



Diagnostic value of computed tomography in periprosthetic infections of the hip

Bilgisayarlı tomografinin periprotetik kalça enfeksiyonlarında tanısal değeri

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Objectives: Computed tomography (CT), despite its value in the diagnosis of musculoskeletal infections, is rarely used in periprosthetic infections of the hip because of excessive metal artifacts. This study was designed to determine the efficacy of CT in suspected cases of periprosthetic hip infections.

Patients and methods: The study included 20 patients (21 hips; 14 females, 6 males) who were examined by CT scans due to high suspicion of infections following hip arthroplasties. Ten patients had a history of infection or drainage after the first operation and 10 patients had local infection findings. The mean age of the patients was 71.1 years (range 46 to 84 years). Evaluations to seek evidence for infections included erythrocyte sedimentation rate, serum C-reactive protein level, direct radiographs of the hips, CT, aspiration in the absence of an active drainage, perioperative Gram staining and microscopic examination of surgical specimens, and postoperative microbiologic studies. Sensitivity, specificity, positive predictive and negative predictive values of each method were calculated with reference to intraoperative macroscopic findings.

Results: On the basis of intraoperative macroscopic findings, a definitive diagnosis of infection was made in 13 hips. Among the methods used, CT had the highest sensitivity (92.3%; 12/13) and negative predictive value (87.5%; 7/8), and was in the second place with its specificity (87.5%; 7/8), and positive predictive value (92.3%; 12/13).

Conclusion: Our data suggest that CT is a highly useful diagnostic tool in distinguishing periprosthetic infections of the hip from other causes that mimic an infectious state.

Key words: Diagnosis, differential; hip prosthesis/adverse effects; prosthesis failure; prosthesis-related infections/radiography; sensitivity and specificity; tomography, X-ray computed.

Amaç: Bilgisayarlı tomografi (BT), kas-iskelet sistemi enfeksiyonlarında değerli bir tanı yöntemi olmasına rağmen, metal artefaktlarının çok olması nedeniyle kalçanın periprotetik enfeksiyonlarında kullanımı nadirdir. Bu çalışmada, periprotetik kalça enfeksiyonlarından kuşku-lanılan olgularda BT'nin etkinliği araştırıldı.

Hastalar ve yöntemler: Çalışmaya, kalça artroplasti ameliyatından sonra periprotetik kalça enfeksiyonlarından kuşku-lanılan ve BT ile incelenen 20 hasta (21 kalça; 14 kadın, 6 erkek) alındı. On hastada ilk ameliyattan sonra enfeksiyon ya da drenaj öyküsü, 10 hastada ise lokal enfeksiyon işaretleri vardı. Hasta grubunun ortalama yaşı 71.1 (dağılım 46-84) idi. Enfeksiyonla ilgili bulgu aramada kullanılan yöntemler şunlardı: Eritrosit sedimentasyon hızı, serum C-reaktif protein düzeyi, düz kalça grafileri, BT, aktif drenajın olmadığı olgularda aspirasyon, ameliyat sırasında alınan örneklerde Gram boyama ve mikroskopik inceleme ve ameliyattan sonra mikrobiyolojik inceleme. Ameliyat sırasındaki makroskopik bulgular temel alınarak, kullanılan her bir yöntemin duyarlılığı, özgüllüğü, pozitif ve negatif öngörü değerleri hesaplandı.

Bulgular: Ameliyat sırasındaki makroskopik bulgular temelinde 13 kalçada enfeksiyon tanısı kondu. Kullanılan yöntemler arasında, BT için en yüksek duyarlılık (%92.3; 12/13) ve negatif öngörü (%87.5; 7/8) değerleri elde edilirken, özgüllük (%87.5; 7/8) ve pozitif öngörü değeri (%92.3; 12/13) açısından BT'nin ikinci sırada olduğu görüldü.

Sonuç: Bulgularımız, periprotetik kalça enfeksiyonlarını enfeksiyonu andıran başka nedenlerden ayırmada BT'nin yüksek ölçüde yararlı bir tanı aracı olduğunu gösterdi.

Anahtar sözcükler: Tanı, ayırıcı; kalça protezi/yan etki; protez başarısızlığı; protezle ilişkili enfeksiyon/radyografi; duyarlılık ve özgüllük; bilgisayarlı tomografi.

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Infection is one of the most frightening complications of the hip arthroplasty operations. It leads to serious obstacles to the primary aims of hip arthroplasty such as pain relief and functional improvement, and also to high rates of morbidity, mortality, and economic burden.^[1-4]

Rest pain is reported to be the main symptom of periprosthetic infections. Other symptoms and signs of infection are generally not present. Therefore, differentiation of the infection from other painful complications of arthroplasty is difficult. On the other hand, since the treatment of infection is quite different, differential diagnosis is absolutely necessary, and just like the clinical symptoms and signs, laboratory tests, radiographs, and sequential nuclear scanning do not have sufficient diagnostic specificity.^[1-9] Labeled leukocyte scintigraphy, albeit highly specific, is not routinely used because of technical difficulties and high cost.^[9] Preoperative hip aspiration is contraindicated when the infection is only superficial.^[2,10] Intraoperative Gram staining and frozen section microscopic studies do not provide evidence for a definitive diagnosis.^[1,10,11]

Computed tomography (CT) is known as an efficient diagnostic tool in musculoskeletal infections.^[7,12,13] However, its use is rare in replaced joints due to excessive artifacts of the prosthesis.^[6,14-16] In the present study, we investigated the role of CT in the differential diagnosis of patients with a suspected periprosthetic infection of the hip. Computed tomography findings of the periprosthetic soft tissues were assessed to predict the presence of infection. Moreover, findings of CT and other diagnostic methods were compared with reference to intraoperative macroscopic findings of the infection.

PATIENTS AND METHODS

Between December 2002 and December 2004, 31 hips of 28 patients were examined by CT following hip replacement, because of pain at rest or the presence of an infection that had developed after the operation. Of these, 20 patients (21 hips; 14 females, 6 males) who underwent a subsequent surgical intervention were included in the study. Eighteen patients (19 hips) had been operated on in other medical centers, with seven patients having a history of multiple operations. The mean age of the patients was 71.1 years (range 46 to 84

years). Fourteen patients had diabetes mellitus. The mean time from the last hip operation was 13 months (range 1 to 60 months). Fifteen hips were treated with cemented hemiarthroplasty (9 bipolar, 6 unipolar), four hips with total arthroplasty (2 hybrid, 2 cementless), and two hips underwent implant removal and placement of an antibiotic impregnated cement spacer. There was a history of infection or drainage after the first operation in 10 patients. There were local infection findings in 10 hips (drainage or sinus tract in 5 hips, and local increase in temperature, induration or erythema in the others).

In the first instance, hemogram, erythrocyte sedimentation rate (ESR), and serum C-reactive protein (CRP) level were determined and direct radiographs of the hips were obtained. An ESR rate of more than 20 mm/h in women and 10 mm/h in men (Test-1, ALIFAX, Italy), and a CRP level above 5 mg/l (Cobas Integra 800, Roche Diagnostics, Mannheim, Germany) were considered abnormal.

Then, CT scans of the hip region (Siemens AR Star, Erlangen, Germany) were obtained, with 5-mm slice thickness and 5-mm intervals. No intravenous contrast material was injected. The sections were obtained in soft tissue (window width 350 HU, window level 35 HU) and bone (window width 1500 HU, window level 400 HU) windows. Soft tissue scans were examined for findings suggesting joint distention, fluid-filled bursae, gas and fluid collection in muscles and perimuscular fat, muscular distention, and fluid collection or the presence of a sinus tract in the subcutaneous fat. All CT scans were evaluated by a radiologist who was blinded to the patients' clinical status.

After CT studies, aspiration was performed in 15 patients who had no active drainage. Following a careful skin preparation, aspiration was performed through a 3-mm skin incision. Using this technique, we intended to eliminate false positive results due to skin flora. In patients with signs of a superficial infection, aspiration was obtained from the suspected region, avoiding penetration of the hip. When there was no aspiration material, physiologic saline solution (2 ml) was injected and aspiration was repeated.

Operations were performed within a mean of nine days (range 1-19 days) after CT studies. In all

the patients, the previous surgical approaches (19 lateral, 2 posterior) were used. At surgery, the presence and localization of any fluid or purulent material, or necrotic and granulomatous tissue were noted. In all cases, careful debridement and irrigation were performed. Gram staining and microscopic examination of the specimen from the most suspected field of infection were performed perioperatively. Detection of a single bacterium in two separate 10x100 powered fields was considered in favor of infection. The presence of abundant polymorphonuclear leukocytes (PMNL) was accepted as supporting evidence for infection. Tissue samples of three separate regions from the acetabulum, trochanter, and femoral shaft were plated into 5% blood agar and eosin methylene blue agar plates and incubated for 48 hours in 5% CO₂ at 37 °C.

The decision about the strategy of the surgical treatment was primarily based on the macroscopic tissue findings. Postoperative antibiotic treatment was designed by a specialist of infection diseases. The type and duration of antibiotic therapy were determined considering the culture and antibiogram results of the intraoperatively taken specimens. In non-infected patients, administration of intravenous cefazolin 3x1 gr for two days was considered sufficient.

To evaluate the analytical performances of the diagnostic tests used, sensitivity, specificity, positive and negative predictive values were calculated in comparison with the intraoperative macroscopic findings as the gold standard.^[17]

RESULTS

White blood cell count was over the normal level (10,000 cell/ μ l) in eight patients. The mean ESR was 58.5 \pm 35.0 mm/h (range 3 to 119) in females and 42.8 \pm 23.0 mm/h (range 16 to 78) in males. An elevated ESR value was found in 11 of the female patients and in all of the male patients. All the patients had elevated CRP levels (mean 76.2 \pm 99.9 mg/l; range 5.2 to 398 mg/l).

Radiographically, periprosthetic radiolucencies were seen in seven cases, with no other signs of infection.

Soft tissue findings of infection were observed on CT images in 13 hips (Table I). Five hips had one, six hips had two, and two hips had three soft tissue findings (Fig. 1-3). The detection of soft tis-

TABLE I

Soft tissue findings on CT scans	
Finding	Number of hips
Increased density, fluid or gas collection in subcutaneous fat tissue	9
Distention, fluid or gas collection in muscles	11
Fluid collection in joint space or around the neck of the prosthesis	3

sue finding was considered an infection. Sensitivity, specificity, positive predictive and negative predictive values of CT was found as 92.3%, 87.5%, 92.3%, and 87.5% respectively.

Aspiration from five patients yielded enough material, whereas 10 patients required saline irrigation. Microbiological study of aspiration materials detected microorganisms in three patients.

Perioperative Gram staining and microscopic examination of surgical specimens revealed bacteria in five cases and abundant PMNL infiltration in eight cases.

On the basis of intraoperative macroscopic findings, a definitive diagnosis of infection was reached in 13 hips. Depending on the intraoperative judgment, surgical interventions included debridement in 10 hips, antibiotic impregnated cement spacer replacement in one hip, Girdlestone procedure in one hip, and single-stage revision arthroplasty in nine hips.

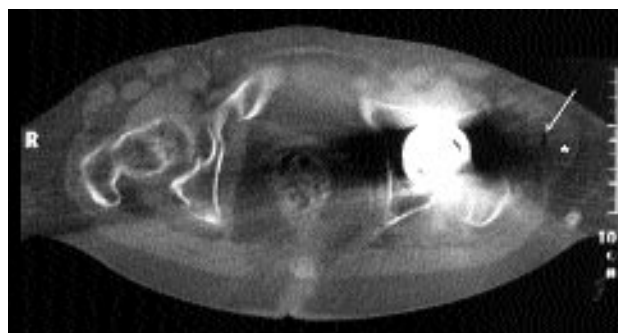


Fig. 1. Axial CT image of a patient following one month of bipolar hemiarthroplasty. There were foci of gas (arrow), fluid collection, and distention of the tensor fascia lata muscle (asterisk) in the left hip, suggesting the presence of infection. At surgery, necrotic and infected material was observed at the same localization as well as joint space. Debridement with joint dislocation was performed. The responsible microorganism was found as *Staphylococcus aureus*.

In eleven hips, microorganisms were isolated from cultures of intraoperative tissue samples, which included *Staphylococcus aureus* (n=5), *Pseudomonas spp.* (n=3), *S. epidermidis* (n=2), *Escherichia coli* (n=2), *Enterobacter* (n=1), and *Proteus mirabilis* (n=1). Three hips were affected by a mixed infection.

During postoperative hospitalization, four patients died following debridement. Patients who underwent revision arthroplasty were followed-up for a mean period of 10 months (range 3 to 21 months), during which no clinical or radiological signs of infection were observed.

Computed tomography scan of a patient who subsequently underwent antibiotic impregnated

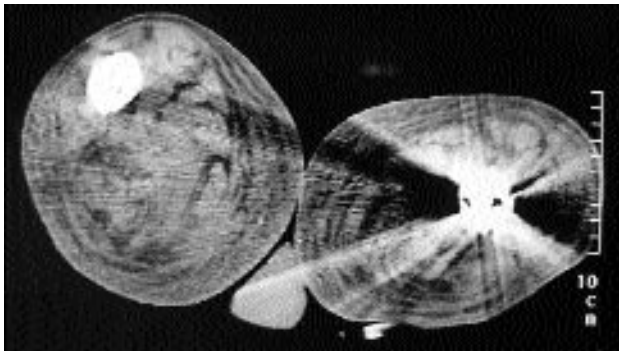


Fig. 2. Axial CT image of a patient who underwent left total hip prosthesis 60 months ago and a subsequent hemiarthroplasty of the right hip 18 months ago. Widely increased density of the perimuscular fat plans and distention of the thigh muscles with fluid collections were observed. CT findings showed bilateral widespread infection. Clinical diagnosis was acute fulminant hematogenic infection. The patient died four days after bilateral debridement. Microbiological studies revealed a mixed infection.

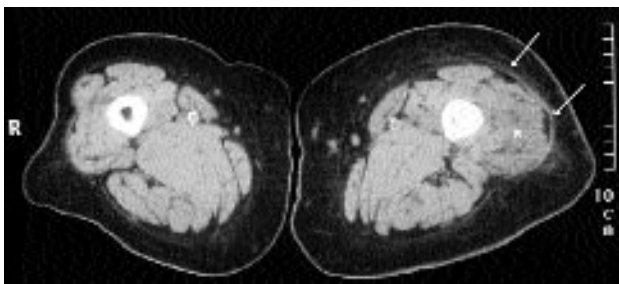


Fig. 3. Axial CT image of a patient after 15 months of left total hip arthroplasty. Distention of the vastus lateralis muscle (asterisk), fascial thickening, and increased density of the perimuscular fat around the muscle (arrow) were noted. CT diagnosis of an infection was confirmed by intraoperative findings. The responsible microorganism was found to be *S. epidermidis*.

cement spacer placement showed a fluid collection around the joint space. Intraoperatively, a serous fluid collection was noted at the same localization; however, there was no sign of infection and Gram staining also was negative. In the light of these findings, infection was ruled out and revision arthroplasty was performed. On the other hand, CT failed to show infection in another patient who, at surgery, was found to have a collection of 3-4 ml purulent material at the region of trochanteric bursae.

The analytical performance rates of all the diagnostic tools utilized are given in Table II.

DISCUSSION

Frequently used imaging methods for periprosthetic infections are direct radiography, arthrography, and sequential nuclear scanning. However, the accuracy of these methods are low.^[1,2,4,5,7,10,18] Labeled leukocyte scintigraphy has 85% to 100% specificity, but major drawbacks such as technical difficulty and high cost limit its routine use.^[9] Computed tomography is a valuable diagnostic tool in musculoskeletal infections. Using this technique, abnormalities such as soft tissue abscesses, small foci of gas, distention and inflammation of muscles, asymmetric fascial thickening, and sinus tracts can be investigated.^[12,13,19] However, the use of this technique is infrequent in patients with joint arthroplasty because of excessive beam-hardening artifacts. In a literature search, we could only find two clinical studies^[6,15] and some case reports^[14,16] about the use of CT in the diagnosis of periprosthetic infections. In both studies, CT was found to be a useful tool in the identification of soft tissue findings associated with periprosthetic infections.^[6,15] Cyteval et al.^[6] showed that a single soft tissue finding has a sensitivity of 100% and a specificity of 87% for the diagnosis of an infection. According to these authors, distention of the joint space and fluid collection in muscle and perimuscular fat are the most frequent and specific signs, respectively, with the frequency of fluid-filled bursae being the same in infected and non-infected cases. Cyteval et al.^[6] also pointed out that periprosthetic bone abnormalities detected by CT were of no value in differentiating between infections and other causes of loosening.^[6] Unlike the above-mentioned study,^[6] we used no artifact-reducing technique and this did not exert an adverse effect on the diagnostic efficacy of CT with our protocol. The most frequent finding in our series was distention of the muscle plans

TABLE II
Analytical performance values of various diagnostic tools

	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
History of infection	61.5 (8/13)	75.0 (6/8)	80.0 (8/10)	54.5 (6/11)
Local infection sign	76.9 (10/13)	100.0 (8/8)	100.0 (10/10)	72.7 (8/11)
High ESR & CRP	92.3 (12/13)	25.0 (2/8)	66.7 (12/18)	66.7 (2/3)
Direct radiograph	15.4 (2/13)	37.5 (3/8)	28.6 (2/7)	21.4 (3/14)
Computed tomography	92.3 (12/13)	87.5 (7/8)	92.3 (12/13)	87.5 (7/8)
Aspiration culture*	42.8 (3/7)	100.0 (8/8)	100.0 (3/3)	66.7 (8/12)
Perioperative Gram staining	38.5 (5/13)	100.0 (8/8)	100.0 (5/5)	50.0 (8/16)
Postoperative microbiologic study	84.6 (11/13)	100.0 (8/8)	100.0 (11/11)	80.0 (8/10)

*Aspiration was performed in 15 hips. CRP: C-reactive protein; ESR: Erythrocyte sedimentation rate.

caused by gas and fluid. We did not encounter any fluid-filled bursae.

In patients undergoing prosthesis implantation, periodical monitoring of ESR and CRP is a part of the routine follow-up to detect the development of an infection. However, in our study, elevated levels of both ESR and CRP, as a single infection marker, turned out to have a low specificity (25%). In accordance with the literature,^[1,8] we found that even the presence of a history or physical examination signs of infection were more helpful than those laboratory tests.

The definitive diagnosis of periprosthetic infections depends on the determination of the responsible microorganism.^[2,20] However, aspiration and biopsy techniques either performed preoperatively or intraoperatively have some limitations for this aim. Aspiration is a controversial issue and its diagnostic efficacy depends on the technique used.^[2,5,10,20] The aspiration technique we used had a high specificity rate (100%) but a low sensitivity (42.8%). We also found that, as reported in the literature,^[1,2,11] the Gram staining and microscopic examination of intraoperative specimens did not offer a high diagnostic value. This suggests that preoperative additional confirmative tools are still needed.

In general, the results of different diagnostic tools are combined to reach a clinical diagnosis. In this process, the power of each tool is desired to be superior to that of the other methods in a distinct field of analytical performance.^[17] In our study, the analytical performance of CT was compared to those of other diagnostic tools. Based on our findings favoring superior performance of CT in all the fields, we suggest that CT be added to the algo-

rithm of the evaluation procedure performed for the differential diagnosis of periprosthetic infections. Moreover, as exclusion of the possibility of an infection is the most important part in choosing between treatment options in failed hip arthroplasties,^[20] CT gains more importance with its highest negative predictive value.

One of the pitfalls of this study could be the high rate of suspicion of infection in the study group. Understandably, this fact has the same effect on the analytical performances of all the tests utilized. Another pitfall is the relatively high frequency of patients presenting with an acute fulminant type^[2,3] infection. Although the diagnosis is relatively easy in this type of infection, differentiation between superficial and deep infections is the most challenging issue. For superficial infections, hip aspiration is contraindicated, while deep infections require dislocation and debridement of the joint.^[2] This type of infection can easily be detected by CT with demonstration of a purulent fluid collection, this making CT a valuable diagnostic tool in decision-making.

Doubtlessly, search endeavors should be encouraged to find new tools to facilitate the differential diagnosis of periprosthetic infections or to help decision-making in the surgical strategy. Nevertheless, CT, whose value has been detracted due to excessive artifacts, may prove to be useful in this field.

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