Prevention of Heterotopic Bone Formation after Total Hip Arthroplasty Using 600 Rad in Single Dose in High Risk Patient

Chang Dong Han¹, Chong Hyuk Choi¹, and Chang Ok Suh²

Nineteen patients received single-dose exposure to 600 rad delivered within 48 hours of total hip arthroplasty (THA) with shielding of the prosthesis region for the prevention of heterotopic ossification. The patients were considered at high risk for developing heterotopic ossification (HO) because of hypertropic osteoarthritis, post-traumatic osteoarthritis or the presence of previously-formed ectopic bone. The average follow-up period was 42 months (range, 37 months - 48 months). At a follow-up study, all hips except one were classified as Brooker class 0. The single exception was classified as class I. All patients were asymptomatic at the last follow-up study and no component demonstrated subsidence or radiolucent line indicative of loosening. The authors concluded that 600 rad, single-fraction radiation therapy is cost effective, convenient and safe for the prevention of heterotopic ossification after total hip arthroplasty.

Key Words: Heterotopic ossification, total hip arthroplasty, radiation

THA is an established procedure employed for treatment of many painful hip diseases. The potential for postoperative growth of heterotopic bone in the soft tissues surrounding the hip joint has long been recognized as a major post THA complication (Brooker et al. 1973; Lazansky, 1973; Ritter and Vaughan, 1977). Complications such as non-union of the greater trochanter, thromboembolism, infection and dislocation of prosthesis can also occur, but HO can be quite extensive, resulting in a return of pain and impairment of joint mobility. Although it’s a common complication, the etiology of HO following THA is not completely understood. Its reported incidence has ranged from 10% ~ 90% primarily because of the various methods of classification of bone response and the study of the heterogenous patient population. Also, the range of clinically significant bone formation has been reported to be approximately 5% of all cases (Brooker et al. 1973; Shauffer, 1989; Maloney et al. 1992).

Several groups of patients are known to be at high risk for developing HO. Patients who had HO following a previous arthroplasty have a great chance for ectopic bone formation (DeLee et al. 1976; Coventry and Scanlon, 1981). Also, patients with diffuse idiopathic skeletal hyperostosis, hypertropic osteoarthritis with extensive osteophyte formation, ankylosing spondylitis, and post-traumatic degenerative joint disease are known to be at increased risk for development of HO (Taylor et al. 1976; Blassingame et al. 1981; Bundrick et al. 1985; Ayers et al. 1986; Fahrer et al. 1988).

Several methods have been thought to selectively
inhibit formation of HO without otherwise compromising the functional result of the surgical procedure, such as medication therapy, irradiation and careful surgical technique. Since Coventry and Scanlon (1981) reported the efficacy of radiation therapy with 2000 rad for prevention of HO, many studies have supported the effectiveness of radiation therapy (Anthony et al. 1987; Hedly et al. 1989; Kennedy et al. 1991; Maloney et al. 1992). Recently, it has been proved to be effective with low doses of radiation which were divided into one or two fractions. It was also recommended that radiation therapy be initiated as soon as possible after operation. Some studies revealed that irradiation after THA can induce the reduction of bony ingrowth. To prevent components from loosening, it was necessary to shield the acetabular and femoral components from the irradiation field.

The purpose of this study was to assess the results for the prevention of HO in high-risk patients using 600 rad of ionizing radiation delivered in a single fraction with shielding of the acetabular and femoral components.

**MATERIALS AND METHODS**

Between June 1990 and May 1992, 19 patients (19 hips) received radiation therapy following THA in an attempt to prevent HO. All acetabular and femoral components were cementless Harris-Galante porous implants. There were 14 men and 5 women, with an average age of 47 years (range 30–77). Each patient was considered at high risk for HO because of the presence of one of the following: hypertropic osteoarthritis in 6 patients, ankylosing spondylitis in 4 patients, postinfectious osteoarthritis in 5 patients, and Brooker class III and IV HO formation after previous THA in 4 patients. All procedures were done using a standard posterolateral approach and were performed by the senior author. Care was taken during the surgical procedure to minimize trauma to the soft tissues and to remove all fine bone particles prior to closure. Heterotopic bone (Brooker class IV) which was developed after previous THA, was excised in 2 patients, because it limited hip motion. In 2 patients in whom Brooker class III HO developed after THA, the heterotopic bone was excised at the time of revision arthroplasty due to femoral stem loosening. Trochanteric osteotomies were performed in 4 patients (1 in revision arthroplasty, 2 in ankylosing spondylitis and 1 in hypertropic osteoarthritis). No control group was included in this study because historical controls have been well documented.

All patients received 600 rad in one fraction through anteroposterior portals centered on the hip joint between 24 and 48 hours after surgery. Before radiation therapy, care was taken to exclude the areas of acetabulum and femoral components from the field of radiation by using a simulator. Under the simulator, the radiation field was determined. The goal was to radiate only the soft tissue around the hip joint and minimize the radiation to the osseous structures. A simulator film was used as a template to plan the size and location for the shields. The exposed field included the area surrounding the

![Fig. 1. Radiation exposure area after shielding of acetabular and femoral component regions.](image-url)
prosthetic femoral neck, the medial region between the lesser trochanter and ischium, and the lateral region between the greater trochanter and ilium. This limited field effectively avoided exposure of the peri-implant area to the single dose 600 rad delivered via cobalt.60 (Fig. 1).

All patients had anteroposterior and frog lateral roentgenograms of the hip preoperatively and at regular intervals until the end of the follow-up period. The response to treatment was based on a comparison of immediate postoperative radiographs and those obtained at the last follow-up evaluation (minimum of 37 months after surgery). The average follow-up period was 42 months (range, 37–48 months). HO was graded according to the classification of Brooker et al. (1973). The radiographs were also evaluated to assess implant loosening in all patients and the non-union of trochanteric osteotomy sites in 4 patients. The acetabular component was analyzed using 3 zones as described by DeLee and Charnley (1976), and the femoral component was analyzed using 7 zones as described by Gruen et al. (1979). Radiolucencies at the implant-bone interface on the acetabulum and femur were measured.

## RESULTS

This regimen proved to be an effective means for preventing HO formation in high risk patients. In 2 hips in which HO had existed as class III preoperatively, we performed revision arthroplasty and in 2 class IV hips, the heterotopic bone masses were excised completely. All hips except one were classified as Brooker class O at follow-up study, regardless of preoperative classification. In one hip in which HO of class IV was excised, small, non-significant islands of bone within the soft tissue (class I) reformed (Table 1). There were no complications or functional impairment from the radiation therapy. All patients were asymptomatic at the time of the last follow-up evaluation. No acetabular or femoral components demonstrated a subsidence, radiolucent line or change in position. There was no evidence that radiation therapy had any deleterious effect on implant stability. Healing of the incision was not delayed despite not being shielded. There were no dehiscences or infection of wounds. The trochanters that were osteotomized during the surgery and subsequently received localized periarticular radiation to hips with shielding of trochanteric osteotomy sites, were all united by 4 months (range, 3 to 6 months). No patient required further surgery and all patients were walking without the use of supportive devices.

### Table 1. Comparison of preoperative HO with HO after irradiation

<table>
<thead>
<tr>
<th>Class</th>
<th>Preop. HO</th>
<th>HO after irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 0</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>Class I</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Class II</td>
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<td>0</td>
</tr>
<tr>
<td>Class III</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Class IV</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

HO: heterotopic ossification

## DISCUSSION

HO is a significant complication which may occur following THA. The affected hip may develop severe limitations of motion and pain which often necessitates a subsequent operation. Even though the reported incidence of HO complications varies widely, the incidence of significant functional deficits was found in 1%–5% of patients (Brooker et al. 1973; Maloney et al. 1992; Han et al. 1994).

Since not all patients form HO after THA, it would be advantageous to identify those patients at risk for this complication: thus treatment for the prevention of HO could be selectively utilized in the high-risk population. Several factors have been shown to correlate with an increased risk. The risk is greatest in those patients who have previously developed HO in the ipsilateral or contralateral hip. Other patients with increased risk of HO included those with diffuse idiopathic skeletal hyperostosis, hypertrophic osteoarthritis, post-traumatic osteoarthritis with extensive osteophyte formation and ankylosing spondylitis (Brooker et al. 1973; Ayers et al. 1986; Warren, 1990). We included the post-
tuberculous osteoarthritis in the high-risk group in this study (Han et al. 1994).

Some therapeutic modalities (mechanical means, pharmacologic agents and radiation therapy) have been known to be effective for the prevention of HO after THR. Among them, attempts to prevent HO formation have centered on postoperative irradiation. Since its introduction in 1981 by Coventry, postoperative irradiation has been shown to be relatively complication-free and effective in preventing HO in high-risk patients. Many authors introduced protocols with their experience and reported good results by their own methods. The protocols differed in the number of fraction, total dose of radiation and initiation day of radiation therapy (Coventry and Scanlon, 1981; Hedley et al. 1989; Ayers et al. 1991; Maloney et al. 1992). Our patients who were treated with 600 rad administered in one fraction in the first 2 postoperative days formed no Brooker class II, III or IV ossification. Only one case showed Brooker class I ossification. Using a similar protocol, Hedley et al. (1989) with 600 rad and Lo et al. (1988) with 700 rad, both experienced results similar to ours. The early administration of radiation is essential. It has been postulated that ionizing radiation alters the DNA content in rapidly dividing cells, preventing differentiation of pluripotential mesenchymal cells into osteoblasts. Thus, osteoid production is inhibited and no substrate exists for subsequent mineralization (Ayers et al. 1986). Kennedy et al. (1991) recommended that the radiation therapy should be done before the fourth postoperative day and Hedley also recommended radiation therapy should be started before the third day. We performed radiation therapy between 24 and 48 hours postoperatively in all cases. It is possible that with multiple-fraction dosing the ossification process begins during the initial dosing and a critical dosage of radiation is not administered until several fractions have been completed. Thus, the dosage required to “turn off” the ossification process may not have been delivered until several days after the initiation of treatment. This inappropriate delay in critical dosing, despite the early initiation of treatment, may explain the greater post-treatment incidence of HO in some of the multiple-fractioned protocols.

Studies in animals receiving postoperative irradiation following implantation of porous prostheses have shown a transient decrease in bony ingrowth as measured by the percent area of ingrowth (Longo et al. 1985). This study supports the use of postoperative irradiation in patients in whom porous implants were used, in that the reduction of ingrowth is temporary and rapidly approaches normal after several weeks. Hedley et al. (1989) insisted that low-dose irradiation does not significantly interfere with bony ingrowth. We attempted to shield the acetabular and femoral components to prevent the loosening of the cementless implant. Since surgery, no patient has demonstrated radiolucent lines about the prosthesis or symptoms of a loose prosthesis.

Trochanteric nonunion is the most frequent complication from postoperative irradiation and has been reported to be 11.5% - 43% (Coventry and Scanlon 1981; Ayers et al. 1991). Trochanteric osteotomies in this series healed uneventfully after 3 to 6 months. Osteotomy sites shielded from radiation therapy healed completely without nonunion. The difference in our results from others, regarding trochanteric healing could be explained by the shielding of the osteotomy site from radiation.

Radiation therapy is a localized treatment that does not induce significant systemic effects. Early experimental efforts were limited due to the fear of sarcoma induction. Radiation induced sarcoma after a locally administered dose of 3000 rad or less has not been reported. Neuhauser et al. (1975) noted radiation induced changes in growing vertebrae of pediatric patients undergoing treatment for abdominal and pelvic malignancies. These changes were evident, however, only when dosages exceeded 2000 rad (Brooker et al. 1973). None of the patients of this study showed the systemic side effects, including sarcoma induction.

Since 600 rad dosing has benefits to the patient who needs transportation to another hospital for irradiation, this method is not only convenient but it is also cost effective compared to a multiple large-fractioned dose. As well, since a lower dose of radiation is used, the concomitant risk for a radiation-induced malignancy may be reduced. Further reduction in dosage is not advisable, as HO formation has been reported following single-dose exposure to 280 rad (Lo et al. 1988).
We have concluded that single dosing with 600 rad with precision-shielding in the first 2 postoperative days is more effective and convenient for prevention of HO than the multiple large-fractioned dosing protocols. This study has also demonstrated that precision shielding is mandatory on the hips containing porous ingrowth implants.

REFERENCES


Hedley AK, Mead LP, Hendren DH: The prevention of heterotopic bone formation following total hip arthroplasty using 600 rad in a single dose. *J Arthroplasty 4*: 319-325, 1989


