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Optimization of the bone single photon emission computed tomography in oncology patients

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ABSTRACT

Introduction: The introduction of hybrid imaging systems such as single photon emission computed tomography/computed tomography (SPECT/CT) has completely changed the scanning procedure of conventional diagnostic nuclear medicine protocols. Modern bone scintigraphy protocols include standardized uptake value quantification and whole body (WB) SPECT/CT scanning modality. The major limitation of these new technologies is the relatively long scanning time. New detector systems with modern reconstruction software have been developed for fast scanning SPECT protocols. These new technologies can produce images of reduced acquisition with the same quality as full scanning acquisition. As a result, new studies suggest that planar WB scintigraphy should be replaced with WB SPECT/CT.

Methods: One hundred oncology patients performed SPECT/CT as a part of their clinical follow-up. Three different scanning and three reconstruction protocols have been evaluated. Two nuclear medicine physicians evaluated with Likert scale image sharpness, lesion visibility, and lesion background detectability. The overall image quality was determined as the sum of these three parameters.

Results: In terms of scan duration reduction on image quality, Volumetrix Evolution for Bone performed during ultra-fast SPECT acquisition achieved the highest score, which is superior compared to the standard SPECT acquisition protocol. The overall image quality was the best with the Volumetrix MI Evolution for Bone protocol for ultra-fast acquisition.

Conclusion: The Evolution for Bone protocol for ultra-fast acquisition showed the best results compared to other protocols. The adoption of the new acquisition SPECT protocol may offer more comfortable examinations, resulting in higher patient satisfaction. The implementation of this new protocol can lead to an improvement in SPECT sensitivity, primarily due to the reduction of SPECT motion artifacts: SPECT has significantly improved nuclear medicine diagnostics. The disadvantage of SPECT methods is the relatively low signal-to-noise ratio and contrast-to-noise ratio. The low number of image photons is a major problem with SPECT imaging, as the signal decreases as the noise (image background) increases.

Keywords: Single photon emission computed tomography; signal-to-noise ratio; contrast-to-noise ratio; RR

INTRODUCTION

Bone scintigraphy provides insight into the entire skeletal system with a relatively low radiation burden for the patient (1). Since the mid-70s of the last century, the rapid development of radiopharmacy and imaging technology has led to the expansion of bone scan usage. 99 mTc radiopharmaceuticals based on diphosphonates have been utilized for Gamma camera scanning (2). Planar bone scintigraphy has been enhanced with 3D visualization of the radiopharmaceutical distribution in the skeletal region based on single photon emission tomography (SPECT). The major advantage of the SPECT modality is its better sensitivity and specificity in comparison to planar imaging methodology (3). Scatter and attenuation correction techniques, along with resolution recovery iterative reconstruction algorithms, are the most commonly used techniques for the reconstruction of SPECT images. On the other hand, the introduction of hybrid imaging systems such as SPECT/computed tomography (CT) has completely changed the scanning procedure of conventional diagnostic nuclear medicine protocols. These new technologies significantly improve image quality, resulting in better diagnostic sensitivity and

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specificity (4). Nowadays, SPECT/CT images of the skeletal system can be used to measure quantitative uptake of the radiopharmaceutical in the same way as positron emission tomography (PET)/CT methodology. This aspect of image interpretation is called standardized uptake value (SUV) quantification. SUV measurement has a significant impact on the sensitivity and specificity of the SPECT/CT study because based on the results from different studies, SUV quantification can determine bone lesions and disease prognosis (5). Besides diagnostic accuracy, quantitative SPECT/CT has a great impact on theranostics since 177Lu is a very popular isotope for dosimetry and therapeutic response in many pathological conditions (6,7). Since SPECT/CT scanning can provide much more information compared to planar bone scintigraphy, many studies highlight the potential of whole-body (WB) SPECT/CT imaging. A major limitation of this technology for many years has been the relatively long SPECT scanning time. This prolonged scanning time can result in patient movement with image artifacts and inadequate fusion between SPECT and CT images. Long scanning time can also result in false SUV measurements in the case of SPECT quantification. Many studies highlight the potential of scan time reduction without degradation of image quality because new, more sensitive detector systems with advanced software applications (iterative reconstruction with resolution recovery) have been developed for new fast SPECT scanning protocols (8). New protocols suggest that planar WB scintigraphy should be replaced with WB SPECT/CT. Conventional WB SPECT/CT covers the surface from the vertex to the mid-thigh, containing three field of view regions. Since SPECT/CT improves the sensitivity and specificity of the nuclear medicine bone scan, WB SPECT/CT can result in an improvement in clinical impact similar to PET/CT and WB magnetic resonance imaging (9). Zacho et al. showed that ultra-fast SPECT/CT can result in almost the same sensitivity and specificity compared to conventional SPECT/CT. Moreover, many studies suggest using reduced SPECT scanning time with new reconstruction modalities based on resolution recovery (10).

The aim of our research was to investigate the possibility of reducing SPECT acquisition duration and to evaluate the impact of reduced acquisition on image quality.

METHODS

We conducted a prospective study involving 100 oncology patients who underwent planar whole-body (WB) bone scintigraphy as part of their oncological follow-up. The routine clinical protocol utilized an activity of 740 MBq Tc-99 m-labeled methylene bisphosphonate, irrespective of the weight of adult patients. Following WB bone scintigraphy, we performed SPECT/CT of specific anatomical regions based on the request of the nuclear medicine physician. Images from the planar and SPECT/CT studies were acquired using the Discovery 670 NM/CT Dual head Gamma camera (GE Healthcare, Waukesha, Wisconsin, USA). In this study, we evaluated three SPECT acquisition and reconstruction protocols. The acquisition protocols were: standard SPECT acquisition with 15 s per view, fast SPECT acquisition with 10 s per view, and ultra-fast SPECT with 8 s per view. The reconstruction protocols utilized were: Volumetrix MI, Evolution for Bone, and CDRC evolution. Since CT scans were performed for every patient, low-dose CT parameters were employed. On completion of the clinical examinations, a total of nine SPECT protocols were evaluated using the Likert scale, with values ranging from 0 to 3; 0 indicating no diagnostic validity, 1 indicating good, 2 indicating very good, and 3 indicating excellent. Parameters assessed by the two nuclear medicine physicians in this study included: Image sharpness, lesion visibility, and lesion background detectability. The overall image quality was determined as the sum of these three parameters.

Research is approved by the Ethical Committee of the Clinical Center of Sarajevo University.

RESULTS

The majority of patients had prostate cancer (n = 54) or breast cancer (n = 30), whereas the remaining 16 patients had other cancer diagnoses.

The total image quality represents the sum of the three parameters graded by the two nuclear medicine physicians. It has been presented with median, interquartile range, and mean values. Statistical significance was denoted by $p < 0.05$.

The analysis of scan duration and reconstruction protocol impact on image quality (Table 1) revealed that Volumetrix Evolution for Bone yielded the best results for every aspect of image quality. In terms of scan duration reduction on image quality, Volumetrix Evolution for Bone performed during ultra-fast SPECT acquisition achieved the highest score (mean value = 14.64), which is superior compared to the standard SPECT acquisition protocol.

Comparison of the image quality between ultra-fast and standard SPECT images indicates the total number of images with the same, reduced, or improved quality (Table 2). These data are crucial for calculating the clinical potential of reduced SPECT acquisition.

Volumetrix MI for oncology exhibited overall good image quality in 44 cases. Nearly identical results were achieved with the CDRC Evolution M protocol. In the ultra-fast

TABLE 1. Total image quality analysis based on the SPECT acquisition duration and reconstruction protocol

Total image quality (acquisition and reconstruction)	Median	IQ range	Mean	*p*
Volumetrix MI for oncology standard	11.00	9.5-12	10.41	<0.001
Volumetrix MI for oncology fast	11.00	9-12	13.31	
Volumetrix MI for oncology ultra-fast	10.00	8-11	9.67	
Volumetrix MI evolution for bone standard	14.00	12-15	13.45	<0.001
Volumetrix MI evolution for bone fast	13.50	12-15	10.91	
Volumetrix MI evolution for bone ultra-fast	15.00	13-16	14.64	
CDRC evolution MI standard	11.00	9-13	11.00	0.071
CDRC evolution MI fast	11.00	9-13	10.42	
CDRC evolution MI ultra-fast	11.00	8-12	10.35	

SPECT: Single photon emission computed tomography

TABLE 2. Total image quality analysis based on the reconstruction protocol for ultra-fast and standard SPECT acquisition duration

Acquisition and reconstruction	Quality assessment	n	%	Sensitivity (%)
Volumetrix MI for oncology ultra-fast meets the criteria of standard	Lower quality	56	56	44.0
	Same quality	21	21	
	Better quality	23	23	
Volumetrix MI evolution for bone ultra-fast meets the criteria of standard	Lower quality	14	14	86.0
	Same quality	22	22	
	Better quality	64	64	
CDRC evolution M ultra-fast meets the criteria of standard	Lower quality	57	57	43.0
	Same quality	18	18	
	Better quality	25	25	

SPECT: Single photon emission computed tomography

SPECT study, Volumetrix MI Evolution for Bone demonstrated better image quality in 64 cases compared to the standard SPECT acquisition protocol. Only 14 cases resulted in lower image quality, whereas 22 cases had the same image quality. The overall image quality was the best with the Volumetrix MI Evolution for Bone protocol, observed in 86 cases.

DISCUSSION

Our results suggest that fast SPECT acquisition is feasible without compromising image quality. Furthermore, fast SPECT scanning time, coupled with adequate reconstruction programs (RR modality), can lead to even better image quality, thereby enhancing SPECT sensitivity and specificity. Ashton et al. conducted a study aimed at validating resolution recovery in routine clinical practice for bone SPECT. They found that Evolution for Bone (protocol with RR modality) can improve image resolution and contrast compared to conventional SPECT reconstruction modalities. Their results demonstrate significant potential for reducing SPECT scanning time; they observed that a 25% reduction in scanning time maintains the same image quality as full scanning time. However, ultra-fast acquisition is still in the testing phase of their research (11).

Our results clearly indicate that halving the SPECT acquisition time is feasible, especially in specific conditions such as painful patients, pediatric patients, and patients with urinary bladder problems. Regarding the general image quality of SPECT images, Hughes and Celler conducted a study to investigate three major SPECT/CT manufacturers and their modern RR modalities. They found that RR modality in all three manufacturers yields excellent image quality. Despite differences in image sharpness, contrast, and resolution, each manufacturer achieved good overall image quality (12).

On completion of their research, Alqahtani et al. recommended the usage of ultra-fast SPECT acquisition, especially when transitioning from planar bone scintigraphy to WB bone SPECT/CT. They discovered that image quality is not compromised with short scanning times because fast SPECT provides more information than planar studies. This new protocol is considered state-of-the-art and should be incorporated into routine clinical practice (8).

When we compared images of ultra-fast and standard protocols, we found that a specific bone oncology reconstruction protocol yielded better results for ultra-fast acquisition. This improvement can be attributed to a combination of optimal reconstruction parameter settings and the resolution recovery modality. Better image quality was achieved in 64 cases, providing sufficient evidence to establish a protocol for routine clinical practice. Livieratos et al. conducted a similar study and found that OSEM reconstruction with RR modality received better grades for short acquisitions compared to conventional FBP reconstruction for full acquisition durations. These results clearly indicate that a reduction in scanning time is feasible (13).

Aldridge et al. evaluated the impact of RR modality on reduced scanning time for tomographic images of bones and the parathyroid gland. The results demonstrated improved quality of both standard and reduced images, clearly indicating that SPECT acquisitions can be acquired in half the time previously required. The SPECT scanning protocol for the parathyroid gland was reduced from 30 to 15 min and for bone SPECT from 20 to 10 min. This optimization greatly benefits movement artifacts and urinary bladder problems since patient throughput is increased (14).

Regarding SPECT acquisition methodology, Shibutani et al. proposed a new methodology where images can be acquired even while moving between detectors. This new methodology, in combination with RR modality, can decrease scanning time by 25 to 50%. With respect to image quality, it is possible to preserve the sensitivity and specificity of the SPECT procedure (15). Similar results were achieved by Picone et al., who investigated a new SPECT acquisition methodology called step-and-shoot continuous (SSC). This methodology, as previously described, acquires data when the detector is stationary and when the detector moves from one view to the next. SSC, in combination with RR modality, reduces examination time by approximately 25% in bone and lung SPECT studies compared to step-and-shoot mode (approximately 2 min per single-bed SPECT study), without compromising image quality and signal quantification (16).

CONCLUSION

The implementation of this new protocol can lead to an improvement in SPECT sensitivity, primarily due to the reduction of SPECT motion artifacts. Furthermore, the adoption of new acquisition SPECT protocols may offer more comfortable exams, resulting in higher patient satisfaction. Beyond the gain in scanning time, this optimization has the potential to enhance lesion detection, improve image quality, and potentially facilitate quantification if adequate software is available for SUV measurement and organ risk stratification in the agnostic procedures.

DECLARATION OF INTERESTS

Author declares no conflict of interests.

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