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Local Validation of the Use of Evolution for Bone^{TM} for Bone SPECT imaging

Running Title:
Local Validation of Evolution for Bone^{TM} for Bone SPECT imaging

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Purpose

In order to locally validate the technique, a retrospective review of a cohort of randomly-selected Single Photon Emission Computed Tomography (SPECT) bone scans reconstructed with OSEM (Ordered Subsets Expectation Maximisation) and Evolution for Bone™ (GE Healthcare) was undertaken.

Materials and Methods

Thirty consecutive bone SPECT patient datasets (17 spine, 9 pelvis, 4 spine and pelvis) were chosen. Poisson resampling was used to simulate reduced count data at 50%, 75% and also 100% of the original number of counts. Evolution for Bone™ applied resolution recovery to the reduced count images. All images were compared to the original OSEM images, currently used as the standard for clinical use. A qualitative blinded assessment was made by two independent observers, and assessed for noise, contrast and resolution.

Results

Both radiologists saw an improvement in resolution ($p = 0.776$), noise ($p = 0.007$) and image quality with all the datasets, compared to images processed purely with OSEM and viewed in Volumetrix (GE Healthcare). However, they completely disagree about contrast, as the two radiologists scored contrast differently, but the results are understandable.

Conclusions

Images with 50%, 75% and 100% of the original counts viewed using Evolution for Bone™ have improved image quality compared to images processed purely with OSEM and viewed in Volumetrix. Evolution for Bone™ therefore has great potential for departments to use to reduce either their patient doses, waiting lists, or both.

Data presented previously at the British Nuclear Medicine Society 42nd Annual Meeting, Harrogate, 11-14th May 2014 and published as abstract in Nuclear Medicine Communications 2014, 35:541-584.

Key Words:

Bone, resolution recovery, wide-beam reconstruction, image quality, single-photon emission computed tomography

Introduction

The use of resolution recovery for bone and myocardial perfusion imaging is becoming increasingly popular in Nuclear Medicine departments. Resolution recovery has the potential to reduce patient doses and imaging times. With patient waiting lists exerting increasing pressure on departments, the requirement for such software is increasing.

Several manufacturers now offer their own resolution recovery software. GE Healthcare offer the Evolution for Bone™ package while other manufacturers have their own implementations.

Resolution recovery packages attempt to improve the quality of SPECT images by incorporating the collimator-detector response (CDR) function into reconstructed SPECT images. CDR is one of the main factors that affect image quality in single photon emission computed tomography (SPECT) images, along with noise in the projections of the resultant image and the attenuation and scatter of photons in the body of the patient. Evolution for Bone™ incorporates the CDR into the reconstructed SPECT images by including the components of intrinsic response, geometric penetration, septal penetration and septal scatter [1].

The effect of resolution recovery on myocardial perfusion imaging has been investigated [2-6] but little has been published regarding the investigation of the effect on bone SPECT imaging. In this paper we investigate the effect of using Evolution for Bone™ (GE Healthcare) SPECT on 15 pelvis and 15 spine images.

Methods

Thirty consecutive bone SPECT patient datasets (17 spine, 9 pelvis, 4 spine and pelvis) were chosen for this study. 8 were male and 22 were female. Images with artefacts were discarded. The clinical indications for referral were known cancer (16 patients; 12 were for breast cancer), 10 with suspected cancer, and 4 for other reasons (inflammatory spondyloarthropathy, rheumatoid arthritis, osteoporosis, hip replacement.) The overall age range of the subjects was 47-86 years (males 51-71, females 47-86).

Resolution recovery programs improve images where there is a less than optimum count rate, either due to lower dose or faster scan times. In order to simulate the reduced-count images, the data was processed through a Poisson resampling program. This program is provided by GE Healthcare as part of the Evolution toolkit. It allows the user to sample images at various reduced count rates e.g. 50%, 60%, 70% of the original counts.

The bone SPECT images were Poisson resampled at 50% and 75% of the full count rate. Evolution for Bone™ was then used to view the images, along with images containing 100% of the counts. The original bone SPECT images were reconstructed using OSEM (2 subsets and 10 iterations) with a Butterworth filter, with a Critical Frequency 0.48 and Power 10. The original images, reconstructed with OSEM Volumetrix, i.e. with no reduced counts, were also displayed for scoring, to act as a control. All patient details were anonymised.

The SPECT slices were scored by two consultant radiologists independently, who viewed the original images processed purely with OSEM in Volumetrix and scored these against the images described above for each patient dataset on two Xeleris machines side-by-side. The radiologists were told which were the original images, but were blinded as to which of the images described above they were scoring against the original images.

The images were scored by both radiologists for noise, resolution and contrast using the following scale as used by Aldridge et al [7]:

+2: Significantly better
+1: Slightly better
0: Equivalent
-1: Slightly worse
-2: Significantly worse

Image quality was calculated as the average of noise, resolution and contrast. An improvement in noise means there is less noise in the image.

Results

Examples of spine and pelvis images for the various reconstructions that were scored by both radiologists are shown in Figs. 1 and 2 respectively.

The results of scoring the images from Radiologist 1 are shown in Fig. 3, and from Radiologist 2 in Fig. 4. The error bars on the bar charts display the standard errors for the results. An improvement in the results for noise means that the radiologists are scoring less noise present in the image.

The differences between the radiologists' scores for resolution, noise and contrast, were tested using an analysis of variance (ANOVA) calculation. The results are as follows:

Resolution: P-value: 0.776
Noise: P-value: 0.007
Contrast: P-value: 0.000

Discussion

Both radiologists saw an improvement in resolution, noise and image quality with all the datasets in Evolution for Bone™, compared to images processed purely with OSEM and viewed in Volumetrix.

Both radiologists agree there is an increase in the resolution of the images viewed in Evolution for Bone™, and give similar scores to this effect, as shown in the bar charts in Figs. 3 and 4, and the high p-value (0.776).

The bar charts show that both radiologists also agree there is less noise in all of the images viewed in Evolution for Bone™, but the small p-value (0.007) shows there is a difference of opinions because they don't agree on the extent of improvement. Radiologist 1 gives higher scores for an improvement in noise for all the datasets viewed in Evolution for Bone™ than Radiologist 2.

The radiologists give markedly different scores for contrast, as shown by both the bar charts in Figs. 3 and 4, and the p-value (0.000). Radiologist 1 scores the contrast to be worse for all the datasets viewed in Evolution for Bone™ than OSEM, but Radiologist 2 scores an improvement in contrast for all the Evolution for Bone™ datasets. It is suspected that the radiologists may have been evaluating contrast in a different way, hence the radically different scoring.

Radiologist 1 scored contrast as the range between black and white c.f. dynamic range. Radiologist 2 scored contrast as how well the abnormality stood out from the normal pathology c.f. contrast resolution.

The results are therefore understandable, as we see an improvement in contrast resolution and a reduction in dynamic range. This makes sense because the effect of resolution recovery is to distribute the counts more widely over the image, which will reduce dynamic range but should increase contrast resolution. However, as a recommendation for future methodology, a set of training images would help to improve correlation between observers in this type of image comparison trial.

Image quality is calculated as the average of resolution, noise and contrast. Both radiologists saw an improvement in image quality with all the datasets viewed in Evolution for Bone™, more so with Radiologist 2 as shown in Fig. 4. The best image quality result from both radiologists was scored as using Evolution for Bone™ with 100% of the original counts, although this does not allow for a reduction in patient dose or scanning time. However, this is an improvement on using the original images.

Overall, the results from using 75% of the original counts are closer to the results from using 100% of the original counts. Surprisingly, the results from using 50% of the original counts are also an improvement. However, the most feasible approach would be to drop down to 75% of the original counts, thereby allowing for a gradual reduction in patient dose or imaging time.

Conclusions

Both radiologists saw an improvement in resolution, noise and image quality with all the datasets, compared to images processed purely with OSEM and viewed in Volumetrix. However, they completely disagree about contrast, as contrast was scored differently for the two radiologists, but the results are understandable. Using Evolution for Bone™ with 100% of the original counts gives the best results from both radiologists, although this does not allow for a reduction in patient dose or scanning time.

As images with 50% and 75% of the original counts viewed using Evolution for Bone™ have improved image quality compared to images processed purely with OSEM and viewed in Volumetrix. there is therefore great potential for reducing patient dose or imaging times by using Evolution for Bone™, or departments will have the choice of both these options to reduce either their patient doses or waiting lists.

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Fig. 1: Examples of reconstructed images of the spine. From left to right: original OSEM image; Poisson resampled image at 50% of the full counts and viewed in Evolution for BoneTM; as for previous image but Poisson resampled at 75% of the full counts; as for previous image but Poisson resampled at 100% of the full counts.

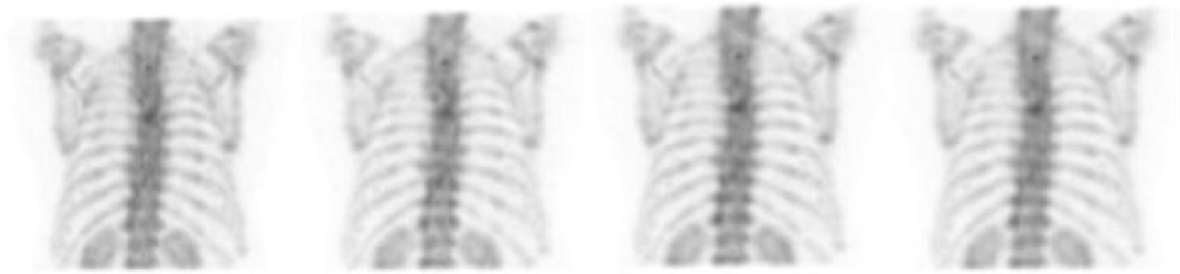

Fig. 2: Examples of reconstructed images of the pelvis. From left to right: original OSEM image; Poisson resampled image at 50% of the full counts and viewed in Evolution for BoneTM; as for previous image but Poisson resampled at 75% of the full counts; as for previous image but Poisson resampled at 100% of the full counts.

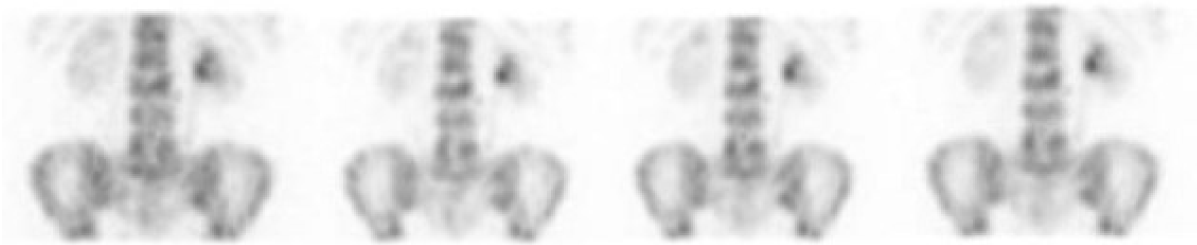

Fig. 3: results of image scoring from Radiologist 1. The error bars on the bar charts display the standard errors for the results.

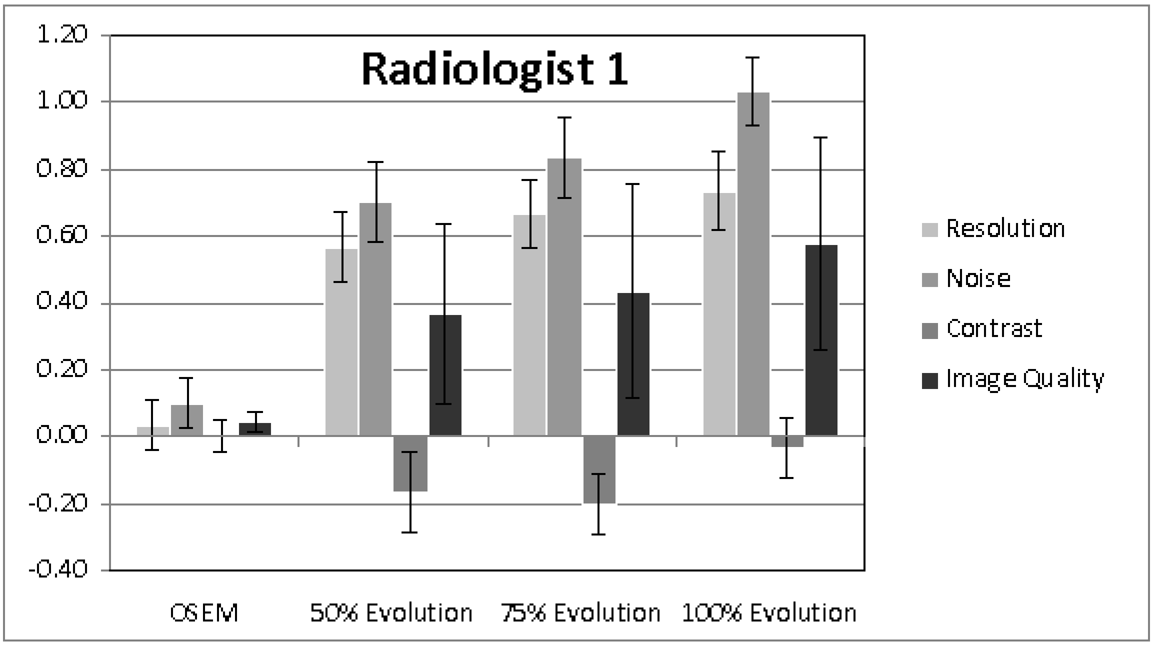

Fig. 4: results of image scoring from Radiologist 2. The error bars on the bar charts display the standard errors for the results.