PRONAV: A NAVIGATION SOFTWARE FOR PROSTATE BIOPSIES

M. BUCKI (1), B. DAULIAC(1), V. DAANEN(1), R. MOALIC(2), J.L. DESCOTES(2), J. TROCCAZ(1),

(1) TIMC Laboratory - IN3S – Faculté de Médecine – Domaine de la Merci – 38706 La Tronche cedex – France
(2) Urology department – CHU de Grenoble – BP 217 – 38043 Grenoble cedex 09 - France

INTRODUCTION

Prostate cancer is the most frequent cancer for men in many countries. In France over a population of approximately 60 million inhabitants 40209 cases were reported in 2000 and this cancer was responsible for 10004 deaths this same year. Its early diagnosis relies on a blood analysis (Prostate Specific Antigen rate) and on a rectal palpation. It is confirmed by the anatomo-pathologic analysis of tissue biopsies taken from the gland. Those samples are generally obtained through the rectum, under echographic control; the biopsy needle is introduced in a guide rigidly attached to the endorectal US probe. The choice of a prostate biopsy protocol (number and placement of needles) has been extensively debated. In comparison few projects deal with the precise execution of planned biopsies (see for instance [2] and [3] for MRI-based robotic and navigation approaches).

Within the framework of a clinical national research project (French PHRC Program) named "Prostate-echo", a collaboration with the urology departments of the Grenoble University Hospital and La Pitié Salpétrière Hospital located in Paris has been set-up to investigate two topics: (1) The construction of a statistical atlas from resected pathologic prostates (cf. [1,4]) for the optimization of biopsy protocols (cf. [4]). (2) The assistance to the accurate execution of a selected biopsy protocol. In this paper, the first elements and tests of the ProNav software for computer-assisted biopsy navigation (second topic) are presented.

MAIN OBJECTIVES

1. Conventional biopsy protocol

The patient is installed in lateral decubitus or in the gynaecologic position. An endorectal echographic probe (7.5 or 10MHz) carrying a guide is introduced and makes it possible to partially visualize the gland whilst taking samples. A dotted line corresponding to the needle trajectory when inserted in the mechanical guide is superimposed with the 2D US image. It helps in orienting the biopsy needle relatively to the gland. The biopsy gun is actuated for each sample when the surgeon considers that the trajectory represented in the image corresponds to the position of the biopsy specified by the protocol. Within the Grenoble hospital, 12 samples are obtained in a symmetrical way (left/right). The patient is installed in gynaecologic position.

2. Difficulties

Various difficulties are inherent to this diagnostic gesture:
- The resected volume is finally very small (a biopsy corresponds to a carrot of about 1x15mm when a prostate has a volume around fifty cc). The quality of biopsy distribution in the prostate is thus of importance. Several studies showed that repeated series of biopsies increase the chances of detection of a cancer.
- The echographic image is two-dimensional; the ability to distribute the biopsies according to the pre-established protocol thus directly depends on the surgeon’s capacity to integrate his gesture in a three-dimensional representation; in other words, of its ability to represent the various echographic images in a common 3D reference frame, the prostate one.

We thus propose to develop a navigation system allowing determining the precise position of biopsies relatively to the gland according to a predefined biopsy protocol.

PRONAV DESCRIPTION

ProNav (Prostate Navigation) is based on the principles of surgical navigation. The general idea is to localize the echographic probe and thus the biopsy needle in a common reference frame and to visualize, in real-time, the 3D position of the carried out biopsies. The ultimate goal is to guide the surgeon towards the predefined trajectories of the selected protocol.

1. Materials

The localizer is a passive Polaris (from NDI[1]). It makes it possible to determine in real-time the position and the orientation of objects (anatomical structures, sensors, surgical instruments) in a fixed reference frame. The endorectal echographic probe is therefore equipped with a "rigid body" (see figure 1). The ultrasound machine is a Kretz system with a bi-plane probe.

Fig.1
The echographic probe and its rigid body.

The echographic images are transmitted to the application running on a portable PC through a video acquisition board. 5 to 10 minutes are necessary to install the equipment and connect the machines before starting the biopsies.

[1] Northern Digital Inc., Waterloo. Ontario, Canada

2. Methods

In the first version of ProNav, the system works in a completely passive way: the imaging data and the biopsy positions are recorded without providing any help to the surgeon. Except the presence of computer equipment and localization devices, the realization of the biopsies thus keeps unchanged. A transverse sweeping of the prostate is first carried out, allowing the surgeon to visualize the whole gland. The images are recorded in order to obtain a pseudo-3D echographic volume. Two reference transverse and longitudinal sections are also recorded. Then, the biopsies take place. For each one the surgeon gives the "signal" for acquisition of both the echographic image and the probe position just before getting the sample.

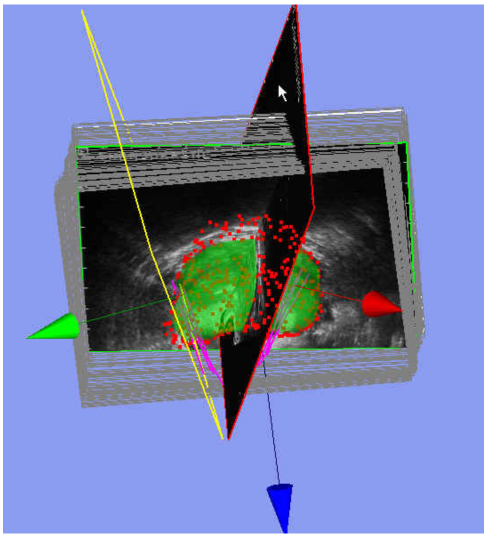

Fig. 2:
3D biopsy visualization: the echographic data, the prostate (red points and green surface), one biospy image plane (in yellow) and the biopsy trajectories (pink lines).

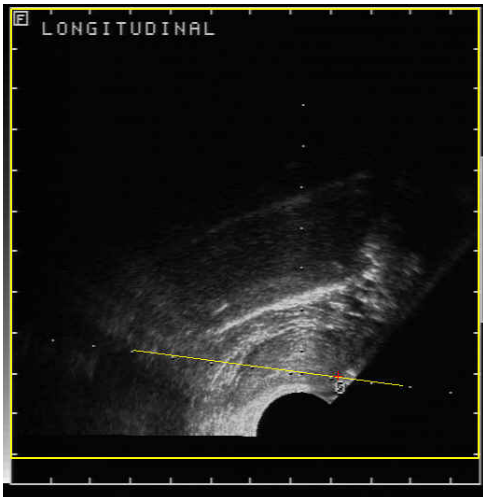

Fig. 3
Echographic image visualizing the biopsy trajectory (in yellow) and the entry point (red cross). It corresponds to the “yellow” pseudo-longitudinal image plane of figure 2.

All data are post-operatively processed and analysed in a software named ProNavReplay (cf. figure 2 and 3).

Some simplifying hypotheses were made in this first version. The most criticable one is that the prostate keeps a constant position as soon as the patient does not move. This is discussed in the last section.

CURRENT RESULTS

The system has been experimented with 7 patients having given their consent after information; one important element of acceptance is the unchanged protocol for the patient.

One difficulty was the hardware set-up in the rather small examination room; for several patients the whole set of biopsies could be not recorded because of rigid body visibility problems.

Magnetic localization could make installation and needle tip tracking easier. However, the robustness of the magnetic localizer must be assessed in this particular environment with metallic objects before selecting such a tool.

For 2 patients, data were inconsistent due to unexpected patient movements due to pain. This requires adding a second rigid body for motion tracking.

The surgeons' reactions were very positive since this 3D visualisation makes possible envisioning a more accurate execution of biopsy protocols. Moreover such a system may contribute to the education of young urologists.

DISCUSSION AND CONCLUSION

Due to some simplifying hypotheses and limitations of the current system, different developments are in progress or are planned. Current work concerns localization issues (rigid bodies, localizer technology). More complex and longer-term issues are related to providing consistent data despite prostate motion due to the patient movement or to the probe mechanical constraints during image acquisition. Real-time tracking of the gland is therefore necessary either based on hardware or software solutions. This must be solved and validated before using the system in the active mode i.e. allowing the surgeon to use this information for assistance during biopsy realization. This last stage requires the adaptation of the protocol will it be optimized or standard through elastic registration. It will also involve the modification of the user interface to make localization information easy to use in the clinical routine.

In this paper, we have described a system for navigating prostate biopsies. Despite some simplifications in the first version, surgeons already react very positively to such a tool which use could make biopsies more accurate and thus would contribute to improved quality tracing of those diagnostic gestures.

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