Short Communication

Anatomical Features of Middle Cerebral Artery Bifurcations and those with Aneurysms

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Abstract

To elucidate the anatomical differences between patients with normal MCA bifurcations and those with bifurcations harboring MCA aneurysms, the analysis of three dimensional MRA or DSA were performed. Sixty two patients without intracranial lesions underwent three-dimensional MRA. The width of M2 branches and lateral angles, were measured. Then the DA ratios (width of larger M2/width of smaller M2) and the LA ratios (lateral angle between M1 and larger M2/lateral angle between M1 and smaller M2) were calculated. The DA and LA ratios were also calculated among 54 cases with aneurysms that were performed three dimensional DSA. Moreover, types of aneurysm were classified among 44 cases (20 were ruptured and 24 were unruptured) using three dimensional DSA. When the neck was located on the extension of the midline of the parent artery, it was defined as C type, and when it was not, it was defined as D type. The DA ratio was 1.5±0.4 in normal MCAs and 1.7±0.7 in MCAs with aneurysms which showed significant difference (p<0.05). The LA ratio was 1.3±0.4 in normal MCAs and 2.1±1.4 in MCAs with aneurysms which also showed significant difference (p<0.01). χ2 test revealed that there were significantly more ruptured cases among C type (14/19) compared with D type (10/25) (p<0.05). Normal cerebral artery bifurcations show close to symmetric structures in the M2 branches and the lateral angles, whereas aneurysmal MCAs do not show these symmetries and among cases with aneurysms C type was dominant in ruptured aneurysms.

ABBREVIATIONS

MCA: Middle Cerebral Artery; DSA: Digital Subtraction Angiography; MRA: Magnetic Resonance Angiography; DA: Daughter Artery; LA: Lateral Angle; ROC: Receiver Operating Characteristic; AP: Aspect

INTRODUCTION

Many intracranial aneurysms occur at arterial bifurcations and hemodynamic stress on these bifurcations is one of the mechanisms of aneurismal formation [1,2]. Evaluation of the three dimensional structures surrounding bifurcations and the aneurisinal neck positions seems to have a possibility to clarify one of the mechanisms of developing aneurysms or causing ruptures of them. We have previously reported some features of the anatomy on the normal middle cerebral artery (MCA) anatomy and analyzed the differences in patients with MCA aneurysms [3].

MATERIALS AND METHODS

Sixty two patients without intracranial lesions underwent three dimensional MRA (Achieva 1.5 Tesla, Philips Medical Systems Nederland B.V.) and the widths of M1 and the superior and inferior M2 branches, as well as their respective lateral angles were measured. The lateral angles in 54 patients with MCA aneurysms are also calculated using three-dimensional digital subtraction angiography (Toshiba Infinix Celeve VC system, Toshiba Inc. Japan). We defined the daughter artery ratio (DA ratio) as width of larger M2/width of smaller M2 and the lateral angle ratio (LA ratio) as lateral angle between M1 and larger M2/lateral angle between M1 and smaller M2. We have also examined 44 MCA aneurysm patients (this study was performed previously and this patients group is a subset of 54 patients mentioned above) which include 20 unruptured
and 24 ruptured cases and the cut-off point of the AP ratio (the maximum distance of dome/width of the neck of an aneurysm) [5] was calculated by the ROC analysis [6]. Moreover, we have classified the aneurismal type due to the neck location among those 44 MCA aneurysm patients. Specifically, when the neck was located on the extension of the midline of the parent artery, it was defined as C type and when it was not, it was defined as D type (Figure 1).

RESULTS AND DISCUSSION

As for the normal bifurcations, the widths of right M1 branch, left M1 branch, right superior branch, left superior branch, right inferior branch and left inferior branch were 2.2±0.3mm, 2.2±0.2mm, 1.4±0.4mm, 1.4±0.4mm, 1.5±0.4mm, 1.5±0.3mm respectively. These values were slightly smaller than that reported previously [7].

These differences might be due to variable imaging conditions or resolutions of the MRA. MRA has the limitation to describe details. Another possible reason might be from the racial differences. The values were not significantly different between right and left sides.

In contrast to the widths of MCA branches, the lateral angle, the DA and LA ratios would be less affected to the imaging conditions of the MRA. Because the lateral angle is calculated by measuring the angle formed by the central axis of the two branches and the DA and LA ratios were the relative values. Thus, these results were compared between MRA group and DSA group. The results of the lateral angles in normal MCA, total aneurysm, unruptured aneurysm and ruptured aneurysm are shown in table 1. These results show that all four lateral angles were statistically wider in the normal MCA than those in the total aneurysm and this may be because aneurysms are space-occupying lesions that dislocate the M2 branches to the lateral side.

The right DA, left DA ratio, right LA ratio and left LA ratio in the normal MCA were 1.5±0.4 and 1.4±0.5, 1.3±0.5, 1.3±0.4 respectively. And all of them were not significantly different between right and left sides. As shown in table 2, the DA ratio was 1.5±0.4 in normal MCAs (this value includes both right and left sides) and 1.7±0.7 in MCAs with aneurysms (Total aneurysm) which showed significant difference (p<0.01). The LA ratio was 1.3±0.4 (this value also includes both right and left sides) in normal MCAs and 2.2±1.4 in MCAs with aneurysms (Total aneurysm); these values were also significantly different (p<0.01). From the results of these values, normal MCA bifurcations show close to symmetric structures on the widths of M2 branches and the lateral angles, whereas aneurismal MCAs do not show symmetries especially for the lateral angles.

Concerning the differences between ruptured and unruptured aneurysms, the DA ratios in ruptured aneurysms and in unruptured aneurysms were 1.4±0.5 and 2.1±0.8 respectively. They showed significant difference (p<0.0001). The cut-off point of the DA ratios between ruptured and unruptured aneurysms by the ROC analysis was 1.7 [3,5]. The cut-off point of the aspect (AP) ratio was 1.8 [5]. In combination of these two ratios, in cases with an AP ratio of 1.8 or greater and a DA ratio less than 1.7, 87% were ruptured cases. On the contrary, in cases with an AP ratio less than 1.8 and a DA ratio of 1.7 or greater, 92% were unruptured cases (Figure 2).

**Table 1:**

<table>
<thead>
<tr>
<th>Lateral angles of the normal MCA and MCA with aneurysm</th>
<th>normal MCA</th>
<th>total AN</th>
<th>LA ratio</th>
<th>p Value</th>
<th>cut point</th>
</tr>
</thead>
<tbody>
<tr>
<td>right superior lateral angle(°)</td>
<td>117.1±22.1</td>
<td>92.3±33.6</td>
<td>1.9±1.3</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>left superior lateral angle(°)</td>
<td>119.7±24.3</td>
<td>93.1±32.5</td>
<td>2.2±1.4</td>
<td>&lt;0.0001</td>
<td>1.6</td>
</tr>
<tr>
<td>right inferior lateral angle(°)</td>
<td>107.2±24.9</td>
<td>93.2±38.3</td>
<td>1.3±0.5</td>
<td>0.0032</td>
<td></td>
</tr>
<tr>
<td>left inferior lateral angle(°)</td>
<td>113.5±25.9</td>
<td>84.2±46.7</td>
<td>1.3±0.4</td>
<td>0.0193</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2:**

<table>
<thead>
<tr>
<th>Daughter artery ratio and lateral angle ratio</th>
<th>normal MCA</th>
<th>total AN</th>
<th>p Value</th>
<th>cut point</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA ratio</td>
<td>1.5±0.4</td>
<td>1.7±0.7</td>
<td>0.0193</td>
<td></td>
</tr>
<tr>
<td>LA ratio</td>
<td>1.3±0.4</td>
<td>2.2±1.4</td>
<td>&lt;0.0001</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**Abbreviations:** MCA: Middle Cerebral Artery; AN: Aneurysm.

**Figure 1.** Left photographs show a 47-year-old man with a ruptured aneurysm. The central axis of the parent artery crosses the line of the neck. This case belongs to C type. Right photographs show a 65-year-old woman with an unruptured aneurysm. The central axis of the parent artery does not cross the line of the neck. This case belongs to D type.
As for the aneurismal type, C type included 14 cases of ruptured aneurysms and 5 cases of unruptured aneurysms. On the contrary, D type included 10 cases of ruptured aneurysms and 15 cases of unruptured aneurysms. Interestingly, there were significantly more ruptured cases among C type compared with D type by \( \chi^2 \) test (\( p<0.05 \)).

When these results are put together, the typical morphological features would be those shown in figure 3. Representative schema of the normal MCA bifurcations shows that the two lateral angles and the widths of the two daughter arteries are close to identical. Those of the bifurcations with unruptured aneurysms show both of the lateral angles and the widths of the daughter arteries are asymmetries. On the hand those of the bifurcations with ruptured aneurysms show that the lateral angles are asymmetry, though the widths of the daughter arteries are close to identical. As for the neck positions, unruptured aneurysms show D type and ruptured aneurysms show C type.

These are the results of retrospective studies and the numbers of the patients are confined and insufficient. In order to clarify the morphological features that would predict which type of bifurcations would develop aneurysms in the future and which type of aneurysms would cause aneurismal rupture, large scale and prospective studies are mandatory.

**CONCLUSION**

Retrospective three-dimensional study on the normal MCA bifurcations, those with unruptured and ruptured aneurysms showed structural differences. However, in order to confirm that these features could be candidates for predictable factors on developing aneurysms or aneurismal rupture, large scale and prospective studies are necessary.

**REFERENCES**
