Clinical Oncology xxx (2017) 1–11

Contents lists available at ScienceDirect

Clinical Oncology

journal homepage: www.clinicaloncologyonline.net

Original Article

Simultaneous ^{68}Ga DOTATATE Positron Emission Tomography/Magnetic Resonance Imaging in Meningioma Target Contouring: Feasibility and Impact Upon Interobserver Variability Versus Positron Emission Tomography/Computed Tomography and Computed Tomography/Magnetic Resonance Imaging

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Received 12 August 2016; received in revised form 16 February 2017; accepted 21 February 2017

Abstract

Aims: The increasing use of highly conformal radiation techniques to treat meningioma confers a greater need for accurate targeting. Several groups have shown that positron emission tomography/computed tomography (PET/CT) information alters meningioma targets contoured by single observers, but whether this translates into improved accuracy has not been defined. As magnetic resonance imaging (MRI) is the cornerstone of meningioma target contouring, simultaneous PET/MRI may be superior to PET/CT. We assessed whether ^{68}Ga DOTATATE PET imaging (from PET/CT and PET/MRI) reduced interobserver variability (IOV) in meningioma target volume contouring.

Materials and methods: Ten patients with meningioma underwent simultaneous ^{68}Ga DOTATATE PET/MRI followed by PET/CT. They were selected as it was anticipated that target volume definition in their cases would be particularly challenging. Three radiation oncologists contoured target volumes according to an agreed protocol: gross tumour volume (GTV) and clinical target volume (CTV) on CT/MRI alone, CT/MRI+PET(CT) and CT/MRI+PET(MRI). GTV/CTV Kouwenhoven conformity levels (KCL), regions of contour variation and qualitative differences between PET(CT) and PET(MRI) were evaluated.

Results: There was substantial IOV in contouring. GTV mean KCL: CT/MRI 0.34, CT/MRI+PET(CT) 0.38, CT/MRI+PET(MRI) 0.39 ($P = 0.06$). CTV mean KCL: CT/MRI 0.31, CT/MRI+PET(CT) 0.35, CT/MRI+PET(MRI) 0.35 ($P = 0.04$ for all groups; $P > 0.05$ for individual pairs). One observer consistently contoured largest and one smallest. Observers rarely decreased volumes in relation to PET. Most IOV occurred in bone followed by dural tail, postoperative bed and venous sinuses. Tumour edges were qualitatively clearer on PET(MRI) versus PET(CT), but this did not affect contouring.

Conclusion: IOV in contouring challenging meningioma cases was large and only slightly improved with the addition of ^{68}Ga DOTATATE PET. Simultaneous PET/MRI for meningioma contouring is feasible, but did not improve IOV versus PET/CT. Whether volumes can be safely reduced according to PET requires evaluation.

Key words: Contouring; ^{68}Gallium DOTATATE PET; interobserver variability; meningioma; simultaneous PET/MRI; target volume

Introduction

Definition of radiotherapy target volumes for meningiomas can be challenging due to equivocal regions of bone thickening, enhancing dural tails and postoperative changes. The increasing use of highly conformal radiation techniques to treat meningioma confers a greater need for accurate targeting to optimise normal tissue sparing while ensuring tumour coverage. The current gold standard imaging for meningioma contouring is contrast-enhanced

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http://dx.doi.org/10.1016/j.clon.2017.03.004

0936-6555/

magnetic resonance imaging (MRI) co-registered to planning computed tomography (CT). Meningioma out-with bone is best visualised on post-contrast T1-weighted MRI [1], but bone is better visualised on CT [2]. Several groups have published data regarding the integration of functional information from positron emission tomography/computed tomography (PET/CT) [3–10] using somatostatin analogues, which exploit somatostatin receptors on meningiomas (^{68}Ga-DOTA), or amino acid-based tracers. Target volumes defined using PET can be smaller or larger than on CT/MRI (Table 1). Whether the addition of PET information improves the accuracy of target volume definition is unclear.

A reduction in interobserver variability (IOV) acts as a surrogate for improved delineation. Khoo *et al.* [11] reported a reduction in IOV when combined MRI and CT was used to define meningioma target volumes compared with CT alone and Grosu *et al.* [10] reported a 10% increase in the median volume of intersection between two observers with the addition of PET.

PET/CT imaging is obtained sequentially and the PET information derived has limitations in terms of spatial resolution (5–7 mm), partial volume effects, noisy reconstruction algorithms and patient motion between the PET and CT acquisition.

Theoretically, PET/MRI has better spatial resolution and it seems that PET/MRI can identify separate small meningiomas not seen on PET/CT [12]. The first case report of PET/MRI for radiotherapy treatment planning identified meningioma infiltration along the falx not identified on PET/CT (with co-registered MRI) [13]. The same group also reported identification of additional small regions of meningioma with PET/MRI, although this may not be clinically relevant [14]. These reports used sequential PET and MRI acquisition. Simultaneous PET/ MRI has recently become commercially available, which could potentially improve co-registration between the imaging modalities.

We therefore hypothesised that the use of simultaneous ^{68}Gallium DOTATATE PET/ MRI may reduce IOV in meningioma target volume definition compared with standard CT/MRI or even MRI plus PET/CT and set out to test this in a clinical series.

Materials and Methods

ARSAC and regional ethical approval was obtained to study ^{68}Ga DOTATATE PET/MRI in radiotherapy planning. Ten patients with meningiomas were selected to undergo duel modality PET imaging in addition to standard radiotherapy planning scans. Suitable participants were identified at the neuro-oncology multidisciplinary meeting on the basis that the consultants in neuro-oncology and neuro-radiology agreed that the cases were particularly challenging as the tumour borders could not be clearly

Table 1
Reports of the use of positron emission tomography (PET) in meningioma radiotherapy contouring

Tracer	Reference	Design	Findings
^{68}Ga DOTATOC	[6]	26 patients All regions FSRT	PTV alterations in 73% PTV ↓35%; ↑38% Main benefit base of skull Pituitary/tumour border unclear
	[7]	26 patients All regions IMRT	CTV alterations in 65% GTV ↑38%; ↓ 50% Most changes in base of skull or after surgery
	[8]*	42 patients All regions SRT (no detail) 2 pts negative PET (?false or true)	GTV alteration in 72% GTV↑23%, GTV↓49% All bidirectional changes Mean GTV↑9cm^3 Additional lesions seen on PET Main changes in bone
	[9]*	16 patients Infracranial extension	Infracranial extension detected by PET > MRI/ CT
	[4]*	48 tumours Skull base	Mean GTV PET/MRI/CT smaller than GTVPET and GTVMRI/CT >10% modification in GTV using PET in 67%
11C-Methionine	[3]†	32 patients Skull base FSRT	GTV alterations 91% PTV ↓16%, ↑75% Mean GTV increase 9.4%
	[10]†	10 patients FSRT Evaluation of IOV with and without PET	↓IOV with addition of PET

*† Reports from the same institution.
FSRT, fractionated stereotactic radiotherapy; IMRT, intensity-modulated radiotherapy; SRT, stereotactic radiotherapy; IOV, interobserver variability; CTV, clinical target volume; GTV, gross tumour volume; PTV, planning target volume; MRI, magnetic resonance imaging; CT, computed tomography.

Please cite this article in press as: Maclean J, et al., Simultaneous ^{68}Ga DOTATATE Positron Emission Tomography/Magnetic Resonance Imaging in Meningioma Target Contouring: Feasibility and Impact Upon Interobserver Variability Versus Positron Emission Tomography/Computed Tomography and Computed Tomography/Magnetic Resonance Imaging, Clinical Oncology (2017), http://dx.doi.org/10.1016/j.clon.2017.03.004