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COMPUTER ASSISTED INTRARENAL ACCESS BY CT AND ULTRASOUND IMAGE FUSION

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Introduction: Percutaneous access to kidney is a challenging technique that meets with the difficulty to reach rapidly and accurately an intra-renal target.
Our system provides the surgeon with a pre-operative 3D planning on computed tomography (CT) images. After a rigid registration with space-localized ultrasound (US) data, preoperative planning can be transferred to the intra-operative conditions and an intuitive man-machine interface allows the user to perform a puncture.

Material and Methods: CT and US images of informed normal volunteer were obtained to perform calculation on the accuracy of registration and punctures were carried out on a kidney phantom to measure the precision of the whole of the system. The general approach included the following steps:

- A 3D pre-operative model was reconstructed from abdominal CT images by the mean of some segmentation computer tools (Analyze©, Nabla©). The surgeon used this model to define a planning by selecting two points, a target and an entry point, which defined the needle trajectory.
- Just before puncture, intra-operative ultrasonic images, space localised by an infrared camera (Polaris® system, NDI Inc), are collected at the end of an inspiration to get a set of 3D points located onto the kidney surface (Fig 1 & 2). As echography was used here like a tool to locate the surface of the kidney, it is not necessary that the target and the entry point be visible in the ultrasound images. For this step, the kidney surface was segmented manually.
- This set of 3D points was matched onto the preoperative model of the kidney, by the mean of a registration technique. The matching transformation applied to the planned trajectory allowed transferring it to the operating room conditions and guarantees its correct execution. The position of the needle, usually used in clinical pratice (18 Gauge – 200 mm long), was known in real-time during the surgical action (thanks to the localizer and a rigid body fixed on the needle, Fig 2) and compared to the planned trajectory (Fig. 4). Therefore, no further image acquisition was needed for this guiding phase.

Fig. 1

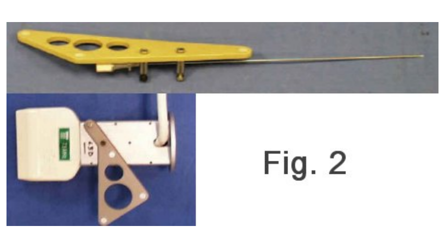

Fig. 2

In a first step, we estimated visually the precision of the registration between CT and echographic images of our human volunteer. In a second step, we performed three punctures on a right and left kidney on a phantom (Model 057 – CIRS). We evaluated the precision of the punctures by carrying out a postoperative scanner with needles in place. By the mean of registration technique, we computed the distance between the preoperative target and the tip of the needle.

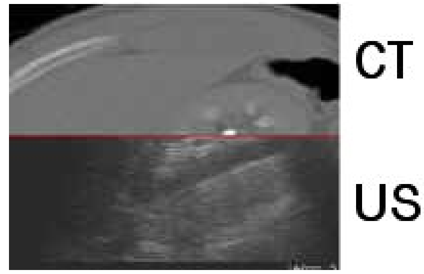

Fig. 3

Results: We carried out millimetric registrations on real data (Fig. 3) and guidance experiments on a kidney phantom showed results of 4.7 mm [3.3 – 6.1] between planned and reached targets. We noticed that the most significant error was related to the needle deflection during the puncture.

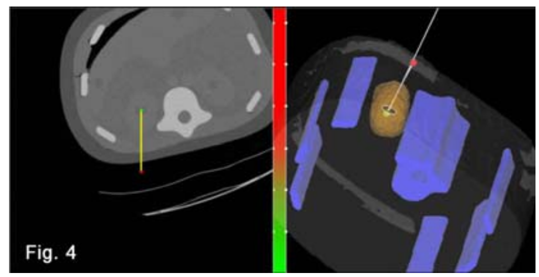
Fig. 4

Conclusion: Preliminary results are encouraging but further work will be undertaken:

- To take breathing into account in real time even if some preliminary studies in our team demonstrate that the position of the kidney between 2 inspirations appear to be reproductible.
- To improve efficiency to register CT and US images without segmentation (one of our study highlights that correlation ratio turned out to be the most accurate and appropriate similarity measure to be used).
- Accuracy. A solution could be to use a magnetic localizer and a coil inside the tip of the needle.