White Paper

UroFusion

TPUS/TRUS Smart Prostate Target Biopsy

esaote

"UroFusion is a safe, quick and easy system to perform good quality prostate target biopsy with accuracy. Also addition tools like 3D prostate volume rendering make possible to have a real time evaluation of prostate deformation and movements."

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Introduction

Ultrasound (US) examination represents the best solution for the doctors to guide the execution of prostate biopsy. It is the only real-time imaging technology that ensures an appropriate compromise in terms of image quality, tissue information, execution time and cost for the hospital. The combination of US images with a second modality as Magnetic Resonance Images (MRIs) makes it possible to use their singular forces, like the real time imaging in the first case and the high spatial resolution in the second, to overcome their limitations. Today, the extended connectivity and the multimodality approach are opening new horizons in radiology imaging, where US devices may play a central role in Cross-Modality Imaging.

Background

Prostate cancer is the most common neoplasm in male patients and is the second/third most common cause of death by cancer in the United States and Europe[1-4]. The most common prostate diseases include prostatitis, benign prostatic hyperplasia and prostate cancer, the similar symptoms of which demonstrate the importance of periodic screening in men[5].

Generally, if no symptoms of prostate disease occur, the routine screening consists of blood PSA examination and Digital Rectal Examination (DRE). If one of these two exams shows an abnormal response, the doctor can suggest a multiparametric MRI (mpMRI) examination; thanks to the merging of anatomical and functional information taken from T2-Weighted (T2W) imaging, Diffusion Weighted Imaging

(DWI), and Dynamic Contrast Enhanced (DCE) imaging, this currently represents the best solution in terms of accuracy for prostate imaging. After the results of the mpMRI examination, the doctor decides whether to proceed with a prostate biopsy to assess the nature of the suspected lesion or suggests active surveillance (AS) of the patient to avoid repeating biopsies[6-7].

Prostate biopsy is the gold standard in the detection of prostate cancer (PCa)[6]. The usual biopsy methodology is US-guided, but due to its high irregularity and the organization of the internal capsules, it is often impossible to distinguish the different characteristics of the prostate tissues. US-guided biopsy can therefore only suffer from a low grade of accuracy. Evolution in the technique has led to the definition of systematic sampling of the prostate with a different number of samples in different areas, in accordance with the risk of developing neoplasms. A maximum of 12-15 samples are taken: 6 generally in the peripheral area, 4 in the transition zone and 2 from the apex. In term of PCa detection rate, systematic biopsy (SB) represents the best solution with a rate of almost 70% of cancer detection[6]. Even so, the statistical relevance of missing significant tumors is pushing research to find other ways to increase its precision.

The evolution of mpMRI image quality and the extended US connectivity and multimodality approach known as fusion imaging have opened the avenue to combine mpMRI images with real-time US results.

This method makes it possible to fix a target on a suspected lesion found on MRI images and, after synchronization with the US modality, to visualize the target on the US in the same location.[7] The combination of mpMRI images and US enables doctors to progress from conventional SB to targeted biopsies (TB).[8,9] The increase in the detection rate due to the combination of TB and SB have resulted in its strong recommendation in the recent Guidelines.[10]

MRI/US fusion imaging can be cognitive or software-based:

1. **Cognitive:**

   if the doctor uses the MRI report and images to assess the location of the lesion and tries to reach it by sampling the same portion during the US-guided biopsy.

2. **Software:**

   if the US system combines automatically the two US and MRI datasets, to provide information about the target localization and increase the sampling accuracy.

"The biplane co-registration system guarantees a more precise fusion and superimposition of US and mp-MRI, an indispensable prerequisite for correct centering of the lesions, even those not identifiable with US."

Dr. Pietro Galluzzi
Director of the Diagnostic and Interventional Ultrasound Operating Unit of Valduce Hospital in Como, Italy

Prostate Biopsy in Transperineal (TP) and Transrectal (TR) configuration

The TR biopsy approach currently represents the most common methodology for prostate biopsy.[11] The procedure is considered low risk for the patient, with 50% suffering from minor complications such as hematuria or hematospermia, to severe complications.

However, there is also a possibility of 4-5% of cases requiring hospital admission due to infection or related complications. As well as representing risk to the patient, these complications can also represent a burden on the National Health Service in terms of increased costs. Other approaches must therefore be considered.[11]

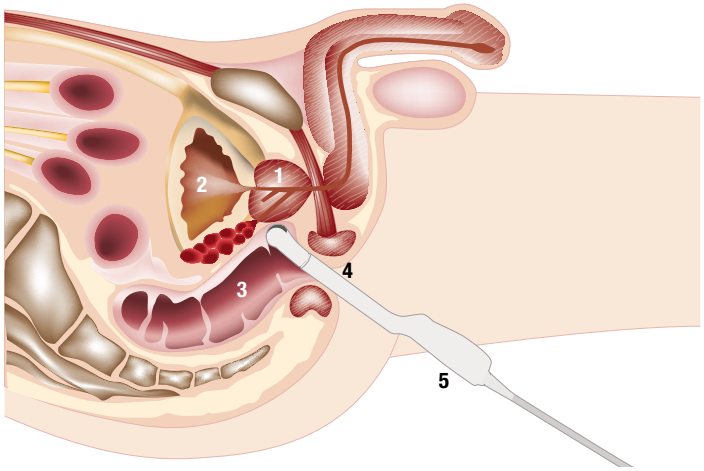

Fig. 1 TR biopsy
1 Prostate
2 Bladder
3 Rectum
4 Anus
5 Ultrasound probe

The TP approach is a safer alternative biopsy technique. This method reduces the risk of post-operative infections and greatly improves cancer detection rates in the anterior and apical areas of the prostate. In addition, based on its low risk, this technique is strongly suggested by the latest Guidelines.[10] Even so, it remains less commonly used, due to its technical difficulty and pain for the patient.[12]

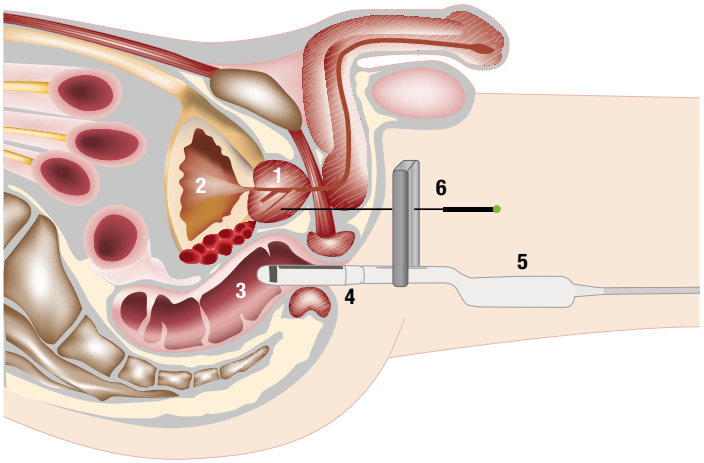

Fig. 2 TP biopsy
1 Prostate
2 Bladder
3 Rectum
4 Anus
5 Ultrasound probe
6 Biopsy grid in front of skin behind scrotum

Equipment

The system is compatible with two dedicated probes: the end-fire probe E 3-12 for a transrectal (TR) approach and the biplanar linear-convex array probe TLC 3-13 for a transperineal (TP) approach.

Fig. 3 Esaote S.p.A. endocavitary probes enable the UroFusion navigation tool, given the option for the doctor to execute the intervention in two configurations: TR with a E 3-12 probe and TP with a TLC 3-13 probe.

The hardware is based on an electromagnetic tracking system, consisting of a magnetic field generator and a receiver antenna positioned on the endocavity probe. The antenna makes it possible to detect the position of the transducer in a three-dimensional field created by the electromagnetic transmitter. The UroFusion software enables simultaneous registration of the datasets of a second DICOM (Digital Imaging and Communication in Medicine) modality and real-time ultrasound. The width of the magnetic field is approximately 70 cm from the magnet.

The quality of the tracking is continuously monitored and is reported on the screen as blue lines in the signal field.

When UroFusion is active, a dedicated environment is displayed on the touchscreen to facilitate the workflow and acquisitions.

Findings and procedures (TP approach)

In this case, the needle access is through the perineum. Today, this approach represents the safest solution for the patient in term of post operative infections, with no risk of multiple occurrences of sepsis. The procedure is split into four steps:

1. Preparation stage:

The operator will import into the US device one or more DICOM datasets, such as MRI, CT, or PET-CT, directly from a PACS or from external media, e.g. a CD or USB stick. Generally, for prostate biopsies, T2-weighted axial and sagittal MRI sequences are imported to be used for navigation. Additionally, the clinician can import other datasets, such as Diffusion Weighted Imaging (DWI) series and Apparent Diffusion Coefficient (ADC) series. UroFusion then makes it possible to combine these with the T2 datasets to help find the precise location of the targets.

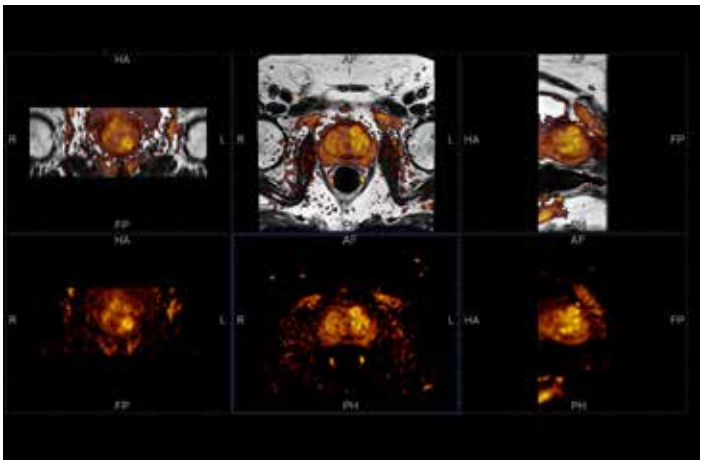

Fig. 4 Updating and superimposing mpMRI images in a UroFusion enviroment. The primary image is represented by the axial axis of the Weighted T2 series and the secondary by the DWI series.

The alignment between the different series can be managed automatically via the "AutoSeriesAlignment" function or manually by the clinician.

Up to 25 targets can be set by the operator, either with a 3D ball using the "Focal lesion" button on the touchscreen, with manual 3D contouring, or finally with automatic 3D contouring of the lesion if well differentiated in the MRI dataset.

The tool also provides the option to obtain a 3D reconstruction of the prostate volume by plotting its contours on different planes of the T2 axial or sagittal datasets. It is not necessary to outline all the frames, as the system is able to automatically reconstruct them and leave the clinician the option to review them at a later time. The prostate is a soft organ which suffers important deformations due to the endocavitary probe and the mp-MRI coil. Also for this reason the mp-MRI volume allows to understand in real-time the compression grade made by the probe and to adequate it to the fusion methodic.

2. Bi-planar co-registration stage:

During this step, the operator synchronizes ultrasound in real time with the MRI dataset. At this stage, the first plane is selected (in the case shown, the doctor started from the sagittal, but it is also possible to start from the axial plane), then the alignment is done by performed by finding certain common markers in the two modalities, e.g. the urethral channel in the equatorial axis, or clearly visible cysts or bones. The prostate volume can assist in this stage, given that the overlap in the US image of the outline plotted on the MRI image can add other reference points for the operator. The physician can also overlap the images of the two modalities to adjust the synchronization. It is then possible to confirm the alignment made by clicking "Confirm the alignment" and going directly to the Navigation stage. The focus of this alignment approach is to better overlap and to fuse the two modalities, indispensable prerequisite for a correct centering of the lesions, even those not identifiable with US.

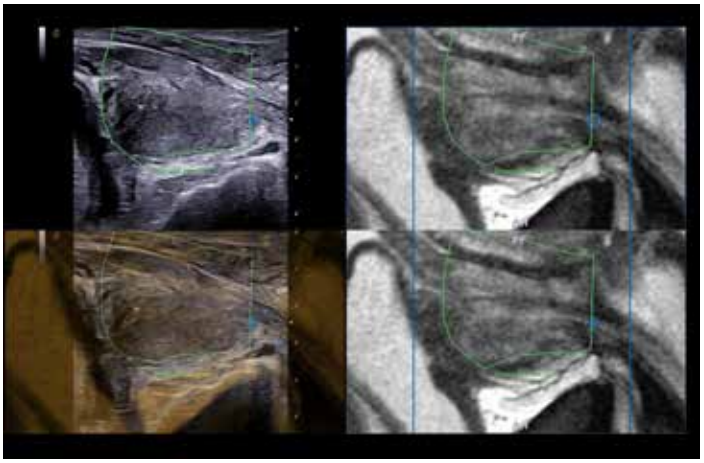

Fig. 5 Bi-planar alignment of the two modalities respect the sagittal axis with the bi-planar probe. In the latter case, the operator uses the 35% overlap of the MRI and US images to gain a better understanding of the quality of the alignment.

3. Fine-tuning stage:

The practitioner can easily adjust or redo the alignment when it is made via different fast tuning systems.

a) With small movements, One-Point Registration enables the repetition of the two modalities, placing a point in the same position in both of them.

b) Freehand Tuning makes it possible to move and rotate the MRI image manually and/or change the MRI image plane, to achieve an alignment of the two modalities without repeating the co-registration phase.

c) Internal Marker Tuning allows the operator to align the different planes of the images by marking the anatomical reference points that are clearly visible in both modalities. The system expects at least three points in the US and MRI dataset to align them.

4. Navigation and biopsy procedure stage:

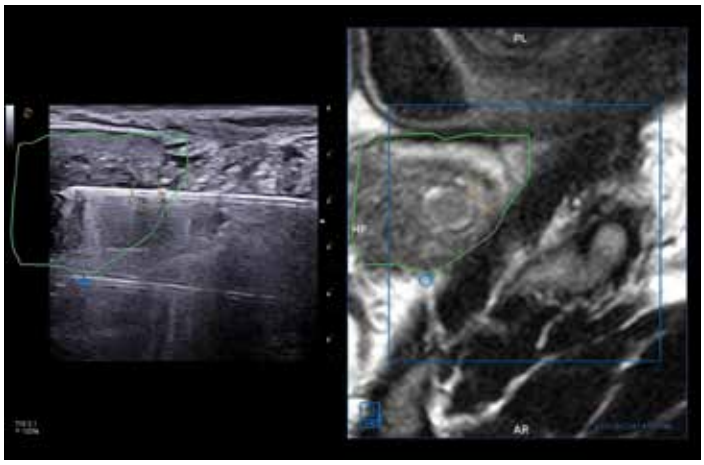

Fig. 6 Live US with the 2nd modality image on the same plane. Image Fusion with B-Mode and MRI dataset. This layout directly shows the two modalities side by side during the biopsy. The contour of the prostate volume makes it possible to observe prostate movements in real time, giving the doctor instruments to rapidly re-synchronize the two modalities.

The system is ready to navigate through the two modalities and the biopsies can be performed under US/MRI image fusion guidance. If more than one second modality dataset has been uploaded, the operator can change between them at any time, setting it as the benchmark. Different display layouts are available.

The physician can display the biopsy line from both the modalities on the monitor.

Also in this stage, it is possible for the doctor to re-align the two modalities if patient movements or contractions occur. Both modalities can be frozen and the alignment rapidly repeated, as in the Freehand Tuning stage.

Another integrated tool is Sample Mapping, used to report the position of each sample taken during the procedure with the option of saving the 3D volume with the mapping, or to review them later.

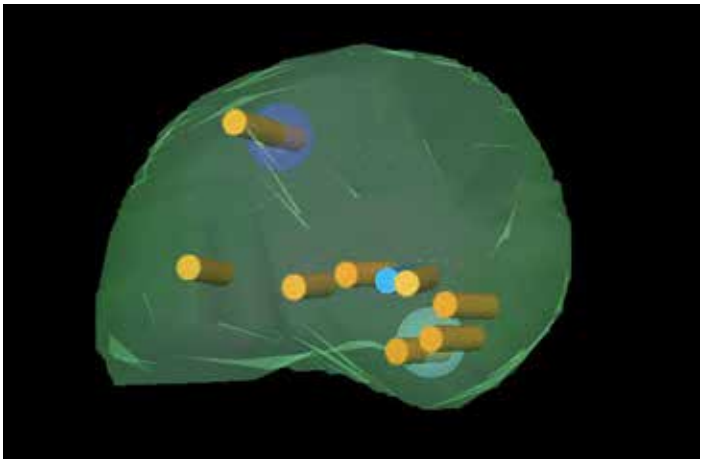

Fig. 7 3D rendering of the prostate gland with core samples mapping.

Findings and procedures (TR approach)

This approach is currently the most commonly used method of prostate biopsy.

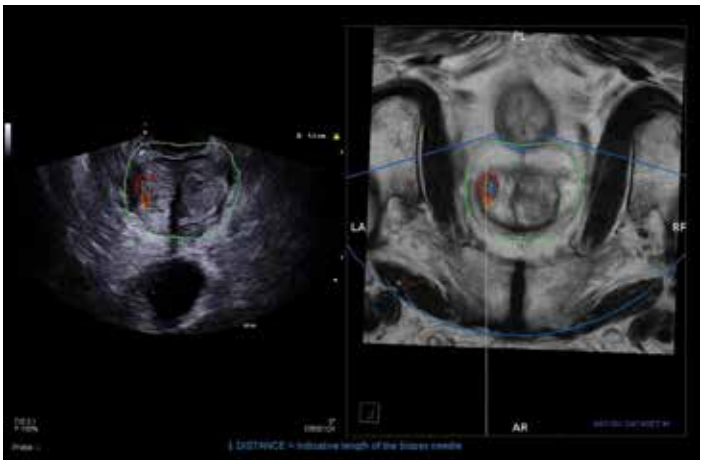

Fig. 8 TR biopsy with the needle guide and sample mapping activated.

Needle access is gained through the rectum and the system automatically sets the needle guide depending on the configuration and leaves the operator the option to set the correct needle configuration on a dedicated menu.

The workflow is the same as the TP approach and the doctor can choose to take the samples from both the axial and sagittal planes.

Advanced features

Once the synchronization is complete, the patient must remain still to maintain a good quality of fusion. But sometimes, despite local anesthesia, the patient can experience involuntary movements or contractions. In these cases, to automatically correct these movements, a movement sensor can be applied to the patient's body. The application area could be the sacral zone if the patient is in lateral decubitus or the iliac crest if the patient is in gynecological position, to minimize the effects of movement artifacts.

UroFusion environment can support additional technologies such as microV, the Esaote tool for microvascularization visualization; QElaXto 2D, is the Esaote 2D shear-wave technique for the stiffness evaluation of the prostate tissue; and CnTI™, the Esaote software for Contrast Enhancement Ultrasound (CEUS).

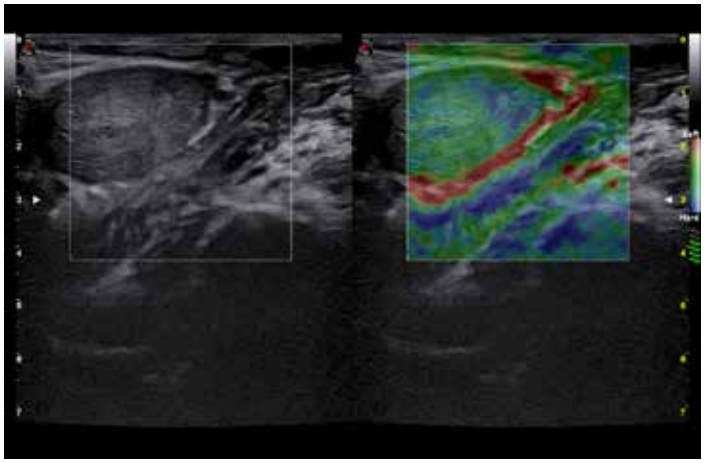

Fig. 9 ElaXto application using the Bi-planar probe. The elasticity study of the tissue in UroFusion environment gives the doctor additional tools to study a lesion, suspected or otherwise.

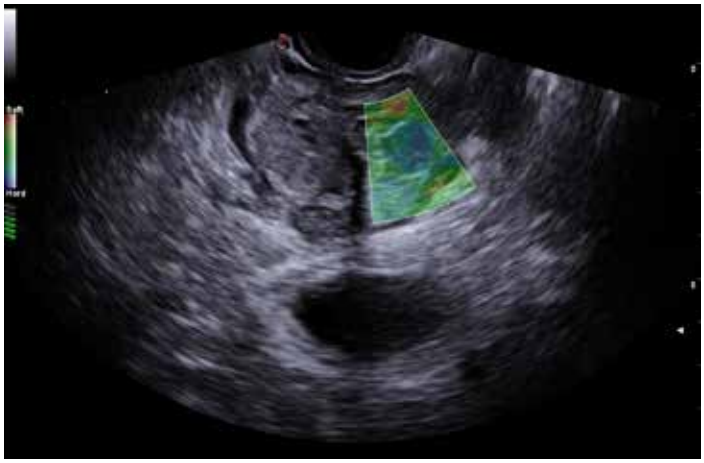

Fig. 10 In this examination, a PIRADS 3 lesion was studied firstly under elastography examination using the ElaXto tool. As can be seen, the lesion has a higher rigidity than the neighboring tissues.

All these techniques, available in real time during a fusion procedure, may improve the intervention capability and accuracy of the doctor, and enhance the quantity and quality of the information available.

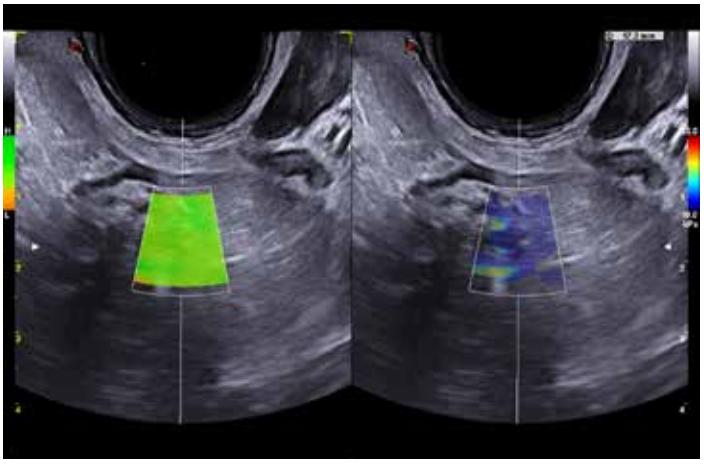

Fig. 11 QElaXto 2D applied to prostate with dual mode visualization to enable the dispersion map (left side). The orange areas indicate low reliability while the green ones indicate high reliability, and the stiffness map imaging (right side).

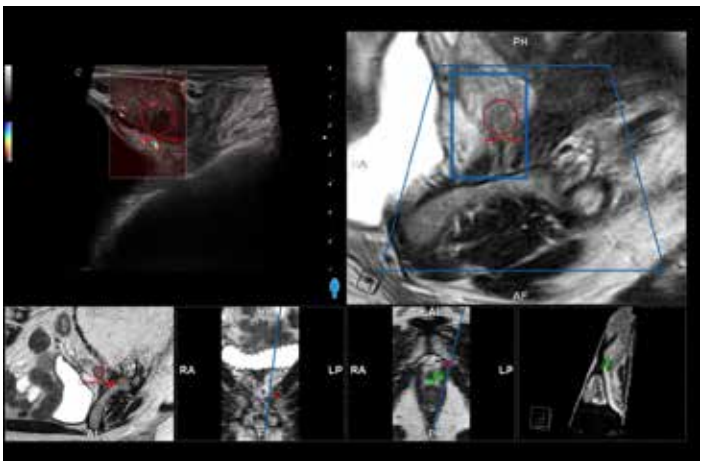

Fig. 12 Study of prostate gland microvascularization using microV expansion.

Conclusions

UroFusion is a completely dedicated prostate TB software package that supports medics in the precision sampling of a suspected lesion, combining the information from both MRI and US images.

The user is able to monitor any patient movement or organ deformation in real time and immediately, with fine-tuning tools, and can easily realign the two modalities.

Additional tools such as the sample mapping are useful for the follow-up if further biopsies are required, and to plan any focal therapy procedure.

The possibility of having a 3D reconstruction of the prostate volume and of the sampling already carried out allows the operator to evaluate both the number of correctly performed samples on the target and to adequate sampled some prostate volumes in the subsequent systematic mapping, especially in bulky prostates.

Target biopsy should become an everyday procedure, according to the guidelines, and UroFusion helps to execute this complex procedure with a smart workflow and with dedicated tools, from preparation to follow-up.

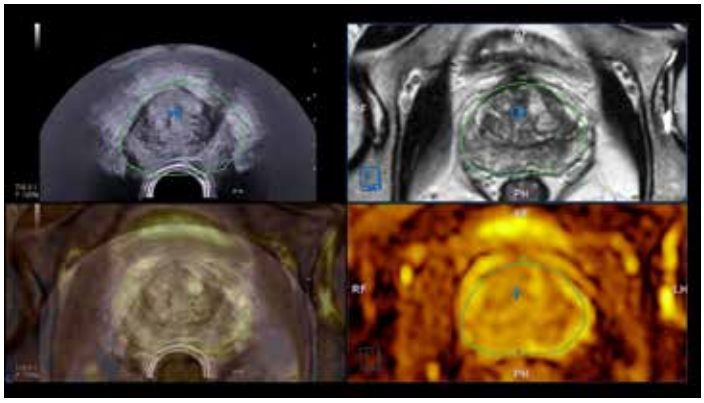

Fig. 13 Example of multimodality overlap of different datasets to search the lesion with a better precision

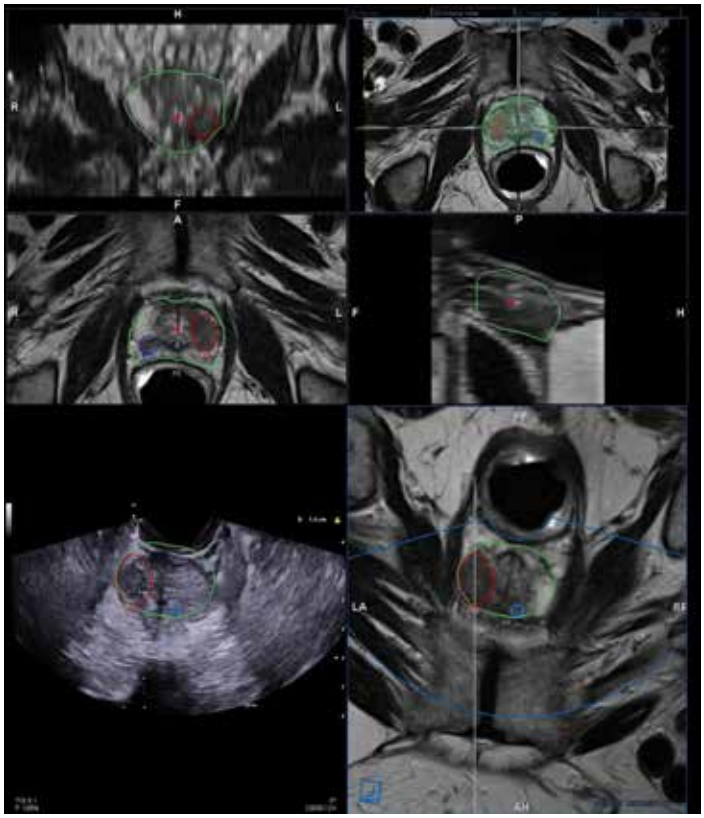

Fig. 14 In this case the MRI examination of the patient reports a PIRADS 5 lesion on the equatorial zone on the left side of the gland and a PIRADS 4 lesion in the contralateral position. Thanks to the possibility of multiple targeting geometries, the doctor can plot the contours of the lesions more efficiently. The contours of the prostate can be used as a benchmark to monitor prostate movements and as support for the alignment. The doctor takes 2-3 samples from the targeted region using the biopsy guide as support to reach it more precisely.

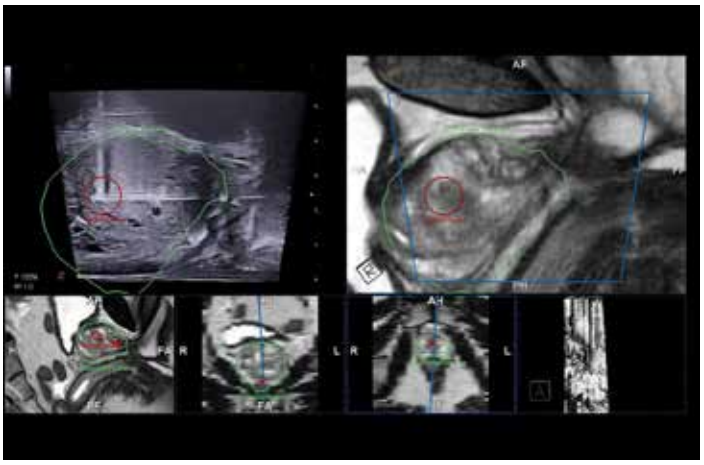

Fig. 15 Live US with the 2nd modality image on the same plane and all the second modality planes. This layout can provide information on the spatial position of the projection axes of the probe according to the synchronization achieved during bi-planar registration. In this image, it is possible to notice the contribution of Fusion Imaging to detect a clear hypointense lesion on the T2W image but not visible on US.

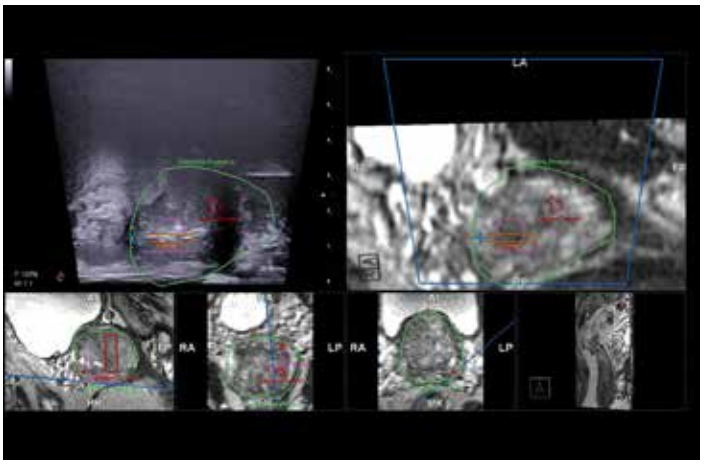

Fig. 16 Prostate mapping in real time in TP approach

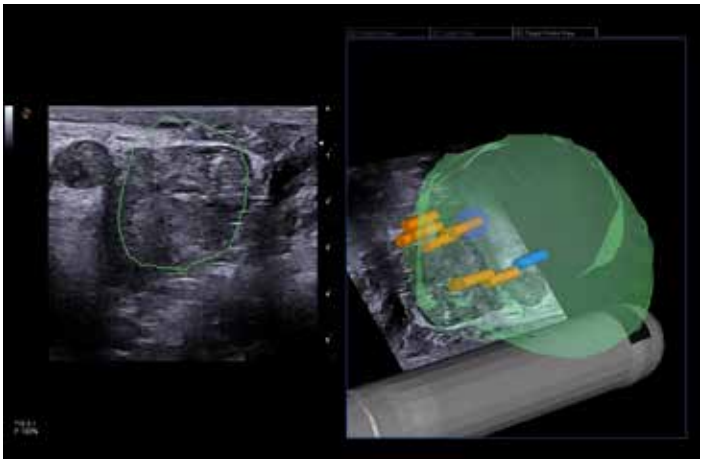

Fig. 17 After the samples are taken from the target area, the doctor progresses to a systematic biopsy of the gland (around 12 samples) to cover any lesions not visible on the MRI. In the MRI volume, the doctor can observe in 3D how the samples are distributed across he gland.

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