quantify the severity of cerebral edema using the EI. This calculation can be user dependent, inconvenient to compute, and is not always predictive of poor outcome. In large anterior midline tumors, the volume of the tumor may be so large as to result in a falsely decreased EI by virtue of the decreased calculated edema volume resulting from the anatomical confines of the frontal calvaria and skull base (Fig. 5).

The patient in Case 4 had an LMS despite having the smallest tumor. Preoperatively this patient had subfalcine as well as left transtentorial herniation and a high EI. Although the operative time was only 4.5 hours, with minimal brain retraction, she had the longest LOS. This was likely related to PONES that was not immediately recognized; perioperative seizures have been associated with cerebral edema.6 For this patient, the bifrontal bone flap was removed urgently 5 days after the initial surgery. The LMS that was present preoperatively persisted even 1 month after surgery. In subsequent cases when LMS was noticed preoperatively, the bifrontal bone flap was not replaced at closure (due to intraoperative swelling, anticipated swelling, or seizures), thereby permitting unimpeded brain swelling and successfully avoiding emergency bone flap removal. These latter patients, despite having larger tumors and a positive LMS, benefited from a reduced LOS in the ICU compared with the patient in Case 4.

The present investigation focuses on the utility of the LMS, a preoperative sign that is easily recognized on T2-weighted MRI studies, as a prognosticator of postoperative complications and increased LOS in the ICU. It is also simple and independent of computation as required for the EI. Therefore, the identification of the LMS will facilitate and prepare the clinician to plan preoperatively for postoperative morbidity.

Conclusions

The LMS, a preoperative phenomenon on MRI, heralds extreme brain edema in the postoperative phase of care after resection of large and giant anterior midline skull base meningiomas. For these large lesions, the LMS is a better predictor of postoperative morbidity than the EI, as the latter does not take into account the redirected edema fluid into the external and sometimes extreme capsules, which is directly related to the confines of the calvaria and the skull base.

Disclosure

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

Author contributions to the study and manuscript preparation include the following. Conception and design: Li. Acquisition of data: Li. Analysis and interpretation of data: Li, Portman. Drafting the article: Li, Portman. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Li. Statistical analysis: Li, Portman. Administrative/technical/material support: Li, Portman, Mohr. Study supervision: Li.

References


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