White Paper

A New Generation of Fusion Imaging:

iFusion with Respiration Compensation

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iFusion with Respiration Compensation

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Backgroud of Fusion Imaging

Diagnosis and interventional therapy by ultrasound (US)-guided hepatic angiography are a key clinical technique starting from scratch and rapidly developing in recent decades. Compared with CT/MR, ultrasound-guided angiography and intervention are characterized by good real-time performance, low cost and no radiation. But it is difficult to obtain definite images by routine ultrasonography or even angiography and to achieve effective guided interventional treatments because some lesions are small in size, deep or interfered by gas.

As a breakthrough technology, fusion imaging can combine the advantages of CT/MR and ultrasonography, as Fig.1 shows. Like car GPS navigation system, 3D image data of CT/MR collected previously has been imported into ultrasonography system, which is equal to the map in GPS system. Real-time ultrasound image is similar to sight of human eyes. Fusion imaging system can extract two-dimensional CT/MR image, which is in accordance with present ultrasonic scanning section, in the 3D data of CT/MR in real-time. After matching with real-time ultrasonic image exactly, the images can be compared, fused, overlapped and demonstrated. With the help of high-resolution image information from CT/MR and real-time advantages of ultrasound , real-time fusion navigation can help users locate lesions more accurately. Diagnosis and treatment with the help of fusion imaging can improve not only users' confidence in diagnosis of intractable liver diseases, but also increase the accuracy of positioning ultrasound-guided interventional therapy in the treatment of liver diseases, and help doctors assess accurately effects of interventional therapies in time .

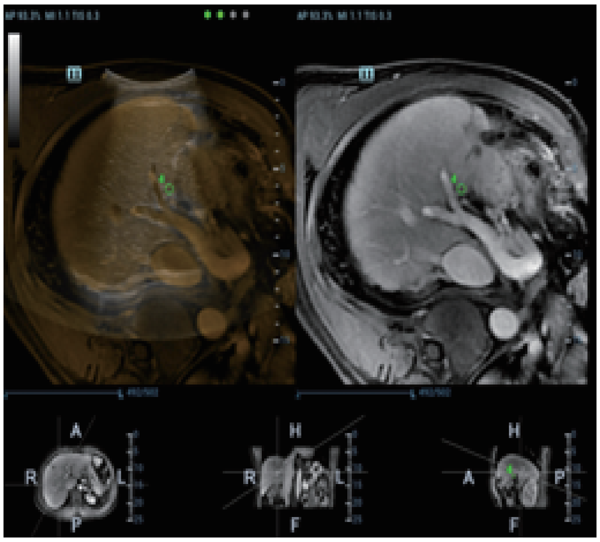

Fig.1 Fusion imaging with hepatic tiny lesion

Limitations on the Development of Fusion Imaging

But, the biggest challenge in clinical application of fusion imaging is the accuracy of image fusion. With static data collection of CT/MR in certain moment and real-time changes of ultrasound image , inevitable breathing movement of the patient is the major influence factor of the accurancy of fusion matching. The new generation Mindray iFusion with respiration compensation can improve the accurancy of fusion imaging to a new level.

Workflows of Routine Fusion Imaging

Generally, there are three basic operation steps of routine fusion imaging, including data import and tagging target marker, registration and fine tunning, real-time fusion navigation.

1) Data Import and Tagging Target Marker

Clinical Significance:

It is convenient to do fast and precise positioning of multiple target tissues during the fusion procedure.

Operation Method:

CT/MR data in DICOM format can be imported into the Fusion system in many ways, including USB disks, CDs or network servers, et al. The data imported can be browsed by users, and it can be visualized in any direction and at any arbitrary angle via MPR (multiple planes rendering).

Mindray's iFusion system can allow users, in the MPR display status, to tag multiple target markers in a spherical fashion on CT/MR images (Normally liver tumors are less than 3 cm in diameter, regular shape and close to sphere.). When tagging, just browse to the maximum radial section of the target tissue and determine its central point and radius by mouse clicking and trackball movement. Meanwhile, target markers can be mapped to fusion image automatically, as shown in the circle in Fig.2. During the procedure of fusion navigation, when the user rescans these targets from different angles, target markers with corresponding colors and serial numbers can be displayed on present section in real time.

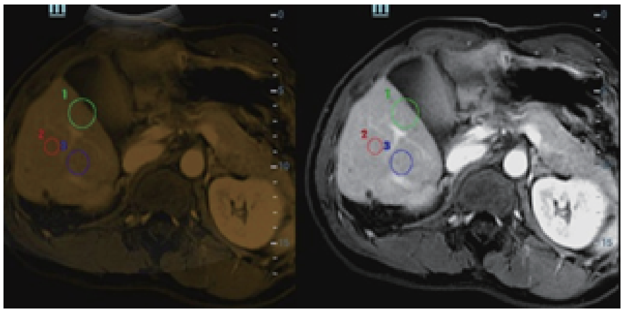

Fig.2 Target markers

Registration and Fine Tunning

Clinical Significance:

Establish an accurate corresponding relationship between ultrasound and CT/MR images, in order to obtain high precision of fusion imaging,.

Operation Method:

iFusion achieves registration in a single plane manner manually. Search the same section in ultrasound and CT/MR, then move the images of CT/MR, so that, the images can be matched, overlapped and demonstrated. Users can either select CT/MR section first, then find corresponding ultrasonic section by probe, or search corresponding CT/MR images after collecting and determining ultrasonic section. It is suggested that initial registration is usually conducted on the scanning plane of the left portal vein's sagittal part.

In clinical applications, the precise registration is usually carried out in two steps: initial registration and fine tunning. Also in a single plane manner manually, fine tunning generally selects a different section from initial registration, in order to achieve the result of multi-dimensional precise matching. During fusion navigation, fine tunning may be carried out at any time if decreased fusion accuracy is found for some reasons such as patient motion.

2) Real-time Fusion Navigation

Clinical Significance:

With the help of CT/MR image and taget markers, fusion navigation can help sonographers to make the diagnosis and treatment more precisely.

Operation Method:

When the registration is completed and confirmed, real-time fusion navigation mode can be entered. Mindray's iFusion supports the ultrasound not only in conventional B-mode, but also Color/Power and CEUS modes. With the help of precise positioning of lesions by iFusion, the combination between CEUS and fusion can further provide more information on blood flow's dynamic perfusion, leading to improved diagnostic confidence of intractable liver diseases and also accurate assessment of interventional therapies. Mindray's iFusion also supports CEUS with dual modes(Fig.3), which can at the same time display ultrasound tissue images, fused images of ultrasound tissue and CT/MRI, CEUS images, and fused images of CEUS and CT/MRI. So it allows users to observe lesions in different types of imaging modes more conveniently, providing more clinical information.

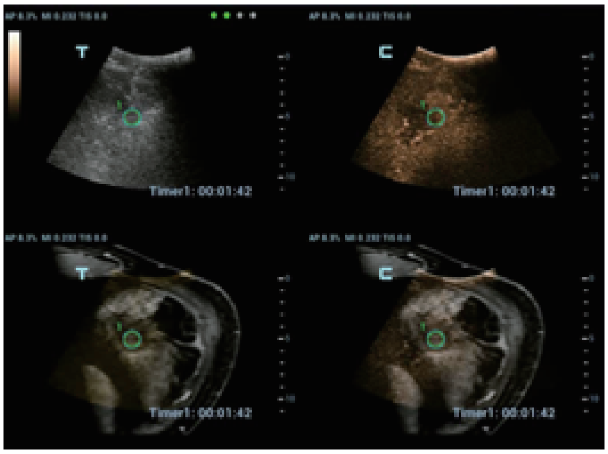

Fig.3 iFusion with CEUS in dual mode

Mindray's iFusion also supports CEUS with dual modes(Fig.3), which can at the same time display ultrasound tissue images, fused images of ultrasound tissue and CT/MRI, CEUS images, and fused images of CEUS and CT/MRI. So it allows users to observe lesions in different types of imaging modes more conveniently, providing more clinical information.

Workflows of the New Generation iFusion with Respiration Compensation

Clinical Significance:

Compensation of respiration-induced fusion errors can improve the accurancy of fusion imaging to a new level and improve the precision of interventional diagnoses and treatments.

Principle of Respiration Compensation:

Generally speaking, CT/MR data is the static data collected in a certain fixed respiration phase, while real-time ultrasound images change in real time with the periodic change of patient's respiration phases. Because of patient's inevitable respiration, although two kinds of images can be registrated accurately at the registration moment, there are still unavoidable patient's respiration-induced errors during the entire procedure of real-time fusion navigation.

Fig.4 A new generation of iFusion with respiration compensation scenario

Based on the motion sensor with the accuracy of millimeter level(the motion sensor is attached to the belly as shown in Fig.4), Mindray's innovative and patented technology of respiratory compensation can remedy the respiration-induced fusion and matching errors greatly, so that, it can improve vastly the accuracy of fusion imaging and confidence in diagnosis, intervention and treatment.

Compared with routine fusion imaging procedure, the new generation iFusion with respiration compensation just needs to add one more step before fusion navigation step: respiration modeling, as shown in Fig.5. The core technology includes respiration gating, respiration modeling and respiration compensation.

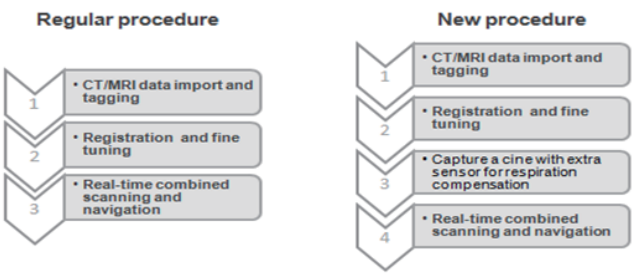

Fig.5 Fusion imaging procedure

1) Respiration Gating

By means of the motion sensor attached to the belly, iFusion can monitor the current phase of respiration in real time and record the phase of respiration during registration. (As is shown in Fig.6, the abscissa represents time and the ordinate represents changes in respiration phase which is reflected by displacement of motion sensor.) The green curve represents the change of real-time respiration phases, the red shot line represents corresponding moment of current selected frame, and the blue horizontal line represents respiration phase at the registration moment. The bigger the difference in respiration phases between present moment and registration moment, the bigger the fusion errors are . As shown by the clinical research, the respiration-induced liver fusion error may be up to more than 1 cm. Based on above information, sonographers can observe the phase difference between the present moment and registration moment, so that they can ensure the credibility of present fusion effectively. This is respiration gating. Meanwhile, respiration gating can provide useful information for subsequent respiration modeling and compensation.

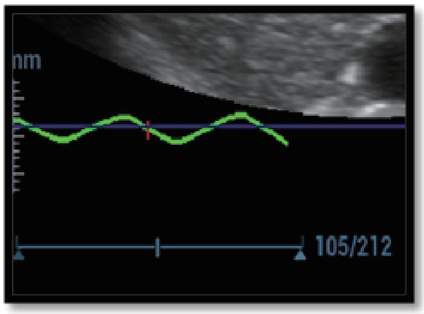

Fig.6 Respiration Gating

2) Respiration Modeling

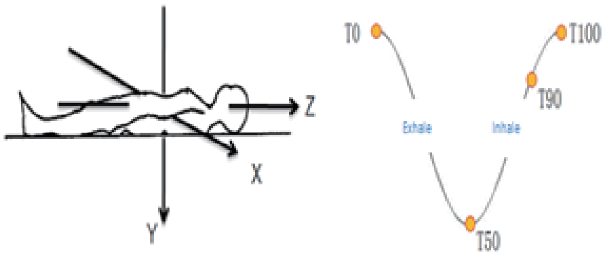

Fig.7 Human body coordinates and respiration phase curve

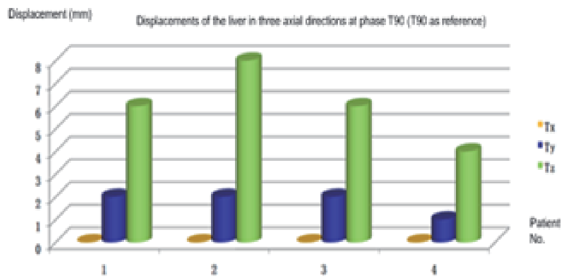

Fig.8 Analysis of human liver movement along respiration

Before compensation, the model of liver motion along with changes of respiration should be established first.

Based on the study of four groups of human abdominal CT data under free-breathing conditions, the motion in human liver caused by respiration , was dominated by displacement, while neither rotation nor deformation were significant. In terms of components in three axial directions of human body coordinates, the displacement along the cephalo-caudal direction (Y axis) was much greater than those along the other two directions (X and Z axis, as is shown in Fig.7,8). Hence, respiration-induced fusion errors can be corrected effectively as long as a model of liver moving along three axial directions can be established accurately.

The approximate workflow of establishing the model of liver motion along with changes in respiration phases is shown as Fig.9. Firstly, stabilize the probe in the longitudinal direction (Because the displacement of liver is dominated by components in this direction), and acquire one ultrasound cine loop of liver under patient's free-breathing conditions. Then, system automatically select several cycles with stable respiration curve and less probe movement for following motion analysis, select ROI area, make speckle tracking analysis of the motion within ROI, and finally combining the data of corresponding respiration phases, the system can analyze and establish the model of liver motion along respiration by Mindray's patented algorithm. It is very easy for users to operate byonly storing one cine loop with the help of motion sensor, then the system can finish the whole of modeling process quickly.

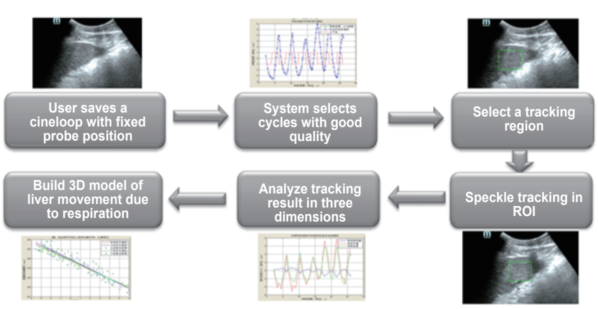

Fig.7 Human body coordinates and respiration phase curve

3) Respiraton Compensation

Based on the established model of liver motion along respiration, the liver displacement between real-time respiration phase and the phase at registration moment can be obtained immediately and be compensated during the whole fusion navigation procedure, by specific algorithms.

It has been proved in clinical experiments that Mindray's respiration compensation technology can correct approximately 80% of fusion errors caused by respiratory motion and markedly improve the fusion accuracy of a full respiration cycle.

Case Study

Case 1.

This case is iFusion with liver ultrasound and MRI, which can test the implementation effect of the new generation of respiration compensation technology in liver fusion imaging. As Fig.10 showed it is the fusion comparison between left image (before compensation) and right image (after compensation) in certain respiratory phase. It is obvious that, the matching between ultrasound and MRI in the right picture is more accurate, especially in the hepatic vessels marked by yellow arrow and red arrow. By comparing with dynamic videos, the effects can be more obvious. The respiration compensation technology can markedly improve the fusion accuracy of full respiration cycles.

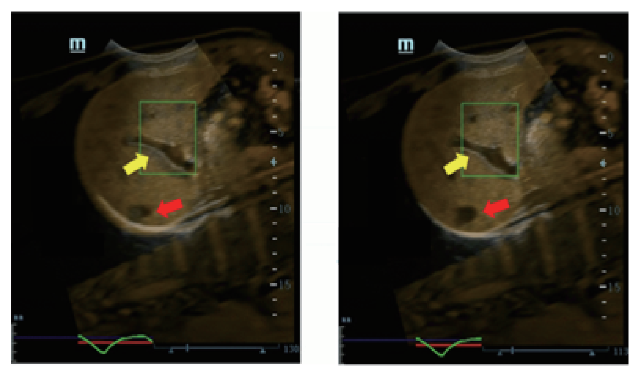

Fig.10 Comparison of before and after respiration compensation (the left is pre-compensation and the right is post-compensation)

Case 2.

This case is diagnosed as suspected liver tumor. On CT, it is distinctly hypoechoic (tagged by green target marker in Fig.11)with no clear tumor boundary; on conventional B-mode ultrasonography, it is obscured as iso-echoic and hard to diagnose. So the lesion location is recorded by target marker on CT, and its positions found on ultrasound with the help of iFusion, and finally further analysis of characteristic of lesions is made by CEUS combined with fusion imaging. By CEUS, the finding displays distinct fast-in and fast-out signs, diagnosing as liver cancer at last. So, iFusion can help the doctors with precise positioning. By providing more useful clinical information through the combination between iFusion and CEUS, the diagnostic confidence of intractable liver diseases can be largely improved.

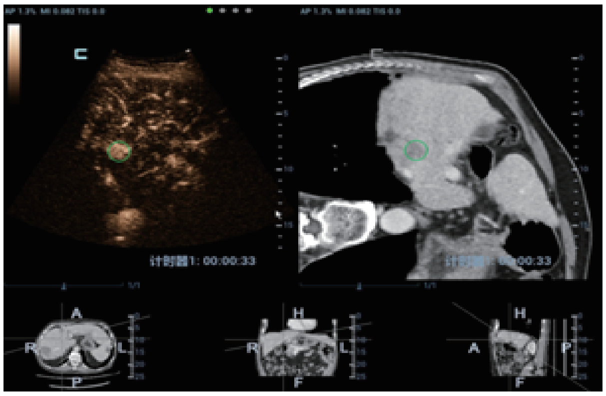

Fig.11 iFusion with CEUS for lesion diagnosis

Case 3.

This case is diagnosed as liver cancer. On MR, the tumor is well-defined, and the ultrasound-guided percutaneous radiofrequency ablation is performed. Pure ultrasound fails to guide insertion of the needle accurately due to small lesions, deep location and iso-echo in routine B-mode ultrasonography. So, with the help of high-resolution MR images, fusion navigation is performed to improve the accuracy of the procedure.. Based on lesion's target marker in MR images, iFusion can help the doctor guide the needle tip to the lesion location accurately, as Fig.12 shows. So, iFusion can increase the accuracy of positioning in ultrasound-guided interventional therapy and treatment effectively.

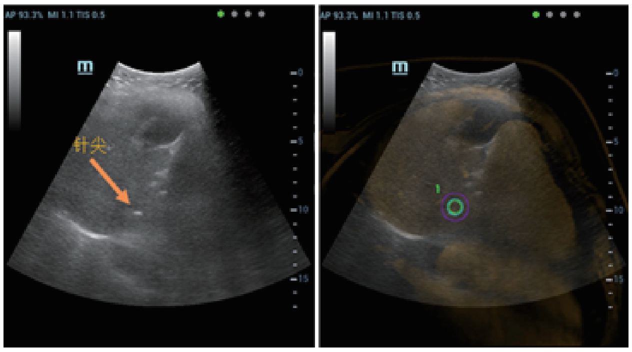

Fig.12 iFusion during intervention procedure

Case 4.

This case has been diagnosed as liver cancer. The ultrasound-guided percutaneous radiofrequency ablation is performed by the doctor. Preoperatively, iFusion has been performed and the lesion location has been tagged with marker. The operation is guided by a 5 mm safety margin. (as Fig.13 shows that green circle represents the maximum diameter of tumor, the purple circle represents the safe margin by extending the diameter of 5mm, which indicates the minimum border of ablation, in order to avoid remnant of tumor). Postoperatively, before the patient leaving the operation room, the iFusion with CEUS is performed immediately for ablation assessment. With the help of precise positioning by iFusion and perfusion information of CEUS, the doctor can diagnose quickly and effectively if the ablation area has completely covered the safe margin. As this case shows, the ablation area without any blood perfusion has covered the safe margin completely, suggesting complete ablation. Timely and effective assessment of postoperation, when the patient is still in the operation room, can avoid second surgical risk resulting from incomplete ablation. So, iFusion can largely help the doctor assess the treatment effects of interventional operation timely and accurately.

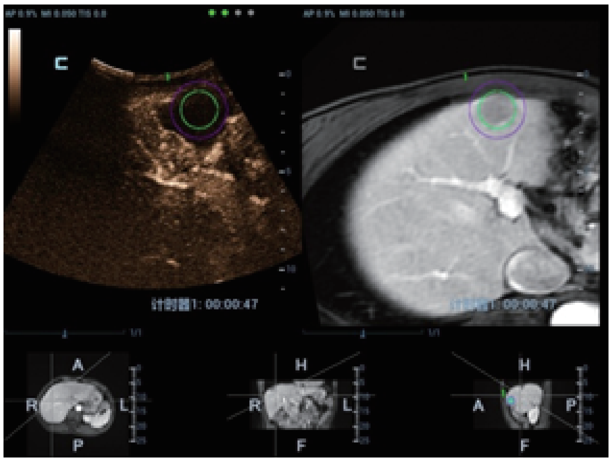

Fig.13 iFusion for treatment evaluation

Conclusion

Mindray's innovative and patented technology of respiratory compensation can establish the model of liver motion along respiration accurately, remedy the respiration-induced fusion errors effectively, and markedly improve the fusion accuracy of full respiration cycles. So that, the accuracy of fusion imaging has been improved to a new level.

The new generation Mindray's iFusion with respiration compensation provides remarkable clinical values with ease of use, supporting various ultrasonic modes at the same time and providing target markers and safe margin. The new generation Mindray's iFusion can provide greatly improved diagnostic confidence of intractable liver disease, more accurate guidance of the hepatic ultrasound-guided interventional therapy and more timely and effective postoperative evaluation of the treatments.

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