Applied Facial Anatomy

Michael F. Klaassen, Kate O'Connor, Patrick J. Beehan, Earle Brown, Lawrence C. Ho, and Kumar Mithraratne

Core Messages

- Cancer staging is important from an anatomical perspective.
- Modern radiological imaging techniques assist the multidisciplinary team managing advanced facial cancer.
- The patterns of cancer spread are predictable and illustrated from a 3D anatomical perspective.

1 Introduction

The anatomy of the face can be considered in multiple dimensions (Figs. 1, 2, 3, 4, 5, 6, and 7). From a 2D perspective, the skin of the face and upper neck integument consists of composite layers of epidermis, dermis, a subdermal plexus of vessels, subcutaneous fat (panniculus adiposus) and superficial fascia (panniculus carnosus), now called the SMAS in the face and platysma in the neck. The subcutaneous plane is rather vascular, while the sub-SMAS plane is relatively avascular. The muscles of mastication are in the periphery of the face (outside the true frontal plane of the face). They generally lie in a deeper plane, whilst the extensive mimetic muscles are superficial and lie centrally in the true front plane, with fine extensions into the overlying facial skin. Motor innervation of facial muscles is usually in the deep surface, but there are exceptions. Arterial supply and venous drainage are paired and run closely alongside the relevant nerves as neurovascular bundles. The sensory nerve supply of the face is from the three divisions of the trigeminal nerve, while the face/neck junction is supplied by the upper cervical nerves. The muscles of mastication are supplied by the trigeminal nerve and the mimetic muscles by the facial nerve branches. The face has a dual arterial supply from both the external and internal carotid arteries though predominantly from the external carotid artery. However, this dual supply has profound implications in clinical practice. The lymphatic drainage system with a network of loco-regional lymph node basins is also relevant to the 2D conceptualisation of the face and neck.

A 3D perspective has significance for the aesthetic reconstruction of the face after cancer resection. The 3D concept considers the various facial planes and contours that contribute to normal facial morphology, facial function and aesthetic beauty [1].

The cutaneous sensory nerve supply is from the three divisions of the trigeminal nerve (ophthalmic, maxillary and mandibular) for the face and cervical 2 and 3 for the face/neck junction. Most sensory nerve branches (V1 and V2) enter through the bony foramina and supply sensation to the overlying area of the skin and soft tissue.

The motor nerves of the trigeminal nerve supply the muscles of mastication (first pharyngeal arch) in the periphery of the face. They are located deeply and enter their target muscle on their deep surface.

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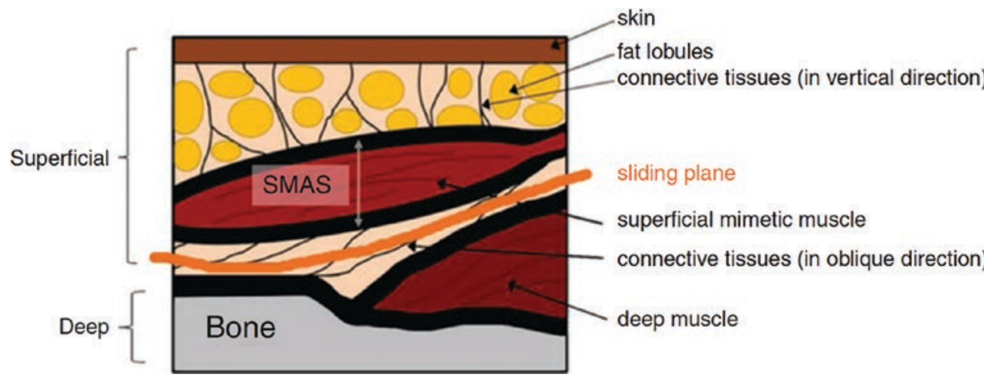

Fig. 1 Organisation of tissues in the human face

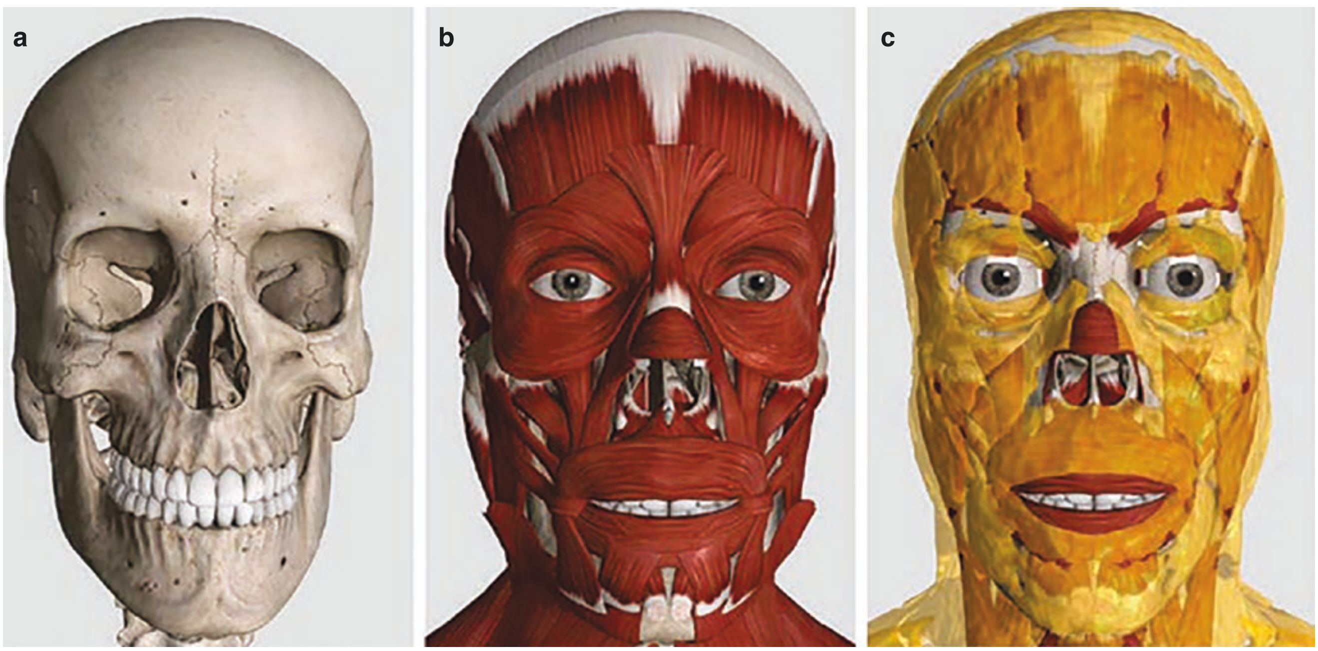

Fig. 2 (**a**–**c**) 2D concepts of applied facial anatomy. (*From* Ho et al. [1]; *with permission*)

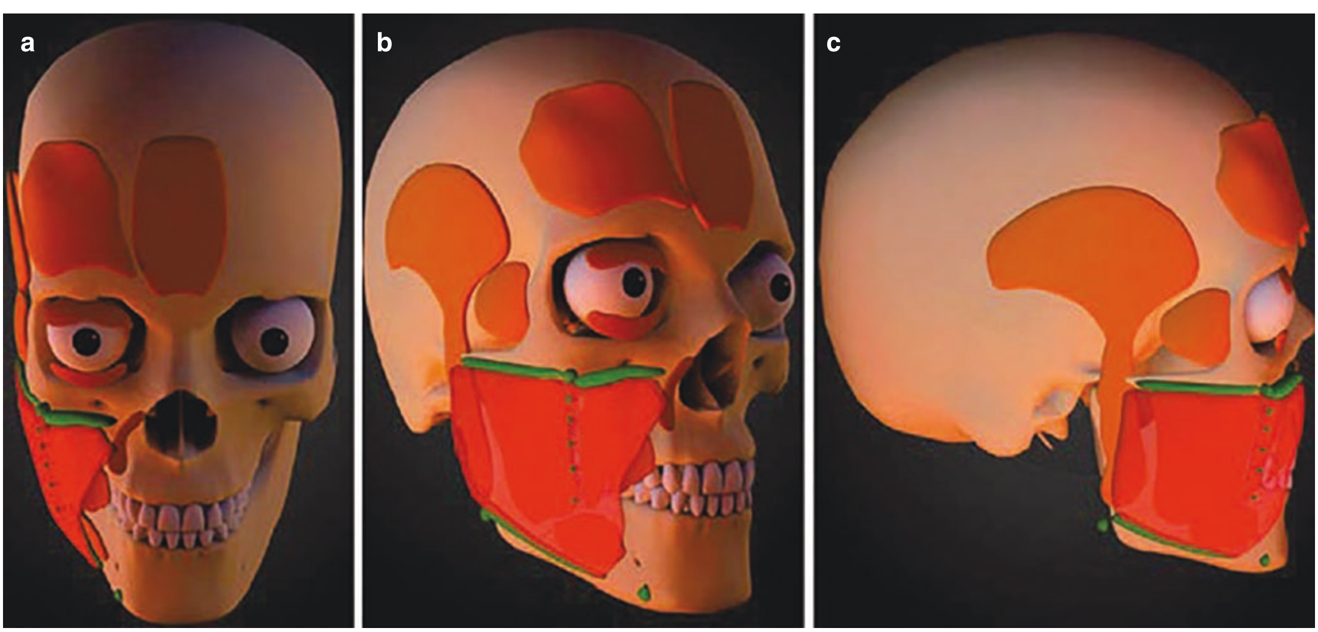

Fig. 3 (**a**–**c**) 3D concepts of applied anatomy

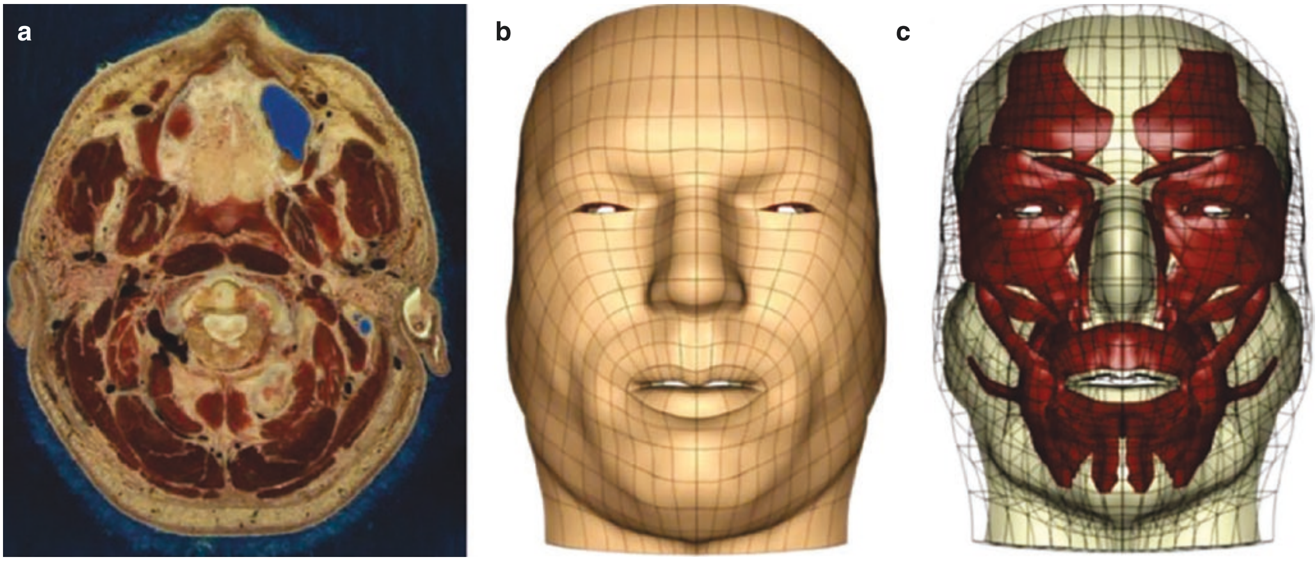

Fig. 4 (**a**–**c**) Mathematical formulation of structure and function for applied facial anatomy (*from* Ho et al. [1]; *with permission*)

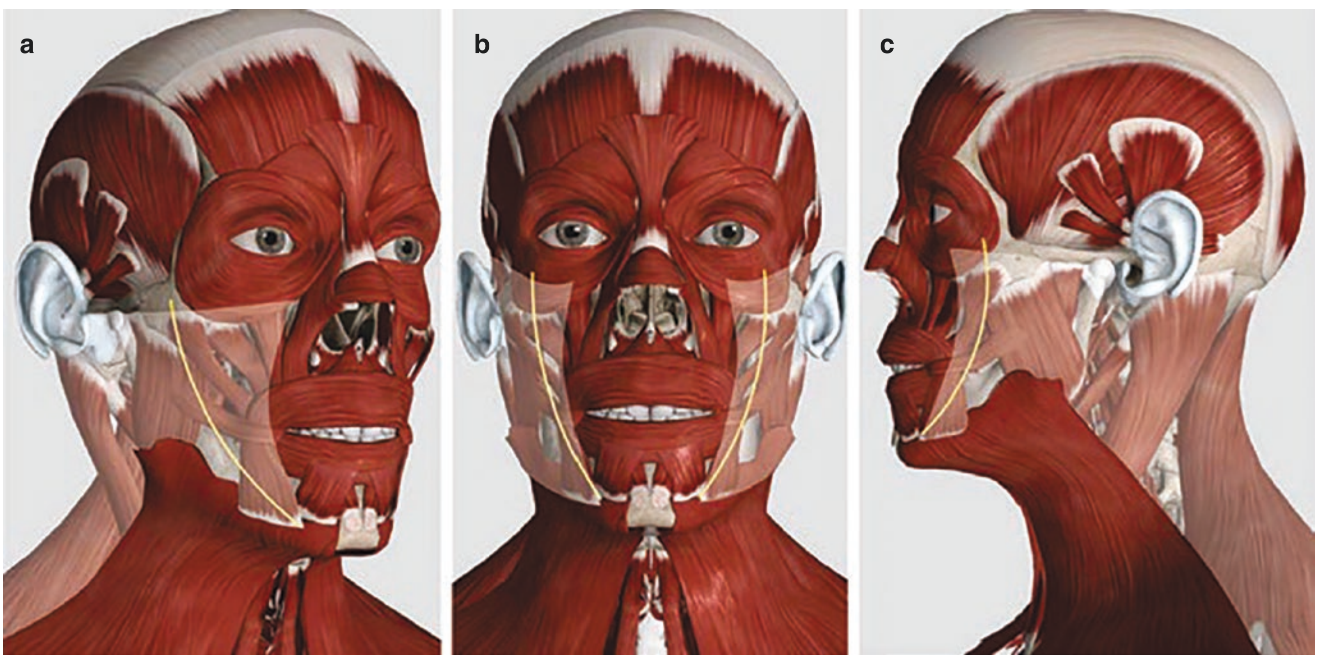

Fig. 5 (**a**–**c**) Lateral facial muscles of mastication and medial facial muscles of animation (*from* Ho et al. [1]; *with permission*)

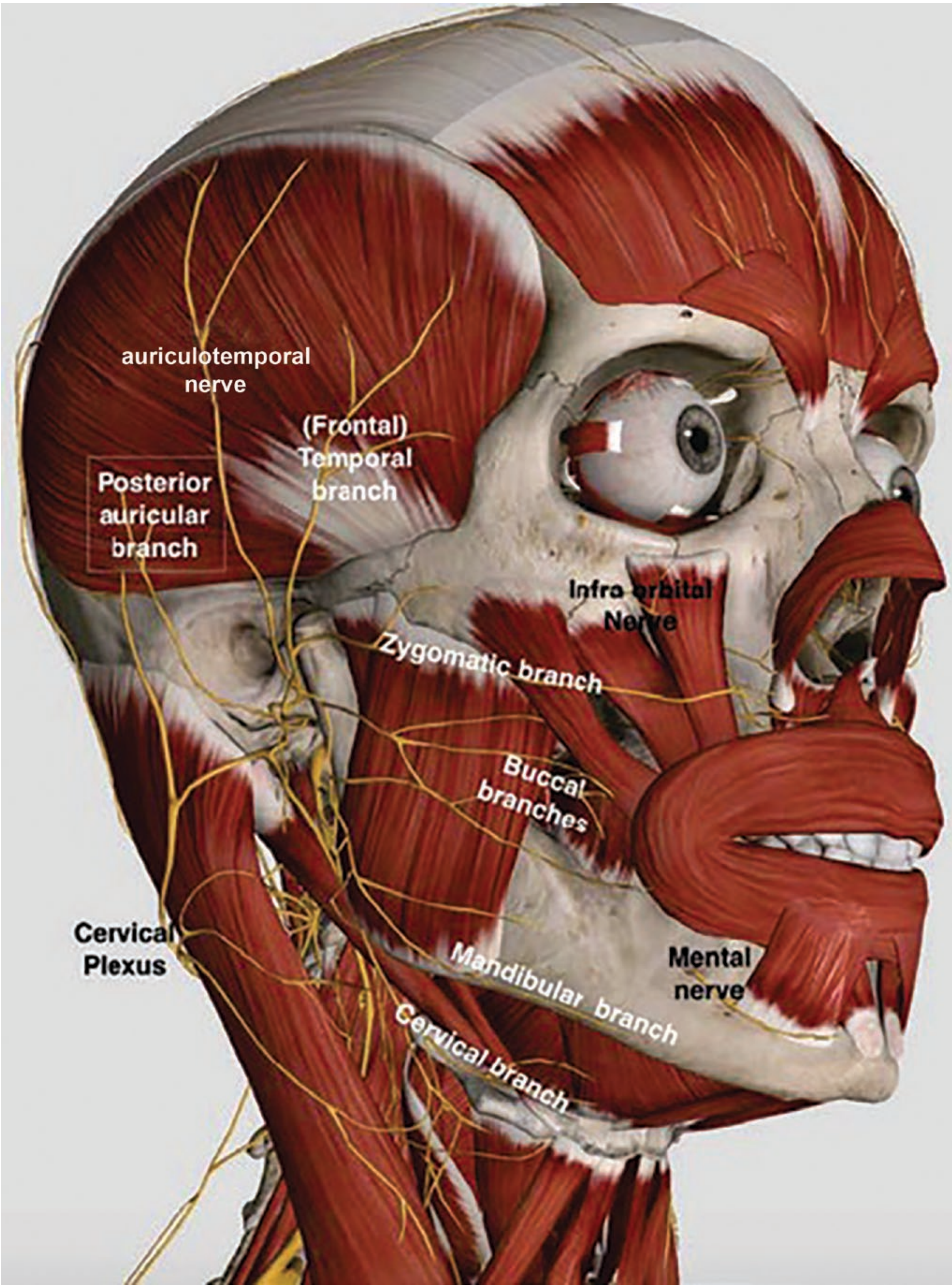

Fig. 6 Sensory and motor nerves of the human face

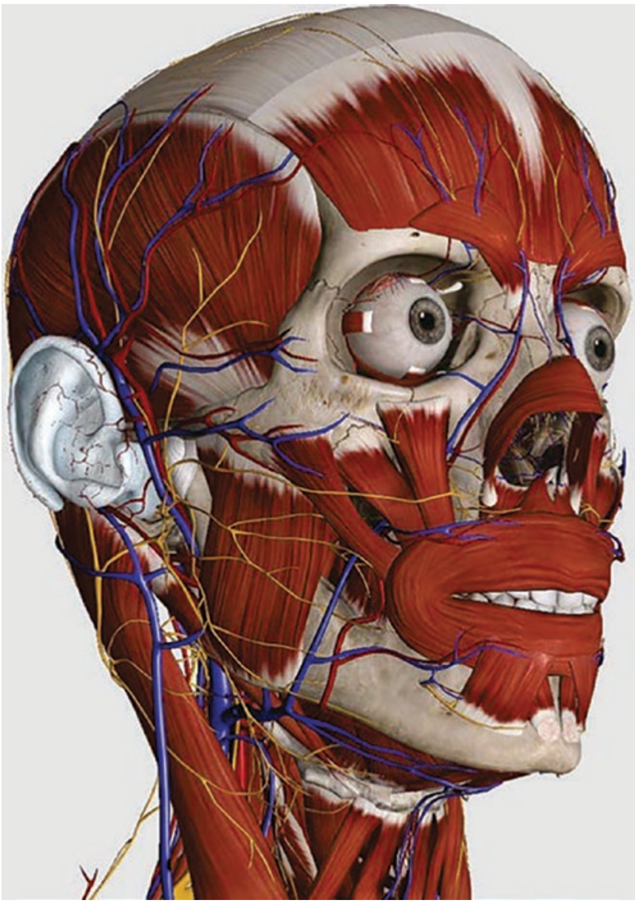

Fig. 7 Neurovascular bundles of the human face

2 Mechanisms of Cancer Spread

The next series of cases represent in radiological detail the mechanisms by which cancers of the face/head and neck spread by direct deep extension, via tissue planes and via lymphovascular or perineural routes.

2.1 Direct Extension

A 56-year-old woman presented with an aggressive SCC of the external auditory canal with deep subcutaneous extension into the infratemporal fossa and the skull base (Fig. 8). The sequential MRI scans are shown.

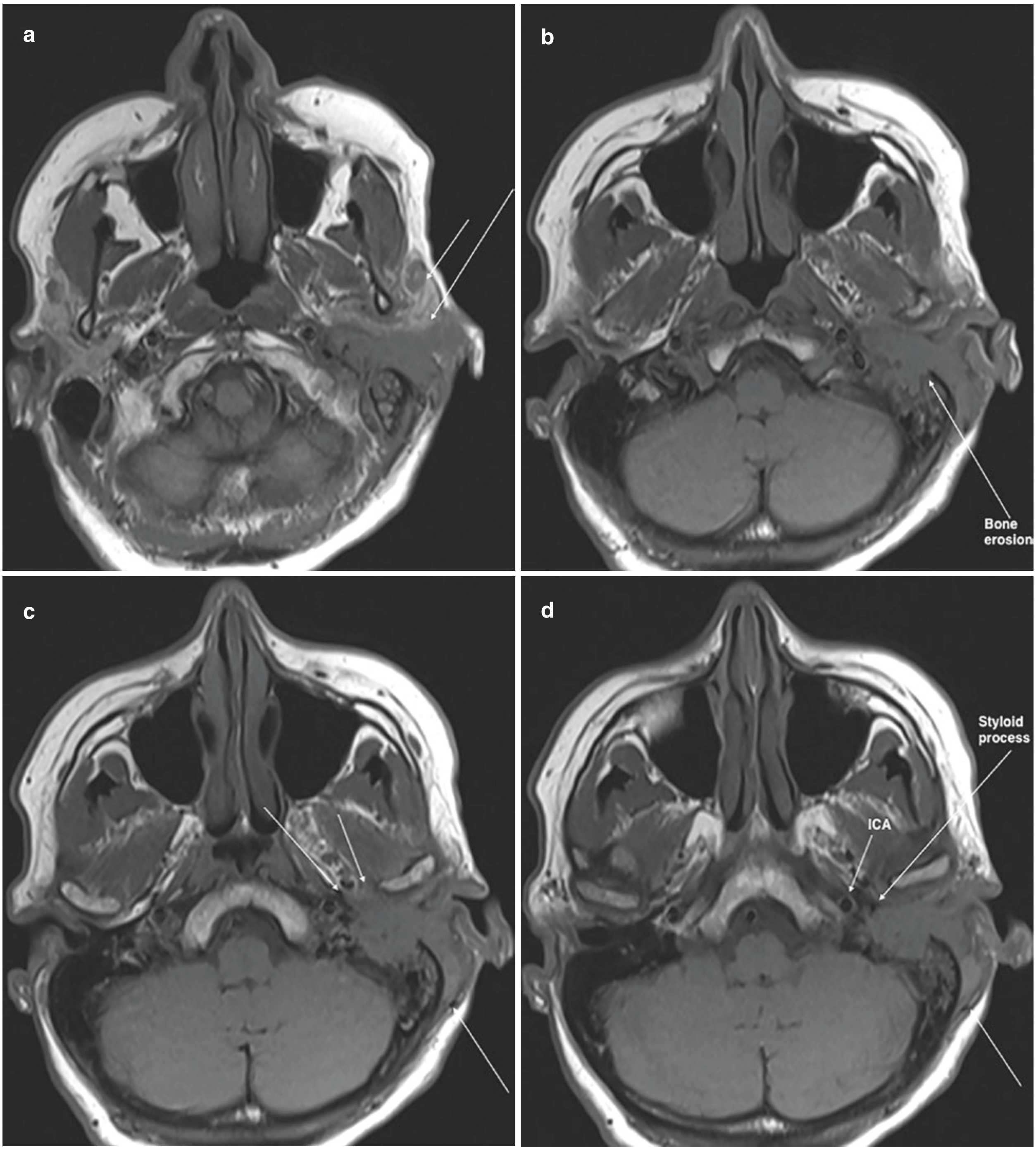

Fig. 8 (**a**) Arrow points to the left external auditory canal SCC in a 56-year-old woman. Note the fluid in the mastoid tip and the increased size of the lymph node in the anterior parotid gland. (**b** and **c**) Bone erosion is seen with loss of black cortex and infratemporal fossa extension with the internal carotid artery just medial to the tumour. (**d** and **e**) L. internal carotid artery, styloid process, bright fluid in the L. mastoid and tumour abutting the mandibular condyle and probably involving the TMJ. (**f** and **g**) Extensive direct spread of aggressive SCC L ear canal into parotid gland, abutting skull base and under the L ear

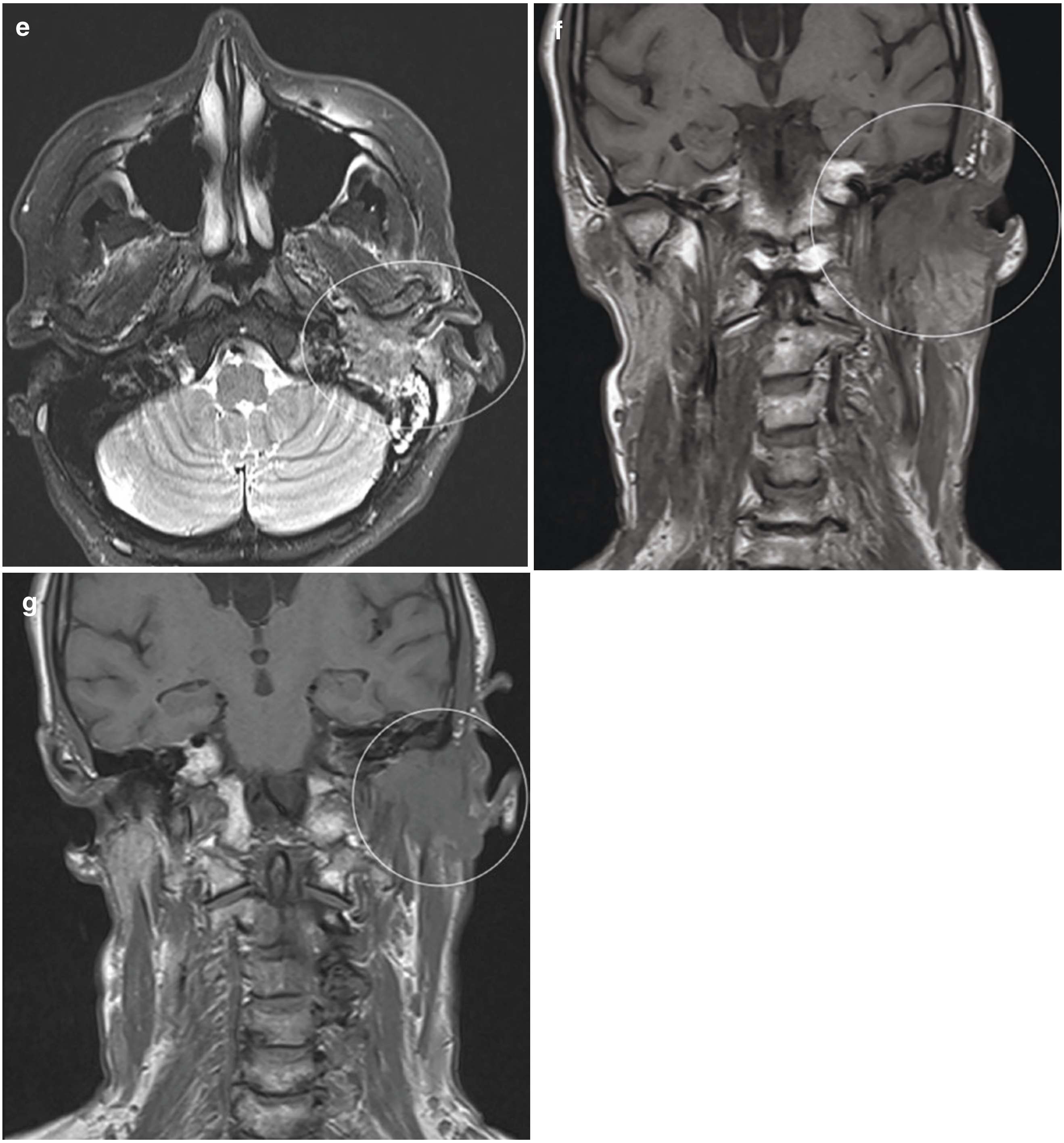

Fig. 8 (continued)

2.2 Spread from the Ear to the Parotid Gland

This is a 93-year-old man's CT images showing an aggressive SCC of his L ear with invasion of the parotid gland (Fig. 9).

Fig. 9 (**a** and **b**) Diffuse lesion invading the L parotid and ear. Note the L preauricular lymph node in **b**. (**c** and **d**) The L preauricular lymph node seen in axial CT and spread of the SCC down the external auditory canal to the L temporal bone. (**e**) The SCC abuts the L parotid gland

Fig. 9 (continued)

2.3 Perineural Invasion

Perineural invasion by cancers of the head and neck is always a bad prognostic indicator and its presence a factor that should be of concern for surgeons, radiologists and oncologists in the MDT. Squamous cell carcinoma is the most common culprit, and the most frequently affected nerves are the trigeminal and facial nerves of the face. Perineural invasion is most often a histological finding and many patients presenting with it are asymptomatic. Perineural tumour spread is defined as macroscopic tumour extension along a nerve from the primary tumour, which is apparent radiologically and sometimes clinically [2].

As experienced surgeons we have all been challenged by the patient with wide and complete excision of the facial squamous cell carcinoma on histological margins, but with later local recurrences and even late presentation with a facial palsy. We then ask ourselves the questions: how could we have recognized the problem of perineural invasion earlier, and what should/could we have done to prevent the neural spread? The significant morbidity and mortality of perineural invasion and tumour spread are reflected in the poor prognosis. There is new science that suggests a role of the nerve microenvironment and the immune system that act as mediators in the pathogenesis of perineural invasion and spread [3].

The following MRI images (Fig. 10) demonstrate the perineural invasion of the facial nerve deep in the parotid gland of a 72-year-old man with a moderately differentiated squamous cell carcinoma.

The 61-year-old man in Fig. 11 had progressive facial nerve symptoms and palsy over 6 months.

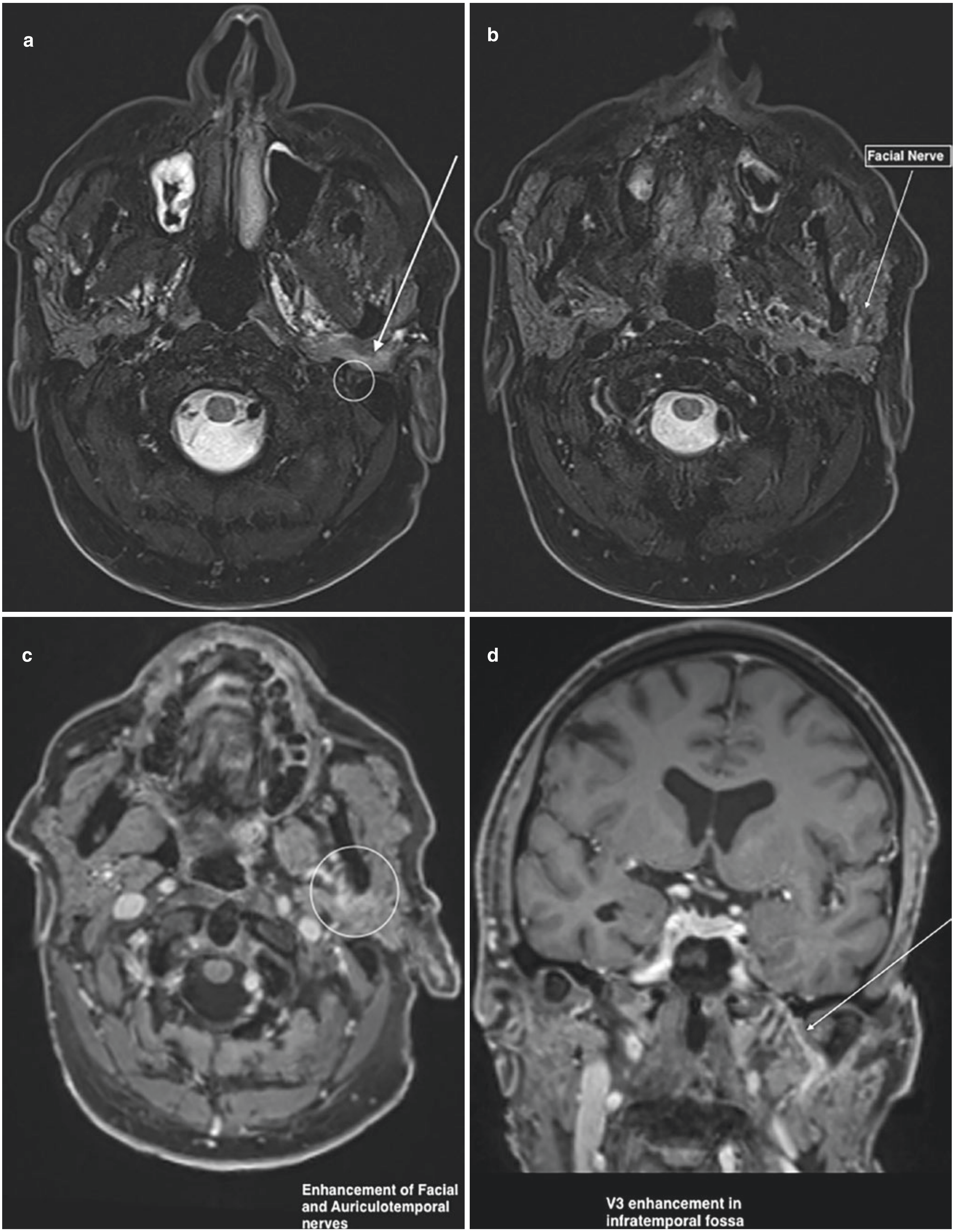

Fig. 10 (**a** and **b**) Moderately differentiated SCC in a 72-year-old man. In (**a**), the arrow shows increased signal in the parotid with the circle defining the stylomastoid foramen. (**b**) shows increased signal in the facial nerve within the parotid gland. (**c** and **d**) (**c**) shows increased signal in the facial and auriculotemporal nerves behind the mandibular ramus. (**d**) shows enhancement of V3 in the infratemporal fossa

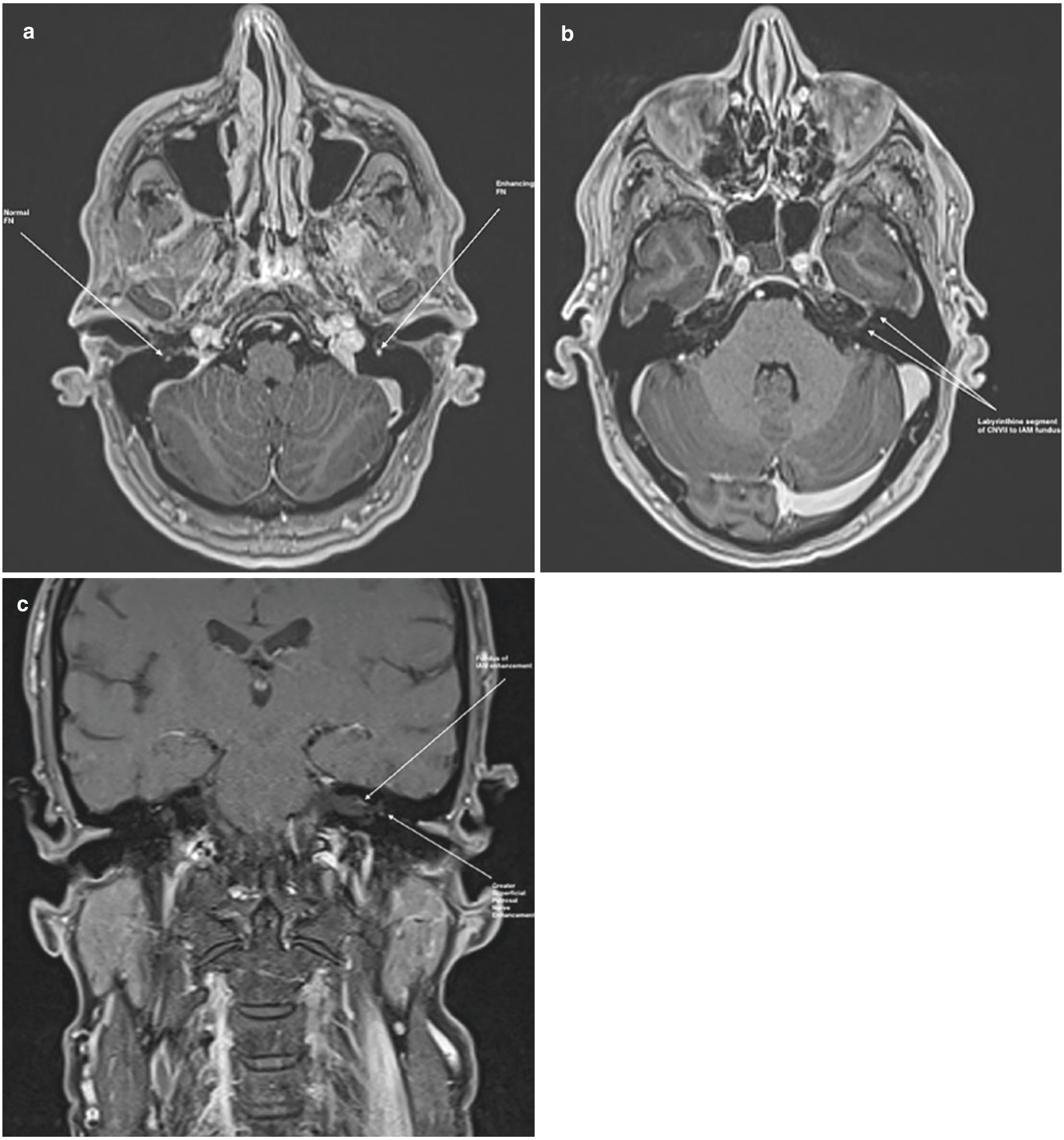

Fig. 11 (**a–c**) Shows the MRI scans in the 61-year-old man with progressive left facial nerve palsy over 6 months, with enhancement of the left facial nerve, at the labyrinthine segment of the internal auditory meatus and the greater superficial petrosal nerve (GSPN)

2.4 Lymphovascular and Perineural Invasion

The 78-year-old man in Fig. 12 has a pT3N3bM0 squamous cell carcinoma invading his left parotid gland with central necrosis of a parotid node and involvement of the greater auricular nerve all the way to the vertebral foramen and spinal canal.

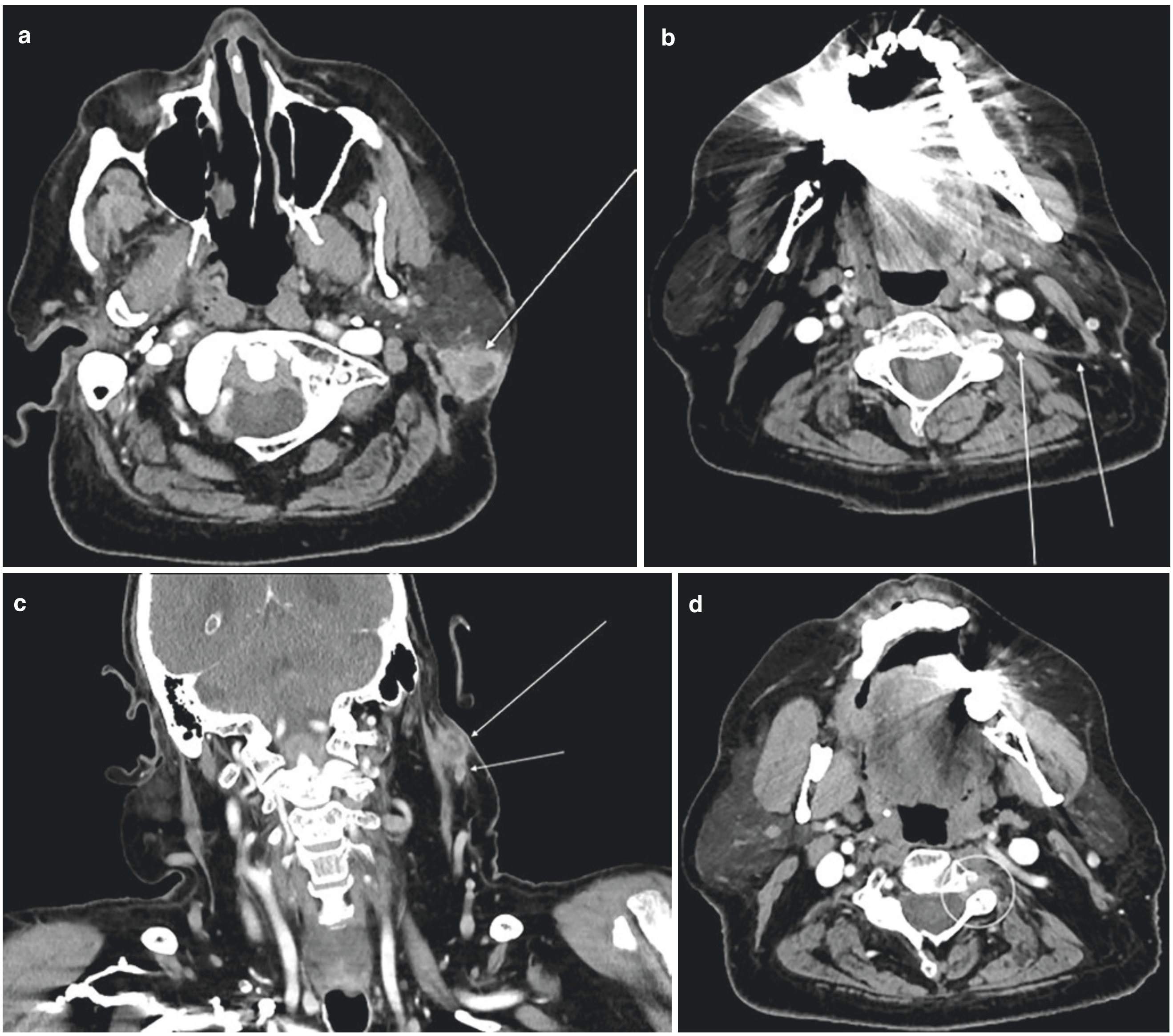

Fig. 12 (**a**–**d**) CT scans of a 78-year-old man with pT3N3bM0 SCC showing necrosis in a posterior left parotid lymph node, thickening and enhancement of the left greater auricular nerve all the way to the vertebral foramen and spinal canal (circle). (**e** and **f**) MRI scans complementing the CT scans of same case showing posterior left parotid SCC and the enhanced left greater auricular nerve traversing the neck

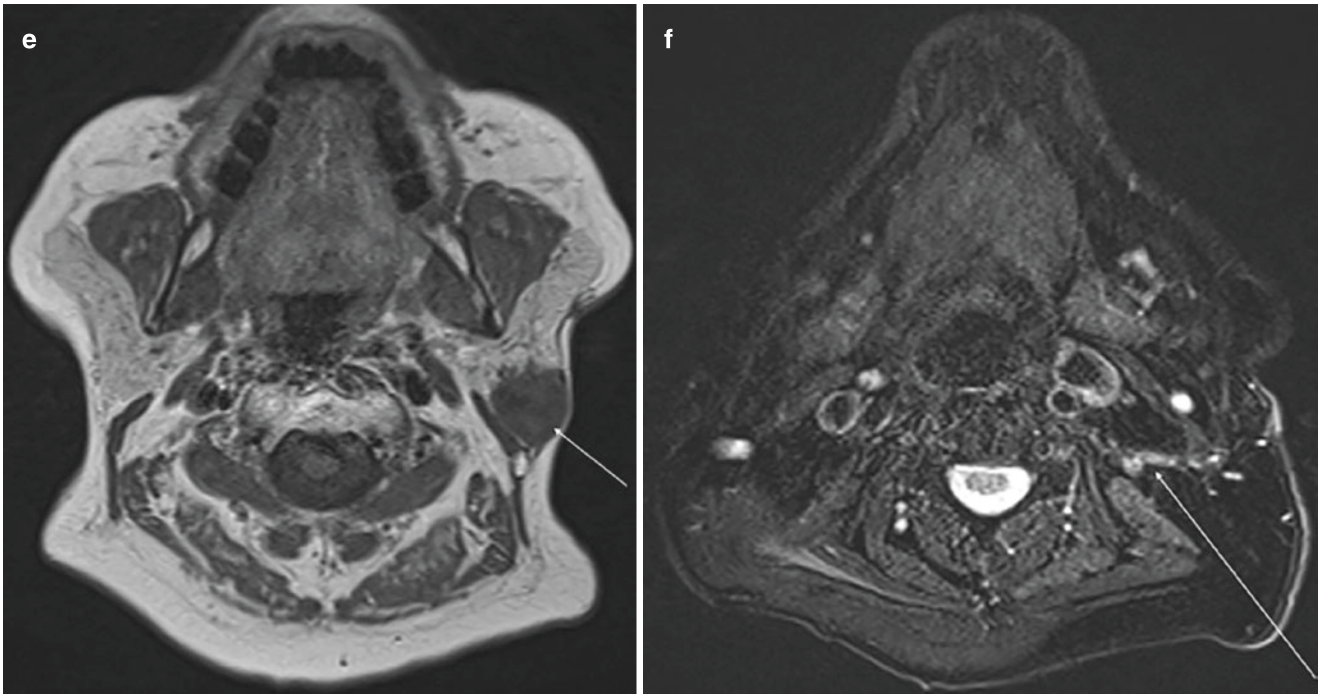

Fig. 12 (continued)

2.5 Metastases with Extranodal Spread

The 79-year-old man in Fig. 13 initially presented with a 7.5-mm-thick poorly differentiated squamous cell carcinoma of his scalp. The series of CT scans show the lymphatic infiltration and spread to the neck, paravertebral muscles, the transverse process of C1, the suboccipital region and effacement of the internal jugular vein.

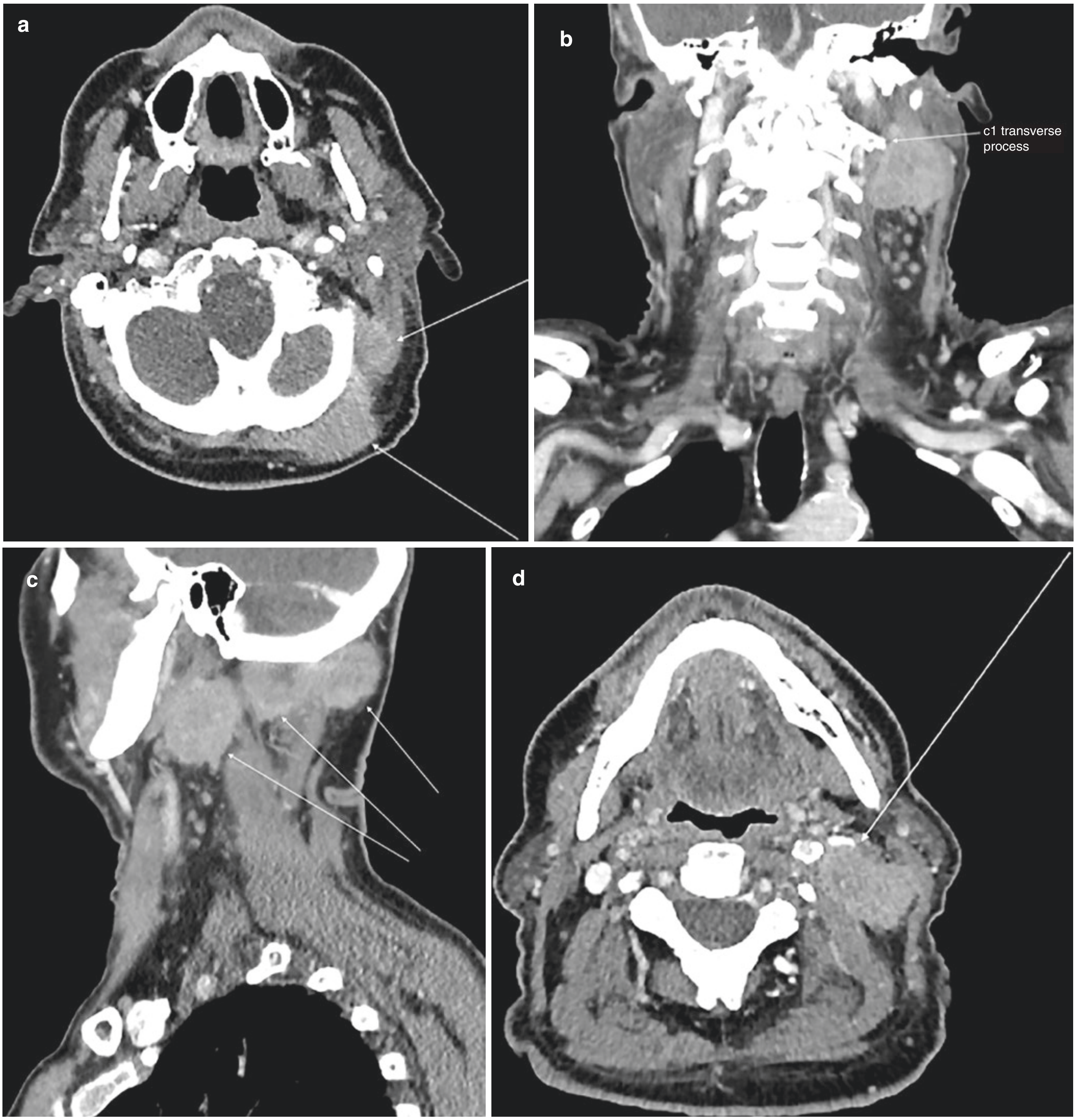

Fig. 13 (**a**–**e**) Poorly differentiated SCC of the scalp in a 79-year-old man, with axial and coronal CT views of lymphatic spread to the left neck, transverse process of C1, suboccipital region, effacement of the IJV and a level 5B node

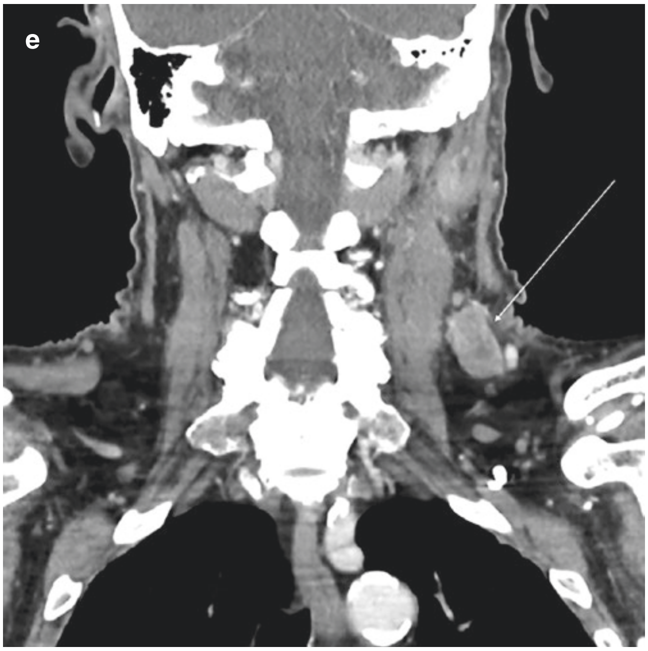

Fig. 13 (continued)

2.6 Periorbital Spread

The 87-year-old woman in Fig. 14 had a recurrent sarcomatous squamous cell carcinoma of her right scalp, which invaded her temporalis muscle and was characterized by perineural invasion. This resulted in orbital and intracranial spread.

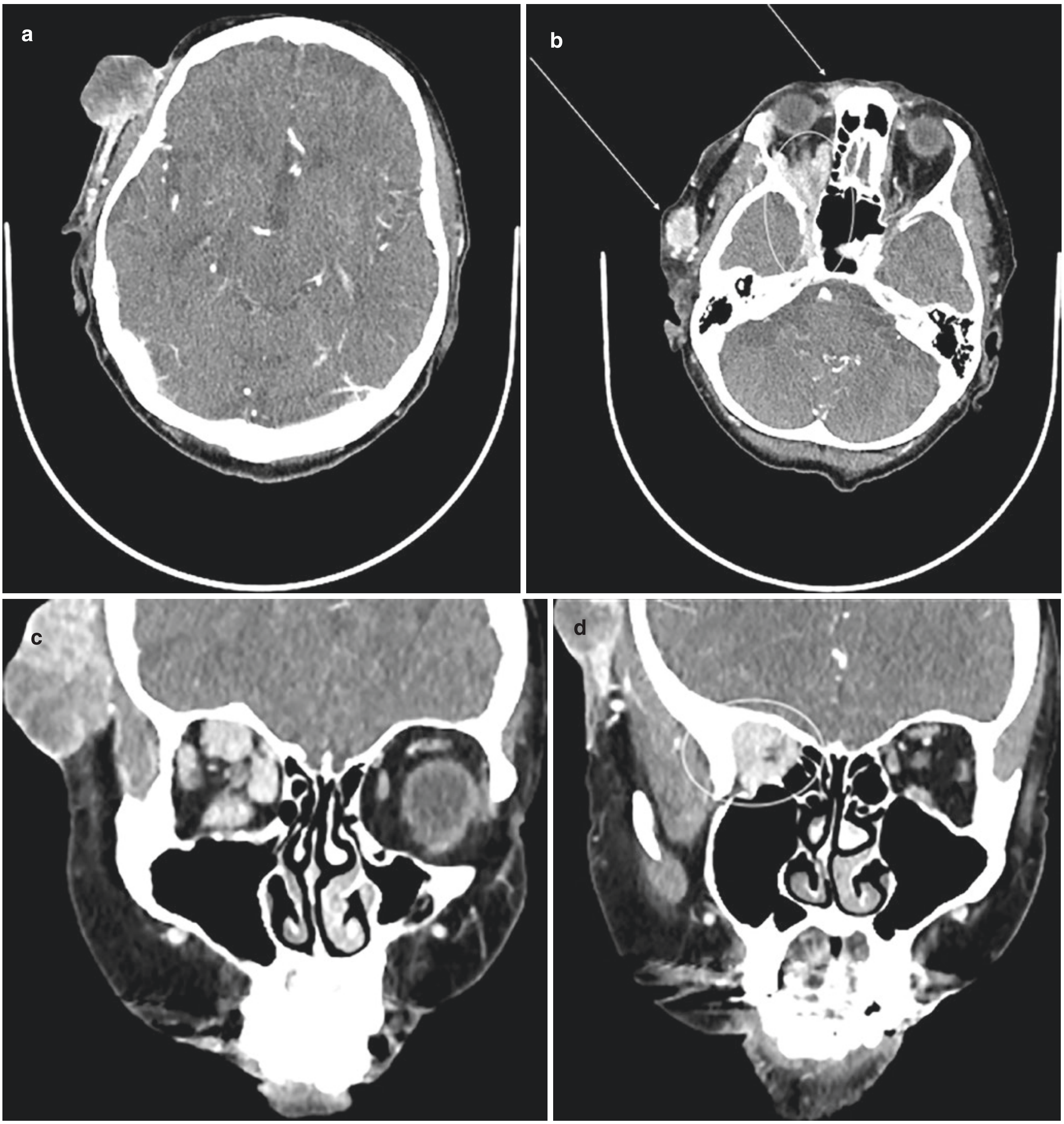

Fig. 14 (**a** and **b**) Recurrent sarcomatous SCC invading right temporalis muscle, right preauricular lymph node and by perineural spread to the apex of the right orbit (ringed), where it extends posteriorly to the right cavernous sinus. Note also the tumour at the medial canthal region. (**c** and **d**) Coronal CT views show involvement of all of the right extraocular muscles and the posterior right orbit where there is compression of the orbital nerve. (**e** and **f**) Axial MRI scans show the right optic nerve surrounded by tumour and the right cavernous sinus invaded by tumour. The posterior arrow indicates enhancement of the right trigeminal nerve in the cistern. (**g** and **h**) Coronal MRI scans show tumour in the inferior orbital fissure and orbital apex (circled), V2 (Maxillary branch of the trigeminal nerve) at the foramen rotundum, the enhanced cavernous sinus (Meckel's cave) and the pre-ganglionic portion of the trigeminal nerve in the pre-pontine cistern

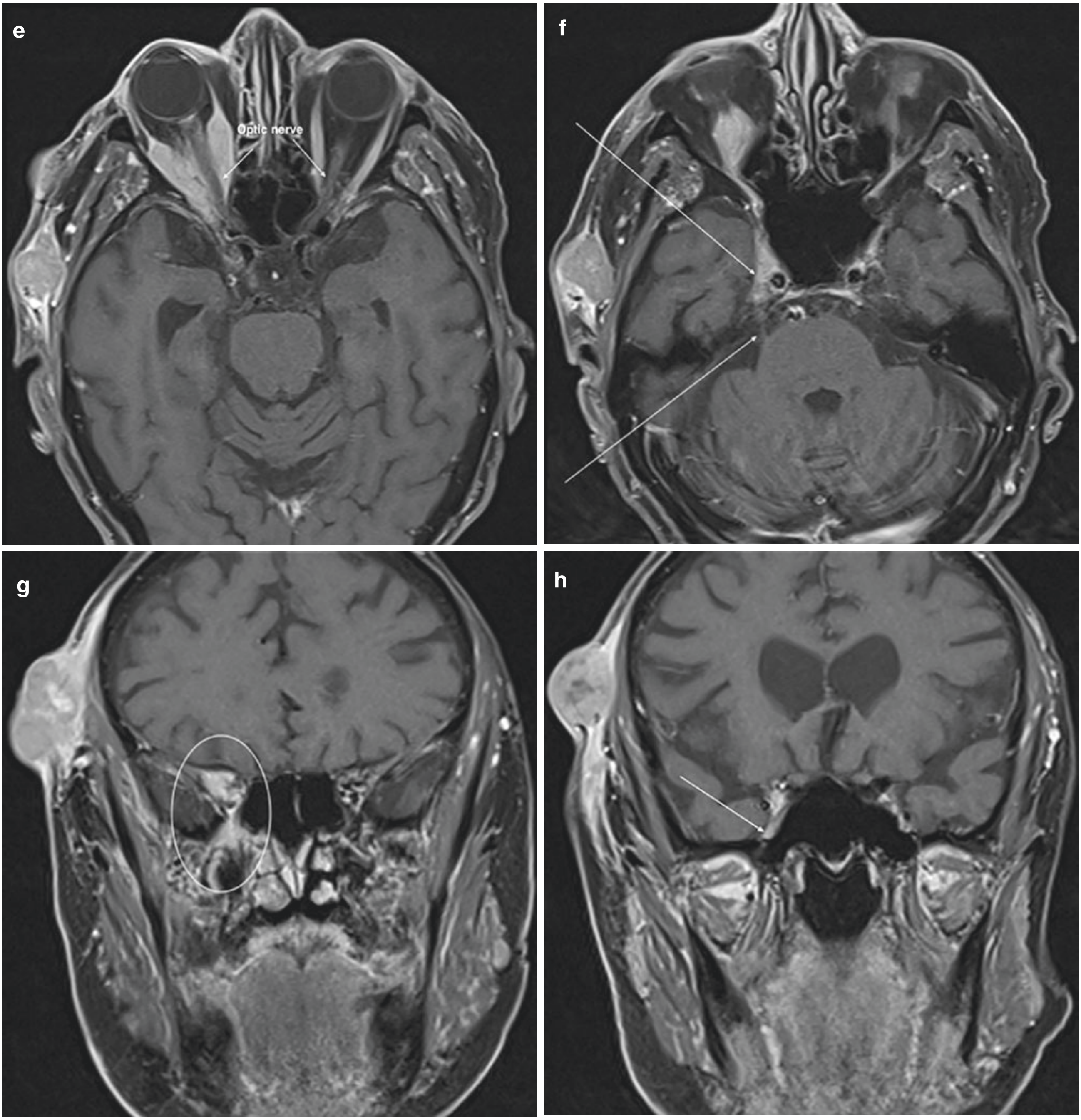

Fig. 14 (continued)

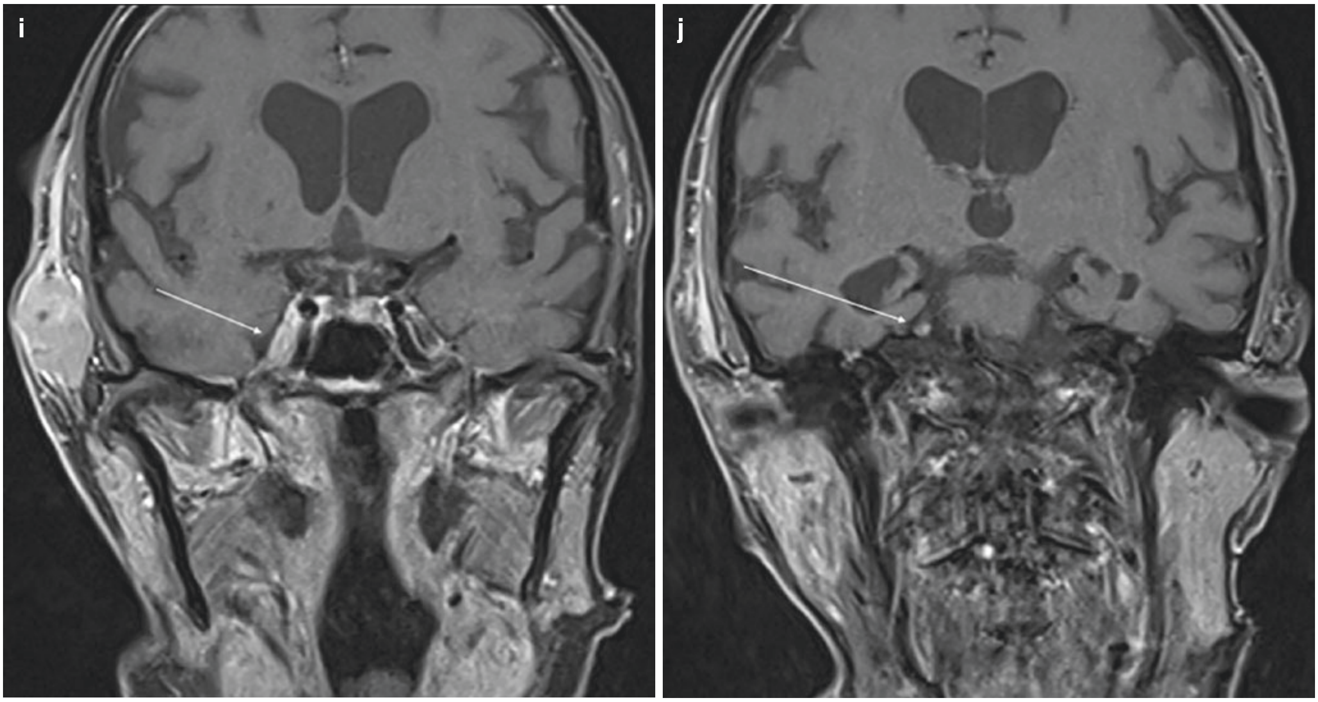

Fig. 14 (continued)

2.7 Peri-auricular Spread

This 93-year-old man (Fig. 15) has a diffuse SCC of his left ear invading the parotid gland with a preauricular lymph node and close to the left temporal bone.

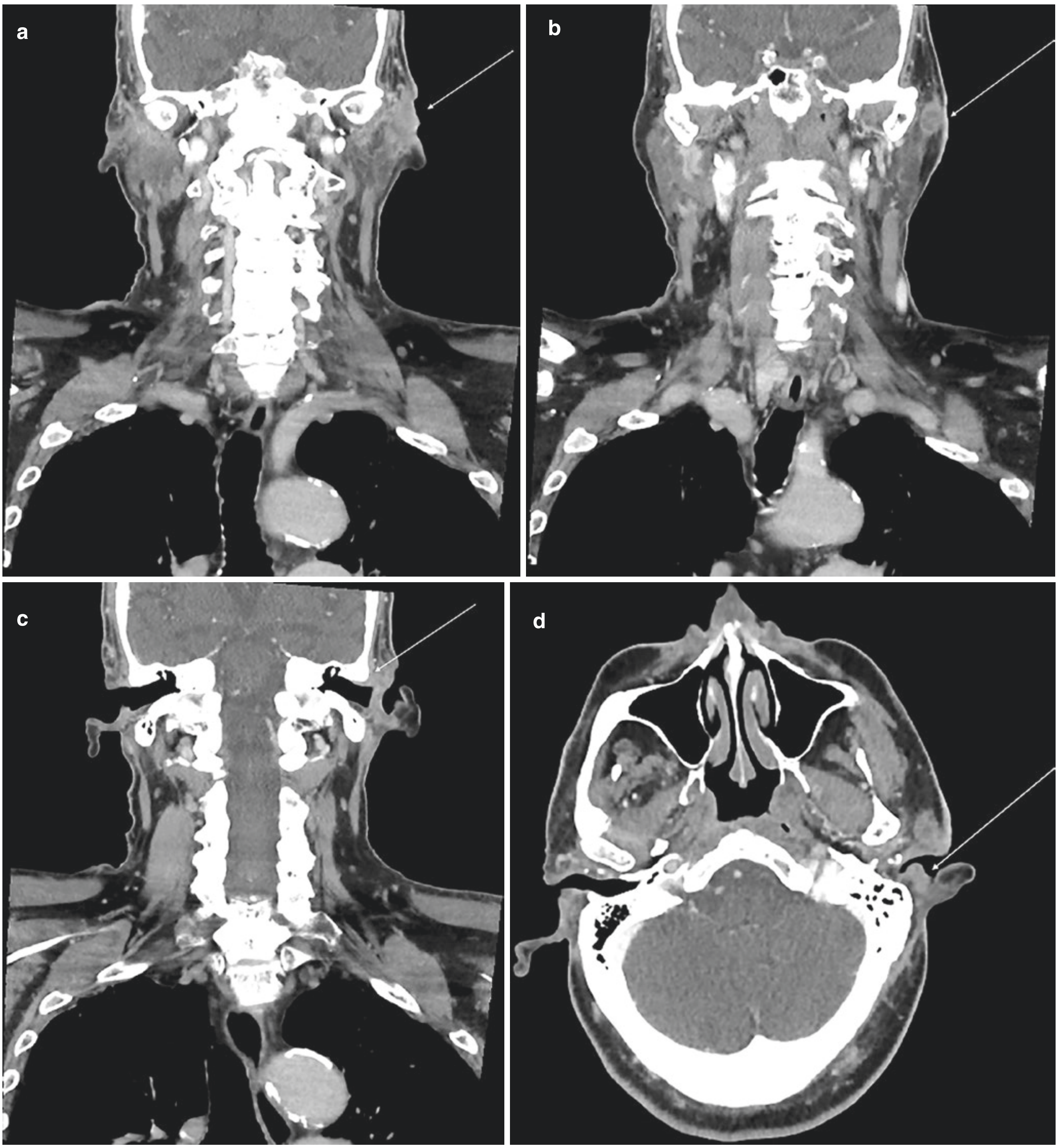

Fig. 15 (**a–d**) A 93-year-old man with aggressive SCC of his left ear invading the parotid, with a preauricular node and close to the left temporal bone. Note the fat plane preserved between the tumour thickening and the temporal bone in the last axial CT view

2.8 Bone Invasion

The 57-year-old man in Fig. 16 shows a squamous cell carcinoma involving the full thickness of the skin of the left occipital scalp and bone erosion of the outer table of the skull.

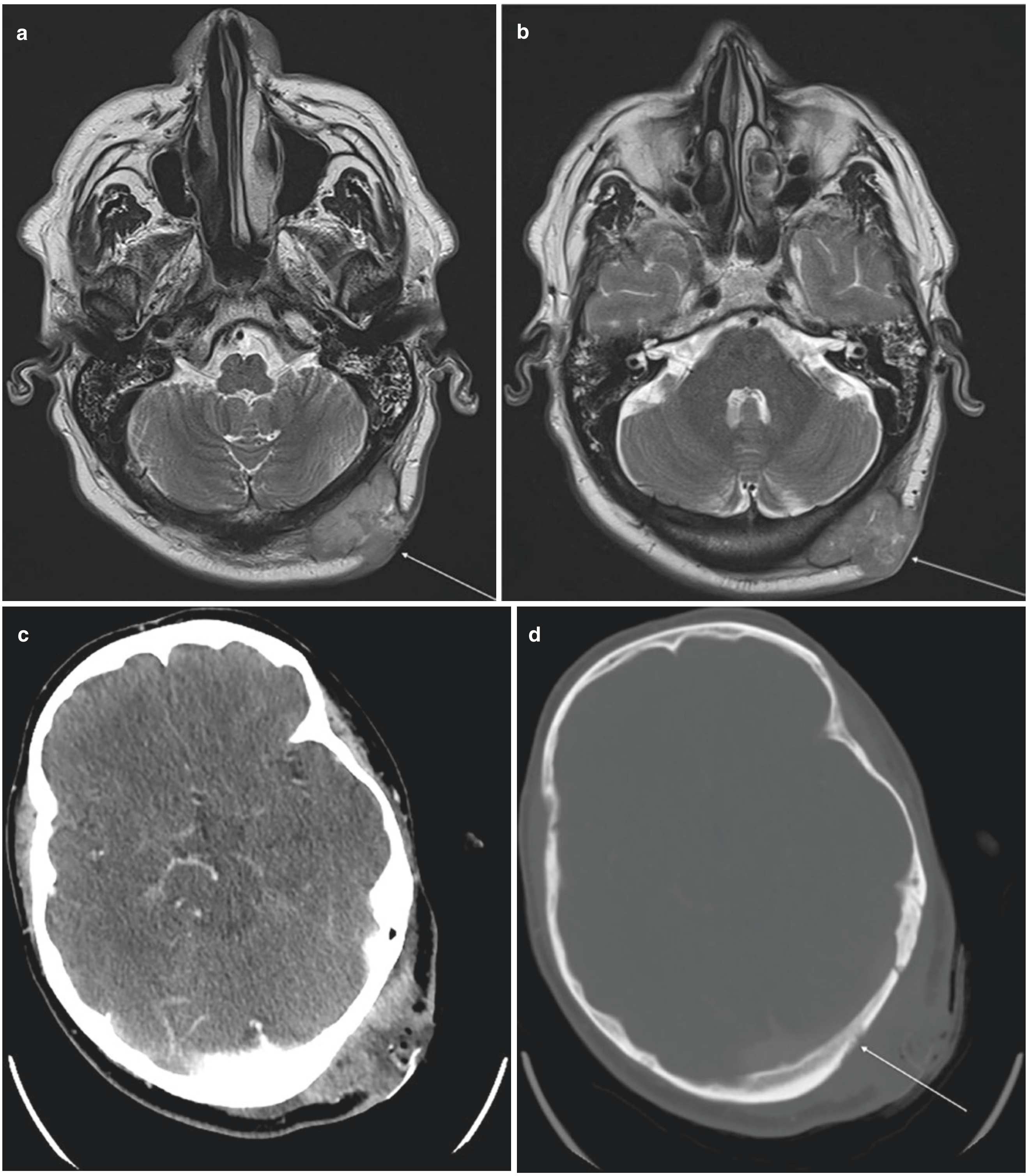

Fig. 16 (**a**–**d**) SCC of the left occipital scalp invading full thickness and eroding the outer table of skull. The first two images are MRI scans, and the second two images are CT scans, showing post-biopsy changes at the surface of the lesion and confirming calvarial invasion

2.9 CT Appearance of Lymph Node Spread

This 78-year-old man (Fig. 17) had a prior resection of a poorly differentiated squamous cell carcinoma 18 months earlier.

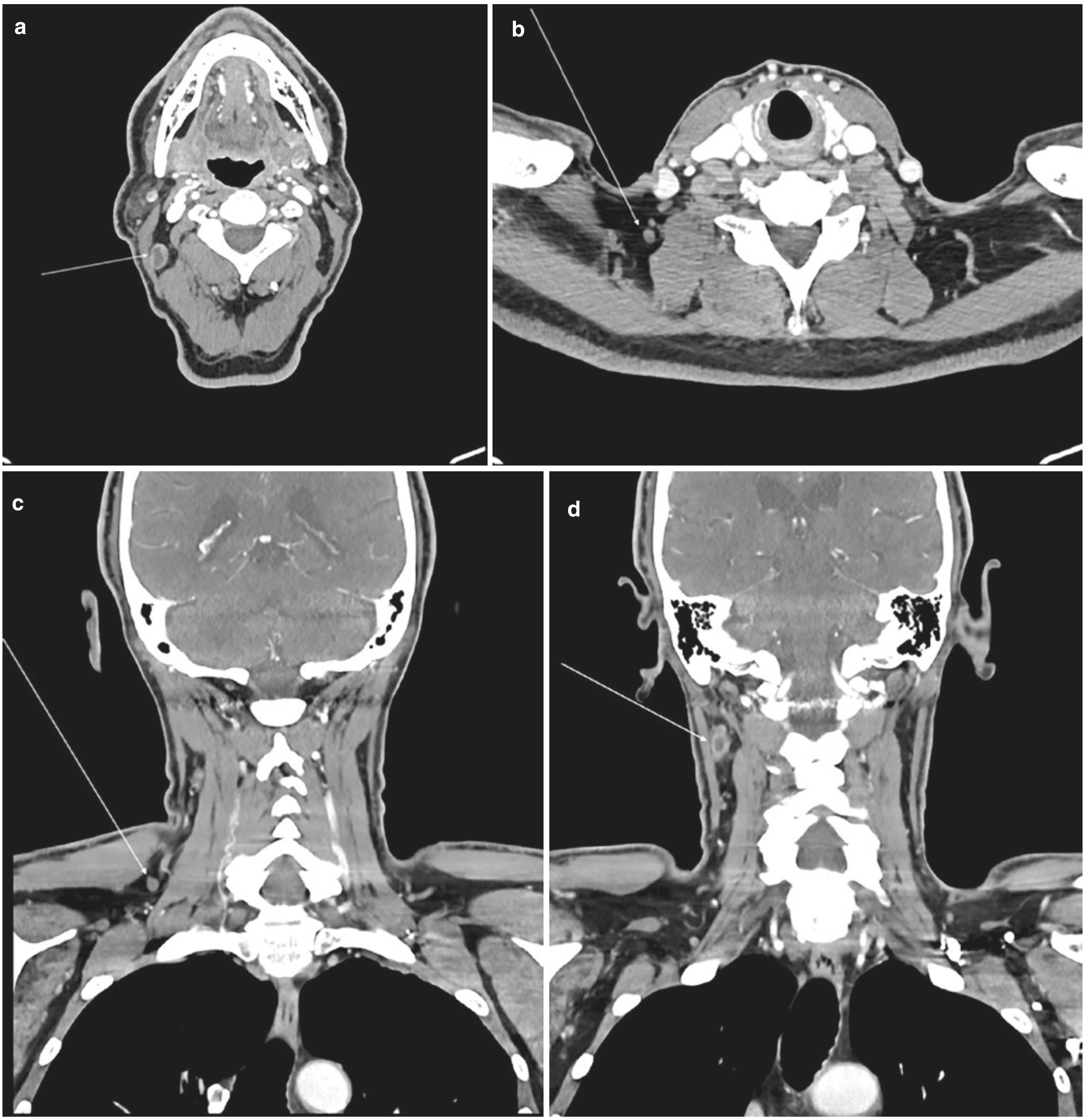

Fig. 17 (**a** and **b**) Axial CT scans show a right level 2B/5A cystic node and a small but suspicious node at level 5B. (**c** and **d**) Coronal CT scans show lymph node involvement at 5B and 5A/2B

2.10 Subdermal Spread

A 52-year-old man (Fig. 18) presented with subdermal and submucosal spread of a nasal tip squamous cell carcinoma into the septum, premaxillary tissues, columella and nasal spine.

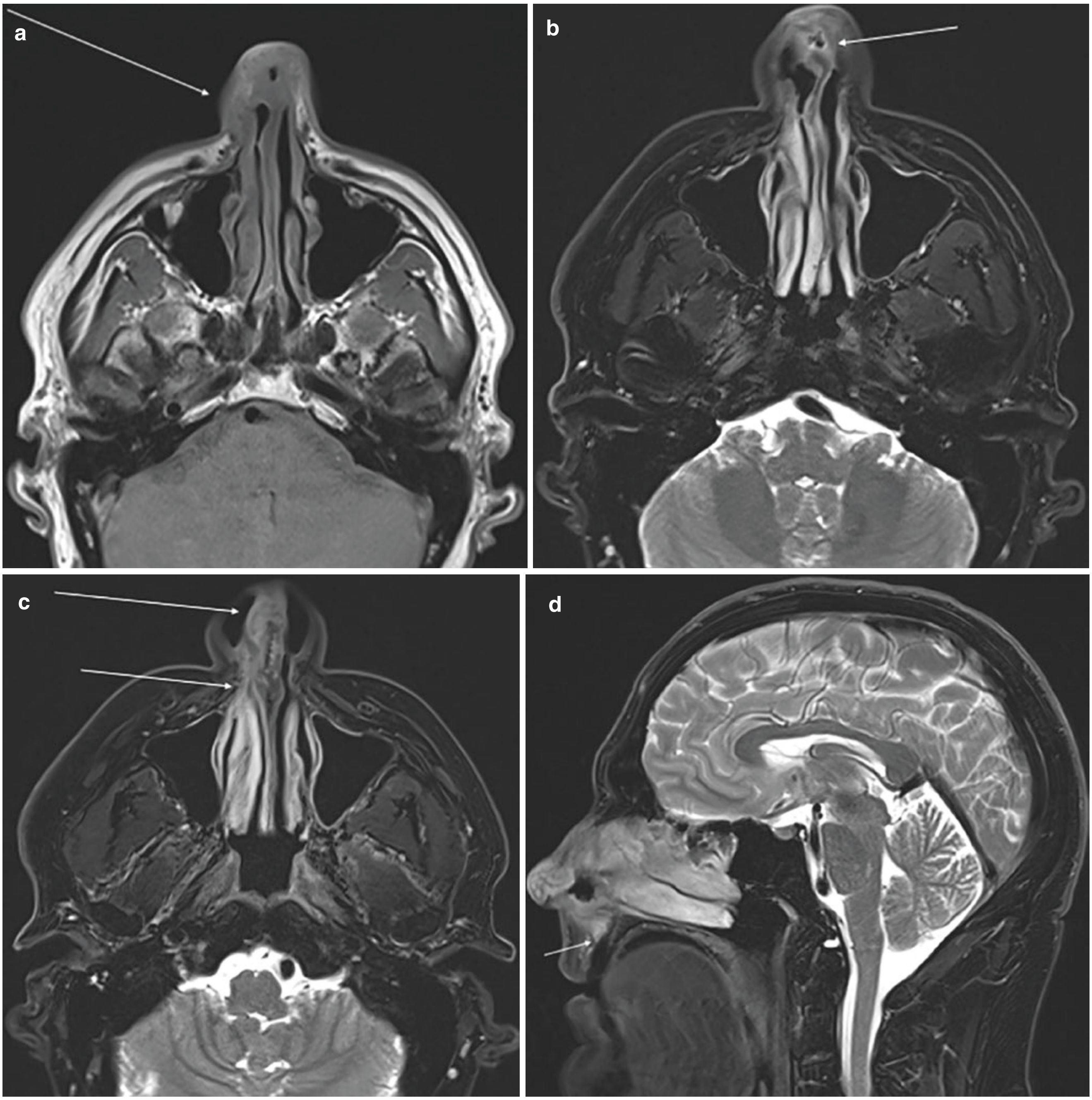

Fig. 18 (**a**–**f**) Subdermal spread of a nasal tip SCC in a 52-year-old man to involve the septum with ulceration, deep submucosal infiltration into the premaxilla and MRI enhancement images of the columella and nasal spine

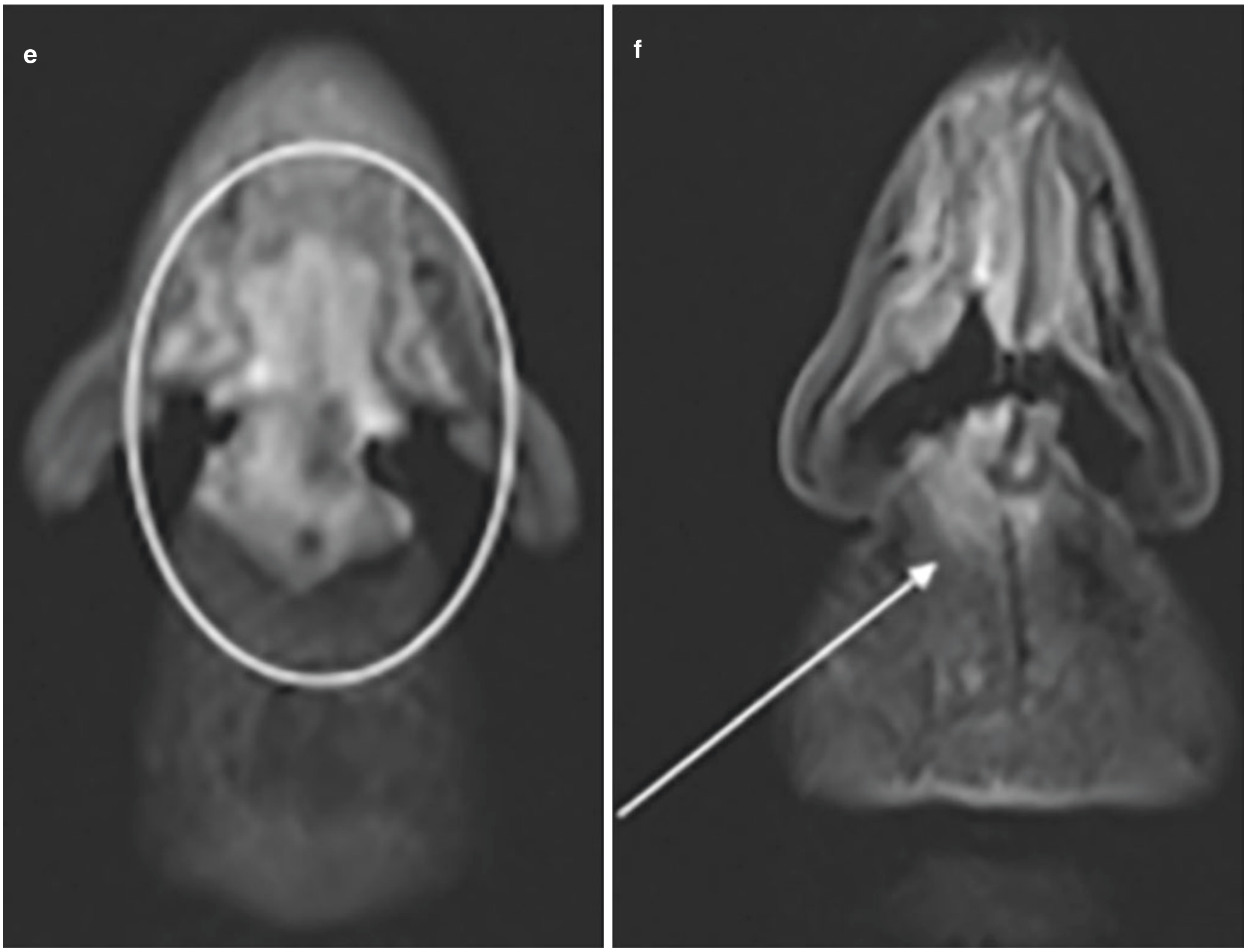

Fig. 18 (continued)

2.11 Skull Base Perineural Spread

The MRI scans in Fig. 19 are of a 63-year-old man with perineural spread into the mandibular branch of the trigeminal nerve all the way to the foramen ovale and cavernous sinus. This degree of advanced facial cancer has life-threatening consequences with intracranial meningitis and cavernous sinus thrombosis.

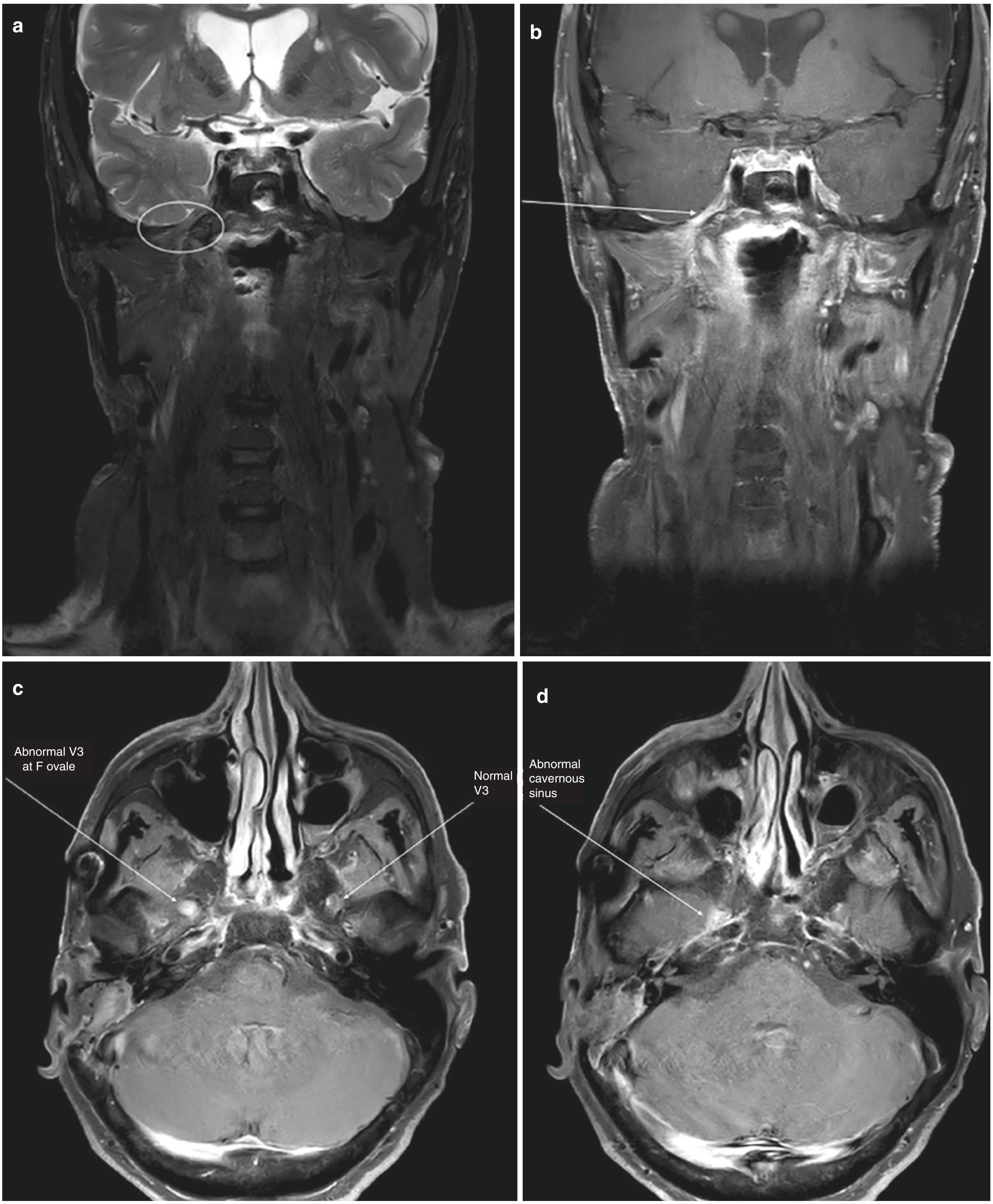

Fig. 19 (**a**–**d**) MRI scans of a 63-year-old man with increased signal in the right V3 (mandibular nerve) at the foramen ovale in the skull base and the nearby cavernous sinus. The abnormal right V3 is contrasted with the normal left V3 at the foramen ovale. A slightly higher MRI slice shows enhancement along the cavernous sinus also

3 Complication Management

The late presentation, neglect or recurrence of extreme facial cancers like the right temple squamous cell carcinoma in the 71-year-old man (Fig. 20) is in reality a failure of CLEAR (**C**omplete **L**ocal **E**xcision + **A**esthetic **R**econstruction) and DRAPE (**D**elayed **R**econstruction **A**fter **P**athology **E**xamination), the important principles of wide and clear cancer excision plus aesthetic and if appropriate immediate reconstruction [4]. Managing the complications of failure to control the cancer locally and regionally is what follows in the remaining sections of this atlas.

The team approach with staging by a multi-disciplinary team, detailed pathological and radiological evidence, pre-anaesthetic workup, definitive or palliative resection, preservation of vital structures, function and immediate aesthetic reconstruction with the simplest flap method available is the oncological protocol. Post-operative care, follow-up and functional rehabilitation are then considered along with adjuvant therapies.

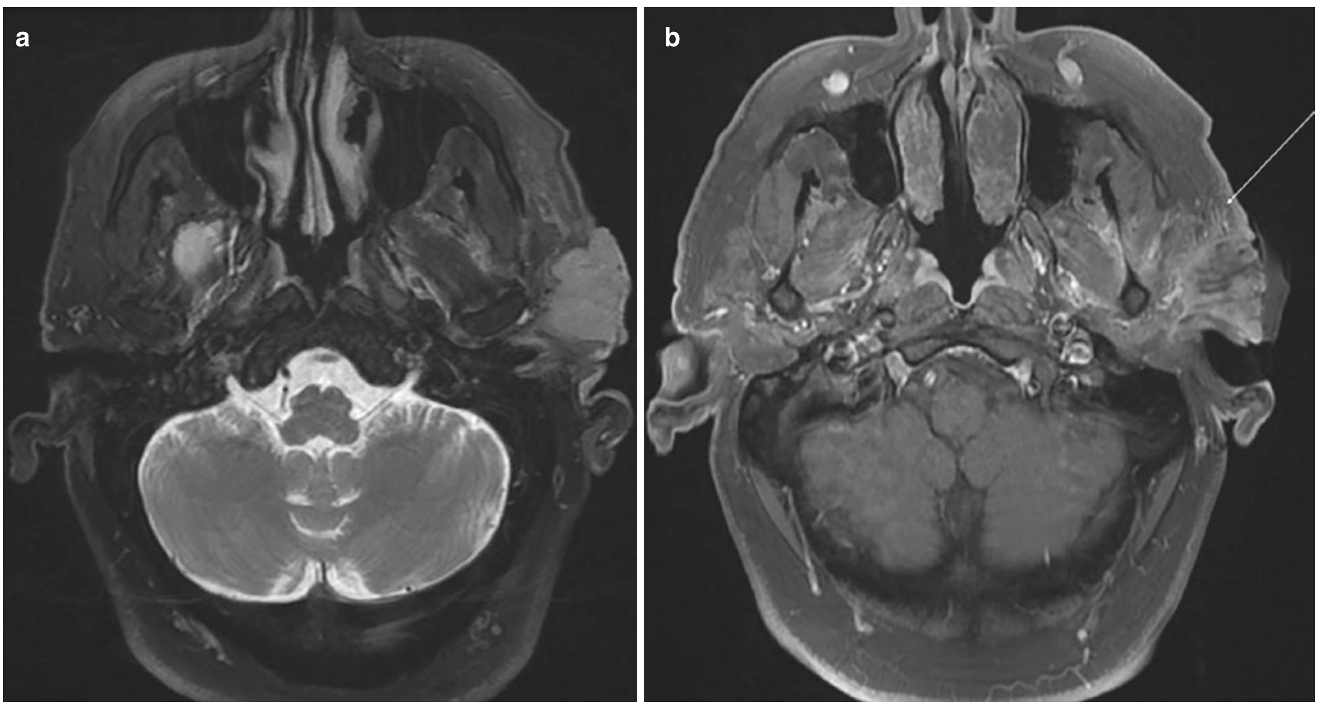

Fig. 20 (**a** and **b**) MRI scans of a 71-year-old man showing SCC invasion of left temple into parotid gland and SMAS layer. The arrow in the second image shows altered signal in the subcutaneous tissues anterior to the mass indicating possible dermal lymphatic involvement

4 Conclusion/Summary

This chapter is a collaboration between plastic surgeons, an experienced head and neck radiologist and a biomechanical research engineer. Applied anatomy is the bedrock on which all of us have practised our crafts and what drew us to the careers we have enjoyed. In extreme facial cancer (including the head and neck structures), an appreciation of 3D and applied anatomy is mandatory for best practice no matter which discipline or specialty you are based from. Failure to control an aggressive cancer locally will inevitably lead to loco-regional recurrence within soft tissue and bone tissue planes and may herald further metastatic spread to the facial skeleton, regional lymph node basins, the orbit, the cranium and intracranially. Poor differentiation of the primary tumour associated with lymphovascular or perineural invasion and spread is the common high-risk factor, which leads to greater challenges for successful clinical management. High-resolution radiological imaging with CT and MRI in a series of head and neck cancer cases is presented to illustrate the common patterns of cancer spread in the face. Which modality is best, MRI or CT? This is often dependent on the individual case and the decisions of the team radiologist. Intracranial extension of common facial skin cancers has dire consequences for life-threatening terminal events including meningitis.

References

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