Original Research

Occult Hip Prosthetic Loosening Diagnosed by [18F] Fluoride-PET/CT

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ABSTRACT

Background: Positron emission tomography using the [18F] fluoride metabolite combined with computerized tomography (F-PET/CT) can be used to analyze the metabolic status of the periprosthetic bone after surgery for total hip arthroplasty.
Methods: To obtain normal PET referent values, 44 patients with 5 models of well-functioning hip prosthetic components were analyzed by F-PET/CT, radiography, and clinical score. Another group of patients having painful total hip arthroplasty, but whose radiography showed no conclusive signs of loosening, was analyzed by F-PET/CT scans before revision surgery.
Results: Preoperative median F-PET scores of the bone metabolic activity were 6.65 (3.3-9.0) for the painful stem group and 1.85 (1.2-3.9) ($P < .01$) for the referent group having the same stem model. At revision surgery, the stems in the painful group were assessed to be loose. At 2-year follow-up, the revised patients were all pain free.
Conclusion: F-PET/CT may be a new diagnostic tool for assessing occult loose stems that are not seen by radiography.
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Introduction

Replacement of a hip joint by total hip arthroplasty (THA) is a successful method, but its long-term success is dependent on the stability of the implant. Success of the THA correlates with stability of the prosthesis and the bone metabolism adjacent to the prosthetic surface.

Plain radiography or radio stereometric analyses are often used to assess component stability. Skeletal metabolism can be analyzed by positron emission tomography using the [18F] fluoride metabolite combined with computerized tomography (F-PET/CT) [1-6]. The method has been used to describe postoperative metabolic events for 4 models of cups and 4 models of stems [3-6]. The F-PET images do not present anatomic structures as in radiographic methods; instead, they present metabolic events [7] such as new bone formation [8] and bone viability [9]. Validating studies have been performed to correlate F-PET images with bone histomorphometry [10-13].

The present study started as an analysis of F-PET/CT images to determine normal values of bone metabolic activity adjacent to well-functioning THA components in referent groups. Our aim was to include patients from our center who had had their components for at least 8 years at follow-up. We aimed at no less than 5 individuals per group for any given prosthetic component model. With this criterion, we obtained enough patients for 3 groups of stems and 2 of cups. Our hypothesis was that the fluoride uptake pattern is a marker for a specific, well-functioning implant. During the course of this study, another clinical group at our hospital was identified. They had the same prosthesis as in one of the referent groups, and although radiologic examination did not show definite signs of loosening, the hips were continuously painful. F-PET/CT scans were also performed on this group as a pilot study. Our hypothesis for this group was that a significantly higher uptake would be a marker for prosthetic loosening. At revision surgery, all stems in this group were found to be loose. The discovery of the group of painful prostheses led us to investigate their standardized uptake values (SUVs) and to compare them with the well-functioning referent group having the same stem model.

Material and methods

Patients

The diagnosis at time of primary THA was primary osteoarthritis for all patients in this study. Three models of stems and 2 models of cups were studied as referent groups (see Table 1). These patients

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(n = 44) in the referent groups (mean age: 69 years, 19 women) of primary THAs had had their prostheses for 8-12 years when the F-PET/CT scan was performed. All had standardized hip radiology (anteroposterior and lateral views), without signs of loosening, as assessed by the radiologist and the orthopaedic surgeon in consensus, and none reported hip pain. Another group of 5 consecutive patients (mean age: 60 years, 2 women) was also studied. This group had had their primary prostheses for 2-4 years and reported a painful hip. The nature of pain and type of revision procedure are listed in Table 1. The same standard hip radiology assessments were performed in this group. Their F-PET/CT scans were performed to clinically analyze their PET uptake. Because of high uptake values, all patients in this group underwent revision THA surgery of the femur—but not the acetabular component. Stability of their stems and cups was assessed through provocation during surgery. During this period at our department, no other patients were revised or assessed by radiology to have a loose stem of this model.

The trial was approved by the Ethics Committee of Uppsala University (Approval number 2013/021) and performed in compliance with the Helsinki Declaration of 1975, as revised in 2000.

Implants

Three femoral and 2 acetabular implants were studied in the referent groups. The 2 uncemented acetabular implants were the hydroxyapatite (HA)-coated TOP cup (Waldemar Link GmbH & Co, Hamburg, Germany) and the porous-coated ABG cup (Stryker, MI) (Table 1). The cemented stem was the Lubinus SP II (Waldemar Link GmbH & Co, Hamburg, Germany). The uncemented femoral components were the short CFP stem (Waldemar Link GmbH & Co, Hamburg, Germany) and the Corail stem (3/9 had a collar) (DePuy, Johnson & Johnson, Warsaw, IN) (Fig. 1). The entire surface of this stem was coated with a 150-μm-thick layer of calcium HA. The painful group (n = 5) consisted of 2 collarless stems and 3 with a collar (Fig. 1).

Follow-up

Clinical outcome was assessed according to the Merle dÁubigne and Postel score modified by Charnley [14], validated by Longo et al [15]. This scoring method is routinely used at our center. Analyses were performed preoperatively and at 2- to 5-year follow-up for the painful group. Radiography of anteroposterior and lateral views, F-PET scan, and clinical score were analyzed 8-12 years postoperatively for the referent groups. Radiographic assessments for the painful group (anteroposterior and lateral views) were made by comparing the radiographs taken immediately after the primary surgery and again before the revision surgery. Possible loosening was assessed by analyzing component migration and radiolucent line. New radiographs for this group were also taken at 2- to 5-year follow-up after the revision surgery. All radiographic assessments
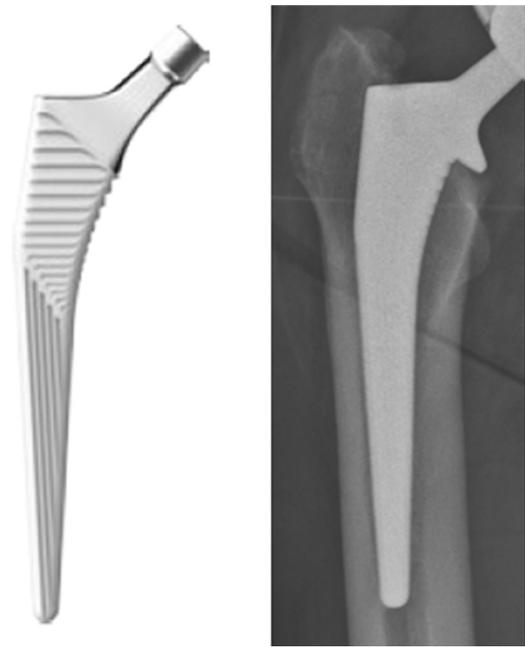

Figure 1. Corail stem. Left, the photograph. Right, the radiograph.

were performed in consensus by a radiologist and an orthopaedic surgeon.

PET analyses

A Siemens/CTI Exact HR+ scanner (Siemens/CTI, Knoxville, TN; 1999) was used for the PET imaging. The HR+ scanner has a field of vision of 15 cm, yielding 63 transaxial slices. Patients were placed supine on the camera bed. and their legs, fixated using a vacuum cushion. A venous catheter was inserted in an antecubital or dorsal hand vein for injection of the fluoride tracer.

Thirty minutes after intravenous injection of 200 MBq of [18F]-natrium fluoride, a section of the whole body was scanned in 2-dimensional whole-body mode. Emission scanning started from the knees (5 min per 15-cm bed position) and moved proximally to cover the entire hip prosthesis area in a single session. Transmission scanning for attenuation correction was performed after completing the emission acquisition.

Immediately after the preoperative PET scan, the patients also underwent CT of the hip and upper femur. The CT image was co-registered and fused with the PET images to indicate the exact anatomical locations in the analysis. All emission scans were corrected for attenuation, scatter, and decay. Reconstructions were performed by ordered subset expectation maximization with 2

Table 1
Painful group.

Case no.	The number of years with the prosthesis	Pain at rest	Pain at increasing activity	The type of the revision procedure
1	4	None	Thigh pain	Exchange only of the stem to a cemented Lubinus SP II.
2	3	None	Thigh pain	Exchange only of the stem to a cemented Lubinus SP II.
3	4	Slight	Thigh and groin pain	Exchange only of the stem to a cemented Lubinus SP II combined with impaction bone grafting.
4	2	None	Thigh pain	Exchange only of the stem to a cemented Lubinus SP II combined with impaction bone grafting.
5	2	Slight	Severe thigh and groin pain	Exchange only of the stem to a cemented Lubinus SP II.

iterations and 21 subsets, using algorithms provided by the scanner manufacturer.

Analysis of the images was performed by visual inspection and numerical analyses, as previously reported by Sorensen et al. SUVs were calculated according to the equation in the following:

$$SUV_{tissue} = \frac{radioactivity\ in\ tissue(Bq/mL)*body\ weight(gram)}{total\ injected\ dose(Bq)}$$

Setting the average body density to 1g/mL, this equation gives a unitless value of the regional tissue activity in proportion to the average radioactivity concentration of the entire body. For analyzing and presenting the bone metabolic activity, we used a PET visualization method called the polar map (Better N HR) according to our modification [6]. Briefly, one region of interest each was calculated for the entire acetabular and femoral surfaces adjacent to the prosthesis.

Statistics

Numerical results are presented as the median (range), unless otherwise stated. Differences were analyzed using the Mann-Whitney U-test. The statistical software SPSS Statistics 25 (IBM Corp., Armonk, NY) was used in the analyses.

Results

Clinical results

The clinical score was good in the referent groups (Table 2). The score was lower for the painful group preoperatively (12.5) compared with follow-up (17.5). (Normal, pain-free function has a score of 18.) There were no preoperative clinical or laboratory signs (inflammatory markers) of infection. On revision surgery, all the stems in the painful group were found to be loose. They were removed either manually or by a few very light blows with a surgical hammer. None of the cups were found to be loose or revised. Five deep intraoperative tissue biopsies per patient were taken from the hip and cultured for 10 days. All cultures were negative in the revised painful hips.

Radiographic results

All stems for the referent groups were assessed stable on plain radiographs. The painful group showed no radiolucent lines in 3 of the cases and thin, partial lines in 2 of them (Fig. 1). One stem had a possible subsidence of 3 mm, but the others had none.

PET results

The prostheses and F-uptake were well visualized on inspection (Fig. 2). SUVs for all groups are shown in Table 2. The median SUV was 6.65 (3.3-9.0) for the painful group and 1.86 (1.2-3.9) for the referent group having the same stem model (P < .01) (Fig. 3). A
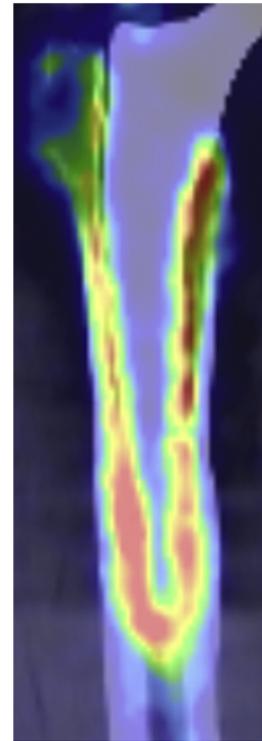

Figure 2. PET image of the painful occult loose stem.

comparison of the median SUV for the painful group with the 2 referent groups having other stem models showed they were significantly different (P < .01).

Discussion

To determine a PET referent for well-functioning prosthetic components, F-PET/CT was used to assess periprosthetic bone metabolism after THA surgery.

Two previous F-PET/CT studies at our institution have analyzed bone metabolism adjacent to surfaces of 2 types (HA-coated and cemented) of porous-coated hip prosthetic stems during the first postoperative year [6]. A third study analyzed bone metabolism adjacent to surfaces of one HA- and one porous-coated cup [5]. These studies show a postoperative elevated metabolism that normalizes within 1 year. In the present study, we included a group of patients who had passed their first postoperative year. The patients in this group had normal radiologic results of their
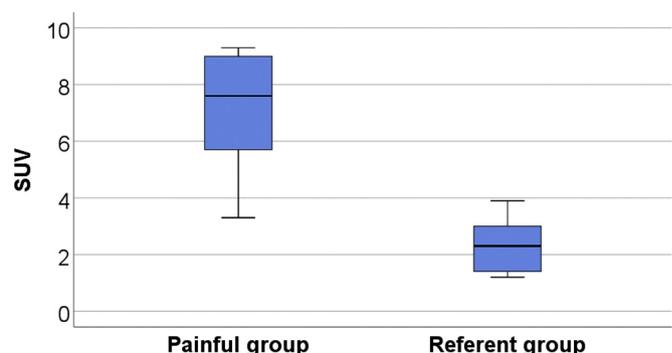
Table 2
Mean clinical scores and the median SUV per group for 5 different prosthetic referent components and for the painful group.

Group	n	Score	SUV	Range
TOP referent	11	17.7	2.90	2.4-4.2
ABG referent	5	17.6	2.60	2.1-3.8
SP II referent	6	17.8	1.97	1.0-2.9
CFP referent	13	17.7	1.95	1.0-2.8
Corail referent	9	17.8	1.85	1.2-3.9
Corail pain	5	12.5	6.65	3.3-9.0

Figure 3. SUVs for the painful group (n = 5) and the referent group (n = 9).

prostheses, but painful hips. F-PET/CT scans revealed a significantly higher uptake value than that in the referent group. Subsequent revision surgery showed these stems to be mechanically loose. The clinical score at follow-up for the revision surgery group was substantially improved, indicating that stem loosening had indeed been the reason for pain. This phenomenon—of patients having hip pain but without radiologic signs of a loose stem—is likely to exist in other centers. Buttaro et al [16] reports a prevalence of 2.1% of painful metaphyseal HA debonding for Corail stems.

The present study has some weaknesses. It was an observational study, the study groups were small and all from a single center, and the PET analyses were performed at different postoperative times for the referent and study groups. However, the study results are still worth consideration. PET values in nonpathologic THAs would remain at the same low value from 1 year postoperatively and onward [6].

Conclusions

F-PET/CT is a tool able to analyze in detail bone metabolic events adjacent to hip arthroplasties. Our findings show the usefulness of F-PET/CT in diagnosing mechanical loosening of hip prostheses. Future F-PET/CT studies of a larger group of painful but radiographically nonloose stems should be compared with a group of radiographically loose stems. Revision surgery should be performed for both groups, and stability of the stems, assessed during surgery. Two years postoperatively, a new F-PET/CT should be performed for both groups.

Conflict of interest

The author declares there are no conflicts of interest.

Acknowledgments

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