Is the distance between mammillary bodies predictive of a thickened third ventricle floor?

Clinical article

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Object. The aim of this study was to correlate intraoperative endoscopic third ventriculostomy (ETV) findings in hydrocephalic patients with the MR imaging appearance of the mammillary bodies (MBs), the fundamental anatomical landmarks of the third ventricle floor (TVF) region.

Methods. The authors reviewed brain MR images and intraoperative ETV records in 23 patients with hydrocephalus as well as MR imaging data from 120 randomized control volunteers of various ages to define the normal intermammillary distance (IMD).

Results. In control volunteers, no measurable IMD (“kissing” configuration) was observed in 91 (85%) of 107 cases, and there was mild MB splitting (mean ± standard deviation, 0.18 ± 0.12 cm) in only 16 cases with age-related cerebral atrophy. Among the 21 patients with complete MR imaging and ETV data sets, 12 ETV procedures were hindered by anatomical anomalies such as a thickened TVF or an “upward balloononing” phenomenon. On preoperative MR imaging in these 12 patients, there was an increased IMD (0.55 ± 0.41 cm) compared with that in the remaining 9 patients (0.27 ± 0.25 cm) who had a normal thin TVF during ETV and in the control group (0.03 ± 0.08 cm). Magnetic resonance imaging and ETV data concordantly displayed nonsplit MBs in 6 of 9 cases with a thin TVF and split MBs in 10 of 12 cases with a thick TVF.

Conclusions. The normal configuration of MBs is no measurable IMD, with mild splitting occurring in patients with age-related brain atrophy. In hydrocephalic patients, a thickened TVF was present almost exclusively with an increased IMD on preoperative MR imaging and separated MBs on endoscopic viewing. Large retrospective series are needed to confirm that a preoperative increased IMD is predictive of a thickened TVF during ETV.

(Key Words: • endoscopic third ventriculostomy • intermammillary distance • mammillary body • neuroendoscopic anatomy • third ventricle floor

Advances in the ETV technique have been based on a detailed understanding of third ventricular anatomy, surgical trajectories, and improved instrumentation. Knowledge of third ventricle anatomy is essential for the safety and reliability of intraventricular endoscopic procedures. Many anatomical variants or anomalies can complicate the ETV procedure and compromise the surgical results—for example, thickening of the TVF, which disturbs the usual anatomical orientation and can render perforation of the floor technically difficult; a narrow foramen of Monro; or the so-called upward balloononing phenomenon, in which, after perforation of the TVF and withdrawal of a Fogarty catheter, the floor herniates into the third ventricle, hindering the endoscopic view.

The operative results mainly depend on the selection of suitable hydrocephalic patients; therefore, specific MR imaging findings in the evaluation of the pathophysiological and anatomical prerequisites are a fundamental part of preoperative planning. Unfortunately, the consistency of the TVF cannot be adequately determined preopera-
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tively based on MR images, even with an advanced MR imaging protocol and 3D reconstruction. However, the distance between MBs, the fundamental anatomical landmarks for ETV, is a linear measure readily assessable on axial MR images and can provide indirect information about the conformation of the TVF. A thorough search of the medical literature failed to reveal any systematic MR imaging evaluation of this particular measure in healthy persons or in an ETV study.

Because in neuroendoscopic studies variable IMDs and a thickened TVF have been commonly observed, we retrospectively evaluated the IMDs on routine MR images both in 23 patients with hydrocephalus who had undergone ETV and in 120 healthy persons to define normal values of the IMD, which to our knowledge has never been reported, and to assess the possible correlation between such preoperative measures and the thickness of the TVF in patients with hydrocephalus.

Methods

Control Volunteers

After exclusion for intracranial pathology, 120 randomized brain MR imaging studies obtained in persons of different sexes and ages were reviewed to evaluate the hypothalamic region. Mammillary bodies were assessable in 107 (89%) of 120 persons; 13 cases were excluded because of the superimposition of vascular structures (5 cases), patient motion (4 cases), or misalignment (4 cases). The ages of the remaining 107 control volunteers (59 males and 48 females) whose mean age was 48.5 ± 19 years (mean ± standard deviation, range 4–85 years), were distributed in the following way: 1st decade = 3 cases, 2nd decade = 8, 3rd decade = 7, 4th decade = 15, 5th decade = 19, 6th decade = 23, 7th decade = 14, 8th decade = 15, 9th decade = 3.

Patient Population

We performed a systematic review of intraoperative videotapes obtained in 23 consecutive patients who had undergone ETV for symptomatic hydrocephalus at the neurosurgical department of the “S. Anna and S. Sebastiano” Hospital of Caserta, Italy, specifically to reevaluate the configuration of the TVF region and the MBs. The patients consisted of 18 men and 5 women (mean age 40.1 ± 18.0 years, range 18–71 years) who had presented with the following pathologies: mass lesion in the posterior fossa (3 cases in the cerebellopontine angle, 2 in the fourth ventricle, and 1 in the supracerebellar region), primitive aqueductal stenosis (5 cases), NPH (3 cases), tectal tumor (2 cases), intraventricular cyst (2 cases), expansion diverticulum of the suprapineal recess (1 case), pineal region mass (1 case), ruptured thalamic cavernous hemangioma with third ventricle hernorrhage (1 case), leptomeningeal carcinomatosis (1 case), and adult Chiari malformation Type I (1 case; Table 1). With respect to the duration of symptomatology, 12 patients had acute hydrocephalus (that is, < 1 month) and 11 had chronic hydrocephalus. All ETV procedures were performed using a rigid endoscope (6-mm, Zeppelin) after inducing general anesthesia in the patient and administering antibiotic prophylaxis (third-generation cephalosporin). A stoma was placed within the tuber cinereum via bipolar coagulation and then dilated with a 2 Fr Fogarty balloon catheter and/or Decq forceps. Few procedures were performed with the help of the neuronavigator (Treon, Medtronic Navigation).

Magnetic Resonance Imaging Protocol and Analysis

The MR images from both the control volunteers and the patients with hydrocephalus were obtained in a 1.5-T MR unit (Eclipse, Philips Medical System) using routine 5-mm-thick T1- and T2-weighted turbo spin echo sequences, after the intravenous administration of Gd chelates when necessary for clinical purposes. For both groups, the inner IMD was measured by drawing on the MR imaging elaboration console the shortest straight line between the discernible border of the medial aspects of the MB on axial T1- (TR 500 msec, TE 10 msec, matrix size 256 × 256) or T2-weighted (TR 4320 msec, TE

| TABLE 1: Summary of characteristics in 23 patients who underwent ETV* |
|---|---|---|---|---|
| Case No. | Diagnosis | Symptom Duration | MBs at ETV |
| | | | IMD (cm) |
| 1 | aqueductal stenosis | chronic | thick | sep | 1.43 |
| 2 | aqueductal stenosis | chronic | thick | sep | 1.07 |
| 3 | NPH | chronic | thick | sep | 0.90 |
| 4 | adult CM Type I | chronic | UWB | sep | 0.72 |
| 5 | aqueductal stenosis | chronic | thick | sep | 0.65 |
| 6 | CPA mass lesion | acute | thick | sep | 0.41 |
| 7 | CPA mass lesion | acute | thick | sep | 0.34 |
| 8 | intraventricular cyst | chronic | thick | sep | 0.29 |
| 9 | CPA mass lesion | acute | thick | sep | 0.24 |
| 10 | aqueductal stenosis | chronic | thick | sep | 0.22 |
| 11 | tectal tumor | acute | thick | adj | 0.15 |
| 12 | pineal mass lesion | acute | thick | adj | 0.15 |
| 13 | thalamic ruptured hemangioma | acute | thin | sep | 0.78 |
| 14 | suprapineal expansion diverticulum | chronic | thin | sep | 0.59 |
| 15 | aqueductal stenosis | chronic | thin | sep | 0.25 |
| 16 | tectal tumor | acute | thin | adj | 0.19 |
| 17 | 4th ventricle mass lesion | acute | thin | adj | 0.18 |
| 18 | NPH | chronic | thin | adj | 0.17 |
| 19 | 4th ventricle mass lesion | acute | thin | adj | 0.14 |
| 20 | NPH | chronic | thin | adj | 0.12 |
| 21 | supracerebellar mass lesion | acute | thin | adj | 0.00 |
| 22 | leptomeningeal carcinomatosis | acute | NA | NA | 0.00 |
| 23 | intraventricular cyst | acute | NA | NA | NA |

* acute = hydrocephalus symptoms lasting < 1 month; adj = adjacent appearance of MBs during ETV; chronic = hydrocephalus symptoms lasting > 1 month; CM = Chiari malformation; CPA = cerebellopontine angle; NA = not assessable during ETV or on preoperative MR imaging; sep = separation of MBs during ETV; thick = increased thickness of TVF on ETV; thin = normal thickness of TVF on ETV; UWB = upward ballooning phenomenon.
120 msec, matrix size 264 × 384) images on which these structures were best evident.

To test the relation between IMD and TVF thickness, patients were classified in a 2 × 2 table according to TVF thickness (thin vs thick) and IMD (above vs below the 95th percentile of the IMD distribution in the controls), and the Fisher exact test was applied. The same approach was used in the patients with hydrocephalus to test the relation between the duration of symptoms and IMD.

**Results**

**Control Volunteers**

In the control group, the mean IMD was 0.03 ± 0.08 cm (95th percentile: 0.2 cm). The most frequently observed configuration of the MB was no measurable distance (0.0 cm, 91 cases [85%]), which we defined as a “kissing configuration;” in the remaining 16 cases (15%), most of which involved patients > 60 years of age and with some degree of age-related brain atrophy, a measurable distance was observed (0.18 ± 0.12 cm), and these cases were classified as having the “split configuration” (Table 2).

However, among all 32 persons older than 60 years, 18 (56%) presented with kissing MBs (even 2 83-year-olds) and only 14 (44%) had some distance between MBs (range 0.09–0.55 cm). Thus, increasing age was not exclusively associated with the split configuration.

The MR imaging patterns in healthy volunteers are exemplified in Fig. 1. The most frequently observed pattern (84 cases [78.5%]) was the kissing MBs and no age-related brain atrophy, then split MBs and age-related brain atrophy (16 cases [15%]), and finally kissing MBs and age-related brain atrophy (7 cases [6.5%]). A pattern of split MBs not associated with age-related brain atrophy was never observed.

**Patient Population**

On intraoperative endoscopic viewing, the MBs were visible in 21 of 23 patients (Table 1), and 2 patterns of MB configuration emerged: the bodies appeared physically separated in 13 cases and adjacent without clear-cut separation in 8 cases (Fig. 2b and d).

Two patients with acute hydrocephalus (Cases 22 and 23; Table 1) were eliminated from subsequent analysis

<table>
<thead>
<tr>
<th>MB Configuration</th>
<th>No. of Cases</th>
<th>IMD</th>
<th>Age &lt;60 Yrs</th>
<th>Age &gt;60 Yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>all</td>
<td>107</td>
<td>0.03 ± 0.08</td>
<td>75</td>
<td>32</td>
</tr>
<tr>
<td>kissing</td>
<td>91</td>
<td>0.00 ± 0.00</td>
<td>73</td>
<td>18</td>
</tr>
<tr>
<td>split</td>
<td>16</td>
<td>0.18 ± 0.12</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>

**Table 2:** Distribution of MR imaging–based IMD values in the 107 controls
due to inadequate assessment of the MBs either on endoscopic viewing (Case 22, leptomeningeal carcinomatosis with multiple metastatic nodules occupying the area of the tuber cinereum) or on both the ETV and preoperative MR imaging (Case 23, large suprasellar arachnoid cyst). In the latter case, however, TVF fenestration could be performed uneventfully.

Endoscopic third ventriculostomy procedures were rated as uneventful in 9 of 21 cases, corresponding to patients in whom perforation of the TVF was easily accomplished given the thin floor. The most common anatomical anomaly that influenced the procedure, observed in 11 cases, was a thickened TVF. This finding significantly prolonged operation time, as it led to increased stretching of the floor and walls of the third ventricle during perforation with consequent ecchymosis and/or minor arterial bleeding. Most thickened TVFs obscured visual control of the basilar artery. The prolonged manipulations of the hindered endoscopic procedures were often associated with ecchymosis of the fornix without clinical complications. In another patient (Case 4; Table 1), the endoscopic procedure was very difficult and prolonged due to an upward ballooning phenomenon, because after perforation of the TVF and withdrawal of the Fogarty catheter, the floor became bubble-shaped, coming upward into the third ventricle and hindering the endoscopic view.

Overall, preoperative MR images showed highly variable inner distances between the MBs (0.43 ± 0.37 cm, range 0.00–1.43 cm; Fig. 2a and c). When correlating MR imaging–based IMD values with endoscopic records, we noted that all cases with visible separation between the MBs on ETV (split MBs) showed an IMD > 0.20 cm (Table 1); however, when no distance was observed between the MBs on endoscopic viewing, a minimal MR imaging–measurable IMD (≤0.20 cm) can still be present (Fig. 2a and b).

Among the 13 patients with split MBs (IMD ≥0.20 cm), 10 presented with a thick and only 3 (Cases 13–15) with a thin TVF at the endoscopic procedure (Fig. 3 and Table 1). Among the 8 patients with an IMD ≤0.20 cm, 6 presented with a thin floor and only 2 (Cases 11 and 12) with a thick floor on the endoscopic procedure.

As shown in Fig. 3, the IMD values were clearly lower in the 9 patients with a thin TVF (0.27 ± 0.25 cm) compared with those in the 12 with a thickened floor, including a case with upward ballooning (0.55 ± 0.41 cm).

Thus, MR imaging and ETV data concordantly displayed nonsplit MBs in 6 of 9 patients with a thin TVF and split MBs in 10 of 12 patients with a thick TVF (p ≤0.05, 2-tailed Fisher exact test), suggesting that the pair of variables (thick TVF and wide IMD) are indeed associated.

Patients with chronic hydrocephalus showed a trend for higher IMD values as compared with those in the acute hydrocephalus group (0.58 ± 0.4 cm and 0.26 ± 0.2 cm, respectively, p = 0.08).
In our retrospective analysis, the MBs on the endoscopic videotapes appeared variably split and correlated well with linear measures obtained on the routine MR imaging axial slices from these patients. As confirmed by statistical analysis, the patients with a thick TVF presented with wider intermamillary splitting than those with a thin TVF (Fig. 3). This finding may represent major help for the neurosurgeon planning an ETV.

Given the small number of cases in the present study, it is far from our intention to provide a pathological explanation, and neither can we give a fixed classification of split MBs. Nonetheless, we stress the fact that in patients with a thick TVF, the mean IMD was 0.55 ± 0.4 cm and in patients with a thin TVF the mean distance was 0.27 ± 0.2 cm. In regard to the duration of symptomatology, 10 patients were considered to have acute hydrocephalus (< 1 month) and 11 to have chronic hydrocephalus. These 2 groups showed no significant difference in TVF thickness: 5 patients with a thick TVF and 5 patients with a thin floor belonged to the acute group, and 6 patients with a thick floor (plus 1 with the upward ballooning phenomenon) and 4 with a thin TVF belonged to the chronic group (Table 1).

To our knowledge, the present anatomical report is the first in which the inner distance of the MBs has been analyzed in a healthy population. Our data on patients with healthy brain clearly indicate that the absence of a measurable IMD is the normal MB configuration at any age. Mild MB splitting occurs mainly in association with age-related brain atrophy. We used ubiquitously available 5-mm-thick conventional fast spin echo T1- and T2-weighted axial images to provide a preoperative tool useful on any MR scanner; however, with the wider diffusion of true volumetric sequences (such as magnetization-prepared rapid gradient-echo sequences) the accuracy of the IMD measurement and its value in predicting a thickened TVF can increase, and the percentage of cases with unassessable MB is likely to decrease. Moreover, specific MR imaging protocols can be implemented in patients eligible for ETV to ensure adequate visualization of the structures in the TVF region. Results in the present study may prompt neurosurgeons who perform neuroendoscopy to review their institutional series of third ventriculostomies to search analogous findings.

**Conclusions**

In patients with hydrocephalus, the thickness of the TVF, which cannot be detected on preoperative neuroimaging studies, may be correlated with the inner distance between MBs as measured on preoperative conventional axial MR images; there is a high incidence of thickened TVFs in patients with an increased IMD. No clear correlation is evident between IMD values and the duration of the clinical history of hydrocephalus.

In healthy controls, there is usually no inner distance between the MBs at any age, with only mild MB splitting in a few cases with age-related atrophy.

Reviews of the intraoperative records of patients who have undergone ETV are warranted to confirm our findings about the predictive value of IMD.
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Disclaimer

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

Acknowledgment

We thank Dr. Franco Servadei, University Hospital of Parma, Italy, for his kind help in revising the manuscript.

References


Please include this information when citing this paper: published online October 31, 2008; DOI: 10.3171/2008.4.17539.

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