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The value of 18-FDG PET/CT in the diagnosis and management of implant-related infections of the tibia: A case series

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ABSTRACT

Background: Positron emission tomography (PET) combined with Computerised Tomography (CT) is gaining ground in clinical settings due to its added value of combined metabolic and anatomical imaging. PET/CT has shown promising results in diagnosing both acute and chronic infection of the axial and appendicular skeleton. PET imaging has an advantage in patients with metallic implants because FDG uptake, in contrast to magnetic resonance imaging (MRI) and standard computed tomography (CT), is not hampered by metallic artifacts. The role of PET/CT in the evaluation of implant-related infections involving the tibia in particular has not been thoroughly studied.
Purpose: To investigate the usefulness of 18-FDG PET/CT in the diagnosis and treatment of implant-related infections of the tibia following osteosynthesis.
Methods: We reviewed 10 patients who underwent internal fixation to the tibia following trauma (4 open fractures, 6 closed fractures) and presented later with clinical signs of a possible implant-related infection. In evaluating the patients we used standard work-up methods (standard radiographs, lab tests) as well as advanced imaging techniques (PET/CT) in order to confirm the diagnosis and decide upon the preferred treatment. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were then calculated for PET/CTs ability to predict presence of infection using intraoperative cultures as the gold standard.
Results: PET/CT validated our working diagnosis 9 out of 10 patients. In particular, it helped distinguish between: infected nonunion ($n = 4$), aseptic nonunion ($n = 1$), soft tissue infection ($n = 2$) and chronic osteomyelitis ($n = 3$). The overall sensitivity and specificity of PET/CT for identifying an osseous infection were 85.7% and 100%, respectively. The PPV and NPV were 100% and 75%, respectively.
Conclusion: PET/CT is a promising imaging modality that can aid in the work up of patients with suspected implant-related infections of the tibia following osteosynthesis, and may be used as a supportive measure in clinical decision making.

Background

Post-surgical infection is one of the most prevalent and challenging complications faced by orthopaedic surgeons and patients. Infections associated with fracture-fixation devices are classified into those with early (less than 2 weeks), delayed (2–10 weeks), and late onset (more than 10 weeks) [1]. The most common microorganisms causing implant-associated infections are Staphylococcus aureus and Coagulase-negative staphylococci [1]. The implant material, shape, and size are all factors that affect the nature of the reactive surface available for bacterial adherence [2].

Establishing the diagnosis of implant-related infections and differentiating soft tissue infection, bone infection and fracture non-union is often difficult with the current imaging techniques,

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especially if normal bone anatomy has been compromised by previous infections or bone regeneration. No single routinely used test is sufficiently accurate to diagnose infection in these conditions. Therefore, a combination of clinical, laboratory, histopathology, microbiology, and imaging studies is usually required.

Magnetic resonance imaging (MRI) is currently the most widely used imaging method and it provides anatomical details as well as visualising abnormalities of bone marrow, joints and surrounding soft tissues with high sensitivity [3].

Yet, FDG PET schintigraphy is potentially superior to MRI and CT, since they are not substantially impeded by implant-associated artefacts or tissue edema. This quality may improve the image interpretation in trauma patients with osteosynthetic metallic implants [4]. In comparison with PET imaging alone, combined PET/CT imaging is supposed to have further advantages in providing additional anatomical information and characterisation of the infectious lesion, which is important for surgical planning and execution [5].

Managing post-operative infections in fractures treated with open reduction and internal fixation is an ongoing dilemma. The nature of the surgical intervention in patients with infected fracture-fixation devices depends on the type of device, the presence or absence of bone union, and the patient's underlying condition [6]. It is widely recognised that deep infections cannot be cured in the presence of hardware [7]. However, premature hardware removal before fracture union had occurred should not be routinely warranted since fracture stability is crucial for fracture union especially in face of an ongoing infection [2,6–8].

Trebse et al. reported good outcomes of hardware retention and the use of antibiotics in well-fixed fractures in patients with a short-term infection without a sinus tract, where a known pathogen was isolated [9]. Currently, there are no evidence-based guidelines to dictate whether hardware should be removed or retained in the presence of an acute infection. Either fracture stabilisation or healing is optimised through the retention of hardware, or the hardware is removed to give the patient the best chance to clear the infectious process; each choice has its own potential downsides [10].

Fractures of the tibia present a clinical challenge that requires special attention. Due to their location and relatively scarce medial soft tissue envelope, the tibia is exposed to frequent injury. Consequently, it is the most commonly fractured long bone [11], frequently ensuing in open fractures more commonly than in any other major long bone. In addition, the blood supply to the tibia is more precarious than that of bones enclosed by heavy muscles, resulting in higher rates of delayed union, nonunion, and infection [11]. Not surprisingly, the tibia is the most common site of posttraumatic osteomyelitis and infected non-union [12], which entails considerable morbidity and can sometimes be even limb-threatening [12].

The purpose of this study is to retrospectively evaluate the diagnostic value of 18-FDG PET/CT in trauma patients with suspected implant-related infections of the tibia, and to assess the clinical influence of PET/CT on the management of these infections.

Materials and methods

The study was approved by our institutional ethics committee. Patients who were eligible for inclusion were retrospectively identified. Inclusion criteria included cases suspected of deep infection following osteosynthesis for fractures of the tibia, who were treated operatively and had a PET/CT examination prior to their surgery.

Between October 2010 and November 2013, 11 limited lower legs 18F-FDG PET/CT scans were obtained in 10 patients with a history of trauma involving the tibia for an evaluation of a suspected post-operative infection.

All patients included were referred to PET/CT by a single Orthopedic Surgery department in a tertiary urban trauma center.

Eight males and two female patients were included in the study (age range 18–53 years, mean age 35 years). The patients were treated in our hospital for their initial trauma which included five closed and four open fractures (Table 1). Seven of the patients sustained a fracture of the tibial shaft, two presented with fractures of the proximal tibia and one had an intra-articular fracture of the distal tibia (a Pilon fracture).

Fractures were classified according to the AO classification [13]. In addition, Gustilo classification [14] was used to describe open fractures. All patients were treated by one of the following treatments: External fixation, open reduction and internal fixation with plating or closed reduction and internal fixation with an intramedullary nail according to the fracture pattern and soft tissue condition (Table 1). All external fixations were converted to internal fixation when their soft tissues injury subsided. In addition, all patients with open fractures underwent irrigation and debridement and were routinely treated with IV antibiotics for three days after their initial fracture fixation.

After discharge, the patients were followed in our trauma outpatient clinic. The status of osseous union and the presence of infection were recorded at the time of their follow-up. Infections were classified according to Trampuz et al. [1] into those with early (less than 2 weeks), delayed (2–10 weeks), and late onset hardware related infection (more than 10 weeks).

As part of their work up, all patients had undergone routine clinical and laboratory studies for the evaluation of implant-related infections including clinical examination, C Reactive

Table 1
Patient demographics, comorbidities, mechanism of injury and fracture classification.

Case	Gender	Age (years)	Underlying conditions	Mechanism	Fracture classification (AO)	Open/closed	Initial surgical treatment
1	M	35	Ethylism	Fall	43-B2	Closed	Plating
2	F	34	–	Fall	42-A3	Closed	IMN
3	M	52	Sarcoidosis	MVA	41-C3	Closed	Ex-Fix → Plating
4	M	21	–	Fall from height	42-A3	Open Gustilo 3A	Ex-Fix → IMN
5	M	18	–	MVA	42-A2	Open Gustilo 3A	Ex-Fix → IMN
6	M	28	Morbid Obesity, BMI > 35	MVA	42-B2	Open Gustilo 3A	IMN
7	M	53	–	Fall from height	41-C2	Closed	Ex-Fix → ORIF with plating
8	M	27	–	GSW	42-B3	Open Gustilo 3B	IMN
9	M	47	–	Fall	42-A1	Closed	Plating
10	F	72	Chronic renal failure, Hypothyroidism	Fall	43-B2	Closed	Plating

M: male, F: female, MVA: motor vehicle accident, IMN: intramedullary nailing, GSW: gunshot wound.