Clinical and MRI features of sacral insufficiency fractures after radiotherapy in patients with cervical cancer

Xi Zhong  
Guangzhou Medical University Affiliated Cancer Hospital

Linqi Zhang  
Guangzhou Medical University Affiliated Cancer Hospital

Tianfa Dong  
Third Affiliated Hospital of Guangzhou Medical College

Hui Mai  
Third Affiliated Hospital of Guangzhou Medical College

Bingui Lu  
Guangzhou Medical University Affiliated Cancer Hospital

Lu Huang  
Guangzhou Medical University Affiliated Cancer Hospital

Jiansheng Li (lijiansheng@gzhmu.edu.cn)  
Guangzhou Medical University Affiliated Cancer Hospital

Research article

Keywords: Insufficiency fracture, Magnetic resonance imaging, Cervical cancer, Radiotherapy

DOI: https://doi.org/10.21203/rs.3.rs-69306/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Background

To determine the incidence, clinical and MRI features of sacral insufficiency fracture (SIF) after radiotherapy (RT) in patients with cervical cancer.

Methods

Our study included 167 patients with cervical cancer after radiotherapy that underwent pelvic MRI for follow-up. MRIs included pre-enhanced T1-weighted, coronal fat-Suppressed T2-weighted (FS-T2W) and enhanced T1-weighted imaging. The clinical and MRI dates were reviewed. The gold standard of SIF was based on radiologic findings, clinical data and follow-up at least 12 months.

Results

28 patients (10.8%) with 47 sites were diagnosed with SIFs, including 9 patients with unilateral SIF and 19 patients with bilateral SIFs. The median age was 60 years (range 41–72 years), and 89.3% (25/28) of patients were postmenopausal. 64.3% (18/28) of patients were symptomatic, and 53.6% of patients (15/28) had concomitant pelvic fractures. The median interval time from RT to SIFs was 10 months (range 3–34 months). For the lesion-wise analysis based on all MR images, all lesions were detected by visualizing bone marrow edema patterns, and fracture lines were detected in 64.6% (31/47) of SIFs. No soft-tissue tumors were founded. For each MRI sequence analysis, coronal FS-T2WI detected the most bone marrow edema pattern and fracture line than T1WI or enhanced T1WI.

Conclusion

SIF is a common complication in cervical cancer after radiotherapy, which has some certain clinical and MRI features. Coronal FS-T2WI may be more useful to detect and characterize these fractures than other imaging sequences.

Background

Radiotherapy (RT) has been considered as one of the most effective therapeutic methods for cervical cancer. Patients’ survival time has been improved since the introduction of platinum-based chemoradiotherapy. However, the late complications have drawn more attention, included postradiation insufficiency fractures (IFs) [1–3]. IFs represent a specific category of stress fracture, which results from normal or physiologic stress placed on the weakened bone with decreased mineralization and elastic resistance [3, 4]. Although postradiation IF was considered a relatively rare complication in cervical cancer, several clinical investigations have reported that IF is more common than previously thought. Recent studies have shown that the incidence of IF ranged from 4.4–45.2% in cervical cancer after RT [5–10]. The most common sits of IF was sacrum, so-called SIF, accounting for 53% of all IFs [11]. Although SIF is a well-defined and original description by Lourie in 1982 [12], which results in many being undiagnosed due to lack of clinical suspicion and often radio-graphically occult [13, 14]. What’s more, an emerging lesion detected by imaging in patients with a history of malignancy could be misinterpreted as bone metastasis, which may result in unnecessary biopsy and aggressive radio-chemotherapy [15]. Hence, accurate diagnosis of these fractures is important.

Recently, the wide use of modern imaging modalities has improved the detection of SIFs, but the diagnostic sensitivity and specificity are still debatable. Bone scan (BS) is sensitive to detect SIF and the so-called “Honda sign” (H-sign) is well known as a characteristic sign, but this sign is often absent [16, 17]. Computed tomography (CT) has been shown to be specific in depicting fracture lines and osteosclerosis for SIF, but it may have limitations in sensitivity [3, 11, 17].

MRI has been proved to be more sensitive to detect occult IFs than CT or BS, owing to the reveal of reactive bone marrow changes [11, 18, 19]. Nonetheless, SIFs may not always show a fracture line, and abnormalities on MRI may occasionally be diagnosed as bone metastases if the radiologist is not familiar with these findings [11, 20]. To our knowledge, only a few studies have assessed the utility of MRI in the diagnosis of SIFs after RT, and the fat-saturation (FS) T2-Weighted and gadolinium contrast-enhanced imaging are particularly useful in differentiating marrow edema secondary to SIFs from malignancy [21–24]. However, the value of these sequences in the detection and characterization of SIFs has not been compared.

Therefore, we carried out this retrospective study to explore the incidence, clinical and MRI features of SIF after radiotherapy in patients with cervical cancer, and compared the ability of pre-enhanced T1-weighted, coronal FS T2-weighted and enhanced T1-weighted imaging in detecting bone marrow edema and fracture line.
Methods

Patients

This retrospective study was approved by the institutional review board, and informed consent was not required. We retrospectively analyzed 167 cervical cancer patients received RT between July 2012 and December 2015. Pre-treatment and follow-up pelvic MRI was available for all patients; the median follow-up time was 45 months (range 25–72). The subject inclusion criteria as follows: (1) Pathology-proven cervical cancer, and received RT, (2) Pre-treatment pelvic MR showed no abnormal sign changes in the sacrum, (3) When emerging signal abnormality in sacrum was visualized after RT, one or more pelvic MRI and/or CT examination was performed during their at least 12 months follow-up. Exclusion criteria: (1) had sacrum metastasis, (2) had a history of pelvic trauma.

Finally, 28 patients (age range, 41–72 years; median age, 60 years) were identified as SIFs, whose clinical notes, symptoms and imaging findings were reviewed.

Imaging Acquisition

MR Imaging

In all 28 subjects, pelvis MRI was performed by using a 1.5 T MR-scanner (Philips Achieva, Philips Healthcare, Best, The Netherlands). MR sequences included an axial T1-weighted spin-echo images (TR /TE, 496ms/10ms; matrix, 256×256; number of excitations [NEX], 2; echo-train length [ETL], 1), an axial T2-weighted spin-echo images (TR /TE, 3500/100 ms; matrix, 512×256; NEX, 2; ETL, 4) and an coronal fat-saturated T2-weighted images (TR /TE, 2400/80 ms; SPAIR TR, 266ms; matrix, 280×306; NEX, 2). Contrast-enhanced axial and sagittal T1-weighted images were also obtained by using a T1-weighted spin-echo sequence. For all scanning sequences, the field of view was 22–26 cm and the section thickness was 5 mm with a 2mm interscan gap was performed.

BS Imaging

Fifteen patients simultaneously underwent BS examination, BS studies were performed by using a SPECT/CT scanner (Philips, Netherlands; 4-slice diagnostic CT). The whole-body scan was performed 3 hours after intravenous injection of 15~25mCi 99mTc-MDP.

CT Imaging

Eleven patients simultaneously underwent CT examination, imaging included the entire pelvis. CT studies were performed using a several MDCT scanners (64-MDCT scanners, Light Speed Series, GE Healthcare). All studies were performed with 120 kVP and milliampere values ranging from 200 to 300 mA.

Image Analysis

All images were analyzed at a diagnostic workstation (Advantage Windows, GE Healthcare, WI). The MRI, CT, and BS studies were analyzed separately in random order by two radiologists (8 and 10 years of experience in musculoskeletal imaging, respectively) in consensus. Radiologists were blinded to the patients' identity and results of the clinical notes.

All patients underwent MRI and were evaluated for the absence or presence of a SIF and locations (unilateral or bilateral) of fractures. Furthermore, the absence or presence of a reactive bone marrow edema and fracture line in SIF was recorded. A bone marrow edema pattern was classified into three grades as follows [11]: (1) severe, the signal intensity on fat-saturated T2-weighted images was similar to that of spinal fluid or urine in the bladder, (2) moderate, bone marrow edema was visualized > 5 mm around the fracture line or had a diameter of > 10 mm if no fracture line was present and the signal intensity was lower than that of spinal fluid and urine in the bladder, (3) mild, bone marrow edema was visualized only along the fracture line (within 5 mm diameter) but not in the periphery. Fracture line was noted by linear low signal intensity on all MR sequences. The presence of bone marrow edema and fracture lines visualized on T1W, FS-T2W and enhanced T1W images were documented separately. Then, combined all MR images, the presence of bone marrow edema and fracture lines were documented. The presence and location of concomitant fractures in other sites (lumbar, pelvis and proximal femur) were also documented.

Presence of an “H-sign” was documented for 15 patients who had BS examination. “H-sign” is an H-shaped increase in areas of abnormal radiotracer uptake on the sacral body and both alae [16]. The presence of osteosclerosis and fracture line was documented for 11 patients who had CT examination.

The conclusive diagnostic criterion was based on all radiologic findings (WBS, CT or MRI), clinical data and follow up at least 12 months [17].

Statistical analysis

All the statistical tests were performed using SPSS Statistics 16.0 (SPSS Inc., Chicago, IL, USA) software package. Categorical data are expressed as numbers and frequency (%), and continuous data are expressed as median and range.
Results

Incidence

Of these 167 cervical cancer patients after RT, we found 10.8% of the patients (28 patients) diagnosed with SIFs in the follow-up by using MRI.

Patients’ clinical features

The clinical history, symptom, interval time from RT to MRI, associated fractures and additional imaging examination in 28 patients with SIF were showed in Table 1.

SIFs were frequently occurred in patients with a postmenopausal status, accounting for 89.3% (25/28) of patients. The median age was 60 years (range 41–72 years), and 85.7% (24/28) of patients aged ≥55 years. 89.3% (25/28) of patients accepted definitive RT, the median dose was 62 Gy (range 50 – 110 Gy); 3 patients accepted postoperative RT, the median dose was 56 Gy (range 50 – 100 Gy).

The median interval time from RT to SIFs by MRI was 10 months (range 3 –34 months), and the great majority of affected patients developed with SIFs within 2 years after RT (92.9%, 26 of 28 patients).

Nine patients (31.0%) developed with unilateral SIFs (Fig.1, Fig.2), and nineteen patients (69.0%) with bilateral SIFs (Fig.3~5). In total of 15 patients (53.6%) developed with concomitant fractures, include L5 fractures (14.3%, 4 patients) (Fig. 3), acetabulum fractures (17.8%, 5 patients) (Fig.3), ilium fractures (21.4%, 6 patients) (Fig. 4) and pubis fractures (14.3%, 4 patients) (Fig. 5).

Eighteen patients (64.3%) had hip pain or low back pain, and ten patients were asymptomatic. 72.2% (13/18) of the symptomatic patients developed with concomitant fractures, but only 20% (2/10) of the asymptomatic patients with concomitant fractures.

MRI findings

A total of 47 lesions were identified as SIFs in 28 patients (9 patients unilateral SIF, 19 patients bilateral SIFs) according to the reference standard. The detection rate of bone marrow edema and fracture line on MRI for the SIFs lesions were showed in table 2.

For the lesion-wise analysis based on all MR images. All SIFs showed reactive bone marrow with hypointensity on pre-enhanced T1WI, hyperintensity on SPAIR-T2WI. According to the grading criterion, severe bone marrow edema patterns were found to be most frequently associated with SIFs (82.9%, 39/47), followed by moderate bone marrow edema (12.8%, 6/47), only two SIFs showed mild bone marrow edema. Fracture lines were also frequently founded in SIFs (Fig.1, Fig.2 and Fig.4), accounting for 64.6% (31/47) of lesions, which was visualized as a linear low signal structure on either T1-weighted, SPAIR-T2W weighted and enhanced T1-weighted images. No soft-tissue tumor was founded in SIFs.

For individual MRI sequence analysis, coronal FS-T2WI detected more bone marrow edema pattern and fracture lines than pre-enhanced T1WI or enhanced T1WI (Table 2). The bone marrow edema pattern detection rates of coronal FS-T2WI, pre-enhanced T1WI and enhanced T1WI were100%, 95.7% (45/47), and 87.2% (41/47), respectively. Furthermore, the fracture lines detection rates of coronal FS-T2WI, pre-enhanced T1WI and enhanced T1WI in SIFs were 60.4% (29/47), 36.2% (17/47), and 51.1% (24/47), respectively.

Additional BS and CT findings

15 patients with SIFs (5 patients, unilateral SIFs; 10 patients, bilateral SIFs) simultaneously underwent WBS, 8 patients (53.3%) showed the typical “H-sign” (Fig.5). 11 patients simultaneously underwent CT (4 patients, unilateral SIFs; 7 patients, bilateral SIFs). Of the 18 SIFs, 15 lesions were involved osteosclerosis change (Fig.3, Fig.4), fracture lines were showed in only 5 lesions, and other three lesions were invisible on CT (Fig.2).

Discussion

In the present study, we found that postradiotherapy SIF was a relatively common occurrence for patients with cervical cancer, and patients have some certain clinical characteristics, such as older ages with postmenopausal status, developed with SIFs within 2 years after RT, involved bilateral sacrum, concomitant fractures. MRI, especially coronal FS-T2W imaging was useful to detect and character SIFs.

The actual incidence of RT-induced is unclear, the incidence in our study was 10.8%, which was relatively higher than previous studies reported between 2.9% and 9.6% [1, 8, 10], this partly ascribed to the fact that SIFs were all detected by MRI. It has been implied that the sacrum is the initial site of fracture and then lead to increased stress on other sites of the pelvis [3, 14]. In our study, almost 53.6% of patients had concomitant fractures, suggested that identification of SIFs should arouse clinical suspicion of fractures in other sites. However, SIFs are most frequently associated with pubis fractures, with a reported coincidence of 78% [25]. We found that only 14.3% patients had coexistent pubis fractures, it was lower than that of the presences of fracture in L5 (14.3%), acetabulum (17.8%), ilium (21.4%).

The clinical presentation of SIF is vague and non-specific. We observed almost two-thirds of SIFs were clinically symptomatic, the incidence was higher than a study reported about one third [22]. First, this may be most likely explainable by the fact that 53.6% of patients with concomitant
fractures were included, and 72.2% of the symptomatic patients developed with concomitant fractures. Multiple site fractures may be contributed to some patients with pain [9]. Second, 82.9% of SIFs presented severe bone marrow edema patterns in present study, which was the same as Blomlie et al. [26] revealed, larger lesions (> 1 cm²) on MRI tended to be more likely painful.

Older patients with postmenopausal status after RT are more susceptible to the development of IF [1, 2, 9, 17]. We found that SIFs frequently occurred in postmenopausal patients, and the median age was 60 years. Based on our results, most of affected patients developed with SIFs within 2 years, and the median interval time from RT to SIFs was 10 months, which is almost similar with previous studies with a median interval time between 8 and 14 months [1, 6, 22]. Supporting a previous study demonstrated that 88.9% of patients with RT-induced SIFs were bilateral [21], we observed over two-third of SIFs have arisen bilaterally.

Although SIFs are rarely life-threatening, they should be deserved special attention because they can influence the quality of life [27]. Only 20–38% of SIF could be identified on plain films [28, 29]. Recently, modern imaging modalities during follow-up have been applied in the detection and characterization of SIFs. Both BS and CT have some limitations, BS is one of the most sensitive imaging modalities for detecting SIF and the “H-sign” regarded as a gold standard for diagnosing SIFs[16]. However, this sign is frequently not presented, reported in just 40% of SIFs[29]. In our study, 53.3% (8/15) of patients who had additional BS showed the typical "H-sign". Although, CT may be useful to ascertain equivocal findings on BS or MR imaging, which has been shown to be less sensitive to detect SIFs than BS or MRI, with a recorded sensitivity between 60 and 75% [11, 28, 30]. In this study, 83.3% of SIFs were detected by CT for patients with had additional CT examinations.

MRI is an alternative technique due to its high soft-tissue contrast, multiplanar imaging, and avoidance of ionizing radiation. MRI is one of the most sensitive imaging techniques to detect RT-induced IF by visualizing the bone marrow edema. Cabarrus et al[11], showed that the overall sensitivity of MRI was significantly higher than CT (100% vs 74.6%), although the sensitivity for detecting fracture lines was similar (93.3% for MRI vs 89.7% for CT). We found all SIFs showed bone marrow edema, and fracture lines were visualized in 64.6% of lesions. Furthermore, MRI is also helpful to differentiate SIF from the bone metastasis, because MRI is very useful to identify the soft-tissue component, the absence of focal or discrete soft-tissue mass around fracture sites is an important sign for distinguishing SIF from malignancy [3, 7, 20, 21]. In present study, no soft-tissue tumor was detected in fracture sites.

The FS-T2W imaging is especially sensitive for visualizing early bone marrow edema, and coronal imaging of sacrum is recommended to be included in suspected cases[3, 30]. Gupta et al. demonstrated that coronal STIR sequence had additional value to the L-spine MRI by increasing significant findings detection in 6.8% of patients, including SIF or sacroiliitis [31]. Compared with previous studies [7, 11, 21, 32], the advantage of our study was that both coronal FS T2-weighted and gadolinium-enhanced T1-weighted imaging were performed for all patients. In line with the previous studies, we found coronal FS-T2WI was more sensitive to detect both bone marrow edema and fracture lines than that of T1WI or enhanced T1WI. In addition, this study revealed that T1WI detected the least fracture lines because of bone marrow edema pattern was also hypointensity, and enhanced T1WI detected least bone marrow edema due to some SIFs with no or mild enhancement, which may be difficult to identify.

There were several limitations to our study. First, our study was retrospectively performed in a single-institution. Second, the follow-up period was inconsistent (range, 25–72 months), which might have resulted in underestimation of the true prevalence of SIF. Third, only a small number of patients undergone simultaneous BS or CT examinations, we were unable to compare the diagnostic ability of MRI with BS or CT. Fourth, none of the IF lesion was diagnosis based on histopathology, as a pathologic diagnosis was generally impractical and actually unnecessary.

**Conclusion**

SIF is a common complication for patients with cervical cancer after radiotherapy, which has some certain clinical and MRI features. MRI, especially coronal FS-T2WI may be more useful to detect and characterize these fractures than other imaging sequences. Knowing well these features help to prevent confusion with metastatic disease and inappropriate treatment.

**Abbreviations**

Radiotherapy: RT; Insufficiency fracture:IF; Sacral insufficiency fracture (SIF); MRI:magnetic resonance imaging; CT:computed tomography; BS:Bone scan; Fat-Suppressed T2-weighted (FS-T2W)

**Declarations**

**Ethics approval and consent to participate**

The Institutional Review Board of Affiliated Cancer Hospital & Institute of Guangzhou Medical University approved this retrospective study and waived the requirement for written informed consent due to its retrospective nature.

**Consent for publication**
Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

We would like to thank the Guangdong Medical Research Foundation (A2020263) for the funding to carry out this project. The funding bodies were not involved in the study design, data collection, analysis, interpretation, writing or revisions of this manuscript.

Authors’ contributions

JSL and XZ conceived and designed this study. LQZ, BGL and LH conducted the study and collected important background data. TFD and HM analyzed the medical images. ZX and LQZ drafted the manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors thank Elixigen Corporation (http://www.elixigen.com) for editorial assistance.

References


Tables

Table 1. The clinical history, RT project, symptom, interval time from RT to MRI, associated fractures and additional imaging examination in 28 patients with radiation-induced SIF detected by MRI.
<table>
<thead>
<tr>
<th>patients</th>
<th>year</th>
<th>Postmenopausal</th>
<th>FIGO staging</th>
<th>RT project</th>
<th>Dose (Gy)</th>
<th>Symptom</th>
<th>Interval (month)</th>
<th>Unilateral or bilateral SIF</th>
<th>Associated fractures</th>
<th>BS</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56</td>
<td>YES</td>
<td>IIA</td>
<td>Postoperative</td>
<td>50</td>
<td>Asymptomatic</td>
<td>10</td>
<td>Unilateral</td>
<td>NO</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>YES</td>
<td>IB1</td>
<td>Definitive</td>
<td>50</td>
<td>Asymptomatic</td>
<td>11</td>
<td>Bilateral</td>
<td>NO</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>64</td>
<td>YES</td>
<td>IIB</td>
<td>Definitive</td>
<td>60</td>
<td>Asymptomatic</td>
<td>9</td>
<td>Unilateral</td>
<td>NO</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>64</td>
<td>YES</td>
<td>IIA</td>
<td>Postoperative</td>
<td>56</td>
<td>Hip pain</td>
<td>6</td>
<td>Bilateral</td>
<td>NO</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>67</td>
<td>YES</td>
<td>IIB</td>
<td>Definitive</td>
<td>50</td>
<td>Low back pain</td>
<td>13</td>
<td>Bilateral</td>
<td>Bilateral pubis, L5</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>YES</td>
<td>IIIA</td>
<td>Definitive</td>
<td>50</td>
<td>Low back pain</td>
<td>13</td>
<td>Bilateral</td>
<td>L5, Left acetabulum</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>58</td>
<td>YES</td>
<td>IB1</td>
<td>Definitive</td>
<td>50</td>
<td>Hip pain</td>
<td>14</td>
<td>Bilateral</td>
<td>L5</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>69</td>
<td>YES</td>
<td>IIIB</td>
<td>Definitive</td>
<td>85</td>
<td>Hip pain</td>
<td>9</td>
<td>Bilateral</td>
<td>Bilateral pubis, L5</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>58</td>
<td>YES</td>
<td>IB1</td>
<td>Definitive</td>
<td>60</td>
<td>Low back pain</td>
<td>4</td>
<td>Bilateral</td>
<td>Left ilium</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>55</td>
<td>YES</td>
<td>IIA</td>
<td>Definitive</td>
<td>50</td>
<td>Asymptomatic</td>
<td>21</td>
<td>Bilateral</td>
<td>Left acetabulum</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>55</td>
<td>YES</td>
<td>IV</td>
<td>Definitive</td>
<td>62</td>
<td>Asymptomatic</td>
<td>8</td>
<td>Unilateral</td>
<td>NO</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>65</td>
<td>YES</td>
<td>IIB</td>
<td>Definitive</td>
<td>50</td>
<td>Asymptomatic</td>
<td>6</td>
<td>Unilateral</td>
<td>NO</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>13</td>
<td>68</td>
<td>YES</td>
<td>IIB</td>
<td>Definitive</td>
<td>56</td>
<td>Hip pain</td>
<td>23</td>
<td>Bilateral</td>
<td>Right ilium</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>56</td>
<td>YES</td>
<td>IVA</td>
<td>Definitive</td>
<td>63</td>
<td>Hip pain</td>
<td>34</td>
<td>Unilateral</td>
<td>Bilateral acetabulum</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>72</td>
<td>YES</td>
<td>IVA</td>
<td>Definitive</td>
<td>90</td>
<td>Asymptomatic</td>
<td>5</td>
<td>Bilateral</td>
<td>Bilateral acetabulum</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>69</td>
<td>YES</td>
<td>IIIB</td>
<td>Definitive</td>
<td>110</td>
<td>Hip pain</td>
<td>6</td>
<td>Unilateral</td>
<td>NO</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>61</td>
<td>YES</td>
<td>IVA</td>
<td>Definitive</td>
<td>90</td>
<td>Hip pain</td>
<td>15</td>
<td>Bilateral</td>
<td>Left pubis</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>18</td>
<td>68</td>
<td>YES</td>
<td>IIB</td>
<td>Definitive</td>
<td>50</td>
<td>Low back pain</td>
<td>7</td>
<td>Bilateral</td>
<td>NO</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>19</td>
<td>57</td>
<td>YES</td>
<td>IIA</td>
<td>Definitive</td>
<td>50</td>
<td>Asymptomatic</td>
<td>3</td>
<td>Unilateral</td>
<td>NO</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>58</td>
<td>YES</td>
<td>IIIB</td>
<td>Definitive</td>
<td>50</td>
<td>Hip pain</td>
<td>12</td>
<td>Bilateral</td>
<td>Bilateral acetabulum, pubis</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>47</td>
<td>NO</td>
<td>IIIB</td>
<td>Postoperative</td>
<td>100</td>
<td>Asymptomatic</td>
<td>11</td>
<td>Unilateral</td>
<td>NO</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>22</td>
<td>53</td>
<td>YES</td>
<td>IIB</td>
<td>Definitive</td>
<td>68</td>
<td>Hip pain</td>
<td>7</td>
<td>Bilateral</td>
<td>Bilateral acetabulum</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>23</td>
<td>65</td>
<td>YES</td>
<td>IIA</td>
<td>Definitive</td>
<td>62</td>
<td>Hip pain</td>
<td>11</td>
<td>Bilateral</td>
<td>Right acetabulum</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>24</td>
<td>65</td>
<td>YES</td>
<td>IIIB</td>
<td>Definitive</td>
<td>78</td>
<td>Hip pain</td>
<td>5</td>
<td>Bilateral</td>
<td>NO</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>25</td>
<td>68</td>
<td>YES</td>
<td>IIB</td>
<td>Definitive</td>
<td>90</td>
<td>Asymptomatic</td>
<td>10</td>
<td>Bilateral</td>
<td>NO</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>41</td>
<td>NO</td>
<td>IIB</td>
<td>Definitive</td>
<td>50</td>
<td>Hip pain</td>
<td>25</td>
<td>Bilateral</td>
<td>NO</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>27</td>
<td>51</td>
<td>NO</td>
<td>IIIB</td>
<td>Definitive</td>
<td>110</td>
<td>Hip pain</td>
<td>5</td>
<td>Unilateral</td>
<td>Right ilium</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>57</td>
<td>YES</td>
<td>IIIB</td>
<td>Definitive</td>
<td>50</td>
<td>Hip pain</td>
<td>12</td>
<td>Bilateral</td>
<td>Bilateral acetabulum</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

FIGO=International Federation of Gynecology and Obstetrics, RT=radiotherapy, BS= bone scan, NA= not available

Table 2. The detection rate of bone marrow edema and fracture line on MRI for the SIFs lesions (n=47)
Bone marrow edema & Fracture line

<table>
<thead>
<tr>
<th>MRI sequences</th>
<th>T1WI</th>
<th>FS-T2WI</th>
<th>Enhanced T1WI</th>
<th>All images</th>
<th>T1WI</th>
<th>FS-T2WI</th>
<th>Enhanced T1WI</th>
<th>All images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>45</td>
<td>47</td>
<td>41</td>
<td>47</td>
<td>17</td>
<td>29</td>
<td>24</td>
<td>31</td>
</tr>
<tr>
<td>Percentage</td>
<td>95.7%</td>
<td>100%</td>
<td>87.2%</td>
<td>100%</td>
<td>36.2%</td>
<td>60.4%</td>
<td>51.1%</td>
<td>64.6%</td>
</tr>
</tbody>
</table>

**Figures**

**Figure 1**

Right SIF in a 58-year-old woman with cervical cancer after radiotherapy. A. BS showed right sacrum increased accumulation (arrow). B. Axial T1WI showed hypointensity. C. Axial T2WI showed moderate hyperintensity. D. Coronal FS-T2WI showed severe bone marrow edema and diagonal fracture line (arrow). E. Axial enhanced T1WI showed mild contrast enhancement.

**Figure 2**
Right SIF in a 65-year-old woman with cervical cancer after radiotherapy. A. Axial T1WI showed hypointensity. B. Coronal FS-T2WI showed severe bone marrow edema with fracture line (arrow). C–D. Axial and sagittal enhanced T1WI showed contrast enhancement. E–F. Coronal and axial CT images showed no overt positive finding.

Figure 3

Bilateral SIFs had coexistent L5, acetabulum fractures in a 68-year-old woman with cervical cancer after radiotherapy. A–B. Axial T1WI and enhanced T1WI showed right sacrum abnormal signal (arrow). C. Coronal FS-T2WI showed abnormal signal in bilateral sacrum, right sacrum showed severe bone marrow edema, and left sacrum showed mild bone marrow edema (arrow). D–E. Coronal FS-T2WI showed acetabulum and L5 fractures. F. Coronal CT image showed osteosclerosis change in L5 and right sacrum.

Figure 4

Bilateral SIFs had coexistent bilateral ilium fractures in a 70-year-old woman with cervical cancer after radiotherapy. A–B. Axial T1WI and T2WI showed bilateral sacrum low signal (arrow). C. Coronal FS-T2WI showed bilateral sacrum and ilium hyperintensity, bilateral sacrum with severe bone marrow edema. D. Axial enhanced T1WI showed mild contrast enhancement in bilateral sacrum. E–F. Axial and coronal CT image showed osteosclerosis change.
Figure 5

Bilateral SIFs had coexistent pubis fracture in a 63-year-old woman with cervical cancer after radiotherapy. A. BS showed bilateral sacrum increased accumulation (white arrow) as an "H-sign", and left pubis increased accumulation (red arrow). B. Axial T1WI showed hypointensity. C. Coronal FS-T2WI showed severe bone marrow edema. D. Axial enhanced T1WI showed contrast enhancement in bilateral sacrum. E. Axial enhanced T1WI showed enhancement with fracture line.