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Research Article

Investigating the Impact of Positron Emission Tomography–Computed Tomography Versus Computed Tomography Alone for High-risk Volume Selection in Head and Neck and Lung Patients Undergoing Radiotherapy: Interim Findings

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ABSTRACT

Introduction: The aim of this study was to quantify the impact of positron emission tomography–computed tomography (PET-CT) on clinical target volume (CTV) selection in non–small cell lung cancer (NSCLC) and head and neck squamous cell cancer (HNSCC) cancer patients.

Methods: Eight radiation oncologists with expertise in either NSCLC or HNSCC prospectively contoured target volumes with and without PET-CT findings. All volumes were contoured manually, and computed tomography (CT)-alone contours were identified as gross tumour volume CT and clinical target volume (CTV) CT, whereas those contoured with the aid of PET-CT were GTV PET and CTV PET. PET-CT contours were used for actual treatment delivery. Test treatment plans were generated based on the CT-alone volumes and applied to the final PET-CT contours. PET-CT had an impact if the test plans failed department quality assurance guidelines. For each patient, the dose to critical structures and any changes in the treatment plan were recorded.

Results: Eighty patients (49 HNSCC and 31 NSCLC) were analyzed. PET-CT impacted 42.9% of HNSCC cases and 45.2% of NSCLC cases. On average, PET-CT volumes were significantly larger than CT-alone volumes for HNSCC cases ($P < .01$) but not for NSCLC cases ($P = .29$). For organs at risk, no statistically significant differences were noted, with the exception of mean parotid dose for the right and left parotids ($P = .0137$and $P = .0330$, respectively).

Conclusions: Interim analysis of data found that the use of PET-CT in the radiation therapy planning process impacted CTV selection, resulting in a major change in radiation therapy plans in 43.7% (HNSCC 42.9% and NSCLC 45.2%) of patients.

RESUMÈ

But : Quantifier l'effet de la TEP-TDM sur le choix du volume cible clinique (VCC) chez les patients atteints d'un cancer du poumon non à petites cellules (CPNPC) ou d'un cancer à petites cellules de la tête et du cou (CPCTC).

Méthodologie et matériel : Huit radio-oncologues possédant une expertise en CPNPC ou en CTCNPC ont tracé le volume cible de manière prospective avec et sans les constats de TEP-TDM. Tous les volumes ont été établis manuellement et les contours établis à l'aide de la TDM seule ont été désignés VCG-TDM, and VCC-TDM, alors que les volumes tracés à l'aide de la TEP-TDM ont été identifiés VCG-TEP et VCC-TEP. Les contours TEP-TDM ont été utilisés pour le traitement. Les plans de traitement tests ont été générés à partir des volumes obtenus par TDM seulement et appliqués aux contours finaux définis par TEP-TDM. La TEP-TDM a eu une incidence si les plans tests échouaient aux lignes directrices d'assurance de la qualité du service. Pour chaque patient, la

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dose aux structures critiques ainsi que les modifications aux plans de traitement, le cas échéant, ont été enregistrés.

Résultats : Les résultats pour 80 patients (49 CPCTC et 31 CPNPC) ont été analysés. La TEP-TDM a eu une incidence dans 42,9 % des cas de CPCTC et dans 45,2 % des cas de CPNPC. En moyenne, les volumes établis par TEP-TDM étaient significativement plus grands que les volumes établis par TDM seulement pour les cas de CPCTC ($p<0,01$) mais non pour les cas de CPNPC ($p=0,29$). En ce qui a trait aux organes à risque, aucune différence statistiquement importante n'a été notée, à l'exception de la dose moyenne à la parotide pour les parotides droite et gauche ($p=0,0137$et $p=0,0330$, respectivement).

Conclusions : L'analyse intérimaire des données indique que l'utilisation de la TEP-TDM dans le processus de planification des traitements de radiothérapie a une incidence sur le choix du VCC, entraînant des modifications importantes aux plans de RT chez 43,7 % des patients (CPCTC 42,9 % et CPNPC 45,2 %).

Keywords: Clinical target volume; head and neck squamous cell carcinoma; impact; non–small cell lung cancer; positron emission tomography–computed tomography; radiotherapy planning

Introduction

Advances in radiation therapy (RT) are increasing precision and accuracy of delivery. To optimize local-regional control and decrease morbidity, radiation oncologists (ROs) are tasked to perfect target volume (TV) delineation.

The clinical target volume (CTV) is one of the most crucial TVs and represents the region that should be treated to a high dose, typically including both the gross tumour and the volumes that are thought to be at risk [1]. Too large a CTV may increase morbidity unnecessarily; too small a CTV may result in decreased probability of cancer eradication. Therefore, accuracy in CTV definition is fundamental to obtain tumour control and reduce side effects [2]. Delineation of TVs is currently one of the main sources of error in RT, and it has been postulated that the success of radiotherapy depends on the accurate delineation of the CTV [2, 3]. This is supported by a recent retrospective study [4] that examined the impact of treatment plans that were considered noncompliant with fundamental principles of RT. Of 97 plans that had deficiencies, 24 were identified as having incorrect target delineation that resulted in a major adverse impact on the treatment outcome.

Several tools are available to the RO to assist in accurate TV contouring including magnetic resonance imaging (MRI), computed tomography (CT), and positron emission tomography (PET) [5]. CT and MRI provide anatomic details but lack the ability to delineate between malignant and nonmalignant tissue; therefore, they may not adequately estimate TVs [6]. By combining imaging at the metabolic level (PET) with precise anatomy imaging (CT), PET-CT is a powerful imaging modality that has the ability to detect radiographically occult lesions as well as identify radiographic abnormalities.

The value of PET-CT in oncology in general is well established. Foremost, for non–small cell carcinoma (NSCLC), it is well-known and reported that PET-CT has high sensitivity (95%) and specificity (81%) for detecting positive nodes, and equally high sensitivity (88%) and specificity (91%) for detecting mediastinal disease [7]. For head and neck squamous cell carcinoma (HNSCC), the sensitivity and specificity of PET-CT for detecting lymph node involvement is superior to other imaging technologies such as CT and MRI [8]. Schwartz et al [9] reported that PET-CT provides significant neck staging improvements in sensitivity (96%) and negative predictive value (98.5%) over CT alone. Specific to RT, a further benefit of PET-CT in RT planning is its ability to increase reproducibility compared with CT alone [10], and therefore decrease interobserver variability. As stated by Kruser et al [11], volumes defined by CT alone are subject to high interobserver variability, and the use of PET-CT has been shown to reduce this variability.

Numerous studies [8,12–16] have reported the impact of PET-CT on radiotherapy and suggest that overall patient management and RT volumes are altered in 30% to 100% of cases when PET information is incorporated. This large range in the estimate of PET impact can be contributed to several factors including study design, study size and, more relevantly, how impact was defined. The definition of PET-CT impact ranges from changes in treatment design, any measured TV change, and dosimetric impact to surgical comparison. For HNSCC specifically, examples of this range of defining PET-CT impact includes any gross tumour volume (GTV) change $>$ 25% [17], any change at all in TV size [18], any "significant" change in TV [12], and any GTV volume change $>$ 20% [11]. In the NSCLC literature, a similar large range of PET-CT impact is observed. Nestle et al [19] summarized the results of 18 trials involving 661 lung patients and found that changes in TVs because of PET-CT ranged from 21% to 100%. Similarly, MacManus and Hicks [14] reported on 14 studies (total number of patients = 509) that compared PET/PET-CT with CT-alone contours and reported similar ranges of 27% to 100%. For the majority of these studies, impact was defined as any volume (GTV) change and or field shape change.

A recent review of published studies [20] on the methods of volume comparison was undertaken and identified common techniques for comparing volume changes. Their findings were in keeping with recent PET-CT literature in which the majority of studies (84%) focussed on using methods of simple volume change assessment with a lower percentage using a dosimetric evaluation (40%). Although an interesting measure, the focus on target size change only