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RESEARCH

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Added value of 3D ultrasound image-guided hepatic interventions by X matrix technology

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Abstract

Background Image-guided hepatic interventions are integral to the management of infective and neoplastic liver lesions. Over the past decades, 2D US was used for guidance of hepatic interventions; with the recent advances in US technology, 3D US was used to guide the hepatic interventions. This study aimed to illustrate the added value of 3D image-guided hepatic interventions by X matrix technology.

Methods This prospective study was performed on 100 patients that were divided into two groups: group A which included 50 patients who were managed by using 2D US probe guidance, and group B which included 50 patients who were managed by using 3D X matrix US probe guidance. Thermal ablation was done for 70 patients; 40 radiofrequency ablation (RFA) (20 by the 2D probe and 20 by the 3D X matrix probe) and 30 microwave ablation (MWA) (15 by the 2D probe and 15 by the 3D X matrix probe). Chemical ablation (PEI) was done for 20 patients (ten by the 2D probe and ten by the 3D X matrix probe). Drainage of hepatic collections and biopsy from undiagnosed hepatic focal lesions were done for ten patients (five by the 2D probe and five by the 3D X matrix probe).

Results The efficacy of US-guided hepatic interventions by 3D X matrix probe was higher than the 2D probe but not significantly higher, with a *p* value of 0.705, 0.5428 for RFA and MWA, respectively, 0.5312 for PEI, and 0.2918 for drainage of hepatic collections and biopsy. The complications related to the use of the 3D X matrix probe were significantly lower than the 2D probe with a *p* value of 0.003. The timing of the procedure was shorter by the usage of a 3D X matrix probe in comparison with the 2D probe with a *p* value of 0.08, 0.34 for RFA and PEI and significantly shorter for MWA and drainage of hepatic collection, biopsy with a *p* value of 0.02, 0.001, respectively.

Conclusions 3D US-guided hepatic interventions by X matrix probe have better efficacy, less complication, and shorter time of procedure than the 2D US-guided hepatic interventions.

Keywords 3D, X matrix, 2D, Ultrasonography, MWA, RFA, PEI, Drainage of hepatic collections, Biopsy

Background

Image-guided hepatic interventions are integral to the management of infective and neoplastic liver lesions [1–5].

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A gamut of hepatic interventions including abscess drainage, thermal ablation, and biopsy of focal liver lesions have significantly improved the morbidity and mortality associated with hepatic surgeries [1, 2, 4–6].

They offer several advantages over other invasive procedures in the liver such as laparoscopy/laparotomy including the absence of a laparotomy scar, shorter hospital stay, avoidance of general anesthesia, and lower risk of complications, morbidity, and mortality [2, 4–6].

Ultrasound (US)-guided hepatic interventions are classified into US-guided thermal ablation (microwave ablation (MWA) and radiofrequency ablation (RFA). US-guided chemical ablation percutaneous ethanol injection

(PEI), US-guided drainage of hepatic collections, and US-guided biopsy from undiagnosed hepatic focal lesions [7].

Currently, conventional 2D US is recognized as the primary modality for guidance while inserting the probes. However, 2D imaging of 3D anatomy requires the physician to mentally integrate and map 2D information to the underlying 3D anatomy as well as the preoperative computed tomography (CT) or magnetic resonance imaging (MRI) [7].

Furthermore, tumor volume and extent, neighboring organ structures (vessels, gallbladder, etc.), and intended insertion paths require a 3D image to be fully visible and in the correct perspective. As minimally invasive techniques for localized treatment of liver infective and neoplastic lesions are being developed, demand for technology ensuring accurate guidance of interventional tools is also increasing [8].

As a result, recent technologies of US machines have been developed to overcome these obstacles, one of the most recent technologies in these US machines is the X matrix technology.

X MATRIX transducer technology in the iU22 X MATRIX ultrasound system has been developed to enable the rapid execution of high-quality examinations in a wide variety of patients. A fundamental component of this development has been the introduction of the X6-1×MATRIX transducer for general imaging. Whereas a conventional abdominal transducer has a single row of approximately 128–256 elements, the X6-1 has a much higher total of 9212 elements arranged in a true matrix. The X matrix technology has many novel benefits such as live X plane allows clinicians to create two real-time full-resolution images simultaneously. While the conventional scan plane is displayed, a second live image displays a parallel or orthogonal plane, and this second plane can be swept merely by using the control panel trackball. Thus, the operator does not have to flex or rotate the wrist to interrogate an organ or pathology [9, 10].

Furthermore, “virtual endoscopy” is now possible, using high-resolution 3D/4D surface rendering with X matrix, which can also provide additional detail of surface structure, such as in micronodular cirrhosis [11].

This study aimed to illustrate the added value of 3D image-guided hepatic interventions by X matrix technology (Fig. 1).

Methods

This prospective study was performed on 100 patients (58 males and 42 females) who were diagnostically proved to have hepatic lesions and were subjected to percutaneous US-guided locoregional hepatic interventions. A written informed consent was obtained from all patients.

Our study was done from March 2020 to August 2023 at the local institutional hospital after approval of the ethical committee of the diagnostic and interventional radiology department—National Liver Institute—Menoufia University (Approval code:00493/2023), the age of the patients ranged from 43 to 74 years with a median age of 58 years (Fig. 2).

Inclusion criteria for HCC patients who were managed by locoregional treatment either thermal (RFA, MWA) or chemical (PEI): Patients diagnosed to have unresectable single HCC (up to 5 cm in diameter) and have Child–Pugh class A or early B and, and for HCC patients who were managed by locoregional treatment or patients treated by percutaneous US-guided drainage or aspiration of abscess or collection or patients with undiagnosed hepatic focal lesions and underwent percutaneous US-guided biopsy; prothrombin time ratio of > 50%, and a platelet count > 50,000 cells/mm^3.

Exclusion criteria for HCC patients who were managed by locoregional treatment either thermal (RFA, MWA) or chemical (PEI): were the presence of vascular invasion and extrahepatic metastases at pre-procedure imaging study, previous treatment for the target HCC, Child–Pugh class C. Ongoing anticoagulant treatment that cannot be stopped and uncooperative patients are also contraindications for patients who were treated by Percutanous US-guided drainage or aspiration of abcess or collection or patients with undiagnosed hepatic focal lesions and underwent percutanous US guides biobsy.

The participants were randomized into two equal groups using a computer-generated list of random numbers sealed in an opaque envelope and were randomly allotted into two groups on a scale of 1:1. Group A included patients who were managed by US-guided hepatic interventions using a 2D convex probe (7.5MHZ); group B included patients wo were managed by US-guided hepatic interventions using 3D X matrix probe (6-1MHZ) using (Phillips IU 22 US machine) (Fig. 3).

The use of a 3D X matrix probe in the Phillips IU22 ultrasound machine was mainly indicated for focal lesions that were nearby vital structures such as (the kidney, gallbladder, pleura) and blood vessels (portal vein, hepatic veins, and IVC), small focal lesions, and focal lesions with difficult access of entry for needle deployment to allow precise needle localization and avoid any complications (Fig. 4).

For hepatic collections that have difficult pathways of needle insertion such as intervening bowel loops also to allow better needle visualization and avoid complications.

Our patients were subdivided into patients who were diagnosed to have hepatocellular carcinoma (HCC) including 90 patients (90%) and this group of patients was managed by thermal ablation for 70 patients (70%):

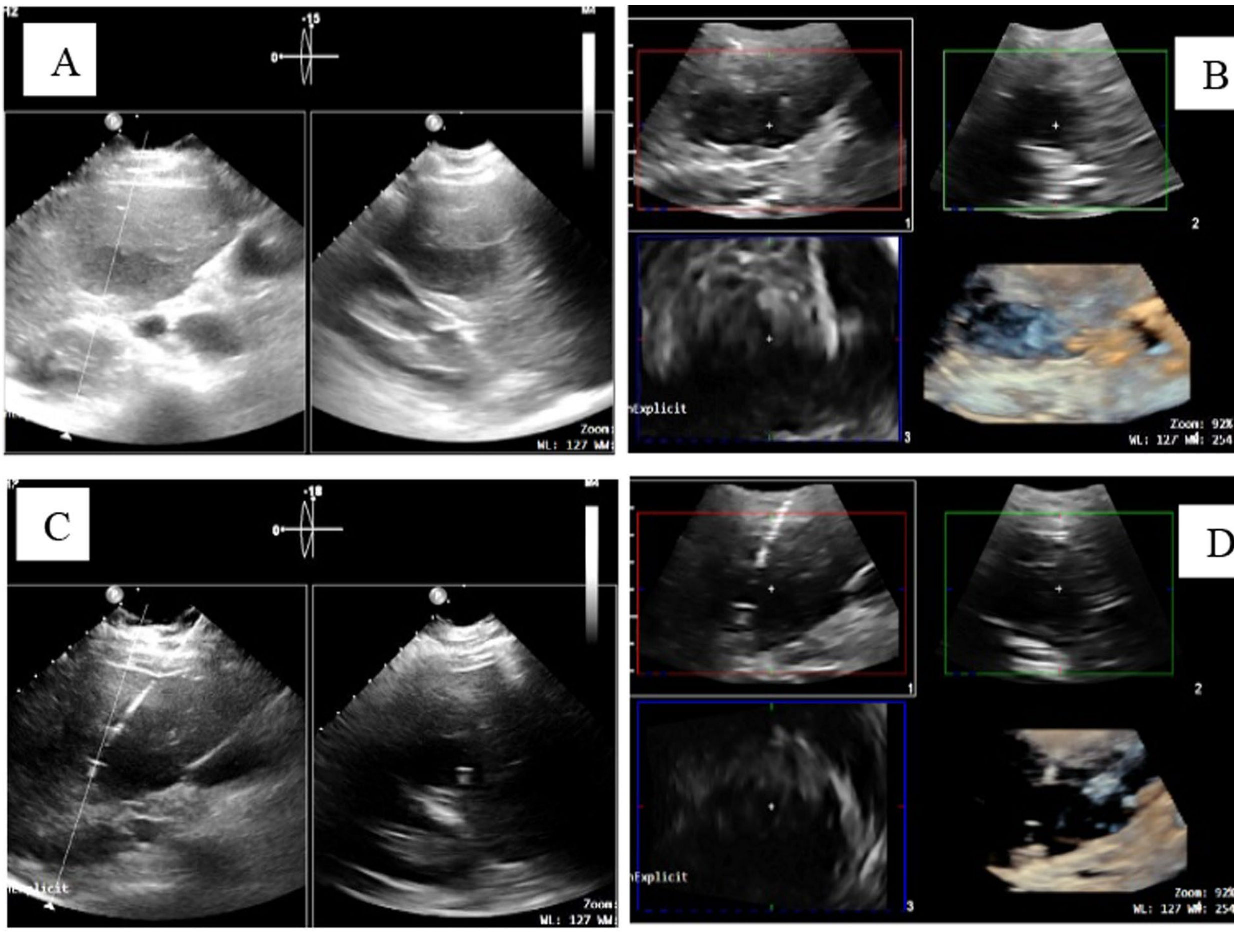

Fig. 1 **A**–**D**, Case (1): A female patient with segment VI hypoechoic focal lesion about 3×2.5 cm shows no specific pattern of enhancement at the triphasic CT with negative tumor markers, the patient was planned for a tru-cut biopsy. **A** X-plane imaging of the X matrix probe showing right hepatic lobe segment VI Hypoechoic focal lesion with the reference plane at the right panel, the orthogonal plane at the left panel, with lateral tilt 15 degrees, **B** 3D images and volume rendering images of the hepatic focal lesion noted at segment VI, **C** X-plane imaging showing the whole needle at the reference plane at the right panel, with the tip of the needle at the center of the lesion at the left panel arrow, with lateral tilt 18 degrees, **D** 3D images and volume rendering images with the tip of the needle noted inside the hepatic focal lesion. Two cores of biopsies were taken and sent to histopathology and it was confirmed to be HCC

RFA was done to 40 patients (20 patients using 2D US guidance, 20 patients using 3D X matrix US guidance), MWA was done for 30 patients (15 patients using 2D US guidance, 15 patients using 3D X matrix US guidance), and chemical ablation (PEI) was done for 20 patients 20% (ten patients under 2D US guidance, ten patients under 3D X matrix US guidance), patients who were diagnosed to have hepatic collections including four patients (4%): US-guided drainage was done (two patients under 2D US guidance, two patients under 3D X matrix US guidance), and patients with undiagnosed hepatic focal lesions including six patients (6%), percutaneous US-guided biopsy of the hepatic focal lesions was done (three patients under 2D US guidance, three patients under 3D X matrix US guidance) (Table 1).

Before management, all patients were subjected to full history and physical examination (History of current problem and Review of body systems: Neurological—Chest—Cardiac—Renal—Hepatic), clinical examination of the general condition of the patient, and laboratory investigations (complete blood count (CBC) including hemoglobin concentration, red blood cells, total leucocytic and platelet counts; liver function tests including serum bilirubin (total, direct and indirect), transaminases (alanine transaminase &aspartate aminotransferase); alkaline phosphatase, gamma-glutamyl transferase& serum albumin; Hepatitis B and C viral serology; quantitative tumor markers; alpha-fetoprotein (AFP), carcinoembryonic antigen (CEA), cancer antigen 19-9 (CA19.9); prothrombin

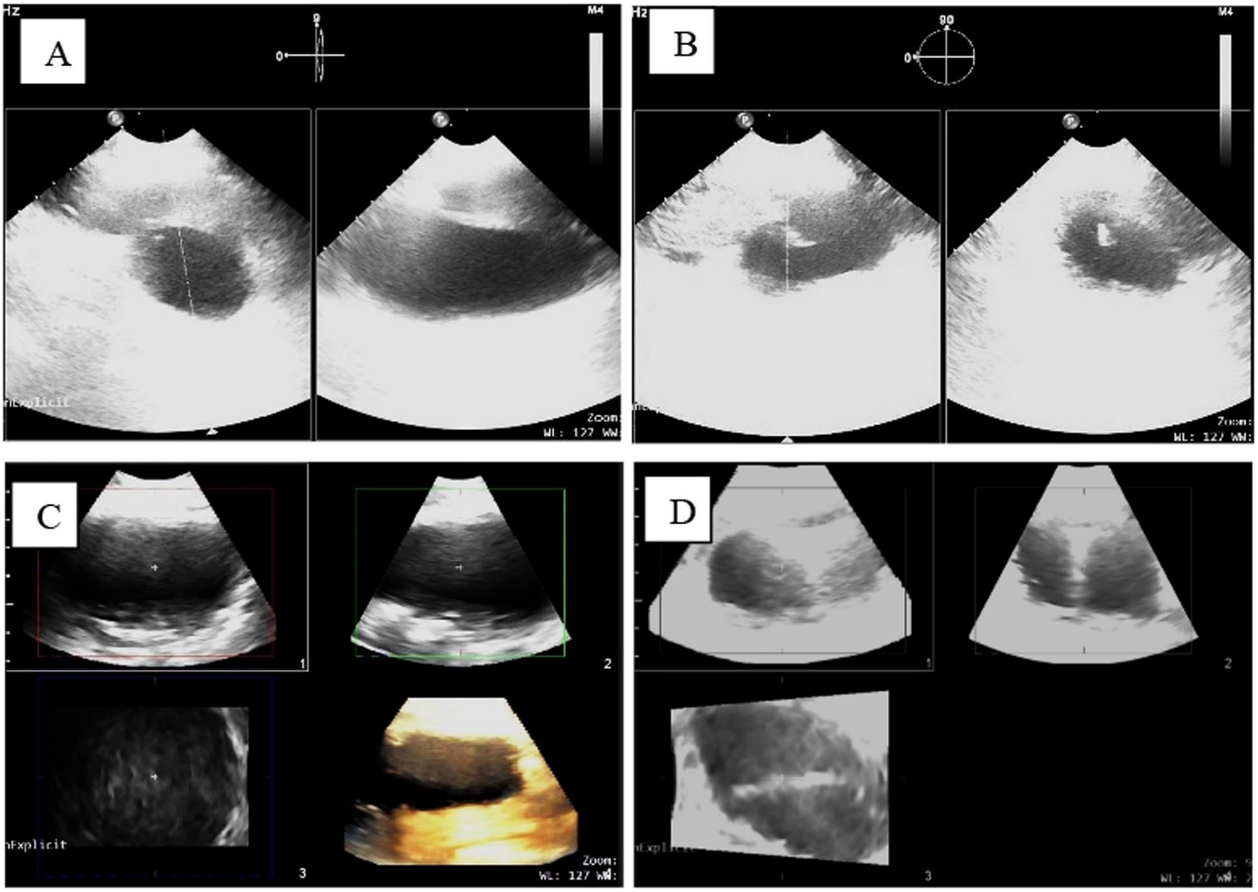

Fig. 2 **A**–**D**, Case (2) A female patient with a left subhepatic abscess about 8×4 cm, the patient was planned for drainage of the abscess by insertion of a pigtail catheter10 F under 3D US guidance. **A** X-plane imaging showing left subhepatic collection (Abscess) at the reference plane, and orthogonal plane with lateral tilt of nine degrees, **B** X-plane imaging of the hepatic abscess with the tip of pigtail noted inside the abscess at the reference plane and the orthogonal plane, **C** 3D images and volume rendering images of the left subhepatic collection, **D** 3D images showing the tip of pigtail inside the left subhepatic collection. Follow-up of the patient by the US reveals total resolution of the left subhepatic collection

time, concentration and International normalized ratio (INR); and C-reactive protein (CRP), erythrocyte sedimentation rate (ESR)).

Preprocedural imaging included routine abdominal US and color Doppler study; chest X-ray, echo, electrocardiogram (EEG) were performed.

Patient preparation

All patients provided written consent and underwent pre-procedural monitoring of the vital signs of patients and pre-procedural medications: analgesics and antibiotics.

(See figure on next page.)

Fig. 3 **A**–**H**, Case (3): A female patient with a right hepatic lobe segment V focal lesion about 2.5 cm**,** confirmed to be HCC by triphasic CT, planned for US-guided percutaneous ethanol injection. **A** Triphasic CT showing arterial enhancement at the arterial phase and washout at the delayed phase the patient was planned for chemical ablation (PEI) under X matrix probe guidance X plane images, 3D and volume rendering images of the hepatic focal lesion at right hepatic lobe segment V, **B**, **C** Under X matrix guidance, the needle tip was placed inside the hepatic focal lesion, **D**, **E** showing the tip of the needle inside the hepatic focal lesion at the X plane, 3D and volume rendering images, percutaneous ethanol injection was done under X matrix probe guidance, **F**, **G** showing the ethanol injection inside the hepatic focal lesion, **H** Triphasic CT was done after one month, there was no enhancement at the arterial phase and no washout at delayed phase denoting adequate management according the Mrecist criteria

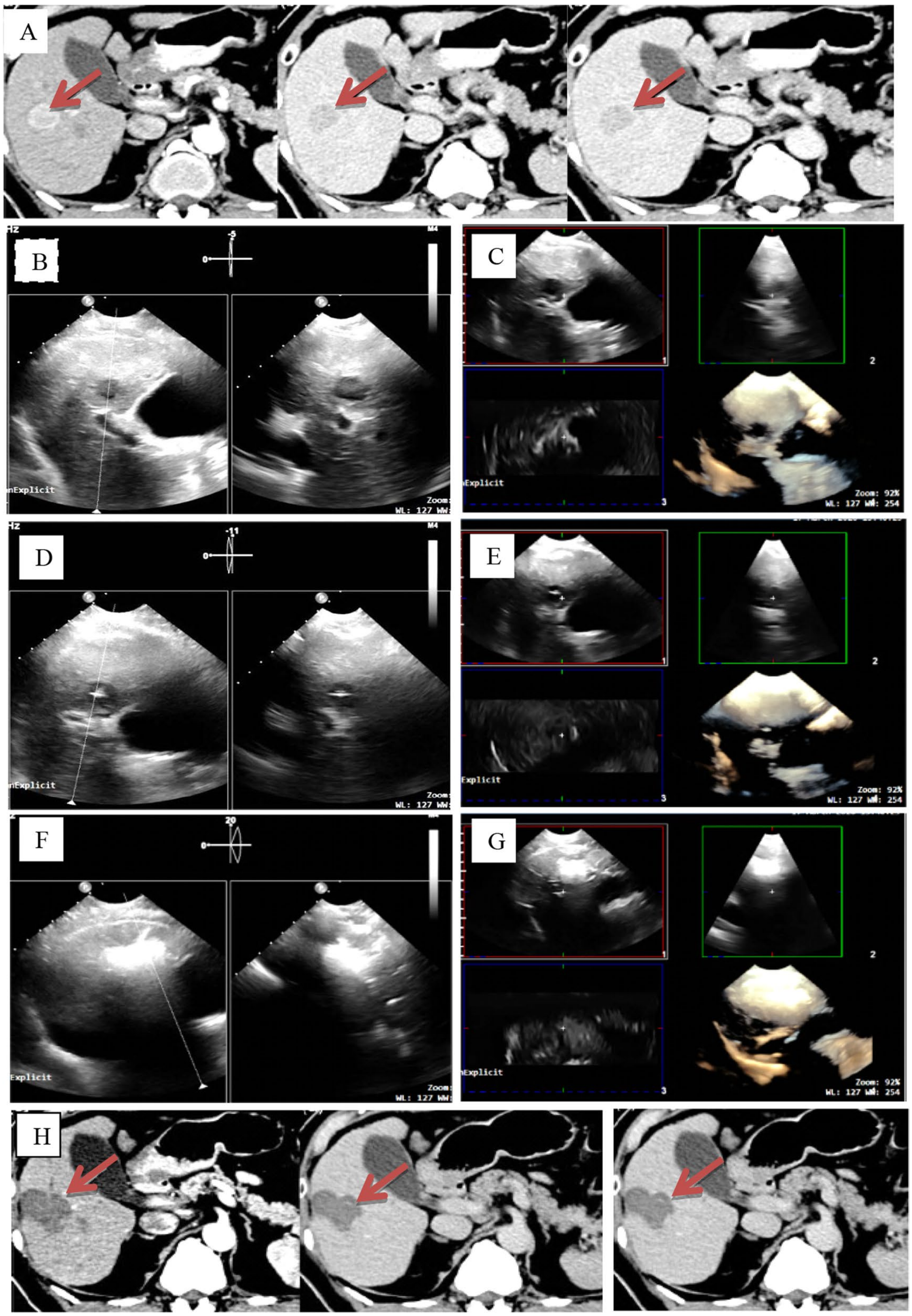

Fig. 3 (See legend on previous page.)

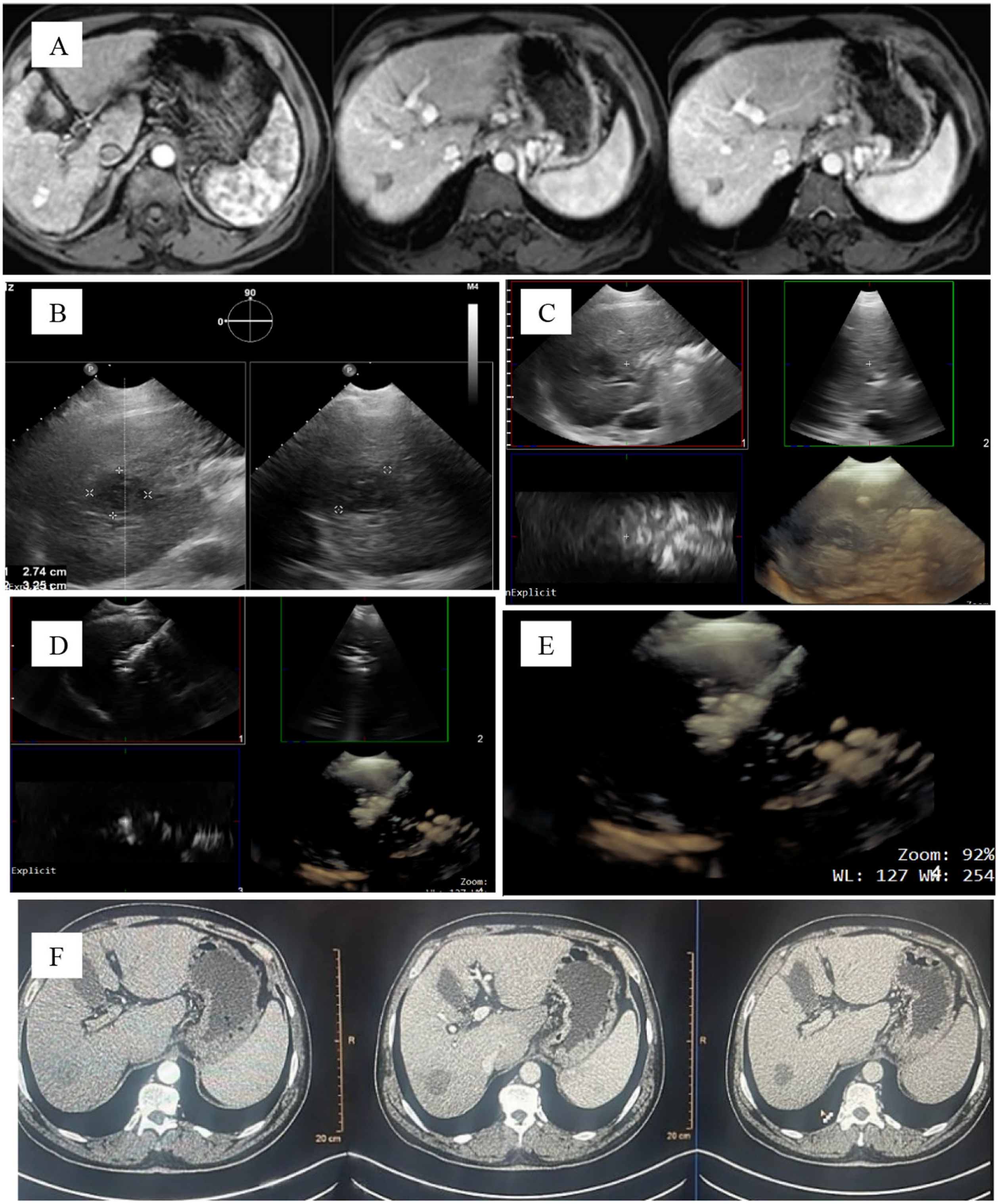

Fig. 4 **A**–**F**, Case (4): A male patient with a right hepatic lobe segment VII focal lesions 2 × 2 cm, confirmed to be HCC by triphasic CT, **A** Trihasic CT scan showing arterial enhancement at the arterial phase and washout at the delayed phase, the patient was planned for US-guided RFA using X matrix probe guidance. **B**, **C** X plane images, 3D and volume rendering images of the hepatic focal lesion at right hepatic lobe segment VII **D**, **E** showing the tip of the needle inside the hepatic focal lesion at the X plane, 3D and volume render images, radiofrequency ablation was done under X matrix probe guidance (F)—Triphasic CT was done after one month, there was no enhancement at the arterial phase denoting adequate management according theMrecist criteria

Table 1 Type of percutaneous locoregional hepatic intervention technique used among studied patients

Technique	(Group A) 2D		(Group B) 3D	
	No	%	No	%
Management of HCC				
RFA	20	20%	20	20%
MWA	15	15%	15	15%
PEI	10	10%	10	10%
Drainage of intrahepatic collections				
Pigtail insertion	2	2%	2	2%
Biopsy of hepatic focal lesion				
Tru-cut biopsy of hepatic focal lesion	3	3%	3	3%
Total	50	50%	50	50%

Data are presented as frequency and percentage, HCC: Hepatocellular carcinoma, RFA: Radiofrequency ablation, MWA: Microwave ablation, PEI: Percutaneous ethanol injection

Procedure

Our study was done by the Phillips IU22 US machine, the 2D US guidance was done by the 2D convex probe, and the 3D US guidance was done by the 3D X matrix probe.

The technique of X matrix 3D includes live X plane which allows us to create two real-time, full-resolution images simultaneously. While the conventional scan plane is displayed, a second live image displays a parallel or orthogonal plane, and this second plane can be swept merely by using the control panel trackball.

Volume (3D) acquisition with the X matrix is electronic, a full 90 by 90 degree volume can be rapidly obtained by a single button touch in less than one second, and the image is obtained in all three planes X, Y, and Z.

All the procedures were done by the same trained radiologist at the diagnostic and interventional radiology department, National liver institute, Menofia university.

For percutaneous locoregional management of HCC that was done for 90 patients (90%)

Under complete aseptic conditions with the usage of local anesthesia (lidocaine 1%) for 20 (20%) patients in PEI and general anesthesia (conscious sedation by fentanyl and midazolam) in 70 (70%) patients in RFA and MWA.

US-guided ablation of HCC was either thermal ablation; (RFA) for 40 patients (40%), the 2D US probe was used in 20 patients and 3D X matrix US probe was used in 20 patients using the angiodynamics RITA 1500 RF generator. The RFA needle was placed in the center of the lesion till full ablation was done by raising the temperature till reaching the coagulative necrosis of the tumor (impedance controlled), and then, tract ablation is done after thermally ablating the tumor as we get out by the RFA needle to prevent tumor seeding and (MWA) for 30 patients (30%); the 2D US probe was used in 15 patients and 3D X matrix US probe was used in 15 patients using the AMICA generator, with inserting the MWA needle inside the tumor to transmit microwaves into the tumor thus achieving the coagulative necrosis.

Chemical ablation (PEI) was done for 20 patients (20%); the 2D US probe was used in ten patients and the 3D X matrix ultrasonography probe was used in ten patients by inserting the Chiba needle (18G x20cm) inside the tumor, and injection of absolute alcohol inside the lesion according to its size over three or four consecutive visits.

Drainage of intrahepatic collection

Drainage of intrahepatic collection was done on four patients (4%) under complete aseptic conditions with the usage of local anesthesia (lidocaine in all patients).

US guidance was done by the 2D US probe for two patients and the 3D X matrix US probe for two patients.

US-guided drainage of the hepatic collections was done by the usage of a pigtail (10 F).

Biopsy of undiagnosed hepatic focal lesions

Biopsy of undiagnosed hepatic focal lesions was done for six patients (6%) under complete aseptic conditions and local anesthesia.

US guidance was done using the 2D US probe in three patients and the 3D X matrix US probe in three patients.

US-guided biopsy was done using tru-cut biopsy needle (18 gauge, 20 cm).

Post-procedural management

All patients were monitored by follow-up of their vital signs.

Post-procedural medications were given for all the patients (antibiotics, analgesics, and anti-inflammatory), and post-procedural follow-up by ultrasonography was done for all the patients.

Follow-up of the patients

For HCC patients who were managed by locoregional treatment (PEI, RFA, MWA), triphasic CT scan or dynamic MRI and AFP were done after one month. If there is complete ablation; follow-up by triphasic CT scan or dynamic MRI was every 3 months for one year and every 6 months for the second year after that.

For patients with intrahepatic collections or abscesses, drainage follow-up was done by US, Triphasic CT scan or dynamic MRI, and laboratory by CBC, ESR, and CRP.

For patients who were subjected to biopsy from hepatic focal lesion, follow-up was done by US after the procedure for 6 h and the biopsy was evaluated by histopathological examination.

Statistical analysis

Data were recorded as (mean ± standard deviation). The results were analyzed with the (Student's t test) for paired value, with "significant" indicating a calculated two-tailed *P* value < 0.05, and data on survival were evaluated by (Kaplan–Meier method).

Results

A total of 100 patients, 58 males (58%) and 42 females (42%) with a median age of 58 years (range 43–74 years), were included in this study.

The patients in our study were divided into two groups: group A included 50 patients (50%) who were managed by 2D ultrasonography guidance, and group B included 50 patients (50%) managed by X matrix ultrasonography guidance.

The efficacy of thermal ablation of HCC patients using RFA technique under the guidance of both 2D and 3D X matrix probes according to Mrecist shows a complete response of 15 (75%) of 20 patients in group A and 16 (80%) of 20 patients in group B, showing that the efficacy in (group B) is higher but not significantly higher with *p* value 0.705 (Table 2).

And MWA for HCC patients under the guidance of both 2D and 3D X matrix probes according to Mrecist shows complete response in 13 (86.70%) of 15 patients in group A and 14 (93.30%) of 15 patients in group B, showing that the efficacy in (group B) is higher but not significantly higher than (group A) with *p* value 0.5428 (Table 2).

The efficacy of chemical ablation of HCC using PEI under the guidance of both 2D and 3D X matrix probes according to Mrecist shows a complete response of eight (80%) of ten patients in group A and nine (90%) of ten patients in group B, showing that the efficacy in (group B) is higher but not significantly higher with *p* value 0.5312 (Table 2).

The efficacy of US-guided biopsy from hepatic focal lesions and US-guided drainage of intra hepatic collection or abscess under the guidance of both 2D and 3D X matrix probes shows adequate biopsy taken and adequate drainage of the hepatic collections in all patients of group B with one inadequate biopsy result at group A (showing higher efficacy of group B but not significantly higher) (Table 2).

The complications related to the ultrasonography-guided procedure were significantly lower in group B 2 (4%) (by the 3D X matrix probe guidance) than in group A 12 (24%) (by 2D probe guidance) with a highly significant *p* value of 0.003 (Table 3).

In RFA, procedure times are lower in group A (14.4 ± 1.9) than in group B (14.9 ± 1.69) with a *p* value (of 0.08). In MWA, procedure time is significantly lower in group B (13.6 ± 2.94) than in group A (15.4 ± 3.2) with *p* value (0.02). In PEI, procedure time is lower in group B (4.1 ± 0.33) than in group A (4.6 ± 0.8) with *p* value (0.34). Ultrasonography-guided biopsy and ultrasonography-guided aspiration of intrahepatic collection procedure

Table 2 Efficacy of percutaneous ultrasonography-guided hepatic intervention using both 2D convex probe (group A) and 3D X matrix probe (group B)

	(Group A) 2D		(Group B) 3D		X2	*p* value
	No	%	No	%		
RFA						
Complete response	15	75	16	80	0.14337	0.705
Partial response	5	25	4	20		
MWA						
Complete response	13	86.70%	14	93.30%	0.37037	0.5428
Partial response	2	13.30%	1	6.70%		
PEI						
Complete response	8	80%	9	90%	0.39216	0.5312
Partial response	2	20%	1	10%		
Ultrasound-guided biopsy and ultrasound-guided drainage						
Adequate biopsy and adequate drainage	4	80%	5	100%	1.11111	0.2918
Inadequate biopsy or drainage	1	20%	0	0%		

Data are presented as frequency and percentage, HCC: Hepatocellular carcinoma, RFA: Radiofrequency ablation, MWA: Microwave ablation, PEI: Percutaneous ethanol injection

Table 3 Complications of percutaneous ultrasonography-guided intervention procedures by using both 2D convex probe (group A) and 3D X matrix probe (group B)

Technique	Complication	(Group A) 2D		(Group B) 3D		X2	p value
		NO	%	NO	%		
RFA	Intraperitoneal bleeding	2	5%	0	0		
MWA	Intraperitoneal bleeding	1	6.7%	0	0		
	Right-sided pleural effusion	2	13.3%	0	0		
PEI	Portal vein thrombosis	2	20%	0	0		
	Post-ablation syndrome	4	40%	2	20%		
Biopsy/pigtail	Intraperitoneal bleeding	1	20%	0	0		
Total		12	24%	2	4%	8.3	0.003*

Data are presented as frequency and percentage, * significant as p value < 0.05. RFA: Radiofrequency ablation, MWA: Microwave ablation, EI: Ethanol injection

Table 4 Average time of ultrasonography-guided intervention procedures done by using both 2D convex probe (group A) and 3D X matrix probe (group B)

	(Group A) 2D	(Group B) 3D	p value
RFA	14.4 ± 1.9	14.9 ± 1.69	0.08
MWA	15.4 ± 3.2	13.6 ± 2.94	0.02*
PEI	4.6 ± 0.8	4.1 ± 0.33	0.34
Ultrasound-guided biopsy ordrainage of hepatic collection	0.8 ± 0.3	0.7 ± 0.08	0.001*

Data are presented as mean ± SD, * significant as p value < 0.05. RFA: Radiofrequency ablation, MWA: Microwave ablation, PEI: Percutaneous Ethanol injection

time are significantly lower in group B (0.7 ± 0.08) than group A (0.8 ± 0.3) with P value 0.001 (Table 4).

Discussion

Image-guided percutaneous locoregional therapies are important for the management of malignant and inflammatory liver lesions [12].

2D US guidance was the cornerstone for the guidance of hepatic interventions.

Now, there are recent advances in 3D US scanning to allow precise identification of the liver anatomy and precise guidance of hepatic interventions.

In our study, we aimed to illustrate the added value of 3D US-guided hepatic interventions by the X matrix study.

Our study was performed on 100 patients (58 males and 42 females), unlike Steven et al., who performed their study on 16 patients (11 males and 5 females), and Hyun Cheol Kim et al., Muhammad Arif et al., who performed a phantom-based study [13–15].

The median age of patients in our study was 58 years (range 43–74 years) which was like Steven et al., whose patients had a mean age of 58 years (range 35–78 years) [13].

For the technique in our study, we divided the patients into two groups and all patients in both groups underwent ultrasonographic guided biopsy from hepatic focal lesions, ultrasound-guided aspiration of hepatic collections, chemical ablation of HCC (percutaneous ethanol injection), thermal ablation of HCC (RFA and MWA).

Boers et al. [16] studied the matrix 3D ultrasound-assisted thyroid nodule volume estimation and radiofrequency ablation, and all the patients were subjected to RFA but in benign thyroid nodules.

Kim et al. [14] studied the ultrasound-guided biopsy of focal lesions using three-dimensional ultrasound with a Matrix Array Transducer all patients were subjected to ultrasound-guided biopsy of hepatic focal lesions.

Arif et al. [15] studied the Needle Tip Visibility in 3D Ultrasound Images and all patients were subjected to ultrasound-guided biopsy and ablation of hepatic focal lesion.

Rose et al. [13] studied the value of three-dimensional US for optimizing guidance for ablating focal liver tumors, and all the patients were subjected to RFA of the liver tumors.

In our study, we divided the patients into two groups: group A which included 50 patients who were managed by using 2D US probe guidance, and group B which included 50 patients who were managed by using 3D X matrix US probe guidance.

In our study, the efficacy of US-guided locoregional management of HCC and hepatic collections was higher under 3D probe guidance than the 2D probe guidance.

Our study also showed that the matrix array transducer allows more needle visibility and more confident deployment of the needles especially near the vital organs like the kidney, gallbladder, and blood vessels (portal vein, hepatic vein, and IVC).

Boers et al. [16] showed that the volume estimation derived by using a 3D matrix transducer can represent the actual volume more closely than those derived with 2D and 3D mechanical transducers and the 3D view facilitates more accurate needle placement that aids radiofrequency ablation.

Kim et al. [14] showed that the 3D US-MAT guidance is likely to be a more reliable method for biopsy than the 2D US guidance.

It also showed that the US beam thickness is inherently wider than the thickness of needle tip itself, the 2D US allows the needle to be seen lateral to the target lesion. Thus, the problem with using the 2D US for needle guidance is that sometimes target lesions are located close to vital structures or are small in size. The use of the 3D US can address such problems by providing additional spatial information; it can simultaneously show the structure of orthogonal planes. By using the 3D US, the needle tip was always visualized in two orthogonal planes projected onto the US monitor during the biopsy procedure, which provided the examiner with increased confidence in accurate needle placement.

Arif et al. [15] showed that all examined needles showed good echogenicity at large angles between US beam and needle tip using 3D data acquisition.

Rose et al. [13] showed that B-mode 3D US with in-line interactive multiplanar reformatted imaging display configurational information unavailable on conventional B-mode 2D US.

This information allows the interventional radiologist to optimally deploy the ablative devices with relative confidence. In nearly half of the ablative procedures, information from the 3D US allowed the operator to alter the device position or number. Although we believe that 3D US is not indispensable for tumor ablative therapy, it may help optimize outcomes when performing these procedures in the liver.

Rose et al. [13] also showed in cases of percutaneous tumor ablation, acoustic windows are limited to subcostal approaches (which require superior angulation of the transducer) or right intercostal approaches (which force the transducer to be aligned in a complex oblique orientation to avoid acoustic shadowing by the ribs). With the use of the techniques described in the Materials and Methods section, 3D US should be able to accurately locate the device tip within or near the tumor and to readily display configurational information when multiple devices are used. In fact, 3D US provided additional helpful information that resulted in the confident placement of the ablative devices in 91% of procedures and altered the deployment of at least one device in 10 of 22 (45%) procedures. Specific features provided by 3D US include the capability of understanding exact 3D relationships of anatomic structures and ablative devices by studying the simultaneous display of three orthogonal imaging planes and retrospectively examining any point within the volume data from any desired perspective. They found that interrogation of the imaging plane perpendicular to the axis of the device was particularly useful. The scroll function of the US imaging allowed them to "drive" down the shaft of a probe or needle. This maneuver permitted (i) visualizes the exact course of the device as it passes from the liver capsule to the tumor, (ii) understands precisely the geometric relationship of the examined device to other needles or probes, (iii) sees how the device was centered within the tumor as it coursed to the deepest aspect, and (iv), in cases of RFA, unequivocally determines the location of the rosette of tines with respect to the tumor and adjacent structures.

The complications in our study were significantly lower by the usage of 3D US guidance, and that was similar to T. Boers et al., Hyun Cheol Kim et al.; Muhammad Arif et al., and Steven et al. who all showed that the complications under 3D guidance were significantly lower than 2D guidance [13–16].

The average time of the procedure in our study was lower under the 3D US guidance and that was unlike Hyun Cheol Kim et al., who showed that the time taken to perform the biopsy procedures was significantly longer under 3D US-MAT guidance compared with 2D US guidance [14].

Limitations and recommendations of the study

In limitations of our study, we included multiple variables as we compared the 2D US and the 3D US regarding the US-guided biopsy, US-guided drainage of hepatic collections, percutaneous ethanol injection, RFA, and MWA, which leads to multiple variables in the statistical analysis so we recommend further studies to concentrate on one variable for comparison.

We recommend the 3D US guidance for locoregional management of hepatic malignant and inflammatory disease more than the 2D US guidance.

The limitation of Kim et al. [14] and Muhammad Arif et al. [15] studies that they performed a phantom-based study, further clinical studies with human subjects would be needed to confirm the validity of their study.

Boers et al. [16] recommended further research wherein the 3D ultrasound scans are utilized in combination with an automatic nodule segmentation method.

Rose et al. [13] did not mention limitations in their study.

Conclusion

3D US guidance by the usage of 3D X matrix probe for the locoregional management of malignant and inflammatory hepatic diseases may be more effective, with less complications and faster procedure time than the 2D ultrasonography guidance in some cases.

Abbreviations

2D Two dimension
3D Three dimension
CBC Complete blood count
CRP C-reactive protein
CT Computed tomography
ESR Erythrocyte sedimentation rate
HCC Hepatocellular carcinoma
MWA Microwave ablation
MAT Matrix array transducer
MRI Magnetic resonance imaging
PEI Percutaneous ethanol injection
RFA Radiofrequency ablation
US Ultrasonography

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Author contributions
EMK and HO conceived and supervised the study; AAK and SA were responsible for data collection. AAK and SA analyzed and interpreted the data. All authors provided comments on the manuscript at various stages of development. All authors read and approved the final manuscript.

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Availability of data and materials
Data and material are available on a reasonable request from the author.

Declarations

Ethics approval and consent to participate:
It was approved by the ethics committee of Menoufia University Hospitals and it was started at from March 2020 to August 2023 at the Diagnostic and Interventional Radiology Department, National Liver Institute, Menoufia University, Egypt. An informed written consent was obtained from the participants (approval No. 00493/2023).

Consent for publication
All patients included in this study give informed consent to publish the data contained within this study.

Competing interests
The authors declare no conflict of interest.

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