

Accuracy of bone SPECT/CT for identifying hardware loosening in patients who underwent lumbar fusion with pedicle screws

Hendrah Hudyana^{1,3}, Alex Maes^{1,3}, Thierry Vandenberghe², Luc Fidlers², Mike Sathekge⁴, Daniel Nicolai¹, Christophe Van de Wiele^{1,5*}

Abstract

Background The aim of this retrospective study was to evaluate the accuracy of bone SPECT (single photon emission computed tomography)/CT (computed tomography) in diagnosing loosening of fixation material in patients with recurrent or persistent back pain that underwent lumbar arthrodesis with pedicle screws using surgery and clinical follow-up as gold standard. **Methods** A total of 48 patients (median age 49 years, range 21–81 years; 17 men) who had undergone lumbar spinal arthrodesis were included in this retrospective analysis. SPECT/CT results were compared to the gold standard of surgical evaluation or clinical follow-up. Positive SPECT/CT results were considered true positives if findings were confirmed by surgery or if clinical and other examinations were completely consistent with the positive SPECT/CT finding. They were considered false positives if surgical evaluation did not find any loose pedicle screws or if symptoms subsided with non-surgical therapy. Negative SPECT/CT scans were considered true negatives if symptoms either improved without surgical intervention or remained stable over a minimum follow-up period of 6 months. Negative SPECT/CT scans were determined to be false negatives if surgery was still required and loosening of material was found.

Results The median length of time from primary surgery to bone SPECT/CT referral was 29.5 months (range 12–192 months). Median follow-up was 18 months (range 6–57) for subjects who did not undergo surgery. Thirteen of the 48 patients were found to be positive for loosening on bone SPECT/CT. Surgical evaluation (8 patients) and clinical follow-up (5 patients) showed that bone SPECT/CT correctly predicted loosening in 9 of 13 patients, while it falsely diagnosed loosening in 4 patients. Of 35 negative bone SPECT/CT scans, 12 were surgically confirmed. In 18 patients, bone SPECT/CT revealed lesions that could provide an alternative explanation for the symptoms of pain (active facet degeneration in 14 patients, and disc and sacroiliac osteodegeneration in 7 patients and 1 patient, respectively). Overall sensitivity and specificity for the detection of loosening were 100 % and 89.7 %, respectively. The positive and negative predictive values were 69 % and 100 %, respectively.

Conclusions This retrospective analysis suggests that bone SPECT/CT bone is a highly sensitive and specific tool for the exclusion of screw loosening in patients who present with recurrent low back pain after having undergone lumbar arthrodesis. In addition, it can identify other potential causes of recurrent low back pain in this patient population.

*Correspondence author: Christophe Van de Wiele
christophe.vandewiele@ugent.be

¹ Department of Nuclear Medicine, AZ Groeninge, Kortrijk, Belgium

² Department of Neurosurgery, AZ Groeninge, Kortrijk, Belgium

³ Department of Morphology and Medical Imaging, University Hospital Leuven, Leuven, Belgium

Pretoria, South-Africa

⁵ Department of Radiology and Nuclear Medicine, University Ghent, Ghent, Belgium

Keywords Bone SPECT-CT · Lumbar fusion · Pedicle screws · Loosening

Introduction

Spinal arthrodesis involving the placement of metallic screws, rods, plates or cages is increasingly performed to improve spinal stability in a variety of spine pathologies, including disc degeneration, spinal stenosis and spondylolisthesis [1].

Following spinal arthrodesis, a significant proportion of patients experience persistent or recurrent pain, with recent studies putting the surgical re-intervention rates around 14 % over 4-year follow-up and 19 % with 11-year follow-up [1, 2]. As patient outcome following surgical re-intervention is poorer than that with primary surgery, the accurate identification of patients who might benefit from re-intervention is critical.

Patients in whom re-intervention may be beneficial include those presenting with metallic loosening, vertebral non-union, incomplete growth of bone grafts, or infection. Standard evaluation of patients experiencing persistent or recurrent pain following spinal arthrodesis includes clinical examination and conventional imaging using plain radiography or CT. Occasionally, MR imaging may also be performed [3]. Conventional imaging is performed for evaluation of hardware position (changes), hardware failure, fusion evolution, alignment of the vertebrae, possible pseudarthrosis and hardware loosening. Loosening on plain radiography and CT is defined as a lucency rim around the hardware that exceeds 2 mm or that has increased in size [3, 4]. Because of the presence of non-specific postoperative changes and metal-related imaging artefacts, interpretation of CT images is often not straightforward and is inconclusive. Thus, whether surgical re-intervention is indicated based on conventional imaging may prove difficult to ascertain [5, 6].

Bone scintigraphy with SPECT (single-photon emission computed tomography) has been suggested as a useful tool for evaluation of patients with persistent back pain after lumbar surgery, as it is not affected by metallic devices [7–9]. In addition, the advent of hybrid imaging, with the combination of SPECT and CT, has significantly improved the anatomical localisation of abnormalities found on SPECT imaging, dramatically improving its specificity [10].

In this retrospective study, we report on the usefulness of SPECT/CT imaging for identifying loosening in a series of 48 patients presenting with recurrent or persistent back pain after having undergone lumbar fusion with pedicle screws. SPECT/CT findings were compared to results obtained from surgical re-intervention and clinical follow-up.

Patients and methods

Patients

We conducted a retrospective evaluation of all bone SPECT/CT scans performed in patients with lumbar fusion in our centre between January 2008 and December 2012 ($n=59$).

Patients who had undergone lumbar spinal fusion but were not specifically referred for evaluation of the fusion material (e.g. evaluation of another lumbar level or for possible vertebral fracture) were excluded ($n=5$). Six additional patients

were excluded because of insufficient available information on outcome (lost to follow-up).

This left 48 patients (17 men, 31 women) for inclusion (see Table 1). The median age was 49 years (range 21–81 years), and the median time from (primary) surgery to SPECT/CT was 29.5 months (range 12–192 months). The indications for primary surgery are listed in Table 1.

Patients were evaluated clinically and radiographically after surgery until the surgeon decided to refer them for bone SPECT/CT due to persistent or recurrent pain. The median time between surgery and first symptoms was 9 months (range 0–156 months).

Methods

Three hours after intravenous injection of 740 MBq technetium-99m hydroxymethylene diphosphonate (Tc-99m HDP), planar bone scanning of the whole body was performed, followed by SPECT imaging, as well as low-dose CT. Imaging was performed on a GE Infinia Hawkeye (GE Healthcare, Milwaukee, WI, USA) gamma camera (two detectors equipped with low-energy/high-resolution collimators, 128×128 matrix, 180° rotation with 60 projections of 20 s). The CT scan consisted of low-dose CT (8-mm slice thickness).

Scans were evaluated by two experienced nuclear medicine specialists. Acquired images were carefully evaluated for misalignment between SPECT and CT data and, if necessary, were realigned using commercially available software. Lesions indicative of loosening on SPECT were defined as markedly elevated activity (compared to background) at typical anatomical sites of hardware loosening: the ends of the pedicle screws, screw shafts, and entry points of the screws. SPECT was evaluated on non-attenuated images to correct for attenuation artefacts caused by the metal hardware. Differences in interpretation were resolved by consensus.

The SPECT/CT results were compared with the gold standard of surgical evaluation of the stability of the fusion material when applicable. If no surgical evaluation was performed, results were compared with clinical follow-up. Positive SPECT/CT results were considered as true positives if findings were

Table 1 Patient demographics

Number of patients (men/women)	48 (17/31)
Median age (years)	49 (21–81)
Median interval between surgery and SPECT/CT (months)	29.5 (11–192)
Median follow-up (months)	18 (1–57)
Indication of primary surgery	
Lysis	4 (8.3 %)
Degenerative	44 (91.7 %)

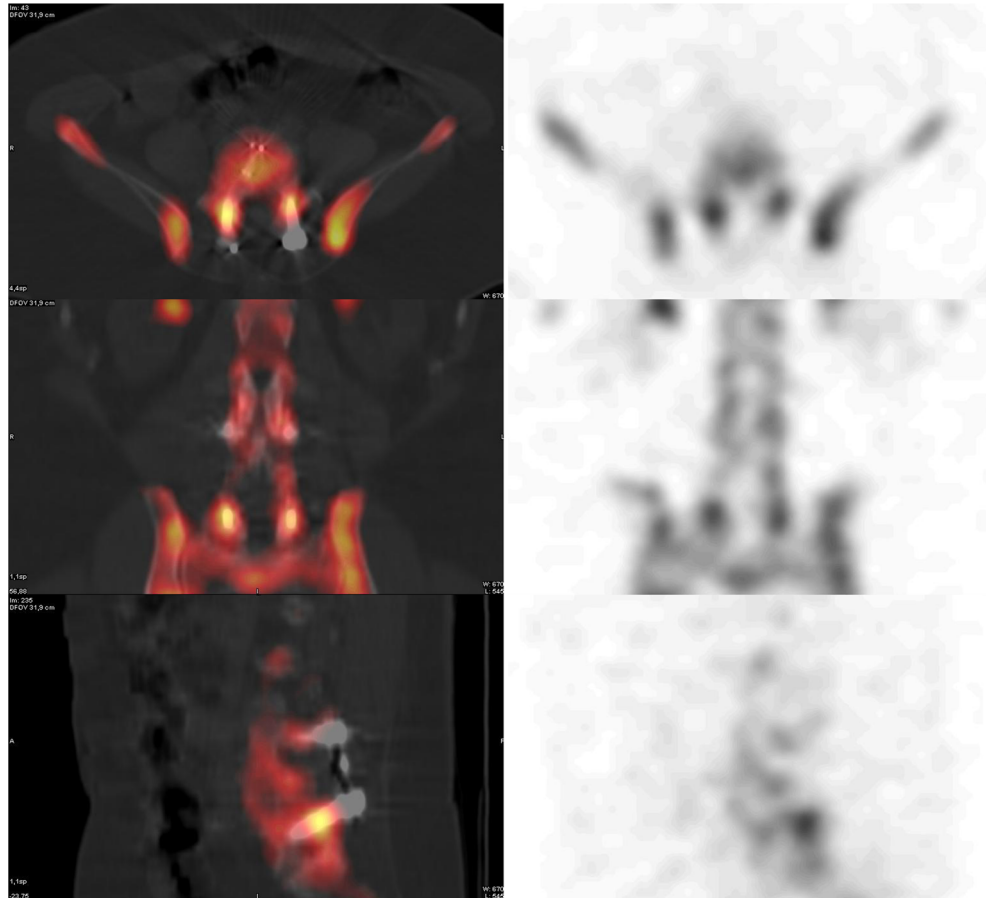
Table 2 Results

	Positive surgery or follow-up	Negative surgery or follow-up
SPECT/CT positive	9	4
SPECT/CT negative	0	35

confirmed by surgery or if clinical and other examinations were completely consistent with the positive SPECT/CT finding. They were considered to be false positives if surgical evaluation did not find any loose pedicle screws, or if symptoms subsided with non-surgical therapy. Negative SPECT/CT scans were considered true negatives if symptoms either improved without surgical intervention or remained stable over a minimum follow-up period of 6 months. The median follow-up duration was 18 months (range 1–57) for subjects who did not undergo surgery. Negative SPECT/CT scans were determined to be false negatives if surgery was still required and loosening of material was found.

Besides the positive or negative evaluation of loosening of the fusion material, other findings in the lumbar spine were noted. That is, we evaluated if any of the other abnormal findings on SPECT could possibly explain the complaints.

Fig. 1 True positive. Hotspot at the entry point of both pedicle screws of L5, markedly above the background activity. Surgery confirmed SPECT/CT results

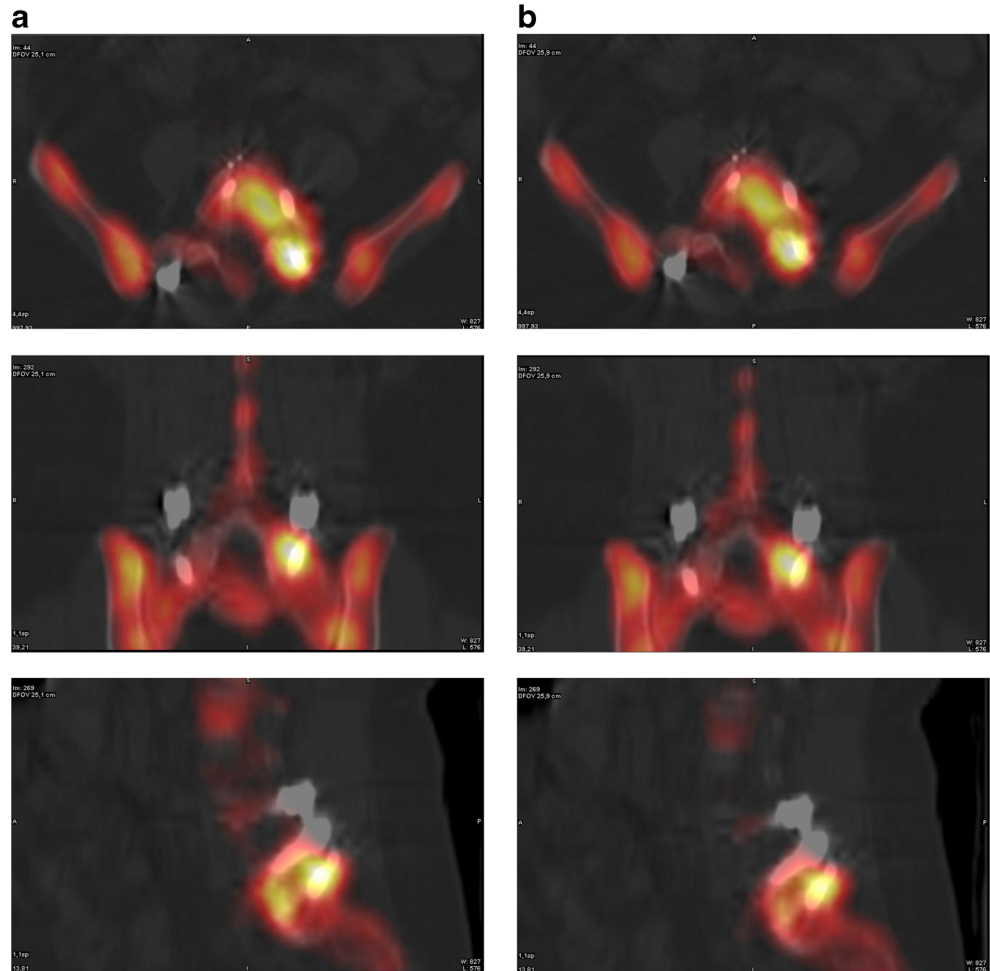


Results

Abnormal findings suggestive of hardware loosening were detected by SPECT/CT in 13 of the 48 patients (see Table 2). In total, SPECT/CT correctly predicted loosening in nine cases, yielding a disease prevalence of 18.8 %. Eight were confirmed through surgical intervention, and one patient was considered positive through long-term follow-up. Re-intervention was recommended by the surgeon but declined by the patient. The patient stayed in follow-up for 39 months, during which time symptoms worsened (corresponding with additional bone scintigraphies showing worsening [stronger] tracer uptake). Four of 13 cases were proven false-positive, as determined by either surgical intervention ($n=1$) or by clinical follow-up during which symptoms subsided without the need for surgical intervention ($n=3$). Image misalignment was excluded in three cases (see Fig. 1) and doubtful in one patient (see Fig. 2).

There were 35 negative SPECT/CT results in total, of which 12 were surgically confirmed as patients underwent surgery either for additional fusion or for removal of the fusion material because of satisfactory fusion stability.

Fig. 2 False positive. **a** SPECT/CT shows a focal hotspot at the entry point of the left L5 pedicle screw as well as the end plates of L5-S1. Symptoms subsided spontaneously after 8 months. **b** After correction of SPECT and CT fusion data: differences from panel *a* are subtle, with bone activity only slightly more to the right. However, the entry point of the left pedicle screw is located slightly more toward the edge of the elevated activity (most evident on axial or coronal views), making diagnosis of loosening of this pedicle screw less definitive, and raising the possibility of facet joint inflammation



Of the remaining 23 patients, 15 experienced lessening or complete subsidence of symptoms during the clinical follow-up period, while 8 showed a stable symptom status.

The sensitivity of SPECT/CT bone scintigraphy for lumbar loosening was 100 %, with specificity of 89.7 % (see Table 3). The positive and negative predictive values (PPV and NPV) were 0.69 and 1.0, respectively. Positive and negative likelihood ratios were 10 and 0, respectively. Overall diagnostic accuracy was 92 %.

In 18 of 35 patients in whom SPECT/CT was negative for loosening, examination revealed lesions that could provide an alternative explanation of the symptoms [e.g. active facet degeneration ($n=14$), disc degeneration ($n=7$) or sacroiliac degeneration ($n=1$)] (see Table 4 and Fig. 3).

Table 3 SPECT/CT diagnostic accuracy

Sensitivity	100 %
Specificity	89.7 %
Negative predictive value	1.00
Positive predictive value	0.69

Discussion

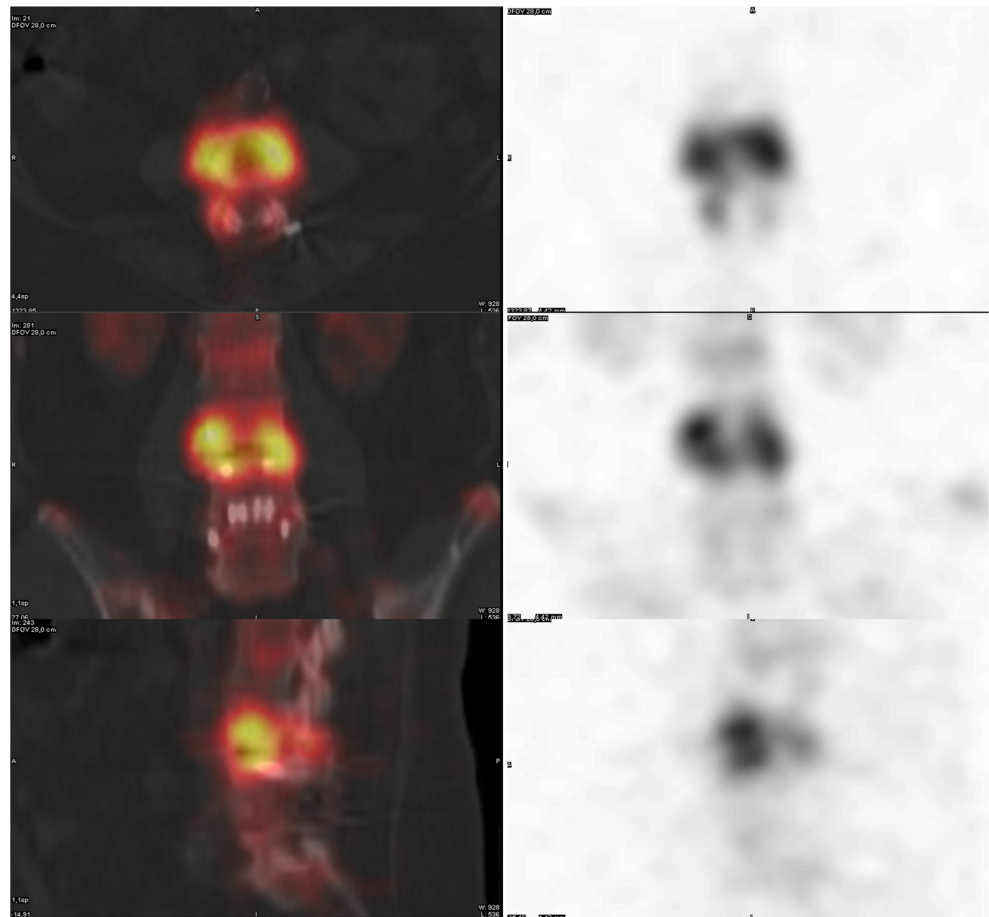
Our data indicate that bone SPECT/CT, with sensitivity of 100 % and specificity of 89.7 %, may be a useful tool for detecting metallic hardware loosening in lumbar arthrodesis indicative of fusion instability.

Although several studies have examined the use of bone scintigraphy for the evaluation of patients after lumbar surgery, few have included integrated SPECT/CT. Sumer et al. assessed the added value of SPECT/CT compared to planar/SPECT imaging in evaluating pain symptoms in a series of 37 patients following lumbar fusion [10]. SPECT/CT resulted in a reclassification of 45.2 % of described lesions. More specifically, the rate of reclassification by SPECT/CT compared with planar/SPECT was 5/12 for

Table 4 Other SPECT/CT findings

Facet degeneration	14
Disc degeneration	7
Sacroiliac degeneration	1

Fig. 3 SPECT/CT shows markedly elevated activity at the end plates of L3–L4 (and also discretely at the right inter-apophyseal joint of L3–L4). Symptoms subsided after disc infiltration of L3–L4



lesions categorized as metal loosening by planar/SPECT, 16/29 for foci with a planar/SPECT diagnosis of insufficient stabilizing function, 7/20 when the planar/SPECT diagnosis had been adjacent instability, and 1/1 for lesions that were indeterminate on planar/SPECT. The authors concluded that SPECT/CT should be the conventional nuclear medical procedure of choice for patients with lower back pain after lumbar fusion. However, they did not assess SPECT/CT findings in comparison to actual clinical outcomes. More recently, Damgaard et al. reported on the diagnostic value of bone SPECT/CT for detecting loosening of metallic fusion material, using surgical evaluation as gold standard, in a small series of nine patients, all of which proved positive for loosening on bone scintigraphy [11]. In their retrospective series, bone SPECT/CT was shown to be true-positive in eight patients and false-positive in one patient. These findings are identical to those obtained in the subgroup of nine patients in our study who underwent re-intervention after positive SPECT/CT. Because patients in whom clinical findings were suggestive of loosening of lumbar fusion material and who presented with negative bone SPECT/CT findings were not included in the study by Damgaard et al., no conclusion could be drawn regarding the diagnostic accuracy of

SPECT/CT for assessing loosening in their study. Finally, Quon et al. performed a prospective pilot study to identify spinal sites requiring surgical revision after fusion surgery, using 18F-sodium fluoride (18F-NaF) PET/CT imaging and surgery or clinical follow-up as gold standard [12]. 18F-NaF PET/CT imaging showed sensitivity of 100 % and specificity of 85.7 % in its ability to identify spinal sites in need of surgical revision; 22 patients were studied. These results, again, are very similar to those obtained in our series, showing sensitivity and specificity of 100 % and 89.7 %, respectively.

This study is the first to report on the diagnostic accuracy of SPECT/CT for detecting pedicle screw loosening in a study population representative of a tertiary referral centre. In our series, 4 of 13 positive scans for loosening proved to be false-positive. It is estimated that bone scintigraphy following lumbar fusion surgery can show markedly increased activity at the operative site up to 1 year post-op [3]. Beyond this length of time, tracer uptake around the metallic hardware, e.g. screws, is assumed to have normalized. Accordingly, if the SPECT-CT scan is performed too soon after fusion surgery, SPECT scan findings may prove false-positive, as was the case for the only false-positive scan reported in the series by Quon et al. at 4 months after surgery. In the present series, all patients

studied were referred for bone SPECT-CT at least 12 months following primary surgery. Accordingly, the interval between intervention and SPECT/CT imaging is unlikely to have contributed to the false-positive findings reported in this series. As the SPECT examination and CT are, by definition, performed sequentially, image fusion mismatches may occur. If the pedicle screw is in close proximity to a facet joint that shows markedly elevated activity, and the fusion of the SPECT and CT data is skewed slightly towards the pedicle screw, increased tracer uptake at the facet may be falsely interpreted as pedicle screw loosening. It is thus of the utmost importance to check the quality of the image registration, especially if focal increased uptake appears to be situated between the facet joint and the pedicle screw (*see Fig. 2*). In our series, misalignment between CT and SPECT findings could not be excluded as the cause of a false-positive finding in one patient. To date, the cause of the false-positive findings in the three remaining patients remains unclear. Despite the high documented specificity of 89.7 % related to the relatively low prevalence of screw loosening of 18.8 % in this series, representative of a clinical setting in a tertiary care centre, a suboptimal positive predictive value of 69 % was found. As the prevalence of lumbar hardware loosening is likely to vary from one study to the next, we also calculated likelihood ratios. A positive likelihood ratio of 10 was obtained, suggesting that a positive SPECT/CT examination has a moderate to large effect on the increased probability of hardware loosening. More importantly, the negative likelihood ratio was 0, suggesting that hardware loosening can be ruled out in the case of a negative SPECT/CT examination. Overall diagnostic accuracy was 92 %, suggesting that SPECT/CT is a highly accurate imaging modality for the diagnosis of lumbar hardware loosening.

Of interest, in 18 of 35 patients with a negative SPECT/CT for loosening, the examination revealed lesions that provided an alternative explanation of the symptoms, e.g. active facet degeneration, disc degeneration, or sacroiliac degeneration. These findings confirm the results of previous studies addressing the added value of bone SPECT without CT for the purpose of identifying osseous sites of increased bone uptake responsible for recurrent low back pain with a cause other than hardware loosening following spinal fusion [9, 13].

Finally, due to the retrospective nature of the study, the added value of bone SPECT/CT in comparison to conventional work-up could not be assessed, and thus far has not been specifically addressed by other studies. Also, because a non-diagnostic CT was obtained in this study, we cannot exclude the possibility that the use of SPECT/CT bone scintigraphy with diagnostic CT would further increase specificity, and thus overall diagnostic accuracy as well. A prospective trial addressing these issues is of clinical interest.

Conclusions

This retrospective analysis indicates that SPECT/CT bone scintigraphy, with diagnostic accuracy of 92 %, is a very useful tool for evaluating loosening of the fusion hardware in the postoperative lumbar spine, with high sensitivity and specificity. Prospective studies are needed to further validate these findings.

Conflict of interest The authors declare that they have no conflict of interest.

This study was performed in agreement with the ethical standards of our institution. Informed consent was not obtained, given the retrospective nature of our study, in concordance with the ethical standards of our institution.

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