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Clinical benefits of new immobilization system for hypofractionated radiotherapy of intrahepatic hepatocellular carcinoma by helical tomotherapy

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ABSTRACT

Objective: A comprehensive clinical evaluation was conducted, assessing the Body Pro-Lok immobilization and positioning system to facilitate hypofractionated radiotherapy of intrahepatic hepatocellular carcinoma (HCC), using helical tomotherapy to improve treatment precision.

Methods: Clinical applications of the Body Pro-Lok system were investigated (as above) in terms of interfractional and intrafractional setup errors and compressive abdominal breath control. To assess interfractional setup errors, a total of 42 patients who were given 5 to 20 fractions of helical tomotherapy for intrahepatic HCC were analyzed. Overall, 15 patients were immobilized using simple vacuum cushion (group A), and the Body Pro-Lok system was used in 27 patients (group B), performing megavoltage computed tomography (MVCT) scans 196 times and 435 times, respectively. Pretreatment MVCT scans were registered to the planning kilovoltage computed tomography (KVCT) for error determination, and group comparisons were made. To establish intrafractional setup errors, 17 patients with intrahepatic HCC were selected at random for immobilization by Body Pro-Lok system, undergoing MVCT scans after helical tomotherapy every week. A total of 46 MVCT re-scans were analyzed for this purpose. In researching breath control, 12 patients, randomly selected, were immobilized by Body Pro-Lok system and subjected to 2-phase 4-dimensional CT (4DCT) scans, with compressive abdominal control or in freely breathing states, respectively. Respiratory-induced liver motion was then compared.

Results: Mean interfractional setup errors were as follows: (1) group A: X, 2.97 ± 2.47 mm; Y, 4.85 ± 4.04 mm; and Z, 3.77 ± 3.21 mm; pitch, 0.66 ± 0.62°; roll, 1.09 ± 1.06°; and yaw, 0.85 ± 0.82°; and (2) group B: X, 2.23 ± 1.79 mm; Y, 4.10 ± 3.36 mm; and Z, 1.67 ± 1.91 mm; pitch, 0.45 ± 0.38°; roll, 0.77 ± 0.63°; and yaw, 0.52 ± 0.49°. Between-group differences were statistically significant in 6 directions ($p < 0.05$). Mean intrafractional setup errors with use of the Body Pro-Lok system were as follows: X, 0.41 ± 0.46 mm; Y, 0.86 ± 0.80 mm; Z, 0.33 ± 0.44 mm; and roll, 0.12 ± 0.19°. Mean liver-induced respiratory motion determinations were as follows: (1) abdominal compression: X, 2.33 ± 1.22 mm; Y, 5.11 ± 2.05 mm; Z, 2.13 ± 1.05 mm; and 3D vector, 6.22 ± 1.94 mm; and (2) free breathing: X, 3.48 ± 1.14 mm; Y, 9.83 ± 3.00 mm; Z, 3.38 ± 1.59 mm; and 3D vector, 11.07 ± 3.16 mm. Between-group differences were statistically different in 4 directions ($p < 0.05$).

Conclusions: The Body Pro-Lok system is capable of improving interfractional and intrafractional setup accuracy and minimizing tumor movement owing to respirations in patients with intrahepatic HCC during hypofractionated helical tomotherapy.

Background

Liver cancer is much more common in men than in women. In men, it is the second leading cause of cancer death in less developed countries and worldwide. In more developed countries,

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it is the sixth leading cause of cancer death among men. An estimated 782,500 cases of newly diagnosed liver cancer and 745,500 related deaths occurred internationally during 2012, with China alone accounting for approximately 50% of case totals and deaths.[1] Most (70% to 90%) primary liver cancers globally are hepatocellular carcinoma (HCC).[1] Radiotherapy has been a mainstay of treatment for locally advanced and medically unresectable HCC.[2,3] Stereotactic body radiotherapy (SBRT) is a safe and effective alternative treatment in patients who are ineligible for ablation/resection of intrahepatic HCC.[4-7]

Current advancements in radiotherapeutic precision have underscored the importance of patient immobilization, target positioning , and organ motion control for treatment success, particularly in complex cases of intrahepatic HCC requiring higher doses. During normal breathing, liver movement ranges from 5 to 50 mm.[8,9] It is, thus, imperative to limit such movement and enhance target positioning through improved and reproducible patient immobilization.[10] Patient comfort, safety, and benefit are also concerns of radiotherapy oncologists and therapists in prior computed tomography (CT) simulations.

The Body Pro-Lok system (CIVCO Medical Solutions, Coralville, IA) provides an easy-to-use modular framework suitable for SBRT setup intricacies, offering respiratory belt and plate options to help control patient breathing through abdominal compression (AC). AC has been widely used in radiotherapy to reduce liver respiratory motion, and for most patients, motion of liver tumors is significantly reduced in 3 dimensions by this means.[10,11] Gutiérrez *et al.*[12] have proven the clinical use of the Body Pro-Lok system in liver SBRT, but only in terms of interfractional setup error. This report details our comprehensive evaluation of the Body Pro-Lok system in conjunction with megavoltage CT (MVCT) for hypofractionated helical tomotherapy of intrahepatic HCC.

Methods and Materials

Patients

All patients studied underwent treatment in our department between January 2012 and December 2015. Each had Child-Pugh A liver function and Karnofsky performance status $>$ 80. On average, 15 fractions (range: 5 to 20) of helical tomotherapy were delivered, with a single-dose range of 2.5 to 10 Gy. Demographics and clinical characteristics of patients studied for interfractional setup errors are shown in Table 1. Overall, 42 patients (men, 37; women, 5; age range: 32 to 80 years) with intrahepatic HCC were selected at random for immobilization by either simple vacuum cushion (group A, $n = 15$) or Body Pro-Lok system (group B, $n = 27$), performing pretreatment MVCT scans 196 and 435 times, respectively. Regarding intrafractional setup errors, 17 patients with intrahepatic HCC immobilized using Body Pro-Lok system were selected at random for weekly MVCT scanning after helical tomotherapy, assessing a total of 46 MVCT re-scans for intrafractional setup accuracy. To evaluate breath control, 12 patients (free of cardiopulmonary disease) immobilized using Body Pro-Lok system were selected at random for 2-phase 4-dimensional CT (4D-CT) scans in abdominal compressive and free-breathing states. Patients with colostomies and ascites were excluded. Patient breathing was kept regular after a training session under AC. This study was approved by the ethics committee of Zhongshan hospital, Fudan university (Ethics approved no: 2011-235), and informed consent was obtained.

Table 1
Patient demographics and clinical characteristics

	Group A ($n = 15$)	Group B ($n = 27$)	p Value
Sex, n (%)			0.435
Men	14 (93.3%)	23 (85.2%)	
Women	1 (6.7%)	4 (14.8%)	
Age, n (%)			0.747
$\leq$ 60 years old	7 (46.7%)	14 (51.9%)	
$>$ 60 years old	8 (53.3%)	13 (48.1%)	
BMI, n (%)			0.750
$\leq$ 24	10 (66.7%)	17 (63.0%)	
24 to 27	2 (13.3%)	6 (22.2%)	
$>$ 27	3 (20.0%)	4 (14.8%)	
Intrahepatic lesions, n (%)			0.963
Solitary	9 (60.0%)	16 (59.3%)	
Multiple nodules	6 (40.0%)	11 (40.7%)	
Diameter, n (%)			0.710
$\leq$ 5 cm	8 (53.3%)	16 (59.3%)	
$>$ 5 cm	7 (46.7%)	11 (40.7%)	
Tumor location n (%)			0.558
Left lobe of liver	5 (33.3%)	7 (25.9%)	
Right lobe of liver	9 (60.0%)	15 (55.6%)	
Left and right lobes	1 (6.7%)	5 (18.5%)	
Postoperative recurrence, n (%)			1.000
Yes	5 (33.3%)	9 (33.3%)	
No	10 (66.7%)	18 (66.7%)	
PTV volume, n (%)			0.827
$\leq$ 300 cc	9 (60.0%)	18 (66.7%)	
300 to 1000 cc	4 (26.7%)	5 (18.5%)	
$>$ 1000 cc	2 (13.3%)	4 (14.8%)	
Normal liver volume, n (%)			0.850
$\leq$ 1000 cc	6 (40.0%)	10 (37.0%)	
$>$ 1000 cc	9 (60.0%)	17 (63.0%)	
Image registration distance, mean $\pm$ SD cm	12.42 $\pm$ 5.88	10.84 $\pm$ 4.34	0.328

SD = standard deviation.