Integrating new imaging modalities in breast cancer management
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Citation for published version (APA):
Pouw, B. (2016). Integrating new imaging modalities in breast cancer management

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Improved accuracy and reproducibility using a training protocol for freehand-SPECT 3D mapping in radioguided surgery

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Clinical Nuclear Medicine, 2015 Sep;40(9):e457-60.
Abstract

Purpose
Freehand-SPECT for optical tracked 3D radioactivity mapping raises popularity for sentinel node biopsy and other radioguided procedures. However, the device appears to be complex, requiring both training and a standardised scan-protocol. Therefore, the aim of this study was to compare handling reproducibility between novice and expert users; subsequently, using additional scans we evaluated a standardised scan-protocol to be tested in novice users after receiving training.

Materials and methods
Three groups (untrained-novices, experts, trained-novices) each one composed by 5 freehand-SPECT users got the same short introduction and the assignment to perform 3 freehand-SPECT-scans with the same time per scan. For the scans a reproducible phantom with an $^{125}$iodine point source was used. Further, we performed probe-trajectory evaluation including pattern, speed and length of scans based on recorded videos and digital target tracking.

Results
The training period encompasses 30 minutes per novice-user. The average error in 3 directions based on 45 measurements was 7.4mm for untrained novices, and 3.2mm for expert users. The trained-novice group had an average error of 2.9mm (a significant 61% reduction), comparable to the expert group. The reproducibility, expressed in a standard deviation, was 4.1mm for the untrained-novice group, 1.3mm for the expert group and 1.1mm for the trained novices (73% improvement). The standardised scan-protocol demonstrated by means of trajectory evaluation a scan-path better systematised.

Conclusion
Scanning with freehand-SPECT for radioguided surgery requires a specific training period to increase handling, reproducibility of 3D imaging, and to enhance its accuracy in the operating room.
Introduction

In specific centres, SPECT is used for Sentinel Node (SN) mapping in breast, melanoma, head and neck, and genitourinary cancers. SPECT-images are obtained preoperatively to allocate the anatomical position of the SN. Nonetheless, during surgery the SPECT-images are of limited use for real-time localisation of SNs, as the SNs are than located using a simple gamma probe. Freehand-SPECT for 3D radioactivity mapping raises popularity for SN biopsy and other radioguided procedures. This technique enables live SPECT-imaging of the radioactivity distribution in patients. Several institutes are currently evaluating the advantages of this technique for clinical practice. It is already used for breast[1,2], melanoma[3,4], prostate[5], head and neck cancer[6] SN mapping, and thyroid cancer[7].

Although freehand-SPECT appears to be very promising for radioguided surgery, the system appears to be complex requiring both training and a standardised scan-protocol. At the NKI-AVL, we experienced variations in the spatial accuracy of the radiotracer localisation when using the freehand-SPECT system.[2] Other institutes demonstrated the same effect and performed studies using robotically assisted freehand-SPECT-scans to reduce observer variability.[8] However, this approach is not feasible in a clinical setting, so we developed a method to optimise the acquisition procedure using freehand-SPECT. For a recently clinical implemented technique it is important to share experiences considering imaging techniques and required training. Therefore, we present a study that compares reproducibility of freehand-SPECT between novice and expert users to underline the effect of observer experience. Furthermore, we evaluated the effect of training and a standardised scan-protocol on the reproducibility of acquisitions.

Materials and Methods

Users

Three groups (untrained-novices, experts, trained-novices) each one composed by 5 freehand-SPECT users got the same short introduction and assignment. The users consisted of: nuclear medicine specialists, nuclear medicine trainees, post-doctorates, PhD-candidates, and students, all users were familiar with conventional gamma probe usage. Expert users were defined as having performed at least 20 freehand-SPECT-scans in a clinical setting (experience varied from 20-200+ freehand-SPECT-scans).
Novices were defined as people with knowledge of the concept of freehand-SPECT but without any user experience. After receiving an extensive individual training, the 5 individuals in the novices group were considered ‘trained novices’.

**Training protocol**

Both experienced and novice users got a briefing explaining: 1) the number of hotspots in the phantom, 2) the number of required measurements per scan, 3) the positioning of the camera, 4) information on the need of constant visibility of the tracking targets, and 5) the need to scan slow and close to the volume of interest.

The extensive individual training consisted of an interactive 30-minute session with an instructor demonstrating acquisition methods and providing advice regarding pitfalls (i.e. missing areas, breaking the line-of-sight, and scan-speed). Common mistakes of each user were pointed out and discussed to increase the acquisition quality.

**Phantom**

For standardised monitoring the overall performances of the freehand-SPECT system a custom-made reproducibility phantom was used. This spherical phantom is made of Perspex for scatter simulation with radioisotope insertion points. At three perpendicular points on the surface CT-markers were fixated allowing distance measurements from the CT-marker to the inserted $^{125}$iodine seed (i.e. golden standard for depth measurements based on a CT-scan). (Figure 1) During the experiments this phantom is placed on a table to allow a good approach from all directions.
Measurements

Three freehand-SPECT-scans per user in each group were acquired blinded for results with a standardised time per scan (2500x0.05s probe measurements) to compensate for intraobserver variation and to study a learning pattern after a view scans. For each acquisition this was followed by measurements of the $^{125}$iodine seed location (e.g. defined as the reconstructed centroid of the hotspot) at the 3 CT-markers on the surface of the phantom. Each measurement provided a depth in mm from the CT-marker to the hotspot. All measurements were averaged per user per group and variations were determined as a measure for reproducibility. The accuracy was defined as the difference between the golden standard and the measured seed location (expressed as average error in mm). Furthermore, we performed probe-trajectory
evaluation including pattern, speed, and length of scans based on recorded videos and digital target tracking.

**Results**

There was no learning curve observed within individual baseline scans. The average error in three directions, from the hotspot to the CT-marker based on 45 measurements, was 7.4mm for untrained novices, 3.2mm for expert users and 2.9mm for the trained-novice group. The latter was comparable with the expert group and significantly better than the first attempts of the novices (p<0.01). The reproducibility, expressed as a standard deviation of the measurements, was 4.1mm for the untrained-novice group, 1.3mm for the expert group and 1.1mm for the trained novices. (Table 1) Altogether the average error of the trained-novice group compared to the novice group decreased with 61%. The reproducibility improved with 73%. In terms of error the trained novices were 11% or 0.3mm on average better than the expert users. The average reproducibility of the trained novices was 17% or 0.2mm in favour for the expert users and were comparable as group (no significant difference).

Trajectory analyses showed that the standardised scan-protocol resulted in a highly structured method to acquire images, resulting in more accurate acquisitions. The total scan length (=speed of the gamma probe movement) used by an untrained novice was 1.5 times more than that for a trained one. The pattern was more structured and demonstrated well-defined surfaces with zigzag trajectory scanning. (Figure 2)
**Table 1:** Results

<table>
<thead>
<tr>
<th>Group</th>
<th>Average error (mm)</th>
<th>Reproducibility of measurements (SD in mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
<td>7.4</td>
<td>4.1</td>
</tr>
<tr>
<td>Expert</td>
<td>3.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Novice after training</td>
<td>2.9</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**Figure 2:** Scan trajectory plotted in a 3-dimensional graph optically tracked coordinates of the gamma probe during the acquisition. (a) Scan trajectory of a novice user. At the right side, a scan trajectory of a novice user after training. The scan trajectory is divided in different colours for a better understanding of the scanned trajectory. It is notable that the novice user has an irregular scan pattern, and the scan trajectory is nonstructured in contrast to the scan trajectory of the user at the right side. (b) This user demonstrates zigzag patterns to cover the entire area from multiple directions. The total scan path for this novice user was 20.8 m and the mean total distance for the novice user after training was 13.4 m.

**Discussion**

The performance of freehand-SPECT has been studied in a number of institutes. Recently, the reproducibility and interobserver variation has been robotically assessed, demonstrating that a robotically optimised scan pattern performed better than a human operator.[8] The results of the current study suggest that the quality of freehand-SPECT-acquisitions can also be enhanced by optimising training and offering standardised acquisition protocols. A significant improvement for the average accuracy of the reconstructed hotspot and reproducibility in between scans was observed. Furthermore, Knowledge about the pitfalls of freehand-SPECT-acquisitions makes users aware and therefore the scan-quality would improve.
Freehand-SPECT is marketed as an easy and quick-to-adopt technique, which in our opinion is correct, however a general training period should be provided before users start clinical work. The step towards intraoperative use is sometimes quick and the required training is neglected in the tight schedules of all those involved resulting in suboptimal results. According to our study, this freehand-SPECT training could encompass only a quick session of less than an hour. We advise that the first clinical use of the device will be under supervision of an experienced user until both parties have enough confidence for individual use. Experience with conventional gamma probes could be beneficial, although we believe that freehand-SPECT scanning is that much different and a complete trainings session is recommended.

Although freehand-SPECT is commercially available, there are still improvements being made in the hardware and software of the system to optimise the scan results and reproducibility. There are now prototypes available where a compact gamma camera (CGC) is optically tracked instead of a gamma probe. CGCs have a larger field-of-view enabling fast high-resolution acquisitions. This approach allows for freehand-SPECT acquisitions with a 16x16 pixel gamma camera with a parallel-hole collimator, and accordingly, gathers quick vast amounts of data available for reconstruction. Initial results demonstrate image and accuracy specifications superior to conventional freehand-SPECT.[9,10]

**Conclusion**

Use of freehand-SPECT for radioguided surgery requires a specific training period to increase the reproducibility of the device handling and to enhance its accuracy in the operating room. This training, for potential clinical end-users, may preferably be performed in a phantom setting using a standardised scan-protocol to enable both scan quantification and comparison with pre-determined standards.

**Acknowledgements**

We would like to thank our colleagues for their time and effort by participating as an observer in this study.
References


