

Evaluation of pelvic ring injuries using SPECT/CT

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Received: 17 April 2014 / Revised: 9 July 2014 / Accepted: 25 July 2014 / Published online: 12 August 2014
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Abstract

Objective The incidence of pelvic fractures is relatively low compared with other fracture locations. The low incidence is in great contrast to the high morbidity and mortality. Particularly in the elderly, with apparently isolated fractures of the pubic rami, these observations are believed to be due to additional occult lesions of the posterior pelvic ring. In these cases diagnosis cannot be established by conventional imaging alone and SPECT/CT is considered as a diagnostic adjunct. The aim of this study was to assess concomitant bony or soft tissue lesions within the pelvic ring in a population of patients with fractures of the anterior elements.

Materials and methods In all patients with no obvious lesions of the posterior pelvic ring on X-rays and CT or with suspicious but inconclusive findings on CT an additional SPECT/CT was carried out in a non-acute setting within 3 days of the trauma.

Results In all cases additional lesions within the pelvic ring were found. Most lesions were vertical sacral fractures, followed by transverse fractures, one non-dislocated fracture of the acetabulum on the side of the pubic rami fracture, and one post-traumatic dilatation of the sacroiliac joint with increased tracer uptake.

Conclusion According to our results after SPECT/CT all patients with pubic rami fracture suffered additional lesions, none detectable previously by X-ray or CT, within the pelvic ring. In this context SPECT/CT has proved to be very helpful in the clinical routine to visualize occult fractures and instability within the sacroiliac joint.

Keywords Pelvic ring · Pubic rami fracture · SPECT/CT

Introduction

Pelvic injuries are relatively rare and occur in 2–8 % of all fractures of the human body [1, 2]. In young patients they are the result of massive and commonly life-threatening external forces, as can be encountered following motorbike accidents or falls from great heights. In these major pelvic traumas, injuries at more than one site within the pelvic ring are common.

In contrast, apparently isolated fractures of the pubic rami occur frequently in elderly patients with osteoporosis and can be classified as minor injuries. However, in many cases they are associated with chronic pain, recurrent pain, increase in morbidity and mortality as well as a decrease in the quality of life [3–5]. In a prospective study Hill et al. showed that patients with a fracture of the pubic ramus had a significantly worse survival rate than an age-matched cohort from the general population [3]. Others found significantly higher morbidity and mortality among patients with pubic rami fractures, comparable with the conditions after femoral neck fractures [5].

These observations are believed to be due to additional occult lesions of the posterior pelvic ring, which are often missed during diagnostic workup [3, 5, 6]. With the use of scintigraphy, Gertzbein and Chenoweth were able to demonstrate that apparently isolated fractures of the pubic rami were in fact associated with additional osseous lesions to the posterior elements [7]. Other studies subsequently confirmed this

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finding and stated that given the adequate imaging modality, an additional lesion in seemingly isolated fractures of the pubic rami can be found in almost every case [8, 9]. In addition to CT, other suitable imaging modalities include MRI and SPECT/CT. Using the latter, it is not only possible to detect a fracture, but also to evaluate the age of the lesion. Therefore, SPECT/CT is a helpful alternative to MRI, especially in patients where MRI is not practicable because of a pacemaker or claustrophobia, for instance, or when patients have pain in a prolonged lying position and motion artefacts lead to inconclusive results. Furthermore, SPECT/CT can detect reactive changes within the surrounding soft tissue that may additionally be causative of pain and that can be visualized.

Knowledge of concomitant lesions of the posterior pelvic ring is important in planning therapeutic concepts such as partial weight-bearing on one side or even percutaneous fixation of the posterior pelvic ring in order to reduce the increased morbidity and mortality.

The aim of this study was to assess concomitant bony or soft tissue lesions within the pelvic ring in a population of patients with fractures of the anterior elements. We hypothesised that in all cases—in young patients with high velocity trauma as well as in older patients with osteoporotic fractures—a lesion of the posterior elements can be detected and evaluated using SPECT/CT too.

Patients and methods

All patients with a suspected pelvic ring injury due to trauma mechanism or complaints without obvious signs of a posterior involvement on the initial conventional X-rays performed in anteroposterior, inlet and outlet view (Multix with an Optitop 150/40/80 tube; Siemens, Munich, Germany; 71–90 kV, 25–40 mAs) undergo a CT (Somatom Definition; Siemens, Munich, Germany; 128-slice dual-source CT; 120 kV, 210 mAs) for evaluation of the posterior pelvic ring. Subsequently, we performed in the context of this study in cases without obvious lesions of the posterior pelvic ring on either of the imaging modalities, or with suspicious but inconclusive findings on the CT, an additional SPECT/CT in a non-acute setting within 3 days of the trauma.

Following these inclusion criteria 13 patients (9 female, 4 male) with one or more fractures of the pubic rami and without obvious lesions of the posterior pelvic ring on conventional X-rays and CTs were included ($n=9$) within the observation period of 7 months. Patients with inconclusive findings on CT were also enclosed ($n=4$). The mean age was 63 years (range 21–87 years). The median age of female patients was considerably lower at 62 years in contrast to 67 years in men. The patients were not evaluated for osteoporosis or other underlying diseases.

These SPECT/CTs were conducted on a hybrid SPECT/CT system with a built-in CT component (Discovery NM/CT 670; GE Healthcare, Waukesha, WI, USA) after injection of a standardized activity of 650–700 MBq ^{99m}Tc -DPD (Technetium-99^m-3,3-diphosphono-1,2-propanedicarboxylic acid, TeceosTM; IBA Molecular, Louvain-la-Neuve, Belgium).

Planar perfusion-phase, early-phase (blood pool), and late-phase spot images, as well as a SPECT/CT datasets (late phase) of the pelvis, were acquired. The perfusion phase images were acquired directly after the injection (while the patient was already on the table) for 3 min (36 images, 5 s per image, matrix 128×128 mm, field of view [FOV] 40 cm). Early-phase images were then performed for approximately 7 min for 500 kilo counts (matrix 256×256 mm, FOV 40 cm). After 3 h, late-phase images (same protocol as for early-phase images), SPECT (matrix 512×512 mm, axial range 40 cm, collimators adapted to body contour) and CT images (matrix 512×512 mm, FOV 50 cm, 120 kV, 100–440 mAs [automated dose modulation], rotation time 0.5 s, slice thickness 1.25 mm) were acquired.

The CT images were reconstructed iteratively using AsIRTM (Adaptive statistical Iterative Reconstruction, GE Healthcare) with a slice thickness of 1.25 mm in all three planes. SPECT and CT images were fused by an automated software algorithm on a dedicated diagnostic workstation (Advantage Workstation 4.5; GE Healthcare).

Uptake on SPECT/CT was graded semiquantitatively. No uptake was defined as scintigraphic signal intensity not higher than the background signal. Normal uptake was defined as scintigraphic signal intensity equal to the physiological signal intensity of the neighbouring normal bone tissue. Low uptake was defined as signal intensity equal to or slightly higher than the physiological bone marrow signal intensity in the anterior superior iliac spine. High uptake was defined as markedly increased signal intensity compared with the physiological bone marrow signal intensity in the anterior superior iliac spine. A fracture was suspected in cases with a low or a high uptake. In those cases the simultaneously implemented CTs were evaluated again, as well as the patient, for clinical signs of fracture. The local ethics committee approved this investigation.

Results

In all cases additional lesions within the pelvic ring could be visualized by SPECT/CT (Table 1): in one case a non-displaced/-dislocated fracture of the acetabulum on the side of the pubic rami fracture could be visualized and in one patient a posttraumatic dilatation of the sacroiliac joint with increased tracer-uptake and with ligament tears in addition to a vertical sacral fracture (Fig. 1) was found. In all remaining

Table 1 Patient demographics, type of anterior pelvic ring injury, and missed posterior lesions

Patient number	Age	Gender	PRF	Missed posterior lesion
1	49	Male	Bilateral	Vertical SF
2	73	Male	Unilateral	Vertical SF
3	81	Male	Bilateral	Vertical SF
4	59	Male	Unilateral	Vertical SF
5	41	Female	Unilateral	Vertical SF
6	87	Female	Bilateral	Vertical and transverse SF
7	21	Female	Bilateral	Ligamentous lesion
8	64	Female	Bilateral	Vertical SF
9	44	Female	Unilateral	Vertical SF
10	66	Female	Unilateral	Vertical SF
11	84	Female	Unilateral	Non-displaced acetabular fracture
12	67	Female	Unilateral	Vertical SF
13	84	Female	Bilateral	Vertical and transverse SF

PRF pubic rami fracture; SF sacral fracture

cases, even in those with initially normal CT-scan, a further fracture of the posterior pelvic ring could be detected (Fig. 2). In particular, these were vertical sacral fractures and in two cases an additional transverse fracture.

Discussion

To the best of our knowledge this is one of the first reports about SPECT/CT being integrated into the clinical workup of

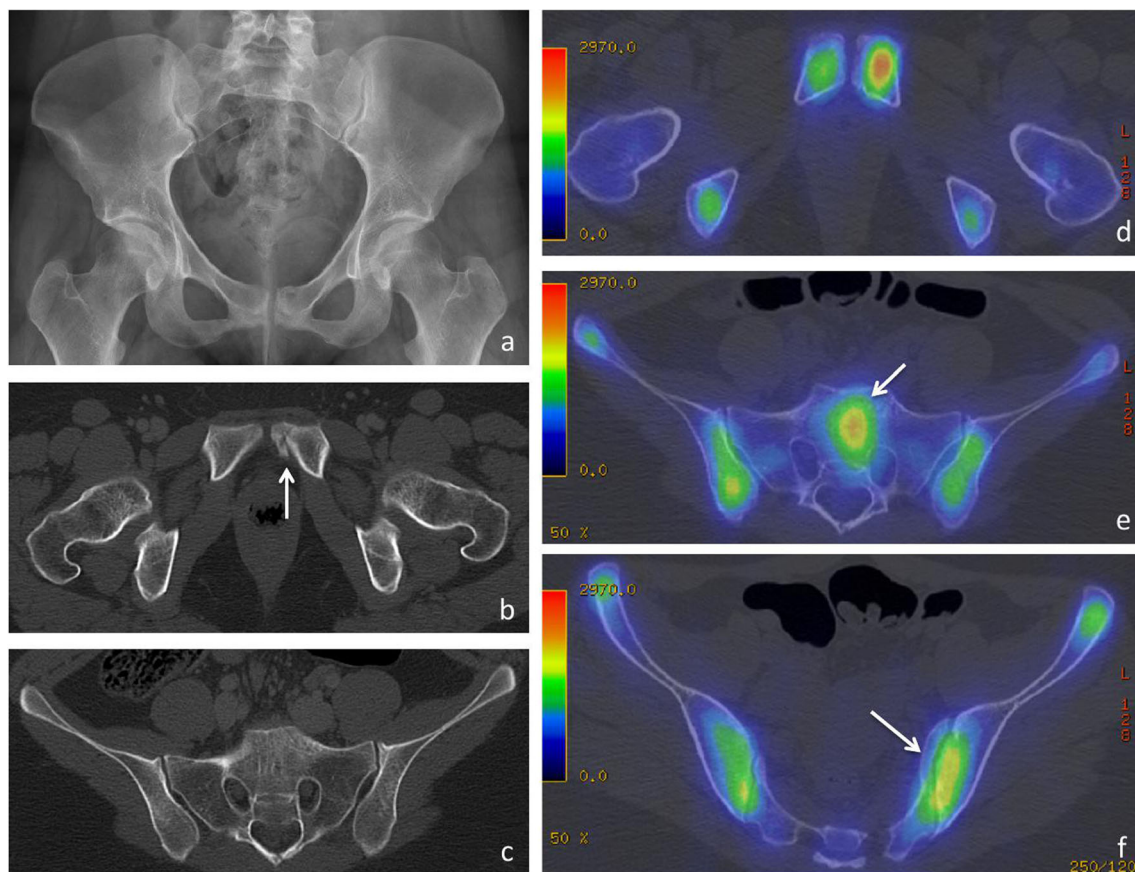


Fig. 1 a–c A 21-year-old patient after a car accident. **a, b, d** Fracture of the pubic ramus (arrow b) and the anterior column of the acetabulum. **b, c** The vertical sacral fracture cannot be satisfactorily visualized by CT. **e** Increased tracer uptake alongside vertical sacral fractures (arrow e) and **f** additional focal uptake with suspected post-traumatic extension and

instability within the sacroiliac joint (arrow f) due to ligamentous lesions. **b, c** The vertical sacral fracture cannot be satisfactorily visualized by CT. **a** Anteroposterior X-ray; **b, c** axial CT; **d–f** axial SPECT/CT

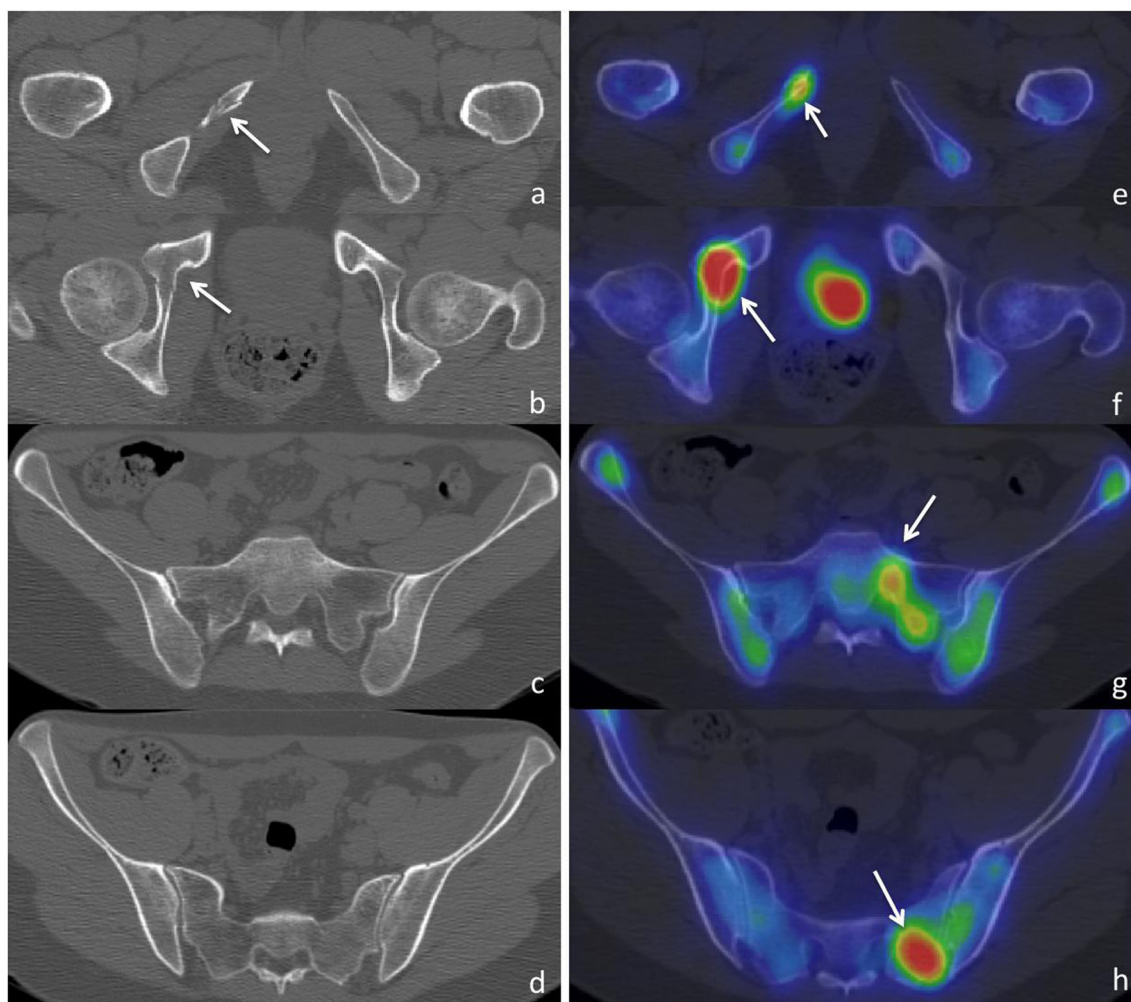


Fig. 2 **a–c** A 41-year-old patient after a bicycle accident. **a, e** Fracture of the lower pubic ramus (*arrow*) and **b, f** the anterior column of the acetabulum (*arrow*). **c, d** On CT there are no signs of posterior

involvement. **g, h** SPECT/CT visualized increased tracer uptake along a non-displaced vertical sacral fracture (*arrow*). **a–d** axial CT; **e–h** axial SPECT/CT

traumatic pelvic ring fractures. We showed that SPECT/CT, even in such a non-acute setting, is a valuable tool for providing an accurate diagnosis of additional traumatic lesions of the pelvic ring not detectable by conventional imaging, and therefore may be considered for integration into the clinical workup of those patients.

Injuries of the pelvic ring are relatively rare compared with other fracture locations. The low incidence is in great contrast to the high mortality rate of 5–20 %. Some studies even report mortality as high as 60 % [10–14]. The predominantly unstable pelvic injuries in young patients—commonly encountered following motorbike accidents or falls from a great height—can easily be diagnosed by means of a conventional X-ray or CT.

In contrast, fractures within a low-energy trauma are frequently missed. Usually, they are attributed to the elderly and affect the pubic rami and sacrum [15]. Depending on the direction of the acting external force, predominantly

ligamentous or osseous lesions occur, which affect the integrity of the pelvic ring.

In particular, fractures of the pubic rami in the elderly patient population may be underestimated considering their substantial morbidity and mortality [3–5]. Commonly, rehabilitation of such patients is difficult and takes a long time. This is believed to be due to additional occult lesions of the posterior pelvic ring [3, 5, 6]. Knowledge of the involvement of the latter structures is important in planning further therapeutic concepts, such as partial weight-bearing on the affected side, or even percutaneous fixation of the posterior pelvic ring.

The fact that anterior lesions of the pelvic ring must be associated with posterior ones was first mentioned by Pennal et al. [16]. They suggested that a disruption of the integrity of the pelvic ring at one place must lead to discontinuity at another. Some years later Gertzbein and Chenoweth were able to confirm this hypothesis using planar scintigraphy [7]. Other studies postulated that, given an adequate imaging modality,

an additional lesion within the pelvic ring can be found in almost every case [8, 9].

Because of the higher sensitivity and specificity of CT, X-ray imaging has lost its impact in identifying and classifying pelvic ring injuries [17–20]. In a previous investigation we were able to demonstrate involvement of the posterior elements in 96.8 % of all 177 examined patients by using CT. Only in 4 patients was no posterior involvement found [9]. However, the CT in the latter study was carried out later during the course of the disease or rehabilitation, while in the study presented here the SPECT/CT was always performed in a non-acute setting and always in patients in whom no second pelvic ring fracture had been identifiable with conventional imaging previously.

While CT is certainly the major imaging modality for traumatic lesions these days, it has its limitations compared with multi-modality imaging such as SPECT/CT. Low-force fractures (as in this study explained above), especially of the posterior pelvic ring, are very often not fractures in the common sense, but rather “infractures”. Thus, this interposition of trabecular structure (e.g. in classical sacral fractures) is almost invisible on CT.

Another reason for missing posterior involvement is the spontaneous repositioning of fractured fragments. For detection of these lesions and of occult fractures SPECT/CT is another suitable imaging modality as bone metabolism is locally increased and perifocal haematoma, necrosis and calcification may occur. The resulting phosphate complex then bonds with the ^{99m}Tc -DPD and the subtle lesion can be visualized [21, 22]. In those cases, the additional metabolic component represents the major difference in detection of those additional pelvic ring lesions. Furthermore, it is possible to evaluate the rough age of the fracture, post-traumatic changes of the joint and reactive changes within the surrounding soft tissue as causes of pain. However, the morphological CT component is provided within this examination, e.g. for evaluation of other fractures and possible complications.

Because of these properties we performed additional SPECT/CT in patients with no obvious lesions of the posterior pelvic ring on X-rays and CT, and in those with suspected but inconclusive findings on a CT where pelvic ring injuries could be suspected owing to clinical symptoms or the trauma mechanism. The aim was to confirm the hypothesis that every fracture at one place in the pelvic ring is associated with further bony or ligamentous lesions at another position.

According to our results after SPECT/CT all patients with a pubic rami fracture suffered additional lesions within the pelvic ring that had not been detected previously. Apart from one patient with an additional fracture of the acetabulum, all concomitant lesions affect the posterior pelvic ring and fractures of the sacrum clearly dominate (Fig. 2).

These results are in line with previous investigations [23, 24]. However, their reported percentage of sacral fractures in

the case of pelvic ring injuries was only around 18–30 % [23, 24]. Other studies described that only in every second case are fractures of the pubic rami combined with lesions of the sacroiliac joint, the sacrum and the ilium [25, 26].

The differences can be attributed to the fact that the previous studies mentioned are older and therefore being conducted with CTs of inferior image resolution or increased slice thickness. In this present study CT images were reconstructed with a slice thickness of 1.25 mm in all three planes.

Further, using hybrid SPECT/CT, occult lesions of the sacrum could be detected by increased local bone uptake due to increased osteoclast activity, such as happened in 11 patients in the present cohort. A suspected ligamentous injury occurred in a young patient owing to reactive changes within the surrounding soft tissue and extension of the sacroiliac joint (Fig. 1). Therefore, we agree to the statement made by Isler and Ganz, that using the appropriate imaging modality in patients with a pubic rami fracture, additional lesions within the pelvic ring, especially of the posterior parts, could be detected [8]. In this context SPECT/CT has proved to be superior to CT following this study. Of course, our recommendation is not to perform SPECT/CT in every patient with a suspected pelvic ring injury. However, in cases with indeterminate CT findings or prolonged or impossible mobilisation because of pain, SPECT/CT can help to visualize occult fractures and instability within the sacroiliac joint due to ligamentous lesions. Therefore, SPECT/CT is a helpful alternative to MRI, especially, as mentioned before, in patients where MRI is not practicable because of a pacemaker or claustrophobia, or motion artefacts leading to inconclusive results.

As a limitation of our study we first have to mention the low sample size, which makes further investigations necessary in order to prove our results in a larger patient population and to optimize statistical power. Consequently, it is not possible to determine the exact fraction of patients with combined anterior and posterior pelvic ring fractures. Furthermore, evaluating the exact fraction of patients is not possible, as we have not registered the total number of patients undergoing imaging of pelvic injuries during the observation period. Last, bone density was not evaluated in this investigation. Concerning this matter, further investigations are need as occult pelvic fractures are more frequent in osteopaenic/osteoporotic bone.

However, being aware of our results and those of previous investigations, we conclude that nearly every fracture of the pubic rami is associated with a concomitant lesion within the pelvic ring, especially of the posterior parts [8, 9, 16]. In addition to CT and MRI, SPECT/CT has proved to be very helpful in clinical routine in visualizing occult fractures and

instability—that had not been detectable with conventional imaging previously—involving the sacroiliac joint and ligamentous lesions.

Disclosures Patrick Veit-Haibach received IIS grants from Bayer Healthcare and Siemens Medical Solutions and speakers fees from GE Healthcare.

Conflict of interest No other conflicts of interest exist.

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