Simulation by stereographic processing of computed tomography for transtrochanteric rotation osteotomy in necrosis of the femoral head

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Summary. *The transtrochanteric rotation osteotomy described by Sugioka will preserve the femoral head in patients with avascular necrosis of the femoral head, but there is controversy about the clinical results. We developed a simulation system for rotation osteotomy, based on stereographic processing through computed tomography, the object being to determine the indication for this procedure and the degree of rotation required. This method makes it possible to determine the degree of rotation needed to displace the necrotic areas from the weightbearing zone; the need for a varus osteotomy can also be assessed. Our clinical results improved when we used this method. CT stereographic drawings in patients with avascular necrosis of the femoral head are useful for assessing the necrotic area.*

Résumé. *L'ostéotomie rotatoire transtrochantérienne décrite par Sugioka doit préserver la tête fémorale dans le cas de patients ayant une nécrose avasculaire, mais il y a une controverse en ce qui concerne les résultats cliniques. Nous avons mis au point un système de simulation pour une ostéotomie rotatoire, basé sur un traitement stéréographique par l'intermédiaire d'une tomodensitométrie, l'objectif étant de déterminer les indices de cette procédure et le degré de la rotation. Cette méthode rend faisable l'établissement du degré de rotation nécessaire pour supprimer les lésions nécrotiques de la zone portante et la nécessité*

d'une ostéotomie de varisation peut aussi être estimée. Cette méthode, que nous avons utilisée, a permis d'améliorer les résultats cliniques. Nous pouvons en conclure que des schémas stéréographiques de tomodensitométrie pour des patients souffrant d'une nécrose avasculaire de la tête du fémur est pratique pour déterminer la zone nécrotique.

Introduction

Sugioka designed a rotation osteotomy for avascular necrosis of the femoral head in 1978 [8]. This prevents collapse of subchondral bone and the development of osteoarthritis when the necrotic area of femoral head is limited anteriorly or posteriorly. The osteotomy is performed at the transtrochanteric level, and either anterior or posterior rotation of the femoral head moves the affected area from the weightbearing part of the joint, thus bringing the unaffected joint surface into position for weightbearing. In theory, the unaffected surface has normal cartilage and subchondral bone, and is able to prevent collapse of the femoral head [9, 10]. In contrast, total hip replacement is indicated when there is extensive necrosis [2].

Since 1978, we have used Sugioka's procedure for treatment of such patients. In our early series, we determined the indication for the procedure with preoperative radiographs and the degree of rotation needed was assessed at operation, based on Sugioka's description [8], but our results were less than satisfactory. Collapse of the femoral head occurred in some patients and femoral head replacements had to be done.

Table 1. Data and results for 15 patients treated by transtrochanteric rotational osteotomy for avascular necrosis of the hips

Case no.	Age/sex	Plan ^a	Cause	Bilat disease ^b	Follow-up (months)	Grade ^c	Rotation		Collapse			Results		
							Anterior ^d	Varus ^d	Postop.	3 years later	Pain	ROM ^e	Limp	Overall
1	44/M	No	Idiopathic	–	5 ^f	2	35		Yes	Yes	Severe	Poor	Severe	Poor
2	48/M	No	Idiopathic	+	172	2	50		No	Yes	None	Poor	Severe	Poor
3	38/F	No	Trauma	–	38 ^f	2	60		Yes	Yes	Severe	Poor	Severe	Poor
4	37/M	No	Alcohol	–	141	2	50	10	No	No	None	Good	None	Good
5	53/F	No	Steroid	+	148	2	60		No	No	Mild	Good	Mild	Good
6	37/F	No	Steroid	+	144	1	50		No	No	Mild	Excellent	Mild	Good
7	31/M	No	Alcohol	+	102	1	60		No	Yes	Severe	Poor	Severe	Poor
8	30/F	Yes	Steroid	+	95	2	–60 ^g		No	No	Mild	Poor	Moderate	Good
9	33/M	Yes	Idiopathic	–	84	1	60		No	No	Mild	Good	Mild	Good
10	20/M	Yes	Trauma	–	78	2	60		No	No	None	Good	Mild	Good
11	37/F	Yes	Steroid	+	52	2	50		No	No	None	Good	Mild	Good
12	32/M	Yes	Steroid	+	50	1	62	13	No	No	None	Excellent	Mild	Good
13	46/M	Yes	Steroid	+	48	2	70		No	No	None	Excellent	Mild	Good
14	29/M	Yes	Alcohol	–	44	2	69	14	No	No	Mild	Excellent	Mild	Good
15	40/F	Yes	Steroid	+	40	2	63		No	No	Mild	Excellent	None	Good

^a Plan, preoperative planning of rotational osteotomy by stereographic processing through computed tomography

^b Bilat disease, bilateral hip disease

^c The hips were graded graphically as follows: grade 1 – necrosis just visible, femoral head still round; grade 2 – flattening of the femoral head (slight collapse); grade 3 – femoral head markedly

collapsed without narrowing of the joint space; grade 4 – advanced changes of the femoral head with narrowing of the joint space

^d Angle of anterior rotation and varus osteotomy

^e Range of motion

^f Revised to bipolar hip replacement at stated follow-up time

^g Posterior rotation

A better long-term appraisal of the osteotomy was needed. A preoperative simulation system of rotation osteotomy, using stereographic processing through computed tomography (CT), was set up to determine the indications for the procedure, and the degree of rotation required [11].

We describe in this paper our simulation system and the clinical outcome of rotation osteotomy for patients with avascular necrosis of the femoral head, before and after the introduction of the method.

Patients and methods

Preoperative planning

The contours of the normal and necrotic areas of the femoral head are traced on the CT scan (Somatom DR3, Siemens, 125 kv, 350 mA) using a transmission digitiser (WT-500LP, Wacom). The area of the necrosis seen on the CT film is defined by the sclerotic line and images of each slice are then transferred to a personal computer, using a graphic board (PC-9801 RA, NEC). We developed the program with BASIC to process the stereographic view and to simulate the rotation osteotomy [11]. For example, in case 9 (Table 1), the necrosis was located at the superolateral area of the femoral head. To simulate a rotation osteotomy, the CT stereographic drawing was rotated around the cervical axis and views from the

proximal side were obtained (Fig. 1). Drawings showing the effect of a varus osteotomy were made in a similar way. We then measured the area of the total femoral head (FH) and of the necrosis (N), using a digitiser and the ratio was calculated. In this case, the total area of the femoral head (FH) and area of necrosis (N) was 19.75 cm² and 7.2 cm², respectively. The relative necrotic area (N/FH) is 36.5%. This ratio decreased to 20% after 60° rotation, but was little changed when the degree of rotation was increased. The effect of varus was negligible (Fig. 2). A 60° anterior rotation osteotomy was carried out in this patient (Fig. 3).

Patients

Between 1979 and 1995, 16 Japanese patients (16 hips) underwent transtrochanteric osteotomy for avascular necrosis of the femoral head. One hip was excluded as the follow-up was too short. Thus, data on 15 hips (15 patients) was obtained. There were 9 men and 6 women with ages ranging from 20 years to 53 years (median 37 years). The cause was trauma in 2; there was a history of alcohol abuse in 3, steroid administration in 7, and no identifiable cause in 3 patients. Of the 13 with nontraumatic osteonecrosis, 9 had bilateral disease, 2 were treated with a bipolar hip replacement (cases 5 and 7).

The hips were graded radiographically as follows: grade 1 – necrosis just visible, and the femoral head still round; grade 2 – flattening of the femoral head (slight collapse); grade 3 – femoral head markedly collapsed without narrowing of the joint space; grade 4 – advanced changes in the femoral head with narrowing of the joint space [8].

Fig. 1. Case 9. A man, 32 years of age, with avascular necrosis of the femoral head. The contours of the normal and necrotic areas (*dotted*) are traced on the CT scan using a transmission digitiser. Simulation by changing the angle of rotation in 10° increments is shown

Fig. 2. Case 9. Change in the relative necrotic area (N/FH) due to the rotation and varus osteotomy. *Closed circles*, no varus osteotomy, *open circles*, varus osteotomy

Follow-up was an average of 82 months (5 months to 172 months). In patients who did not require arthroplasty, the average was 92 months. The grading of clinical results was based on pain, limp (none, mild, moderate, severe), and range of motion (excellent, good, poor).

Results

The clinical results are shown in Table 1. Before the present series was undertaken, the angle of rotation was decided at operation (cases 1 to 7). The average estimate of this angle at operation in this group was 52° (range 35°–60°). After the simulation system was started, the mean rotation angle was 62° (range 50°–70°), excluding posterior rotation (Case 8). Varus osteotomy was added in three hips (Case 4, 12 and 14), in two (Fig. 4) as a result of the preoperative planning (Fig. 5). Analysis of the postoperative anteroposterior radiographs revealed the necrotic segment in the weightbearing region in two hips (Cases 1 and 3) indicating incomplete rotation. These cases deteriorated further with collapse and/or secondary arthritic changes (Fig. 6). Incomplete rotation in case 1 was shown retrospectively with this simulation system (Fig. 7). These two hips required bipolar hip replacement with acetabular reaming because of continued pain, or progress of symptoms. One other patient had a poor clinical and radiographic result and is awaiting total hip replacement (Case 7). The other patients have been followed from 40 to 172 months.

Fig. 3 a, b. Case 9. **a** Radiograph of the left hip before operation. **b** 6 months after

Fig. 4 a, b. Case 12. A man, 33 years of age, with necrosis of the femoral head. Radiographs **(a)** before operation, and **(b)** 6 months after

Before we began to use the simulation system, we had only 4 hips with good clinical results, including relief of pain, functional hip motion and limping.

Since we set up our new simulation procedure, progressive collapse of the head has never occurred (cases 8–15). The angle of rotation could be clearly determined by the simulation, and the excellent results are attributed this.

Discussion

The treatment of femoral head osteonecrosis by a biological means rather than by replacement is desirable. Although Sugioka's transtrochanteric rotation osteotomy preserves the femoral head in patients with avascular necrosis, the clinical results are controversial [3, 4, 5, 6, 12]. This technique is not indicated when there is extensive necrosis, so it is important to be able to estimate the extent before operation. Sugioka and others used the frog lateral

Fig. 5. Case 12. Change in the relative necrotic area (N/FH) due to rotation and varus osteotomy. Closed circles, no varus osteotomy; open circles, 15° of varus osteotomy

radiographs of the femoral head to determine the indication for his technique. Stereographic quantification of the area with plain radiographs is, however, extremely difficult and only views of the femoral head rotated by 90° can be obtained.

Sugioka and others also decided the angle of rotation at operation and did not give descriptions of preoperative stereographic planning. It is not possible to determine at operation whether the area of osteonecrosis is moved enough to bring unaffected joint surface into position for weight-bearing; consequently, precise preoperative planning is needed.

The femoral head can be rotated anteriorly between 60° and 100° into a position so that the new weightbearing portion is well apposed. Our simulation indicates that more than 60° of rotation does

Fig. 7. Case 1. Stereographic drawing and simulation by changing the angle of anterior rotation (0°, 45°, 60°, 75°). The dotted area is the area of necrosis

not increase the new weightbearing area (Figs. 3, 5). Dean and Cabanela found that excessive rotation of the femoral head at operation will stretch the quadratus femoris and the posterior branch of the medial circumflex artery which lies within the muscle [1]. The minimum required angle of rotation can be obtained by our method.

This operative technique is indicated for patients with a relative necrotic area (N/FH) of <20% as estimated in the simulated rotation os-

Fig. 6a-c. Case 1. A man, 44 years of age, with idiopathic necrosis of the femoral head. He was the first patient to be treated by rotation osteotomy at Kinki University Hospital. Radiographs (a) show that, although a well apposed weightbearing portion seemed to be created with 35° of anterior rotation at operation, (b) collapse of the femoral head occurred 5 months later, and (c) a bipolar replacement was done

teotomy. Recent observations using magnetic resonance imaging (MRI) show that the femoral head will collapse progressively when the necrosis involves one-fourth (25%) of the diameter or more [7]. We have used our preoperative planning system since 1983 to treat cases of avascular necrosis of the femoral head and 18 patients underwent transtrochanteric rotation osteotomy with an improved outcome.

CT stereographic drawings for patients with this condition are a valuable method of assessing the necrotic area. The indication for rotation osteotomy, the optimal degree of rotation, and the need to add varus to the osteotomy can all be accurately determined before operation in each patient.

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