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VARIABILITY OF GROSS TUMOR VOLUME DELINEATION IN HEAD-AND-NECK CANCER USING PET/CT FUSION, PART II: THE IMPACT OF A CONTOURING PROTOCOL

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Abstract—The purpose of this study was to assess the efficacy of a gross tumor volume (GTV) contouring protocol on interobserver variability between 4 physicians in positron emission therapy/computed tomography (PET/CT) treatment planning of head-and-neck cancer. A GTV contouring protocol for PET/CT treatment planning was developed utilizing 4 stages: Preliminary contouring on CT alone, determination of appropriate PET windowing, accurate image registration, and modification of CT contouring with correctly formatted PET/CT display and rules for modality disagreement. Two neuroradiologists and 2 radiation oncologists (designated as A, B, C, and D, respectively) were given a tutorial of PET/CT coregistered imaging individualized to their skill level, which included a step-by-step explanation of the protocol with clinical examples. Opportunities for questions and hands-on practice were given. The physicians were asked to re-contour 16 head-and-neck patients from Part I on PET/CT fusion imaging. Differences in volume magnitude were analyzed for statistical significance by analysis of variance (ANOVA) and paired t-tests ($\alpha < 0.05$). Volume overlap was analyzed for statistical significance using Wilcoxon signed-rank tests ($\alpha < 0.05$). Volume overlap increased significantly from Part I to Part II ($p < 0.05$). One previously significant difference between physicians disappeared with the protocol in place. The mean fusion volume of Physician C, however, remained significantly larger than that of Physician D ($p < 0.01$). This result is unchanged from Part I. The multidisciplinary contouring protocol significantly improved the coincidence of GTVs contoured by multiple physicians. The magnitudes of the volumes showed marginal improvement in consistency. Developing an institutional contouring protocol for PET/CT treatment planning is highly recommended to reduce interobserver variability. © 2009 American Association of Medical Dosimetrists.

Key Words: **GTV delineation, PET/CT fusion, Head-and-neck cancer, Interobserver variation.**

INTRODUCTION

The use of ^{18}flurodeoxyglucose positron emission tomography (FDG-PET) in radiotherapy planning has drastically increased with the ability to coregister functional image sets with anatomical image sets such as computed tomography (CT) and the implementation of integrated PET/CT scanners. The fusion of PET and CT imaging data not only provides metabolic information superimposed upon an anatomical map, but integrated PET/CT scanners decrease acquisition time by using CT for attenuation correction of PET.[1]

Physicians use PET/CT to improve tumor localization, which is critical for treatment techniques such as intensity modulated radiation therapy (IMRT) that make highly conformal plans with steep dose gradients. As IMRT is of particular use in head-and-neck cancer (HNC), PET/CT is now being investigated for its efficacy in head-and-neck IMRT, with promising preliminary results.[2,3]

Several studies in the literature have investigated the effect of PET/CT coregistered imaging on HNC target volume definition generally with good indications.[4–8] PET/CT has been reported to reduce interobserver (IO) variation in HNC,[8–10] but our previous experience has shown that significant IO variation occurs with PET/CT compared to CT alone.[11]

One solution recommended by sources in the literature is the implementation of an explicit set of instructions in the form of a contouring protocol.[12–14] The efficacy of a structured protocol on IO variation is not trivial: One group achieved success with a contouring protocol for lung tumors on CT alone,[15] but another did not; IO variation persisted despite the use of a contouring protocol.[16] A multidisciplinary team of physicians at our institution has designed a GTV delineation protocol for PET/CT treatment planning of HNC. The goal of the current study is to test the efficacy of this contouring protocol in reducing IO variation in GTV delineation of HNC in PET/CT treatment planning.

The abstract of this study was accepted for poster display at ASTRO 2006 in Philadelphia, November 5–9, 2006.

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Table 1. Patient characteristics

Patient No.	Age (years)	Sex	Location	Type
1	47	M	Nasopharynx	SCC
2	77	F	Cervical esophagus	SCC
3	51	M	L nasal vestibule	SCC
4	58	M	Nasopharynx	SCC
5	56	M	L tonsil	SCC
6	41	M	Nasopharynx	SCC
7	45	M	R maxillary sinus	NHL
8	53	M	Larynx	SCC
9	54	F	L base of tongue	SCC
10	74	M	L orbit	B-cell lymphoma
11	49	M	Nasopharynx	SCC
12	53	M	R base of tongue	SCC
13	41	M	L base of tongue	SCC
14	75	M	Glottis	SCC
15	97	F	L optic nerve	Melanoma
16	58	M	R base of tongue	SCC

Abbreviations: SCC, Squamous cell carcinoma; NHL, non-Hodgkin's lymphoma.

METHODS AND MATERIALS

Study participants

The physicians and patients involved in the current study are the same as the previous study,[11] henceforth referred to as "Part I." Physicians A and B were neuroradiologists and Physicians C and D were radiation oncologists with 17, 15, 4.5, and 13 years experience, respectively. Sixteen (16) HNC patients, 13 men and 3 women of varying diagnoses (Table 1), underwent PET/CT simulations as per the previous scan protocol between April 2004 and February 2005 and were re-enrolled in the current study. Physicians were given several months in between studies (range = 4.3 to 9.3 months, mean = 5.8 months) to minimize any memory bias.

Contouring protocol

The contouring protocol was developed by physicians in the radiation oncology, radiology, and nuclear medicine departments at St. Vincent's Hospital and Comprehensive Cancer Center. The 4-stage procedure included:

1. Determination of GTV on the CT scan alone. CT windowing was left to the physician's discretion.
2. Determination of appropriate PET window. Using a monochromatic display (typically inverted grayscale) to view the PET images alone, the lower window was set to zero and the upper window was set to a level at which heterogeneities in the tumor uptake could be visually identified (to avoid saturation of the activity window).
3. Image fusion. Several steps were important:
   a. Monochromatic PET display (not blue-gold or other multicolor schemes). Monochromatic display was essential to optimal fusion viewing. Multicolor patterns are often non-continuous in their color assignments and tend to create false borders between activity levels. Physicians involved in protocol development agreed that yellow monochrome offered the best contrast against the CT and between varying levels of PET activity.
   b. Activity levels adjusted to those set in step 2.
   c. Adjust blending level of CT vs. PET. Protocol developers agreed that 70%/30% PET/CT was an acceptable on-screen balance of the 2 modalities.
   d. Image registration check. Physicians were encouraged to check the registration of the images by looking for bony landmarks and correlating brain soft tissue and brain activity.
4. Fusion contouring. Using the previously drawn CT contour as a guide, physicians drew new contours (or adjusted the existing one) to incorporate the properly adjusted PET information. Rules were created for any disagreements of malignancy between the 2 modalities:
   a. If a minor discrepancy existed, the smallest GTV that would include both indications was chosen provided that: (1) Tissue exists on the CT that could be gross tumor, and (2) no completely different structure (vessels, spinal cord, etc.) overlaps with the suspicious area that precludes gross tumor from being there.
   b. If a major discrepancy existed, the CT and PET images were scrutinized: (1) If tumor exists on CT but not on PET, check PET to see if tumor has lower uptake than expected for malignancy.[17–20] (2) If tumor exists on PET but not CT, investigate other explanations for uptake in normal tissue, such as fibrosis or infection, or (3) check adjacent structures for physiologic or pathologic uptake.

Tutorial

Each physician was given a short educational session on PET/CT by a nuclear medicine physician and a tutorial of the contouring protocol developed at the institution. The tutorial was individualized to their skill level and included a step-by-step explanation of the protocol with clinical examples. Opportunities for questions and hands-on practice with the protocol were given.

Although the tutorial followed the protocol unambiguously and physicians were urged to follow each step explicitly during actual contouring, it was stated that some steps (such as the amount of blending and color preference) were recommendations and were discretionary within reason. Physicians were allowed to switch back and forth between single modalities, and were encouraged to shift activity leveling on PET to observe various iso-activity contours, but it was emphasized that each physician should perform each step of the protocol *before* any discretionary changes.