Technologist-Based Implementation of Total Metabolic Tumor Volume into Clinical Practice

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Metabolic tumor volume (MTV) is defined as the total metabolically active tumor volume seen on ^{18}F-FDG PET/CT examinations. Calculating MTV is often time-consuming, requiring a high degree of manual input. In this study, the MTV calculations of a board-certified nuclear radiologist were compared with those of 2 nuclear medicine technologists. As part of the technologists' educational program, after their classroom time they were trained by the radiologist for 30 min. The technologists calculated MTV within 7.5% of the radiologist's calculations in a set of patients who had diffuse large B-cell lymphoma and were undergoing initial staging ^{18}F-FDG PET/CT. These findings suggest that nuclear medicine technologists may help accelerate implementation of MTV into clinical practice with favorable accuracy, possibly as an initial step followed by validation by the interpreting physician. The aim of this study was to explore whether efficiency is improved by integrating nuclear medicine technologists into a semiautomated workflow to calculate total MTV.

Key Words: oncology; PET/CT; quality assurance; MTV; PET/CT; tumor segmentation

Metabolic tumor volume (MTV) can be calculated from ^{18}F-FDG PET/CT by many methods and may help predict patient outcomes, especially for those with diffuse large B-cell lymphoma (DLBCL) (1–5). MTV is a volume defined either by quantitatively or manually selected segments representing the metabolically active tumor on ^{18}F-FDG PET/CT (1). Total MTV is calculated by adding the MTV of all malignant lesions and is a method for measuring total tumor burden. Total MTV has shown promise in the initial staging of DLBCL and in determining its treatment response (2,4,6,7). However, tumor segmentation of ^{18}F-FDG–avid lesions on PET/CT is often time-consuming. Advancements in threshold-based segmentation methods for filtering out background activity or signal-to-background ratios have been proposed to increase the efficacy of results (3).

Therefore, the optimal tumor segmentation method varies with the purpose of the study.

DLBCL is the most common type of non-Hodgkin lymphoma (8). The current standard for staging DLBCL is the Lugano classification, which includes a 5-point Deauville score when staging with ^{18}F-FDG PET/CT (9), yet many studies support the significant prognostic value of total MTV in DLBCL (2–7,9). This study explored the use of nuclear medicine technologists for clinical implementation of total MTV.

MATERIALS AND METHODS

Two nuclear medicine technologists at Mayo Clinic in Rochester underwent a 30-min training session by a board-certified nuclear radiologist on distinguishing physiologic from pathologic lymphomatous ^{18}F-FDG uptake. The technologists previously completed 4 mo of technologist classroom time and 8–12 h of experience observing the technologist side of clinical PET practice ($\sim$85 examinations per day). The technologists had no other PET education or image interpretation experience. The patient cohort comprised 10 random patients with DLBCL who were treated at a large tertiary referral center between June 22, 2016, and September 24, 2018. The technologists independently evaluated the examinations from these patients before and after systemic therapy. The technologists and the radiologist separately reviewed the images using the LesionID workflow (MIM Software Inc.). The workflow automatically segments PET lesions on the basis of an absolute SUV_{max} threshold. The threshold was set using the SUV_{max} within a 3-cm spheric region of interest within normal liver. The workflow then segmented everything with an SUV_{max} greater than the liver threshold. The technologists and the radiologist separately evaluated each segmentation to distinguish lymphoma from nonlymphomatous or physiologic segmentation. The nonlymphomatous segments were deleted after noting the anatomic location, and the total MTV was then calculated. If the student was uncertain whether a segment included lymphoma, the segment was included in the MTV calculation.

RESULTS

The mean ($\pm$SD) MTVs of the 10 patients were 446.0 cm^3 ($\pm$555.6 cm^3) and 38.5 cm^3 ($\pm$77.6 cm^3) for the radiologists and 414.8 cm^3 ($\pm$597.6 cm^3) and 27.7 cm^3 ($\pm$57.3 cm^3) for the technologists in the pre- and posttherapy examinations, respectively (Fig. 1). The mean MTVs were 7.5% and 28.0% higher for the radiologists than for the technologists in the
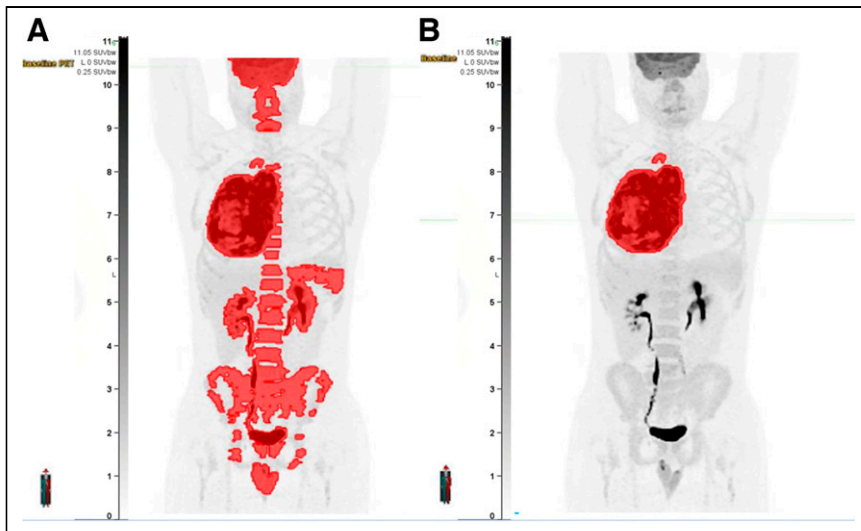
FIGURE 1. (A) Maximum-intensity projection from ^{18}F-FDG PET in patient with DLBCL demonstrating automated segmentation using normal-liver SUV as threshold, with volumetric regions of interest produced throughout body. (B) After manual input from technologists, segments around physiologic uptake are removed and only lymphomatous lesions are segmented.

pre- and posttherapy examinations, respectively. In 2 of the 10 patients, the technologists missed critical segments: a mediastinal mass that was perceived as physiologic heart uptake and a scalp lesion mistaken for physiologic brain activity. The mean number of nonlymphomatous segments removed was 20.6 (range, 8–28) and 18.3 (range, 9–41) for the radiologist and 19.2 (range, 7–33) and 17.8 (range, 7–49) for the

technologists in the pre- and posttherapy examinations, respectively. Common sites of removed physiologic segmentation included the urinary bladder (5%), brain (5%), lung (7%), mouth (8%), bowel (8%), kidney (22%) and musculoskeletal system (25%). Statistical analysis revealed no significant difference in total MTV or number of lesions between technologists and radiologist (Table 1).

DISCUSSION

Our study demonstrates a potential role for technologists in calculating total MTV for patients with DLBCL. We developed an effective 2-step MTV calculation workflow: in the first step, the technologist sets a threshold, removes obvious erroneous segments, and flags uncertain segments; in the second step, the radiologist reviews and finalizes the segmentation for MTV calculation. The technologist might then review the final segmentation for continuous feedback and quality improvement, especially around areas with high physiologic uptake, which were the regions of discordant reporting between the technologists and the radiologist. There was a minor difference in calculation of the total MTV between the technologists and the radiologist, with the technologists missing 2 major lymphomatous lesions.

TABLE 1
Comparison of Technologists' and Radiologists' Pretherapy and Posttherapy MTVs ($P = 0.893$) and Number of Lesions ($P = 0.771$)

Patient no.	Timing	MTV (cm^3)		Student and radiologist absolute difference in MTV	Total lesions (n)	
		Technologist	Radiologist		Technologist	Radiologist
1	Posttherapy	0	0	0	10	15
1	Pretherapy	60	428	368	31	27
2	Posttherapy	0	0	0	7	12
2	Pretherapy	4	11	7	9	20
3	Posttherapy	0	0	0	14	14
3	Pretherapy	102	102	0	10	10
4	Posttherapy	106	214	108	27	41
4	Pretherapy	1,059	1,041	18	28	28
5	Posttherapy	0	0	0	12	12
5	Pretherapy	48	47	1	33	27
6	Posttherapy	171	171	0	24	15
6	Pretherapy	1,573	1,581	8	17	23
7	Posttherapy	0	0	0	49	39
7	Pretherapy	4	4	0	22	22
8	Posttherapy	0	0	0	11	11
8	Pretherapy	1,296	1,130	166	11	17
9	Posttherapy	0	0	0	10	9
9	Pretherapy	0	0	0	24	24
10	Posttherapy	0	0	0	14	15
10	Pretherapy	2	102	100	7	8

Our results demonstrate that technologists with minimal training can aid radiologists in tumor segmentation using a fixed absolute threshold of normal-liver SUV_{max}. This threshold method has proven favorable in calculating MTV to aid in predicting prognosis and outcomes (*1,10–12*).

Segmenting tumors on ^{18}F-FDG PET remains challenging because of the relatively low resolution of PET images, the partial-volume effect, the high variability of biodistribution, and the high intensity of physiologic uptake (*12*). To increase the efficiency of tumor segmentation, an alternative to the use of technologists is the use of artificial intelligence and machine learning (*13–15*). Early studies have shown promise in using a deep learning method to generate total MTVs prognostic of outcome in a large group of patients with DLBCL (*13*).

CONCLUSION

Our results on a group of patients with DLBCL suggest that the use of technologists as a preliminary step in calculating total MTV has favorable accuracy. However, more data are needed to support this approach.

DISCLOSURE

No potential conflict of interest relevant to this article was reported.

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