CLINICAL STUDY

Hepatic Microwave Ablation Zone Size: Correlation with Total Energy, Net Energy, and Manufacturer-Provided Chart Predictions

Paul B. Shyn, MD, Jeffery R. Bird, MD, R. Marie Koch, MD, Servet Tatli, MD, Vincent M. Levesque, MSc, Paul J. Catalano, ScD, and Stuart G. Silverman, MD

ABSTRACT

Purpose: To determine whether total energy (TE) reaching the microwave (MW) applicator or net energy (NE) exiting the applicator (after correcting for reflectivity) correlates better with hepatic MW ablation zone dimensions than manufacturer-provided chart predictions.

Materials and Methods: Single-applicator, nonoverlapping ablations of 93 liver tumors (0.7–5.9 cm) were performed in 52 adult patients. TE and NE were recorded for each ablation. Long axis diameter (LAD), short axis diameter (SAD), and volume (V) of each ablation zone were measured on magnetic resonance imaging or computed tomography after the procedure and retrospectively compared with TE; NE; and manufacturer-provided chart predictions of LAD, SAD, and V using correlation and regression analyses.

Results: For treated tumors, mean (± SD) TE and NE were 49.8 kJ (± 22.7) and 36.4 kJ (± 19.4). Mean LAD, SAD, and V were 5.8 cm (± 1.3), 3.7 cm (± 0.8), and 44.1 cm^3 (± 25.4). Correlation coefficients (95% confidence interval) with LAD, SAD, and V were 0.46 (0.28, 0.61), 0.52 (0.36, 0.66), and 0.52 (0.36, 0.66) for TE; 0.42 (0.24, 0.58), 0.55 (0.39, 0.68), and 0.53 (0.36, 0.66) for NE; and 0.51 (0.34, 0.65), 0.63 (0.49, 0.74), and 0.60 (0.45, 0.73) for chart predictions. Using regression analysis and controlling for TE, SAD was 0.34 cm larger in patients with cirrhosis than in patients without cirrhosis.

Conclusions: Correcting for reflectivity did not substantially improve correlation of energy values with MW ablation zone size parameters and did not outperform manufacturer-provided chart predictions. Correlations were moderate and variable using all methods. The results suggest a disproportionate influence of tissue factors on MW ablation results.

ABBREVIATIONS

LAD = long axis diameter, MW = microwave, NE = net energy, SAD = short axis diameter, TE = total energy, V = volume

Percutaneous image-guided ablation is a widely accepted treatment option in the management of liver malignancies using various ablative technologies (1,2). Microwave (MW) ablation is emerging as a favored thermal technique (3). Potential advantages compared with radiofrequency ablation include greater tissue energy penetration, higher ablation temperatures, and fewer heat sink effects (4–6). When using computed tomography (CT) or ultrasound to guide radiofrequency ablation or MW ablation, the ability to monitor the ablation is limited (6–9). Accurate predictions of ablation zone sizes are needed to ensure that tumors are completely treated and nearby vital structures are unharmed.

From the Department of Radiology (P.B.S., J.R.B., R.M.K., S.T., V.M.L., S.G.S.), Harvard Medical School, Boston, Massachusetts; Abdominal Imaging and Intervention (P.B.S., J.R.B., R.M.K., S.T., V.M.L., S.G.S.), Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115; and Department of Biostatistics and Computational Biology (P.J.C.), Dana-Farber Cancer Institute, Boston, Massachusetts. Received January 22, 2016; final revision received April 30, 2016; accepted May 9, 2016. **Address correspondence to** P.B.S.; E-mail: pshyn@partners.org

None of the authors have identified a conflict of interest.

From the SIR 2015 Annual Meeting.

J Vasc Interv Radiol 2016; XX:∎∎∎–∎∎∎

http://dx.doi.org/10.1016/j.jvir.2016.05.009

Prediction of MW ablation zone dimensions for selected power and time settings is generally based on ex vivo animal data that correlate power and time settings with observed ablation zone dimensions (10–13). Manufacturers typically provide empiric charts based on ex vivo data; however, in vivo ablation zones are often smaller and more variable than desired (14). A potential alternative to the use of manufacturer charts for predicting ablation zone dimensions is to correlate cumulative energy reaching the applicator (total energy [TE]) or cumulative energy exiting the applicator (net energy [NE]) with ablation zone sizes (15). Reflected energy is the fraction of TE not crossing the tissue-applicator interface into surrounding tissues. NE exiting the applicator is determined by subtracting reflected energy from TE and is thought to more accurately quantify energy entering tissues during an ablation (15,16). Some commercially available MW ablation devices display estimates of both TE and NE (16). If NE correlates better with ablation zone dimensions than TE and manufacturer chart predictions, real-time monitoring of NE might be more useful in predicting ablation zone size and improving consistency of ablation results in patients. The purpose of this study was to determine whether TE reaching the MW applicator or NE exiting the applicator (after correcting for reflectivity) correlates better with hepatic MW ablation zone dimensions than manufacturer-provided chart predictions.

MATERIALS AND METHODS

Subjects and Tumors

This retrospective study was conducted with institutional review board approval and in compliance with the Health Insurance Portability and Accountability Act. The need for informed consent was waived. The department database of percutaneous image-guided tumor ablation procedures yielded 101 consecutive MW ablation procedures performed to treat 78 patients from August 2011 to March 2013. Of these, 42 procedures in 26 patients were excluded because multiple, overlapping ablations were performed, precluding measurements of single-application ablation zone dimensions. The resulting study cohort included 59 procedures in 52 patients to ablate 93 tumors using a single applicator and single energy application. Mean patient age was 55 years (range, 31–85 y); 30 patients were male. There were 1–6 tumors (mean 1.6) treated per procedure. Most tumors were liver metastases (n = 58); primary tumors included colorectal (n = 17), adrenal cortical (n = 8), bronchial carcinoid (n = 7), gastrointestinal stromal (n = 6), endometrial (n = 4), esophageal (n = 3), neuroendocrine (n = 3), melanoma (n = 2), non–small cell lung (n = 2), pancreatic (n = 1), breast (n = 1), prostate (n = 1), ovarian (n = 1), adenoid cystic (n = 1), and cholangiocarcinoma (n = 1). The remaining tumors were hepatocellular carcinoma (n = 32) and benign hepatic adenomas (n = 3). The mean longest tumor diameter was 2.1 cm (range, 0.7–5.9 cm).

Hepatocellular carcinomas were diagnosed with CT or magnetic resonance (MR) imaging in 19 tumors (American College of Radiology Liver Imaging Reporting and Data System, version 2014 category LR-5) (17,18) and percutaneous biopsy in 13 tumors (category LR-3 or LR-4). All patients with hepatocellular carcinoma had cirrhosis (Child-Pugh class A or B); no other patients had cirrhosis. Percutaneous biopsy diagnosed 32 metastatic tumors before or at the time of ablation; 26 metastases were diagnosed based on their development as new liver masses without benign imaging features in patients with a pathology-proven primary tumor (n = 18) or pathology-proven metastatic disease elsewhere (n = 8). Two hepatic adenomas were diagnosed by imaging characteristics, and 1 hepatic adenoma was diagnosed by biopsy.

Ablation Procedures and Techniques

All patients had an international normalized ratio < 1.5 and platelet count > 50 × 10^9/L. Each percutaneous ablation procedure was performed with an anesthesiologist providing either general anesthesia (n = 46) or intravenous moderate sedation (n = 13). One of 2 staff radiologists with 10 years and 15 years of ablation experience, respectively, performed the procedures. All ablations were performed with a 2.45-GHz MW system (AMICA; HS Medical, Boca Raton, Florida) using 1 16-gauge (n = 49) or 14-gauge (n = 10) applicator. One applicator placement and 1 application of energy were used to treat each tumor. CT with CT fluoroscopy guidance (SOMATOM Sensation Open 40; Siemens Healthcare, Malvern, Pennsylvania) was used in 53 procedures; ultrasound (Logic E9; GE Medical Systems, Milwaukee, Wisconsin) was also used in 16 of these 53 procedures. Fluorodeoxyglucose positron emission tomography/CT with CT fluoroscopy guidance (mCT; Siemens) was used in 6 procedures.

The treatment objective was an ablation zone completely encompassing the tumor with a minimum 5–10 mm margin. Ablation time and power were selected with reference to the manufacturer-provided chart (HS Medical) that correlates various combinations of power and ablation time with predicted ablation zone dimensions (AMICA Necrosis Table [package insert]. Boca Raton, FL: HS Medical: revised 2013). The chart provides separate values for 14-gauge and 16-gauge applicators that were derived empirically using ex vivo bovine liver at room temperature. A manufacturer-recommended correction factor of −10% for long axis and short axis dimensions was applied to chart values for in vivo use.

Tract ablation was applied after 41 tumor ablations. During 20 procedures, 21 ancillary maneuvers were