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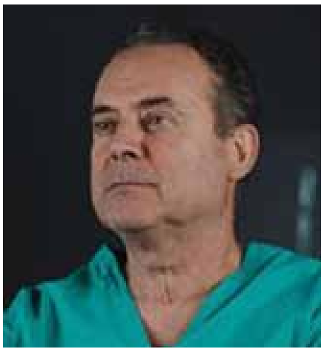
The importance of ultrasound in modern diagnostic and interventional radiology

Imaging in general is an indispensable part of modern medicine, with ultrasound playing a particularly important role. Thanks to continuing technological innovations, many modern ultrasound systems now contain advanced features which previously were limited to top-of-the-range models.This has contributed to the expansion of applications of the technique, now in routine use in many Point-of Care applications. Other recent advances involve fusion of real-time ultrasound images with datasets from other 3D imaging modalities such as MRI, CT & PET — an approach which is having a significant impact in interventional radiology.



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Prof. Giancarlo Bizzarri talks about his experiences with modern ultrasound imaging and the future potential of the technology

Q *In your opinion just how important is ultrasound in today's radiology departments and what are the main ta+sks that are best carried out by ultrasound imaging ?*

Well, let's remember first of all that ultrasound is a powerful medical imaging technology that does not involve the use of ionizing radiation, so it is safe, has no side effects, and offers an unmatched real-time imaging capability. It is a complete diagnostic tool with clinical applications in all medical fields, and is particularly suitable for diagnostic use during pregnancy, in neonates, pediatrics and in adults. The technology can be used to examine the thorax, abdomen, heart, soft tissue, musculoskeletal structures, blood vessels, and the brain.

Over the last decade, the power of ultrasound has been significantly increased through the introduction of several technical developments, such as color-Doppler, contrast enhanced ultrasound, harmonic imaging, and elastography [Figure 1].

Nowadays, many medical specialists other than radiologists make regular use of ultrasound in their daily practice. For example, ultrasound is frequently used outside radiology departments as "point of care" or "bed-side" ultrasound while, thanks to its flexibility and ease-of-use, ultrasound has been successfully introduced in emergency departments.

But we have also to remember that such diagnostic applications are just one side of the ultrasound coin — the real-time nature of ultrasound has resulted in its increasing use to guide interventional procedures.

Figure 1. The power of ultrasound has been significantly increased over the last decade by the development of several new technologies such as color Doppler, contrast-enhanced ultrasound (CEUS), harmonic imaging and elastography.

For example, in our department of Interventional and Diagnostic Radiology, although the number of diagnostic ultrasound examinations has been reducing over time, 90% of all interventional procedures are now performed with the exclusive or combined use of ultrasound.

In terms of overall usage of ultrasound, the reduction in the number of ultrasound examinations carried out in the radiology department has been compensated by the increase in ultrasound in Point-of-Care applications. It should be noted however that the use of ultrasound in the radiology department has the advantage of cost-efficiency since it is possible to justify specific accessories necessary for particular applications e.g. software,, probes, etc., around a single central system that would not be possible in several different POC systems.

Figure 2. Modern ultrasound systems are intuitive and easy to use, with the result that the ultrasound specialist can focus on the patient, rather than on manipulating the system itself.

Q *You mentioned ease-of-use of modern ultrasound systems. Just how important is this?*

The constant requirement for increased productivity in hospitals, diagnostic centers and private practices has been one of the main driving forces behind the simplification of the practical use of ultrasound systems. The need for reduced costs and optimization of the available resources has been a huge stimulus to the development of ultrasound instruments, one example being that advanced features which used to be only available on large top-of-the-range systems can now be found on compact and portable devices.

The widespread and growing use of ultrasound has caused industry to focus on design, ergonomics, and ease of use of systems[Figure 2]. The development of intuitive and simple user interfaces has allowed the operator to focus on the patient rather than on manipulating the system itself, with the result that diagnostic confidence has also been increased. In addition, the introduction of purely digital scanners makes it possible to produce easy-to-use, self-adjusting equipment, which has stimulated the main semiconductor manufacturing companies to begin large-scale production of integrated circuits specially for ultrasound systems.

This has resulted in a further reduction of costs and equipment miniaturization, which in turn has led to more widespread use of advanced diagnostic technology in fields which until a few years ago were considered exotic, such as in ambulances and rescue vehicles, in playgrounds, in military applications and even in space stations.

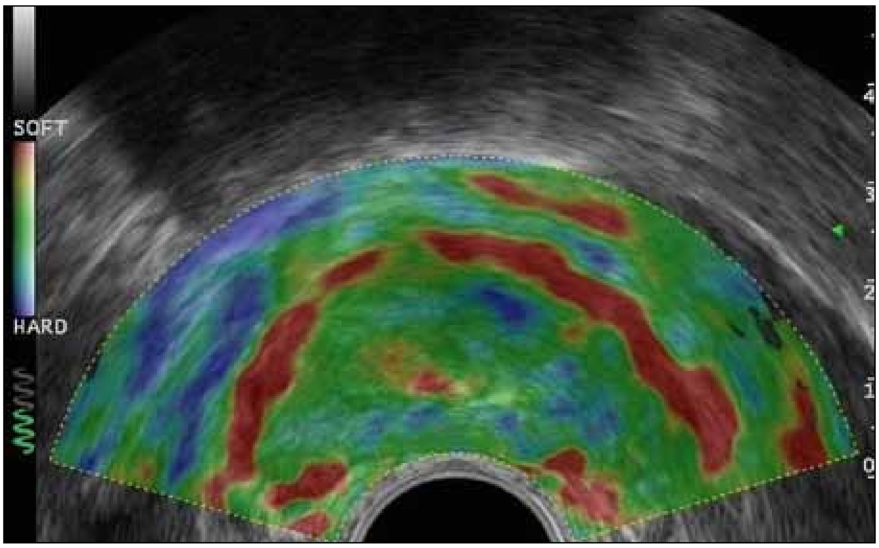

Figure 3. Strain elastography or shear wave techniques are highly promising for the characterization of thyroid, breast, musculoskeletal, prostate, and hepatic lesions

Q *So looking forward now, what are the main emerging developments which are likely have an impact on everyday clinical practice?*

Diagnostic ultrasound is a varied and complex field, and some approaches are more effective than others at providing high-tech answers to current requirements in radiology. Highly promising developments include:

• Non-invasive measurement of tissue elasticity using strain elastography or shear wave techniques is highly

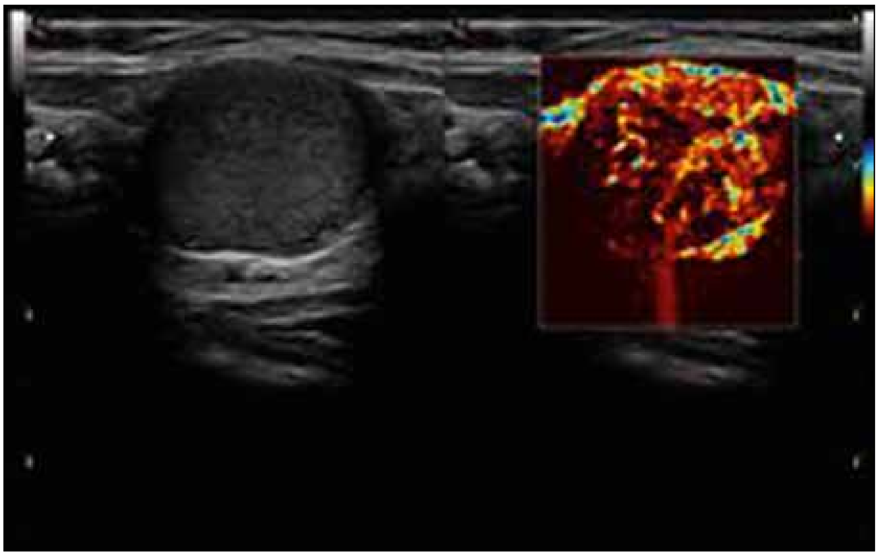

Figure 4. New algorithms for advanced hemodynamic evaluation such as Esaote microV allow the detection of low-velocity blood flow and microvascularisation, for example in thyroid lesions, breast cancer, or in the early diagnosis of degenerative rheumatic disease.

useful for the characterization of thyroid, breast, musculoskeletal, prostate, and hepatic lesions [Figure 3].

- The introduction of new algorithms for color Doppler in advanced hemodynamic analysis allows the detection of low-velocity blood flow and microvascularization, for example in the presence of thyroid lesions, breast cancer, or in the early diagnosis of degenerative rheumatic disease. [Figure 4].
- Contrast-enhanced ultrasound (CEUS) has high sensitivity, deep penetration and high resolution. In addition, in the near future tissue-specific contrast media agents are likely to be available for a wide range of clinical applications. Speaking of contrast agents, it should be noted that there are no issues with the safety of ultrasound contrast agents. This is in contrast to the current debate on the significance of recent findings showing the deposition in the brain of gadolinium from Gadolinium Based Contrast Agents used in MRI
- Real-time image fusion techniques allow ultrasound to be spatially co-registered with multiple image diagnostic modalities, such as those from MRI, CT, PET, and scintigraphy, to create a virtual environment that maximizes anatomic localization and lesion characterization [Figure 5]. This advanced multimodal imaging has applications in both diagnostics and, more importantly, in minimal-invasive surgery techniques and interventional procedures involving organs such as the liver, prostate, neck, spine, and even the lungs and head, thus increasing diagnostic and localization accuracy and reducing radiation doses, time, and costs.

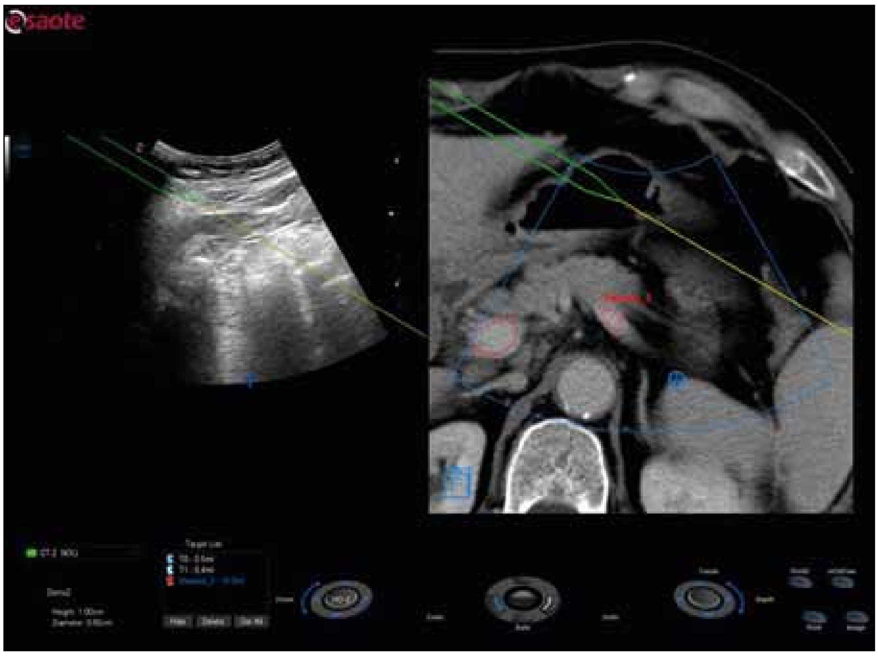

Figure 5 Real-time image fusion techniques allow ultrasound to be spatially co-registered with multiple volumetric image diagnostic modalities, such as those from MRI, CT, PET, and scintigraphy,

Q *This multimodal, real-time approach combining ultrasound and MRI, PET, and CT datasets seems to be a very hot topic nowadays. Just exactly what are the main benefits of this approach?*

As I said, we can combine the top performance and exclusive solutions of ultrasound systems with the specific information offered by MRI, PET, CT, and scintigraphy. Specifically developed for interventional imaging, fusion imaging technology provides additional clarity and precision when ultrasound-guided interventional procedures are required [Figure 6].

Interventional radiology (IR) requires dedicated features and solutions to allow the optimal management of many kinds of clinical problems. In radiology, we have access to various types of imaging techniques such as MRI, CT, PET, fluoroscopy, nuclear medicine imaging, etc., but in order to provide the best patient care, it is often not enough to use just one of these techniques. Image fusion merges real-time ultrasound data such as Doppler, CEUS, and Elastosonography with the functional 3D information from other systems.

In this way, we can combine the advantages of real-time ultrasound imaging with the benefits of the other modalities, not only in the abdominal area (especially for the liver and kidneys), but also in a whole-body radiology approach that can offer benefits in pain management medicine, neurology, urology, and even endocrinology.

By merging information from different modalities, fusion imaging technology

Figure 6. Specifically developed for interventional imaging, fusion imaging technology provides additional clarity and precision when ultrasound-guided interventional procedures are required.

can also provide a real-time, accurate, low-cost, and radiation-free solution in the field of research and teaching.

Q *So this three-dimensional approach seems to becoming increasingly accepted in IR, but what about two-dimensional images?*

The cognitive localization of lesions with real-time ultrasound while still making use of secondary 2D technology represents a significant challenge in everyday clinical practice.
Recently, an advanced technique has been developed that makes it possible to precisely locate a lesion or other anatomical landmark on real-time ultrasound via co-registration of the probe position with a 2D secondary modality, instead of simply guessing the correct position of the probe in a cognitive way.
In our experience, the use of these body mapping technologies with x-rays and scintigraphy can result in a high level of accuracy, with very easy matching and precise real-time tracking. These new 2D mapping techniques provide significant support in the accurate diagnosis and proper planning of surgical and interventional procedures [Figure 7]

Figure 7. New 2D mapping techniques provide significant support in the accurate diagnosis and proper planning of surgical and interventional procedures

Q *So could this become more of a "point of care approach", not strictly related to classical radiology?*

Because techniques such as BodyMap 2D virtual navigation, 3D fusion imaging, and virtual biopsy can increase the diagnostic confidence in different parts of the body, there are countless possible applications in urology, endocrinology, pneumology and hepatology, gynecology, and many more fields, each having its dedicated interface and tools.
Simplified and automatic fusion technologies and customized protocols will reduce the learning curve for the operator, and will thus help to make all these techniques more widespread.
Multipurpose equipment, oriented to the productivity of cross-functional departments, and of application in fields as varied as lung biopsy, back pain, renal ablation to name but a few, will make it possible to provide a real shared ultrasound service, as we already see in interventional radiology today.

Q *What about new developments in this innovative approach and likely future impact?*

Nowadays, the main efforts in the field of medical imaging are being directed towards prevention, diagnosis, selection of optimal (i.e. personalized) local or systemic therapy, guidance in local treatment, assessment of the result of therapy, both local or systemic, and monitoring of disease progression.
All these objectives require information to be not only archived and communicated, but also co-registered and processed by fusion and virtual reality software algorithms.
In the near future, these new technologies will be integrated into all imaging and diagnostic modalities, PACs, Oncology Information Systems, and Hospital Information Systems, thus going beyond the simple radiological environment and spreading throughout all diagnostic and therapeutic fields.