The Influence of Heterotopic Ossification on Functional Status of Hip Joint Following Total Hip Arthroplasty

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Purpose: The functional failure induced by heterotopic ossification (HO) following total hip arthroplasty (THA) was analyzed and correlated to the radiologic failure.
Patients and Methods: From July 1997 to July 2001, 315 patients (345 hips) received THA indicated by a hypertrophic osteoarthritis of higher degree (Kellgren grade III, IV). All patients were irradiated prophylactically for prevention of HO on the evening before surgery with a 7-Gy single fraction. The patients' median age was 66.3 years. Radiologic failure was assessed by comparison of pre- and postoperative hip X-rays (immediately and 6 months after surgery). Analysis of radiographs was performed according to the Brooker Score. Clinical failure was appraised by measurement of passive range of motion (ROM) of the hip joint with a standard goniometer. The t-test was used for statistical analysis.
Results: 281 patients (81.5%) did not develop HO. HO of Brooker grade I or II was found in 58 patients (16.8%). Six patients (1.7%) developed HO Brooker grade III or IV. There was a significant negative correlation between the degree of radiologic and clinical failure. ROM differed significantly between patients with HO Brooker grade 0, I, II and patients with HO Brooker grade III, IV. Comparing the pre- and postoperative ROM, all patients with Brooker grade 0, I and II showed a significant improvement of flexion, internal and external rotation, abduction and adduction movement. Patients with HO Brooker grade III and IV showed no improvement of ROM in the postoperative follow-up.
Conclusion: The development of HO following THA influences the physical function of the hip joint dependent on the degree of ossification. HO of lower degree (Brooker I, II) does not influence the clinical outcome, whereas HO of higher degree (Brooker III, IV) reduces the function of hip arthroplasty. Therefore, the purpose of a prophylactic therapy must be to reduce HO of higher degree.

Key Words: Hip arthroplasty · Prophylactic radiotherapy · Heterotopic ossification · Hip function

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Der Einfluss heterotoper Ossifikationen nach Totalendoprothese des Hüftgelenks auf die Gelenkbeweglichkeit

Ziel: Der Einfluss heterotoper Ossifikationen (HO) nach Totalendoprothese des Hüftgelenks (TEP) auf die Gelenkbeweglichkeit wird untersucht.
Patienten und Methodik: Von Juli 1997 bis Juli 2001 erhielten 315 Patienten (345 Hüften) eine TEP. Als Operationsindikation lag bei allen Patienten eine höhergradige Koxarthrose vor (Kellgren III, IV). Die Patienten wurden am Vorabend der Operation mit einer Einzeldosis von 7 Gy als Ossifikationsprophylaxe bestrahlt. Das mediane Alter der Patienten betrug 66,3 Jahre. Die Klassifikation der HO wurde anhand prä- und postoperativer Röntgenaufnahmen (am Operationstag bzw. 6 Monate nach Operation) nach dem Brooker-Score durchgeführt. Folgende präoperative und in der Nachsorge erhobene Beweglichkeitsparameter (ROM) wurden in Abhängigkeit von der HO-Entwicklung miteinander verglichen: Flexion, Außen- und Innenrotation, Ab- und Adduktion. Der t-Test für gepaarte Stichproben wurde für die statistische Analyse verwendet.
Ergebnisse: 281 Patienten (81,5%) entwickelten keine HO, 58 Patienten (16,8%) HO Grad I/II und sechs Patienten (1,7%) HO Grad III/IV. Die erhobenen ROM unterschieden sich signifikant bei den Patienten, die keine oder niedriggradige HO (Brooker I, II) entwickelt hatten, und denen, die höhergradige HO (Brooker III, IV) aufwiesen. Die Patienten mit HO Brooker 0, I und II zeigten im Gegensatz zu den Patienten mit HO Brooker III und IV postoperativ eine signifikante Verbesserung der Werte für Flexion, Innen- und Außenrotation, Ab- und Adduktion.
Schlussfolgerung: Die Entstehung von HO nach TEP beeinflusst in Abhängigkeit von deren Ausmaß die postoperative Hüftbeweglichkeit. Dabei sind HO Grad I und II nicht, Grad III und IV von großer klinischer Relevanz. Daher muss eine prophylaktische Therapie insbesondere darauf abzielen, die Inzidenz höhergradiger HO zu reduzieren.

Schlüsselwörter: Hüftendoprothese · Prophylaktische Bestrahlung · Heterotope Ossifikation · Hüftgelenkbeweglichkeit

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Introduction

Total hip arthroplasty (THA) is the most frequent arthroplasty in Germany [13]. Heterotopic ossification (HO) is a common postoperative complication [11, 25]. Factors associated with the development of HO after THA include previous HO, sex and age, idiopathic skeletal hyperostosis, ankylosing spondylitis, and hypertrophic osteoarthritis [1, 2, 6, 8, 18, 37]. The reported prevalence of HO varies between 8% and 90% [24, 28]. About 30% of these patients develop functional impairment [25, 34]. Since severe HO reduces hip prosthesis function, prophylactic treatment for prevention of HO is demanded for all patients. In the last 3 decades both, prophylactic radiotherapy and the prophylactic use of nonsteroidal anti-inflammatory drugs (NSAIDs) were shown to be effective for prevention of HO by numerous prospective and retrospective studies [16, 21–23, 29, 32–34]. In most of these studies, however, the effectiveness of prophylactic therapy was only defined as radiologic failure as described by Brooker et al. [5]. A systematic analysis of the functional failure defined as the range of motion (ROM) of the hip joint is rare in literature.

Therefore, the purpose of this study was to assess the physical function of the hip joint following THA and prophylactic preoperative radiotherapy and to correlate the physical results with those of radiography.

Patients and Methods

From July 1997 to July 2001, 315 patients (345 hips), received THA. All patients were irradiated preoperatively (on the evening before surgery) with a 7-Gy single fraction for prevention of HO. Prior to radiotherapy all patients underwent simulation. Treatment was via anterior-posterior opposed fields with the dose prescribed to the central axis midplane depth. Radiotherapy was delivered with ^{60}Co. Source-to-axis distance was 80 cm.

The patients' median age was 66.3 years. Hip surgery was done in 172 (49.8%) male and 173 (50.1%) female patients (Table 1). The indication for surgery was hypertrophic osteoarthritis of higher degree (III, IV). The hypertrophic osteoarthritis was graduated according to Kellgren & Lawrence [15] (Table 2).

Radiologic treatment results were assessed by comparison of pre- and postoperative hip X-rays (immediately and 6 months after surgery). Analysis of radiographs was performed by a panel of four experts (two radiotherapists, one orthopedist, one radiologist) according to the Brooker Score (Table 3) [5].

Table 1. Patient characteristics.

Tabelle 1. Patientencharakteristik.

Patients (n)	315	
Hips [n (%)]	345	(100)
Median age (years)	66.3	
Gender		
• Male [n (%)]	172	(49.8)
• Female [n (%)]	173	(50.1)
Right hip [n (%)]	179	(51.9)
Left hip [n (%)]	166	(48.1)
Hypertrophic osteoarthritis [n (%)]	345	(100)
• Grade III (Kellgren) [n (%)]	130	(37.7)
• Grade IV (Kellgren) [n (%)]	215	(62.3)

Functional treatment results were defined as passive ROM of hip joint measured with a standard goniometer. In hip flexion measurement, the subject lay on his back, and the observed leg was kept knee flexed and the other leg straight. The central pivot of the goniometer was placed over the greater trochanter, the stationary arm of the goniometer was aligned with the body and the medioaxillary line taken as 0, and the moving arm of the goniometer was placed parallel to the longitudinal axis of the femur on the lateral surface of the thigh, pointing toward the lateral condyle.

Hip adduction was measured with both legs abducted at the same time, the subject lying on his back. The stationary arm of the goniometer was placed perpendicular to a reference line anteriorly between the iliac crest, the central pivot was placed over the anterior superior iliac spine, and the mov-

Table 2. Modified grading system of hypertrophic osteoarthritis according to Kellgren & Lawrence [15].

Tabelle 2. Modifizierte Einteilung der hypertrophen Osteoarthritis nach Kellgren & Lawrence [15].

I	Definite osteophytes
II	Beginning joint space narrowing
III	Presence of two of the following: joint space narrowing, osteophytosis, subchondral sclerosis, cyst formation
IV	Presence of three of the following: joint space narrowing, osteophytosis, subchondral sclerosis, cyst formation

Table 3. Brooker grading system of heterotopic ossification [5].

Tabelle 3. Stadieneinteilung der heterotopen Ossifikationen modifiziert nach Brooker et al. [5].

0	No soft-tissue ossification
I	Separate small foci of ossification about the hip
II	Ossification projecting from the proximal femur or pelvis with $\geq$ 1 cm between opposing bone surfaces
III	Ossification projecting from the proximal femur or pelvis with < 1 cm between opposing bone surfaces
IV	Ossification completely bridging the proximal femur and pelvis

ing arm aligned with the axis of the femur in the midline of the thigh. In hip adduction the investigator raised the contralateral leg and took the observed leg to adduction. The goniometer lay over the hip as in abduction.

The internal and external hip rotations were measured with the subject in the sitting position, with the knee bent at a right angle. In the starting position, the center of the goniometer was placed over the tuberosity of the tibia, and both arms of the goniometer were placed vertically parallel to the longitudinal axis of the tibia on its anterior surface. Then, the moving arm was moved to overlie the anterior surface of the tibia after it had been swung laterally or medially, whereas the stationary arm remained in the starting position before hip rotation.

The statistical significance of comparing the measured values was determined using the t-test for dependent samples. Differences were reported to be statistically significant at $p \leq 0.05$. Statistical analysis was performed using STATISTICA (Kernel-Version 5.5).

Table 4. Overall mean value of range of motion (ROM) measured preoperatively and 6 months postoperatively.

Tabelle 4. Mittelwerte der Hüftbeweglichkeit (ROM) aller Patienten (präoperativ und 6 Monate postoperativ gemessen).

	ROM Preoperatively	Postoperatively	p value
Flexion	83°	89°	$p < 0.01$
Internal rotation	3°	11°	$p < 0.01$
External rotation	9°	18°	$p < 0.01$
Abduction	12°	24°	$p < 0.01$
Adduction	8°	15°	$p < 0.01$

Results

Radiologic Failure

281 patients (81.5%) did not develop HO. HO of Brooker grade I or II was found in 58 patients (16.8%). Six patients (1.7%) developed HO Brooker grade III or IV.

Physical Examination

Table 4 shows the ROM values before and 6 months after surgery. The overall measured values of flexion, internal and external rotation, abduction and adduction improved significantly.

Correlation of Radiologic and Clinical Failure

There was a significant correlation between the degree of radiologic failure and clinical failure (Table 5).

The increase of ROM differed between patients with HO Brooker grade 0, I, II and patients with HO Brooker grade III/IV. Comparing the pre- and postoperative ROM, patients with Brooker grade 0, I and II showed better flexion, internal and external rotation, abduction and adduction movement. Flexion improved significantly in patients with HO Brooker 0 and I/II by 7° and 9° ($p < 0.01$). Internal and external rotation was doubled and tripled, respectively, in these patients ($p < 0.01$). Additionally, abduction increased from 12° to 24° for both, patients with HO grade 0 and I, II ($p < 0.01$). Pre-/postoperatively measured adduction was 8°/14° for HO grade 0 and 8°/15° for HO grade I/II ($p < 0.01$).

In patients with HO grade III/IV there was no significant improvement of ROM. Flexion was increased by 1°, internal rotation by 7°, and external rotation by 2° ($p > 0.05$). Abduction improved from 15° to 22° ($p > 0.05$), and pre-/postoperatively measured adduction was 8°/16° ($p > 0.05$).

Discussion

Radiotherapy plays an important role in the treatment of benign diseases, especially in the prevention of HO [4, 14, 26, 30, 35, 36]. In the past, clinical studies showed that the incidence of HO following hip arthroplasty was reduced by either prophylactic radiotherapy or the use of NSAIDs [17, 19, 20, 27, 31]. The effectiveness of prophylactic therapy was assessed by radiography at least 6 months after surgery. In the literature the extent of HO is normally premised on the classification system by Brooker et al. [5]. This scoring system is based only

Table 5. Correlation of mean range of motion and grade of heterotopic ossification (Brooker).

Tabelle 5. Korrelation der Hüftbeweglichkeit und Ossifikationsgrad (Brooker).

	Grade of heterotopic ossification (Brooker)								
	Brooker 0			Brooker I/II			Brooker III/IV		
	Preoperatively	Postoperatively	p-value	Preoperatively	Postoperatively	p-value	Preoperatively	Postoperatively	p-value
Flexion	83°	90°	$p < 0.01$	81°	90°	$p < 0.01$	85°	86°	$p > 0.05$
Internal rotation	9°	18°	$p < 0.01$	9°	19°	$p < 0.01$	12°	19°	$p > 0.05$
External rotation	3°	11°	$p < 0.01$	2°	9°	$p < 0.01$	2°	4°	$p > 0.05$
Abduction	12°	24°	$p < 0.01$	12°	24°	$p < 0.01$	15°	22°	$p > 0.05$
Adduction	8°	14°	$p < 0.01$	8°	15°	$p < 0.01$	8°	16°	$p > 0.05$

on radiologic signs and does not consider whether HO influences the clinical function of the hip or not.

In our study all patients were irradiated preoperatively with a 7-Gy single-dose fraction. The overall incidence of HO was 18.5%. The reported overall incidence and the results published in other studies using preoperative radiotherapy for prevention of HO are higher than those of studies using postoperative radiotherapy [11, 22, 23, 32, 33]. Thereby, especially HO of lower (Brooker grade I and II) and not of higher degree (Brooker grade III and IV) increased. So far, there is no consensus in the literature whether HO of lower degree influences the functional status of the hip or not. For the evaluation of the effectiveness of prophylactic therapy the functional result is more important than the radiologic one.

The results of the German pattern-of-care study by Seegenschmiedt et al. showed that only 4% of the participating departments of radiotherapy were able to specify the functional results following THA and prophylactic irradiation for prevention of HO [33]. Even though several authors suggest that only HO of higher degree (Brooker III, IV) results in a reduced postoperative functional outcome, an analysis of hip function and a correlation between the extent of HO and the functional situation of the hip is rare in literature [10, 25, 28]. Brooker himself originally concluded that HO grade I, II and III did not significantly alter the functional results after THA and that only HO grade IV was significant [5]. Seegenschmiedt et al. reported that HO Brooker I and II did not deteriorate the Harris Hip Score, whereas patients with HO Brooker III and IV had a lower Harris Score following THA [31, 33]. The Harris Hip Score is a grading system to assess both, the functional status of the hip joint and the quality of life basing on information about pain, functional capacity, deformity, and ROM [12]. In contrast to Seegenschmiedt et al. several studies demonstrated that the Harris Score for Brooker grades 0–II did not differ significantly from that for grades III and IV [3, 9, 17]. Although Effenberger et al. reported no correlation between Harris Score and the extent of HO in patients with revision of arthroplasty, they found a negative correlation between Broker grades and range of flexion, an important finding, because range of flexion is the most important motion for walking [9]. Additionally, Burd et al. showed a significant relationship of forward flexion with the grade of HO for patients with acetabular fractures [7]. Whereas in the study by Effenberger et al. the range of flexion was already reduced in patients with HO Brooker grade II, in the study by Burd et al. even HO grade I decreased flexion. In our study of 345 hips with severe coxarthrosis, we demonstrated that the ROM of the hip, especially the range of flexion, was not reduced in patients with HO grade I and II compared to those without HO. From this point of view the increased incidence of HO of lower degree (Brooker I and II) after preoperative compared to postoperative prophylactic radiotherapy seems to be of no importance for the clinical outcome following THA.

Conclusion

HO Brooker I and II did not influence the functional status of the hip following THA. Hence, for comparison of the results of previous radiologic studies the incidence of HO of higher degree (Brooker III and IV) should be given more consideration than the overall incidence. For prospective studies on the effectiveness of radiotherapy or NSAIDs not only the radiologic, but also the clinical failure has to be investigated. To be able to compare the clinical results, a standardized system, e.g., the Harris Hip Score, which considers subjective and objective functional hip parameters, should be used to classify hip function.

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