Received:
24 November 2014

Revised:
19 March 2015

Accepted:
31 March 2015

doi: 10.1259/bjr.20140791

Cite this article as:

Zhang X, Bai S, Li H, Hu H, Duan X, Chen M, et al. CT and MRI findings of radiation-induced external auditory canal carcinoma in patients with nasopharyngeal carcinoma after radiotherapy. *Br J Radiol* 2015;88:20140791.

FULL PAPER

CT and MRI findings of radiation-induced external auditory canal carcinoma in patients with nasopharyngeal carcinoma after radiotherapy

¹X ZHANG, MM, ²S BAI, MD, ³H LI, MD, ¹H HU, BS, ¹X DUAN, MM, ¹M CHEN, BS, ¹D WANG, MM, ¹Y CHEN, MM, ¹F ZHANG, MM and ¹J SHEN, MD

¹Department of Radiology, Sun Yat-sen Memorial Hospital, Sun Yat-sen University, Guangzhou, Guangdong, China

²Department of Radiotherapy, Sun Yat-sen University, Guangzhou, Guangdong, China

³Department of Radiology, Cancer Center, Sun Yat-sen University, Guangzhou, Guangdong, China

Address correspondence to: Professor Jun Shen

E-mail: shenjun@mail.sysu.edu.cn

The authors Xiang Zhang and Shoumin Bai contributed equally to this work.

Objective: To summarize the radiological and clinical features of radiation-induced external auditory canal carcinomas (RIEACCs) in patients with nasopharyngeal carcinomas (NPCs) after radiation therapy.

Methods: CT, MRI and clinical features in 16 patients with histologically proven RIEACCs were retrospectively reviewed. There were 2 females and 14 males, with a median age of 52.5 years at the time of diagnosis of RIEACC. Imaging parameters including lesion extent, size, margin, shape, bone destruction, adjacent structure invasion, density/signal intensity, and pattern and degree of enhancement were assessed. Clinical features including clinical staging, histological type, treatment and radiation dose (RD) of primary NPC as well as the histological type, staging of radiation-induced tumour and the latent period between NPC and RIT were recorded.

Results: All patients had a single RIEACC. The lesions had a size of 3.5 ± 1.4 cm and were localized ($n = 7$) or

extensive ($n = 9$). Most of the lesions were partially or ill defined with an irregular shape and had an intermediate density/signal pattern and moderate homogeneous enhancement. The latent period of RIEACCs ranged from 10 to 20 years in nine patients with a RD of 68–70 Gy; from 2 to 10 years in five patients with a RD of 68–74 Gy; and more than 20 years in two patients with a RD of 70 or 72 Gy.

Conclusion: An external auditory canal (EAC) mass with homogeneous, intermediate CT density or signal intensity in patients with NPC after radiotherapy is highly suggestive of RIEACC, which should be included in the routine surveillance for patients with NPC after radiotherapy.

Advances in knowledge: RIEACCs could occur as short as 2 years after radiotherapy in patients with NPC and have distinct features from otitis media and sarcomas. This EAC malignancy should be included in routine surveillance for patients with NPC after radiotherapy.

Radiotherapy is the conventional and main treatment method in patients with nasopharyngeal carcinoma (NPC). As one of the most common carcinogenic agents, ionization radiation can induce many complications such as radiation encephalopathy and radiation-induced tumours (RITs) in the irradiation field. The reported incidence of RITs ranges from 0.04% to 7% in post-radiation NPC.¹ Among them, radiation-induced sarcomas (RISs) such as fibrosarcoma and osteosarcoma arising in the paranasal sinuses and the nasal cavity are the most common tumours.^{1–3} Their imaging features have been well documented previously.^{1–3}

Radiation-induced external auditory canal carcinomas (RIEACCs) are rare, but are another clinically challenging problem of RITs in patients previously irradiated for nasopharyngeal neoplasm.⁴ Previously, MRI findings of only four cases of radiation-induced squamous-cell carcinomas (SCCs) in the external auditory canal (EAC) had been described.¹ To date, there are few reports describing radiological features of RIEACCs. The CT and MRI features of RIEACC are far from well described. In this study, CT, MRI and clinical data in 16 cases of pathologically proven RIEACCs in patients with irradiated NPCs were retrospectively reviewed, and their main CT and MRI findings and clinical features were summarized.

Table 1. Imaging features and interobserver agreements in 16 patients with radiation-induced external auditory canal carcinomas

Imaging features	Number of patients
Tumour extent	
Localized	<i>n</i> = 7 (43.8%)
Extensive	<i>n</i> = 9 (56.3%)
Kappa value	0.875
Tumour size (cm) (mean $\pm$ standard deviation)	3.5 $\pm$ 1.4
Tumour margin	
Well defined	<i>n</i> = 6 (37.5%)
Partially ill defined	<i>n</i> = 3 (18.8%)
Ill defined	<i>n</i> = 7 (43.8%)
Kappa value	0.899
Tumour shape	
Regular	<i>n</i> = 8 (50%)
Irregular	<i>n</i> = 8 (50%)
Kappa value	0.875
External auditory canal destruction (<i>n</i> = 7) ^a	
None	<i>n</i> = 2 (28.6%)
Partial	<i>n</i> = 2 (28.6%)
Extensive	<i>n</i> = 3 (42.9%)
Kappa value	0.788
Signal intensity on MRI (<i>n</i> = 15)	
<i>T</i> ₁ weighted imaging	
Isointensity	<i>n</i> = 8 (53.3%)
Slight hypointensity	<i>n</i> = 7 (46.7%)
Kappa value	0.865
<i>T</i> ₂ weighted imaging	
Isointensity	<i>n</i> = 1 (6.7%)
Slight hyperintensity	<i>n</i> = 14 (93.3%)
Kappa value	0.773
Enhancement degree on MRI (<i>n</i> = 14)	
Mild	<i>n</i> = 1 (7.1%)
Moderate	<i>n</i> = 12 (85.7%)
Intense	<i>n</i> = 1 (7.1%)
Kappa value	0.770
MR contrast enhancement pattern (<i>n</i> = 14)	
Homogeneous	<i>n</i> = 12 (85.7%)
Heterogeneous	<i>n</i> = 2 (14.3%)
Kappa value	0.759

^aExternal auditory canal destruction was determined in seven patients with CT scan.

METHODS AND MATERIALS

Patients

This study was approved by the institutional review board, of Sun Yat-Sen Memorial Hospital and patients' informed consent was not required in accordance with the requirements of a retrospective study. Patients with RIEACCs following radiotherapy for NPCs were retrospectively collected from the medical records of Sun Yat-Sen Memorial Hospital between April 2001 and January 2013. Eligibility for the study was based on the criteria for RIT as described by Cahan *et al*:⁵ (1) a prior history of radiotherapy; (2) the occurrence of tumour within the irradiated field; (3) histological confirmation of the nature of the lesion; (4) a latent period of no less than 2 years between irradiation and recurrence of a second primary tumour. We selected patients whose latent period was more than 2 years. Patients who had a history of other malignancies or a carcinoma in the continuous sites from primary tumour, such as malignant neoplasm of oropharynx, were excluded.

There were 16 patients enrolled in the study. All patients were southern Chinese, with 14 males and 2 females, aged from 27 to 77 years with a median age of 52.5 years at the time of diagnosis of RIEACC. All patients had a single tumour in one side of the EACs. In total, 16 lesions were found. There were seven poorly differentiated, one moderately differentiated, eight well-differentiated tumours. The tumours were staged according to the Pittsburgh tumour staging system as previously described:⁶ (1) Stage T1: tumour limited to the EAC without bony erosion or evidence of soft-tissue involvement. (2) Stage T2: tumour with limited EAC bone erosion (not full thickness) or limited (<0.5 cm) soft-tissue involvement. (3) Stage T3: tumour eroding the osseous EAC (full thickness) with limited (<0.5 cm) soft-tissue involvement or tumour involving the middle ear and/or mastoid. (4) Stage T4: tumour eroding the cochlea, petrous apex, medial wall of the middle ear, carotid canal, jugular foramen or dura; with extensive soft-tissue involvement (>0.5 cm), such as involvement of the temporomandibular joint or styloid process; or evidence of facial paresis. The main symptoms were the masses of the EAC (*n* = 8), bloody otorrhoea (*n* = 5) and earache (*n* = 3). The clinical data including the clinical staging, histological types, treatment and radiation dose (RD) of primary NPCs as well as RIT staging, treatments and latency between NPC and RIT were reviewed.

Imaging technique

All the 16 patients had cross-sectional imaging examination. One patient had CT examination alone, nine patients had MRI alone and the other six patients had both CT and MRI. All the seven patients had plain CT scan without the use of contrast media. In 15 patients who had MRI scans, both plain and contrast-enhanced MRI were performed except for one patient who had only plain scan.

CT scans were in seven patients were performed with a 64-slice spiral scanner (SOMATOM® Sensation 64; Siemens Healthcare, Erlangen, Germany). The scan parameters were as follows: a peak voltage of 120 kV, a tube current of 300 mAs, a rotation time of 0.33 s, a collimator of 12 $\times$ 0.6 mm, a pitch

Figure 1. A radiation-induced external auditory canal carcinoma in a 27-year-old male 2 years after nasopharyngeal carcinoma radiotherapy. Transverse T_1 weighted imaging (a) and T_2 weighted imaging (b) show a strip-like, well-defined mass (arrows) and concomitant otitis media (asterisks). The tumour shows isointense signal on T_1 weighted imaging, slightly hyperintense signal on T_2 weighted imaging, and homogeneously moderate enhancement on contrast-enhanced coronal T_1 weighted imaging (arrows) (c). Axial CT (d) shows no bone destruction of the external auditory canal wall (arrowheads).

of 0.8, a field of view (FOV) of 197×197 mm and a reconstructive slice thickness of 1 mm.

MRI in 15 patients was performed by using 1.5-T (Gyrosan Intera; Philips Medical Systems, Best, Netherlands) or 3.0-T scanner (Achieva; Philips Medical Systems) with a head and neck synergy coil. The scan range included the EAC and whole neck. The sequences included axial and coronal spin echo T_2 weighted imaging, and axial T_1 weighted imaging. The acquisition parameters were repetition time (TR)/echo time (TE) = 550/18 ms for T_1 weighted imaging, TR/TE = 3000/90 ms for T_2 weighted imaging. Other parameters included a field of view of 230×230 mm to 250×250 mm; an acquisition matrix of 253×320 to 240×304 , section thicknesses of 5 mm, an inter-section gap of 1 mm, a flip angle of 90° and two to three signal averages. Contrast-enhanced sagittal, coronal and transverse T_1 weighted images were obtained after intravenous injection of gadopentetic acid dimeglumine (Magnevist®; Bayer Schering Pharma, Berlin, Germany) at a dose of 0.1 mmol kg^{-1} of body weight.

Image analysis

Two experienced radiologists (JS with 19 years' experience in diagnostic imaging and XD with 7 years' experience in

diagnostic imaging of head and neck) who were blinded to the final diagnosis of RIEACC assessed the images independently. Image interpretation discrepancies were resolved by consensus. The qualitative analysis included the following imaging parameters: (a) lesion extent (localized or extensive) defined as localized if the lesion was limited in the EAC (Stage T1 or T2)⁶ and as extensive if the lesion broke through EAC to adjacent structures such as the middle ear or brain (Stage T3 or T4).⁶ (b) Margin (well, partially or ill defined) considered as well defined if more than two-thirds of the tumour margin was sharply demarcated from the surrounding tissue and ill defined if less than one-third of the margin was sharply defined; and intermediate cases were considered partially defined.⁷ (c) Shape (regular or irregular) defined as regular if the lesion was round, oval or strip-like and otherwise as irregular. (d) EAC bone destruction (none, partial or extensive) determined on CT images where it was defined as partial if less than half of the EAC wall was corroded and as extensive if more than half of the wall or the adjacent bone was corroded such as the middle ear, mastoid process, inner ear, carotid canal, petrous apex or temporal squama. (e) Density/signal intensity (hypointense or isointense or hyperintense, in relation to the adjacent muscle signals). (f) Patterns of enhancement (homogeneous or heterogeneous). (g) Degrees of enhancement (mild, moderate or intense) defined as mild if the

Figure 2. A radiation-induced external auditory canal carcinoma in a 64-year-old male 14 years after nasopharyngeal carcinoma radiotherapy. Transverse T_1 weighted imaging (a), T_2 weighted imaging (b) and contrast-enhanced T_1 weighted imaging (c) show a nodular, well-defined mass (arrows) and concurrent otitis media (asterisks). The tumour shows isointense signal on T_1 weighted imaging, slightly hyperintense signal on T_2 weighted imaging and homogeneously moderate enhancement on contrast-enhanced T_1 weighted imaging (arrows). The otitis media had no enhancement on contrast-enhanced T_1 weighted imaging. Axial CT (d) shows an intact external auditory canal wall (arrowheads).

enhancement was lower or similar to the adjacent muscle; as moderate if greater than the muscle but lower than the sigmoid sinus; and as intense if similar to the sigmoid sinus. The presence of lymphadenopathy in the head and neck regions and concurrent otitis media were also assessed. The diagnosis of lymph node involvement was determined on the basis of central necrosis and size criteria.⁸ Interobserver variabilities were calculated using a Cohen's kappa analysis.

Quantitative image analysis was performed by a third radiologist (XZ with 4 years' experience in head and neck radiology). For each lesion, the size of the lesions was measured at its greatest diameter in both the axial and the coronal planes and noting the largest one.

RESULTS

Imaging findings

Imaging characteristics of 16 patients with RIEACCs are shown in Table 1. The kappa analysis indicated a good concordance between interobserver assessments with regard to each qualitative parameter ($\kappa = 0.759\text{--}0.899$; Table 1). The tumours had a size of 3.5 ± 1.4 cm (ranges, 1.2–7.4 cm), including seven localized lesions (Figures 1 and 2) and nine extensive lesions

(Figures 3–5), where adjacent structures such as the middle ear cavity ($n = 8$), mastoid ($n = 8$), temporomandibular joint ($n = 1$) and brain ($n = 4$) were invaded. Most of the lesions were partially or ill defined with an irregular shape. All seven localized lesions were well-differentiated tumours. Nine extensive lesions included seven poorly differentiated tumours, one moderately differentiated tumour and one well-differentiated tumour. All the seven patients who received CT examination showed isointense density masses on CT images. In 15 patients who received MRI, 8 lesions manifested as isointense signal, while seven patients manifested as slightly hypointense signal on T_1 weighted imaging. All lesions had slightly hyperintense signal on T_2 weighted imaging except one lesion with isointense (Figures 1–5). Most of the lesions ($n = 12$) exhibited homogeneously moderate enhancement after the injection of contrast agents. The concurrent inflammation in the tympanic cavity or/and mastoid was found in 13 patients (Figures 1–3). There was no lymphadenopathy found in head and neck regions.

Clinical features

Clinical profiles related to primary NPCs and RIEACCs in 16 patients are summarized in Table 2. The pathological diagnosis of NPCs was undifferentiated carcinoma (WHO Type III)

Figure 3. A radiation-induced external auditory canal carcinoma in a 45-year-old male 15 years after nasopharyngeal carcinoma radiotherapy. Transverse T_1 weighted imaging (a) and T_2 weighted imaging (b) show a large irregular mass with a partial ill-defined margin (white arrows) and concurrent otitis media (asterisk). The tumour shows isointense signal on T_1 weighted imaging and heterogeneous slightly hyperintense signal on T_2 weighted imaging (white arrows). Coronal T_2 weighted imaging (c) shows invasion of the left temporal bone and temporal lobe (black arrows). Axial CT (d) shows bone destruction of the external auditory canal wall and middle ear (arrowheads).

in 15 patients and differentiated non-keratinizing carcinoma (WHO Type II) in 1 patient.⁹ Six and ten patients had clinical TNM stage of II and III NPCs, respectively. All the EAC lesions in 16 patients were SCC histologically. The latent period from the beginning of the radiation treatment for NPCs to the occurrence of RIEACCs ranged from 2 to 30 years (median of 11 years), including nine patients from 10 to 20 years with a RD from 68 to 70 Gy (mean dose of 68.7 Gy); five patients from 2 to 10 years with the RD from 68 to 74 Gy (mean dose of 70.4 Gy); and two patients more than 20 years with the RD from 70 or 72 Gy. Among the five patients who had a latency range from 2 to 10 years, two of them had received the conventional radiotherapy alone, one of them had received the intensity-modulated radiotherapy (IMRT) alone, one of them accepted IMRT with combined neoadjuvant chemotherapy and the remaining one patient underwent conventional radiotherapy and neoadjuvant chemotherapy.

In 16 patients, radical excision of EAC tumours was performed in 10 patients, radiotherapy in 3 patients, chemotherapy in 2 patients and gamma knife radiosurgery in 1 patient. During 1- to 18-month follow-up, local recurrence was found in two patients of 3 months and 9 months, respectively, after resection

of EAC tumours, and no local recurrence or distant metastasis was found in the remaining patients.

DISCUSSION

Radiotherapy is the main treatment modality for NPCs.⁹ With the increase of survival rate, patients who receive radiotherapy for NPC have more opportunities to suffer from oncogenic side effects. Nowadays, the number of RITs reported is gradually increasing.² In the head and neck, the predilection sites of RISs were the paranasal sinuses, nasal cavity, neck and mandible, with most histological types of RISs being fibrosarcoma and osteosarcoma. Regarding carcinomas induced by radiation, SCC of the temporal bone is the most common form.^{1,4} In our series, all RISs of external auditory canal were histologically proven SCCs, which is consistent with this finding.

It has been reported that most of RITs have predilection for arising in the high-dose maxillary regions, while SCCs arise more frequently in the high-dose region of the tongue and the low-dose region of the EAC.⁴ A total dose of ≥ 55 Gy would increase the risk of RISs.¹⁰ Moreover, the SCC or sarcoma was believed to develop much earlier in the high-dose regions than in the low-dose regions.⁴ In our study, patients suffered from

Figure 4. A radiation-induced external auditory canal carcinoma in a 40-year-old male 3 years after nasopharyngeal carcinoma radiotherapy. Transverse T_1 weighted imaging (a) and T_2 weighted imaging (b) show an irregular, ill-defined mass (white arrows). The tumour shows isointense signal on T_1 weighted imaging and isointense signal on T_2 weighted imaging (white arrows). Contrast-enhanced sagittal T_1 weighted imaging (c) shows homogenously moderate enhancement with the mass (white arrows) and involvement of adjacent temporal lobe (black arrows). Axial CT (d) shows destruction of the external auditory canal dorsal wall and mastoid (asterisk).

RIEACCs with the latency range from 2 to 30 years (median of 11 years) after radiotherapy for NPCs, which is shorter than that of 10–30 years (mean of 21 years) reported by Goh *et al.*⁴ The reason might be that in our series, higher radiation intensity (>55 Gy) was applied for the treatment of primary lesions. In our study, almost one-third of patients had RIEACCs 2–10 years after radiotherapy. It is noted that all of our patients had TNM Stage II–III NPCs, and two of the five patients who had the latency of 2–10 years received IMRT. It is known that the usage of IMRT would include larger volumes of normal tissue being exposed to lower doses. These findings suggested that one of the trade-offs of IMRT might be a higher incidence of radiation-induced SCCs in patients with NPCs.¹¹

Currently, there is no universally accepted staging system for carcinomas of the temporal bone. In 1990, a staging system based on pre-operative clinical and CT findings was proposed by a group at the University of Pittsburgh.¹² Since its introduction, the Pittsburgh classification has been increasingly used to classify SCC of the temporal bone and has been demonstrated to be reliable and reproducible.⁶ Based on the Pittsburgh staging system, the 2-year survival rates for primary SCC of the temporal bone were as follows: T1 lesions, 100%; T2, 80%; T3, 50%;

and T4, 7%.⁶ The 5-year survival rate for early disease (T1 and T2 tumours) was 86%; for T3 tumours was 50%; and for T4 tumours was 41%.¹³ Patients with tumours limited to the EAC had a 5-year survival rate of 100%, patients with tumour invasion of the temporal bone of 63%, and patients with tumour infiltration beyond the temporal bone of 38%.¹³ Recently, the University of Pittsburgh-modified TNM staging system has been reported.¹⁴ According to this comprehensive staging system, the prognosis for patients with SCCs of the EAC was excellent, where the 5-year disease-specific survival (DSS) and recurrence-free survival (RFS) for patients with early stage disease (Stages I and II) was 100% and the 5-year DSS and RFS rates for patients with advanced disease (Stages III and IV) were 65.1% and 59.6%, respectively.¹⁴ Therefore, it is important to identify the lesions early.

Clinically, RIEACCs had no specific symptoms. CT and MRI are major radiological modalities of choice in the evaluation of EAC lesions.¹⁵ CT has great advantage in assessing the extent of temporal bony erosion, and MRI has the potential to detect the nature and invasion extents of the tumours. Whereas, the CT imaging features of RIEACCs are not distinct from their primary counterparts, with shared manifestations of soft-tissue masses,

Figure 5. A radiation-induced external auditory canal carcinoma in a 57-year-old male 15 years after nasopharyngeal carcinoma radiotherapy. Transverse T_1 weighted imaging (a), T_2 weighted imaging (b) and contrast-enhanced T_1 weighted imaging (c) show an irregular, ill-defined mass (arrows). The tumour shows isointense signal on T_1 weighted imaging, slightly hyperintense signal on T_2 weighted imaging and homogeneously intense enhancement on contrast-enhanced T_1 weighted imaging (arrows). Axial CT (d) shows destruction of the external auditory canal walls, mastoid (arrowheads) and temporomandibular joint (asterisk).

bone destruction and invasion to contiguous structures. In our series, most of RIEACCs manifested as soft-tissue mass with irregular shape and tended to be ill defined or partially ill defined with extension to adjacent structures. It is noted that all localized tumours in our series were well differentiated, whereas the majority of extensive tumours were poorly differentiated.

On MRI, most radiation-induced carcinomas (RICs) were reported to be homogeneous, low or intermediate signal on T_1 weighted imaging, intermediate signal on T_2 weighted imaging and moderate, homogeneous enhancements.¹ In our study, the majority of RIEACCs showed isointense signal or slightly hypointense signal on T_1 weighted imaging, slightly hyperintense on T_2 weighted imaging and homogeneous, moderate enhancement. These signal features were consistent with the findings previously reported.¹ In contrast, the presence of concurrent inflammation of the EAC or middle ear showed obvious hyperintense signal on T_2 weighted imaging because of inflammatory exudation, on which RIEACCs can be easily identified.

The diagnosis of RIEACCs should be differentiated from other malignant lesions of the EAC including primary carcinomas, RIS and benign tumours. A detailed comparison of the imaging findings in our series with other series of radiation-induced EAC

carcinoma,¹ non-radiation-induced EAC carcinoma^{13,15} and RIS of the temporal bone^{3,16} are shown in Table 3. The large size, extensive local invasion and bony destruction are their common features, however, RIEACCs are less common than primary carcinomas, and patients have a prior history of radiation treatment for the NPC. The signal characteristics of sarcomas were variable, and they were often more heterogeneous and more significant contrast enhanced than RICs.⁴ The necrotizing external otitis also could manifest with extensive bone destruction and adjacent structure invasion. Though it was difficult to differentiate them from RIEACCs radiologically, elderly diabetic patients with acute onset and early serious symptoms were the main features clinically to differentiate from RIEACCs. When RIEACCs are limited in EAC and there is a lack of damage of the EAC wall and other bone structures, it is difficult to distinguish them from some polyps or benign tumours. Nevertheless,

Table 2. Clinical profiles related to primary nasopharyngeal carcinomas (NPCs) and radiation-induced external auditory canal carcinomas (RIEACCs) in 16 patients

Clinical profiles	Number of patients
Clinical TNM stage of NPCs	
I	<i>n</i> = 0 (0%)
II	<i>n</i> = 6 (37.5%)
III	<i>n</i> = 10 (62.5%)
IV	<i>n</i> = 0 (0%)
Treatment for NPC	
Radiotherapy alone	<i>n</i> = 14 (87.5%)
Radiotherapy plus neoadjuvant chemotherapy	<i>n</i> = 2 (12.5%)
Radiation technique	
Conventional radiotherapy	<i>n</i> = 14 (87.5%)
Intensity-modulated radiotherapy	<i>n</i> = 2 (12.5%)
Radiation dose for nasopharynx (Gy)	
68–70	<i>n</i> = 11 (68.8%)
>70	<i>n</i> = 5 (31.3%)
Radiation dose for external auditory canal (Gy)	
60–70	<i>n</i> = 14 (87.5%)
40–45	<i>n</i> = 2 (12.5%)
Radiation dose for neck region (Gy)	
50–60	<i>n</i> = 7 (43.8%)
>60	<i>n</i> = 9 (56.3%)
T stage of RIEACC	
T1	<i>n</i> = 6 (37.5%)
T2	<i>n</i> = 1 (6.25%)
T3	<i>n</i> = 4 (25%)
T4	<i>n</i> = 5 (31.3%)

Table 3. Comparison of imaging features between non-radiation, radiation-induced external auditory canal (EAC) carcinoma and radiation-induced sarcomas of the temporal bone

Imaging features	RIEACC of our series <i>n</i> = 16	RIEACC of other series ¹ <i>n</i> = 4	Non-RIEACC ^{13,15} <i>n</i> = 27 ¹³	Radiation-induced sarcoma ^{3,16} <i>n</i> = 2
Tumour extent	Mostly extensive	Mostly extensive	Mostly extensive	Extensive
Tumour size	1.2–7.4 cm	2.7–8.5 cm	NA	3.5 cm; ³ NA ¹⁶
Tumour margin	Mostly ill defined or partially ill defined	Mostly ill defined or partially ill defined	Mostly ill defined or partially ill defined	Ill defined
Tumour shape	Mostly irregular	Mostly irregular	Mostly irregular	Irregular
Adjacent structure invasion	Middle ear, mastoid, temporomandibular joint or brain	Middle or inner ear, middle cranial fossa, temporal lobe, parapharyngeal region or parotid gland	Middle or inner ear, middle or posterior cranial fossa, temporal mandibular joint, parapharyngeal space, parotid gland, brain, cranial nerves, jugular bulb, internal carotid artery and dural sinuses	Extensive
EAC destruction on CT	Frequently present	Frequently present	Frequently present	Present
Signal intensity on MRI	Slightly hypointense to isointense signal T1WI, slightly hyperintense signal on T2WI	Hypointense to isointense signal on T1WI, isointense signal on T2WI	Homogeneous intermediate on T1WI, hypointense on T2WI	Hyperintense ¹⁶
Enhancement pattern on MRI	Homogeneously moderate enhancement	Homogeneously moderate enhancement	Heterogeneously moderate contrast enhancement	Heterogeneous enhancement ¹⁶

NA, not available; RIEACC, radiation-induced external auditory canal carcinoma; T1WI, *T*₁ weighted imaging; T2WI, *T*₂ weighted imaging.

most benign lesions lack a history of radiotherapy and the lesions frequently exhibit slower growth rate than do RIEACCs. Careful imaging follow-up or biopsy is necessary when the nature of lesions cannot be determined.

CONCLUSION

In conclusion, RIEACCs are rare malignant complications for NPC patients after radiation treatment. Owing to the desirable prognosis of RIEACCs, this entity should be identified when a mass or node-like lesion is present in the EAC for NPC

patients after radiotherapy. MSCT and MRI are helpful for assessing the nature and extension of lesions. The homogeneous signal pattern and moderate enhancement help the differential diagnosis of RIEACCs from inflammation and RISs of temporal bone. The RIEACCs should be considered in the routine surveillance for patients with NPC after radiotherapy.

FUNDING

This work was supported by the Program for New Century Excellent Talents in University of China (No. NCET-11-0538).

REFERENCES

1. Abrigo JM, King AD, Leung SF, Vlantis AC, Wong JK, Tong MC, et al. MRI of radiation-induced tumors of the head and neck in post-radiation nasopharyngeal carcinoma. *Eur Radiol* 2009; **19**: 1197–205. doi: [10.1007/s00330-008-1265-6](https://doi.org/10.1007/s00330-008-1265-6)
2. Cai PQ, Wu YP, Li L, Zhang R, Xie CM, Wu PH, et al. CT and MRI of radiation-induced sarcomas of the head and neck following radiotherapy for nasopharyngeal carcinoma. *Clin Radiol* 2013; **68**: 683–9. doi: [10.1016/j.crad.2013.01.004](https://doi.org/10.1016/j.crad.2013.01.004)
3. King AD, Ahuja AT, Teo P, Tse GM, Kew J. Radiation induced sarcomas of the head and neck following radiotherapy for nasopharyngeal carcinoma. *Clin Radiol* 2000; **55**: 684–9. doi: [10.1053/crad.2000.0503](https://doi.org/10.1053/crad.2000.0503)
4. Goh YH, Chong VF, Low WK. Temporal bone tumours in patients irradiated for nasopharyngeal neoplasm. *J Laryngol Otol* 1999; **113**: 222–8. doi: [10.1017/s0022215100143622](https://doi.org/10.1017/s0022215100143622)
5. Cahan WG, Woodard HQ, Higinbotham NL, Stewart FW, Coley BL. Sarcoma in irradiated bone. Report of eleven cases. *Cancer* 1948; **1**: 3–29. doi: [10.1002/1097-0142\(194805\)1:3.0.CO;2-7](https://doi.org/10.1002/1097-0142(194805)1:3.0.CO;2-7)
6. Moody SA, Hirsch BE, Myers EN. Squamous cell carcinoma of the external auditory canal: an evaluation of a staging system. *Am J Otol* 2000; **21**: 582–8.
7. Ban X, Wu J, Mo Y, Yang Q, Liu X, Xie C, et al. Lymphoepithelial carcinoma of the salivary gland: morphologic patterns and imaging features on CT and MRI. *AJNR Am J Neuroradiol* 2014; **35**: 1813–19. doi: [10.3174/ajnr.A3940](https://doi.org/10.3174/ajnr.A3940)
8. van den Brekel MW, Stel HV, Castelijns JA, Nauta JJ, van der Waal I, Valk J, et al. Cervical lymph node metastasis: assessment of radiologic criteria. *Radiology* 1990; **177**: 379–84. doi: [10.1148/radiology.177.2.2217772](https://doi.org/10.1148/radiology.177.2.2217772)

9. Wei WI, Sham JS. Nasopharyngeal carcinoma. *Lancet* 2005; **365**: 2041–54. doi: [10.1016/S0140-6736\(05\)66698-6](https://doi.org/10.1016/S0140-6736(05)66698-6)
10. Patel SG, See AC, Williamson PA, Archer DJ, Evans PH. Radiation induced sarcoma of the head and neck. *Head Neck* 1999; **21**: 346–54. doi: [10.1002/\(SICI\)1097-0347\(199907\)21:43.0.CO;2-B](https://doi.org/10.1002/(SICI)1097-0347(199907)21:43.0.CO;2-B)
11. Hall EJ, Wu CS. Radiation-induced second cancers: the impact of 3D-CRT and IMRT. *Int J Radiat Oncol Biol Phys* 2003; **56**: 83–8. doi: [10.1016/S0360-3016\(03\)00073-7](https://doi.org/10.1016/S0360-3016(03)00073-7)
12. Arriaga M, Curtin H, Takahashi H, Hirsch BE, Kamerer DB. Staging proposal for external auditory meatus carcinoma based on preoperative clinical examination and computed tomography findings. *Ann Otol Rhinol Laryngol* 1990; **99**: 714–21. doi: [10.1177/000348949009900909](https://doi.org/10.1177/000348949009900909)
13. Pfreundner L, Schwager K, Willner J, Baier K, Bratengeier K, Brunner FX, et al. Carcinoma of the external auditory canal and middle ear. *Int J Radiat Oncol Biol Phys* 1999; **44**: 777–88. doi: [10.1016/S0360-3016\(98\)00531-8](https://doi.org/10.1016/S0360-3016(98)00531-8)
14. Bacciu A, Clemente IA, Piccirillo E, Ferrari S, Sanna M. Guidelines for treating temporal bone carcinoma based on long-term outcomes. *Otol Neurotol* 2013; **34**: 898–907. doi: [10.1097/MAO.0b013e318281e0a9](https://doi.org/10.1097/MAO.0b013e318281e0a9)
15. Ong CK, Pua U, Chong VF. Imaging of carcinoma of the external auditory canal: a pictorial essay. *Cancer Imaging* 2008; **8**: 191–8. doi: [10.1102/1470-7330.2008.0031](https://doi.org/10.1102/1470-7330.2008.0031)
16. Debnam JM, Guha-Thakurta N, Mahfouz YM, Garden AS, Benjamin RS, Sturgis EM, et al. Radiation-associated head and neck sarcomas: spectrum of imaging findings. *Oral Oncol* 2012; **48**: 155–61. doi: [10.1016/j.oraloncology.2011.08.017](https://doi.org/10.1016/j.oraloncology.2011.08.017)