Factors influencing progressive collapse of the transposed necrotic lesion after transtrochanteric anterior rotational osteotomy for osteonecrosis of the femoral head


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Abstract

Background: Transtrochanteric anterior rotational osteotomy (ARO) for osteonecrosis of the femoral head (ONFH) can preserve for a long-time collapsed femoral head. Progressive collapse of anteriorly-transposed necrotic lesion leads to secondary arthritic changes and clinical failure. Critical factors influencing collapse of the transposed necrotic lesion after ARO remain largely unknown. Therefore, we performed a retrospective study of ARO to determine: (1) if preoperative collapse influences collapse of the transposed necrotic area, (2) if any other factor may influence collapse of the transposed necrotic area.

Hypothesis: We hypothesized the degree of preoperative femoral head collapse influences progressive collapse of the transposed necrotic lesion after ARO.

Materials and methods: We reviewed 47 hips in 42 patients with ONFH treated with ARO between 2000 and 2005 with a mean follow-up of 11.4 years (10–14 years). The occurrence of progressive collapse of the transposed necrotic lesion after ARO was examined using lateral radiographs taken at least once every year after ARO. The following factors were statistically analyzed: age, sex, body mass index, Harris Hip Score (HHS), preoperative level of collapse, extent of the necrotic lesion and postoperative intact ratio (ratio of the transposed intact articular surface of the femoral head).

Results: Progressive collapse of the transposed necrotic lesion (progressive collapse group) was seen in 17 hips (36.2%) during a mean period of 1.8 years (0.5–3.7 years) after ARO, which has developed within 4 years in all cases. Preoperative level of collapse in the progressive collapse group (4.4 ± 1.4 mm) was significantly larger than that in the non-progressive collapse group (2.1 ± 1.0 mm), which was independently associated with progressive collapse of the transposed necrotic lesion in multivariate analysis (P < 0.0001) with cut off point of 2.98 mm. In univariate analysis, lower preoperative HHS, severe extent of the necrotic lesion and the lower postoperative intact ratio were also associated with progressive collapse of the transposed necrotic lesion, but were not associated as independent factors in multivariate analysis.

Discussion: The current study suggests that progressive collapse of the transposed necrotic lesion after ARO depends mainly on the preoperative level of collapse (cut-off point = 2.98 mm).

Level of evidence: IV; retrospective case series.

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1. Introduction

Transtrochanteric anterior rotational osteotomy (ARO), developed by Sugioka in 1972, is a joint-preserving procedure for osteonecrosis of the femoral head (ONFH) [1]. In patients with collapsed anterior necrotic lesions of the femoral head, anterior rotation of the femoral head enables relocation of the weight-bearing region of the hip joint to the intact posterior aspect of the femoral head [1]. Several studies have demonstrated that ARO can preserve for a long-time collapsed femoral head [2,3]. The ratio of the transposed intact articular surface of the femoral head (postoperative intact ratio) is thought to be associated with progressive collapse after ARO [4].

Even with an adequate postoperative intact ratio, some ARO cases show progressive collapse of the transposed necrotic lesion on lateral radiographs, which leads to secondary arthritic changes with hip pain. Hisatome et al. [5] reported that 8/19 (42.1%) patients with a percentage extent of necrotic area greater than 50%
developed progressive collapse of the transposed necrotic lesion with a mean follow-up of 6.4 years (3.4–12.4 years) after ARO. Therefore, certain critical factors other than the postoperative intact ratio may also be related to progressive collapse of the transposed necrotic lesion after ARO, but their influence is not well known.

Therefore, we performed a retrospective study of ARO to determine:

- if preoperative collapse influences collapse of the transposed necrotic area;
- if any other factor may influence collapse of the transposed necrotic area.

We hypothesized preoperative level of collapse influences progressive collapse of the transposed necrotic lesion after ARO.

2. Patients and methods

2.1. Patients

The present retrospective study was approved by our institutional review board. ARO was performed on 71 hips in 65 patients with an Association of Research Circulation Osseous (ARCO) classification of stages 3 (n = 67) or 4 (n = 4) for the treatment of ONFH between January 2000 and December 2005 at our institution [6]. Four hips already showed preoperative osteoarthritic changes, and 20 hips in 19 patients were lost to follow-up within 10 years. These 24 hips in 23 patients were excluded from the study. Therefore, we reviewed 47 hips in 42 patients who underwent ARO for the treatment of ONFH, with a mean follow-up of 11.4 years (10–14 years) (follow-up rate, 70.1%). Patients included 31 men (35 hips) and 11 women (12 hips) with a mean age of 40 years (20–61 years) at the time of surgery, and a mean body mass index (BMI) of 23.0 kg/m² (15.6–32.8 kg/m²). The etiology of osteonecrosis was associated with corticosteroid usage in 29 hips, alcohol abuse in 16 hips, and post-traumatic in two hips.

2.2. Methods

During the study period, all surgeries were performed by five orthopaedic surgeons with sufficient experience in various types of osteotomies, including ARO, using the original method described by Sugiioka [1]. ARO was generally indicated for ONFH patients with femoral head collapse (ARCO Stage 3) for whom one-third or more of the intact area in the posterior region of the femoral head was obtained on a lateral radiograph. The surgical procedure of ARO involved: osteotomy of the greater trochanter; intertrochanteric osteotomy; and osteotomy that passed from the proximal flare of the lesser trochanter inferolaterally to obtain an intact ratio of more than 34% after ARO. The degree of anterior rotation ranged from 70–90°. During these osteotomies, care was taken to preserve the medial femoral circumflex artery located in the adipose tissue just inferior to the quadratus femoris.

2.3. Method of assessment

Clinical assessments were performed based on the Harris Hip Score (HHS) obtained preoperatively and at the final follow-up [7]. For patients who underwent conversion to total hip arthroplasty (THA), the final follow-up was defined as the preoperative assessment for conversion to THA.

The diagnosis of ONFH in all patients was based on the diagnostic criteria, including the findings on plain radiographs and magnetic resonance (MR) imaging [8]. Radiological influencing factors included preoperative level of collapse, extent of the necrotic lesion, and postoperative intact ratio. The preoperative level of collapse was evaluated by the longer depth on both anteroposterior and lateral radiographs using the method described by Yoon et al. [9] (Fig. 1). The extent of the necrotic lesion was evaluated by the necrotic angle on mid-slice of coronal and axial views on T1-weighted imaging using the modified Kerboul method [10] (Fig. 2a and b). The postoperative intact ratio is expressed as the ratio of the transposed intact articular surface of the femoral head on anteroposterior radiographs using the method previously reported [4] (Fig. 2c). Reproducibility of all the measurements was evaluated by respective intraclass correlation coefficients.

Progressive collapse of the transposed necrotic lesion was defined as ≥ 2 mm progression on lateral radiographs taken at least once every year after ARO using the same method as for the measurement of the preoperative level of collapse. The progression of joint space narrowing was also defined as ≥ 1 mm progression on both anteroposterior (AP) and lateral radiographs using the method described by Zhao et al. [4].

All radiological evaluations were performed using the Image J software program (National Institutes of Health, Bethesda, MD, USA), which can measure length on radiographs in 0.1 mm units. Radiographs were taken using the same technique throughout this study period, with standardized beam positions and radiographic penetration [4].

2.4. Statistical analysis

The 47 cases were divided into two groups: those with progressive collapse of the transposed necrotic lesion (progressive collapse group) and those without (non-progressive collapse group). Two observers (Y.K., K.S.) measured all radiological parameters independently and blinded twice at monthly intervals. The intra- and inter-observer reliabilities were assessed using the intraclass correlation coefficients.

Age, BMI, both pre- and postoperative HHS, and the radiological factors (preoperative level of collapse, extent of the necrotic lesion, and postoperative intact ratio) were compared between the two groups using t-statistics, which had no missing values. Sex, etiology of ONFH, the rate of conversion to THA, and the rate of postoperative complications after ARO were compared between the two groups using the Chi² test or Fisher’s exact test. Statistical significance was considered to exist at P < 0.05. A multivariate analysis was performed using a logistic regression model for the variables with P < 0.05, including preoperative HHS, preoperative level of collapse, extent of the necrotic lesion and postoperative intact ratio. To evaluate the cut-off point for the preoperative level of collapse predicting progressive collapse of the transposed necrotic lesion after ARO, a receiver-operating characteristic (ROC) curve was used. Kaplan–Meier survival curves including lost to follow-up were also produced, with occurrence of progressive collapse of the transposed necrotic lesion after ARO as the end-point (95% confidence intervals are reported). All statistical analyses were performed using the JMP Pro 11 software package (SAS Institute, Cary, NC, USA).

3. Results

The intra-observer reliabilities of the measurements (preoperative level of collapse, extent of the necrotic lesion, and postoperative intact ratio) were almost perfect (0.936, 0.896, and 0.943, respectively), and the inter-observer reliabilities of these measurements were substantial (0.906, 0.871, and 0.793, respectively), indicating good reproducibility.

The mean preoperative HHS in all 47 cases was 57.7 ± 11.7 (29–75), which significantly improved to 81.7 ± 17.0 (37–100) at
On both anteroposterior (a) and lateral (b) radiographs, the maximum depth of collapse was defined as AB (a) and A′B′ (b) on the line passing through the center of the femoral head (O) using concentric circles. The preoperative level of collapse was taken as the greater of the two measurements (AB or A′B′).

The necrotic angle was measured on mid-slice of coronal (a) and axial (b) views on T1-weighted imaging. The extent of the necrotic portion was determined using the two-dimensional sum of angles \( \text{angle}(A + B) \); c: postoperative intact ratio measured on anteroposterior radiographs taken 1 month after the surgery. Point B was determined by drawing a perpendicular line from the midpoint of A (the edge of acetabulum) and E (the lowest point of teardrop) to the acetabular roof. Point C represents the lateral edge of the load-bearing portion, and point D represents the medial edge of the intact articular surface. The length between A and B represents the load-bearing portion of the acetabulum (A–B), and the length between C and D represents the intact area of the femoral head contacting the load-bearing portion of the acetabulum (C–D). The postoperative intact ratio is expressed as the ratio of (C–D)/(A–B).

The radiological evaluation of transposed necrotic lesions assigned 17 hips (36%) to the progressive collapse group and 30 hips (64%) to the non-progressive collapse group (Fig. 3). Progressive collapse of the transposed necrotic lesion was seen within 4 years during a mean follow-up of 1.8 years (0.5–3.7 years) after ARO (Fig. 4). The 10-year survival of ARO (including the 20 hips in 19 patients lost to follow-up) was 64.8% (95% CI: 51–75). The data from the two groups are summarized...
in Table 1. In univariate analysis, preoperative HHS, extent of the necrotic lesion and postoperative intact ratio and preoperative level of collapse were associated with progressive collapse of the transposed necrotic lesion (Table 1). Multivariate analysis revealed that only preoperative level of collapse was independently associated with progressive collapse of the transposed necrotic lesion after ARO (Table 2). ROC analysis showed that the cut-off point was 2.98 mm (sensitivity = 82%, specificity = 93%) (Fig. 5).

Regarding postoperative complications after ARO, there was one case of delayed bone union in each group and two cases of superficial infection in the non-progressive collapse group. The rate of complications in the progressive collapse group (5.9%) was not significantly different from that in the non-progressive collapse group (10.0%, P = 0.85) (Table 3).

Progression of joint space narrowing was observed in 8/47 (17%) hips at the final follow-up, and of these eight hips, seven hips (88%) were in patients in the progressive collapse group. Five patients in the progressive collapse group and one patient in the non-progressive collapse group underwent conversion to THA at a mean of 9.1 years (5.9–12.2 years) after the initial ARO surgery. The rate of conversion to THA in the progressive collapse group (29.4%) was significantly higher than that in the non-progressive collapse group.
which necrotic important Langlais 4. acetabular operative failure Preoperative Extent Complication Postoperative Preoperative

<table>
<thead>
<tr>
<th></th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative level of collapse (mm)</td>
<td>5.94</td>
<td>2.28–31.2</td>
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<tr>
<td>Postoperative intact ratio (%)</td>
<td>0.91</td>
<td>0.77–1.01</td>
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<td>Extent of necrotic lesion (%)</td>
<td>1.02</td>
<td>0.99–1.05</td>
<td>0.16</td>
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<tr>
<td>Preoperative HHS</td>
<td>0.96</td>
<td>0.87–1.06</td>
<td>0.45</td>
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CI: confidence interval; HHS: Harris Hip Score [7]. *P*-values less than 0.05 indicate significant difference.

![ROC curve](image)

**Fig. 5.** ROC curve demonstrating that a preoperative level of collapse of 2.98 mm, which maximizes sensitivity (true positives) while minimizing 1-specificity (false positives), was the threshold value for progressive collapse of the transposed necrotic lesion after ARO.

**Table 3**

<table>
<thead>
<tr>
<th>Complication (%)</th>
<th>Progressive collapse group (n=17)</th>
<th>Non-progressive collapse group (n=30)</th>
<th>P-values</th>
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</thead>
<tbody>
<tr>
<td>Delayed bone union</td>
<td>1 (5.9)</td>
<td>3 (10)</td>
<td>0.85</td>
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(3.3%, *P*<0.05) (Table 1). No patient had any complications after conversion to THA.

4. Discussion

In the current study, multivariate analysis showed that preoperative level of collapse was independently associated with progressive collapse of the transposed necrotic lesion after ARO. Langlais and Fourastier [11] reported that progressive collapse of the transposed necrotic lesion can develop in contact with the acetabular major weight-bearing zone, leading to joint incongruity in hip flexion. Considering that these mechanisms cause clinical failure after ARO, the preoperative level of collapse is an extremely important factor affecting clinical outcomes after ARO. ONFH has been generally reported to follow a progressive course of femoral head collapse [12]. Therefore, we consider that ARO should be performed as soon as possible after the occurrence of femoral head collapse to prevent progressive collapse of the transposed necrotic lesion.

This study has several limitations. First, we evaluated the preoperative level of collapse on plain radiographs, which is considered to be less uniform compared with computed tomography (CT). However, we chose to evaluate progressive collapse of the transposed necrotic lesion on sequential lateral radiographs during follow-up, and the intraclass correlation coefficient showed that sufficient reproducibility was acquired. Second, we limited the subjects of the current study to cases followed for more than 10 years after ARO in order to assess the presence or absence of progressive collapse of the transposed necrotic lesion after ARO, resulting in the loss of 19 cases (20 hips) followed for less than 10 years. Nevertheless, we believe that the current study provides information on the accurate timing of progressive collapse of the transposed necrotic lesion after ARO.

Hisatome et al. [5] reported that 8/19 (42.1%) patients with a percentage extent of necrotic area greater than 50% developed progressive collapse of the transposed necrotic lesion. Similarly, the current univariate analysis results showed that progressive collapse of the transposed necrotic lesion was associated with the extent of the necrotic lesion, as well as preoperative level of collapse. Therefore, in patients with a large necrotic lesion, careful attention should be paid to progressive collapse of the transposed necrotic lesion after ARO, even if there is less than 3 mm of preoperative collapse. On the other hand, multivariate analyses indicated that preoperative level of collapse (cut-off point = 2.98 mm) was the only prognostic indicator of progressive collapse of the transposed necrotic lesion. Therefore, THA may need to be considered for ONFH patients with >3 mm of preoperative collapse, even if the patients meet the indication for ARO with regard to preoperative intact area. However, joint-preserving surgeries also seems to be a viable surgical treatment option to delay osteoarthritic changes in young patients with >3 mm of preoperative collapse [13–15]; when these patients choose to have ARO after both THA and ARO have been explained to them, the surgeons should inform them in advance of the risk of developing collapse of transposed necrotic lesion after ARO.

5. Conclusions

The current study suggests that progressive collapse of the transposed necrotic lesion after ARO is mainly dependent on preoperative level of collapse, and occurs in those with preoperative collapse of >2.98 mm.

**Ethical review committee statement**

The present retrospective study was approved by our institutional review board.

**Disclosure of interest**

None of the authors declare conflict related to the current study. Y. Nakashima outside the current study declares grants from Kyocera and lectures supported by Kyocera Zimmer and Depuy. G. Motomura declares grants from a Research Grant for Intractable Diseases from Japan Agency for Medical Research and Development (AMED) and a grant-in-Scientific Research from the Japan Society for the Promotion of Science during the conduct of the study.
The other authors declare that they have no competing interest.

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