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Radiation dose in CT-guided microwave liver tumor ablation

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Introduction. Ablation is one of most important methods of liver tumor treatment. However, radiation is one of disadvantages of CT-guided procedures including ablation. The purpose of this study is to assess the factors that have impact on radiation doses during CT-guided microwave liver tumor ablation.

Material and methods. Radiation doses of CT-guided liver tumor ablations were collected in 127 patients. They were then compared in terms of number of lesions, lesion size and depth, use of additional localization needles and hydrodissection as well as tumor location.

Results. The median radiation doses of ablations of multiple tumors (2348 mGy*cm) were significantly higher (p = 0.03) than those of single tumors (1784 mGy*cm). No statistically significant differences were noted when other factors (lesion size, depth, location, use of localization needles and hydrodissection) were taken into consideration.

Conclusions. The number of lesions is the most important factor in terms of expected radiation doses in CT-guided microwave liver tumor ablations.

Key words: microwave ablation, radiation dose, CT-guided ablation

Introduction

Thermal ablation is an established method of liver tumor treatment [1, 2]. It is frequently performed with CT-guidance due to its high spatial resolution as well as the ability to precisely visualize needles and organs [3]. However this method of guidance is associated with radiation that can potentially increase the risk of malignancy [4, 5]. The risk is low but not negligible and, according to the ALARA concept, the radiation should always be kept as low as reasonably possible. This study is an attempt to estimate those factors affecting radiation doses during CT-guided liver ablation procedures.

Materials and methods

The institutional bioethical committee waived the need for formal consent due to retrospective nature of this study. 127 consecutive patients (85 males, 42 females) underwent liver tumor ablations between 2018 and 2019; 88 of them had single tumor, while 39 patients had multiple (89) tumors. Among the tumors there were 43 hepatocellular carcinomas (HCCs) and 134 metastases: breast cancer (n = 4), neuroendocrine tumors (NET) (n = 4), colorectal cancer (n = 126). The mean age of the patients was 69 years (range 25–91).

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	n total	Mean	Standard deviation	Minimum	Median	Maximum	p value
DLP for single tumors [mGy*cm]	88	2377	1697	450	1784	7518	0.03
DLP for multiple tumors [mGy*cm]	39	2333	746	967	2348	3839	

All procedures were performed percutaneously with a microwave ablation device (Solero, Angiodynamics, Lantham, NY, USA), under general anesthesia. The ablations were done under CT-guidance using 320 slice Toshiba Aquilion One scanner (Toshiba/Canon, Nasu, Japan). Ultrasound was done just before every procedure to make sure no new lesions were visible and the tumor was still ablatable. Non-enhanced CT was performed at the beginning of every procedure to visualize the tumor. Then 3-slice (quick-check) scans were done during the procedure, every time the needle was advanced into the tumor.

After the ablation needle was removed, a 3-phase CT scan was done to estimate the ablation zone size and location, with a special focus on oncological margins of at least 5–10 mm. The following parameters were used for spiral CT scans: 120 kV and 300 mA for spiral scans or 50 mA (quick-check scans). No real-time CT-fluoroscopy was used during the procedures.

In 48 patients who had large tumors (>20 mm), one or two localization needles were used (Chiba, 21G, Cook, Bloomington, IN, USA). Those needles were placed to mark the borders of the tumors that required multiple ablation sessions. Hydrodissection was performed in 5 patients. A thin (22 G) needle was placed under CT guidance in a narrow (1–3 mm) space between the liver and adjacent stomach, colon or kidney. Between 50 and 200 ml of normal saline was then injected to isolate these structures from the heat produced during ablation and to prevent thermal damage to those organs.

Data on radiation doses in terms of dose length product were collected from the dose report generated by the scanner. The effective dose in mSv was calculated by multiplying by a factor of 0.015 [6]. The carcinogenic effect of the procedure, defined as excess risk of malignancy, was calculated at 5% per sievert [7].

The CT images from the procedures were retrospectively reviewed and the following data were collected: number of lesions, lesion size, number of localization needles inserted, hydrodissection application, lesion depth (from the entry point on the skin), location of the lesion (liver segment).

Statistical analysis

The Shapiro-Wilk test was used to assess the normality of distribution of the investigated parameters. Differences were tested by the Wilcoxon rank-sum test and Kruskal-Wallis test. Pearson's correlation was used to analyze the association between DLP versus depth and DLP versus diameter. The values p < 0.05 were considered statistically significant. Statistical analysis was done using R environment (version 3.3.2, The R-Foundation, Austria).

Results

Ablations of multiple tumors were associated with higher radiation doses than single tumors in terms of DLP. Median DLP (mGy*cm) for single tumors was 1784 (range: 450–7518) while for multiple tumors it was 2348 (967–3839) and the difference was statistically significant (p = 0.03) (tab. I). The median effective doses were calculated at 26.8 mSv and 35.2 mSv respectively.

There was no statistical significance (p = 0.23) (fig. 1) in DLP increase in patients in whom localization needles were
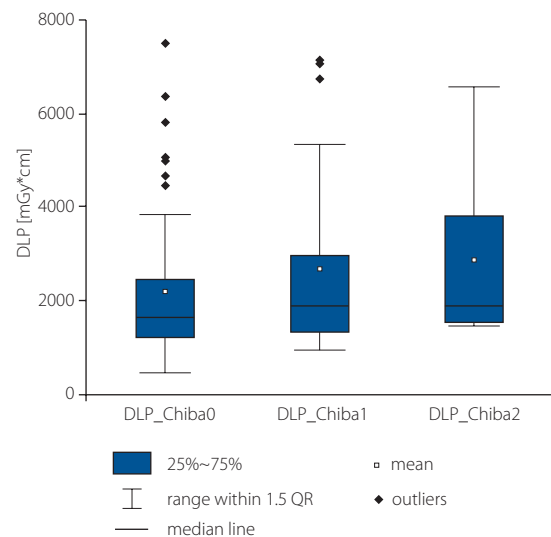

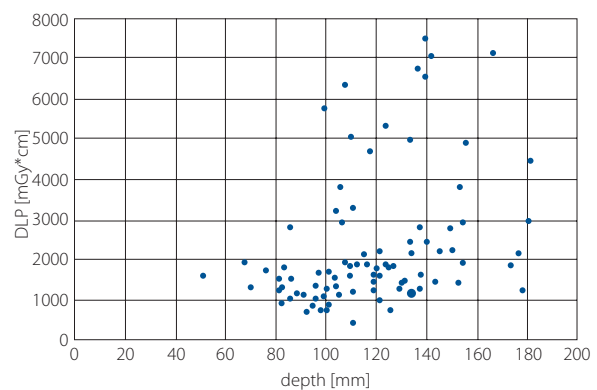**Figure 1.** Radiation doses (DLP) by a number of localization needles used

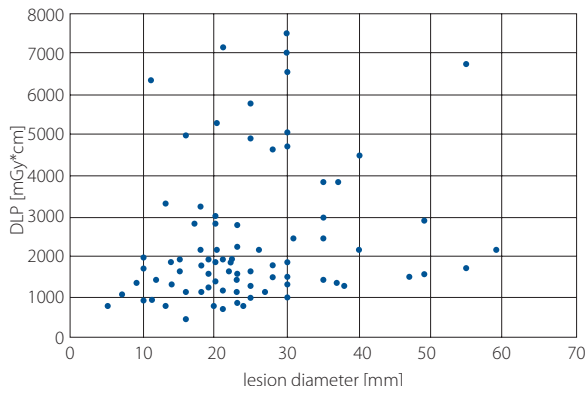**Figure 2.** Radiation doses (DLP) by lesion depth

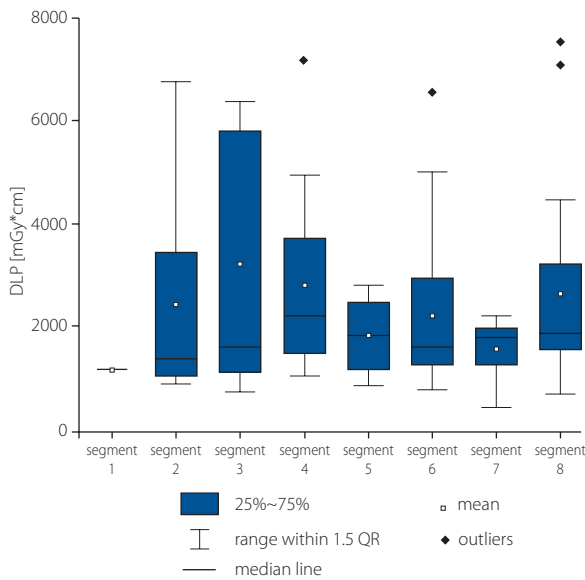**Figure 3.** Radiation doses (DLP) by lesion diameter

Figure 4. Radiation doses (DLP) in ablations of lesions in particular liver segments
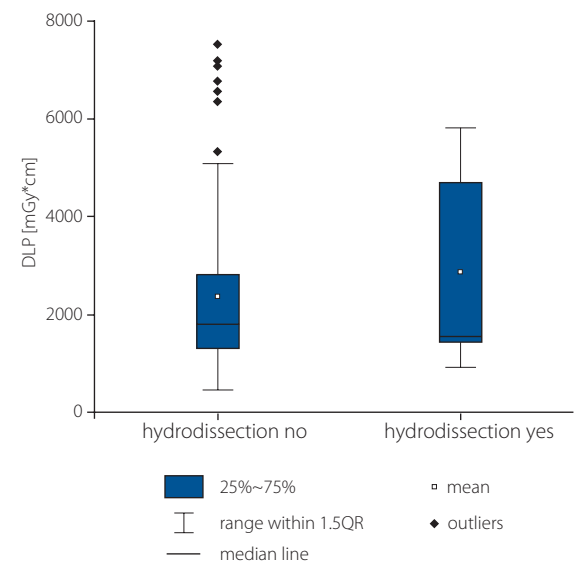

Figure 5. Radiation doses (DLP) during ablation without and with hydrodissection

used. The correlation between DLP and lesion depth or size was very weak and was not statistically significant (fig. 2 and fig. 3). Similarly, the location (by liver segment, fig. 4) of the lesion and the use of hydrodissection (fig. 5) did not have a statistically significant impact on the radiation doses. The estimated lifetime excess risk of malignancy was calculated at 0.10% for ablations of single lesions and 0.14% for ablations of multiple lesions.

Discussion

CT-guidance is frequently used in percutaneous liver tumor ablation due to its excellent spatial resolution and ability to visualize organs and needles with high quality. In many cases ultrasound is not able to show all tumors, especially in a cirrhotic liver or after chemotherapy. Additionally, ultrasound is not a reliable way to show the ablation zone and margin size which is an independent predictor of local tumor progression [8].

Radiation is one of the disadvantages of this method and doses should be kept as low as reasonably achievable (ALARA). The radiation doses in terms of DLP had quite a wide range (450–7518 mGy*cm). Out of several parameters, the number of ablated lesions was a factor that had a significant impact on the radiation dose. Ablation of multiple tumors caused higher radiation than procedures done on single lesions (median 2348 *vs.* 1784 mGy*cm which corresponds to 35 *vs.* 26 mSv).

The results are comparable to other studies. In a publication by Hu et al. [9] the radiation doses acquired during CT-guided ablation were slightly higher and estimated at 41.1 mSv. Similar results were reported by McCarthy et al. [10] where the estimated radiation dose was 30.7 mSv. It is worth noting that the results are similar in many aspects even though the procedures were performed in different centers on different CT scanners.

As opposed to the results of the study by McCarthy et al. [10], hydrodissection was not a factor that would cause a statistically significant increase in radiation dose. The small number of patients that had this additional measure applied in our study could be the reason for such results. However, this result corresponds to other data in our study, especially the application of localization needles as both techniques (hydrodissection and localization needles) require additional punctures and should have a similar impact on the radiation dose.

The lack of statistical significance between radiation doses in the ablation of small and large lesions was somewhat unexpected since large lesions require more needle repositioning and thus more scans. Radiation doses for patients with additional localization needles did not show statistically significant differences. Higher radiation doses in such procedures were expected since they required additional scans to insert the needles precisely into the tumor's border. Moreover, there was a lack of statistical significance when lesion size, depth or location (liver segment) were taken into consideration.

The range of radiation dose values was fairly wide so it remains possible that factors other than the number of lesions have a significant impact. If the effects of lesion size, depth, location (liver segment), hydrodissection and additional needles on radiation doses exist, they seem to have been dominated by other, unknown factors. The effect of "difficulty" of the procedure could be such a factor. Some tumors are more difficult to ablate than others, but no clear parameters have been defined so far. It is possible that the difficulty of the procedure depends on many factors and such complexity makes it hard to clearly define it. That said, the search for such parameters could be a subject of further studies.

This study did not include contrast injections as a factor potentially affecting the radiation dose [10] since all patients had a contrast enhanced CT after needle removal. This step is necessary to assess margin size which predicts the risk of local tumor progression [11]. The majority of radiation doses in CT-guided procedures comes from helical scans [12]. Limiting such scans by replacing some of them with quick-check scans can significantly reduce the radiation dose in CT-guided procedures [13]. However, it can be difficult in such complex procedures as ablations where the operator needs to have high quality visualizations of large volumes of liver tissue. While limiting radiation in CT-guided procedures is important, it should not be done at the cost of reducing the effectiveness of precise needle placement.

The excess risk of malignancy was calculated at 0.10 (single lesions) or 0.14% (multiple lesions) which compares favorably with 0.43% of children and young adults who underwent regular CT scans [14]. The radiation doses acquired by patients who underwent liver tumor ablations correspond to doses acquired during 2–4 multiphase abdominal CT scans.

Liver tumor ablation is a safe procedure with very low major complication rates, from 1.1% [15] to 5% [16], with practically no post-procedural mortality. This compares favorably to liver tumor resection where complications tend to be more frequent, e.g. 27.5% [16]. The results of our study show that excess risk of malignancy in liver tumor ablation is low and in our opinion it should not be a major factor when making decisions on liver tumor treatment. Considering the high efficacy of ablation in liver tumor treatment [17] and its low carcinogenic effect, the potential health gains outweigh the risks of the procedure. The retrospective nature of this study is one of its limitations. Variations in ablation technique between the operators may have also affected the outcomes. Also, the applied conversion factor that was derived from ICRP [7] is designed to estimate the risk to the general population more than individual patients.

Conclusions

The radiation doses and excess risk of malignancy in CT-guided liver ablation are low. The risks are higher in ablations of multiple tumors, however lesion size, depth and location or application of hydrodissection or additional needles do not have a significant impact on radiation dose.

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