The most common primary malignant tumour of the kidneys is renal cell carcinoma (RCC). RCCs are often asymptomatic due to their slow growth and they are often detected incidentally during examinations for unrelated symptoms or diseases in an advanced stage.\(^1\)

Surgical resection of the tumour remains the standard treatment, with partial nephrectomy showing similar outcomes to nephrectomy in small tumours.\(^2\) Therefore, accurate assessment of dignity of renal lesions, as well as tumour size, is crucial in selecting the best therapeutic management. However, it is often difficult to assess dignity of incidental renal masses, especially if only monophasic computed tomography is initially available or when dealing with complex renal cysts and cystic renal tumours.

It has been demonstrated that contrast-enhanced ultrasound (CEUS) and image fusion is a powerful tool for the assessment of renal lesions.\(^3,4\)

The first-line imaging modality used to assess focal renal lesions is often abdominal ultrasound. On the one hand, new software options such as tissue harmonic imaging (THI), the spatial compounding technique and the Speckle reduction technique, as well as contrast-enhanced ultrasound, nowadays has great potential with regards to the detection and characterisation of focal renal lesions (Fig. 1). On the other hand, new ultrasound hardware techniques, including xMATRIX technology and image fusion, could close the gap between the cross-section modalities. 

New technical developments, such as image-fusion techniques, have further increased the number of tools available to the sonographer.\(^5,6\) The combination of image fusion with magnetic resonance imaging or computed tomography, including the contrast-enhanced ultrasound examination, could improve the detection and characterisation of unclear renal lesions, with a rapid and reliable diagnosis. This article illustrates the principle and clinical impact of recently developed techniques, with focus on the xMATRIX technology, in the field of ultrasound imaging of renal lesions.

**Tissue harmonic imaging**

The tissue harmonic imaging technique allows an improved demarcation of a lesion by modification of soft-tissue depiction. Inhomogeneities in the tissue induce defocusing and/or phase shifts in conventional ultrasound images, which results in a significant loss of lateral resolution and contrast resolution.\(^5\)

The compression and decompression of the ultrasonic pulses within the tissue oscillations that correspond to twice the frequency of the selected fundamental frequency. These harmonic echo components increase as they travel through the tissue before attenuating because of depth. This leads to better image quality and improved resolution.\(^6\)

**Spatial compounding/SonoCT**

Spatial compounding is based on the ability for a transducer to send out sound waves in multiple directions at different angles. Several co-planar images are then combined in real time to form a single image. The advantage of this technique is an improved signal-to-noise ratio, which allows both a reduction of artifacts and improved contrast resolution, which results in clearer demarcation of individual tissue structures.\(^5,6\) Philips, for example, names this technique SonoCT.

**Speckle reduction/XRES**

In ultrasound imaging, speckle is known as ‘noise’ and is an inherent imaging artifact. As a result, contrast resolution and spatial resolution are impaired because surrounding soft tissues are obscured, making clear differentiation of anatomy difficult.

Speckle reduction allows a smoother and more homogeneous appearance of
the surrounding structures by suppressing the artifacts that occur when no edges or borders are seen. However, the borders of a lesion are preserved. A variety of smoothing algorithms, leading to increased smoothing and homogenisation of the surrounding tissue, may be applied. Philips, for example, names this technique XRES.

3-D ultrasound

3-D ultrasound imaging is becoming an increasingly well-established option for volumetric analysis and visualisation of various organs. This examination technique can be used in clinical practice for both diagnostic and interventional purposes. Generally, there are two different acquisition techniques. In the freehand technique, manual acquisition is performed, and the movement and image information obtained is combined into a data cube. Each imaging plane can be

Figure 1: Unclear hypo-echogenic renal lesion (yellow arrows). No vascularisation is detectable by using the color doppler settings. An unequivocal malignancy assessment is not possible without contrast agent.

Figure 2: Real-time X-Plane display an unclear renal lesion. (a) renal lesion (yellow arrow), the second plane is reconstructed at a right angle (red arrows) to the selected plane. (b) represents the second plane of the unclear renal lesion (yellow arrows) and the complete extent of the lesion in the second plane.

Figure 3: 3-D ultrasound volume of a hypoechoic renal mass (yellow arrows) in x-plane (a), y-plane (b) and z-plane (c).

Figure 4: Real-time-resolved 3-D contrast-enhanced ultrasound display the contrast uptake of the renal mass (yellow arrows) and confirm the suspicion of a renal cell cancer.

Figure 5: Second patient: Image fusion in side-by-side view of a patient with an hypo-echoic kidney lesion in the upper pole (yellow arrows) of the right kidney in standard ultrasound (b) and the corresponding hypodense lesion in the respective CT-image (a). Additional acquisition of the transducer position in the topogramm (c). The diagnosis was histological and confirmed as renal cell cancer.
spatially associated with a certain position of the transducer. By contrast, the data acquisition with the wobbler technique uses a mechanically driven converter. For each of the acquired data volumes, multiplanar reconstructions (MPR) can be performed in any arbitrary plane.  

With the development of a new generation of ultrasound probes, with more than 9000 active transducer elements and the xMATRIX technology (Philips iU22, X6-1, Philips Medical Systems, Bothell, WA), the limitations of the freehand and wobbler techniques are overcome. The large number of transducer elements allows a high-spatial 2-D resolution in the near and far fields and a nearly constant voxel resolution in the entire 3-D volume (Fig. 2). In addition to conventional ultrasound imaging, the examination can at any time be supplemented by multiplanar real-time imaging (Fig. 3) or a 3-D real-time ultrasound examination (Fig. 4).  

**Image fusion**  
For image fusion, a magnetic field generator and a curved array transducer (1–5MHz) or the xMATRIX (X6-1MHz) transducer are required as hardware components. Additionally, dedicated software (PercuNav, Philips iU22, Philips Medical Systems, Bothell, WA) that enables the detection of the transducers by a positioning system is necessary. The positioning system calculates the exact position of the respective transducer. Most times, the magnetic field generator will be placed on the patient’s left side. For data registration, the DICOM data are uploaded to the ultrasonic device. Standard DICOM data sets of all cross-sectional modalities (CT, PET-CT, MRI, PET-MRI) could be used for image fusion. Patients will usually be examined in the supine position to mimic the situation of the CT or MRI setting. Two options are available regarding registration: using the first option registration could be done manually by setting and by determining respective fixed points. A minimum of three common points must be selected. Using the second option, registration could be done manually by setting and by determining plane registration. A minimum of one common point must be selected. After successful registration and image fusion, the registered MRI- or CT-images are shown simultaneously with the respective ultrasound sectional plane. All special ultrasound techniques, such as duplex-US or CEUS, can be integrated in the image fusion examination (Fig. 5). The co-registration procedure will take approximately five to ten minutes, depending on the cooperation and habits of the patient.  

**Conclusions**  
With the development of the xMATRIX technology, combined with new software and hardware options (including image fusion), ultrasound imaging has increasingly established itself as a primary method of examination.  

**Key points**  
- Renal cell carcinomas are often asymptomatic because of their slow growth and they are often detected incidentally during examinations for unrelated symptoms.  
- Surgical resection of the tumour remains the standard treatment, with partial nephrectomy showing similar outcomes to nephrectomy in small tumours.  
- Accurate assessment of renal lesions is crucial in selecting the best therapeutic option.  
- New technical developments, such as image-fusion techniques, have further increased the number of tools available to the sonographer for the assessment of renal lesions.  
- With the development of the xMATRIX technology, combined with new hard- and software, ultrasound imaging has increasingly established itself as a primary method of examination.

**References**  