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Algorithmic interpretation of head and neck computerized tomography (CT) images

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ABSTRACT

Introduction.: There are few text resources to guide the otolaryngology resident systematically through the interpretation of Head and Neck CT Images. The residents struggle with the interpretation of CT Images. Our aim was to develop a comprehensive algorithmic technique for interpreting computerized tomography (CT) images of the head and neck using anatomic details and related CT images.
Methods.: A prospective observational study conducted in an academic hospital.
Thorough literature search for descriptive articles regarding head and neck CT highlighted deficits in existing interpretation techniques. Systemic interpretation algorithm was constructed and used as a learning tool (lecture) for the junior Otorhinolaryngology and Head & Neck Surgery (ORL HNS) residents group of the Saudi Board. Questionnaire was formulated that emphasized the steps and skills involved in the interpretation of head and neck CT by investigating radiological and clinical anatomy in the CT images. The questionnaire was answered by the group of junior residents and by a group of senior residents and consultants (except for head and neck consultants).
Results.: The results were analyzed and compared for both groups, revealing a higher score in the junior (algorithm) group compared with the other group.
Discussion.: This structured comprehensive algorithm for the interpretation of head and neck CT scans is an effective and reliable reference tool that may enhance and refine ORL HNS resident training and knowledge.

1. Introduction

CT scan plays a vital role in the diagnosis, treatment plan and evaluation of head and neck disease, especially in malignancy. It is routinely used by otolaryngologists to stage the disease and keep track of disease progression as well as metastasis.[1] It is also a critical tool in the investigation of trauma, infections, bone erosion, conductive hearing loss, middle ear, cholesteatoma, and sialoliths.[2]

There are few text resources to guide the otolaryngology resident systematically through the interpretation of Head and Neck CT Images. As a result the residents struggle with the interpretation of CT Images, whether in the grand rounds or clinical meetings or exam. Therefore, it is of great value and interest to develop a systematic algorithm that could make this process easier for current and future residents.

A search in the internet showed that there were no articles describing comprehensive, algorithmic techniques for interpreting CT images of the head and neck that could be used as a reference by residents in training for clinical practice. This is because the interpretation of CT images is performed based on information gained from personal experience in addition to a thorough literature search. Additionally, only fragmented information is available on this topic; the remaining information is derived from discussions and academic lecture notes.

Our aim was to develop a comprehensive algorithmic technique for interpreting computerized tomography (CT) images of the head and neck using anatomic details and related CT images.

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2. Materials and methods

This prospective observational study was conducted in an academic hospital as a survey (questionnaire) that emphasized the steps and skills involved in head and neck CT interpretation by investigating radiological anatomy in CT images. Accordingly, by obtaining baseline information regarding the residents deficits in CT image interpretation, a systemic interpretation algorithm was constructed and was used as a learning tool for a group of new residents; this group was compared with another group of residents who were given the usual references for CT image interpretation. A CT head and neck image interpretation quiz was administered to both groups, and the results were analyzed to determine whether the new algorithm differed from the usual resources.

Comprehensive literature search of Articles with description of CT images of the Head and Neck was conducted. CT Head and Neck images showing the anatomical landmarks and images with the different variable anatomy were collected along with the algorithmic description of the CT images as described and presented by Radiology expertise.

The participants were divided to two groups of ORL surgeons: consultants (except for head and neck surgeons), registrars and senior residents were allocated into the "Seniors" group, whereas junior residents (those in post-graduate years 2 and 3) were assigned to the "Juniors" group. *Only the junior group* was briefed on the algorithm. The summarized proposed algorithm was presented for 30 min using power point slides after the weekly resident educational activity. This was a weekly educational activity mandatory to attend for the entire otolaryngology trainee

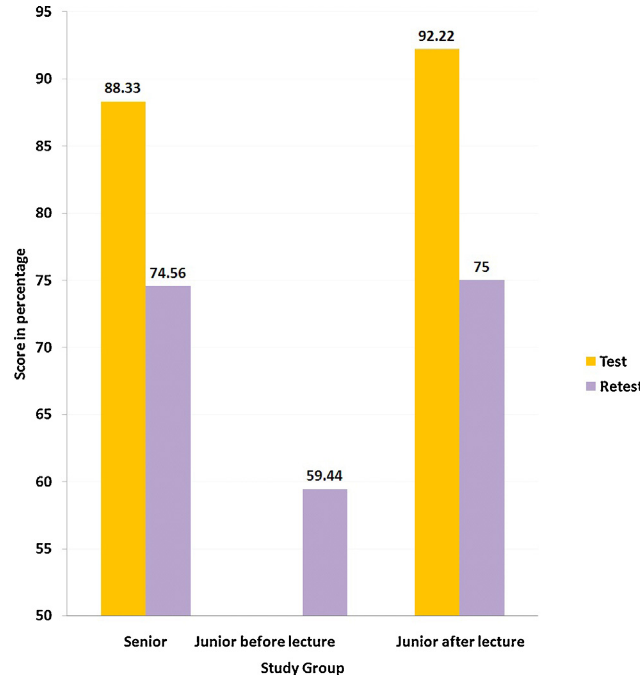

Fig. 1. Comparison of the results of Senior and junior group in the test and Comparison between Senior and junior group, junior group performance before and after the lecture in retest.

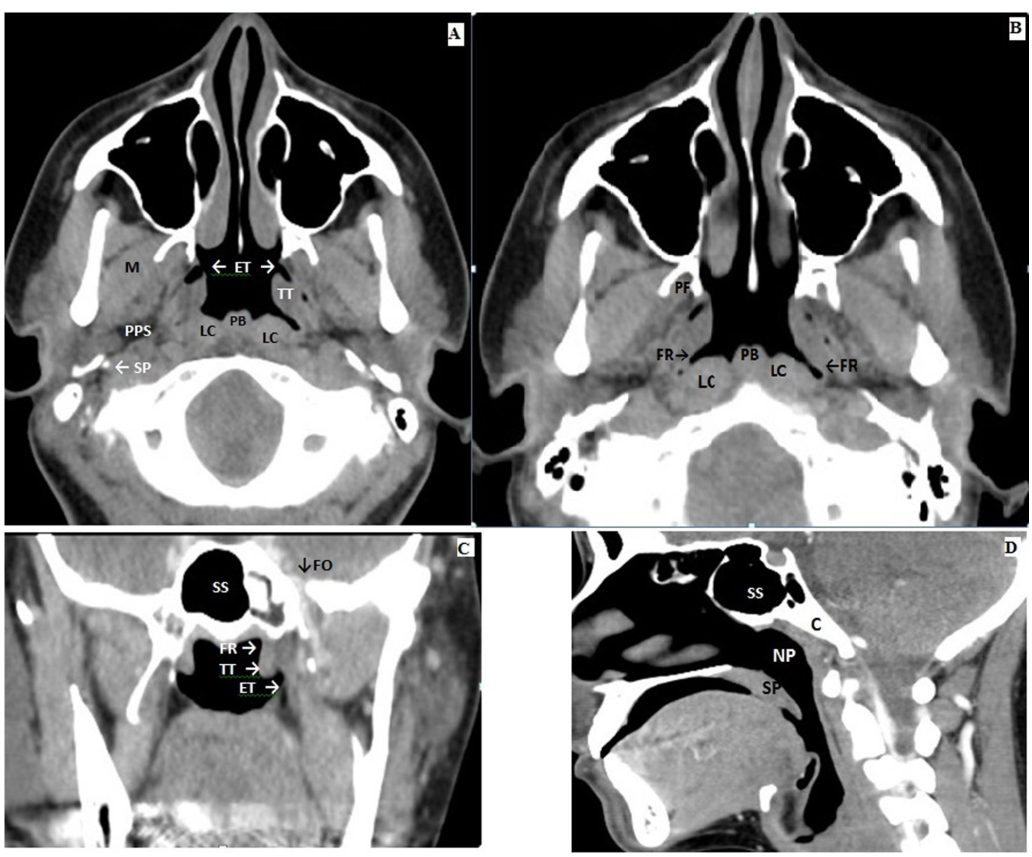

Fig. 2. (A) Nasopharynx; Eustachian tube (ET), Torus tuba-rius (TT), longus colli muscle (LC), parapharyngeal space (PPS), masticator space (M), styloid process (SP), retroantral fat (RAF), Pharyngeal bursa (PB). (B) Nasopharynx fossa of rosenmullar (FR), longus colli muscle (LC), Pterygoid fossa (PF), Pharyngeal bursa (PB). (C) Nasopharynx Foramen ovale (FO), sphenoid sinus (SS), Eustachian tube (ET), Torus tubarius (TT), fossa of rosenmullar (FR). (D) Nasopharynx sphenoid sinus (SS), Clivus (C), Nasopha-rynx (NP), soft palate (SP).

Table 1
Performance of the Senior and Junior (Algorithm) group.

Questions	Seniors Gr (no of correct answers/no of questions)	Juniors Gr 30 (no of correct answers/no of questions)
Two basic CT questions	100% (60/60)	100% (60/60)
Four radiological–clinical anatomy of head CT	81.66% (98/120)	85.8% (103/120)
Five radiological–clinical anatomy of neck CT	92.66% (139/150)	95.33% (143/150)
One lymph node levels on CT images	70% (21/30)	86.66% (26/30)

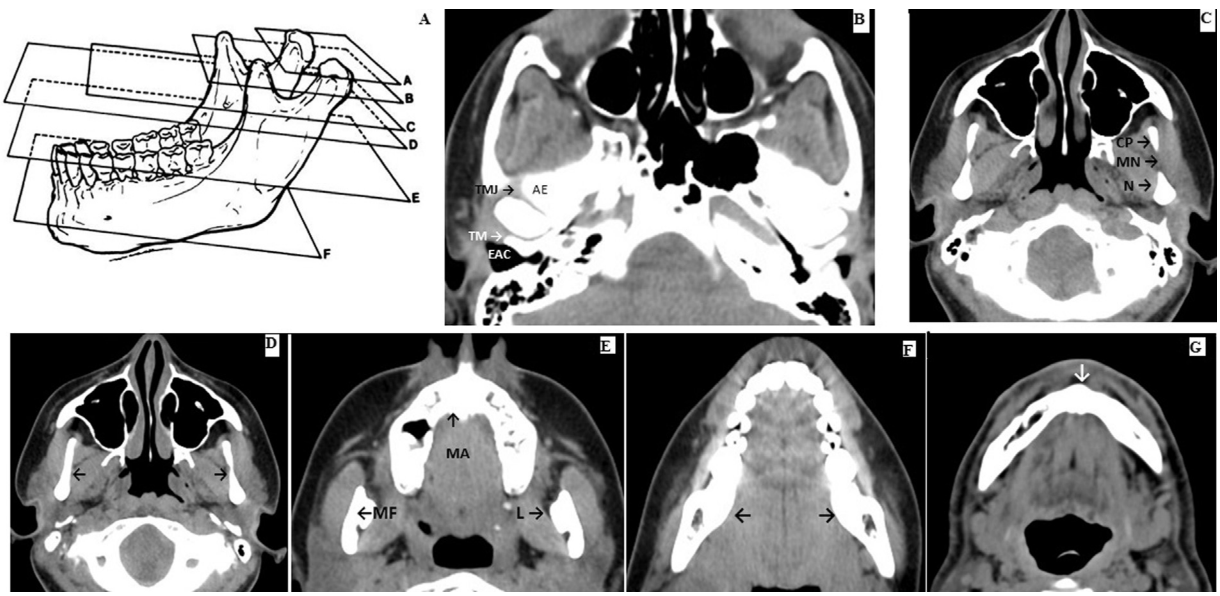

Fig. 3. (A) Mandible (4) copied from Ref. 6. (B) Mandible Articular eminence (AE), temporomandibular joint (TMJ), tympanic part of the temporal bone (TM), external auditory canal (EAC). (C) Mandible Coronoid process (CP), mandibular notch (MN), neck of the mandibular condyle (N). (D) Mandible, Mandibular rami (arrows). (E) Mandible Mandibular foramen (MF), Lingula (L), max-illary alveolus (MA). (F) Mandible Mandibular body (arrows). (G) Body of the mandible: mental protuberance (arrow).

in the program in the Riyadh region. The CT images used in the slides are shown in Figs. 2–13.

A Questionnaire was structured with emphasis on certain aspect in the knowledge of CT Head and Neck. The questionnaire was constructed based on the important landmarks and anatomical structures which have oncological importance in the diagnosing and staging the tumor and to choose the best modality of intervention for each case. These are the most common questions asked in the clinical rounds, tumor board, combined head and neck clinic, ground rounds and during teaching sessions in almost all tertiary cancer centers by expert consultants in the Head and Neck Surgery and Radiation Oncology.

- Two general questions concerning basic radiological data about CT images:
  - Identifying the CT view cuts (coronal, sagittal, axial).
- The laryngotracheal cartilages framework as a constant landmark.

- Four questions concerning the radiological–clinical anatomy of a head CT.
  - Nasopharynx, Rosenmullar fossa, torus tubarius, nasopharyngeal opening of eustachian tube.
- Mastication space and its subsites (temporal, pterygoid, masseter, buccal spaces) and the relation of each muscle to the mandible.
- Parapharyngeal spaces at the skull base and its contents (pre styloid vs post styloid space).
- Basilar artery and arteries of the Circles of willis.
- Five questions concerning the radiological–clinical anatomy of a neck CT.

Fig. 4. Oral cavity; Pterygomandibular Raphe (PMR), angular vein (AV), hook of hamulus (H), Parotid duct (D), medial ptrygoid muscle (MP), masseter muscle (m), styloid process (S), carotid (c), internal jugular vein (IJ).

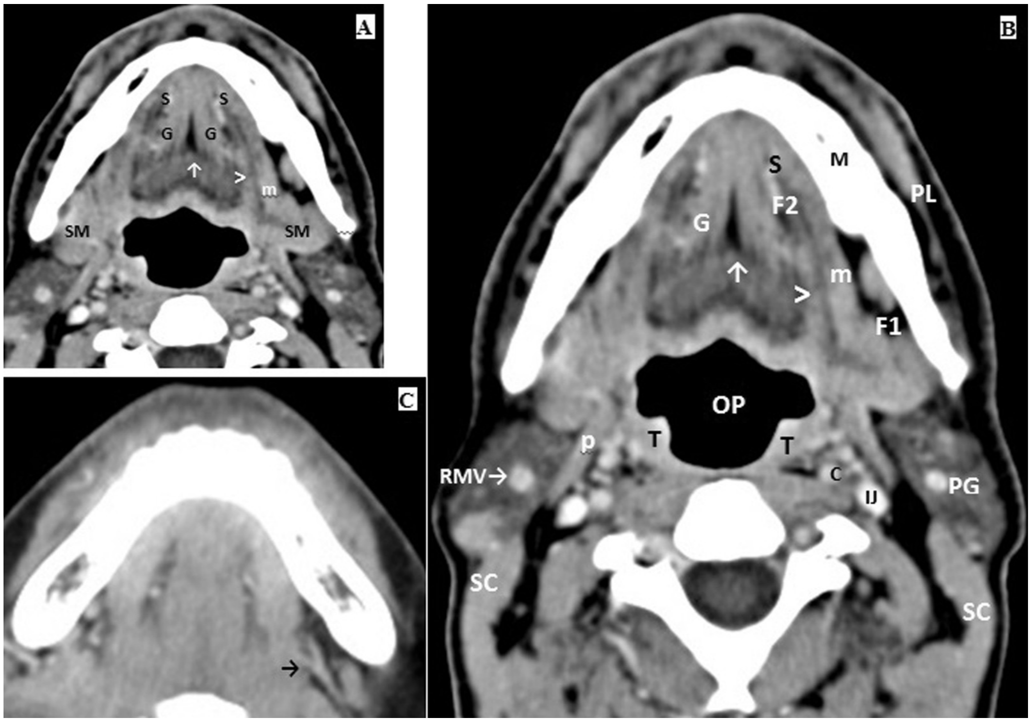

Fig. 5. (A) Floor of Mouth: Mylohyoid muscle (m), Genioglos-sus/Geniohyoid complex (G), sublingual gland (S) hyoglossus muscle (arrow head) Lingual septum (Arrow). (B) Floor of the mouth: internal carotid artery (C), Internal jugular vein (IJ), Retromandibular vein (RMV), Mandible (M), Oro-pharynx (OP), Tonsils (T), parotid gland tail (PG), sublingual gland (S), Mylohyoid muscle (m), Genioglossus/Geniohyoid complex (G), posterior belly of digastrics muscle (p), Platysma (PL),sternocleidomastoid muscle (SC), hyoglossus muscle (arrow head), Lingual septum (Arrow), fat in submandibular space (F1), face sublingual space(F2). (C) The lingual artery (arrow).

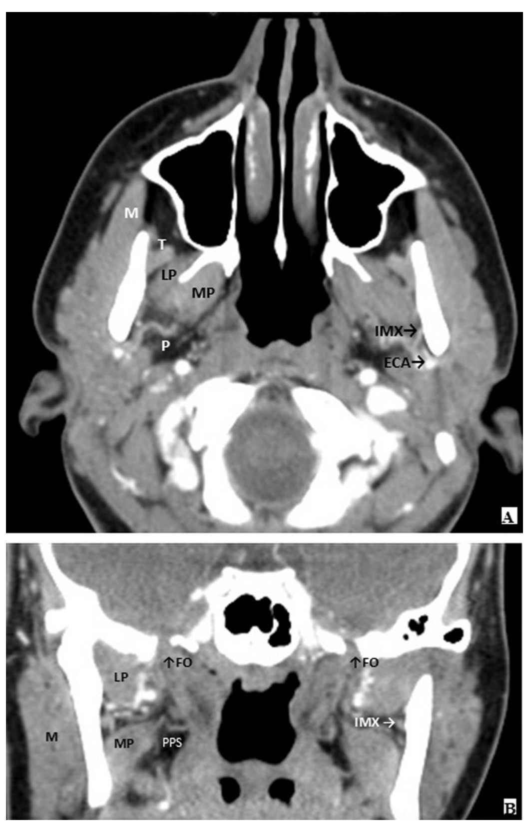

Fig. 6. (A) Mastication space; Internal maxillary artery (IMX), Ex-ternal carotid artery (ECA), prestyloid fat of parapharyngeal space (P), lateral pterygoid muscle (LP), medial pterygoid muscle (MP), temporalis muscle (T), masseter muscle (M). (B) Masticator Space, Internal maxillary artery (IMX), later-al pterygoid muscle (LP), medial pterygoid muscle (MP), temporalis muscle (T), masseter muscle (M), Foramen ovale (FO), parapharyn-geal space (PPS).

The great vessels of the neck and how to differentiate between them; IJV, CCA, ICC and ECA.

- The larynx and its subsites.
- Parotid Gland and its relation of facial artery, retromandibular vein, and how to differentiate between deep and superficial lobe, how to differentiate between the parotid, submandibular gland and muscle according to density of the tissue on the scan.
- Tongue base, glossoepiglottic folds.
- Muscles of Tongue.
- One question concerning the lymph node levels on a CT image.

In the radiological–Clinical anatomy of the cervical lymph nodes level

The questionnaire was submitted just after completion of the power point presentation and answered by both groups.

To test the validity of the algorithm and the questionnaire, the intervention was retested after one year on a different cohort of trainees. The same questioner was used. The retested senior group had 19 participants and the retested junior group 15 junior residents. This time one more step was added and the knowledge of junior group tested both before and after the presentation to assess their improvement.

3. Results

The following images present slides from the algorithm.

The questionnaire was distributed to a group of junior residents and a group of senior residents (with 30 surgeons in each group).

The questions concerned basic radiological data, head CT images, neck CT images, and CT interpretation of the radiographic-clinical anatomy of the lymph node levels. In the seniors group, correct answers were provided by 100%, 81.66%, 92.66% and 70% of the residents, respectively. In the juniors group, correct answers were given by 100%, 85.8%, 95.33% and 86.66% of the residents, respectively. (Table 1)

The subsequent retest showed that the juniors attained 59.44% (107 out of total 180) before the lecture was presented and it improved to 75% (135 out of 180) after the presentation. The seniors scored 74.56%. (Fig. 1)The performance of the junior group after the lecture was better than the seniors' performance, which proves the validity of the algorithm as a teaching tool.

4. Discussion

CT uses a tightly collimated X-ray beam that is differentially absorbed by body tissues to provide highly detailed images. The Hounsfield unit is the unit of attenuation; water is 0 HU, fat ranges between −80 to −100 HU, calcium and bone range between 100 to 400 HU, and most fluids are between 0–30 HU.

A CT scan with contrast is the gold standard imaging modality for both the diagnosis and staging of almost all head and neck malignancies.

CT imaging of the head and neck varies slightly from the CT technique used in other parts of the body.

The patient should lie on the table in the supine position with the neck slightly extended. The exam should be performed with the patient breathing quietly. The display slice thickness should not exceed 3 mm or the acquisition display slice thickness. However, in pediatric patients, a thicker slice (≤fth) may be appropriate. The gantry angle should be parallel to the hard palate. In patients with a large amount of dental hardware artifacts, additional images can be performed with a different gantry angle to avoid the streak artifact. All studies should be reconstructed in the soft tissue algorithm. Additional reconstruction with a suitable edge-enhancing algorithm or technique to improve bone and cartilage visualization may be obtained in patients with a history of infection, tumor, or trauma. Intravenous contrast is recommended in patients without contraindications to its administration. A non-contrast exam may be performed to evaluate salivary stones or in patients undergoing radioiodine therapy for thyroid cancer. If the examination is performed for a vocal cord tumor, axial sections should be parallel to the vocal cords or hyoid bone. Most conditions requiring CTs of the soft tissue of the neck can be evaluated with scans including the area between the skull base (sellar floor) and the top of the aortic arch. For studies specifically performed to evaluate vocal cord palsy, the inferior extent of the CT examination must include the right subclavian artery (right vocal cord palsy) or the aortopulmonary window (left vocal cord palsy). Very thin sections (1.0 to 1.5 mm) with multiplanar reconstructions limited to the larynx may be helpful to evaluate patients for vocal cord neoplasms. Scans obtained during phonation or the Valsalva maneuver may be useful in assessing laryngeal function.[3,4]

4.1. The nasopharynx

The nasopharynx is bounded anteriorly by the posterior nasal choana, posteriorly by the prevertebral fascia, superiorly by the sphenoid sinus and the clivus, laterally by the parapharyngeal space and inferiorly by the oropharynx. A defect of the pharyngobasilar fascia forms the sinus of Morgagni (the nasopharyngeal opening of the Eustachian tube). The fossa of Rosenmuller, or lateral pharyngeal recess, is located posterior and superior to the torus tubarius[5] (Fig. 2A–D).

4.2. The mandible

Mandibular CT scans are obtained somewhat obliquely because the mandible has irregular contours; the gantry angle (+15 to +20) at the orbitomeatal line is important in CTs of the oral cavity and oropharynx to avoid dental artifacts and for improved visualization [6] (Fig. 3A–G).

Fig. 7. Pterygopalatine fossa (arrows), Zygomatic arch (Z), Fora-men ovale (FO).

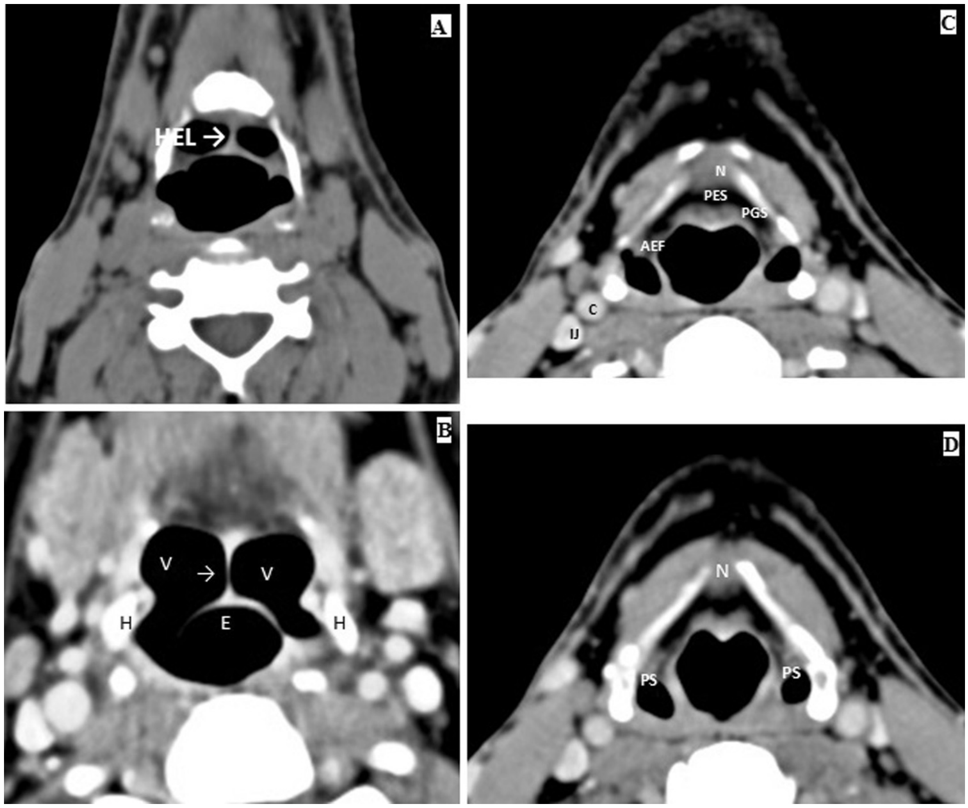

Fig. 8. (A) Larynx; Hyoepiglottic ligament (HEL). (B) Larynx hyoid bone (H), vallecula (V), epiglottis (E), median glos-soepiglottic folds (arrow). (C) Larynx thyroid notch (N), preepiglottic space (PES), paraepiglottic space (PGS), aryepiglottic folds (AEF), carotid (c), internal jugular (IJ). Preepiglottic space best visualized in the CT scan at the level of the superior thyroid notch. There is no clear boundaries between those spaces on the axial cut. (D) Larynx, pyriform sinus (PS), thyroid notch (N). (E) Larynx cuneiform (arrow) and corniculate (arrow head) cartilages, pyriform sinus (PS), thyroid notch (N) (corniculate car-tilage often identified at the lower end of aryepiglottic folds, cune-iform cartilage may be seen embedded at the lower part of aryepiglottic folds). (F) Larynx Foot processes of arytenoids cartilage (A) and false cords (FC). False vocal cords can be identified by the soft tis-sue density anteriorly behind the thyroid cartilage. There is air filled areas on either sides of the false cords represent the exten-sion of the ventricles. G) Larynx true cords (TC), thyroid cartilage (T), vocal process of arytenoids cartilage (A), cricoids cartilage (C). The true vocal cords identified at the level of the cricoarytenoid junction and the medial surface showed smooth couture. There is only 1–2 mm soft tissue density in the anterior commissure behind the thyroid cartilage. (H) Larynx cricoids cartilage (C), central medullary space of cricoids (arrow), thyroid cartilage (T). (I) Larynx cricoids cartilage (C), central medullary space of cricoids, thyroid cartilage (T), inferior horn of thyroid cartilage (IC). (J) Larynx subglottic space, cricoids cartilage, thyroid gland. Normally, the inner lamina of the cricoid is smooth because it lined by mucosa only, any soft tissue thickness between the cri-coid and mucosa considered significant.

4.3. The oral cavity

The oral cavity consists of seven subsites: the oral tongue, hard palate, floor of the mouth, upper and lower alveolar ridges, buccomasseteric and gingivobuccal regions and the mandible. The oral tongue is mobile; it includes the midline septum and contains muscle fibers (of the intrinsic and extrinsic muscles). The extrinsic muscles (styloglossus, hyoglossus, geniohyoid and genioglossus) can be observed in a CT scan; however, the intrinsic muscles of the tongue (the longitudinal, transverse and vertical muscle groups) are difficult to individually identify on CT scans (Fig. 4).

The mylohyoid is a sheet-like muscle that separates the submandibular and sublingual spaces. These two spaces communicate with each other at the posterior margin of the mylohyoid muscle.

The lingual septum separates the paired geniohyoid and genioglossus muscles. Both of these muscles are difficult to distinguish on CT scans, explaining why this structure is called the geniohyoid genioglossus complex (Fig. 5A and B).

The floor of the mouth is U-shaped; it is formed by the mylohyoid muscle and contains the submandibular duct, sublingual gland, hyoglossus muscle, lingual nerve and artery and hypoglossal nerve. The hypoglossal muscle is a strip of muscle that can be identified in the posterior sublingual space. The lingual artery can be identified medial to the sublingual gland and the sublingual fat[6–9] (Fig. 5B and C).

4.4. The masticator space

The masticator space is enveloped by an investing layer of the deep cervical fascia. The investing fascia is split into two layers. The inner layer envelops the medial pterygoid muscle, and the outer layer envelops the masseter muscle, covers the zygomatic arch and attaches to the temporalis muscle. The split layers are fused again at the borders of the mandibular rami and completely envelop the masticator space[10] (Fig. 6A and B).

4.5. The pterygopalatine fossa

Located just medial to the masticator space and connected to it via the pterygomaxillary fissure, the latter appears to curve anteriorly to continue as the inferior orbital fissure, which represents a direct communication between the orbit and the infratemporal fossa.

The pterygopalatine fossa is also connected to the nasal cavity via the sphenopalatine foramen, to the oral cavity via the lesser and greater palatine foramina, and to the middle cranial fossa via the foramen rotundum.

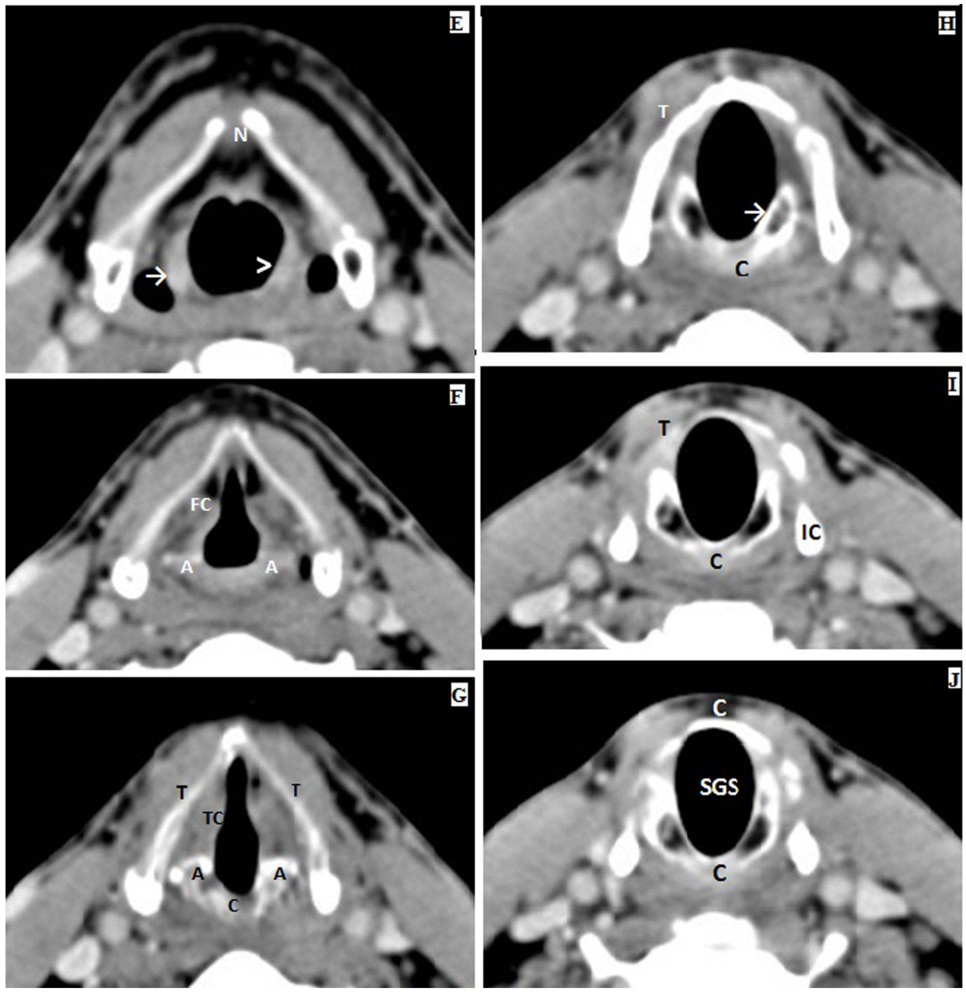

Fig. 8. (Continued)

Important indicators of pterygopalatine fossa tumors include the following: obliteration of fat, enlargement of foramina (indicating perineural extension), atrophy of muscles innervated by the trigeminal nerve, and increased enhancement in the region of Meckel'e cave (the gasserian ganglion)[11] (Fig. 7).

4.6. The larynx

The larynx consists of three unpaired cartilages (the cricoid, thyroid and epiglottic cartilages) and the hyoid bone. There are three small paired cartilages (the arytenoid, cuneiform and cornuculate cartilages).

Head and neck surgeons divide the larynx into the endolarynx and exolarynx. The endolarynx is divided into the supraglottic, glottic and subglottic areas. The supraglottis consists of the epiglottis, the aryepiglottic folds, the arytenoid processes of the arytenoid cartilage, the laryngeal ventricles and the false vocal cords. It extends from the tongue base to the inferior apex of the ventricles.

The glottic larynx consists of the true vocal cords and the anterior and posterior commissures.

The hyoid bone is a U-shaped bone that represents the superior boundary of the larynx; it contains a central body and two superior and posterior lateral horns.

The thyroid cartilage is shield-shaped and consists of two laminae fused in the midline, forming a 90° angle in males and a 120° angle in females. The thyroid cartilage has two superior projections (cornu) toward the hyoid bone and two similar inferior projections, which articulate with the cricoid cartilage.

The cricoid cartilage is a signet ring-shaped structure that is wide posteriorly and narrow anteriorly. It lies above the first tracheal ring.

The epiglottis is a leaf-like cartilage sheet that lies behind the hyoid bone. It is attached to the thyroid laminae by the thyroepiglottic ligament and is attached to the lateral pharyngeal wall by the two lateral glossoepiglottic folds and the single medial glossoepiglottic fold. The superior border of the epiglottis is located behind the hyoid bone and is known as the free margin. The aryepiglottic folds are a reflection of the lateral and inferior mucosa of the epiglottis on to the arytenoids.

The pre-epiglottic space contains fat and lies anterior to the epiglottic area, extending from the hyoid bone to the anterior commissure.

The paraglottic space is bounded by the thyroid cartilage laterally, the pyriform fossa posteriorly and the medial aryepiglottic folds medially.

Images that extend inferiorly to the lung apex (lung window) should be obtained, especially in patients with recurrent disease[12] (Fig. 8A–J E,F,G,H,I,J).

4.7. Lymph node levels on CT scans

Level IA (submental nodes) lies between the medial margins of the anterior bellies of the digastric muscles.

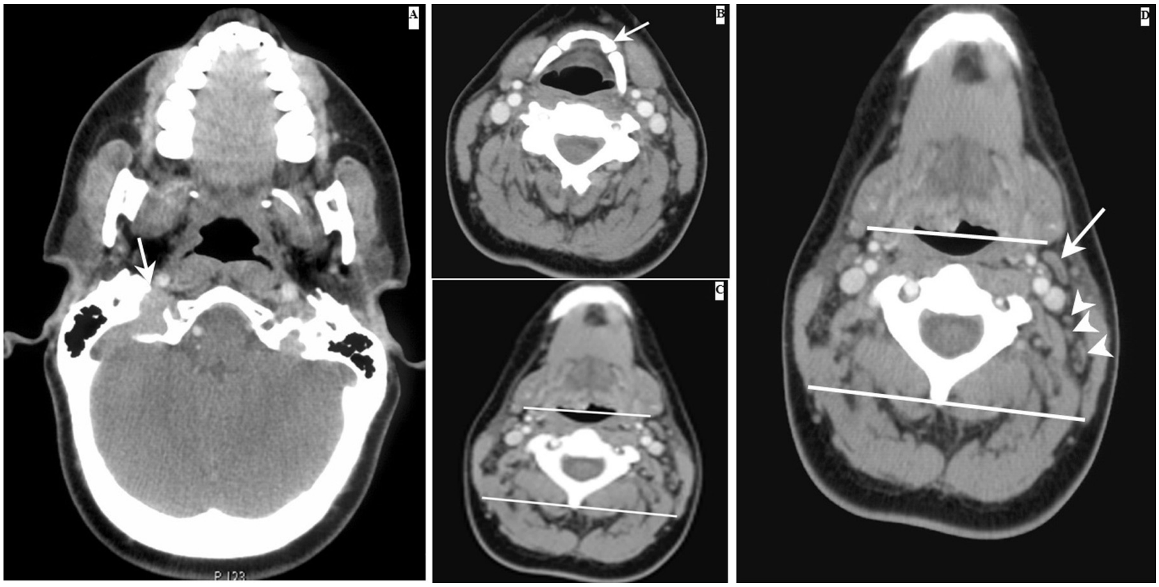

Fig. 9. (A) Level II, Superior margin of level II lymph nodes bounded by jugular foramen of skull base [11] Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (B) Level II, Lower margin is bounded by the hyoid bone (arrow)[11] Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (C) Level II located anterior to a transverse line connecting the posterior edge of sternocleidomastoid muscle (long line) to the posterior a transverse line connecting the posterior edge of the submandibular glands (small line). (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (D) Level IIA located anterior, medial and lateral to internal jugular vein (arrow), Level IIB located posterior to the internal jugular vein and have identifiable fat plane between the lymph node and the vein (arrowheads).[11] Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2.

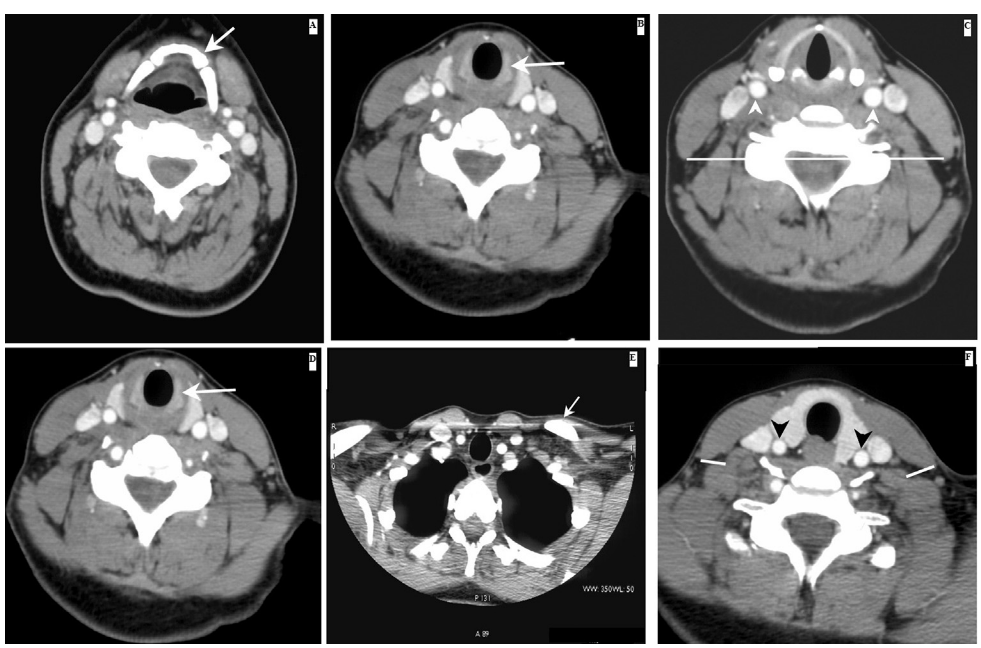

Fig. 10. (A) The hyoid bone denotes the superior extent of the level III nodes (11) (Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. (B) The cricoid cartilage form the lower border of level III (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (C) Level III lymph nodes located to a line connecting the posterior margins of ster-nocleidomastoid muscle and lateral to the medial margin of either the common carotid artery or the internal carotid artery (arrowhead = internal carotid arteries) (11) Neurographic journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (D) Cricoid cartilage (arrow) form the superior boundary of level IV nodes) [11] Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (E) The clavicle form the inferior margin of level IV[11] Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (F) Level IV, The nodes are anterior and medial to the oblique line drawn between the posterior edge of the sternocleidomastoid muscle and posterolateral edge of the anterior scalene muscle and lateral to the carotid artery (arrowheads). (11) (Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org.

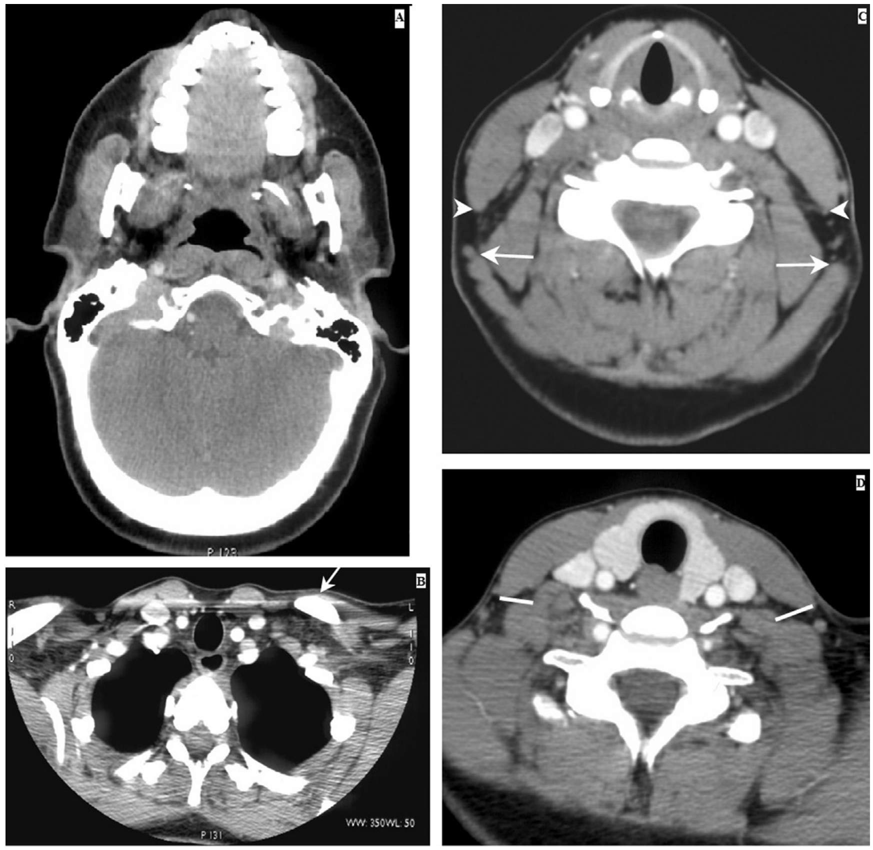

Fig. 11. (A) The skull base form the superior margin of level V nodes (11) Neurographic jour-nal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (B) level V Extends inferior to the level of the clavicle. (11) Neurographic Journal, Jour-nal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2 www.asnr.org. (C) Level VA lie between the skull base at the level of cricoid cartilage, unlike level II, III, level VA are behind the posterior edge of sternocleidomastoid muscle (arrowhead) and anterior to the trapezius muscle(arrow). (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (D) Level VB located between the lower margin of cricoid cartilage and the clavicle, they are behind an oblique line connecting the posterior edge of sternocleidomastoid muscle and posterolateral edge of anterior scalene muscle. (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2.www.asnr.org.

Level IB (submandibular nodes) lies lateral to the anterior belly of the digastric muscles.

Level IIA is located anterior, medial or lateral to the internal jugular vein and encompasses the nodes that are posterior to and directly about the internal jugular vein.

Level IIB is located posterior to the internal jugular vein and is identifiable by the fat plane between the lymph node and the vein (Fig. 9A–D).

Level III lies between the lower border of the hyoid bone and the lower margin of the cricoid cartilage, anterior to a line connecting the posterior margins of the sternocleidomastoid muscle. There are nodes lateral to the medial margin of either the common carotid artery or internal carotid artery (Fig. 10A–C).

Level IV lies between the lower margin of the cricoid cartilage and the clavicle and is lateral and medial to the common carotid artery. These nodes are anterior and medial to an oblique line connecting the posterior edge of the sternocleidomastoid muscle and the posterolateral edge of the anterior scalene muscle (Fig. 10D–F).

Level VA lies between the skull base and the lower margin of the cricoid cartilage, behind the posterior edge of the sternocleidomastoid muscle.

Level VB is located between the lower margin of the cricoid cartilage to the clavicle, behind an oblique line connecting the posterior edge of the sternocleidomastoid muscles and the posterolateral edge of the anterior scalene muscle (Fig. 11A–D).

Level VI (supraclavicular nodes) is located at or caudal to the clavicle and lateral to the carotid arteries on each side of the neck (Fig. 12A–C).

Level VII lies caudal to the top of the manubrium in the superior mediastinum, between the medial margin of the left and right common carotid arteries, and extends caudally to the level of the innominate vein (Fig. 12D and E).[13]

4.8. Post-cricoid region

(Fig. 13A–E).[14]

5. Conclusions

Knowledge of how to interpret CT scans of the head and neck is acquired through different methods that require time and effort. No single article is able to impart this knowledge. Our proposed algorithm significantly improved the performance of the junior residents, despite the different references and resources that were available to the group of senior residents. We recommend adopting this algorithm as a valid teaching tool for residency training.

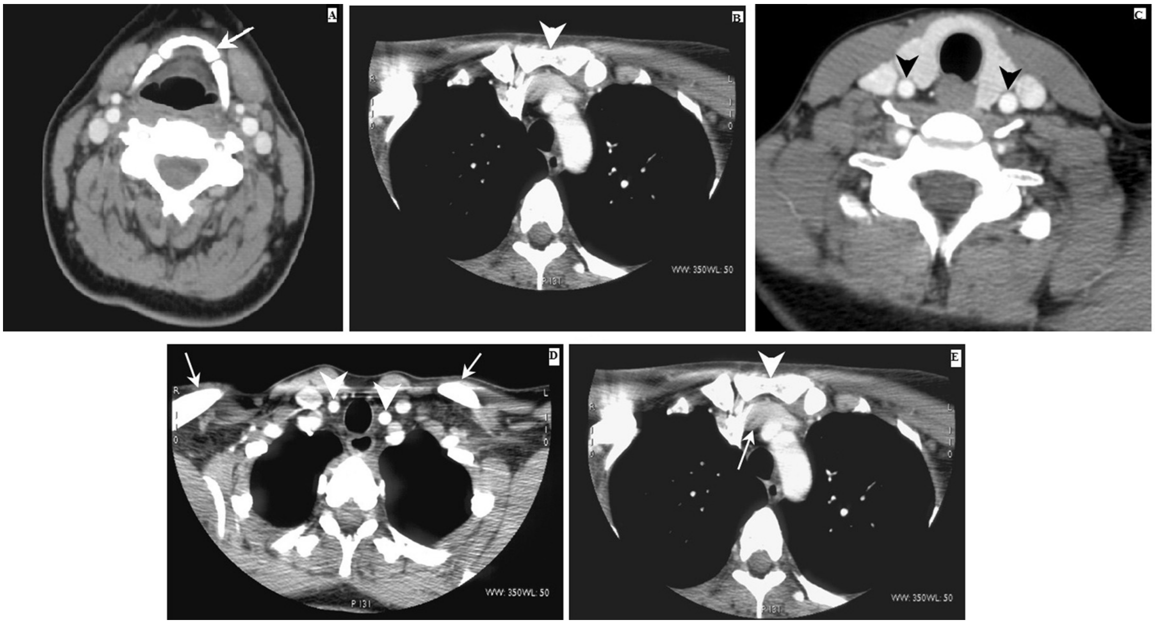

Fig. 12. (A) Level VI nodes, Superior border formed by hyoid bone (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (B) level VI nodes Inferiorly extend to the top of manubrium (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2. www.asnr.org. (C) Level VI nodes Located between the medial margins of left and right com-mon(arrowheads) and internal carotid arteries. (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol.2, Issue 2, Article 2. www.asnr.org. **D** Level VII, The supraclavicular nodes are located at or caudal to the clavicles (ar-rows) and lateral to the carotid arteries (arrowheads). (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2.www.asnr.org. (E) Level VII lie caudal to the top of the manubrium (arrowhead) between the medial margin of left and right common carotid arteies, and extend caudally to the level of innominate vein (arrow = unopacified innominate vein). (11) Neurographic Journal, Journal of American Society of Neuroradiology (ASNR), Mukherji et al. Vol. 2, Issue 2, Article 2.www.asnr.org.

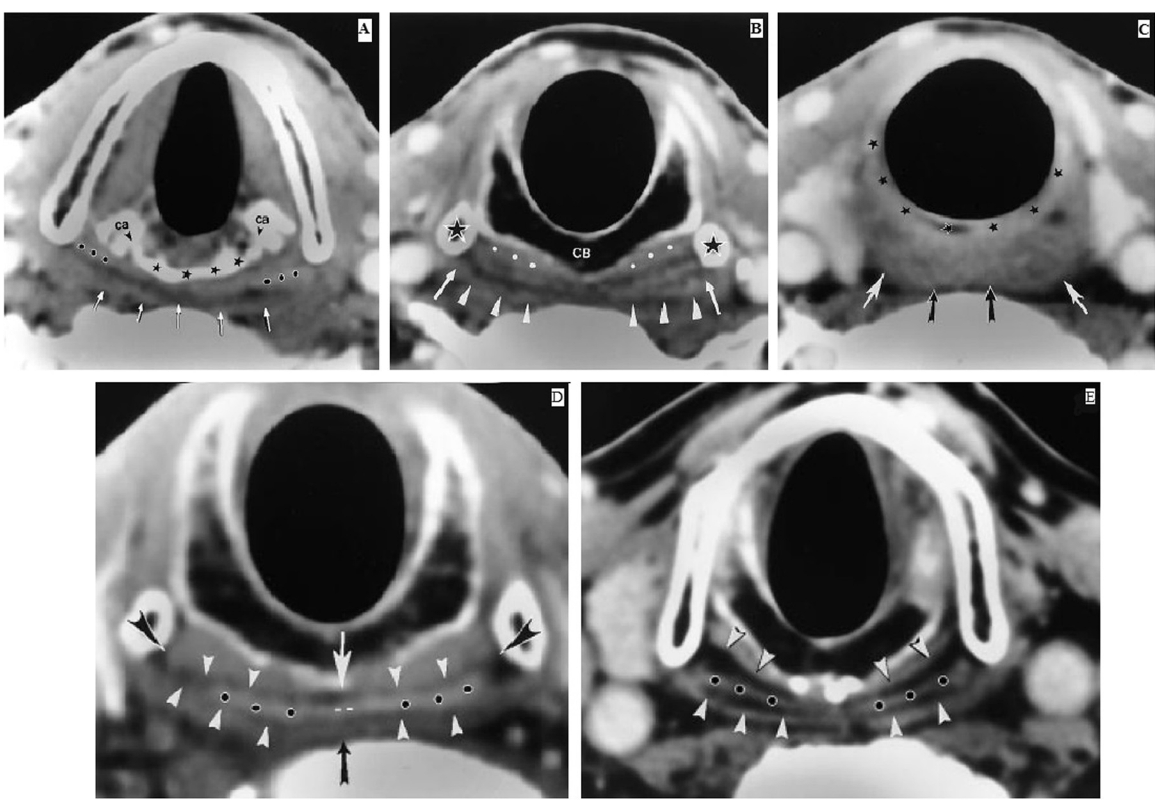

Fig. 13. (A) Post Cricoid: margin of appearance at cricoid region (stars), cricoarytenoid joint (arrowheads), posterior normal wall (arrows) is well demonstrated, with enhanced mucosa (circles).[14] (B) Post Cricoid: middle portion of cricoid cartilage (CB), at this level, attachment of postcricoid mascultre (arrows) to the inferior horn of thyroid cartilage (stars). The mascular wall of postcricoid contains: posterior cricoarytenoid (dots) and inferior constrictor muscle (arrowheads).[14] (C) Post Cricoid: enhancement of inferior border of cricoid cartilage (stars), the be-ginning of change in the posterior muscular wall (arrows), complete lack of intramural fat at this level.[14] (D) Post Cricoid: enhancement of mucosa of post cricoid (circles), which is surround-ed by thin intramural fat plane (small arrowhead), the mucosal enhancement makes measuring the thicknesses of the anterior (area between white arrow and interrupted line) and posterior (area between black arrow and interrupted line) mural walls of postcricoid region easier. The musculature is measured between the medial margins of inferior horns of thyroid cartilage (area between large arrowheads).[14] (E) Post Cricoid: postcricoid region showed prominent symmetric intramural fat planes (arrowheads) adjacent to the mucosa (circles) of the middle cricoid cartilage.[14]

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Competing interests

None.

Conflict of interest

None.

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