ma and liver metastases in a primarily curative or a palliative approach. The accurate placement of the applicator into the center of the tumor can be very challenging especially in tumors with limited visibility and accessibility. Modern robot assisted navigation systems enable precise path planning in 3D and the exact applicator insertion. This paper presents a study comparing the microwave ablation technique using novel robotic navigation versus the standard manual approach under CT fluoroscopy.

Methods

We present a retrospective single center analysis of 54 microwave ablations of 38 patients (10 female, 28 male, mean age 66 years) which was conducted for the period between January 2014 and January 2015. We evaluated patient dose, procedural time, procedural accuracy, complication rate and ablation success for each ablation. 32 ablations were carried out under manual CT control while 22 ablations were performed using novel robotic guidance (MAXIO, Perfint Healthcare, India). 38 tumors were hepatocellular carcinoma and 16 were metastases (2 pulmonary, 2 breast, 2 prostate, 10 colorectal). After 6 weeks follow-up examinations with MRI and CT were performed on all patients. A two-sided Student's t test was used to analyse the significance of the data and p values less than 0.05 were considered statistically significant.

Results

In 8 of the 22 robotic guided ablations (36.3 %) a manual positional correction of the applicator was performed with a mean correction of 2.3 mm. Total procedure time (time from the last planning CT scan to the final control CT scan) was 17.6 min under robotic guidance and 23.8 min using the manual approach with a significant mean time difference of 6.2 min ($p = 0.02$). The total dose-length product was significantly lower under robotic navigation (2187 mGy cm) compared to the manual approach (2899 mGy cm; $p = 0.04$). Under the robot-assisted tumor ablation no complications were observed. In the manual approach group one patient with pre-existing intrahepatic cholestatis developed postinterventional bilioma requiring a CT guided drainage. There were 4 cases of incomplete thermal ablation, 2 in each group. There was no significant difference between both groups regarding the procedural accuracy.

Conclusions

The robotic guided approach for tumor ablation helps to reduce these patient dose and shortens the total procedure time when compared to the manual approach while maintaining a high accuracy There were no significant differences in complication rate and ablation success in the 6-week follow up.

Intra-interventional image fusion and needle placement verification for percutaneous CT-guided interventions

G. Toporek[1], J. Engstrand[2], H. Nilsson[2], A. Michos[3], P. Harbut[4], J. Freedman[2], H. Lu[1], S. Weber[1]
[1]University of Bern, ARTORG Center for Biomedical Engineering, Bern, Switzerland
[2]Karolinska Institutet, Department of Clinical Sciences, Danderyd Hospital, Stockholm, Sweden
[3]Department of Radiology, Danderyd Hospital, Stockholm, Sweden
[4]Department of Anesthesiology, Danderyd Hospital, Stockholm, Sweden

Keywords Percutenous thermal ablation · Navigation system · Needle position verification · Liver

Purpose

In computed tomography (CT)-guided percutaneous thermal ablation procedures, an accurate needle applicator placement is crucial for successful treatment, providing a sufficient post-ablation margin around the tumor [1]. Stereotactic image-guidance systems can improve outcomes of image-guided CT-guided interventions with respect to precision and time requirements [2]. In such systems an applicator path is planned using contrast-enhanced CT images and subsequently, the applicator is placed using a navigation feedback. An additional verification scan can be used to verify the applicator placement with respect to the original plan.

The aim of this study is to evaluate a targeting accuracy of a stereotactic navigation system for CT-guided interventions using an intra-interventional image fusion and needle placement verification module (CAS-ONE IR by CAScination AG, Bern, Switzerland, [3]). The accuracy assessment was performed retrospectively on 20 patients with malignant liver lesions, scheduled for percutaneous local microwave ablation (MWA).

Methods

1. Navigation system

The navigation systems consists of a mobile navigation rack with touch screen monitors and an optical tracking camera (Vicra, NDI). During the intervention, a previ-ously acquired CT scan is transferred to the navigation system and the interventionalist defines multiple needle paths using a simple touch screen interface. A set of retro-reflective marker spheres attached to the patients thorax and upper torso enables real-time patient tracking. A 4-DOF aiming device (iSYS, Medizintechnik, GmbH, Austria), see Fig. 1a) allows alignment of the physical needle trajectory ac-cording to the virtual plan and provides stabilization of the needle during the insertion and in consequence reduces geometric inaccuracies introduced by applicator's bending and user's hand-tremor [3].

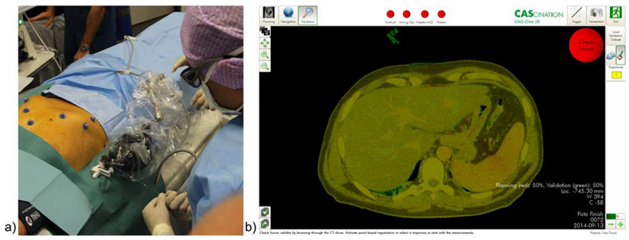

Fig. 1 **a** Insertion of a treatment applicator stabilized with 4-DOF aiming device. **b** Color-coded image fu-sion of needle control and pre-interventional planning scan containing pre-planned needle trajectories

2. Intra-interventional validation module

Following an interventional applicator placement, pre-interventional contrast-enhanced planning CT is fused with the post-insertion native verification CT using visible anatomical landmarks in the available scans as well as available coordinate information from imaging (assuming an anesthetized, non-moving patient with breathing control). The fused image dataset (red coloring refers to planning and green to verification scan, Fig. 1b), allows for direct comparison of the planned with the resulting trajectory by measuring geometric displacement (i.e. target positioning error TPE) in the lateral and longitudinal axes.

3. Evaluation

Following needle (i.e. microwave applicator) placement interventionalist co-registered planning with the control image datasets and confirmed correctness of image fusion by assessing the fiducial co-registration error (FRE). Within the control scan, the resulting applicator trajectory (tip and skin-entry) was manually marked and directly compared to the planned trajectory in the coordinate system of the co-registered image data sets. Subsequently, lateral and longitudinal components of the target positioning Error (TPE) were computed by the system and presented to the interventionalist (see Fig. 2b).

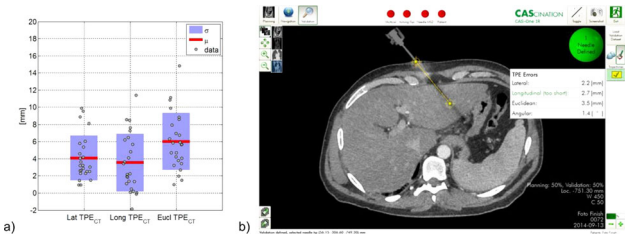

Fig. 2 **a** Components of needle targeting accuracy (TPE) separated into three components: lateral, longitudinal and Euclidean. **b** Intra-interventional validation displays TPE on the left side of the planned trajectory

Results

20 patients (16 males, 4 females) with 28 liver tumors (20 HCC, 7 CRLM, 1 GIST) of an average diameter of 17 ± 9 mm and average location depth of 88 ± 27 mm, underwent stereotactic CT-guided percutaneous MWA procedures. All patients were anesthetized and respirated using a high-frequency jet ventilation technique in order to reduce the respiratory motion of the liver [4]. Two patients were excluded from the study because of technical issues with the aiming device.

Average co-registration fiducial registration error (FRE) was 1.0 ± 0.6 mm and visual assessment by the interventionalist was enabled using the color-coded blending viewer. Average lateral, longitudinal and Euclidean needle positioning errors (TPE) were 4.1 ± 2.6, 3.7 ± 3.2 and 6.0 ± 3.3 mm, respectively (see Fig. 2a).

Conclusions

Fast and online intra-interventional image fusion and treatment verification module was presented and used to evaluate targeting accuracy of the navigation system on 20 patients. It can conclude that navigated percutaneous microwave ablation is sufficiently with a lateral targeting accuracy (4.1 ± 2.6 mm). The data suggests, that navigated percutaneous application of microwave ablation is accurate and thus efficacious. Furthermore, navigation support might potentially enlarge the group of patients to whom a minimal invasive approach as an alternative to surgical resection, could be offered. In addition, the available accuracy compares favorably with other navigation approaches [2, 5].

TPE reported by intra-interventional image fusion and treatment verification module might be beneficial for the interventionalist for correcting the depth (longitudinal component) or before making a decision of repositioning the needle (lateral component). Such information might reduce the probability of bleeding or tumour seeding due to avoidance of unnecessary needle re-placements.

In on-going research a multiplanar reconstructions of the CT images will be included into the verification module and their influence on the general performance and usability will be evaluated.

References

[1] Flanders VL and Gervais D A. Ablation of liver metastases: current status. Journal of vascular and interventional radiology. 2010 August;21(8 Suppl):214–22.

[2] Wood BJ, Kruecker J, Locklin J, Levy E, Xu S, Solbiati L, et al. Navigation Systems for Ablation. Journal of vascular and interventional radiology. 2011 Au-gust;21(8):1–19.

[3] Wallach D, Toporek G, Weber S, Bale R and Widmann G. Comparison of free-hand-navigated and aiming device-navigated targeting of liver lesions. International Journal of Medical Robotics and Computer Assisted Surgery. 2013 February; 10(1):35-43.

[4] Denys A, Lachenal Y, Duran R, Chollet-Rivier M and Bize P. Use of High-Frequency Jet Ventilation for Percutaneous Tumor Ablation. Cardiovascular and interventional radiology. 2014 February; 37(1):140-6

Alternatives for intraoperative imaging in IOERT

V. García-Vázquez[1], E. Marinetto[1], P. Guerra[2], M.F. Valdivieso[3], F.A. Calvo[4], E. Alvarado-Vásquez[5], J.A. Santos-Miranda[5], C.V. Sole[6], M. Desco[1], J. Pascau[1]

[1]Departamento de Bioingeniería e Ingeniería Aeroespacial, Universidad Carlos III de Madrid, Madrid, Spain

[2]Departamento de Ingeniería Electrónica, ETSI Telecomunicación, Universidad Politécnica de Madrid, Madrid, Spain

[3]GMV SA, Tres Cantos, Spain

[4]Departamento de Oncología, Hospital General Universitario Gregorio Marañón, Madrid, Spain

[5]Servicio de Oncología Radioterápica, Hospital General Universitario Gregorio Marañón, Madrid, Spain

[6]Service of Radiation Oncology, Instituto de Radiomedicina, Santiago, Chile

Keywords IOERT · Intraoperative imaging · Radiotherapy · CT · Dose distribution

Purpose

Intraoperative electron radiation therapy (IOERT) is a technique that combines surgery and therapeutic radiation delivered to an unresected tumour or to a post-resection tumour bed, with displacement of uninvolved organs or protection of dose-limiting tissues. The radiation is delivered by a specific applicator docked to the linear accelerator and placed directly over the tumour bed or the residual tumour [1]. Compared to photon radiotherapy, the electron beam dose profile is much steeper, with a characteristic dose gradient (dose becomes lower than 10 % in only a few centimeters). Dose distribution is estimated with an IOERT treatment planning system (TPS) based on radiation attenuation for each tissue type, among other factors. This information is obtained from a patienťs preoperative CT image and a scanner-specific calibration that converts CT numbers into physical density. Preoperative CT images cannot represent intra-surgical patient modifications such as retraction and displacement of structures, tumor resection or the use of protections. Several CT imaging devices that could be introduced in the IOERT protocol, either in the surgical room or in the linear accelerator room, may solve these limitations. The purpose of this study is to evaluate the image quality offered by different CT devices when they are used to estimate dose distribution for IOERT treatments.

Methods

Several CT scanners with potential application in IOERT procedures were studied in this work: a portable C-arm with large field of view (FOV) with 3D imaging capability (O-arm Surgical Imaging, Medtronic, USA), a linear accelerator with on-board kilovoltage cone beam CT (TrueBeam STx, Varian Medical Systems, USA) and a mobile CT (BodyTom Portable CT Scanner, NeuroLogica Corporation, USA). A conventional CT simulator (Aquilion Large Bore CT system, Toshiba, Japan) was used to acquire reference images to obtain gold standard dose estimations.

Two phantoms were acquired with those CT devices: model 062 electron density phantom (CIRS Inc., VA, USA) and model 057 triple modality 3D abdominal phantom (CIRS Inc.). The first phantom was used to estimate for each device the conversion factors from CT numbers into physical density values. Cylindrical regions of interest (ROIs) were drawn centered in every plug of the electron density phantom and outside it. ROI mean values and their corresponding physical densities were the inputs to an in-house implementation of stoichiometric calibration [2]. This process takes into account that the phantom is made of tissue equivalent materials that may duplicate tissue densities but not usually replicate their chemical composition. The output, i.e. the relationship between CT numbers and physical densities, was introduced into the IOERT TPS (radiance, GMV, Spain, [3]) in order to consider patient's tissue inhomogeneity. The abdominal phantom was used to simulate an IOERT scenario (tumour in the paraspinal muscle). In order to protect the right kidney, a