A new solution for IGRT in SBRT of liver lesions, based on 3D US imaging combined with Active Breathing Control.

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INTRODUCTION

Accurate tumor positioning in SBRT of liver lesions is of major importance, because high dose gradients are delivered in a few fractions. The use of electronic portal imaging (EPI) for verification is not sufficient, because lesion displacement can be independent of bony anatomy. Also Cone Beam CT (CBCT) does not help to visualize the lesions itself, since no iv contrast is used. Therefore, we implemented 3D ultrasound (3DUS) as IGRT tool in SBRT of liver lesions. Our previous results demonstrated that liver deformation and blurring of the US scan as a result of breathing motion, influenced the hampered our image segmentation. As a result we studied the additional value of Active Breathing Control (ABC) during 3D US.

The aim of this study is to establish the use of 3D ultrasound (US) combined with Active Breathing Control (ABC) for IGRT in liver lesions.

METHODS AND MATERIALS

A 3DUS device (Clarity, Elekta) was investigated for SBRT of 8 patients on 58 treatment fractions. In 2 patients at 16 treatment fractions the 3DUS was also performed under ABC conditions using the SDX system (DynR, France).

The 3DUS and mid-ventilation CT images were fused, the lesion together with surrounding structures were contoured and beams and isocenter were imported into the Clarity system. Prior to each treatment, 2 US scans were performed in free breathing (FB). For patients treated with ABC, 2 additional scans in breath hold (BH) mid-ventilation were acquired.

A misalignment between reference and actual US resulted in a 3D table shift, which was independently defined by 3 observers. The inter- and intra-observer variation with and without BH mid ventilation US scanning were analyzed. The mean 3D US shift was compared to the 3D EPI shift and defined as: $\Delta X,Y,Z=(EPIx,y,z-USx,y,z)$.

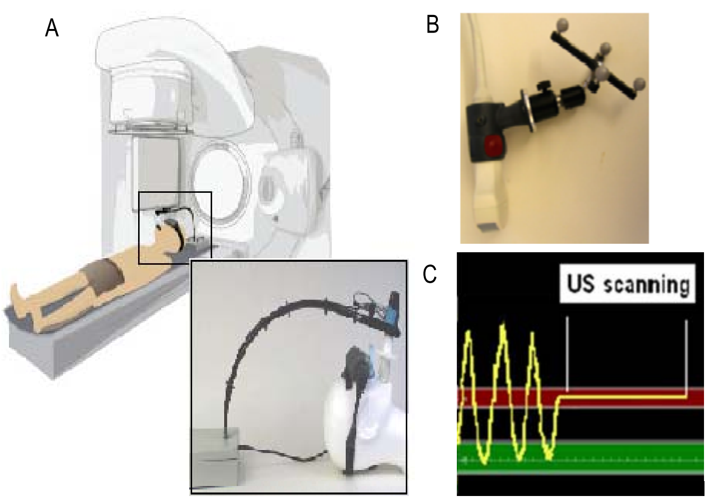

Fig 1:Illustration of (A) the SDX spirometer system; (B) the design of the liver probe; (C) the display of the breath signal as illustrated by the video goggles and the sequential breath hold phase used for US scanning.

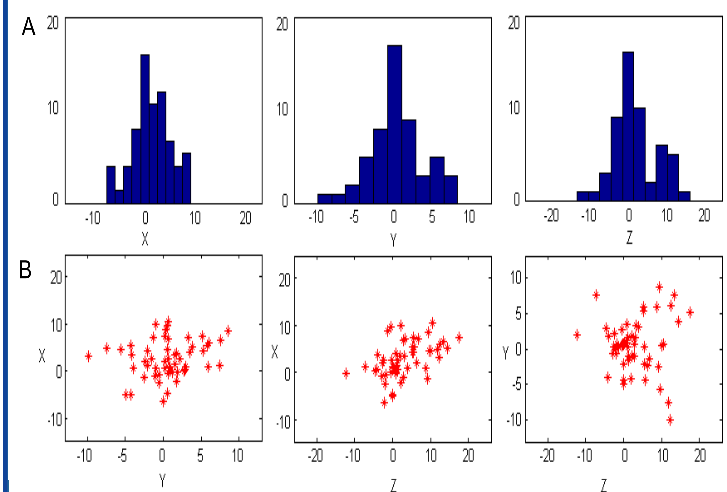

Fig 2 (A): histogram of deviations between EPI and US shifts in respectively X, Y and Z direction and (B) deviations in respectively X/Y, X/Z and Y/Z plotted in scatter diagrams.

RESULTS

In this study we demonstrated that the combination of US scanning and ABC optimized our image quality and resulted in a smaller inter- and intra-observer-variation of image segmentation. The inter-observer variation, defined as the mean SD of respectively the FB and BH US scans, in the 2 patients was reduced in left/right from 1.7 mm to 1.0 mm, in ant/post from 3.0 mm to 1.8 mm and in sup/inf from 4.9 mm to 2.6 mm with a mean reduction of 42% ($p<0.01$). The intra-observer variation changed in left/right from 0.7 mm to 0.2 mm, in ant/post from 1.6 mm to 0.2 mm and sup/inf from 1.7 to 0.8 mm with a mean reduction of 66% ($p<0.01$).

We demonstrated a significant difference between US and EPI image guidance. The mean 3D table shifts in 58 treatment fractions in FB consisted of 3.6 mm in left/right [1.0 to 8.9 mm], 2.6 mm in ant./post. [1.9 to 10.5 mm] and 5.4 mm in sup./inf. direction [0.4 to 15.1 mm].

	X (mm)	Y (mm)	Z (mm)
Δ EPI/US	3.6	2.6	5.4
Inter-observer FB	1.7	3.0	4.9
Inter-observer BH	1.0	1.8	2.6
Intra-observer FB	0.7	1.6	1.7
Intra-observer BH	0.2	0.2	0.8

CONCLUSIONS

3DUS imaging for image guidance in SBRT of liver lesions is an accurate and feasible method, although its accuracy is often hampered by breathing motion. Therefore, ABC-based breath-hold in mid-ventilation during 3DUS imaging represents an important advancement in 3DUS IGRT, since it can significantly reduce the intra- and inter-observer variability in 3DUS-based 3D table shift correction.

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