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Overview

Standardisation of Target Volume Delineation for Carotid-sparing Intensity-modulated Radiotherapy in Early Glottis Cancer

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Abstract

Aims: Recently, carotid-sparing intensity-modulated radiotherapy (IMRT) for early laryngeal glottis (T1/T2N0M0) cancer has generated interest in the hope of avoiding long-term carotid toxicity, as well as concerns relating to geographical misses and long-term normal tissue toxicity. The aim of this review was to summarise the current literature on carotid-sparing IMRT for early glottis cancer, with particular focus on definitions of target volumes and the carotid arteries as organs at risk. In addition, we make suggestions for standardisation of these structures, dose constraints and dose reporting.
Materials and methods: From 73 references, 16 articles met the criteria for inclusion in this systematic review. These papers described two case reports, 11 planning studies and three prospective studies.
Results: There was variation in all target volume definitions with no clear consensus. The greatest variability was in clinical target volume definition. Carotid artery and spinal cord delineation were not always defined and most studies did not use a carotid artery constraint. Of the eight studies that reported carotid artery delineation, no two studies delineated the same length of carotid artery, yet most studies reported mean doses. Most studies used IMRT with three to seven fields. Five studies used arc therapy and two studies used tomotherapy.
Conclusion: This review highlights a lack of consensus in target volume definitions in carotid-sparing IMRT. Ultimately, long-term prospective data are required to show the benefit of carotid-sparing IMRT. Pooled data will prove useful as most studies will report on small numbers of patients. Therefore, adopting a consensus now on target volume definition, dose constraints and dose reporting will be crucial.

Key words: Carotid sparing; glottic cancer; radiotherapy

Statement of Search Strategies Used and Sources of Information

We carried out a systematic search of Pubmed (1 January 2000 to 31 December 2015) for English language articles using the search terms: ‘carotid’, ‘radiotherapy’, ‘larynx’.

Introduction

The treatment of early laryngeal glottis (T1/T2N0M0) cancer involves the use of primary radiotherapy, typically using two parallel-opposed lateral radiotherapy beams. Consequently, the carotid arteries are usually included in the treatment field as collateral structures, exposing them to endothelial injury and subsequent risk of stroke or transient ischaemic attack, with a hazard ratio (95% confidence interval) ranging from 2.09 (1.38–3.22) to 5.6 (3.1–9.4) in patients with head and neck cancer [1]. Treating the entire larynx allows for an adequate margin (planning target volume; PTV) to account for movement during swallowing, which can be up to 3.5 cm in the superior–inferior direction [2]. Vocal cord motion during regular breathing should also be accounted for when treatment volumes are significantly reduced [3].

Recently, carotid-sparing intensity-modulated radiotherapy (IMRT) has generated interest in the hope of avoiding long-term carotid toxicity, as well as concerns

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relating to geographical misses and long-term normal tissue toxicity [4]. This technique requires the larynx clinical target volume (CTV) and PTV margins to be redefined to address the balance between local control and late normal tissue toxicity. Adequate allowance for laryngeal movement during swallowing and breathing is crucial in determining a PTV that balances vocal cord displacement and sparing the carotid arteries.

The aim of this review was to summarise the current literature on carotid-sparing radiotherapy for early glottis cancer, with particular focus on definitions of target volumes and the carotid arteries as organs at risk (OARs), and suggestions for standardisation of these structures, dose constraints and dose reporting.

Materials and Methods

Search Strategy and Selection Criteria

We carried out a systematic search of Pubmed (1 January 2000 to 31 December 2015) for English language articles using the search terms: 'carotid', 'radiotherapy', 'larynx'. The abstracts or available data of this search were reviewed to include or exclude references for full-text review. Articles reporting on patients treated with IMRT for early glottis cancer or planning studies investigating carotid-sparing IMRT in this population were eligible for inclusion, as were case reports. Studies that did not investigate or report radiation doses to the carotid arteries were excluded from this review.

Relevant references not clearly identifying patient populations or study design were included in the initial review to avoid erroneous exclusion. The full-text articles from the selected references were scrutinised to select the final set of articles for review and analysis. The reference lists of these articles were also reviewed, and references from relevant titles were obtained and reviewed according to the above selection criteria.

Data Abstraction and Analysis

The outcomes of interest were: target volume [gross tumour volume (GTV), CTV, PTV] definitions, carotid and spinal cord OAR definition, carotid and spinal cord OAR dose constraint and reporting. Field set-up, planning technique and dose prescription were also recorded. Each parameter was considered and reported separately.

Results

The search revealed 73 references (Figure 1). Of these, 43 were published after 1 January 2000, and confirmed the concept of carotid-sparing radiotherapy is a recent one. Fifteen references met the inclusion criteria from the initial search. Two studies were based on the same patient cohort and reported twice – the reference not related to carotid-sparing radiotherapy was excluded in each case (15–2 = 13). A full-text review of these articles revealed a further three references that met the inclusion criteria. Therefore, 16 references met the inclusion criteria for this

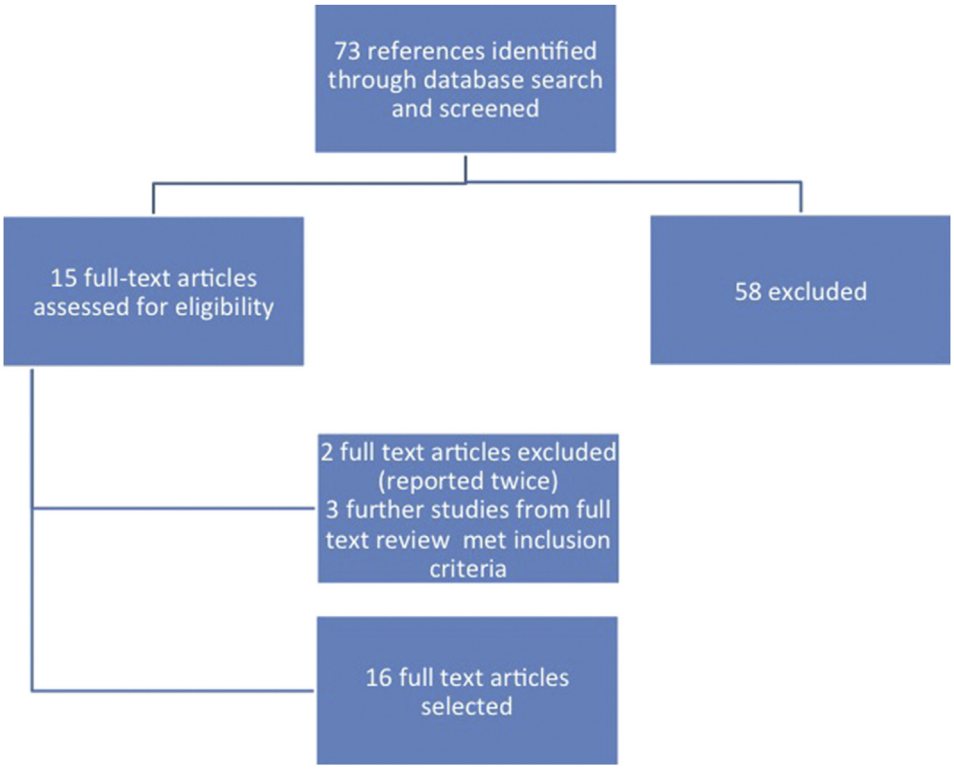

Fig 1. Flow diagram of the literature search.

review [5–20]. These included two case reports, 11 planning studies and three prospective studies (one published in abstract form only).

Outlining

Gross tumour volume

The GTV definition varied from none ($n = 5$) [7,9,11,17,19] to bilateral true vocal cords [5,8]. This was defined based on endoscopy findings and any diagnostic imaging for some studies [6,20]. Gomez *et al.* [5] defined the GTV on computed tomography findings only. Some studies did not delineate a GTV [7,9,11,17,19]. Mourad *et al.* [13] did not report any target volume delineation for any structures.

Clinical target volume

There was considerable variation in CTV delineation. Most studies included the vocal cords, arytenoids and 1.5 cm of subglottis, whereas others restricted the CTV to a 0.3–0.5 cm margin on the true vocal cords [8,20] or the whole involved vocal cord [11]. In general, the major modification to the CTV was to bring the posterior border forward to cover the arytenoids and cricoid cartilage and to exclude the hypopharynx.

Planning target volume

The PTV was constructed by expanding the CTV in the following range of ways: from no expansion [6,10] to a uniform 1 cm expansion [5,18]. Some studies [12,15] applied standard field borders instead of a defined PTV. Prescribed doses varied – the most common prescribed dose ($n = 9$) was 63 Gy/28 fractions.

Organs at Risk

Spinal cord

Most studies did not define spinal cord delineation or spinal cord planning at risk volume (PRV). Two studies [7,9] defined the spinal cord 1 cm superior and inferior to the PTV and a 3 mm PRV. Riegel *et al.* [12] delineated the spinal cord to cover the superior and inferior extent of the CTV. Most studies did not report the spinal cord constraints. Those that did report constraints varied from a maximum dose of < 20 Gy [6] to a maximum dose of < 45 Gy [7,9,10,17].

Carotid arteries

Some studies contoured both carotid arteries as a single OAR (see Table 1). Others defined a left and right carotid OAR. The superior and inferior extent of the carotid arteries varied, and was often not reported. Only three studies [7,9,19] applied a 3–5 mm PRV. Carotid artery constraints were applied in only two studies: Riegel *et al.* [12] (mean dose as low as possible) and Zumsteg *et al.* [18] (mean dose <52 Gy).

Planning Techniques

Most studies used IMRT with a three- to nine-field technique. Four studies [10,12,19,20] used arc therapy (Table 2). Two studies developed tomotherapy plans to deliver radiotherapy [14,17]. The study by Matthiesen *et al.* [19] also developed radiotherapy plans using proton therapy and used three uniform scanning beams.

Image-guided Radiotherapy

Five studies used daily image guidance [6,8,14,16,20]. The CTVs and PTVs in these studies were smaller than conventional fields and did not include all the cartilaginous structures of the larynx. Chatterjee *et al.* [14] was the only study to maintain the traditional larynx CTV, but did edit the PTV away from the carotid arteries.

Kinematics

Two studies [17,20] advised patients not to swallow during treatment in order to try to minimise the displacement that occurs during swallowing. Neither study described whether patient compliance during treatment was assessed. Single vocal cord irradiation was investigated in two studies [13,16], but only one study used daily image guidance with cone beam computed tomography [16].

Discussion

This review highlights a lack of consensus in target volume definitions. As field sizes get smaller with carotid-sparing techniques, it is even more important to ensure the tumour is always encompassed within the treated volume. GTV delineation is, therefore, crucial and endoscopy and diagnostic imaging findings should be incorporated in this process and reported in studies. Four-dimensional computed tomography scanning [3] and magnetic resonance imaging co-registration [21] may improve GTV localisation and, perhaps more importantly, quantify vocal cord motion during breathing and allow for adaptation of treatment to account for this. It is also clear that CTV definition is variable and should be clarified before this technique becomes standard clinical practice and studies begin to report outcome data. Risk of microscopic spread to the cartilaginous structures of the larynx is low in correctly staged early glottis cancers (hence, some of these patients may be adequately treated with laser resection), yet these are often included in the CTV. CTV definitions also seem to have been defined according to laryngeal motion and, strictly speaking, should be reclassified as PTV definitions as they refer to the internal target volume. We believe PTV delineation should be dependent on whether or not centres have access to daily image-guided radiotherapy (IGRT). We advocate more generous PTV margins that include both vocal cords and other cartilaginous structures of the larynx for those centres without an IGRT programme.

The larynx PTVs in most studies were similar to a standard larynx field except in the posterior direction, where the field is reduced to allow for carotid sparing. This PTV did not differ dramatically from standard practice and would be relatively easy to introduce into clinical practice. IGRT and

Table 1
Target volume definitions

Study	GTV	CTV	PTV	OAR	OAR defined
Gomez *et al.* [5] ($n = 3$)	Bilateral TVC (defined on CT)	larynx (FVCs + TVCs, anterior + posterior commissure, arytenoids and aryepiglottic folds) and subglottic region, extending from the level of hyoid bone to the bottom of cricoid	5 and 10 mm	Bilateral carotid OAR, no PRV Spinal cord	No No
Rosenthal *et al.* [6] ($n = 6$)	Gross tumour (defined on endoscopy and CT)	Anterior limit = inside the skin as far as possible but to encompass thyroid cartilage with 5 mm margin; posterior = the posterior limit of thyroid and cricoid cartilages. Minimum 4 cm × 4 cm field size used	None	Separate right and left carotid arteries. No PRV Spinal cord	No No
Chera *et al.* [7] ($n = 5$)	None	CTV = arytenoids cartilages, FVCs, anterior and posterior commissures, TVCs, and 1–1.5 cm of subglottis. Two CTVs created: bilateral CTV + unilateral CTV	3 mm in lateral and anterior directions	Bilateral carotid OAR Carotid PRV = 3 mm margin Spinal cord	Spinal cord and carotid arteries contoured 1 cm beyond superior and inferior extent of PTV
Tiong *et al.* [8] (Abstract) ($n = 50$)	Bilateral TVCs (not defined)	0.5 and 1cm margins on GTV (2 × CTVs) = CTV60 Further 0.5–2 cm margin = CTV50	5 mm	None	No
Sert *et al.* [9] ($n = 5$)	None	CTV = arytenoids cartilages, FVCs, anterior and posterior commissures, TVCs, and 1–1.5 cm of subglottis.	3 mm	Bilateral carotid OAR Carotid PRV = 3 mm margin Spinal cord	Spinal cord and carotid arteries contoured 1 cm beyond superior and inferior extent of PTV
Atalar *et al.* [10] ($n = 5$)	Not defined	CTV – encompass thyroid with 5 mm anterior margin, cricoid, arytenoids, FVCs, anterior and posterior commissures, TVCs and 1–1.5 cm of subglottis; borders extended to hyoid superiorly and to bottom of cricoid inferiorly	None	Left and right carotid OARs, no PRV Spinal cord	No No
Osman *et al.* [11] ($n = 10$)	None	Whole involved VC based on CT imaging – CTV66	2 mm	Bilateral carotid OAR Spinal cord	Level of C2 to C6, no PRV No
Riegel *et al.* [12] ($n = 11$)	Not defined	Whole larynx Superior – hyoid Inferior – bottom of cricoid Anterior – skin Posterior – posterior to arytenoids	0	Left and right carotid OARs contoured Spinal cord	1.2 cm superior and inferior of CTV, no PRV To cover superior and inferior extent of CTV

(*continued on next page*)

Table 1 (*continued*)

Study	GTV	CTV	PTV	OAR	OAR defined
Mourad *et al.* [13] (case report) ($n = 1$)	Gross tumour (not defined)	Not defined	Not recorded	Right carotid OAR, no PRV Spinal cord	No No
Chatterjee *et al.* [14] ($n = 5$)	Not defined	Superior – cranial border of thyroid cartilage Inferior – caudal edge cricoid Anterior – anterior edge thyroid cartilage Posterior – include arytenoid Lateral – include entire thyroid cartilage	5 mm, edited off carotid	Left and right carotid OARs Spinal cord	Superior = skull base Inferior = sternoclavicular joint, no PRV No
Garcez *et al.* [15] ($n = 10$)	Not defined	Not defined	Not defined – standard 5.5 × 5.5 cm fields centred on VCs	Left and right carotid OAR Spinal cord	8 cm length of left and right carotid, no PRV No
Janssen *et al.* [16] ($n = 77$)	Gross tumour (not defined)	10–15 mm	2–3 mm	Left and right carotid OARs, no PRV Spinal cord	No No
Hong *et al.* [17] ($n = 10$)	None	CTV = arytenoids, FVCs, anterior and posterior commissure, TVCs, and 1–1.5 cm of subglottis	3 mm lateral and anterior, 1 mm posterior	Bilateral carotid OAR Spinal cord	2 cm superior and inferior to PTV, no PRV No
Zumsteg *et al.* [18] ($n = 48$)	Gross tumour (defined on endoscopy)	Entire larynx, including anterior and posterior commissures, and arytenoids, from top of thyroid cartilage to bottom of cricoid	10 mm	Left and right carotid OARs Spinal cord	On slices of PTV, no PRV No
Matthiesen *et al.* [19] ($n = 10$)	None	CTV = arytenoids, FVCs, anterior and posterior commissures, TVCs, and 1–1.5 cm of subglottis.	5 mm	Bilateral carotid OAR Spinal cord	1 cm superior and inferior to PTV, 3–5 mm PRV No
Ward *et al.* [20] (case report) ($n = 1$)	Gross tumour (defined on endoscopy and CT	CTV63 = GTV CTV51.8 = CTV63 + 3 mm in superior–inferior direction and extended to include both TVCs and ipsilateral arytenoid	2 mm	Left and right carotid OAR, no PRV Spinal cord	No No

GTV, gross tumour volume; CTV, clinical target volume; PTV, planning target volume; OAR, organs at risk; PRV, planning at risk volume; VC, vocal cords: TVC, true vocal cords; FVC, false vocal cords; CT, computed tomography.

Table 2
Planning constraints, dose reporting and dose prescription

Study	Spinal cord constraint	Carotid constraint	Carotid dose reported	Field set-up	Dose prescription	Image guidance?
Gomez *et al.* [5]	None	None	Mean	3–4 anterior fields	63 Gy/28 (2.25 Gy/fraction) over 38 days	No – planning study
Rosenthal *et al.* [6]	V90 < 10 Gy Maximum dose 20 Gy	None	Mean Median V35, V50	3 fields (0, 70, 290)	63 Gy/28	Yes – daily (planning study)
Chera *et al.* [7]	Maximum < 45 Gy	None	Median Maximum median point dose	7 equispaced beams	63 Gy/28 (2.25 Gy/fraction)	No – planning study
Tiong *et al.* [8]	Not reported	None	Not reported	5 fields	60 Gy/25 50 Gy/25	Yes – CBCT
Sert *et al.* [9]	Maximum < 45 Gy	None	Median Mean V63, V50, V35	9 fields	62.25 Gy/28	No – planning study
Atalar *et al.* [10]	Maximum < 45 Gy	None	Mean V35, V50	3 or 5 fields IMAT	63 Gy/28	No – planning study
Osman *et al.* [11]	Not reported	None	Maximum V35	5 fields	66 Gy/33	No – planning study
Riegel *et al.* [12]	Maximum < 25 Gy	Mean carotid dose as low as possible	Maximum Mean V63, V50, V35	VMAT 3-field IMRT	63 Gy/28	No – planning study
Mourad *et al.* [13]	Not reported	None	Mean	IMRT – fields not defined	63 Gy/28	No
Chatterjee *et al.* [14]	None	None	Mean Median	Tomotherapy (carotid-sparing)	55 Gy/20	Daily MVCT – retrospective (planning study)
Garcez *et al.* [15]	Not reported	None	Maximum Mean	Anterior wedged pair	50 Gy/16	No – planning study
Janssen *et al.* [16]	Not reported	None	Mean V63, V50, V35	IMRT 4–5 fields	66–70 Gy/33–35	Yes – KV and CBCT
Hong *et al.* [17]	Maximum < 45 Gy	None	Maximum V63, V50, V35	IMRT 3 fields Tomotherapy	67.5 Gy/30	Daily (retrospective planning study) Patient asked not to swallow
Zumsteg *et al.* [18]	Not reported	Mean carotid < 52 Gy	Median Mean V50, V40	IMRT 4 fields	63 Gy/28	No
Matthiesen *et al.* [19]	Not reported	None	Maximum Mean D20, D50, D90	IMRT 5 fields RapidArc – single arc Protons	63 Gy/28	No – planning study
Ward *et al.* [20]	Not reported	None	Maximum Mean V50	VMAT	63 Gy/28	Daily CBCT Patient asked not to swallow

CBCT, cone beam computed tomography; IMRT, intensity-modulated radiotherapy; VMAT, volumetric modulated arc therapy; MVCT, megavoltage computed tomography; KV, kilovoltage.

four-dimensional computed tomography planning to account for motion during breathing, as well as swallowing, would potentially allow for further reduction in PTV margins [22].

It is important to remember that the time spent swallowing during a patient's treatment has been calculated to be less than 1% [23,24]. One study reported maximum anterior and superior displacements of 6.3 mm and 11.5 mm, respectively [23], and the other reported maximum displacements of 25 mm (superior) and 8.3 mm (anterior) [24]. The obvious question is: is there a need to account for swallowing if this accounts for only 1% of a patient's time on treatment? We would argue that, in the absence of an advanced IGRT programme with daily imaging, a dramatic shrinkage in treatment volumes is not advisable. It is also important to account for the vocal cord displacement that occurs during breathing. In the context of a multicentre clinical trial, the use of PTV margins and

treatment volumes that are easy to implement for most centres and which do not differ dramatically from current standard of care seems a sensible approach.

We have outlined recommendations for target volume delineation, dose constraints and reporting in Table 3. In order to avoid underestimating GTV extent, we would advocate a GTV of the bilateral true vocal cords. This would also account for the location of the GTV when the vocal cords medialise during respiration. The PTV should encompass the cartilaginous structures of the larynx to confidently ensure GTV coverage throughout breathing and swallowing for centres that do not use IGRT.

We recommend that carotid arteries are labelled as left and right carotid OARs (Table 3). Investigators testing the benefits of hemi-larynx radiotherapy by sparing the contralateral vocal cord or arytenoid may prefer to label carotid OARs as ipsilateral and contralateral carotid arteries, to reflect their proximity to the GTV. In addition, a single carotid OAR that incorporates both carotid arteries will underestimate the mean carotid dose in this setting. It is important to standardise delineation of the carotid OAR and PRV in order to determine mean doses as accurately as possible and realistically account for expansion and contraction during the cardiac cycle. Previous studies [5,6,16] have reported mean carotid doses of between 18 and 29 Gy, but none of these studies defined the carotid OAR or applied PRV margins. Chera *et al.* [7] contoured carotid OARs 1 cm superior and inferior to the PTV and applied 3 mm PRV margins. Most studies reported carotid artery mean doses, yet there is no consensus as to the length of carotid artery included in the OAR. Variability will result in significant differences in mean carotid artery doses and may not be comparable from study to study.

We recommend defining the carotid OAR as the extracranial extent of the carotid artery (inferiorly from the aortic arch on the left and brachiocephalic trunk on the right and extended superiorly to at least 2.5 cm superior to the hyoid bone) (Table 3). We believe this carotid OAR is reasonable to calculate realistic mean doses to a defined, reproducible length of carotid artery. The average diameter of the common carotid artery is around 6.1 mm (standard deviation 0.8) for women and 6.5 mm (standard deviation 1.0) in men [25]. During the cardiac cycle, the carotid artery luminal diameter can change by up to 15% [26]. A 15% increase in 6.5 mm is 0.98 mm, so a further 1 mm margin (before applying the PRV) adequately accounts for carotid diameter changes during the cardiac cycle.

The lack of a carotid OAR dose constraint for most of these studies is a weakness and should be more clearly defined in future prospective studies. The length/volume/diameter of carotid artery does not seem to be important. Rather, the carotid artery behaves as a serial organ and it is the dose of radiotherapy to a particular section of artery that is important [1]. It would be reasonable to set a stringent

Table 3
Recommendations for target volume delineation, dose constraints and reporting for carotid-sparing intensity-modulated radiotherapy in early larynx cancer

Dose prescription 55 Gy/20 fractions over 4 weeks	GTV	CTV	PTV	Spinal cord OAR	Carotid OAR
Target volume delineation	Bilateral TVCs	GTV + 1 cm – edited back to cartilages	Arytenoids, FVCs, anterior and posterior commissure, TVCs, and 1–1.5 cm of subglottis	Foramen magnum superiorly to 2.5 cm below PTV	Extracranial extent of carotid artery (inferiorly from the aortic arch on the left and brachiocephalic trunk on the right and extended superiorly to at least 2.5 cm superior to the hyoid bone) – labelled as left and right carotid OAR
PRV	N/A	N/A	N/A	3–5 mm	4–6 mm (1 mm to account for diameter increase in systole)
Dose constraints	<110% prescribed dose	<110% prescribed dose	95–107% prescribed dose	Maximum <39 Gy (<45 Gy in 2 Gy/fraction) PRV maximum <41 Gy (<48 Gy in 2 Gy/fraction)	Maximum < 35 Gy to carotid OAR + 1 mm Mean carotid PRV dose as low as possible (aim < 20 Gy)
Dose reporting	Maximum, median, mean	Maximum, median, mean	Maximum, median, mean	Maximum	Maximum, median, mean dose to left and right carotid OAR and PRV

GTV, gross tumour volume; CTV, clinical target volume; PTV, planning target volume; OAR, organ at risk; PRV, planning at risk volume; TVC, true vocal cords; FVC, false vocal cords.

constraint of a maximum dose of <35 Gy [27,28] to show a positive effect of carotid-sparing radiotherapy on future neurological events.

The spinal cord should be contoured (from the foramen magnum superiorly to at least 2.5 cm below the PTV) and a spinal cord PRV created by a 3–5 mm expansion (depending on institutional policy) in all directions of the spinal cord OAR. It is important to note that reported spinal cord constraints are derived based on standard fractionation (2 Gy per fraction) and some studies used hypofractionated regimens [14,15]. This becomes important when spinal cord dose constraints are set at 45 Gy for IMRT or arc therapy. Standard dose fractionation for treatment using parallel-opposed lateral beams (such as 55 Gy in 20 fractions over 4 weeks frequently used in the UK [29]) may be applied for IMRT. Spinal cord constraints should be stringent and reported in 2 Gy per fraction when treating patients with IMRT (Table 3).

Carotid-sparing IMRT may reduce mean carotid OAR doses from the prescribed PTV dose to <20 Gy and maximum carotid OAR doses to 32 Gy in treated patients [6,20]. Newer radiation techniques such as proton therapy may provide incremental benefits for carotid sparing [19]. The use of magnetic resonance imaging for radiotherapy planning may further enhance tumour localisation and quantification of motion during treatment [30]. These techniques, however, are only useful and comparable with other techniques and studies if accepted definitions of target volume delineation are applied.

There are some limitations to consider. Tumour location may dictate the feasibility of carotid sparing, and this technique may only be reasonable for tumours located on the anterior cord. With four-dimensional computed tomography planning and IGRT, vocal cord displacement can be more accurately studied in a prospective setting and potentially allow for further reduction in PTV margins. The use of magnetic resonance imaging in radiotherapy planning may allow for assessment of the displacement of vocal cord tumour. These techniques, however, will be restricted to centres with the relevant experience and may not be generally applicable. Therefore, in order to address both carotid sparing and local control, we would suggest that the technique that makes the greatest allowance for uncertainties in target volume delineation and radiotherapy planning would be applicable in most cancer centres that treat these tumours. In the context of a clinical trial, multicentre participation will be crucial for accrual and generalisability of results.

Conclusion

Ultimately, long-term prospective data are required to show the benefit of carotid sparing. A lower radiotherapy dose to carotid arteries may reduce the incidence of radiation-induced atherosclerosis and subsequent stroke risk. Pooled data will prove useful as most studies will report on small numbers of patients. Therefore, adopting a consensus now on how to define target volumes, dose constraints and dose reporting will be crucial to allow this to occur in the future.

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