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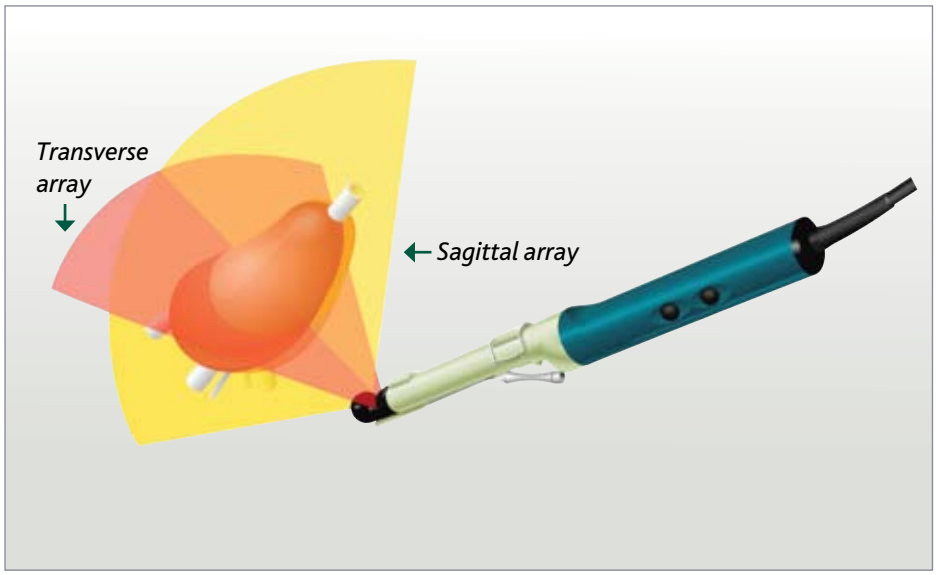
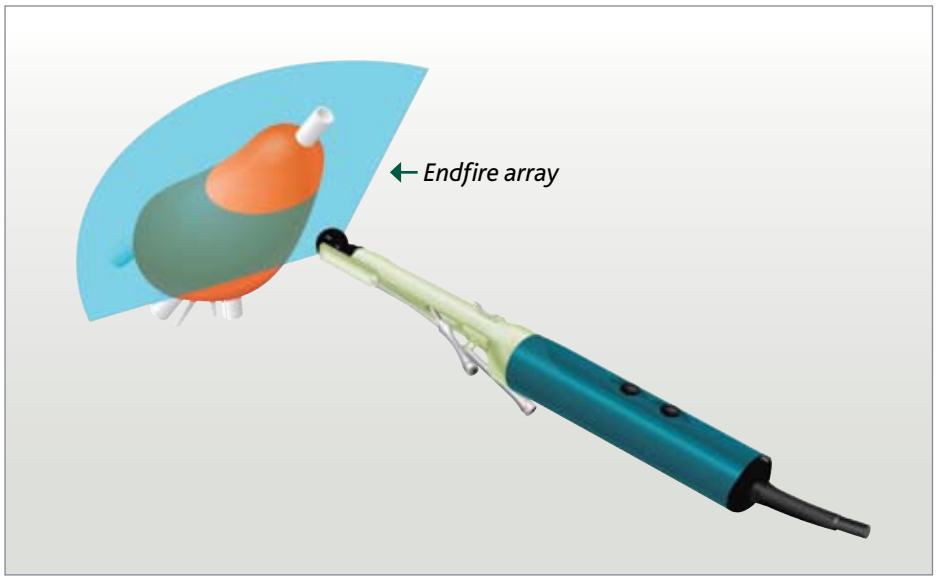
Simultaneous biplane and endfire ultrasonography of the prostate

Application Note





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Simultaneous biplane and endfire ultrasonography of the prostate

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B-K Medical is the market leader in ultrasound for urologists. We introduced the first simultaneous biplane transrectal prostate transducer to the worldwide market , which today is widely used for prostate examinations and biopsies.
To give urologists the optimal tool for prostate examinations, B-K Medical has developed the new 8818 transducer, which combines both simultaneous biplane and endfire imaging in one probe.
The 8818 comes with a dual biopsy guide that can be used to take biopsies in either mode. It is a powerful tool that enables urologists to examine any prostate, in any plane, with control and ease.
This application note explains the uses and benefits of simultaneous biplane and endfire imaging, as well as briefly looking at other modes such as tissue and contrast harmonic, Doppler and 3D imaging.

Background

The American Cancer Society states that prostate cancer is the most frequently diagnosed cancer in men. It estimates that in the U.S. in 2006, there will be 234,460 new cases diagnosed, and 27,350 deaths from prostate cancer.

Overall, the incidence of prostate cancer in the western world has increased steadily over the last two decades, and in the UK it has doubled over the same period. (1)

The possibilities and limitations with staging

Accurate staging is critical to the management of prostate cancer, and the more information about the cancer the staging provides, the more informed the decision can be made as to the type of treatment the patient should have.

Although screening tests, such as DRE, TRUS and PSA used as a serum marker, help in prostate cancer detection, the lack of specificity and sensitivity confuse the diagnosis (2). PSA alone offers only poor specificity: One in three cases of prostate cancer is associated with normal diagnostic values. Another issue related to the diagnostic value of PSA is the difficulty in distinguishing between prostate cancer and benign prostate disorders, particularly in the PSA range 4-10ng/ml. (3,4).

Transrectal ultrasound is most frequently used to guide and improve the accuracy of prostate biopsies, and methods are still being investigated to help reduce the number of understaging errors and the rate of false negatives. Saturation biopsy techniques (20-24 cores) have been proposed (5).

If extracapsular tumor extension goes undetected, the risk of treatment failure may increase (6,7).

Concerning the sensitivity of cancer detection, it has been proposed that more lateral needle placement would improve sampling of the peripheral zone (8).

Anatomy of the prostate

For ultrasound purposes, the prostate can be said to consist of five zones: three glandular (the peripheral zone, transition zone and central zone) and two non-glandular (the periurethral zone and the fibromuscular stroma). The semi-transparent schematic drawings (Figures 1,2 and 3) represent the ultrasound anatomy of the prostate.

The peripheral zone

The peripheral zone makes up 70% of the glandular tissue. Eighty to 85% of prostate cancers arise here (9).

A healthy peripheral zone displays a homogeneous isoechoic ultrasound pattern.

The "surgical capsule" that separates the peripheral zone from the transition zone appears as a distinct boundary in ultrasound.

The transition zone

The transition zone consists of two separate lobes that lie superior to the verumontanum, lateral to the proximal urethra, and posterior to the fibromuscular stroma.

The transition zone is the site of benign prostatic hyperplasia (BPH). In a non-hypertrophied prostate gland, it makes up 5% of the glandular tissue. Enlargement of the transition zone due to BPH may alter the contour of the prostate in older men, compressing the peripheral zone or displacing it laterally.

Ten to 20% of prostate carcinomas arise in the transition zone.

The central zone

The central zone makes up 25% of the glandular tissue. Five to 10% of carcinomas arise here.

The central zone lies posterior to the urethra and superior to the verumontanum. It surrounds the ejaculatory ducts.

The anterior fibromuscular stroma

The anterior fibromuscular stroma forms the anterior surface of the gland. It may be up to 1 cm thick, but thins out over the distal portion of the gland. The anterior fibromuscular stroma is more prominent sonographically in younger, non-BPH patients. It is thought that it may be a barrier to the spread of cancer.

The periurethral zone

The periurethral zone is a mid-line structure of cylindrical, internal smooth muscle sphincter that runs from the base of the verumontanum to the back of the bladder neck. Its function may be to prevent semen from flowing backwards into the bladder.

The periurethral zone includes the internal urethral sphincter, while the external sphincter is distal to the apex of the prostate.

The peripheral zone makes up to 70% of the glandular tissue in young patients not affected by BPH (see Figures 2 and Figure 23, Appendix 2). Later in life the transition zone tissue tends to develop BPH and by its growth occupy a significant percentage of the glandular tissue. This limits the volume of the peripheral zone to much less than 70% (see Figures 3 and 22, Appendix 2). Eighty to 85% of prostate cancers have been shown to arise from the peripheral zone (9), which certainly makes this zone an area from which biopsies must be sampled.

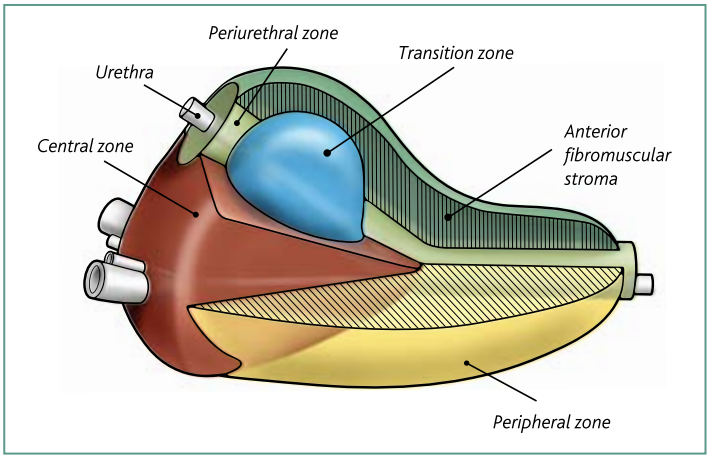


Figure1. Ultrasound anatomy of the prostate – sectional view.

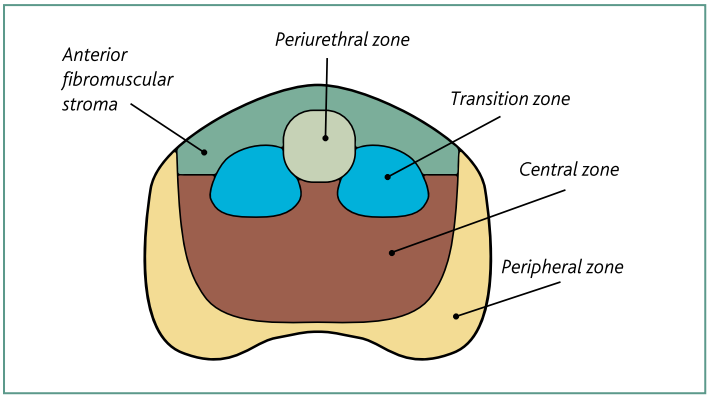


Figure 2. Ultrasound anatomy of the prostate – transverse section.

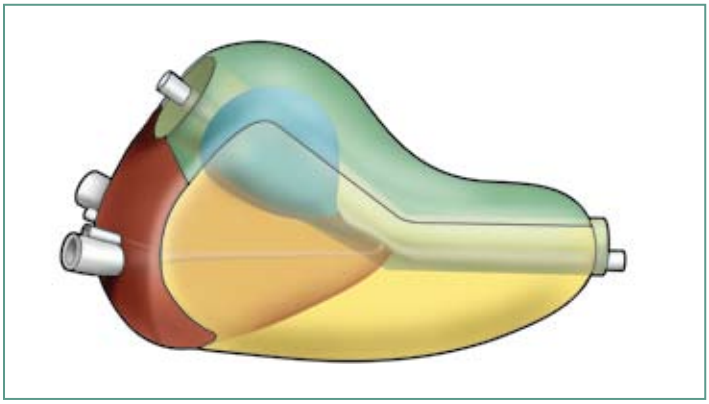


Figure 3. Ultrasound anatomy of the prostate – semitransparent view. Figures 1-3 courtesy of John Mc-Neal, 1983

The new 8818 prostate transducer: Both simultaneous biplane and endfire imaging

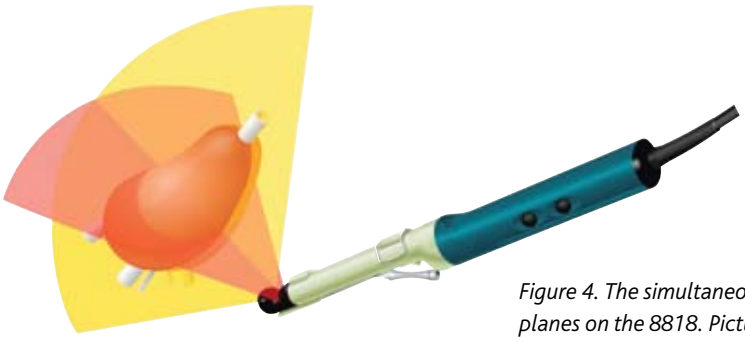


Figure 4. The simultaneous biplane planes on the 8818. Pictured with dual biopsy guide

Figure 5. The end fire plane on the 8818. Pictured with dual biopsy guide

Two transducers in one: simultaneous biplane and endfire imaging

The 8818 prostate transducer combines the functionality of two probes into one. You can perform both simultaneous biplane and endfire imaging with it. Each mode has its strengths–and each its limitations. But the limitations of simultaneous biplane can be overcome by using endfire, and those of endfire greatly improved upon by using biplane. By combining both modes in one slim transducer, the prostate "opens up" for urologists–its sections become easily accessible for examination and safer, more precise biopsies. Control remains in the user's hands; the transducer is easy to maneuver and is designed so that it is straightforward to switch between simultaneous biplane and endfire imaging, without removing the transducer from the patient.

Figures 4 and 5 illustrate how the arrays on the 8818 are positioned. The 8818 is built on the an "iso-center" principle, whereby the scanning planes intersect with each other. The sagittal array on the 8818 forms a 210° arc. A section of the sagittal array together with the transverse array provide simultaneous biplane scanning, where real-time transverse and sagittal images can be viewed on the scanner screen. The lower frontal section of the sagittal array provides endfire imaging, and the field view of the sagittal array in either mode is 140°. Each button on the handle of the 8818 corresponds to one of the scanning modes (Figure 18b). Pressing either button activates or freezes scanning in the chosen plane.

Simultaneous biplane images

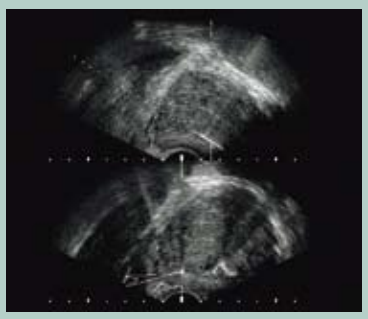


Figure 6. Targeting the right lateral peripheral zone for a biopsy. The arrow on the transverse (lower) image points to the marker which indicates the projection of the path that the needle will follow in the sagittal (upper) image. Note that this target is exactly in the lateral peripheral zone. Many urologists consider biopsies in this area difficult if only based upon the sagittal image.

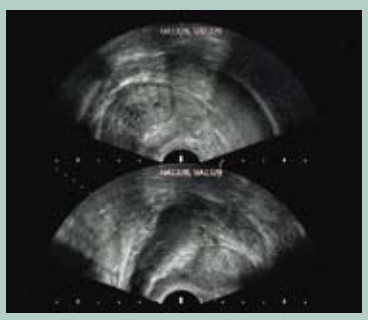


Figure 7. Targeting the left lateral deep biopsy.

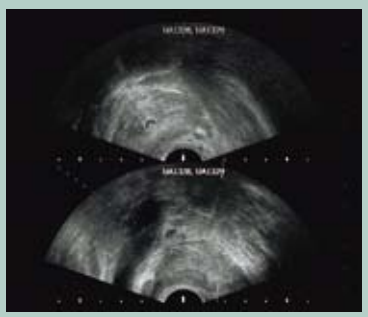


Figure 8. Targeting the left lateral mid biopsy.

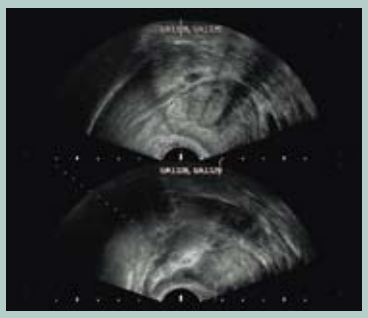


Figure 9. Targeting the right lateral deep biopsy.

A long press on the sagittal button changes the mode to endfire scanning.

Before you scan, the transducer should be covered with a condom. Apply gel to the transducer head, making sure all the crystals are covered. This will improve images by preventing image artifacts caused by air bubbles. Then pull the condom over the transducer. You should also apply a small amout of gel to the outside of the condom prior to scanning, as gel creates a good acoustic contact between the skin and the transducer.

Follow the biopsy needle in two planes

A one-plane view of the prostate can make it difficult to complete a biopsy regimen because you can't be certain you are sampling from the targets you intend to. A simultaneous biplane view enables you to more correctly target the sections you want for biopsies. You can see exactly where and how deep the puncture is (Figures 6-10,12,13).

For example, simultaneous biplane is excellent for taking biopsies in the peripheral zone of the prostate, where most cancers occur (9; please see appendix1). In older men, the transition zone tissue tends to develop BPH and, by its growth, cause the peripheral zone to become thin and difficult to target (Figure 6). A real-time transverse image, together with a sagittal image, provides a clear indication that the needle in the longitudinal plane is in the correct area, for quicker and more accurate biopsies. The wide sector angle on the 8818 transducer easily accommodates both the right- and left lateral peripheral zone in one image (see Figure11). You cannot get nearly as good orientation to follow a particular biopsy scheme with only a one plane view.

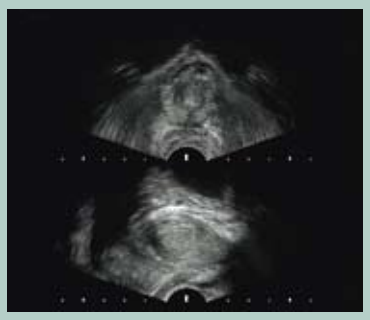


Figure10. Biplane ultrasound image at the level of rami symphysis pubis. Transverse image (upper) together with the corresponding sagittal image (lower). Note the strong echo from the ramus and the bulbospongiosus muscles inferior- and lateral to the urethra.

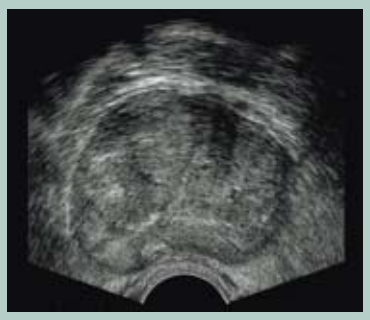


Figure 11. Even a large prostate can conveniently be imaged in the 140° large sector of the 8818 transducer.

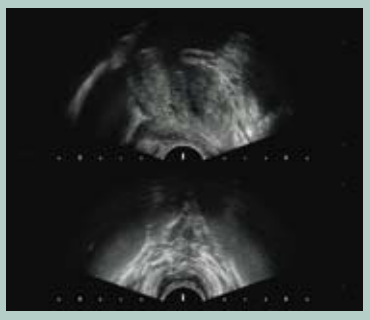


Figure 12. Biplane image at the level of rami symphysis pubis, transverse image (lower) together with the corresponding sagittal image (upper). Note that both the external anal sphincter and the external urethral sphincter are seen.

Why endfire imaging is suitable for apical biopsies

Any biopsy regimen must include at least two biopsies that are from the left and right apical area of the prostate yet still close to the parasagittal plane. In some patients however, simultaneous biplane has some limitations for biopsies in the apical section of the prostate. Because the transducer features transverse and sagittal images, the biopsy channel must permit the biopsy path to be identified in two perpendicular planes. The biopsy channel cannot be placed over one of the transducer arrays when the transducer is set to simultaneous biplane mode, as this would prevent imaging from one of the arrays in that situation.

If you attempt apical biopsies with a dedicated simultaneous biplane biopsy channel, the needle may end up piercing tissue at a small, but significant distance behind the sagittal image projection.

Examining the anatomy slightly caudal to the apex more closely (see Figures 13 and 14) identifies the puborectalis muscle complex together with other muscles such as the urethral sphincter and the rectourethalis muscle.

Positioning the transducer further in the oral direction at the level of the rami symphysis pubis verifies that the transverse image (Figure 12, lower) now is below the level of the puborectalis

muscle, and close parasagittal biopsies may interfere with both this muscle and the external urethral sphincter.

Endfire is suitable for the two apical biopsies because the biopsy guide for endfire imaging is placed immediately behind the imaging array. This ensures the shortest possible biopsy path to the apex, thereby helping you to avoid accidental piercing of other pelvic floor structures. (Figure 18). Simultaneous biplane mode, however, is still the best choice for getting the best orientation possible for precise prostate biopsies.

Other imaging possibilities

Simultaneous biplane or endfire imaging on the 8818 can be complemented with color and power Doppler, (Figure 15), together with tissue harmonic (Figures 16 and 17) and contrast harmonic imaging.

3D ultrasound data sets can be utilized in addition to simultaneous biplane and endfire images. 3D ultrasound lets you get even more information from images, especially if you uses volume render mode technique (please see Appendix 2).

Future opportunities and considerations

Multiple biopsy regimens have been suggested, ranging from a 10-core regimen (10,11) to 24-core saturation biopsy scheme (5).

The PSA threshold for initiating prostate biopsies has been lowered, and some centers will today use values as low as 2.5ng/ml. As well, the percentage of free PSA to total PSA plays an important role. A low percentage (<11%) has been used to decide to perform a second set of biopsies. Logical questions must be raised regarding the appropriate treatment, if any, of an elderly male with one positive biopsy out of a larger number of biopsies, a low PSA value, and a low Gleason score. In the last few years

Figure 13 (at top right) is a snapshot from a real-time biplane ultrasound image. The transverse image (upper) is recorded at the level where the puborectalis muscle is seen protruding anteriorly with the internal obturator muscles (hypoechoic due to the direction of the ultrasound projection) seen both left and right lateral following the ramus inferior ossis pubis. Inferior to the urethra and superior to the rectum, the dorsum penis is seen at the level of the centrum tendineum perinei, possibly also partially including the bulbospongiosus muscle (Figure 14). The sagittal (lower) image shows the prostate imaged from the verumontanum (colliculus seminalis) to the apex demonstrates Denonvillier's fascia inferiorly in the image together with musculus rectourethralis.

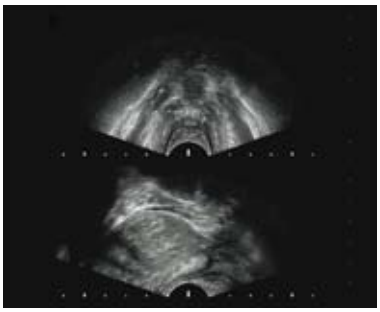


Figure 13.

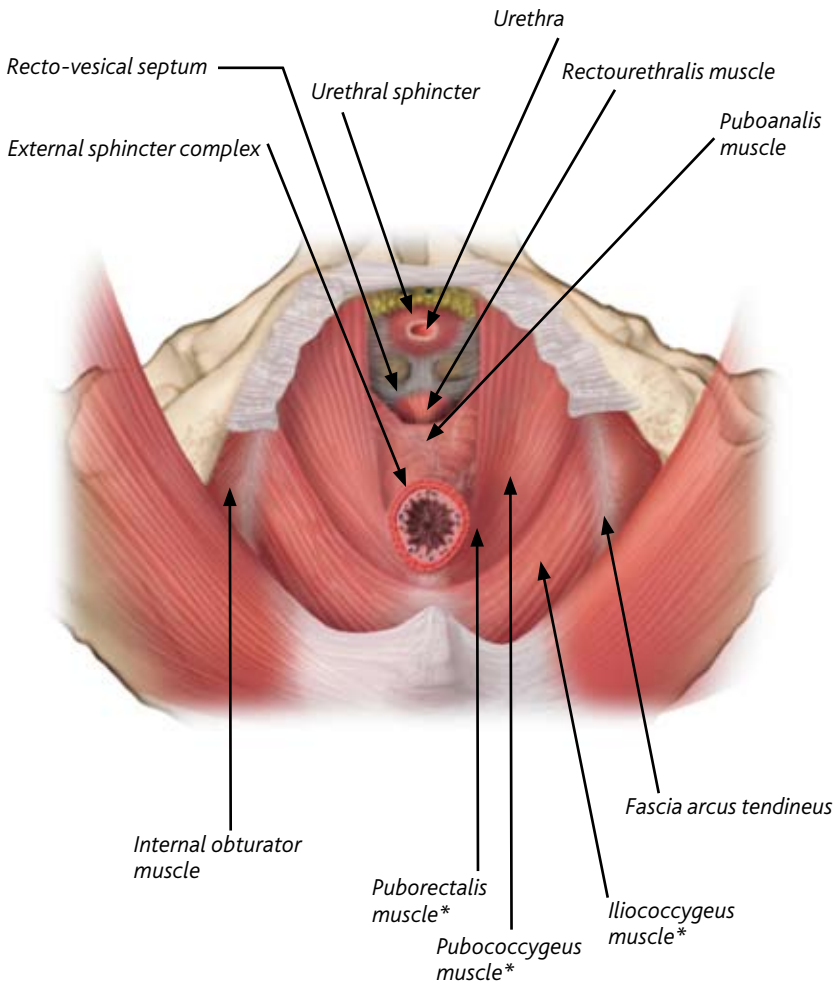


Figure 14. The male pelvis.

**= levator ani*

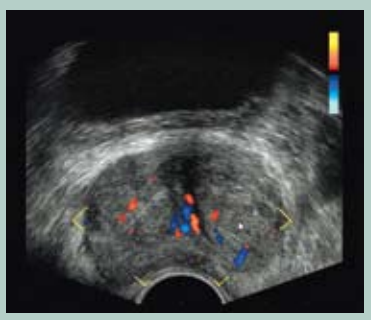


Figure 15. Transverse image at the level of Verumontaneum. Note the flow in both sides lateral to the colliculus.

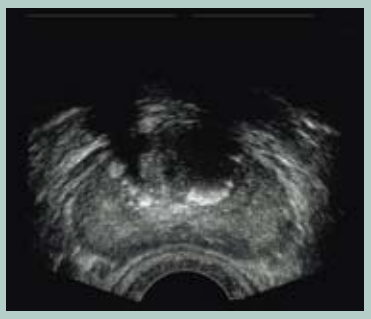


Figure 16. Tissue harmonic imaging of the prostate.

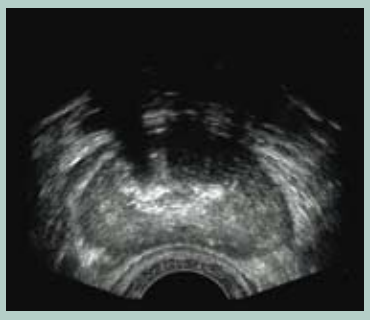


Figure 17. The same image as Figure 16, but without tissue harmonic imaging.

biomolecular investigation techniques have been developed, such as kallikrein or similar proteases, growth factors and neuroendocrine markers (4). Extensive research in new therapeutic approaches is increasing around the world, including targeting angiogenesis, immune regulation and stromal-epithelial interactions.

For the foreseeable future, however, TRUS, combined with a scientifically accepted biopsy regimens, will remain the standard.

Conclusion

B-K Medical is the global leader for specialized ultrasound solutions for urology. The 8818, together with B-K Medical scanners, such as the Pro Focus, provides users with a powerful solution that is easy to use and operate.

You can comfortably hold and maneuver the 8818. Press the buttons on the handle to change planes, or to freeze, save or print the image.

The puncture guides for the 8818 are designed especially for prostate biopsies, making it quicker and easier for you to complete a regimen.

The Pro Focus scanner makes 3D ultrasound easy. With just the press of a button on the scanner keyboard, you can get reconstructed 3D images on the screen, as the optional 3D feature is fully integrated into the Pro Focus software. You can browse through 3D data sets, share information with your colleagues and take the time you need to study images.

If you want more information on B-K Medical solutions for urology, you can start at www.bkmed.com. On the back of this application note is contact information for our regional offices.

Figures 18, a, b, c.
a) (top right). The 8818 with the dual guide attached
b) (middle). Buttons on the handle of the 8818 that allow you to switch between simultaneous biplane and endfire imaging
c) (bottom right). The 8818 dual biopsy guide.

References

1) Foster CS, Cornford P, Forsyth L, Djamgoz MBA, Ke Y:
The cellular and molecular basis of prostate cancer.
BJU Int 1999; 83: 171-94.

2) Vo T, Rifkin MD, Peters TL:
Should ultrasound criteria of the prostate be redefined to better evaluate when and where to biopsy?
Ultrasound Q 2001; 17: 171-176

3) Hoelt W, Muller MM, Lunglmayr G:
The prostate specific antigen era in the United States is over for prostate cancer: what happened in the last 20 years?
J. Urol. 2004 Oct 1297-1301

4) Watson RGW, Schaken JA:
Future opportunities for the diagnosis and treatment of prostate cancer.
Prostate Cancer and Prostate Diseases 2004; 7: 8-13

5) Derweesh IH, Rabets J, Patel A, Jones S, Zippe C:
Prostate Biopsy.
Contemporary Urology December 2004; 28-44

6) Epstein JI, Carmichael MJ, Pizov G, Walsh PC:
Influence of capsular penetration on progression following radical prostatectomy. A study of 196 cases with long-term follow-up.
J. Urol. 1993; 150: 135

7) Epstein JI:
Incidence and significance of positive margins in radical prostatectomy specimens.
Urol. Clin. N. Amer. 1996; 23: 652

8) Greene D:
Prostate cancer detection by transrectal ultrasound.
Urology News 2000; 5: Issue 1.8

9) Stamey TA:
Making the most out of six systematic sextant biopsies.
Urology 1995; 158:1886

10) Philip J, Ragavan J, Desouza J, Foster CS, Javle P:
Effect of peripheral biopsies in maximising early prostate cancer detection in 8-, 10- or 12-core biopsy regimens.
BJU Int 2004; 93: 1218-1220

11) Fink, KG, Hutarew G, Pytel A, Esterbauer B, Jungwirth A, Dietze O, Schmeller N T:
One 10-core prostate biopsy is superior to two sets of sextant prostate biopsies
BJU Int. 2003 Sept; 92(4): 385-388

Appendix 1: Peripheral zone biopsies

New biopsy regimens

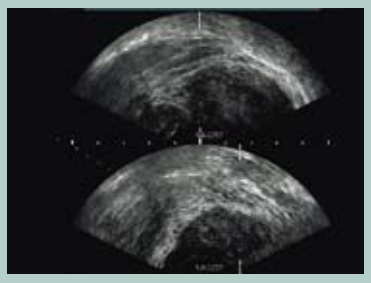
Several studies show that a biopsy regimen that includes a higher number of peripheral zone biopsies can possibly increase detection rates.

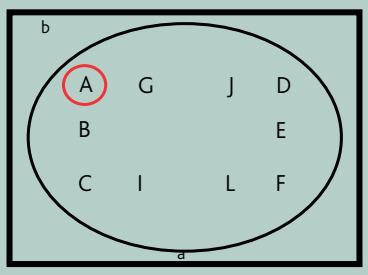
A recent study (10) concluded that parasagittal sextant biopsies per se are inadequate in prostate biopsy protocols, and 28.2% of TRUS-detectable cancers would have been missed in the group of patients had only a sextant biopsy regimen been applied. A systematic 12-core biopsy protocol for detecting early prostate cancer was performed.

The different permutations and combinations of the 12-biopsy samples were assessed. 98.6% of the TRUS-detectable cancers detected by the 12-core scheme were found by applying a 10-core strategy, whereby two parasagittal mid-zone biopsies are excluded, but six cores taken from the left and right peripheral zone are included (see Figures 1 - 3). The reason for achieving the high cancer detection rate is likely due to the fact that most cancers occur in the peripheral zone(9).

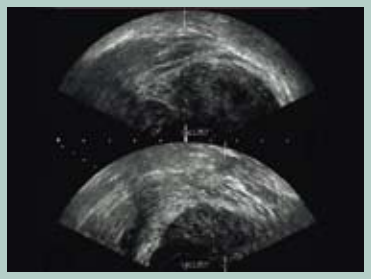
With simultaneous biplane ultrasound, the doctor can use the transverse image view to position the probe optimally to take extreme bilateral biopsies in the peripheral zone.

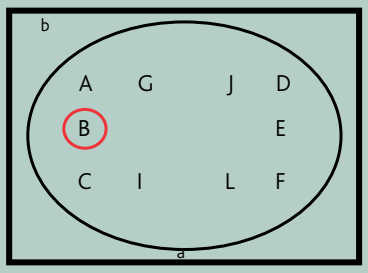
Examples of simultaneous ultrasound images from a 10-core biopsy scheme



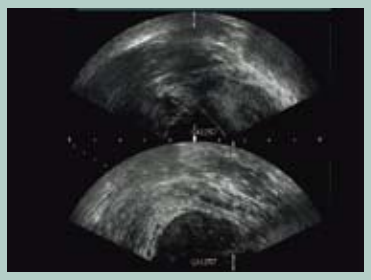


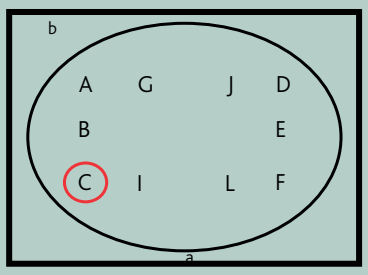
Figures 19a and 19b. Targeting the extreme right lateral deep peripheral zone(A).





Figures 20a and 20b. Targeting the mid right lateral peripheral zone(B).





Figures 21a and 21b. Targeting the extreme right lateral low peripheral zone(C).

To the right of the above ultrasound images are corresponding representations of the biopsy regimen. In those drawings, a=apex and b=base.

Appendix 2: Enhancing 3D images

Surface and volume rendering

Surface render mode

One common technique in ultrasound is surface render mode, which is used, for example, to capture images of an unborn baby's facial contours.

Surface rendering techniques only give good results when a surface is available to render. This explains why the most common example is that of a fetus imaged while floating in amniotic fluid. These techniques fail when a strong surface (a shift in the ultrasound impedance of tissue) cannot be found, such as in the subtly layered structures within the anal canal, rectal wall, prostate etc.

High resolution 3D ultrasound acquires four to five transaxial images per 1mm of acquisition length (in the Z-plane). Due to this resolution in the Z-plane, which typically is close or equal to the axial- and transverse resolution of the 2D image, 3D post processing facilities can offer significantly more features than available in relatively low resolution 3D data sets.

An ultrasound image has under normal circumstances no depth due to the requirements of keeping lateral resolution of the image as high as possible. The image may be compared to looking at a photographic image on a piece of paper. Ray tracing techniques may overcome this limitation.

Volume render mode

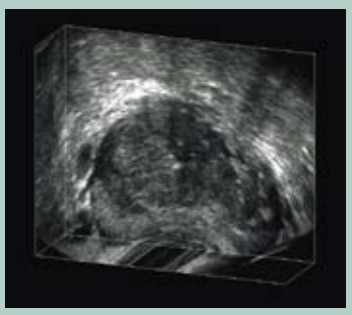
Volume rendering techniques (Figures 1,2) use a ray tracing model as their basic operation. A ray or beam is projected from each point on the display screen back into and through the volume data. As the ray passes through the volume data it reaches the different elements (voxels) in the data set. Depending on the various render mode settings, the data from each voxel may be discarded, used to modify the existing value of the ray, or stored for reference to the next voxel and used in a filtering calculation. All of these calculations result in the current color or intensity of the ray being modified in some way. At some point, the ray reaches the limit of its ability to penetrate the volume data. The current color or intensity value that the ray has acquired at this point is then shown on the display screen at the position where the ray trace started.

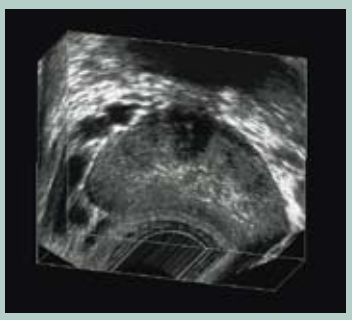
Other rendering modes

Some rendering modes also apply global operations to the ray calculations: Maximum Intensity Projection (MIP) tries to find the brightest or most significant color or intensity along a ray path.

Transparent modes (Figure 3) allow the separation of color and intensity data and selective control of the transparency of the two components. Using this method, it is possible to reduce the intensity of the gray scale voxels so that they appear as a light fog over the color information. Color information hidden behind an obstruction can then be made visible. Both of these methods require the ray trace to pass through the entire volume and, in the case of transparent display methods, to pass through the entire volume twice.

The volume render effect may in particular be dramatic if a number of voxels inside an acquired 3D data set are produced from scanning hypoechoic structures. A hypoechoic focal lesion in the prostate is a good example. Voxel values behind, for example, a strongly reflective interface will also result in an illusion of looking into a semi-transparent dark cavity in the anatomy.





Figures 22 (above) and 23 (middle): Volume render mode. Note the significant difference of the proportions of the peripheral zone in relation to the entire prostate in these two males.

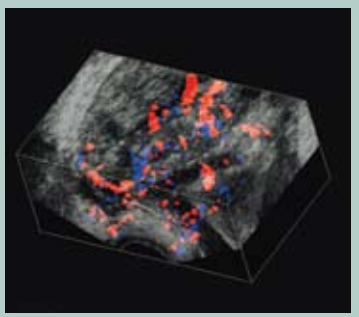


Figure 24. 61Y male coronal image of the prostate with color transparency mode enabled.

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