Software for 3D Quantitative Tumor Accessibility Assessment in Image-Guided Percutaneous Liver Ablations

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Purpose

Thermal ablation therapies, e.g., radiofrequency, microwave, and cryo-ablation, are options for local treatment of hepatic tumors [1, 2]. Those minimally invasive treatments, by percutaneous and interstitial delivery of energy probe directly to lesions under image guidance, is particularly suitable for non-surgical candidates [3]. In some cases, however, the direct approach to lesion is unavailable, due to proximity of critical anatomical structures to the probe trajectory. Such critical structures include, but are not limited to, ribs, vertebras, lungs, major blood vessels, bile ducts, intestines.

Therefore, it is essential that physicians evaluate accessibility of tumors to ensure the safety and feasibility of the percutaneous approach, before making a decision to use it. If the percutaneous approach is not safe and feasible, physician must select a more invasive alternative, such as thoracoscopy- or laparoscopy-assisted ablation, or on laparotomy. This decision making process necessitates an objective method to estimate the accessibility, because erroneous decision can lead to unnecessary risks associated with insufficient tumor access with the percutaneous approach, or complexity and invasiveness of alternative approaches.

In this study, we propose a new quantitative method to assess the accessibility of tumors using a 3D patient-specific model made from preoperative computed tomography (CT) or magnetic resonance imaging (MRI). The method assesses all points on the skin as entry points for percutaneous insertion of ablation probes and suggests possible entry points for tumor access without interfering with the obstacles. Based on the assessment, we define an accessibility score to potentially help physicians make an objective decision on treatment approach.

Methods

Subjects. This retrospective study protocol was approved by the institutional review board of Shiga University of Medical Science. Five patients with primary or metastatic liver tumors, who underwent MRI-guided microwave thermo-ablation therapy recently (4 males and 1 female, 42-73 yo), were enrolled. All patients underwent contrast enhanced CT within two months before percutaneous ablations for liver malignancy. The inclusion criteria for percutaneous ablations are as follows: maximum tumor diameter lt 30mm; number of lesions lt 3; tumor not attached to the major Glisson’s sheath, absence of ascites, absence of tumor thrombosis; and platelet count gt 50,000/µl. **Liver Ablation Protocol.** Tumor ablations were performed in a 0.5 T open MRI (Signa SP/i, GE Healthcare, Milwaukee, WI) by the same board certified surgeons experienced with MR-guided percutaneous liver ablations, **3D Patient-Specific Models.** CT or MRI obtained within two months before the thermo ablation procedures were manually segmented into liver, body surface, and other organs by the same board certified surgeon using a 3D Slicer. At first, outlines of organs, vessels, and bones were marked up using “Level Tracing Tool” and were adjusted manually. The segmented images were converted into 3D surface models using the Marching Cube algorithm available in 3D Slicer. The models, other than the skin, were used as “obstacles” for needle insertion in our assessment. The skin model was trimmed to an area that covers the surface of both lobes of the liver because needles are inserted from this area of the skin in most cases. **Software for**

Tumor Accessibility Assessment. We developed a new software plug-in module to calculate and visualize the accessibility of liver tumor with a percutaneous approach for medical image analysis software 3D Slicer (http://www.slicer.org/). The software uses the "ray-tracing" method in which the target tumor serves as a light source to identify the area of the skin that allows direct approach to the target tumor with a straight needle [4]. The software takes the Body Surface model, Obstacle model, and a fiducial point in the liver model as inputs. The software also examines each line that connects the fiducial point and the center of each polygon cell on the Body Surface model and check if the line intersects the Obstacle model. If it does not intersect, the cell is identified as an accessible area. The polygon is colored based on the accessibility to visualize the results in 3D (Fig. 1). For quantitative analysis, the software calculates the ratio of the total accessible area to the total area of the Body Surface model as the accessibility score (AS) for the specified fiducial point in the liver. Additionally, the software calculates and visualizes the distance between the target tumor and each polygon of the accessible area on the Body Surface model (Fig. 1). **Evaluation.** We calculated the AS for the all five subjects using the developed software. The AS was correlated with the duration of operation as an index of complexity of the procedure.

Results

Patient-specific models of the five patients were created from the CT images. Figure 1 shows a 3D representation of the results of the accessibility analysis of the 3D Slicer. The mean AS was 0.281 ± 0.079. Pearson's correlation coefficient between operation time and AS was -0.803 (Fig. 2).

Conclusion

The developed software provides a 3D representation of tumor accessibility that can be used in pre-surgical simulation to evaluate accessibility (i.e., operability of a tumor and possible skin area to be punctured). In addition, the AS is well correlated with the duration of operation, which is associated with the complexity of the operation. Therefore, the AS may be a candidate predictor of the complexity of the operation, which can be used as a quantitative way to evaluate the accessibility of tumors.

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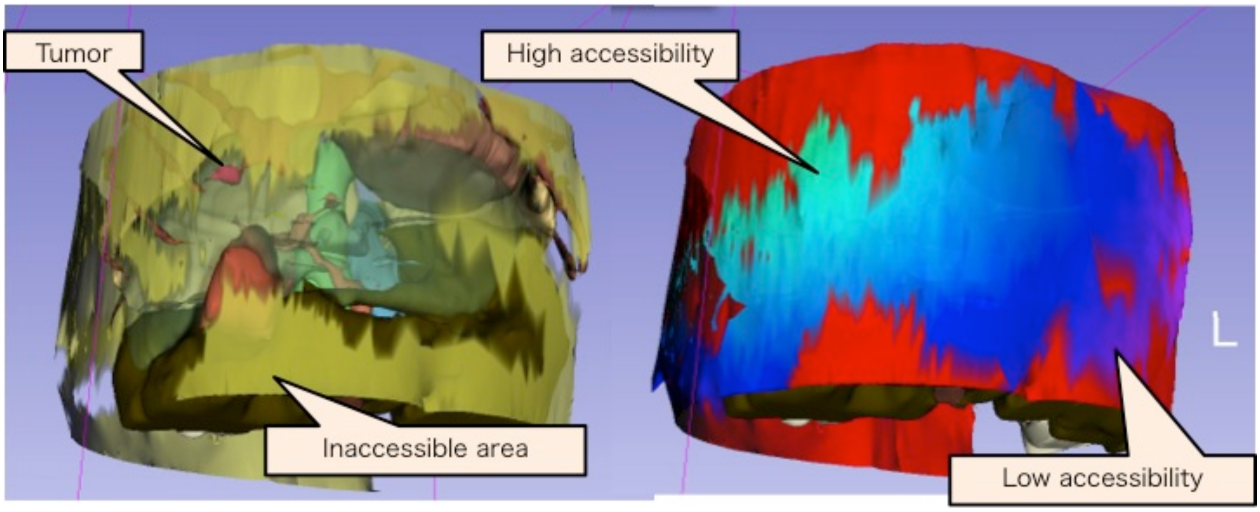

Figure 1. 3D representations of the tumor, Obstacle, and Body Surface models (left), and Body Surface model color-coded by the distance from the target tumor (right) are shown. The inaccessible area on the skin is colored yellow in the left and red in the right.

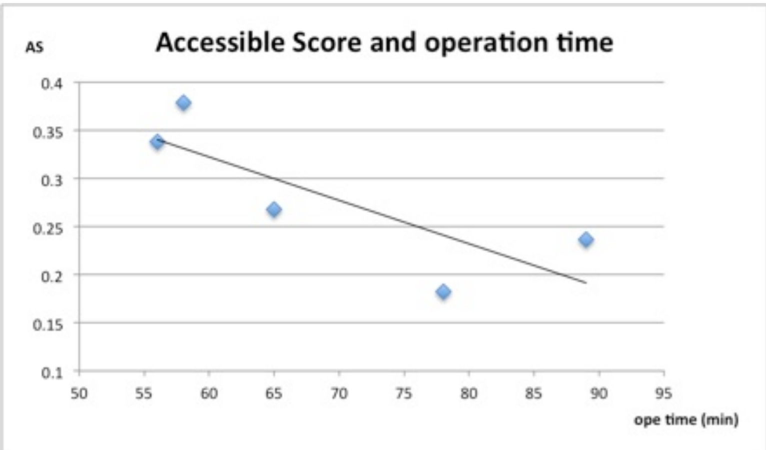

Figure 2: The scatter plot shows the correlation between the operation time and the Accessibility Score (AS) for each specific case.