Neuroradiology

Assessment of epidermoid cyst with trigeminal neuralgia before neuroendoscopy: A high-resolution MR study based on 3D-FIESTA and MR angiography

Long Wang\textsuperscript{a}, Xiaoming Zhang\textsuperscript{b}, Meng Zhao\textsuperscript{b}, Qian Wang\textsuperscript{b,}\textsuperscript{*}

\textsuperscript{a} Department of Radiology, Jining No. 1 People’s Hospital, Six Jiankang Road, Jining, China
\textsuperscript{b} Department of Radiology, Qilu Hospital of Shandong University, No.107 Wenhuaxi Road, Jinan, China

\textbf{ARTICLE INFO}

\textbf{Keywords:}
Epidermoid cyst
Trigeminal neuralgia
Facial pain
Magnetic resonance imaging

\textbf{ABSTRACT}

\textbf{Purpose:} To assess the value of preoperative 3D-FIESTA and MR angiography (MRA) in endoscopic resection of epidermoid cysts presenting with trigeminal neuralgia (TN).

\textbf{Methods:} 3D-FIESTA and MRA were performed before neuroendoscopy in 32 cases of epidermoid cysts with TN, and the tumors were grouped into types A, B, C, and D according to the relationship between the tumor and adjacent nerves and arteries (Hitoshi Kobata’s classification). Evaluation of the neuroendoscopic resectability of different types of tumors, included gross total tumor removal (GTR), subtotal tumor removal (STR), and partial tumor removal (PTR). During the 5-year follow-up, symptoms were assessed based on facial pain relief using the Barrow Neurological Institute (BNI) score.

\textbf{Results:} The coincidence rate between MRI classification of the tumor and the operation was 100%. Type B tumors were the most common (18/32, 56.3%). Type A tumors showed the highest resectability (9/9, 100%), followed by type B tumors (14/18, 77.8%). Moreover, microvascular decompression was performed in all 4 cases of type C and 1 case of type D tumors. During follow-up, 23 patients showed marked improvement in symptoms (15, 8 of BNI I or II), 8 cases showed partial improvement (BNI III), and only 1 case of type C tumor was associated with poor facial pain relief, which recurred 5 years later (BNI IV).

\textbf{Conclusions:} Preoperative high-resolution MR can accurately analyze the relationship between epidermoid cysts and adjacent nerves and arteries. It could act as a powerful tool in the evaluation of tumor resectability and the prognosis of surgery.

1. Introduction

Intracranial epidermoid cysts are benign tumors that develop from the ectodermal residue in the early embryonic stage and account for 0.2
\textsuperscript{1,2}–1.8\% of brain neoplasms.\textsuperscript{1,2} Approximately half of the tumors in the cerebellar-pontine angle (CPA) region are epidermoid cysts, which typically cause trigeminal neuralgia (TN), particularly in young patients.\textsuperscript{3,4} Other symptoms of cranial nerve stimulation may also occur, such as facial spasm, brainstem dysfunction, and hydrocephalus. CPA epidermoid cysts are treated surgically, and the retrosigmoid approach is the first choice. The endoscope is an extremely useful tool for excision of CPA epidermoid cysts due to its large field of vision, good lighting, and accessible observation.\textsuperscript{5,6} When the tumor is large, the adjacent structures can be conglutinated and the peripheral nerves and blood vessels can be injured during the operation, leading to subtotal tumor resection. Therefore, the preoperative evaluation of lesions is essential.

Magnetic resonance imaging (MRI) is the most commonly used imaging tool for diagnosing CPA tumors. On routine MR images, the surrounding cerebrospinal fluid (CSF) of tumor is dark on T1WI and bright on T2WI, and made the tumor boundaries blurred. Diffusion-weighted imaging (DWI) is sufficiently sensitive to detect tumors due to the classic high signal intensity, which is helpful in the qualitative assessment and localization of lesions.\textsuperscript{7} However, due to the limited resolution, DWI images could not accurately delineate the lesion boundary or

\textit{Abbreviations:} CPA, Cerebellar pontine angle; MRI, Magnetic resonance imaging; 3D-FIESTA, Three-dimensional fast imaging employing steady-state acquisition; TOF MRA, Time-of-flight MR angiography; TN, Trigeminal neuralgia.

\textit{E-mail address:} wangqql@email.sdu.edu.cn (Q. Wang).

https://doi.org/10.1016/j.clinimag.2022.08.006
Received 19 March 2022; Received in revised form 29 June 2022; Accepted 7 August 2022
Available online 9 August 2022
0899-7071/© 2022 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
relationship with the adjacent blood vessels and nerves. To guide the operation and evaluate the prognosis, more details are needed prior to surgical resection. Three-dimensional fast imaging employing steady-state acquisition (3D-FIESTA) and time-of-flight MR angiography (TOF MRA) are high-resolution MR techniques, resulting in excellent contrast between the structures of the CPA, including tumors, cerebrospinal fluid (CSF), nerves, and adjacent vessels.\(^5\) We performed preoperative 3D-FIESTA and TOF MRA examinations in 32 patients with CPA epidermoid cysts presenting with TN, compared the imaging classification with that of neuroendoscopy, evaluated the resectability of the tumors, and followed up the facial pain relief of the patients.

2. Subjects and methods

2.1. General information and clinical manifestation

Thirty-two cases of patients (6 males, 26 females) with epidermoid cysts induced TN were admitted to undergo neuroendoscopic surgery, with the age ranging from 24 to 66 years (mean 45 years). The duration of disease ranged from 1 to 20 years (mean 4.6 years). All cases exhibited attacks of severe facial pain along the trigeminal nerve divisions, most of which included sharp shooting pain in the cheek and lips, or like having an electric shock in the jaw, teeth or gums. Other neurological dysfunction was presented, including five cases of vertigo, 3 cases of hemifacial spasm, 4 cases of tinnitus, 2 cases of diplopia, and 2 cases of dysphonia. All patients provided written informed consent, and the study was approved by our institutional review committee.

2.2. Imaging protocol and analysis

Epidermoid cysts diagnoses were done by the high-resolution MRI using a 3.0 Tesla MR scanner (Signa; GE Medical Systems, Milwaukee, WI, USA). Patients underwent 3D-FIESTA and TOF MRA centered on the tumor location. The following pulse sequences were used: (1) 3D-FIESTA sequence (repetition time/echo time: 6.1 ms/1.5 ms, 60° flip angle, 240 × 240 mm field of view, 512 × 512 matrix, 2 acquisitions); (2) TOF MRA (repetition time/echo time = 22 ms/3.2 ms, 15° flip angle, 240 × 240 mm field of view, 256 × 512 matrix, 1 acquisition).

Original 3D-FIESTA and TOF MRA images were transmitted to the GE ADW4.4 workstation, and reconstructed to observe the relationship between the lesions and the peripheral nerves and blood vessels. The multiplanar reformation (MPR) technique was used to visualize the relationship between the lesions and surrounding nerves and blood vessels in various directions. The MRI images of all patients were observed and analyzed by two experienced radiologists who assessed the range, shape, boundary, and signal intensity of the lesions. The relationship between the tumor and the peripheral nerves and vessels, such as wrapping, pushing, and shifting, was recorded. The relationships between lesions and adjacent nerves and arteries were grouped into four types according to Hitoshi Kobata’s classification, as shown in Table 1.

### Table 1

<table>
<thead>
<tr>
<th>Hitoshi Kobata's classification</th>
<th>The relationship among the CPA epidermoid cyst, the trigeminal nerve, and the artery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>The nerve is completely encased by the tumor without displacement.</td>
</tr>
<tr>
<td>Type B</td>
<td>The nerve is compressed and distorted by the tumor.</td>
</tr>
<tr>
<td>Type C</td>
<td>The nerve is located between the tumor and an artery (usually the superior cerebellar artery), displaced by the tumor and compressed by the artery.</td>
</tr>
<tr>
<td>Type D</td>
<td>The nerve is directly compressed by an artery displaced by the tumor located in the same side.</td>
</tr>
</tbody>
</table>

Note: CPA = Cerebellopontine angle, TN = trigeminal nerve.

2.3. Surgical procedure

The same standard microsurgery technique was used in all operations, and tumors were removed by microscopically assisted neuroendoscopy using a suboccipital retrosigmoid approach. The degree of removal was recorded as gross total tumor removal (GTR), subtotal tumor removal (STR), or partial tumor removal (PTR) based on the degree of removal of the cyst contents and the capsule. Vascular decompression was performed when nerve compression by a neighboring artery was identified during surgery.

2.4. Follow-up

All patients were followed up once a year for five consecutive years with clinical assessment of facial pain relief. Outcomes were evaluated using a standardized questionnaire. Facial pain after surgery was scored as levels I–IV according to the Barrow Neurological Institute (BNI) pain intensity scoring criteria: I: no pain; II: occasional pain, not requiring medication; III: some pain, controlled with medication; IV: some pain, not controlled with medication; V: severe pain/no pain relief).\(^10\)

2.5. Statistical analyses

The Statistical Package for the Social Sciences (SPSS for Windows, version 19.0; SPSS, Inc., Chicago, IL, USA) was used for statistical analysis. Mean analysis was used for quantitative data. Independent samples tests were used in group comparisons. Significance was considered when \(p < 0.05\).

3. Results

3.1. Clinical data and MR findings

There were 13 cases of lesions located on the left side and 19 on the right side. The clinical characteristics and MR findings are presented in Table 2.

The nerves and small arteries of the CPA showed low signal intensity on the 3D-FIESTA images and isointensity, and high signal intensity on the TOF MRA images, respectively. This imaging feature was used to distinguish between nerves and arteries. The tumor volumes ranged from 0.63 to 88.2 cm\(^3\) (mean 18.1 cm\(^3\)). Trigeminal nerves were embedded, stretched, or pushed by tumors to varying degrees. In 5 cases, the trigeminal nerves were closely adjacent to the small arteries. Tumor classification was verified by endoscopy in all patients, and the coincidence rate between MRI classification and surgery was 100%. In this study, type B tumors were the most common (18/32, 56.3%), followed by type A (9/32, 28.1%), type C (4/32, 12.5%), and type D (1/32, 3.1%) (Fig. 1).

### Table 2

<table>
<thead>
<tr>
<th>Tumor classification</th>
<th>Age (y)</th>
<th>Female/total n (%)</th>
<th>Age of onset (y)</th>
<th>Duration (y)</th>
<th>MR derived tumor volume (cm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>46</td>
<td>7/9</td>
<td>45 (28, 62)</td>
<td>1.0 (1,10)</td>
<td>6.75 (0.63, 88.21)</td>
</tr>
<tr>
<td>Type B</td>
<td>46</td>
<td>17/18</td>
<td>40.5 (22, 54)</td>
<td>2.5 (1,20)</td>
<td>14.30 (2.64, 38.90)</td>
</tr>
<tr>
<td>Type C</td>
<td>57</td>
<td>2/4</td>
<td>48.5 (41, 57)</td>
<td>5.0 (1,16)</td>
<td>35.78 (10.92, 38.60)</td>
</tr>
<tr>
<td>Type D</td>
<td>38</td>
<td>0/1 (0.0)</td>
<td>37</td>
<td>1</td>
<td>19.5</td>
</tr>
</tbody>
</table>

Note: Type A = Cerebellopontine angle, TN = trigeminal nerve.
Fig. 1. Tumor classification based on 3D-FIESTA and TOF MRA imaging.
(A) Type A epidermoid cyst (left side), the trigeminal nerve (white arrow head) was entirely encapsulated by the tumor (asterisk) and slightly deformed without obvious displacement.
(B) Type B epidermoid cyst (right side), the trigeminal nerve was partly wrapped and obviously compressed with dragging and shifting.
(C) Type C epidermoid cyst (left side), the tumor was mainly located on the outer side of the trigeminal nerve, and the superior cerebellar artery (white arrow) was on the inner side of it. The nerve was located between the artery and the tumor, and was compressed by both.
(D) Type D epidermoid cyst (right side), the tumor was located on the lateral side of the trigeminal nerve and compressed the nerve together with the adjacent superior cerebellar artery.
3.2. Tumor resectability

In most cases, the tumor was completely resected (n = 25/32, 78.1%). Type A tumors had the highest resectability ratio, followed by Type B, Type C, and Type D tumors (9/9, 14/18, 1/4, and 1/1, respectively) (Fig. 2). Five cases of tumors were under-resected (15.6%), including 4 cases of type B tumors and 1 case of type C tumors. Only 2 cases of type C tumors were partially removed because of adhesions to the brain stem and vascular structure. Vascular or microvascular decompression was performed for all type C and D tumors (Table 3).

3.3. Follow-up

During the 5-year follow-up, nearly two-thirds of the patients had excellent results and were scored as BNI I (15 cases) or II (8 cases); all the cases were type A or type B tumors (Table 4). Eight patients were assessed as having improved pain relief and were scored as BNI III (8/32, 25%), including four Type A, three Type B, and one Type D patient. One Type C patient scored as BNI IV still experienced facial pain following PTR resection and microvascular decompression (1/32, 3.1%), and the tumor relapsed 5 years later with additional surgery.

4. Discussion

Epidermoid cysts are slowly growing benign tumors that increase in size by an average of 1 cm per year.1 The slow tumor growth accounts for the asymptomatic course, and the tumor fills the normal subarachnoid spaces without displacement of neurovascular structures over a long period. When the tumor volume is sufficiently large, the surrounding structures can be wrapped or compressed, and neurological symptoms would appear. The peak age of onset of epidermoid cysts causing TN is between 30 and 43 years.1,2,14 The present study found the average age of onset to be 40.4 years, with a mean disease duration of 4.6 years, which is consistent with the literature. Some studies indicate that epidermoid cysts occur more frequently in men than in women, with the male-to-female ratio ranging from 4.6:1 to 1.5:1.14,15 In this study, the male-to-female ratio was 1:4.3 (6:26), possibly because these patients were admitted due to TN and the patients with insidious epidermoid cysts were not included.

TN is the first and main symptom of epidermoid cysts in the CPA. In a cohort of 134 patients who were diagnosed with TN, further neuroimaging revealed that 10% of the patients had CPA tumors and 71% of them had epidermoid cysts.16 Therefore, young patients with TN should be screened by neuroimaging to identify tumors, especially epidermoid cysts. Although the precise mechanism remains to be elucidated, direct compression or wrapping of the epidermoid cyst around the root of the trigeminal nerve, vascular translocation resulting from tumor growth, and chemical stimulants produced by tumors may lead to TN.2,17

3D-FIESTA is a balance-steady-state free precession sequence with high contrast and excellent spatial resolution, and it has been proven advantageous in the display of intracranial nerves. By post-processing the volume data, the fine structure of the CPA can be visualized in detail. On 3D-FIESTA images, epidermoid cysts appear as gray signals and are easily differentiated from the high-brightness CSF and the low-signal nerve and blood vessels.17 TOF MRA imaging is based on the phenomenon of flow-related enhancement. As a result, arteries with fast blood flow present as high signals, while nerves show medium signals and epidermoid cysts show low signals. Thus, the contrast between the tumors and arteries on TOF MRA images is greater than that on 3D-FIESTA images.18 The combination of the two imaging techniques can compensate for the limitations of each individual technique, and maximize their advantages. In this study, we evaluated and classified 32 cases of epidermoid cysts under the guidance of high-resolution MR prior to surgery, allowing for visualization of the tumor, trigeminal nerve, and adjacent small arteries. Type A and B lesions were the most common, while type C lesions had the worst prognosis and greatest recurrence.

It has been reported that the capsule of the epidermoid cyst is the only active part of the tumor, and tumor recurrence is inevitable if it remains. Thus, the ideal surgical treatment is to remove the entire tumor capsule.19,20 However, the tumor has a peculiar growth feature of wide extension in the subarachnoid space and push or wrap adjacent neurovascular structures, making complete removal difficult in some cases.

![Fig. 2. A 37-year-old female patient suffered from right cheek and lip pain for 10 years. (A) 3D-FIESTA and (B) TOF MRA revealed a Type B epidermoid cyst at right cerebellopontine angle region. The right trigeminal nerve (white arrow head) was compressed and displaced by tumor (asterisk), and no vessel was found nearby. (C) The intraoperative video screen shot of neuroendoscopy from same patient. The tumor around the trigeminal nerve (white arrow head) had been partially removed, and the residual pearl-like tumor mass (asterisk) was located inner side of the free trigeminal nerve.]

---

Table 3

<table>
<thead>
<tr>
<th>Tumor classification</th>
<th>Tumor resectability</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GTR</td>
<td>STR</td>
</tr>
<tr>
<td>Type A (n = 9)</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Type B (n = 18)</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Type C (n = 4)</td>
<td>1 + VD</td>
<td>1 + VD</td>
</tr>
<tr>
<td>Type D (n = 1)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total n (%)</td>
<td>25 (78.1)</td>
<td>5 (15.6)</td>
</tr>
</tbody>
</table>

Note: GTR = gross total tumor removal; STR = subtotal tumor removal; PTR = partial tumor removal; VD = vascular decompression.

Table 4

<table>
<thead>
<tr>
<th>Tumor classification</th>
<th>Facial pain relief (BNI score)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Type A</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Type B</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Type C</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Type D</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total n (%)</td>
<td>15 (46.9)</td>
<td>8 (25)</td>
</tr>
</tbody>
</table>

Note: BNI score = Barrow Neurological Institute pain intensity scoring criteria.
Complete tumor resection may cause nerve or vessel damage, resulting in neural dysfunction. In such cases, the purpose of the operation is not to completely remove the tumor, but to protect the peripheral nerves and vascular structures. As a result, when there is adhesion of the tumor to adjacent structures such as the brainstem, peripheral nerves, and blood vessels, subtotal resection is recommended. Postoperative residual tumor should nonetheless be minimized, and the adhering part of the tumor should be microscopically removed as much as possible. Furthermore, according to a study by Alvorad, the recurrence time of epidermoid cysts is approximately equal to the patient's age plus nine months. Therefore, postoperative follow-up is important for evaluation of prognosis. In addition to the facial pain scoring system, MRI, especially high-resolution MRI is suitable for follow-up because of its imaging advantages. However, in clinical practice, only some patients can cooperate with routine or high-resolution MR examinations during follow-up, and this would limit the potential of our findings. Our study was performed with a small sample size, and therefore further studies with larger patient samples are needed to validate and extend the present results.

5. Conclusion

Preoperative high-resolution MRI of CPA epidermoid cysts plays an important role in the formulation of surgical protocols and prognosis. 3D-FIESTA combined with TOF MRA can accurately diagnose the tumor and clearly display the relationship between the tumor and the surrounding nerve and vascular structures. This provides a basis for tumor resectability and is suitable for long-term follow-ups.

Author contributions


Formatting of funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

There are no conflicts of interest to declare.

References


