Bone and muscle mass after hip arthroplasty

A quantitative computed tomography study in 20 arthrosis cases

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We performed a prospective, quantitative computed tomography (QCT) study of bone mineral density (BMD), cortical bone volume, bone mass and muscle volume in 20 patients who were operated on with cemented total hip arthroplasty because of unilateral arthrosis. Both extremities were measured preoperatively, 3 and 6 months after the operation by a single-energy computer tomograph equipped for bone mineral densitometry.

Preoperatively, we found a 25 percent decrease in muscle volume of the thigh on the arthrosis side compared to the contralateral side, but only a 6 percent decrease in bone mass, mainly of the cortical bone volume in the middle femur. In the cancellous bone of distal femur and proximal tibia there was a reduction in BMD of 11 and 14 percent, respectively, compared to the contralateral side. After 6 months, we found no changes in cortical bone mass, either on the operated femur or on the contralateral, control femur. The BMD of cancellous bone in distal femur and proximal tibia had not changed. However, the thigh muscle on the operated side showed a strong recovery; 6 months after the operation there was a 19 percent gain on the operated side.

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Posttraumatic osteopenia after fractures and other injuries is a well known phenomenon (Nilsson 1966, Nilsson and Westlin 1969, Ahl et al. 1988, Abbaszadegan et al. 1991). However, it is often impossible to distinguish between the osteopenia caused by the concomitant disuse or immobilization after the injury and the post-traumatic effect upon the bone. A total hip arthroplasty operation offers a possibility to distinguish between these different forms of osteopenia, since the operation could be sufficient to induce post-traumatic changes in the bone. This post-traumatic osteopenia would not be accompanied by an immobilization or disuse osteopenia because of the patient's improved mobility after the operation. The aim of this study was to investigate if the bone loss is posttraumatic in origin or just an effect of the arthrosis disease.

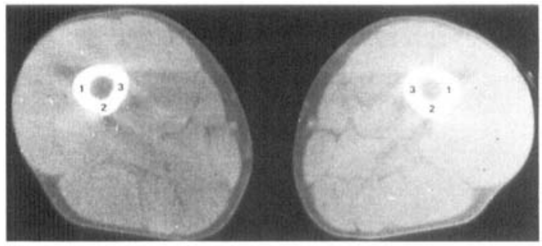
Patients and methods

This study included 12 women and 8 men with a mean age of 72 (55–82) years who had unilateral coxarthrosis and no earlier fracture or other disability of the contralateral leg. None of the patients underwent hormonal therapy. The bone mineral density (BMD), the cortical bone volume and the transverse area of the thigh muscle were measured in the middle femur, and the BMD in the distal femur and proximal tibia within 1 month before the operation; in 5 patients we made 2 identical preoperative measurements, with complete reposition of bone and CT scanner, within 1 week to examine the precision error of the method. All patients were operated on and given a cemented total hip prosthesis through a posterior approach, and the postoperative course was without complications. The same regions were scanned 3 and 6 months after the operation. The aim of this study was to investigate any posttraumatic changes in the bone; therefore, the follow-up time was restricted to 6 months.

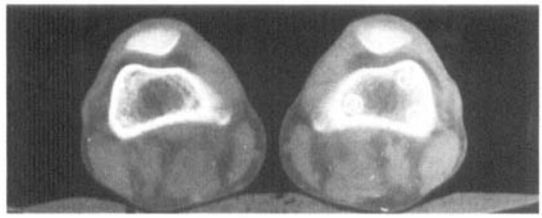
Evaluation of bone and muscle

The BMD and the volumes were measured by a computer tomograph (General Electric Pace Plus™, Milwaukee, Wisconsin) equipped for bone mineral densitometry. This software converts the attenuation to equivalent bone mineral densities. It is also possible to calculate a specific subarea of the scan. Thresholding was used to segment an image into regions of interest on the basis of gray level (Hounsfield units); this facilitates determination of the transverse muscle area. The patient was scanned while lying on a reference phantom containing calibrated densities of calcium hydroxyapatite (150, 75, and 0 mg/cm^3) in a flexible water-equivalent plastic. One localization scan (ScoutView™) was performed of the distal femur and the knee joint (Figure 1). The femurs were scanned in the

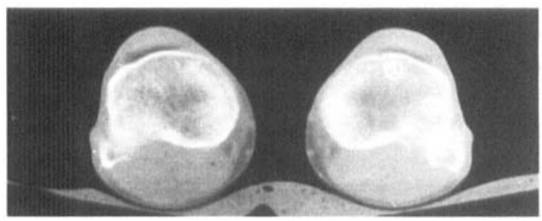
Figure 1. Localization scan. "Scout view".



Scan through middle femur.



Scan through distal femur.



Scan through proximal tibia.

diaphyses 20 cm and 5 cm proximal to the distal limit of the lateral femoral condyle and the tibiae 2 cm distal to this reference point. If there was a difference in leg length due to the arthrosis or the operation, this localization scan facilitated the scanning at the proper locations. From these scans three circular regions (0.04 cm^2) of interest were chosen in the cortical bone (lateral, posterior, and medial) in the proximal femoral scan, and three regions (0.65 cm^2) were chosen in the periphery of the cancellous bone in the distal femoral scan and the tibia scan. The mean value of these three circular regions was estimated as the bone mineral density at that location.

The volumes of the cortical bone in the middle femur and the thigh muscle were measured with thresholding from the proximal scan. Hounsfield units (HU) for lean body tissue are well below 100; fat has a negative number and water has about zero. HU for all normal musculature in the human body has been found to be between 32–89 (Termote et al. 1980). In preparation of the bovine bone samples, we found the dense cortical bone to have approximately 1300 HU, this HU number was verified when the patients' cortical regions in the femur were measured (780–1260 HU). Therefore, window intervals between 10–100 HU (muscle) and 101–2000 HU (cortical bone) were chosen to measure the volumes. The total bone mass of the cortical bone in the middle femur was calculated as the average BMD multiplied by the bone volume at that location.

To check the accuracy of the method we measured the cortical BMD in 8 different bovine femoral diaphyses which were subsequently ashed. The bone samples were sawed perpendicular to the long axis and placed in the CT scanner where three circular regions (0.04 cm^2) of interest were chosen in the cortical bone (lateral, posterior, and medial). The volumes of the samples were measured with volume displacement; thereafter the bone samples were burned in a furnace at 600 °C for 24 hours. The remaining bone was weighed and the true cortical bone mineral density was calculated. The mean (SD) deviation was found to be 0.27 (4.4) percent.

To check the precision of the method we made double measurements preoperatively of all parameters in 5 of the patients. The precision error of the method was 2 percent in BMD of the cortical bone in the middle femur, 4 percent in BMD of the cancellous bone in the distal femur, 7 percent in BMD of the cancellous bone in the proximal tibia, 2 percent in cortical bone volume, and 3 percent in muscle volume of the middle femur.

The Student's *t*-test for paired observations was used to analyze the differences between the legs preoperatively and also the changes with time on each measuring site. The analyses were performed on a Macintosh® II computer with the statistical package

Table 1. Bone mass, bone volume, bone mineral density (BMD) and muscle volume of the middle femur, and BMD of the distal femur and proximal tibia in 20 patients with coxarthrosis. Mean values are given. Preoperative difference between legs and longitudinal differences in both legs. Differences in mean percent, – indicating bone loss

	Preop			3 months				6 months			
	OP	CO	diff	OP	diff	CO	diff	OP	diff	CO	diff
Middle femur											
Bone mass	7.5	8.0	–6 [a]	7.5	0	8.1	1	7.5	0	8.1	1
Bone volume	6.74	7.12	–5 [a]	6.95	3	7.18	1	6.86	2	7.25	2
BMD	1107	1115	–1	1078	–3	1113	0	1093	–1	1113	0
Muscle volume	52	69	–25 [a]	58	12 [a]	68	–1	62	19 [a]	70	1
Distal femur											
BMD	153	171	–11 [a]	163	7 [a]	177	4	156	2	170	–1
Proximal tibia											
BMD	121	141	–14 [a]	127	5	137	–3	122	1	130	–8

Mass (Bone mass calculated as BMD × bone volume; g in a 1-cm-thick slice), volumes (cm^3) and BMD ($mg \times cm^{-3}$).
[a] $P < 0.05$.

StatView SE + Graphics™. Differences were considered significant at P-values < 0.05.

Results

The absolute values of the measured parameters and the calculated bone mass are displayed in Table 1. In the cortical bone of the middle femur there was a preoperative decrease in bone mineral density of 1 percent and in bone volume of 5 percent on the arthrosis side compared to the control side. The total loss in bone mass at that location was 6 percent. The cancellous bone in the distal femur and proximal tibia of the diseased leg had a preoperative decrease in BMD of 11 percent and 14 percent, respectively, compared to the contralateral side. The muscle volume of the thigh was reduced by 25 percent on the arthrosis side. After 6 months we found no changes in bone mass of the cortical middle femur on neither side. The cancellous bone in the distal femur and proximal tibia showed no changes although a small positive effect on bone mineral seemed to be present on the operated side after 3 months. The muscle of the thigh showed a fast recovery; 6 months after the operation there was 19 percent gain on the operated side even though it was still smaller than the control side. We noted no change in muscle volume of the control leg.

Discussion

The knowledge of bone mineral changes after total hip arthroplasty is sparse. Hypothetically one could assume the development of a post-traumatic osteopenia as after fractures or other trauma (Nilsson 1966, Westlin 1974, Ahl et al. 1988, Abbaszadegan et al. 1991). However, in the patients operated on with arthroplasty because of arthrosis, this could be counteracted by a gain in bone mass because of improved mobility after the operation. The most common noninvasive methods of bone measurements in clinical use are single-photon absorptiometry, dual-photon absorptiometry and quantitative computed tomography (QCT). Advantages with the former two methods are high accuracy and low cost but they are unable to separate between the cortical and the metabolically more active cancellous bone. There are also positioning errors with these two methods that lowers their precision. QCT overcomes these difficulties because of its three-dimensional ability. Another advantage with the QCT method is the ability to measure soft tissue volumes; thus it is possible to follow the results of the improved gait and mobility after the arthroplasty.

The accuracy error of QCT in radius is less than 3 percent but greater than 15 percent in the spine (Barden and Mazess 1989); this difference in accuracy of QCT is mainly due to the marrow fat in cancellous spinal bone. We checked the accuracy of our CT scanner by measuring bovine cortical bone and found an accuracy error of less than 3 percent (mean ±SD). In order to minimize the accuracy error in vivo, we expressed the results as a percentage of the corresponding values for the contralateral leg. The precision of QCT is within 1 percent in the radius and 3-6 percent in the spine (Barden and Mazess 1989). We made double measurements in five patients and found a precision of the same order.

Preoperatively, there was a small loss in bone mass of the cortical middle femur on the arthrosis side

(Table 1). Almost all of this was due to a reduction in bone volume. After 6 months we found no difference in bone mass caused by the operation. Lindberg and Nilsson (1984) measured the bone mineral content in the distal end of the femoral shaft with single-photon γ-absorptiometry in patients with coxarthrosis treated by total hip arthroplasty. They found a 10 percent net loss after a year in women, whereas men returned to their preoperative bone mineral content. In our series we found no sex differences. Kiratli et al. (1991) measured BMD of the proximal femur with dual-energy x-ray absorptiometry in patients with unilateral coxarthrosis who were operated on with a porous coated uncemented arthroplasty and found a preoperative bone loss on the arthrosis side of 17 percent in the cortex of the medial femoral neck. We have made measurements of the cortical density below the prosthesis and could not confirm their findings. One reason might be that the medial femoral neck is a more sensitive region for different forms of osteopenia. In the cancellous bone of the distal femur and proximal tibia we found an 11 and 14 percent difference in BMD preoperatively and no significant changes occurred on either side after 6 months at these locations. This latter finding is in accordance with Rüegsegger et al. (1986), who assessed the cancellous bone of the distal tibia with CT in a longitudinal study of 10 patients who had total hip arthroplasty. They found a preoperative decrease in bone mineral density of 5 percent on the diseased side. Following the operation, there was a small (1 percent) drop in bone density on both sides after 6 months that was restored after one year.

The preoperative differences are interpreted as caused by disuse on the diseased side. An alternative explanation could be an overuse of the contralateral leg, as has been described in an experimental arthritis study in the dog (Søballe et al. 1991). However, as we noted a strong restoration of the musculature on the diseased leg postoperatively, this overuse on the healthy side, if existing preoperatively, should have disappeared after 6 months. We did not note any decrease in muscle volume nor in the bone mineral on the healthy side after the operation, which supports the interpretation that the preoperative differences are caused by disuse on the diseased side.

The cancellous bone is metabolically more active than cortical bone. Wolff (1892) pointed out how changes in mechanical force act upon the size, shape and trabecular orientation of bone, form follows function. This implies that the bone adapts to functional demands by remodeling to reflect the distribution of stresses. We found no changes in the cancellous bone in the distal femur and proximal tibia after 6 months, and even after a decade of hip function the preoperative bone mass will not increase (Adolphson et al. 1992). Therefore, the osteopenic cancellous bone does not seem to be able to adapt to the increased activity after the operation.

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