Crucial Magnetic Resonance Imaging (MRI) anatomy of the head and neck in cancer staging.

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Learning objectives

Our purpose is to provide an educational exhibit illustrating the crucial head and neck anatomy in magnetic resonance imaging (MRI) utilized in the correct local staging of head and neck cancers. The approach is based on anatomic localization, with an emphasis on the anatomy of the nasopharynx, oral cavity, oropharynx, hypopharynx, larynx, nodal levels, deep cervical spaces and utilization of diffusion weighted images (DWI) to identify possible regions of locoregional tumor that need more meticulous characterization and evaluation. This is not designed to be a comprehensive review of all the anatomy of the head and neck, but to illustrate the most important anatomical landmarks to recognize in head and neck oncological imaging.
Background

This is a retrospective case review of a broad range of pathologically and clinically proven cases of head and neck neoplasms accumulated from 2000-2012 at a tertiary referral university medical center and from 2010-2012 at a large private practice clinic with MRI service to the local university medical center. These are organized by location of the primary neoplasm and pertinent anatomy for the local staging. High quality anatomical and DWI images are used to illustrate the findings.
Findings and procedure details

Legend: 1) BM: Bone marrow; 2) CN: Cranial nerve; 3) EBV: Epstein-Barr virus; 4) IJV: Internal jugular vein; 5) NHL: Non-Hodgkin lymphoma; 6) PPS: Parapharyngeal space; 7) SCM: Sternocleidomastoid muscle; 8) SCC: Squamous cell carcinoma

I-DEEP SPACES OF THE NECK

Fig. 1: Deep spaces of the neck

References: Radiología, Centro de Diagnóstico - Granada/ES

HOW TO LOCALIZE A LESION TO THE CORRECT DEEP SPACE:
Find the center of the mass and evaluate how it displaces the parapharyngeal space (PPS). For example, a lesion in the carotid space will displace the PPS medially and anteriorly (See Fig. 1 on page 27). This schema works for the four spaces which surround the PPS: parotid, carotid, masticator and mucosal.

For the prevertebral and retropharyngeal space, evaluate the displacement of the prevertebral muscles: the prevertebral muscles are displaced ANTERIORLY by a prevertebral lesion and POSTERIORLY by a retropharyngeal lesion.
II- RELEVANT CLINICAL INFORMATION

Lesions that respect the facial planes tend to be benign or non-aggressive malignant lesions, while lesions that cross facial planes tend to be aggressive both for neoplastic (benign and malignant) and non-neoplastic etiologies.

-Parotid space (orange in Fig. 1 on page 27): Bordered anteriorly by the masticator space and medially by the carotid and parapharyngeal space, it contains the parotid gland (which is divided into superficial and deep lobes), blood vessels, the facial nerve (in the deep parotid lobe) and lymphatic tissue (parotid lymph nodes). Malignant lesions that affect this space include the salivary gland neoplasms (mucoepidermoid carcinoma, adenoidcystic carcinoma, malignant mixed tumor, etc.), SCC, adenocarcinoma, NHL.

-Parapharyngeal space (blue in Fig. 1 on page 27): Extends from skullbase to hyoid bone and contains only fat, it is divided into anterior and posterior portions by the styloid process. Malignant lesions include malignant tumors from salivary gland rest and more commonly direct invasion.

-Masticator space (red in Fig. 1 on page 27): Contains the muscles of mastication, ramus and posterior body of the mandible, the inferior alveolar vein and artery and the masticator and inferior alveolar nerve. Malignant lesions include soft tissue and osseous sarcomas, non-Hodgkin's lymphoma (NHL) and minor salivary gland malignancies. It is important to note that perineural spread through the mandibular branch of the trigeminal nerve (CN V3) can reach the brain as it enters through the foramen ovale.

-Carotid space (green in Fig. 1 on page 27): Extends from the aortic arch to the skull base, contains CN IX-XII, the mayor blood vessels of the neck (the carotid arteries and jugular veins), and lymph nodes. Malignant lesions include SCC direct invasion or metastasis, NHL.

-Mucosal space, including the nasopharynx, oropharynx, hypopharynx and larynx (white in Fig. 1 on page 27): Over 90% of tumors are squamous cell carcinoma (SCC) in origin, although there is an extensive list of possible malignant neoplasms. There is a strong relationship between Ebstein-Barr virus (EBV) infection and SCC, especially in the nasopharynx.

III-DWI AND ADC VALUES IN NECK ONCOLOGICAL IMAGING

DWI images (Fig. 2 on page 27) utilized to determine restriction of lesion of interest. Although still being developed as a tool to evaluate malignant potential and tumor response of a neoplasm, it is extremely useful during the radiological evaluation, as it
more clearly identifies masses or lymph nodes that might have malignant potential than purely anatomical images.

**Fig. 2:** DWI and ADC values

*References:* Radiología, Centro de Diagnóstico - Granada/ES

**IV- DEEP CERVICAL LYMPH NODE CHAIN LEVELS**

A significant percentage of tumors, especially SCC in the oral and oropharynx region, present with cervical lymphadenopathy. Lymph node involvement is crucial in staging, thus an accurate assessment of all nodal chains is required, **Fig. 3** on page 28
**Fig. 3:** Deep cervical lymph node chain

**References:** Radiología, Centro de Diagnóstico - Granada/ES

- **Level I:** Submental (IA) and submandibular (IB). Along the body of the mandible to the angle, then inferomedially to the hyoid bone and then superomedially back to the mandible. Drain the submandibular and sublingual glands, cheek, nose, lips (typically bilateral), gums, soft palate, floor of the mouth, anterior tongue.

- **Level II:** Upper and anterior to the sternocleidomastoid muscle (SCM). The anterior upper third of the SCM, above the level of the hyoid bone. Anterior, lateral or medial to IJV (IIA) or posterior to IJV (IIB). Drain the oral cavity, oropharynx, nasopharynx (retropharyngeal nodes first), hypopharynx, parotid gland, lips, soft palate (IIA)

- **Level III:** Middle and anterior to SCM. The anterior middle third of the SCM, between the level of the hyoid bone and the level of the cricoid cartilage. Drain the oral cavity (level I and II affected first), oropharynx, hypopharynx

- **Level IV:** Lower and anterior SCM. The lower third of the SCM, beneath the level of the cricoid cartilage. Drain the oropharynx (level II and III affected first), hypopharynx, larynx and thyroid gland
-Level V: Posterior triangle. The triangle formed by the posterior border of SCM, anterior border of trapezius and superior border of the clavicle. Drain the larynx, thyroid gland, hypopharynx (levels II-IV affected first), base of tongue, tonsils

- Level VI: Anterior compartment. The anterior part of the neck along the hyoid bone to its lateral tip then inferiorly along the anterior border of SCM. Drain the larynx, thyroid gland, infraglottic tumors.

Submental level 1A (red arrow, Fig. 4 on page 28)

![Fig. 4: Submental level 1A](image)

**References:** Radiología, Centro de Diagnóstico - Granada/ES
Submandibular upper jugulodigastric IIA (orange arrow), upper posterior to jugular vein IIB (double orange arrow) and superior posterior triangle VA (green arrow), Fig. 5 on page 29.

**Fig. 5:** Submandibular upper jugulodigastric IIA (orange arrow), upper posterior to jugular vein IIB (double orange arrow) and superior posterior triangle VA (green arrow)

**References:** Radiología, Centro de Diagnóstico - Granada/ES

Middle level III (blue arrow, Fig. 6 on page 30)
**Fig. 6:** Middle level III  
*References:* Radiología, Centro de Diagnóstico - Granada/ES  

Lower level IV (yellow arrow, *Fig. 7* on page 31)
Fig. 7: Lower level IV

References: Radiología, Centro de Diagnóstico - Granada/ES

Lower posterior triangle VB (green arrow) and anterior /prelaryngeal / vesperal space VI (purple arrow), Fig. 8 on page 32.
Fig. 8: Lower posterior triangle VB (green arrow) and anterior /prelaryngeal / vesperal space VI (purple arrow)

References: Radiología, Centro de Diagnóstico - Granada/ES

Retropharyngeal- Retropharyngeal nodes (not technically part of cervical deep nodes), Fig. 9 on page 33.
**Fig. 9**: Retropharyngeal nodes (not technically part of cervical deep nodes)

**References**: Radiología, Centro de Diagnóstico - Granada/ES

Definition of lymphadenopathy in head and neck: More than 15 mm for jugulodigastric lymph nodes, more than 10 mm for other nodes (except retropharyngeal lymph nodes, pathologic at a diameter of more than 8 mm)

**V-KEY ANATOMICAL STRUCTURES OF THE NECK**

**A- Nasopharynx**

Fossa of Rosenmüller must always be evaluated in otomastoiditis to rule out an obstructing mass (eustachian tube connects middle ear with nasopharynx), **Fig. 10** on page 34.
**Fig. 10**: Fossa of Rosenmüller

**References**: Radiología, Centro de Diagnóstico - Granada/ES

Waldeyer ring (white circle, Fig. 11 on page 35), is a ring of lymphoid tissue that can be affected in nasopharyngeal tumors and neoplasms affecting the cavum. Part of the oral cavity, the midline raphe of the tongue contains the neurovascular bundle, it is important to evaluate if it is affected, as well as to rule out contralateral involvement (precludes partial glossectomy).
**Fig. 11:** Waldeyer ring  

**References:** Radiología, Centro de Diagnóstico - Granada/ES  

**B- Oral Cavity**

Squamous epithelium in oropharynx from endoderm= poorly differentiated, aggressive carcinomas. Squamous epithelium in oral cavity from ectoderm= differentiated, less aggressive lesions.

Mylohyoid muscle: Main supporting structure of the floor of the mouth, serves as a key anatomic landmark separating the sublingual space from the submandibular space, **Fig. 12** on page 36.
**Fig. 12:** Mylohyoid muscle

**References:** Radiología, Centro de Diagnóstico - Granada/ES

Retromolar trigone (Fig. 13 on page 37) is a fatty recess that cannot be assessed clinically, it is imperative to rule out invasion radiologically. SCC in this region has a predilection for lymph node involvement.
Extrinsic muscles of the tongue (Fig. 14 on page 38), important to evaluate, as atrophy or edema may correspond to perineural spread of disease and invasion of the hypoglossal nerve (CN XII). It also represents T4a tumor staging.
Fig. 14: Extrinsic muscles of the tongue

References: Radiología, Centro de Diagnóstico - Granada/ES

Mandible and osseous invasion imply T4 disease, look for abnormal low or intermediate signal on T1W or abnormal enhancement. Always evaluate alveolar nerve recess, fat infiltration implies perineural disease, Fig. 15 on page 39.
**Fig. 15:** Alveolar nerve recess

**References:** Radiología, Centro de Diagnóstico - Granada/ES

**C- Pharynx/ Laryngopharynx / Hypopharynx**

The hypopharynx is limited anteriorly by the larynx (thus why some authors call it the laryngopharynx), inferiorly by the esophagic sphincter and inferior border of the cricoid cartilage, superiorly by the oropharynx and the hyoid cartilage, posteriorly by the constrictor and longitudinal muscles. It is divided into three distinct regions: piriform fossa or recess, postcricoid region and posterior wall.

Hyoid, thyroid and cricoid cartilages, **Fig. 16** on page 40. They are key structures as they not only define anatomical landmarks used to separate node levels and neck levels, they are key structures in tumor staging. Involvement of these structures **indicates T4a stage** (T3 if internal margin of thyroid cartilage affected in supraglottic tumors). They tend to calcify in old age, disruption of calcification indicates tumoral disease.
The most common location for tumors in this region is the piriform recess/piriform sinus (60-85%), Fig. 17 on page 41, thus it is imperative to rule out any disease in the radiological evaluation. Neoplasms in this region tend to show "skip growth" and to disseminate underneath the epithelium, thus they present in advanced stages and tend to have the poorest prognosis. Invasion of the piriform sinus represents T2 stage in supraglottic tumors.
Fig. 17: Piriform recess/piriform sinus

References: Radiología, Centro de Diagnóstico - Granada/ES

D- Larynx

The larynx is composed of three regions:

1) SUPRAGLOTTIS, which contains the false vocal cords, the ventricles, vallecula, the arytenoid cartilages and the aryepiglottic folds

2) GLOTTIS, which contains the true vocal cords and the anterior and posterior commissure
3) INFRAGLOTTIS, located inferior to the true vocal cords. The anatomy of the larynx is extremely complicated, and thus it is imperative for the head and neck radiologist to be familiar with its structures. As well, laryngeal tumors are five times more common than pharyngeal neoplasms.

Supraglottis (Fig. 18 on page 42, Fig. 19 on page 43): The vestibule is the main pathway of extension from glottic tumors into the supraglottis. The supraglottis has an extensive lymph node network, this 25-50% of tumors present with cervical lymphadenopathy, often bilateral. They tend to originate in the epiglottis, and present at a later stage than glottic tumors, as they do not affect phonation. Tumors in the supraglottis are three times LESS common than the glottic tumors. **Pre-epligottic fat invasion represents T3 disease.**
Fig. 18: Supraglottis

References: Radiología, Centro de Diagnóstico - Granada/ES
Glottis (Fig. 20 on page 44): Glottic tumors are the most common in the larynx. They tend to present earlier than in the rest of the regions since they affect the vocal cords and thus phonation. The glottis, specifically the space of Renke where the true vocal cords lie has NO LYMPHATIC TISSUE. Thus, neoplasms localized to the true vocal cords can be cured with surgical excision or radiotherapy. If glottic tumors present with adenopathy is because they have spread beyond the glottis or into the anterior and posterior commissures, which are rich in lymphatic networks. Invasion of the anterior or posterior commissure implies contralateral extension of tumor. **Arytenoid cartilage invasion represents at least T2 disease.**
**Fig. 20:** Glottis  

**References:** Radiología, Centro de Diagnóstico - Granada/ES

Infraglottis (Fig. 21 on page 45): Primary tumors are extremely rare and tend to be from locoregional invasion. They have a predilection for anterior extension through the cricothyroid membrane laterally or cricothyroid ligament centrally.
Fig. 21: Infraglottis

References: Radiología, Centro de Diagnóstico - Granada/ES
Fig. 1: Deep spaces of the neck

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Fig. 2: DWI and ADC values
Fig. 3: Deep cervical lymph node chain
**Fig. 4:** Submental level 1A

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Fig. 5: Submandibular upper jugulodigastric IIA (orange arrow), upper posterior to jugular vein IIB (double orange arrow) and superior posterior triangle VA (green arrow)

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Fig. 6: Middle level III

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Fig. 7: Lower level IV

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**Fig. 8:** Lower posterior triangle VB (green arrow) and anterior /prelaryngeal / vesperal space VI (purple arrow)

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**Fig. 9:** Retropharyngeal nodes (not technically part of cervical deep nodes)

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Fig. 10: Fossa of Rosenmüller

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Fig. 11: Waldeyer ring

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Fig. 12: Mylohyoid muscle

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Fig. 13: Retromolar trigone

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Fig. 14: Extrinsic muscles of the tongue

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Fig. 15: Alveolar nerve recess

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Fig. 16: Hyoid, thyroid and cricoid cartilages

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Fig. 17: Piriform recess/piriform sinus

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Fig. 18: Supraglottis

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Fig. 19: Supraglottis

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**Fig. 20:** Glottis

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**Fig. 21:** Infraglottis

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Conclusion

The viewer of this exhibit will gain or refresh information about critical MRI anatomy for the staging of head and neck cancers useful in clinical practice and for preparation for certifying examinations. The images provided aid in recognition of critical anatomical structures that must be thoroughly evaluated and categorized in order to arrive at the correct staging of head and neck cancers.

Staging of head and neck can present a diagnostic challenge. Critical anatomy that needs to be recognized and evaluated for the correct staging of these tumors is fundamental to optimize patient care and outcome.
References


