Trans-rectal ultrasound (TRUS) guided biopsy with MRI-TRUS fusion: feasibility study using a multipurpose magnetic tracking system

Poster No.: B-0390
Congress: ECR 2017
Type: Scientific Paper
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Keywords: Interventional non-vascular, Genital / Reproductive system male, Ultrasound, MR, Biopsy
DOI: 10.1594/ecr2017/B-0390

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Purpose

Multi-parametric MRI (mpMRI) represents a breakthrough in the diagnosis and management of prostate cancer with a sensitivity and specificity dramatically superior to TRUS [1-2-3].

Notwithstanding the accuracy of mpMRI, prostate biopsy is still considered the gold standard for the histological characterization and clinical management of prostate cancer. Currently, systematic TRUS guided biopsy is accepted as the technique of choice as it is friendly, well-tolerated and inexpensive. As it consists of a randomized sampling, the major limit is represented by the possibility of missing clinically significant tumors especially located in "difficult" prostatic areas and, on the other hand, the risk of overdiagnosis of clinically insignificant tumors or precancerous lesions [1].

The introduction of mpMRI with its outstanding sensitivity and specificity (Fig 1) has introduced the necessity of performing targeted biopsies on areas with a pathological signal. In fact, there are increasing evidences that targeted biopsies have a better cancer detection rate than systematic biopsies alone [4-5-6].

Targeted biopsies can be carried out in three different ways

a) MRI guided in bore biopsy;

b) TRUS guided biopsy with cognitive approach;

c) TRUS guided biopsy with TRUS-mpMRI fusion.

At first sight, MRI guided biopsy could appear the best solution, but we need to consider many disadvantages and limits. The procedure is expensive, time consuming, less tolerated and is performed mainly with a transperineal approach that is more painful and requires extensive local anesthesia or sedation [1-7]. Furthermore, the procedure cannot be performed in a true real-time modality.

TRUS-guided biopsy with cognitive approach is intuitive, inexpensive and preserve all the advantages of TRUS guided biopsy but is susceptible to human errors [8].

TRUS-guided biopsy with TRUS-mpMRI fusion is the most promising as it combines all the advantages of TRUS guided biopsy, included the possibility of systematic sampling when necessary, together with the sensitivity of mpMRI.

Virtual Navigator by image fusion techniques (also known as interactive localizing techniques) has been proposed in the last two decades in order to spatially coregistrate a real-time modality (i.e. US) with high resolution isotropic 3D CT and MRI or functional images (i.e. PET-CT). In this way the operator is allowed to use, at the same time, the information from multiple imaging modalities which enhances diagnostic and localization
capability. Image fusion can be achieved by Electro-Magnetic (EM), optical or mechanical devices. There are some advantages of EM device over optical and mechanical device:

a) The tracked device can reside out of generator sight;

b) Multiple devices can be tracked at the same time;

c) Devices can be tracked also within the patient's body without signal attenuation;

d) There are no significant limitation to operator position and movements.

These advantages make EM tracking systems flexible and suited for multipurpose applications.

The main technical limitation of EM tracking systems is that the ferromagnetic environment can cause interference and distortion of magnetic coordinates. However, a new generation of EM tracking systems has reduced susceptibility to the effects of the metal hardware [9-10-11].

Other possible drawbacks are the necessity of expensive dedicated image-fusion hardware and software, and the difficulty of obtaining a precise image fusion considering the anatomical distortion that can be induced by physiological changes or by the TRUS probe itself.

The aim of our study is to evaluate the feasibility of TRUS guided biopsy with TRUS-mpMRI fusion using an ultrasound scanner equipped with a multipurpose Electro-Magnetic (EM) tracking system.
Fig. 1: Typical appearance of prostatic cancer (white arrow) on T2 weighted sequences (Fig 1a) and on DWI sequences (Fig 1b). Patients underwent TRUS biopsy that demonstrated prostatic cancer with 5+4 Gleason score.

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Methods and materials

For the present study a MyLabTwice ultrasound scanner (ESAOTE, Italy) equipped with an EM tracking system and Virtual Navigation (VN) software was used (Fig 2). The procedure was performed on 20 patients (average age 75) with an end-fire (3-9 MHz) transrectal probe with single use guiding system and a reusable tracking bracket for magnetic sensor (CIVCO, USA) (Fig 3). All the patients enrolled had a preliminary mpMRI or at least bi-parametric MRI performed within one month of the biopsy. MRI images were loaded onto a US scanner and evaluated with navigation software for the presence of abnormal signal intensities (Fig 4), and if suspicious lesions were identified they were targeted (Fig 5). Images were also evaluated as regards the presence of cystic lesions. Patients received a double antibiotic prophylaxis (Ciprofloxacina 500 mg x2 starting 1 day before and continuing for a total of 5 days and Ceftriaxone 1g e.v. just before the procedure). Common coagulation parameters were evaluated within one week of the procedure.

With the patient in the left-side decubitus, the support for the magnetic generator was fastened under the knees so that the generator was no more than 20-30 cm away from the perineal region (Fig 6). TRUS guided periprostatic nerve block anesthesia (mepivacaina 2% 10ml.) was performed.

Spatial co-registration was obtained overlapping the midline sagittal scans, including the urethra.

The navigation modality was activated (Fig 7) and the co-registration accuracy was evaluated using, if present, cystic lesions visible on both US and T2W MRI images (Fig 8). The targeted biopsy was performed with at least 2 samples for each target using a fully automatic 180 mm. 18G Trucut-needle (Fig 9). A systematic biopsy was then carried out with the same needle. The time required for co-registration was recorded.
Fig. 2: Magnetic generator (black arrow) on the plastic support and the magnetic sensor (white arrow) connected to the US unit (Fig 2a). The magnetic generator produce a spatially encoded 3D magnetic field (red arrows) that allows the system to know the position of the magnetic sensor (Fig 2b).

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Fig. 3: Fig 3a shows the end-fire probe and the bracket (black arrow). They are assembled (Fig 3b) in order to fasten the magnetic sensor (Fig 3c, white arrow) in the correct position.

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Fig. 4: mpMRI shows an abnormal area (hypointhesity on T2 W images and increased perfusion) located the middle anterior stroma and transition zone (14AS, 9A)

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Fig. 5: Using the MPR representation, a 3D target is manually defined.

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Fig. 6: TRUS-MRI fusion guided biopsy was performed in the same way than systematic TRUS guided biopsy. The patient lies on the left side. The support (black arrow) is positioned in order to have the magnetic generator (white arrow) close to the sensor without interfering with operator movements.

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Fig. 7: After the spatial co-registration was obtained by overlapping midline sagittal scans, the navigation modality was activated.

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Fig. 8: If retention cysts (visible on both TRUS and T2W MRI) are present they can be used to check the co-registration accuracy. In this case you can see a good co-registration demonstrated by an almost perfect overlapping of a small cyst (white arrow) visualized on TRUS and MRI.

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Fig. 9: After a good coregistration is obtained, a targeted biopsy is performed with Virtual Navigator.

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Results

The targeted TRUS guided biopsy with MRI-TRUS fusion using EM tracking system was introduced in the daily practice of our department without any significant change to the current procedure followed for systematic TRUS guided biopsy. The time required for the TRUS-MRI co-registration was in all cases less than 5 minutes (with an average of 4 minutes). The time required for each targeted biopsy was similar to the one necessary for the systematic sample, thus demonstrating that the different visualization environment on the US monitor did not affect the confidence of the operator. The co-registration accuracy calculated using prostatic retention cysts demonstrated that the maximum error was less than 5 mm in all case on the sagittal plane used for the TRUS guided biopsies.
Conclusion

Our feasibility study demonstrates that TRUS guided biopsy with MRI-TRUS fusion using an EM tracking system can be easily incorporated in the conventional procedure for systematic biopsies. This result offers a valuable opportunity to all patients (both biopsy-naïve and not), referred for a systematic prostatic biopsy, which already performed a prostatic mpMRI. In fact, no significant additional cost as regard time consumption and personnel requirement was generated. As regard the cost of the equipment, we should consider that the EM tracking systems are currently embedded in many commercial US scanners, and can be used for countless interventional and diagnostic applications [10]. Realistically, the break-even-point can be rapidly reached in any standard radiological department.

The accuracy of the TRUS-MRI co-registration using an EM tracking system appears to be adequate and similar to what has been reported for MRI guided in bore biopsies [1].

Considering that systematic TRUS guided biopsy misses a considerable number of significant prostate cancers visible on mpMRI [1-4-5], the introduction of an easily available and sustainable system for targeted biopsy is desirable. In patients with persistent increased PSA levels and a previous negative systematic biopsy, TRUS-MRI fusion guided targeted biopsy should be the technique of choice [12-13].

Although accurate, the MRI guided in bore biopsy requires specific hardware and software, is time consuming and expensive and should be limited to particular clinical settings. It should most likely be used as a second line technique in the case of divergence between TRUS-MRI fusion guided biopsies and clinical data, or between mpMRI PI-RADS and histopathological score after a TRUS-MRI fusion guided biopsy [1]. Furthermore, the access to sustainable TRUS-MRI fusion systems, along with the increasing popularity of simplified prostate MRI protocols such as Biparametric-MRI [14-15], can pave the way to the development of new algorithms in the diagnosis and management of prostate cancer.
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