Introducing Computer-Assisted Surgery into combined PET/CT image based Biopsy

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Introduction: A Positron Emission Tomography/Computer Tomography (PET/CT) image based biopsy procedure uses co-registered PET and CT images to help radiologists diagnosing, reaching and removing a piece of bone from the suspected tumour area. The general approach is to generate one co-registered PET/CT image so that the supposed tumour can be localized; followed by the needle insertion towards to the tumour. However, to precisely reach the target, several other CT scans are needed so that the radiologist can follow and redirect the needle trajectory according to what is seen in the images. This process, thought effective, exposes both (radiologist and patient) to unnecessary radiation. Every time the he (she) approaches to redirect the needle trajectory he (she) is exposed to the tracer radiation injected into the patient body. Moreover, for every CT scan, the patient receives radiation. It is clear the procedure can be optimized by reducing the number of needed CT scans and providing another way to follow the needle trajectory.

It was showed [1] it is possible to use such data sets with standard navigation system, but for this type of biopsy other constraints come into play. As an example one can point out the PET/CT data set manipulation for procedure planning, and an intuitive virtual visualization of the procedure. In [2], a lightweight navigation system to be used on ct-guided pain therapy was implemented, but it does not consider PET image. On this work we introduce and present some preliminary results of a computer navigated solution for PET/CT image based biopsy that covers the points mentioned above.

Materials and Methods: The navigation platform consists of a computer, a touch screen, a small screen, a NDI Vicra camera, a marker shield for patient tracking, and specially designed marker shields for needle tracking and calibration. For the feasibility study, a phantom composed of a plastic bone fixed into an acrylic box (Figure 1a) was created. It was referenced into the CT using four BrainLAB CT markers (Art. No. 41740); and tracked using a NDI marker shield. As targets, 4 capsules (Figure 1b) were filled with radioactive tracer (F-18 FDG) and placed into wholes drilled in the bone.

The software was designed to avoid changing the current procedure. It has two main modules planning and navigation. In the former, the user can mainly define the needle trajectory (compound by a target and a skin entrance point). Important areas to be avoided and the best configuration for PET/CT visualization can be defined as well. In the latter, the coronal (Figure 1c), axial and sagittal views are displayed. In addition, an eagle shooting viewer is presented on a small screen (Figure 1d) standing right besides the procedure area. This viewer has its virtual camera standing on the entrance point and looking to the target; and it allows the user to see all degrees of freedom in one view.

In order to track the biopsy needle, a marker shield is necessary. An "off the shelve" marker shield could not be used as they are heavy and do not fit easily on the needle. Hence, a lighter prototype was designed (Figure 1e). It consists of a needle support with a passive marker shield. Finally, a calibration block prototype was also created. It is a marker shield with wholes (called calibration places) of well-known dimensions and location for fitting the needle axis.

An additional module for registration purposes was developed. It calibrates the needle automatically when holding it inside its respective calibration place. It takes around 3s to implicitly average a set of tip positions and calibrate it. For the patient to data registration the conventional pair point matching was used. The points can be defined very fast with the user interface, and digitized by holding the calibrated needle tip on the desired position for a few seconds. The whole procedure takes less then 2 minutes.

The experiments were performed as follow: the capsules with radioactivity were loaded into the phantom; it was scanned on a Siemens Biograph hi-resolution 16; the capsules were removed, and modelling dough was put on their place to mark the needle position; the PET/CT data was loaded into the navigation system and the capsules were defined as targets; the wax gel was put over the targets to simulate a 100mm layer of soft tissue; and, several trials were conducted. The off-centre distances were measured with a ruler. Each trial was done in a one-way direction i.e. the needle was not pulled back until the end.

Results (Figure 1e): Out of 10 trials on the 5mm diameter capsule, 8 ended up inside the target with an average off-centre distance of 1.4mm; 2 of them were out with an off-centre distance of 3mm. On the 10mm diameter capsule, 5 out of 5 trials were inside the target with an average off-centre distance of 0.4mm. The average time of the trials was 2min.

Discussion: This work introduced a computer navigated solution for PET/CT image based biopsies. The radiologist's feedback on software workflow was positive, as it was very close to the current procedure. The only additional steps introduced were the needle calibration, and data set registration, but as they are fast and nearly transparent to them, it was not considered a problem. The prototypes for the new designed support and the calibration block worked very well. They provided way of tracking and calibrating the needle without disturbing the procedure. The first experiments showed promising results. Only 2 out 15 did not hit the target completely, but as it was also off-centre into the virtual view we concluded that it was due to the one way policy adopted during the tests.

As future work, the registration will be made completely automatic; the marker shield prototypes will be evaluated in a release version; and a set of experiments will be prepared and conducted to better quantify the system on different aspects.

1. Militz M, Hungerer S, Haug A, "Pet-Ct-Fluoro-Matching On long Bones? – First Experiences", 8th CAOS-International Proceedings, pp. 53-54, 2008

2. Tiesenhausen C V, Weber S, Hoffmann KT, Lueth TC, "A New Mobile And Light-Weight Navigation System For Interventional Radiology", CARS, pp. 412-417, 2005
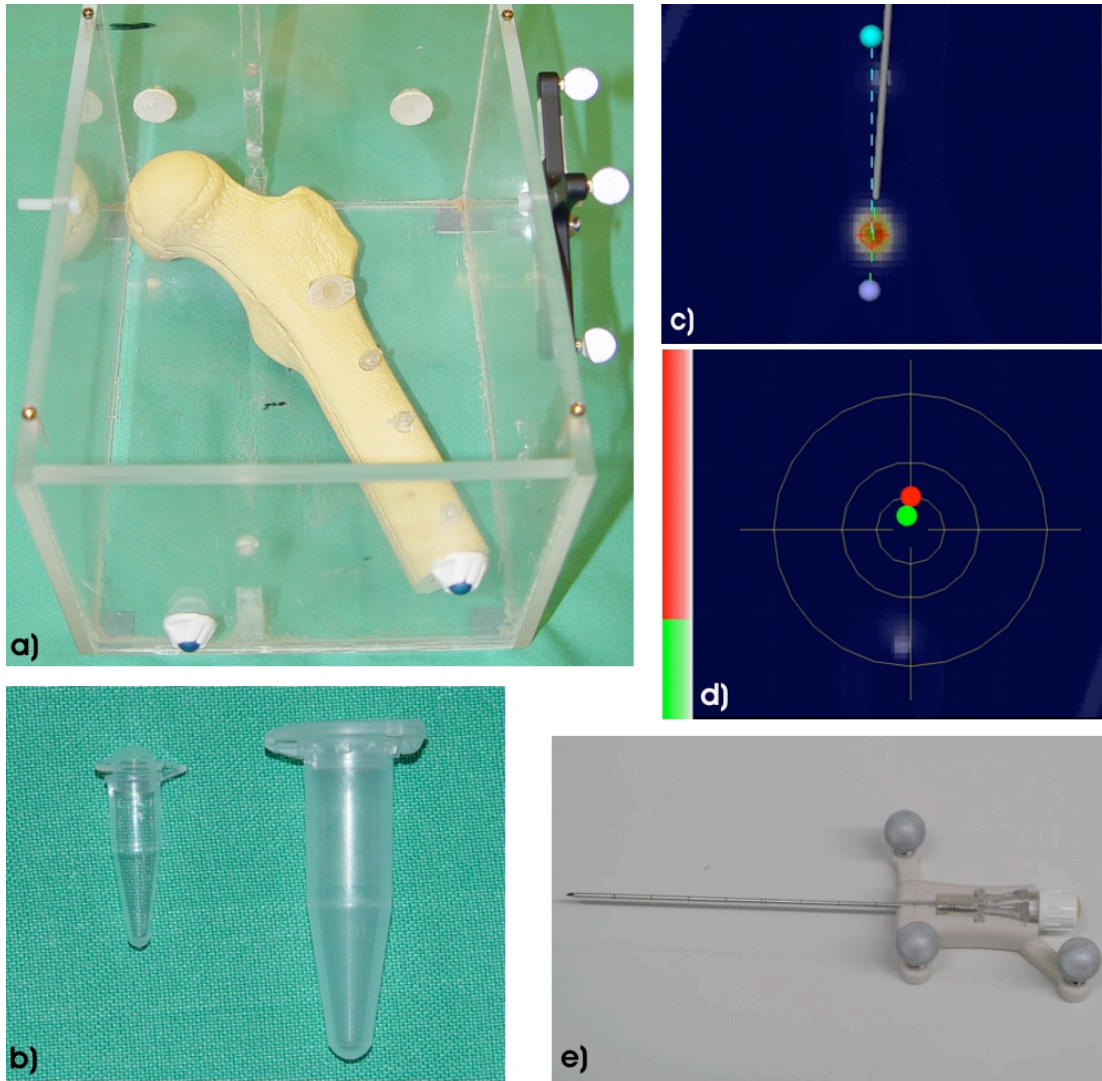
f)

Capsule Diameter	Off-Centre Distance (mm)										Average
5mm	2	0	3	1	1	3	2	1	1	2	1.6
10mm	1	0	0	1	0	x	x	x	x	x	0.4

Figure 1: a) Bone phantom attached to the acrylic box. BrainLab CT markers and NDI tracker are also fixed to the box. b) Capsules used as target. The left one has 5 mm of diameter, and the right one 10 mm. c) Coronal plane cutting the target with the planned trajectory and the current needle position. d) Eagle Shooting Viewer with a distance bar on the left, and the needle tip and its projection on the target plane as points. e) Needle support prototype. f) Table with experiment results.

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