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EDITORIAL

Augmented Reality: From Video Games to Medical Clinical Practice

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Over the last several years, spatial computing technology has allowed the development of simulated reality environments interacting with users. The first technology made available was virtual reality (VR) that completely immerses the user in an artificial, digitally created, three-dimensional (3D) world through head-mounted displays, with limited or no direct interaction between real world and the user. Such VR technology is increasingly used in many different fields, ranging from entertainment and gaming, to sports, to educational applications. In the medical field, it has applications for simulation of surgical procedures and training (e.g., viewing interventional procedures through stereoscopic viewers), but by itself cannot be employed to directly perform interventional procedures.

Augmented reality (AR), the next technologic phase, overlays and merges digital content on the real world, enhancing reality with superimposed information in the user's environment [1]. This can be achieved using projection-based devices (monitor screens), mobile-based devices (smartphones, tablets) or see-through head-mounted displays (goggles with cameras) [2]. Since its inception, AR has been applied to the very same fields as VR (entertainment, gaming), but with the additional important capability of augmenting the virtual landscape with information from the real world. In the medical field, AR has been initially employed to gather all the patients' related information in a single environment usually appearing on the operator's goggles. Subsequently, owing to the possibility of interacting with the 3D volume (gesture control), AR has been used to augment surgical procedures (most notably for neuro, vascular, orthopedic, plastic and urologic surgery) creating 3D anatomic volumes from MRI and CT scans or angiographic images that manually overlaps over patients lying on real operating fields [3]. Thus, the real advantage of AR lies in its capability to automatically superimpose the patient's reconstructed 3D volume so that the physician wearing goggles can visualize the pathological target to be biopsied or treated in the exact position where it is located through the patient without the need for invasive cutting or manipulation. This represents a transition from pure visualization to guidance tool. This has been made possible by the development of segmentation algorithms that enable automatic achievement of the 3D reconstruction of the target lesion and surroundings to millimetric precision, and by the introduction of electromagnetic or optical (cameras and markers) tracking systems, computer vision algorithms which match 3D volumes and the real world and increasingly sophisticated AR devices (i.e., goggles, tablets, smartphones).

Although recently advanced image-guidance systems (laser systems, real-time image fusion, robotics) are the key to success for many modern Interventional Oncology (IO) procedures, AR can represent a further step forward, as it has already been demonstrated on the operating field, on phantoms, animal models and cadavers [4], and on real patients [5]

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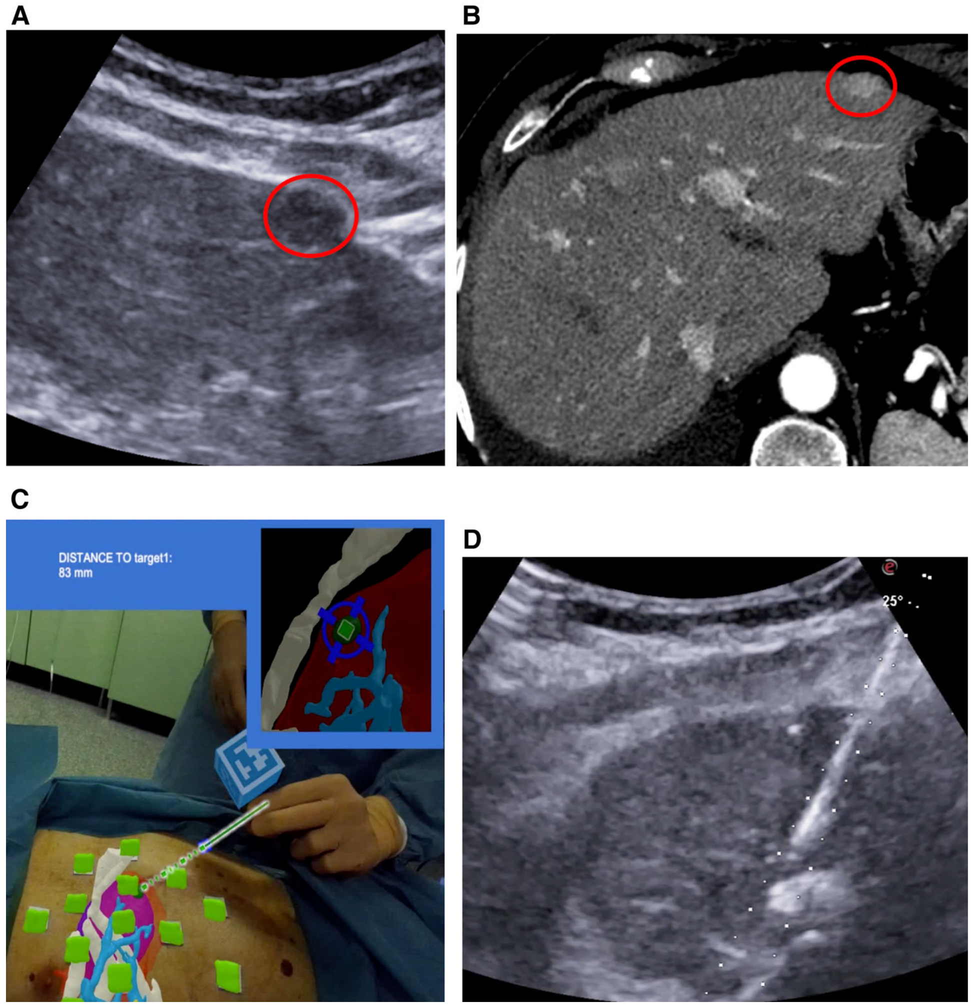

Fig. 1 Augmented reality-guided microwave ablation of 1.2 cm hepatocellular carcinoma at segment 2 (red circles in **A**, **B**). The tumor is precisely targeted following the predefined trajectory line (**C**). **D** Sonography confirms targeting precision before starting ablation

(Fig. 1). Major advantages of AR over already existing guidance modalities include: ease of use, short learning curve (particularly for young operators, usually very skilled in videogames and computer applications), reduced procedural time compared to more traditional guidance systems, reasonably low price of systems and a reduced or no need for radiation during procedures. Moreover, software that allows the precise assessment and quantification of tumor ablation margins in 3D can be already integrated into AR devices, enabling the immediate evaluation of the technical success of interventional procedures and support of operative decisions [6]. These advantages of AR, the latest offshoot of image-guidance modalities, most certainly hold great potential to facilitate and increase the diffusion of Interventional Oncology procedures worldwide. Displaying anatomical structures and pathologies hidden under the patient's skin through wearable goggles or smartphones is no longer fun science fiction, but it is now reality. Although AR may have started as a gaming toy, it now looks more than ever like a medical tool with important longstanding implications.

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