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ORIGINAL ARTICLE

The role of bone SPECT/CT in patients with persistent or recurrent lumbar pain following lumbar spine stabilization surgery

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Abstract

Purpose Despite recent advances in lumbar spine stabilization surgery (LSSS), a high number of patients continue to complain of persistent/recurrent lumbar pain after LSSS. Conventional imaging (plain radiography, CT and MRI) is commonly performed to assess potential lumbar pain generators, but findings are equivocal in approximately 20% of patients. The purpose of this study was to assess the diagnostic performance of ^{99m}Tc-HDP bone SPECT/CT in identifying potential pain generators in patients with persistent/recurrent lumbar pain after LSSS but in whom conventional diagnostic imaging is inconclusive.

Methods A total of 187 patients (median age 56 years, 70 men) with persistent/recurrent lumbar pain following LSSS with inconclusive conventional imaging (plain radiography, CT and/or MRI) underwent ^{99m}Tc-HDP bone SPECT/CT and were included in the study. Tracer uptake on SPECT/CT, as an indicator of ongoing or altered osteoblastic activity, was assessed in the lumbar spine stabilization segment(s) and in adjacent segments. Uptake intensity was graded as (1) high (the same as or more than iliac crest uptake), (2) mild (the same as or more than nondiseased vertebral uptake but less than iliac crest uptake), or (3) negative (normal scan). Mild and high uptake were regarded as positive.

Results In 160 of the 187 patients (85.6%), SPECT/CT showed positive mild or high tracer uptake in the LSSS region. More than half of the patients had abnormal tracer uptake in the stabilized segments (56.7%) and/or in the adjacent segments (55.6%). Although positive stabilized segment findings were commonly seen at <2 years (70.3%) and the rate decreased with time after LSSS, they were seen at >6 years after surgery in 38.2% of patients. In 51.4% of patients, abnormal activity was seen in the adjacent segments <2 years after LSSS, suggesting early/accelerated degeneration after surgery. The proportion of patients with abnormal activity in the adjacent segments increased to 67.3% at >6 years after LSSS ($p < 0.05$). Positive SPECT/CT findings in the stabilized segments were more frequent in patients with three or more stabilized segments ($p < 0.05$), but were not more frequent in the adjacent segments. Overall, positive SPECT/CT guided therapy in 64% of patients, which included facet joint/nerve root injections or re-do surgery at active sites and/or adjacent sites.

Conclusion Bone SPECT/CT is a sensitive diagnostic tool for identifying altered osteoblastic activity, which might be a pain generator in patients with persistent/recurrent pain after lumbar surgery especially when conventional imaging is inconclusive.

Keywords Lumbar spine stabilization surgery · SPECT · SPECT/CT

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Introduction

Low back pain is a common disorder, with international studies having found prevalence rates between 12% and 35% and lifetime prevalence rates ranging from 49% to 80% [1, 2]. It is caused mainly by degenerative spinal disorders, such as spondylolisthesis, degenerative scoliosis, degenerative disc disease and recurrent disc herniations [3, 4]. The management of low back pain varies from conservative to more invasive methods, such as spinal stabilization surgery that involves the placement of metallic screws, rods, plates or cages. Such surgery is increasingly performed to improve spinal stability in a variety of spine pathologies, including disc degeneration, spinal stenosis and spondylolisthesis [5]. It is estimated that more than 300,000 lumbar spinal fusion procedures are performed annually in the United States [6], and a continuously rising trend has also been observed in other parts of the world [7, 8].

Unfortunately, recurrent pain after spinal surgery is a well-known problem. It is reported that up to 10–20% of patients experience persistent/recurrent pain after lumbar spinal instrumentation and fusion [9], with studies estimating the surgical reintervention rate to be around 14% over a 4-year follow-up period and 19% over 11 years [5, 10]. As patient outcomes following surgical reintervention are relatively poor in comparison with those following primary surgery, accurate identification of patients who might benefit from reintervention or targeted therapy to the site of the pain is critical.

Standard evaluation of patients with persistent or recurrent pain following spinal stabilization surgery includes clinical examination and conventional imaging using plain radiography, CT or MR imaging [11]. Conventional imaging is performed for the evaluation of hardware position (changes), hardware failure, fusion evolution, alignment of the vertebrae, possible pseudarthrosis and hardware loosening [12]. In general, because of the presence of nonspecific postoperative changes and metal-related imaging artefacts, the interpretation of CT images is often challenging and inconclusive. Thus, whether surgical reintervention is indicated based on conventional imaging may prove difficult to ascertain [13].

The value of bone scintigraphy with single-photon emission tomography/computed tomography (SPECT/CT) in patients with persistent or recurrent back pain after lumbar spine stabilization surgery (LSSS) has been addressed in a number of studies and the technique has been suggested to be a useful diagnostic tool for identification of postsurgical lumbar spine pathology [9, 10, 14–21]. However, most of these studies were based on a small sample size and lacked robust reference standards. Nevertheless, it has been concluded that the use of SPECT and SPECT/CT adds value in assessing patients following spinal stabilization [22].

The primary aims of this study were (a) to evaluate the osteoblastic activity or uptake patterns in patients with persistent or recurrent pain after LSSS and (b) to assess the value of bone SPECT/CT in the management of lower back pain.

Materials and methods

This was a retrospective, single-centre cohort diagnostic study with patient inclusion conforming to the principles outlined in the Declaration of Helsinki second revision. Due to the retrospective character of the study, ethical approval was waived by the institutional ethics committee.

Patients

A retrospective evaluation was conducted of all bone SPECT/CT scans performed on consecutive patients with LSSS. Patient selection for the study is shown in the flow chart in Fig. 1.

Inclusion criteria The study included patients older than 18 years who underwent SPECT/CT at our institution between 2013 and 2015 for the evaluation of persistent/recurrent back pain after LSSS and inconclusive conventional imaging. All patients were clinically assessed by orthopaedic surgeons or neurosurgeons specialized and experienced in lumbar spine surgery. The referral for bone SPECT/CT imaging was based on the clinical setting and was decided at spine multidisciplinary meetings as second-line imaging for evaluation of the stabilized spine and detection of potential pain generators, adapted from current clinical guidelines [23]. Patient demographics, clinical history and clinical data were collected from the electronic medical records for up to 1 year following SPECT/CT.

Exclusion criteria Patients who were not specifically referred for evaluation of the stabilization material after LSSS (e.g. evaluation of another lumbar level or for possible vertebral fracture), patients in whom stabilization surgery was secondary to a destructive bone malignancy (including multiple myeloma) and patients with known metabolic bone disease (such as osteogenesis imperfecta) were excluded from the study.

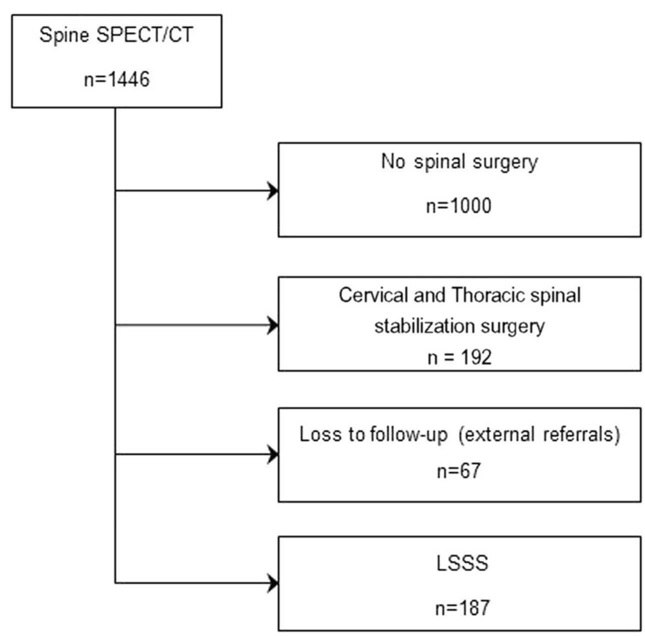

Fig. 1 Selection of patients with lumbar spine stabilization surgery (LSSS)

Lumbosacral spine SPECT/CT imaging

Lumbosacral spine SPECT/CT imaging was performed 4 h following intravenous injection of 800 MBq ^{99m}Tc-HDP according to a procedure adapted from the EANM and BNMS guidelines for bone scintigraphy [24].

Lumbosacral spine SPECT/CT image evaluation

Tracer uptake on SPECT/CT was systematically evaluated at the following locations:

1. *Stabilized segment*, including: (a) endplates/cages, (b) facet joints/posterolateral bony consolidation and ©) screws.
2. *Adjacent segments*, including: (a) endplates and (b) facet joints of the superior adjacent segment, and ©) endplates, (d) facet joints and (e) sacroiliac joints of the inferior adjacent segment. The superior and inferior adjacent segments were considered up to two levels above and below the stabilized segment. If the lower level of the stabilization was at L4–L5 or L5–S1, the activity in the sacroiliac joints was also included in the inferior adjacent segment.

The intensity of uptake on SPECT/CT was based on visual assessment and scored as follows: (1) negative/normal (uptake intensity similar to that of the background), (2) mild (uptake intensity above that of the background but less than that of the iliac crest), and (3) high (uptake intensity above that of the iliac crest). Background activity was determined as the highest activity in at least three normal-appearing vertebral bodies located (more than two levels) above the stabilized segment. A representative image showing the anatomic levels systematically evaluated and uptake is shown in Fig. 2.

SPECT/CT images were reported in consensus by a dual accredited radiologist/nuclear medicine physician (with >3 years of experience in reading musculoskeletal SPECT/CT scans) and a nuclear medicine physician with extensive SPECT/CT experience (>10 years) with an interest in musculoskeletal imaging.

Impact of SPECT/CT on clinical management

Patient management was divided into targeted (including facet joint/nerve root injections, re-do surgery) and non-targeted/conservative (including physiotherapy, pain control or wait-and-see approach) in relation to SPECT/CT findings.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corporation, Armonk, NY, USA). Differences in frequency of SPECT/CT findings were assessed by Pearson's chi-squared test. Two-sided p values <0.05 were considered statistically significant.

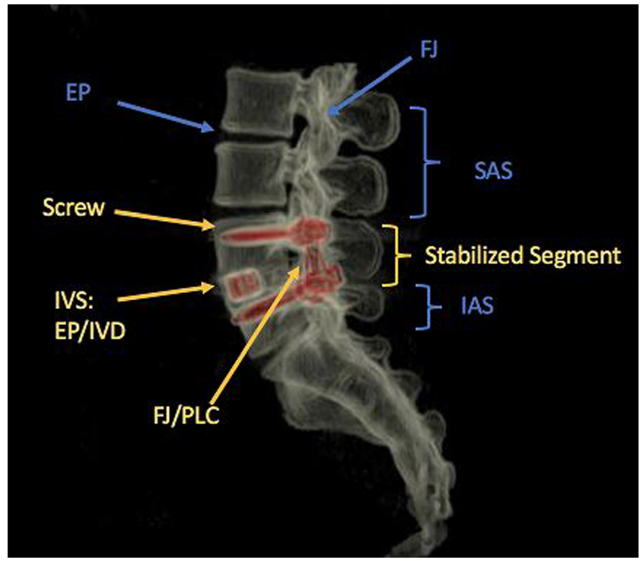

Fig. 2 Volume-rendered three-dimensional reformatted CT image of a stabilized L4–L5 spine showing the common structural compartments. The stabilized segment includes the intervertebral space (*IVS*) with endplates and intervertebral device (*EP/IVD*), transpedicular screws, posterolateral consolidation (*PLC*) and facet joints (*FJ*). The adjacent segments comprise the superior adjacent segment (*SAS*) and the inferior adjacent segment (*IAS*), which include the endplates (*EP*) and facet joints (*FJ*) at these levels. On the corresponding SPECT/CT images, the osteoblastic activity was systematically evaluated in all these structural compartments. There is increased osteoblastic activity (*red*) surrounding the screws and the EP/IVD in the stabilized segment, but there is no increased osteoblastic activity in the adjacent segments

Results

Baseline characteristics

A total of 187 patients were included in the study. Patient characteristics are shown in Table 1. All patients were symptomatic at the time of imaging, with a history of lower back pain of more than 6 weeks in spite of conservative therapy and after inconclusive plain radiography, CT and/or MR imaging findings.

SPECT/CT analysis

Of the 187 patients with persistent/recurrent back pain after LSSS, 160 (85.6%) had positive findings on bone SPECT/CT, showing increased osteoblastic activity in the stabilized segments (n = 107, 57.2%) and/or the adjacent segments (n = 104, 55.6%). The main findings on SPECT/CT are summarized in Table 2.

Table 1 Baseline characteristics of the 187 included patients

Characteristic	Value
Age (years), median (Q1–Q3)	56.0 (46.0–67.0)
Male gender	70 (37.4%)
History one or more lumbar spine surgical procedure	104 (55.6%)
Time between the latest LSSS and SPECT/CT	
Months, median (Q1–Q3)	34 (17.0–75.0)
<2 years	74 (39.6%)
2–6 years	58 (31.0%)
> 6 years	55 (29.4%)
Indication for LSSS	
Degenerative disease	181 (96.8%)
Trauma	4 (2.1%)
Congenital disease	2 (1.1%)
Type of LSSS	
Rigid stabilization	172 (92.0%)
Dynamic stabilization	10 (5.3%)
Noninstrumental stabilization	5 (2.7%)
Number of stabilized lumbar spine segments	
One	80 (42.8%)
Two	67 (35.8%)
Three or more	40 (21.4%)

Data are presented as number (percent) unless otherwise indicated.
Q1–Q3 interquartile range, *LSSS* lumbar spine stabilization surgery

Stabilized segments In the stabilized segments, high tracer uptake was commonly seen in the vertebral endplates/cages (28.3%) and was less frequent in the facet joints/posterolateral bony consolidations (14.4%). High activity around the fixation screws was seen in less than 6% of patients (Table 2). The prevalence of positive SPECT/CT findings was not significantly different between male and female patients (61.2% and 38.8%, respectively; $p = 0.36$) or between patients with and without prior lumbar spine surgery (55% and 45%, respectively; $p = 0.68$).

Adjacent segments In the adjacent segment, high tracer uptake was seen more frequently than mild tracer uptake (40.6% and 15.0%, respectively; $p = 0.001$; Table 2). The superior adjacent segment was more often affected than the inferior adjacent segment. A significantly higher percentage of patients showed high tracer uptake in the endplates and facet joints of the superior adjacent segment than those of the inferior adjacent segment (endplates 19.3 vs. 5.9%, $p = 0.001$; facet joints 19.8 vs. 7.5%, $p = 0.001$; Table 2).

The abnormal SPECT/CT findings were further analysed according to the time between LSSS and SPECT/CT (categorized as <2 years, 2–6 years and >6 years). In the stabilized segments, the overall prevalence of abnormal SPECT/CT findings decreased over time from 52 of 74 (70.3%) at <2 years to 34 of 58 (58.6%) at 2–6 years and further to 21 of 55 (38.2%) at >6 years after LSSS ($p = 0.002$). While 50% of patients showed high tracer uptake early after surgery (<2 years after LSSS), the prevalence decreased to only 31% at 2–6 years and to a minimum of 5.5% at >6 years after LSSS ($p = 0.04$). A relatively steady percentage of 20.3–32.7% of patients showed mild tracer uptake in the stabilized segments over time (Fig. 3a). Surprisingly, a high percentage of patients with persistent/recurrent lumbar pain after LSSS already showed abnormal tracer uptake in the adjacent segments at <2 years after LSSS (38 of 74, 51.4%). The prevalence further increased to 67.3% at >6 years after LSSS, and a greater

Table 2 SPECT/CT findings in 187 patients after LSSS

Location	Positive SPECT/CT	Mild tracer uptake	High tracer uptake	*p* value[a]
Stabilized segment(s)	107 (57.2%)	40 (21.4%)	67 (35.8%)	NS
Endplates (including cage)	88 (47.0%)	35 (18.7%)	53 (28.3%)	NS
Facet joints/posterolateral consolidation	50 (26.7%)	23 (12.3%)	27 (14.4%)	NS
Screws	19 (10.1%)	9 (4.8%)	10 (5.3%)	NS
Adjacent segments (superior and inferior)	104 (55.6%)	28 (15.0%)	76 (40.6%)	0.001
Superior adjacent segment				
Endplates	41 (22.2%)	5 (2.7%)	36 (19.3%)	0.001
Facet joints	66 (35.3%)	29 (15.5%)	37 (19.8%)	NS
Inferior adjacent segment				
Endplates	13 (7.0%)	2 (1.1%)	11 (5.9%)	0.023
Facet joints	23 (12.2%)	9 (4.8%)	14 (7.5%)	NS
Sacroiliac joints	18 (9.6%)	6 (3.2%)	12 (6.4%)	NS

Data are presented as number (percent).
NS not significant
[a] Differences between the percentages of mild and high tracer uptake assessed using Pearson's chi-squared test, with $p < 0.05$ considered significant

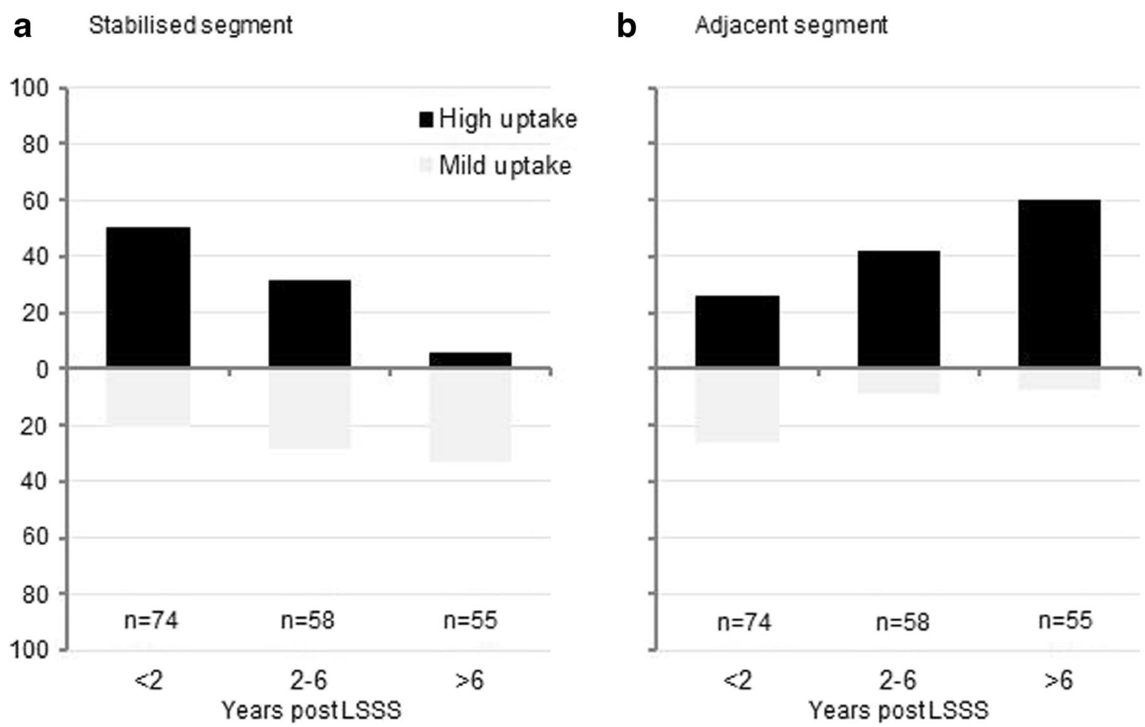

Fig. 3 Percentages of patients showing mild tracer uptake (*grey*) and high tracer uptake (*black*) in (**a**) stabilized segments and (**b**) adjacent segments according to the time between LSSS and SPECT/CT (<2 years, 2–6 years and >6 years)

proportion of these patients (60.7%) showed high tracer uptake than mild uptake ($p = 0.03$) (Fig. 3b).

Furthermore, positive SPECT/CT findings were further analysed according to the number of stabilized segments (categorized as one segment, two segments, or three or more segments). Compared with patients with one or two stabilized segments (47.6% and 56.7%, respectively), abnormal SPECT/CT findings in the stabilized segments were noted more often in patients with three or more stabilized segments (77.5%, $p = 0.018$). A greater proportion of these patients (60.0%) showed high uptake than mild uptake (17.5%) in the stabilized segments, indicating ongoing mechanical stress (Fig. 4a). In the adjacent segments, the prevalence of positive SPECT/CT findings was high, but not significantly different among the subgroups of patients with one, two, or three or more stabilized segments (47.8% to 67.5%; Fig. 4b).

Figure 5 provides representative patient examples.

Management

Of the 160 patients with positive SPECT/CT findings, 64% (most of whom had activity in the adjacent segments on SPECT/CT) underwent targeted management specifically and/or adjacent to SPECT-positive sites, including nerve root/facet joint injections or re-do surgery. Of the 27 patients with negative SPECT/CT findings, 63% underwent conservative management (Table 3).

Discussion

Bone SPECT/CT is a feasible imaging modality in patients with persistent/recurrent pain after LSSS, as shown by the finding of mild to high tracer uptake in 85.6% of such patients who had failed conservative therapy and in whom conventional imaging remained inconclusive. To our knowledge, this is the largest cohort of patients with persistent/recurrent pain after LSSS to be imaged with ^{99m}Tc-HDP SPECT/CT.

Despite advances in spine stabilization surgery, the percentage of patients with persistent/recurrent pain remains high. Conventional CT or MR imaging is widely used in these circumstances, but fails to diagnose potential pathology and pain generators in >50% of patients. Although a powerful modality for detecting well-developed bony bridging, CT is of limited value for the diagnosis of early evolving non-union, with a low positive predictive value for pseudarthrosis [25]. Additionally, the relationship between CT findings and symptomatology is often not congruent [26, 27]. MRI, although offering superior delineation of soft tissue pathology, is highly susceptible to artefacts from implant material [28] and also fails to show a strong correlation with the severity of clinical symptoms [29, 30].

In this study determining the value of SPECT/CT in patients after LSSS, metabolic SPECT imaging was positive in >80% of patients with equivocal findings after LSSS. This is in accordance with the known sensitivity of bone scintigraphy, particularly bone SPECT/CT, in detecting bone abnormalities

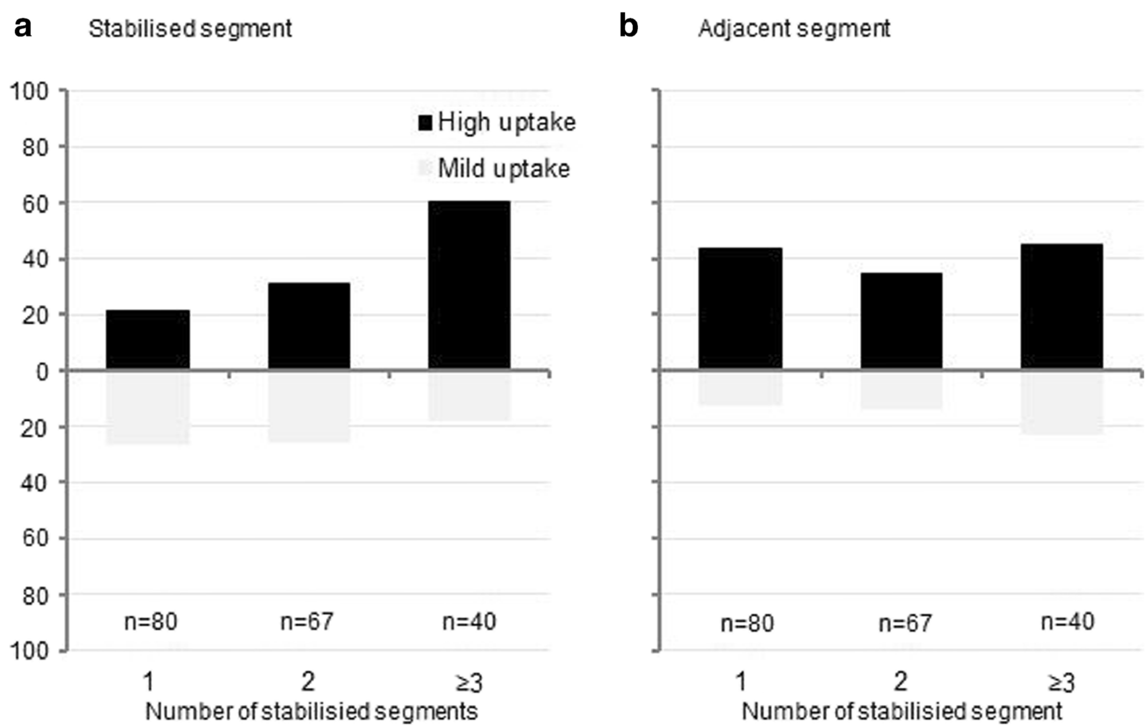

Fig. 4 Percentages of patients showing mild tracer uptake (*grey*) and high tracer uptake (*black*) in (**a**) stabilized segments and (**b**) adjacent segments according to the number of stabilized segments (one, two, or three or more)

that are likely to be pain triggers/generators or are foci of ongoing metabolic processes involved in attempts at bone healing. Previous studies have demonstrated that bone SPECT/CT can predict the short-term benefits of targeted therapy, particularly in patients with facet infiltration [31, 32]. Furthermore, in a study assessing SPECT/CT evaluation in 99 patients with chronic low back pain and no history of spinal surgery, Russo et al. found that in >40% of the facet joints, the scintigraphic pattern did not correlate with degree of degeneration on CT [33]. This indicates the value of SPECT/CT as an addition to conventional imaging and its ability to precisely localize active facet joints which may provide improvement in diagnosis and treatment of patients with lower back pain [33]. However, final determination of the potential pain generator should be a collective decision based on various evaluation methods.

In this study, the endplates/cages were the areas that most frequently showed high osteoblastic activity in the stabilized segment(s). The intervertebral cage harbours bone graft material which can have different osteoblastic properties on bone scan. It is also associated with various complications such as subsidence, peridevice lucency and bony defects through the bone bridging that can be associated with instability [6, 34].

The rationale for analysis of patients according to the time between LSSS and SPECT/CT lies in the fact that clinical follow-up data have shown that the causes of back pain may differ between early and late time points after surgery [35]. In our study, high focal osteoblastic activity in the stabilized segment(s) was commonly seen in patients who had a SPECT/CT scan within the first 2 years after surgery, but increased tracer uptake might still be seen in some patients even 6 years after surgery. The median time between surgery and the SPECT/CT examination in stabilized segments with increased uptake was 31.5 months (25.5 months for high-grade osteoblastic activity), while the median time between surgery and the SPECT/CT examination in stabilized segments without increased uptake was 59 months.

Collier et al. [36] found that in uncomplicated spinal stabilization, there is a steady decrease in osteoblastic activity with time from surgery. However, even in the absence of a definite radiological correlate, increased osteoblastic activity in stabilized segments beyond a year after surgery might represent increased stress and microinstability [37]. Furthermore, biomechanical studies have demonstrated that, as a result of immobilization, fusion can result in a reduction in disc spaces within stabilized segments and may allow a small degree of motion depending on the type of stabilization surgery [38]. However, this is still within normal limits and in theory this could explain the presence of persistent mild osteoblastic activity within the stabilized segments in a number of SPECT/CT-positive patients, suggesting that potentially part of the 'fusion' process and osteoblastic activity persists but reduces over a much longer time than suggested in the literature (Table 2) and is unlikely to be a result of surgical instability.

In the adjacent segments, we observed high osteoblastic activity in the facet joints (27.2%) and the vertebral endplates

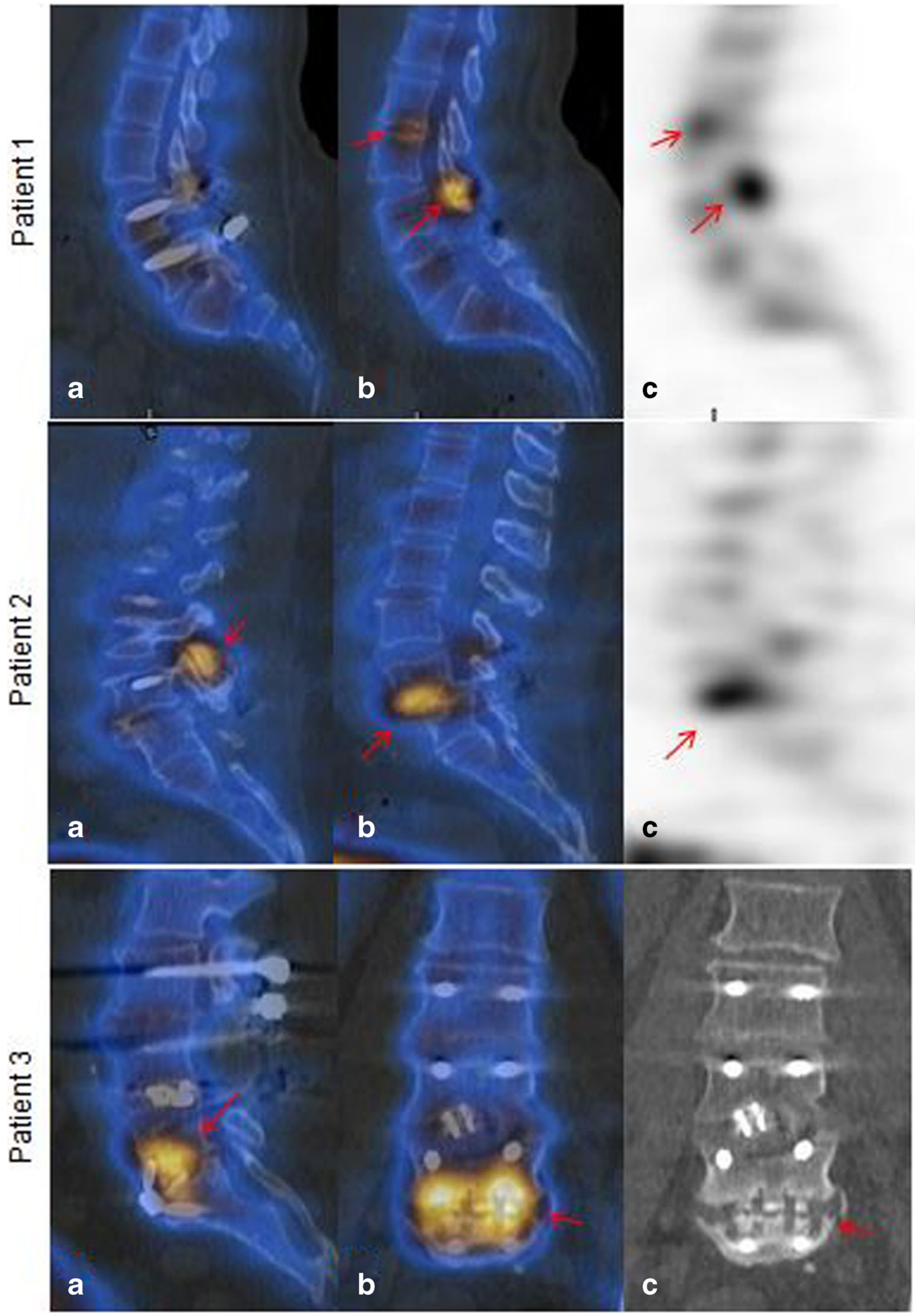

Fig. 5 Representative patient examples. *Patient 1*: a 79-year-old patient with L4–L5 stabilization surgery 1.5 years before SPECT/CT. Sagittal fused SPECT/CT images (**a**, **b**) and sagittal SPECT image (**c**) show increased osteoblastic activity at the L3/L4 facet joint and milder osteoblastic activity at the L2/L3 endplates (**b, c** *arrows*) indicating active adjacent segment degeneration. *Patient 2*: a 71-year-old patient with L4–L5 stabilization surgery 5 years before SPECT/CT. Sagittal fused SPECT/CT images (**a**, **b**) and sagittal SPECT images (**c**) show L4–L5 stabilization with increased osteoblastic activity at the L3/L4 facet joint in the superior adjacent segment (**a** *arrow*) and increased osteoblastic activity at the L4/L5 endplate in the stabilized segment (**b**, **c** *arrows*) indicating active adjacent segment degeneration and instability at L4/L5. *Patient 3*: a 50-year-old patient with L3–S1 stabilization <1 year before SPECT/CT. Sagittal fused SPECT/CT image (**a**), coronal fused SPECT/CT image (**b**) and coronal CT image (**c**) show increased osteoblastic activity in the L5/S1 intervertebral space (**a**, **b** *arrows*) and a lucent line through the bony bridging within the intervertebral device (**c** *arrow*) indicating instability at L5/S1

(25.1%). In general, the adjacent segments are often subjected to increased stress following spinal stabilization surgery secondary to altered mechanics [39]. In our study, the superior adjacent segments showed higher osteoblastic activity than

Table 3 Patient management during the first year after SPECT/CT (with either nontargeted, conservative therapy or targeted therapy) in relation to SPECT/CT findings

	SPECT/CT-positive (n = 160)	SPECT/CT-negative (n = 27)
Targeted therapy (facet joint/nerve root injections, re-do surgery)	103 (64%)	10 (37%)
Nontargeted therapy (physiotherapy, pain control, wait-and-see)	57 (36%)	17 (63%)

the inferior segments analysed ($p = 0.001$). This might reflect the fact that the superior segments were subjected to greater stress. In addition, the high osteoblastic activity in the adjacent segments was mostly seen in patients 6 years or more after surgery and may be explained by the fact that the effect of fusion on the adjacent segments is a time-related process. However, in our cohort, specifically in patients with no history of previous lumbar spine surgery prior to stabilization surgery, increased osteoblastic activity in the adjacent segment was seen as early as 10 months after surgery. It is postulated that this may reflect possible acceleration of early degenerative changes which were present prior to surgery. Therefore preoperative assessment with bone SPECT/CT may offer added value in determining which segments should be fused in the preoperative setting.

The number of stabilized segments and its relationship to the pattern of osteoblastic activity has not been analysed in previous SPECT/CT studies in patients who have undergone LSSS. Comparing the presence of increased osteoblastic activity in subgroups according to the number of segments stabilized showed that the length of the stabilized segments was associated with the presence of positive SPECT/CT findings within the stabilization. In this study, increased tracer uptake was often seen in patients with three or more segments stabilized. However, positive SPECT/CT findings were not seen in the adjacent segments, as there was no significant difference among the subgroups. Additionally, previous conventional imaging studies have shown that radiological changes seen in adjacent segments are not influenced by the length of the fusion [39]. Our study yielded similar information, in that there was no statistically significant difference in the positive adjacent segments between those patients with only one segment stabilized and those with three of more segments stabilized.

Finally, management decision making remains complex in patients presenting with persistent or recurrent pain after spinal stabilization surgery. In this study, most patients with positive SPECT/CT findings (64%) underwent targeted management. Although 36% of the SPECT/CT-positive patients did not undergo targeted management, this is not surprising, as many of them had already undergone more than one spinal intervention and had had some form of targeted therapy prior to SPECT/CT, with a poor outcome. Furthermore SPECT/CT helped avoid unnecessary targeted management in >60% of patients with negative SPECT/CT findings. Lehman et al. [40] assessed the clinical value of bone SPECT/CT of the spine and sacrum and its impact on patient management, and found that the SPECT/CT results led to a change in management in 168 of 212 patients (79%). However, the study included a heterogeneous group of patients with various indications, and a postoperative spinal complication was specified as an indication for bone SPECT/CT in <1% of patients.

It is important to note that many patients with pain after spinal stabilization surgery have comorbidities, e.g. they may be overweight or obese, and may also have mental health issues which might limit the choice of management method. Furthermore, appropriate management decision making takes into account evaluation methods beyond imaging, such as neurophysiological/psychological assessment and correlation with the results of clinical examination, which may not always match the SPECT/CT findings. Nevertheless, we found that in the difficult group of patients in whom routine imaging had not been conclusive, SPECT/CT was able to play a key role in guiding targeted management.

This study had a number of limitations, including its retrospective nature, referral bias (only those patients selected by the clinician for scintigraphic assessment were included), the lack of interval control between previous imaging modalities and SPECT/CT and the lack of correlation with the gold standard of surgical exploration. Furthermore, due to the absence of a uniform standardized proforma for use before and after SPECT/CT to permit assessment of management outcome, the potential value of SPECT/CT in predicting the success of therapy could not be fully assessed. Prospective studies are needed to assess the outcomes of patient management and the accuracy of bone SPECT/CT in patient diagnosis. Additionally, correlation between osteoblastic activity uptake patterns and postural balance and compensatory changes in spinopelvic alignment after surgery may lead to a greater understanding of the changes in the biomechanical distribution and stress loading after spinal stabilization surgery.

Conclusion

Bone SPECT/CT can determine and localize focal osteoblastic activity in >80% of patients presenting with persistent/recurrent pain after spinal stabilization surgery. Positive osteoblastic activity in the stabilized segment was commonly seen in patients with a more recent history of surgery and in those with three of more stabilized segments. However, persistent mild osteoblastic activity in the stabilized segment years following surgery suggests that the time to normalization of osteoblastic activity in the operated site is in fact longer and more variable than the time quoted historically in the literature. Osteoblastic activity in adjacent segments was frequently observed in patients with a longer time from surgery and was commonly seen in the superior adjacent segments. In this complex group of patients, SPECT/CT played a key role in guiding targeted management. Bone SPECT/CT should be used routinely in the assessment of patients with persistent or recurrent pain after spinal surgery.

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Compliance with ethical standards

Disclaimer None.

Conflicts of interest None.

Ethical approval Due to the retrospective character of the study, ethical approval was waived by the institutional ethics committee. The study conforms with the principles outlined in the Declaration of Helsinki second revision.

Informed consent All patients gave written informed consent to the procedures performed and the fact that all data may be used for retrospective scientific analyses.

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