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Potential Pitfalls of Steatopygia on Bone Scintigraphy and the Added Value of Single Photon Emission Computed Tomography and Single Photon Emission Computed Tomography/Computed Tomography

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Highlights of the Study

- Fat attenuation is well known in nuclear medicine; however, the effect of steatopygia on bone scans of obese patients is poorly understood and not widely recognized.
- This study sheds the light on significant attenuation brought about by steatopygia which may hide abnormalities and edge artifacts that may stimulate pathological conditions.
- Single photon emission computed tomography/computed tomography (SPECT/CT) clarifies the confusion in some of these cases and improves diagnostic accuracy.

Keywords
Steatopygia · Obesity · Bone scintigraphy artifact · Attenuation · Crease edge artifact

Abstract
Objectives: The aims of the study were to assess the prevalence of steatopygia on bone scintigraphy of obese patients and to evaluate its effect on the appearance of the lumbar spine, and the added benefit of single photon emission computed tomography (SPECT) and SPECT/computed tomography (SPECT/CT) in overcoming possible artifacts. ***Methods:*** Patients with BMI ≥30 who underwent bone scintigraphy between 2016 and 2019 were included. Three nuclear medicine consultants reviewed the studies to determine whether significant steatopygia was present, and whether it resulted in attenuation of underlying lumber spine and crease edge artifact. SPECT or SPECT/CT images were reviewed to evaluate their impact on diagnosis. ***Results:*** 56 out of the 100 patients were noted to have steatopygia on planar images. Among the group of 80 obese patients, 50% showed steatopygia, while in the group of 20 morbidly obese patients, 80% showed steatopygia. 32 of the 56 patients with steatopygia had significant attenuation at the lower lumber vertebrae. Nine of these patients showed crease edge artifact. SPECT and SPECT/CT clarified the scintigraphic abnormalities noted in all patients including those with edge artifact alleviating diagnostic difficulty. Among the 9 patients with edge artifact, 6 patients

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showed normal appearance on SPECT/CT images while three showed true abnormalities. ***Conclusions:*** Steatopygia is common on bone scintigraphy of obese patients, higher in females and morbidly obese patients. Obesity-related artifacts in bone scintigraphy, including attenuation effect and edge artifact, are common in this patient group. SPECT or SPECT/CT improves the diagnostic accuracy by overcoming the effects of steatopygia seen on planar images.

Introduction

Over the last 30 years, there has been an exponential growth in the prevalence of obesity worldwide with doubling rates for adult and childhood obesity (6–11 years) and tripling rates of adolescent obesity (12–19 years) [1–3]. Obese patients suffer from health conditions that require radiologic procedures more than the non-obese patients [4–7]. With the increasing number of obese patients, there has been an increase in the number of radiological images that became difficult to interpret [8–10].

Bone scintigraphy continues to be a powerful diagnostic tool in many benign and malignant bone diseases. Understanding the disease process and technical factors that affect the studies is crucial for effective and accurate interpretation of scans. Many factors can influence the quality and appearance of images in bone scintigraphy and consequently the interpretation of the studies. These include injection technique, camera type and set-up, image acquisition, processing, and display techniques. Other factors related to the patient include age, body habitus, hydration status, and comorbid conditions such as diabetes and renal diseases [11]. Also, the addition of single photon emission computed tomography (SPECT) images, which can be fused with SPECT/computed tomography (CT), to the planar images can improve the diagnostic accuracy of the study [11].

Body habitus can have a significant impact on the image quality of bone scintigraphy [11, 12]. This can vary between societies based on the prevalence of obesity and the distribution of body fat constitutionally. Breast and fat crease attenuation may result in imaging artifacts at multiple regions including the lumbar spine [7, 11, 13, 14].

Steatopygia is described as prominent fat tissue in the region of the buttocks (steato: fat, pygia: buttocks) [12]. It results from the high degree of fat accumulation in and around the buttocks that can extend to the outside of the thighs. It may negatively affect the quality of bone scintigraphy as it may lead to diagnostic pitfalls [11, 15, 16]. Steatopygia can cause marked attenuation and decrease the number of counts in the lumbar spine and pelvic region obscuring underlying pathological conditions. In addition, the folded skin may create a thicker amount of soft tissue overlying the imaged area of interest causing abnormally increased uptake at the edge of the fat crease in a linear fashion mimicking a true abnormality. Subsequently, this may result in crease edge artifacts that can be mistaken for pathological lesions. The objective of this retrospective study is to assess the prevalence of steatopygia on bone scintigraphy of obese patients and to evaluate its effect on the appearance of the lumbar spine on bone scintigraphy and the added value of SPECT and SPECT/CT in overcoming fat attenuation and soft tissue-related artifacts if present.

Methods

Bone scans performed in two general hospitals in Kuwait between July 2016 and June 2019 were reviewed. The patients' weight and height were recorded, and their BMI was calculated. Only obese patients with a BMI of 30 and above were included in the study.

All patients received a standard dose of 740–925 MBq (20–25 mCi) of Tc-99m methylene diphosphonate for bone scintigraphy intravenously, and two or three-phase images were acquired as per the departmental protocol. A dual-head gamma camera (Discovery GE 16 slice SPECT/CT) equipped with a large field of view, low energy, high resolution, parallel hole collimator was used with an energy window set at 20% and centered at 140 keV. Flow images were obtained at 3 s per frame for 60 s followed by regional and whole body blood pool images at approximately 10 min post-injection. Delayed whole body images were then performed at 3 h post-injection using a 256 × 1,024 matrix with a speed of 8 min per meter where the patient was positioned supine with arms at the side. This was followed by static views of the area of interest using a 256 × 256 matrix.

For SPECT images, a matrix size of 64 × 64 with non-circular acquisition mode was used for patients who underwent either SPECT or SPECT/CT scans. Sixty projections were acquired at 20 s per projection with 6° angle and 180° arch. Butterworth filter is used with cut-off 0.43, order 7. For CT, helical acquisition with voltage is set at 140 kV, current at 80 mA, pitch of 0.5, and rotation speed at 1 s per rotation. The slice thickness was set at 2.5 mm.

Three nuclear medicine consultants reviewed the early and delayed planar images as well as SPECT/CT images of all the included patients to determine the presence and significance of the steatopygia. Attenuation was determined when bone uptake was less in the area of lumber spine compared to other bony structures. Steatopygia was considered significant if it results in enough attenuation that partially obscured the vertebrae's visualization on delayed images affecting proper interpretation and evaluation of the study. The presence of crease edge artifact was considered if there is an apparent increase in uptake of the vertebrae at the level of the fat crease.

Table 1. Impact of steatopygia on planar bone scan among patients studied

Patient gender	Total number (%) of patients with steatopygia	Number (%) of patients with steatopygia who have significant lumbar attenuation on bone scan	Number (%) of patients with steatopygia who have crease edge artifact
All patients, *n* (%)	56 (56)	32 (57)	9 (16)
Females, *n* (%)	44 (79)	25(78)	9 (100)
Males, *n* (%)	12 (21)	7 (22)	0 (0)

When available, SPECT or SPECT/CT images were also reviewed to clarify the scintigraphic abnormalities of planar images. Any disagreement was resolved by consensus.

Statistical Analysis

The IBM Statistical Package for Social Sciences version 23 (SPSS Inc., Chicago, IL, USA) was used to perform all statistical analysis. Group statistics, providing basic information about group comparisons, including the sample size (n), mean, and standard deviation were calculated and presented as mean ± standard deviation The independent sample *t* test was conducted to compare the means between groups in order to determine statistical significance. The data were sorted into two groups based on the value of BMI: 30–39.9 (obese group) and ≥40 (morbidly obese group).

Results

One hundred obese patients fulfilled the inclusion criteria: 66 females and 34 males with a mean age of 53 years and a mean BMI of 36. Among the patients included, there were 56 patients with noted steatopygia (44 females and 12 males) as shown in Table 1. Based on our data of all the 100 patients, there is a statistically significant correlation between BMI and steatopygia ($p = 0.003$). Of the 80 patients in the obese group, 39 (48.75%) patients had steatopygia while 41 did not. There was no statistically significant correlation between BMI and steatopygia in this obese group ($p = 0.206$). On the other hand, of the 20 patients in the morbidly obese group 17 (85%) patients had steatopygia and 3 did not. In this morbidly obese group, there was a statistically significant correlation between BMI and steatopygia ($p = 0.013$).

Among the 32 patients (25 females and 7 males) with steatopygia, we observed significant attenuation (Fig. 1) at the lower lumber vertebrae noted on the planar images (Table 1). Nine patients additionally showed crease edge artifact (Table 1). Among the 56 patients with steatopygia, 41 patients had SPECT (4) or SPECT/CT (37). SPECT and SPECT/CT clarified the nature of the scintigraphic abnormalities noted in all patients including patients with crease edge artifact (Table 2). Among the 9 patients with crease edge artifact, 6 patients showed normal appearance on SPECT and CT images; 3 patients showed true abnormalities, one osteolytic lesion, one osteoblastic lesion, and one vertebral fracture which were clarified on CT images. Eleven patients had degenerative changes clearly seen on SPECT or SPECT/CT but obscured on planar images by fat attenuation (Table 2; Fig. 2, 3). Accordingly, SPECT and SPECT/CT had an impact on the management of at least 14 patients due to clarifying the diagnosis after overcoming the attenuation or crease effects.

Discussion

A study by Uppot et al. [17] examined radiological reports between 1989 and 2003, during which a steady increase in obesity rates was observed [15]. It was noticed that there had been a linear increase of reports claiming that the quality of the collected images was "limited due to body habitus." Obesity has been previously reported to affect the image quality in chest radiography by decreasing photon penetration and increasing attenuation through the subcutaneous fat [6, 11, 17–20]. This can also affect bone densitometry studies, causing false higher values at the level of the crease. However, diffuse fat attenuation may also underestimate values of lumbar spine bone density [15]. This was also observed in vivo as lumbar spine bone mineral density was underestimated using dual-energy X-ray absorptiometry [21].

In nuclear medicine, obesity can negatively affect the quality of the acquired images in different ways. First, attenuation and scattering of photons caused by overlying fat tissue degrade the image quality by increasing the noise and decreasing the count rates, thus decreasing the signal-to-noise ratio. This may result in attenuation of the underlying structures and therefore loss of visibility of

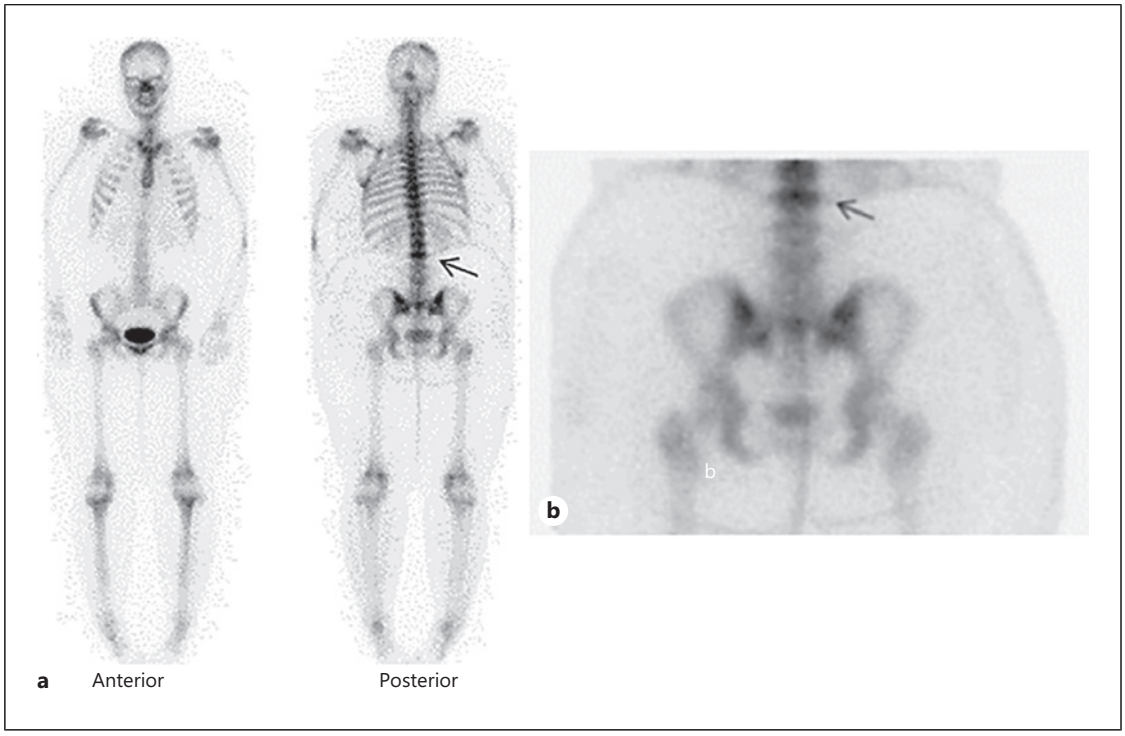

Fig. 1. a 3 h delayed whole body planar images. **b** Posterior static image of the lumbar spine and pelvis of a 23-year-old female with BMI of 45.7. The images demonstrate significant fat attenuation at the lower lumbar spine with a crease edge artifact (arrow) along the line of the fat crease.

Table 2. Findings on planar, SPECT, and SPECT/CT studies among patients with steatopygia

Study	Planar	SPECT or SPECT/CT
Patients, *n*	56	41
Degenerative changes not seen on planar due to attenuation	11	Definite diagnosis in all 11 patients
Edge artifact	9	All resolved (6 confirmed artifacts, 3 true pathologies)

smaller details and pathological lesions [9, 22, 23]. Second, the folded skin may create a thicker amount of soft tissue at the edge of the fat crease that may apparently increase the number of counts in a linear fashion resulting in crease edge artifact. If this artifact is at the level of a vertebral body, it could be mistaken for pathologic lesions including tumors and compression fracture [24, 25].

Steatopygia-related artifacts are under-recognized and can be overlooked leading to misinterpretations. Our study shows that more than half (56%) of the included patients had a noted steatopygia. There was a statistically significant correlation between BMI and steatopygia with a p value of 0.003. However, the high prevalence along with the statistically significant correlation with BMI from our data indicates that steatopygia is a common feature of the body habitus of obese patients. In addition, there was a statistically significant correlation between steatopygia and the morbidly obese group but not with the obese group. This is likely because the higher the BMI, the thicker the subcutaneous fatty tissue.

Of the 56 patients with steatopygia, 32 (57%) had a significant visual attenuation of the underlying lumbar vertebra. This attenuation resulted in decrease of the number of counts causing suboptimal evaluation of that region. On the other hand, another 9 patients (16%) showed crease edge artifact. This artifact resulted in an apparent linear abnormality in the lumbar spine that could be mistaken for pathological lesions. Our group has previously reported the effects of steatopygia and the added benefit of SPECT alone [12]; to the best of our knowledge, there are no

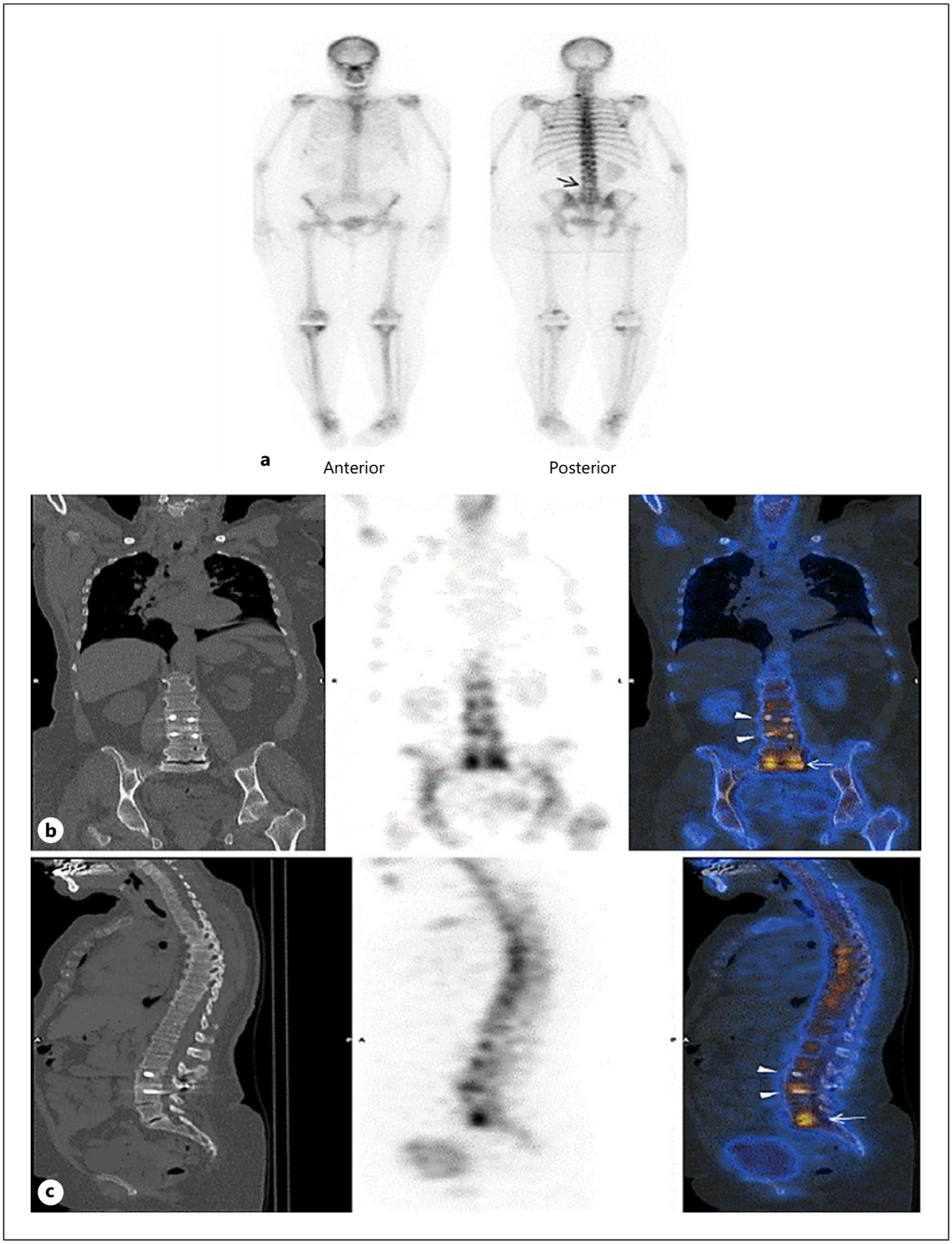

Fig. 2. a 3 h delayed planar images of a 67-year-old male with a BMI of 40.4 and a history of spinal surgery and hardware insertion at L3-L4 a year earlier. The images demonstrate fat attenuation at the lower lumber spine (arrow). Selected SPECT/CT images, coronal (**b**) and sagittal (**c**), demonstrate the postsurgical changes at L3-L4 (arrowheads) and degenerative endplate disease at L5-S1 (arrow). These changes were not seen on planar images since the attenuation effect of steatopygia obscured the findings.

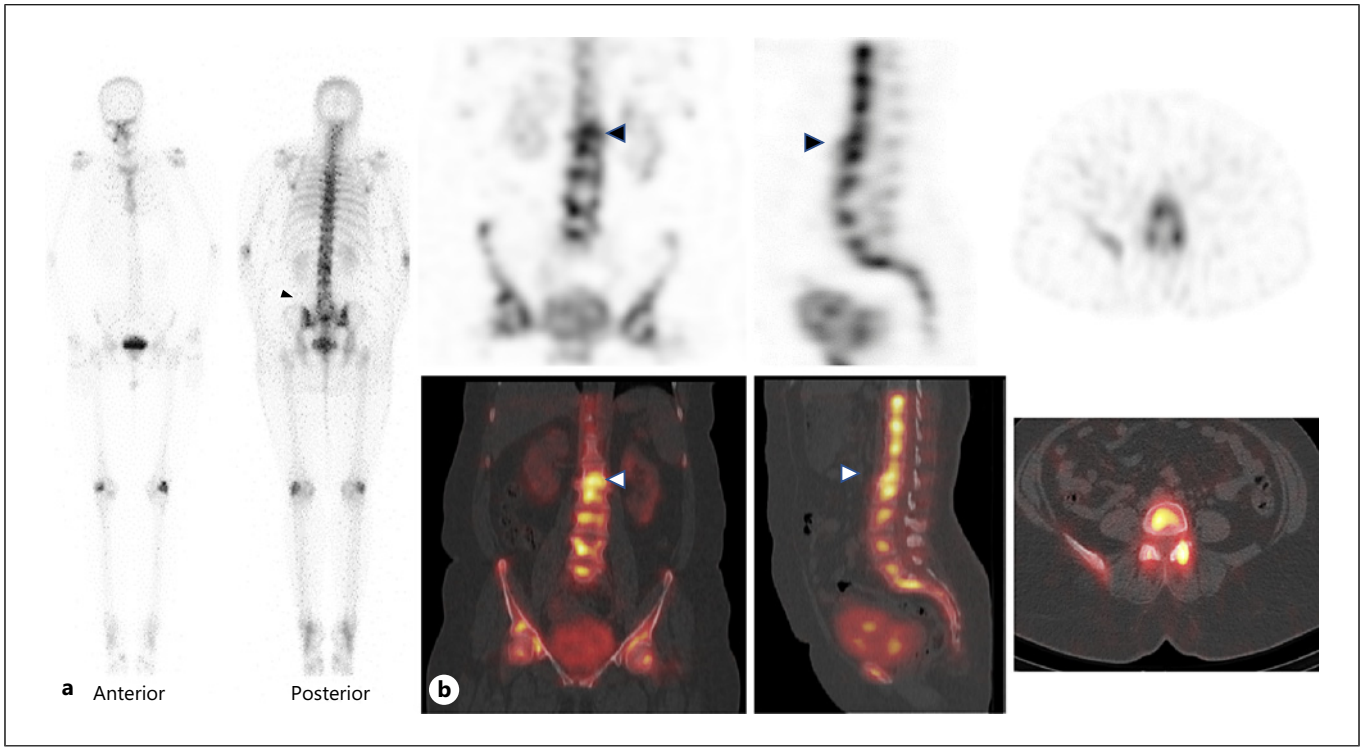

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Fig. 3. a 3 h delayed planar images of a 63-year-old female with a BMI of 41.9 demonstrate apparent decreased counts at the lower lumbar spine (arrowhead) likely representing fat attenuation with crease edge artifact above it. **b** SPECT/CT images show clearly degenerative endplate disease at the level of L1-L2 (arrowhead) corresponding to and hidden by the crease edge artifact. Also, there is a left-sided degenerative facet joint disease on the axial images which was masked on the planar images.

published studies on the prevalence of this attenuation and edge artifacts on bone scintigraphy. However, based on our results, these artifacts appear to be common in obese patients and therefore careful evaluation of bone scintigraphy is warranted to avoid misinterpretation.

In terms of gender, 66% of the patients in this study were females. In addition, females represented 79% of patients with steatopygia, 78% of patients with significant lumbar attenuation, and 100% of patients with crease edge artifact. These results are consistent with the literature where gender differences in fat distribution were identified. Females usually have more peripheral subcutaneous fat tissue, while males usually have more central and visceral fat tissue. These gender differences were attributed to the effects of sex hormones, cell-specific properties, and the microenvironment in fat depots [26].

In order to overcome these obesity-related artifacts in bone scintigraphy, SPECT or SPECT/CT can be used [12, 23]. Multiple techniques, in addition to SPECT/CT, have been used to optimize the image quality when performing bone scintigraphy in obese patients. These patients are usually given the maximum allowable dose of the radioisotope to achieve adequate quality of the study. However, sometimes the given weight-based dose may exceed the maximum allowable injected activity [27]. In addition, different algorithms for the correction of attenuation have been used to improve the image quality at a substantially lower injected dose in obese patients [28]. Another alternative is to use a longer acquisition time to collect higher number of counts to increase the signal-to-noise ratio [29]. Yet, another technique is to narrow the acceptable energy window or to use asymmetrical window to decrease the number of scattered photons [27].

In our study, 41 out of the 56 patients with steatopygia underwent SPECT or SPECT/CT. SPECT or SPECT/CT images were useful to eliminate the soft tissue attenuation of the lumber spine. Additionally, SPECT or SPECT/CT could help detect and localize degenerative changes at the lumber spines that were missed on the planar images in 11 patients. SPECT or SPECT/CT helped clarify the edge artifact in all the 9 patients who had it. Six out of these 9 patients were confirmed to have no underlying pathological lesions. In the other 3 patients, the edge artifact was unmasked to reveal underlying true pathological conditions,

which were osteolytic lesion, osteoblastic lesion, and a compression fracture. These findings are consistent with previously published articles regarding the added value of SPECT/CT in improving the accuracy of bone scintigraphy in obese patients. Therefore, SPECT/CT should be considered, if available, when performing bone scintigraphy in obese patients to overcome the attenuation effect and to clarify the crease edge artifact [11, 13, 14, 23].

Our study has several limitations. It is a retrospective study with a relatively small number of patients. Given the retrospective nature of this study, the energy window and the imaging time were fixed as per the standard imaging protocol in our department. Also, only 41 out of the 56 patients with steatopygia were found to have SPECT or SPECT/CT of the lumbar spine as some of the patients had SPECT/CT of other body areas.

Conclusion

This study shows that steatopygia is common in obese patients and has higher prevalence in females and morbidly obese patients. Obesity-related artifacts, including attenuation effect and crease edge artifact, are common in this patient group. Careful attention should be paid to these artifacts to avoid misinterpretation of bone scintigraphy. Adding SPECT or SPECT/CT of the lumbar spine to the planar imaging is recommended as it improves the diagnostic accuracy in these patients by overcoming the effects of steatopygia artifact seen on whole body and spot planar images.

Statement of Ethics

Approvals were obtained from the Ethics Committees at the Faculty of Medicine in Kuwait University and the Ministry of Health of the State of Kuwait. Patient consent was not needed for a retrospective study as no personal patient data were used.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Saud Alenezi: review of images, and writing and approval of manuscript; Shorouk Dannoon: collection of raw data, data analysis, and writing and approval of manuscript; Naheel Alnafisi: review of images and approval of final manuscript; Jehan alshammari: collection of images and approval of final manuscript; Abdelhamid Elgazzar: identification of research idea, review of images, and writing and approval of manuscript.

Data Availability Statement

Data are available upon request.

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