Attitude tracking technology

New techniques expand horizons in minimally invasive urology

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Electronics and computer science are merging more and more with modern urology. From the development of robotic surgery to fine-tipped video 'chip-on-a-stick' endoscopes, urologists are lucky to be working in a very technological environment.

The latest emphasis in uro-oncology is to preserve, within the limits of oncological safety concerns, the treated organ, and thus focal therapy is gaining more ground in the treatment of urological tumours. Since oncological results of focal therapy are improved mainly by increasing the precision in targeting the center of the tumour, our efforts were focused in developing a technology that is capable of assisting the physician in this area[1].

Our research focuses in creating a system that is able to assist the movements of the surgeon while performing some of the percutaneous maneuvers that are guided by ultrasonography.

In percutaneous focal therapy procedures results are highly operator-dependent, mainly because of the lack of precision in positioning the needles. For example, if we aim to target the center of a renal tumour 3.5cm in diameter and we misplace the needle by 2 mm, we will miss 1.4 cubic centimeters of remnant tumour tissue (Figure 1a, b). This represents a major cause of oncological failure, and some innovative solutions will have to be found to improve needle targeting, in order for transcutaneous focal therapy to be more reproducible.

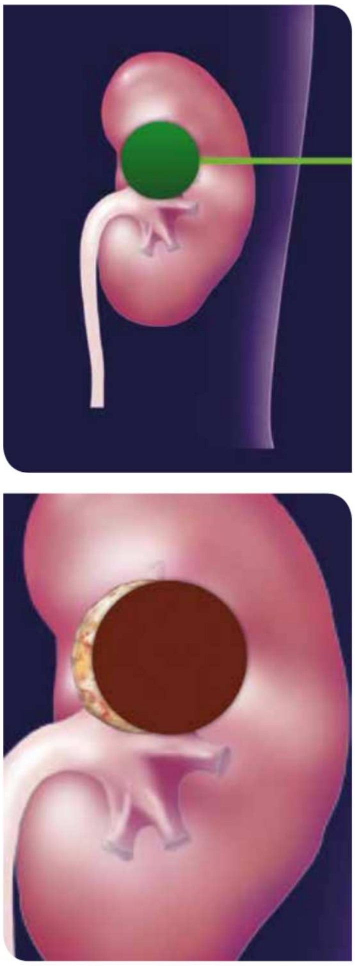

Fig. 1a and 1b: First picture shows the correct procedure with necrosis that covered the whole tumour. Second picture shows the possibility of misplacing the focal therapy needle and to obtain a tumour volume that is not destroyed by the energy used

Some researches in this area focused in creating a robotic arm, specialized in needle placement (Dan Stoianovici, Johns Hopkins, USA) guided by CT, MRI or ultrasonography[2, 3]. This technology eliminates not only the human error from the imagistic targeting system, but from the puncturing system as well.

Still, we believe it remains very complicated to automatically generate the puncture trajectory, which depends on varying factors: the vicinity to other organs or functional structures, puncturing the least amount of normal tissue, avoiding important vascular or nervous structures and so on.

Even closer to our area, covering the targeting of the collecting system, Rassweiler et al used augmented reality technology to access the collecting system of the kidney using an iPad[4]. In this situation of augmented reality, the precision of the superposition of the virtual image over the real object (a calyx) depends both on the accuracy of the virtual image reconstruction and on the accuracy of the position of all objects in the scene: kidney, tip of the needle, ribs etc.

Our choice was to design a system that assists the surgeon to target a point (middle of a round tumour, certain point or plane of the prostate for precise biopsy guided by MRI) doing pretty much what actual image fusion systems do.

By attaching an accelerometer to the ultrasound probe, we can read in real-time the position of the probe on a computer (Figure 2). By manipulating the probe, we can mark landmark points, such as the poles of the kidney, apex of the prostate, base of the prostate and we can get the direction to the targeted point as a relative coordinate to our previous memorized landmarks. The computer will generate the relative coordinate by analyzing the MRI or CT images of the current patient.

For example, if we want to target the middle of a round renal tumour, we select the proper programme, and search with the equipped ultrasound probe one margin of a tumour; then we press a button to tell the computer that we found our first landmark. We rotate the probe until we find the other margin of the tumour and we mark it as the second landmark.

By selecting the "Center of a round tumour" algorithm, the computer will use the two memorized landmarks to generate the trajectory that meets the center of the tumour. A LED bar controlled by the computer will guide the right direction of the ultrasound probe so that the ultrasound-guided puncture will meet the center of the tumour. This is the simplest situation where no other imagistic study is required except intraoperatory ultrasonography.

If we want to target a certain area from the prostate, we have to calculate the relative position from the apex and base of prostate using MRI imaging of the suspected tumour. Using this instrument we can puncture exactly in the suspect area, possibly avoiding unnecessary prostate biopsies, and perhaps even important morbidity.

Fig. 3:The in vitro experiment using the ultrasound probe with the Wiimote and the puncturing system on the marked silicon tubules immersed in the ballistic gel

Fig. 2: The Wiimote and the biopsy kit, rigidly attached to the ultrasound probe

Technically, we used the accelerometers, data transmitting technology and the LEDs that are built in the Wiimote device from Nintendo. But all these features can be found in almost all the smartphones and tablets on the market nowadays. We programmed the Wiimote so that we used its buttons: „Home" for calibration procedure, „1" and „2" for setting landmarks, „Shoot" for lock or reset, and the LEDs bar for assisting the puncture.

In order to prove the functionality of the system we imagined some in vitro models to test its efficacy. We immersed in ballistic gel groups of 20 graded rubber segments and we tested the procedure with a biopsy needle aiming for the center of each rubber segment (Figure 3).

We performed the procedure both guided by the LED bar as well as with the system of attitude tracking switched off. The results were definitively in favor of the attitude tracking assisted procedure (Figure 4).

These results open the gates to an enormous range of opportunities, from very precise diagnostic procedures to increased precision of focal therapy. Attitude tracking technology will hopefully push these methods globally by making them more objective and not as much surgeon-dependent.

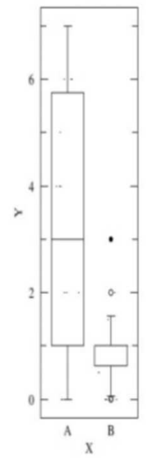

Fig. 4: The error from the center targeted to the actual reached point measured for both groups:"A" ultrasound-guided only and "B" ultrasound-assisted by attitude tracking technology. Box plot for the Student t test comparing errors in both groups.

Following further developments, we postulate that this technology will be very useful not only in assisting very difficult and delicate maneuvers, but also in the training of young doctors, improving the transferability of the most difficult surgical techniques.

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