Effects on Acetabular Development of Resection of the Labrum Acetabulare (Limbus) in the Hip Joint

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Summary: The effect of resecting the hip joint limbus on acetabular development was studied. Ten infant Japanese monkeys were used as experimental subjects. The limbus was resected on one side and the developmental effects were observed. The period of observation ranged from 12 to 31 months with a mean of 17 months. After histological examination of the resected limbus, the monkeys were divided into two groups, group A (5 cases) in which the hyaline cartilage had not been resected, and group B (5 cases) in which the hyaline cartilage had been resected. Every 2 months after the operation, each monkey was x-rayed and the acetabular angle, acetabular index, acetabular edge angle and Wiberg’s Center-Edge angle were measured and the differences between the resected and unoperated sides were subjected to regression analysis. Neither Group A nor Group B developed acetabular dysplasia.

Key words acetabular development, hip joint, Japanese monkey, limbectomy, limbus

INTRODUCTION

The hip joint limbus (Articulatio coxae labrum acetabulare) is a fibrous tissue bordering the limbus acetabulum with a physiological function that is not yet clear. In 1958, Hollinshead [8] suggested after anatomic observation that it may play a role in increasing the acetabular depth and influencing joint stability. In 1982, Takechi [23] measured the pressure both inside and outside of the limbus in a study using amputated human lower limbs, and reported that the limbus served as a valve to maintain a negative pressure, albeit the effect was very slight. Also, in 1988, Shibutani [21] examined the hip joint limbus with a scanning electron microscope and speculated that it may have the physiological function of embracing and holding down the head of the femur.

On the other hand, it is known that in congenital hip joint dislocation the hip joint limbus lies between the acetabulum and the head of the femur, and it can often be a factor hindering repositioning. Somerville [22] claims that if this joint limbus is not resected, deep concentric reduction of the head of the femur will not be acquired. However, Severin [19] has reported that when the head of the femur is kept in the correct position, the limbus will disappear and the head of the femur will attain a deep concentric reduction. Moreover, many previous investigators [7,11,13,14,26,27] have reported that acetabular development was somewhat inhibited in limbus resection cases in comparison with the non-resected groups.

The aim of this study is to clarify whether resection of the hip joint limbus has a direct influence on the development of the acetabulum. Resection of the limbus was performed on one of the hip joints of infant Japanese monkeys, and the other hip joint was left untreated as a control. Measurements were made by simple x-rays. This is an interim progress report.

MATERIALS AND METHODS

Identification of the existence of the limbus (labrum acetabulare)

The existence of the limbus of the hip joints was confirmed macroscopically in three adult Japanese...
monkeys obtained from Kurume University Animal Center.

**Limbus resection**

Ten one-year-old Japanese monkeys (Macaca fuscata) bred at Kurume University Animal Center were used in the present experiments. Body weights were approximately 1000 g (range, 820 g to 1430 g; average, 1056 g) (Table 1).

The animals were deeply anesthetized with an intramuscular injection of Ketalar (ketamine hydrochloride) 20 mg/kg body weight. Limbus resection was performed from the lateral position using a posterior approach. The dorsal portion of the limbus was resected, which is the load bearing portion in the quadruped monkey (Fig. 1). The other hip joint was left untreated as a control.

The resected limbus was decalcified with EDTA, stained with Hematoxylin-Eosin and examined microscopically. After examination, the animals were divided into two groups consisting of five animals each. Group A (animals 1, 2, 3, 4 and 5) were resected without the cartilage component, whereas Group B (animals 6, 7, 8, 9 and 10) were resected with the cartilage component (Table 1, Fig. 2). Every two months after the operation, the hip joints in all animals were x-rayed in the 90 degree spreizung position using a Fuji Film computed radiography system, FCR-300. To easily observe the dorsal side of the acetabulum, x-rays were taken at three different angles-straight on, 30 degrees above and 30 degrees below the standard posterior-anterior view (standard P-A view) (Fig. 3).

The acetabular angle, acetabular index (AI), and

<table>
<thead>
<tr>
<th>Group</th>
<th>Body weight at time of operation (g)</th>
<th>Final Body weight (g)</th>
<th>Length of post-operative observation</th>
<th>Operation side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal. 1 A</td>
<td>1050</td>
<td>2970</td>
<td>30 months</td>
<td>Right</td>
</tr>
<tr>
<td>Animal. 2 A</td>
<td>1130</td>
<td>2560</td>
<td>20 months</td>
<td>Left</td>
</tr>
<tr>
<td>Animal. 3 A</td>
<td>1080</td>
<td>2540</td>
<td>20 months</td>
<td>Right</td>
</tr>
<tr>
<td>Animal. 4 A</td>
<td>850</td>
<td>2260</td>
<td>12 months</td>
<td>Right</td>
</tr>
<tr>
<td>Animal. 5 A</td>
<td>820</td>
<td>2080</td>
<td>12 months</td>
<td>Right</td>
</tr>
<tr>
<td>Animal. 6 B</td>
<td>1430</td>
<td>3150</td>
<td>31 months</td>
<td>Left</td>
</tr>
<tr>
<td>Animal. 7 B</td>
<td>1290</td>
<td>3040</td>
<td>22 months</td>
<td>Right</td>
</tr>
<tr>
<td>Animal. 8 B</td>
<td>1065</td>
<td>2149</td>
<td>12 months</td>
<td>Right</td>
</tr>
<tr>
<td>Animal. 9 B</td>
<td>990</td>
<td>2120</td>
<td>12 months</td>
<td>Left</td>
</tr>
<tr>
<td>Animal.10 B</td>
<td>850</td>
<td>2080</td>
<td>12 months</td>
<td>Left</td>
</tr>
</tbody>
</table>

**Table 1. Body weights of animals**

Fig. 1. Resected portion of the limbus. The dorsal side limbus, which is the load bearing side in a quadruped monkey, was resected.

Fig. 2. Locations of the resected portions of the limbus. Histologically, the limbus consists of collagen fiber and fiber cartilage which is found along the border of the acetabular cartilage. In Group A the limbus resection did not include the hyaline cartilage, whereas in Group B the resection did include the hyaline cartilage.
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Fig. 3. Angles for the x-ray images. In addition to the standard posterior-anterior images, x-rays were taken at 30 degree above and 30 degree below angles to improve the observations of the dorsal side.

Fig. 4. Method of evaluation of the x-ray images.

Fig. 5. A photograph showing the horizontal section of the hip joint of an adult Japanese monkey. The arrow points to the limbus.

 acetabular edge angle (AEA) were measured on the roentgenograms. The Wiberg’s center-edge angle (CE) was also measured from the standard posterior-anterior side x-ray (Fig. 4). Except for the AEA, the measured difference between the control side and the resected side was determined as follows.

\[
\delta \text{ Acetabular angle} = \text{resected side acetabular angle} - \text{control side acetabular angle}
\]

(30 degrees above, standard P-A view, 30 degrees below)

\[
\delta \text{ AI} = \text{control side AI} - \text{resected side AI}
\]

(30 degrees above, standard P-A view, 30 degrees below)

\[
\delta \text{ CE} = \text{control side CE} - \text{resected side CE}
\]

(standard P-A view)

Simple linear regression was performed for Group A and Group B using the above values as dependent variables and number of weeks (W) as the independent variable, and the regression slope was measured. The periods of observation of the animals in both groups varied, so a further analysis was performed using the natural logarithm of the number of weeks (ln W) as the independent variable. The longest period of observation was 31 months and the shortest period was 12 months, with an average of 17 months.

RESULTS

The limbus in the Japanese monkey

The hip joints of three adult Japanese monkeys were examined macroscopically. The limbus was identified as a belt-like structure inside the capsular articularis (Fig. 5).

Relationship between limbus resection and acetabular development

The influence of hip joint limbus resection on acetabular development was explored by examining x-ray images.

Group A: The results for Group A are shown in Table 2. The \(\delta\) acetabular angle in the standard P-A view generally had a significant negative slope. For individual animals in Group A, the \(\delta\) acetabular angle at 30 degrees below had a significant positive slope in animal 1, the \(\delta\) AI in animal 2 had a significant negative slope measured in the standard P-A view, but no consistent trends were found for the group as a whole. One animal in Group A is shown in Fig. 7.
TABLE 2.
Results of the statistical analyses (Group A)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group A (W)</th>
<th>Group A (lnW)</th>
<th>Animal 1</th>
<th>Animal 2</th>
<th>Animal 3</th>
<th>Animal 4</th>
<th>Animal 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>30° above α Acetabular angle</td>
<td>0.000</td>
<td>-0.181</td>
<td>0.015</td>
<td>0.007</td>
<td>-0.008</td>
<td>-0.042</td>
<td>0.033</td>
</tr>
<tr>
<td>Standard P-A α Acetabular angle</td>
<td>-0.034**</td>
<td>-0.868*</td>
<td>-0.016</td>
<td>0.000</td>
<td>-0.005</td>
<td>0.017</td>
<td>-0.05</td>
</tr>
<tr>
<td>30° below α Acetabular angle</td>
<td>0.014</td>
<td>-0.028</td>
<td>0.039*</td>
<td>-0.013</td>
<td>0.040</td>
<td>-0.026</td>
<td>0.042</td>
</tr>
<tr>
<td>30° above Δ Al</td>
<td>0.018</td>
<td>-0.093</td>
<td>-0.110</td>
<td>-0.015</td>
<td>0.308</td>
<td>0.075</td>
<td>0.052</td>
</tr>
<tr>
<td>Standard P-A Δ Al</td>
<td>-0.014</td>
<td>-0.357</td>
<td>-0.005</td>
<td>-0.041*</td>
<td>0.061</td>
<td>-0.071</td>
<td>0.054</td>
</tr>
<tr>
<td>30° below Δ Al</td>
<td>0.052</td>
<td>0.819</td>
<td>0.013</td>
<td>0.067</td>
<td>0.269</td>
<td>-0.054</td>
<td>-0.037</td>
</tr>
<tr>
<td>Δ CE angle</td>
<td>-0.006</td>
<td>-0.032</td>
<td>0.000</td>
<td>0.021</td>
<td>-0.004</td>
<td>-0.037</td>
<td>-0.035</td>
</tr>
</tbody>
</table>

AEA no different no different no different no different no different

*P<0.05  **P<0.01

Fig. 6. Examination of the Δ acetabular angle with the standard P-A view for Group A. These are regression graphs. The plots of Group A animals against the number of weeks and against the natural logarithm of the number of weeks have significant negative slopes. The animal with the longest follow-up observation period, animal 1, had a negative value throughout the study period. None of the other four subjects had a significant slope either against the number of weeks or against the natural logarithm of the number of weeks.
TABLE 3.
Results of the statistical analyses (Group B)

<table>
<thead>
<tr>
<th></th>
<th>GroupB (W)</th>
<th>GroupB (lnW)</th>
<th>Animal.6</th>
<th>Animal.7</th>
<th>Animal.8</th>
<th>Animal.9</th>
<th>Animal.10</th>
</tr>
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<tbody>
<tr>
<td>30° above</td>
<td>0.004</td>
<td>0.187</td>
<td>-0.001</td>
<td>-0.024</td>
<td>-0.009</td>
<td>0.068</td>
<td>0.007</td>
</tr>
<tr>
<td>Acetabular angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30° below</td>
<td>-0.004</td>
<td>-0.195</td>
<td>-0.020*</td>
<td>-0.008</td>
<td>0.099*</td>
<td>-0.001</td>
<td>-0.041</td>
</tr>
<tr>
<td>Acetabular angle</td>
<td>0.045**</td>
<td>1.068*</td>
<td>0.043</td>
<td>0.017</td>
<td>0.006</td>
<td>0.080</td>
<td>-0.021</td>
</tr>
<tr>
<td>30° above</td>
<td>-0.030</td>
<td>-0.317</td>
<td>-0.076</td>
<td>-0.074</td>
<td>0.038</td>
<td>0.093</td>
<td>-0.045</td>
</tr>
<tr>
<td>AI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30° below</td>
<td>-0.017</td>
<td>-0.264</td>
<td>-0.050</td>
<td>-0.044</td>
<td>-0.059</td>
<td>0.077</td>
<td>-0.03</td>
</tr>
<tr>
<td>Standard P-A</td>
<td>0.007</td>
<td>0.208</td>
<td>-0.031*</td>
<td>-0.006</td>
<td>0.095</td>
<td>0.074</td>
<td>0.008</td>
</tr>
<tr>
<td>30° below</td>
<td>-0.009</td>
<td>0.144</td>
<td>-0.014</td>
<td>0.013</td>
<td>0.045</td>
<td>0.293*</td>
<td>-0.044</td>
</tr>
<tr>
<td>CE angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AEA</td>
<td>operative side negative</td>
<td>no different</td>
<td>no different</td>
<td>operative side negative</td>
<td>no different</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P<0.05  **P<0.01

Fig. 7. X-ray images of animal 2 in Group A, 20 months after the operation. The left side was operated on. The 30 degrees above acetabular angle of the operated side was 21.2 degrees, and that of the control side was 21.6 degrees; the AI of the operated side was 41.9 and of the control side was 40.6. With the AEA, there is a negligible difference between the operated and control sides. The standard P-A view acetabular angle of the operated side was 21 degrees and that of the control side was 19.5 degrees. The AI of the operated side was 49 and that of the control side was 45.8. The CE angle of the operated side was 14 degrees and that of the control side was 17 degrees. For the AEA, there was a negligible difference between the operated and control sides. In the image taken from the 30 degrees below position, the acetabular angle of the operated side was 16.9 degrees and that of the control side was 18.1 degrees. The AI of the operated side was 38.4 and that of the control side was 43.6. For the AEA, there was a negligible difference between the operated and control sides.
Fig. 8a. This figure shows the $\delta$ acetabular angle regression graphs for Group B as a whole based on the images obtained in the 30 degree below position. The results show a significant positive slope both when plotted against the number of weeks and against the natural logarithm of the number of weeks.

Group B: Group B animals generally had a significantly positive slope for the $\delta$ acetabular angle at 30 degrees below (Table 3). Four of five animals in Group B had a positive slope for the $\delta$ acetabular angle at 30 degrees below, however none of the slopes were significant (Fig. 8 a,b). The $\delta$ acetabular angle in the standard P-A view for animal 6 had a negative slope, animal 8 had a positive slope in the standard P-A view, and the $\delta$ AI for animal 6 at 30 degrees below had a negative slope; but for the whole group, no obvious trend was apparent (Table 3).
Fig. 9. Radiographs taken 12 months after the operation in animal 9 of Group B. The left side was operated on. All the x-rays show an abnormal formation of the tail side acetabulum and an enlargement of the head of the femur. In the image taken at 30 degrees above, the acetabular angle of the operated side was 21.5 degrees and that of the control side was 21.8 degrees. The AI of the operated side was 36.5 and that of the control side was 42.4. The AEA for both the left side and right side were positive. In the image taken from the standard P-A view, the acetabular angle of the operated side was 25.7 degrees and that of the control side was 24.9 degrees. The AI of the operated side was 41 and that of the control side was 45.6. The CE angle of the operated side was 0 degrees and that of the control side was 20 degrees. The AEA of the left side was negative. The image taken from 30 degrees below shows that the acetabular angle of the operated side was 26.1 degrees and that of the control side was 21.3 degrees. The AI of the operated side was 31.4 and that of the control side was 36.3. The AEA of both the left and the right sides was positive.

Fig. 10. X-rays of animal 7 in group B taken 22 months after the operation. The operated side was on the right. In the image obtained from 30 degrees above, the acetabular angle of the operated side was 17.1 degrees and that of the control side was 19.2 degrees. The AI of the operated side was 46.1 and that of the control side was 44.9. The AEA of both the left side and the right side was positive. The image taken from the standard P-A view shows that the acetabular angle of the operated side was 27.1 degrees and that of the control side was 26 degrees. The AI of the operated side was 48 and that of the control side was 44.9. The CE angle of both sides was 5 degrees. The AEA of both sides was negative. The picture taken from 30 degrees below shows an acetabular angle of 21.4 degrees on the operated side and 19.1 degrees on the control side. The AI of the operated side was 45.2 and that of the control side was 41.4. The AEA of both the left and right sides was negative.
For the CE findings, only animal 9 had a significant positive slope.

This x-ray is shown in Fig. 9. Dysplasia of the acetabulum is apparent in the lower region of the posterior side. The head of the femur is enlarged and acetabular expansion was recognized. No other subjects in either group had a similar change. An animal from Group B is shown in Fig. 10.

AEA: The x-ray of animal 6 in Group B taken from the 30 degree lower position on the resected side had a negative AEA, but this recently became positive. In animal 9 which already had a formation abnormality two months after the operation, the AEA was negative in an x-ray taken from the lower position, and 10 months later the AEA was negative in the frontal standard P-A view as well.

No other monkeys in either Group A or Group B displayed any difference between the right and left sides (Tables 2 and 3).

DISCUSSION

It is well known that the hip joint limbus in congenital hip joint dislocation is an obstruction between the acetabulum and the head of the femur, and often acts as a factor that inhibits proper repositioning. To deal with this problem Severin [19] and Carloiz and Georges [4] developed the Docking Theory [5] based on several cases in which stabilization of the head of the femur in the correct taxis position resulted in the gradual thinning of the varus hypertrophic limbus which became valgus.

On the other hand, Somerville [22] claimed that the Docking Theory did not apply in all cases and reported that even if thinning of the limbus occurred, the thinned limbus could still adhere to the bottom of acetabulum resulting in a permanent disorder of the joint. He therefore insisted that the inverted acetabular limbus must be completely removed.

Iwasaki et al. [11] reported that even after limbus resection and deep concentric reduction was completed, the development of the acetabulum was not improved in many cases, and therefore the resection itself might be the cause. Hatanaka et al. [7], Matsuo [13], and Yamamuro [26] obtained similar results. However, Inomata [10] reported that limbus resection tended to improve acetabulum development; and Umegaki [25] and Terashima [24] reported that even when acetabulum development was good, many cases developed a deformation of the head of the femur.

Many reports discuss a variety of possible influences of the limbus on acetabulum development, but none of these studies were based on actual limbus resection followed by observations on the development of the acetabulum. Furthermore, the reports mentioned above were based on studies in which the method of operation, preservation method, age of subjects during treatment and degree of dislocation differed so widely that it has been impossible to determine the influence of the limbus on acetabulum development.

Azuma [1] analyzed the reports of animal experiments in which the existence of the limbus was implicitly assumed but not demonstrated. To clarify this matter the hip joints of all the commonly used experimental animals were checked and only the primates had a limbus similar to that in humans. Thus the hip joints of infant Japanese monkeys were used as the experimental model in the present study. The limbus was resected and acetabulum development was observed. The monkey observed for the longest time in this study has reached four years of age and the average age of all the monkeys has reached two and a half years. Japanese monkeys reach maturity at four years of age, therefore the four year-old monkey has reached an age equivalent to that of a 10 year-old human. This is a good time to prepare an interim progress report.

In results achieved thus far, the \( \delta \) acetabular angles in the standard P-A view of Group A had a significant increase in negative slope. This indicates that the acetabular angle on the resected side has a better value than on the untreated side, but also presents the possibility of over-development due to the operation itself. For the individual subjects in Group A, the \( \delta \) acetabular angles in the subject observed for the longest time, animal 1, had negative values throughout the experimental period, whereas none of the other four animals had a significant slope (Fig. 6). Evaluation of the other individual animals also did not yield any significantly negative slopes. The negative value of animal 1 appears to be an anomaly.

A few other measured values had a significant negative slope, but there is no consistent overall tendency. These results indicate that there is no clear developmental disorder in the acetabulum after limbus resection. An acetabular dysplasia occurred only in animal 9 of Group B. No other case showed any abnormality.

Acetabulum development involves an increase in size and depth of the acetabular cartilage, which is a complex consisting of a triradiate stem part (Y car-
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tilage) and a cup shaped part (cartilage part of joint), that progresses by stimulation from the spherical femoral head. In the process of ossification of the acetabular cartilage complex, secondary centers of ossification appear in the ilium, pubis and ischium. However, these various centers are called by many different names. Schmidt [18] designated the ossification center inside the Y cartilage as os acetabuli and that in the joint cartilage as acetabular epiphysis. Brailsford [3] describes the os acetabuli as that region at the highest and most lateral border of the superior lip of the acetabulum. Posenti [17] defined the os acetabuli as the center in the joint cartilage of the pubis, acetabular epiphysis as the center in the joint cartilage of the ilium, and the small epiphysis as the secondary ossification center in the joint cartilage of the ischium.

O’Hara [15,16] described 31 cases of limbus resection in congenital hip joint dislocation, and noted a deficit in the front outer region of the acetabulum in all cases. According to his observations, the secondary center of ossification in the joint cartilage of the ilium (which he refers to as the lateral acetabular epiphysis, and Brailsford refers to as the os acetabuli) appears in humans near the age of ten and contributes to the concentration of the hip joint. He assumed that the observed deficit in the front outer part of the acetabulum was due to the resection of the epiphysis and limbus in infancy before it had a chance to develop, and he therefore opposes any resection of the limbus. Hosomi [9] reported that the concentration of the hip joint was somewhat worse histologically in cases with hyaline cartilage resection than in those in which the resection did not include the hyaline cartilage.

In the present experiments, the resection in Group B included the hyaline cartilage. In this group a tendency towards an increase of the acetabular angle as measured from the 30 degree lower position was noted, and this finding indicates that a clear increase of the acetabular angle may eventually appear. But no CE angle abnormality was noted except in animal 9 which had a developmental abnormality from the dorsal side. If O’Hara [16] is correct, the resection in animal 9 may have been deeper than in the other animals resulting in damage to the secondary center of ossification associated with the ischium, which Posenti refers to as the small epiphysis. However, according to O’Hara the secondary centers of ossification in the acetabular cartilage complex begin to appear around puberty in humans, which is near an age of 8 to 10 years, and that any changes in congenital hip joint dislocation patients undergoing limbus resection should appear in the x-rays at this time. It is therefore possible that such changes have not yet had sufficient time to become apparent in our monkeys.

These results show, however, that after an average follow-up period of 17 months, limbus resection had no effect on acetabulum formation.

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