The role of ultrasound and cone beam CT fusion for guidance of thermal liver ablation

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Learning objectives

• Describe the use of ultrasound (US) and cone beam CT (CBCT) image fusion in guiding thermal ablation of liver tumours.

• Express the potential of this novel tool to achieve higher precision with real-time US imaging than that obtained by pre-acquired CT or MRI images.
Background

Image-guided ablations are currently proposed as first treatment choice for small hepatocellular carcinomas (HCC).

Ultrasound (US) is the most commonly-used image guidance option for percutaneous ablations in consideration of its broad distribution, real-time capability, and good general visualization of liver tumours and normal structures. However, the technical feasibility of US-guided ablations is often limited by poor lesion visualization, due to lack of echogenicity difference or difficult localization in the liver. For this reason, other imaging modalities such as computed tomography (CT), magnetic resonance (MR), or cone beam CT (CBCT) have been used to perform liver ablations.

Fusion imaging of US with CT/MR has been successfully used to improve liver lesion targeting, particularly in cases of lesions which are poorly visible at real-time US.

However, the main limitation to image fusion in thermal ablation consists in the use of CT or MRI images acquired days before the procedure, with the patient in a different position and often in a different respiratory phase.

CBCT, a new tool in angiography performed in the angio-room at the time of treatment, with the patient already in the correct decubitus with an active tracker placed on the patient can provide a data set well-suited to precise matching with real-time US images.
Findings and procedure details

CBCT is a novel technique that uses a C-arm with a flat panel detector that rotates around the patients in a time sufficiently short (around 7s) in both arterial and portal phase to ensure good quality raw data collection (3D images on a selected volume usually with a relatively small field of view) (Fig.1).

A dedicated active patient tracer is placed on the upper abdomen and included in the field of view.

An electromagnetic transmitter is placed near the area of interest and electromagnetic sensors are attached to a bracket connected to the US probe and to the patient's active tracer. Both the transmitter and the sensors are connected to a position sensing unit embedded in the ultrasound machine. The position sensing equipment allows the ultrasound system to track the transducer's position, and therefore the image position, within the electromagnetic field.

Fusion imaging performed exactly in the same decubitus as per CBCT, is performed by co-registration of the 3D contrast-enhanced CBCT dataset with real-time ultrasound images. Using the active tracer placed on the patient upper abdomen during the CBCT scan, it allows for a precise matching between CBCT and real-time US images.

In our practice, an anesthesiologist was purposely requested to ensure that each apnea was of precisely the same volume and depth so as to ensure standardization of diaphragmatic excursion, to limit motion artefacts as much as possible and therefore a better image matching. Moreover, general anesthesia allowed for the possibility of completely concentrating on the ongoing procedure.

The ablation needle is deployed along the planned path to the target lesion under continuous US visualization, aiming to target the centre of the lesion, as preoperatively identified by US and CBCT (Fig.2; Fig.3; Fig.4; Fig.5). Lesions can be treated with a commonly available microwave system (Fig.6; Fig.7) and after the procedure, a final contrast-enhanced CBCT is carried out in order to confirm the correct tumor ablation.

Follow-up with a contrast-enhanced CT scan is carried out at 1 and 9 months (Fig.8; Fig.9).

Moreover, specific software is used to process images after volume acquisition and for overlapping volume images: each CBCT volume can be fused with that previously acquired as further control of needle deployment and ablation area position (Fig.10).

Several technical aspects limit the application of CBCT as the sole method for liver tumor ablation guidance.
Motion artefacts for the slower rotation time, patient positioning in an off-centre position and decubitus where the patient is forced to have both arms above the head are among the main limits of this technique. In particular, the limited field of view compared to CT might limit CBCT application especially for lesions located in the periphery of the right liver or in severely obese patients (for this reason a careful pre-treatment simulation is carried out to exclude not feasible patients).
Images for this section:

Fig. 1: Cone-beam CT

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Fig. 2: Fusion imaging (ultrasonography and CBCT) showing a precise matching of liver margins and liver vessels.

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Fig. 3: Computed tomography (CT) scan before treatment demonstrates a small hypodense nodule (arrow) located in the liver dome.

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Fig. 4: US-CBCT fusion imaging before treatment of a 65-year-old patient with hepatocellular carcinoma. Fusion CBCT allows for a better visualization of the lesion that is barely detectable on US.

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Fig. 5: US-CBCT fusion imaging of a 65-year-old patient with hepatocellular carcinoma, showing the targeted lesion (doble red-yellow circles) on both imaging modalities.

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Fig. 6: US-CBCT fusion imaging showing thermal ablation treatment of a 65-year-old patient with hepatocellular carcinoma. Fusion imaging allows for a better visualization of the lesion and of the needle under a continuous US visualization aiming to target the center of the lesion (yellos plus marker).

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Fig. 7: US-CBCT fusion imaging allows for a better visualization of the lesion (arrow), of the needle (arrow head) and of the gas due to the treatment (asterisk) with a perfect overlap of anatomical plans with ultrasonography.

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**Fig. 8:** Computed tomography scan shows post treatment imaging of the lesion at 1 month (arrow).

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**Fig. 9:** Computed tomography scan shows post treatment imaging of the lesion at 9 months (arrow).

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Fig. 10: A post treatment CBCT volume image can be fused with that previously acquired as further control of ablation area position to precisely assess the completeness of treatment with adequate safety margins during the same ablative session, and, if needed, to immediately administer a second treatment.

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Conclusion

Even if US/CBCT fusion is still at an initial stage, it is a feasible method for precisely guiding percutaneous thermal ablations and CBCT bears the potential to overcome the majority of the limitations of US/CT or US/MRI fusion imaging.

Having the patient already in the desired treatment position and under general anesthesia, it would be possible to avoid the CBCT limitations described, such as motion artifacts due to breath or body unintentional movement. At the same time, the acquisition of CBCT exactly in the same position as that employed in the US-guided procedure should ensure a better image matching, mainly because of curarization and a very precise apnea control.

The possibility to repeat the same CBCT acquisition with the same conditions after treatment might be helpful to precisely assess the completeness of treatment with adequate safety margins during the same ablative session, and, if needed, to immediately administer a second treatment.

Furthermore, as the role played by CBCT in interventional oncology is increasing, in keeping with the current recommendations in the CIRSE/SIR protocol guidelines for selective TACE, its availability in angiographic suites will probably increase in the near future.
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