European Journal of Radiology 89 (2017) 136–139

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Review Article

Optimal CT scanning parameters for commonly used tumor ablation applicators

Adam E.M. Eltorai [b], Grayson L. Baird [a,b,c,e], Nicholas Monu [a,b,e], Farrah Wolf [a,b,e], Michael Seidler [a,b,e], Scott Collins [a,e], Jeomsoon Kim [d,e], Damian E. Dupuy [a,b,e,*]

[a] Department of Diagnostic Imaging, USA
[b] Warren Alpert Medical School of Brown University, USA
[c] Lifespan Biostatistics Core, USA
[d] Department of Medical Physics, USA
[e] Rhode Island Hospital, USA

ARTICLE INFO

Article history:
Received 13 September 2016
Received in revised form
22 December 2016
Accepted 5 January 2017

Keywords:
Tumor ablation
CT-guidance
Artifact reduction
Applicator

ABSTRACT

Purpose: CT-beam hardening artifact can make tumor margin visualization and its relationship to the ablation applicator tip challenging. To determine optimal scanning parameters for commonly-used applicators.

Materials and methods: Applicators were placed in ex-vivo cow livers with implanted mock tumors, surrounded by bolus gel. Various CT scans were performed at 440 mA with 5 mm thickness changing kVp, scan time, ASiR, scan type, pitch, and reconstruction algorithm. Four radiologists blindly scored the images for image quality and artifact quantitatively.

Results: A significant relationship between probe, kVp level, ASiR level, and reconstruction algorithm was observed concerning both image artifact and image quality (both $p = < 0.0001$). Specifically, there are certain combinations of kVp, ASiR, and reconstruction algorithm that yield better images than other combinations. In particular, one probe performed equivalently or better than any competing probe considered here, regardless of kVp, ASiR, and reconstruction algorithm combination.

Conclusion: The findings illustrate the overall interaction of the effects of kVp, ASiR, and reconstruction algorithm within and between probes, so that radiologists may easily reference optimal imaging performance for a certain combinations of kVp, ASiR, reconstruction algorithm and probes at their disposal. Optimum combinations for each probe are provided.

1. Introduction

Microwave, cryoablation, and radiofrequency tumor ablation are image-guided, percutaneous procedures used to effectively treat nonsurgical, solid-organ tumors while preserving surrounding healthy tissue [1–11]. Beam hardening artifacts can occur under CT guidance when the metal applicators interface with material of different attenuations [12]. Tumor margin visualization can be compromised by the artifact, possibly hindering border ablation that may lead to clinically significant effects [13–16].

To better understand ablation device-associated CT-beam hardening artifact influences on tumor margin visualization, we recently investigated[17] the effects of various scanning conditions on currently used tumor ablation applicators. With the goal of reducing applicator-associated artifacts to improve tumor margin visualization, this study aimed to determine optimal combinations of scanning parameters for several of the most commonly used applicators in tumor ablation practice.

2. Methods

2.1. Materials

Four of the most commonly used tumor ablation applicators were selected for analysis: Cool-tip Single RF electrode (Covidien), BSD SynchroWave Short Tip, Endocare Cryoprobe 2.4, NeuWave Medical LK.

As previously described [17], applicators were placed in ex-vivo cow livers (National Beef Packing Company, Kansas City, MO, USA)

* Corresponding author at: Department of Diagnostic Imaging, Warren Alpert Medical School of Brown University, Rhode Island Hospital, 593 Eddy Street, Providence, RI 02903, USA.
E-mail address: ddupuy@comcast.net (D.E. Dupuy).

http://dx.doi.org/10.1016/j.ejrad.2017.01.005
0720-048X/

Table 1
Scan conditions.

Series	Scan	Time (seconds)	Pitch	mA	kVp
kVp variation	Helical	0.5 rotation	1.75	440	80, 100, 120, 140
Pitch variation	Helical	0.5 rotation	0.5, 0.94, 1.37, 1.75	440	120
Time variation	Axial	0.5, 0.7, 1.0, 2.0	–	440	120

*Each series was reconstructed in soft, standard, and lung algorithms along with ASiR 30, 60, and 90.

at the same predetermined position with implanted mock tumors and surrounded by bolus gel (Bolx I Gel Bolus, QFix Systems, Avondale, PA, USA) to simulate surrounding soft tissue in the images. As previously described, white baby potatoes (Ahold USA, Inc., Quincy, MA, USA) were used as the mock tumors to simulate tumor-normal liver interface [18].

2.2. Scanning

Optima CT580 scanner (GE Medical Systems, Milwaukee, WI) was used for image generation. Various CT scans were performed at 440 mA with 5 mm thickness changing kVp, scan time, ASiR, and reconstruction algorithm (Table 1).

2.3. Scan interpretation

Four experienced CT readers separately scored the images for image quality and artifact quantitatively. Each measure was scored on scale for 1–10, with 1 being “poor” and 10 being “excellent.” The readers were blinded to the applicator specifications.

2.4. Statistical methods

All analyses were conducted with SAS software 9.4 (SAS Inc. Cary, NC). Image artifact and quality score were modeled with PROC GLIMMIX using a generalized mixed model assuming a binomial distribution with sandwich estimation. Differences between combinations of probes, kVp levels, ASiR levels, and reconstruction algorithm were assessed using least squares estimation with Bonferroni corrections. Agreement between readers was calculated using Kendall’s Coefficient of concordance for ordinal response for each applicator and overall for both image quality and artifact. Alpha was set at the 0.05 level for all analyses and interval estimates were calculated for 95% confidence.

3. Results

3.1. Agreement

Suitable agreement was demonstrated across probes for artifact (0.80) and quality (0.66). Agreement for each probe is presented in Table 2.

A significant relationship between probe, kVp level, ASiR level, and reconstruction algorithm was observed concerning both image artifact and image quality (both $p = < 0.0001$). Specifically, there are certain combinations of kVp, ASiR, and reconstruction algorithm that yield better images than other combinations. In particular, Probe 1 performed equivalently or better than any competing probe considered here, regardless of kVp, ASiR, and reconstruction algorithm combination. For clarity and ease of interpretation, the differences between combinations of kVp, ASiR, and algorithm between probes is illustrated in Figs. 1 and 2 and within each probe is illustrated in Fig. 3. These figures illustrate the overall interaction of the effects of kVp, ASiR, and reconstruction algorithm within and between probes, so that radiologists may easily reference optimal imaging performance for a certain combinations of kVp, ASiR, reconstruction algorithm and probes at their disposal. Optimum combinations for each probe are provided in (Table 3).

Table 2
Kendall’s Coefficient of Concordance for ordinal response.

Probe #	Artifact	Quality
1	0.79	0.67
2	0.90	0.71
3	0.72	0.66
4	0.77	0.59
Overall	0.80	0.66

All $p < 0.001$.

4. Discussion

With the goal of reducing applicator-associated artifacts to improve tumor margin visualization under CT guidance, we aimed to determine optimal combinations of scanning parameters for several of the most commonly used applicators in tumor ablation practice. We found significant relationships and interaction effects between probe, kVp level, ASiR level, and reconstruction algorithm with regard to both image artifact and image quality. Moreover, for each probe certain combinations of kVp, ASiR, and reconstruction algorithm yielded better images than other combinations. We summarized optimum combinations for each probe so that interventional radiologists may easily reference optimal imaging parameters for individual probes.

Interestingly, regardless of kVp, ASiR, and reconstruction algorithm combination, performed equivalently or better than any competing probe considered here. Such results could be used to inform applicator device development. The methods used for scan setting optimization could be applied to other applicators, such as biopsy needles.

There are several limitations in this study. The use of a single CT scanner may call into question the generalizability of the results. However, this enabled control of data acquisition variability. The *ex vivo*, mock tumor experimental setup is a pre-clinical surrogate for clinical conditions. Because of the sheer number of possible factors to consider, an exhaustive review of all possible factors and their respective levels would not be feasible in terms of time and resources and the complexity of the results would be overwhelming. For example, there are 144 different scan setting combinations when considering 4 probes, 4 kVp levels, 3 ASiR levels, and 3 reconstruction algorithms alone. If we were to compare all of these combinations, there would be 10,296 difference comparisons made. With this in mind, we chose to evaluate the parameters we felt would most likely improve image quality and reduce artifact while other possible factors of image quality and artifact were held constant.

Table 3
Optimal scanning conditions for each applicator.

Probe #	ASiR	KvP	Reconstruction
1 – Cool-tip single RF (Covidien)	30	140	Soft
2 – BSD SynchroWave Short Tip	30	120	Lung
3 – Endocare Cryoprobe 2.4	60	120	Lung
4 – NeuWave Medical LK	30	140	Lung