JBR–BTR, 2012, 95: 45-58.

PROCEEDINGS OF THE 24TH ANNUAL MEETING AND REFRESHER COURSE OF THE EUROPEAN SOCIETY OF HEAD AND NECK RADIOLOGY (ESHNR), BRUGGE, 08-10.09.2011

PROFERRED PAPERS

NEW TECHNICAL POSSIBILITIES IN HEAD & NECK IMAGING: HOW DOES IT WORK?

Latest technical advances in CT for head & neck imaging

C. Argaud[1]

Head and Neck imaging presents a combination of challenges related to lesion and fine anatomy visualization and characterization and dose management.

Lesion visualization has been improved recently by high definition scanning techniques, which consists of increasing substantially the number of samples acquired throughout the rotation to deliver a very high spatial resolution at all acquisition speeds. Primary application of such techniques has been temporal bone imaging and also neck imaging. These high definition techniques rely on a new detector material, which is 100 times faster than conventional detectors, and allows to more than double the number of projections throughout the rotation and reach a very high resolution without any penalty on the dose delivered to the patient.

Lesion characterization in soft tissues has always been a challenge in conventional CT, especially for small lesions. Additional examinations may be required to verify the diagnosis, adding time and cost to the patient's diagnostic pathway. Gemstone Spectral Imaging (GSI) is a novel, dual energy acquisition that improves the diagnostic power of CT to characterize soft tissue(s). This is achieved by transforming the CT attenuation data into various material densities. The spectral properties of iodine and water can be highlighted for the demonstration of lesion perfusion or to derive virtual non-contrast images from a contrast enhanced examination. The additional information provided by the GSI acquisition enables an improved assessment of lesion structure and perfusion. This has led to a significant breakthrough in the diagnostic power of CT for the characterization of lymph nodes, hemorrhagic lesions and tumors. Mono - chromatic KeV images can be generated from the GSI acquisition. These monochromatic data sets are used to improve image quality by reducing artifacts and increasing lesion conspicuity. The monochromatic image depicts how the imaged object would look if the X-ray source produced X-ray photons at a single energy level. Artifacts related to metal implants, coils and clips can be drastically reduced, which makes a quick and easy assessment of vessel patency possible around neuro clips, or allows to better follow-up patients with spine instrumentation for spinal canal visualization.

Lesion characterization can be also improved using large coverage dynamic scanning techniques to study brain perfusion or lymph nodes perfusion pattern. This has led to improvements of thyroid solitary nodes characterization which was well correlated with 99mTc04 thyroid planar imaging.

Radiation dose is a major concern in computed tomography (CT) imaging, especially for sensitive organs or populations. Dose management rules have been rewritten by the introduction of **iterative reconstruction techniques into the clinical practice**. Iterative reconstruction works on the basis of estimating a solution, and then refining it by several iterations. The process of refining consists of increasing the accuracy of the initial computation by modeling the signal generation process.

The Adaptative Statistical Iterative Reconstruction (ASiR) from GE Healthcare has been the first iterative reconstruction method available in routine practice. It models noise root causes in the signal generation, refines the current estimate of the solution by modeling photon statistics and the scanned object, and thus subtracts noise in the final image. As a result, dose saving of 50% can be obtained while maintaining or even improving image quality. Some papers report that average dose for cervical spine examinations could be reduced to 1.1 mSv (Linsenmaier et al., ECR 2011) while preserving the image quality.

New Model Based iterative Reconstruction techniques (MBiR) go further by modeling the CT system optics in the reconstruction process. As a result, spatial and contrast resolution can be improved while dose is much further reduced. MBiR improves head and neck lesion visualization while reducing the dose at unprecedented levels. Such reconstruction technique would allow scanning at equivalent doses of conventional XRay exams.

Conclusion: high definition scanning mode, Gemstone Spectral Imaging and large coverage perfusion techniques have allowed significant improvements in lesion visualization and characterization by bringing function into CT imaging and pushing the limits of anatomy study. Iterative Reconstruction techniques have set a new paradigm in dose management while also improving image quality.

1. CT Advanced Applications Manager, Europe, Middle East & Africa, GE Healthcare.

Diffusion weighted MR Imaging: what you should know

F. De Keyzer[1]

Diffusion-weighted magnetic resonance imaging (DWI) is based on the Brownian motion of water protons in the tissue, and as such provides information on the underlying cell density and structures. DWI aims to make images with different diffusion sensitization (indicated by the b-value, in s/mm^2), and the differences between these images can be quantified using the apparent diffusion coefficient (ADC). While the theory of DWI is already known for more than two decades, the clinical applicability of this technique was low due to signal-to-noise and scan time limitations. Nowadays, it is being used for detection and characterization of tumoral tissues, and for follow-up after treatment in many areas of the body. However, the head and neck area remains one of the most difficult areas for DWI due to the high prevalence of air-tissue boundaries, the overall low signal, and the movement and pulsation artefacts that are very common.

In order to avoid or minimize these issues, a number of precautions and optimizations are required. In this talk, we will discuss the most important sequence parameters and patient handling effects, which should help in acquiring the best possible DWI images in the head and neck region. We will cover the trade-offs that exist when choosing b-values, matrix sizes, shim blocks and sequences. Knowing the advantages and repercussions of each of these choices should also allow better interpretation of the images and allow better comparison of own results with literature reports.

1. Department of Radiology, University Hospitals Leuven, Leuven, Belgium.

New developments in ultrasound and interventional procedures

L. Steyaert[1]

Ultrasound

There is a tremendous technical evolution in the diagnostic imaging equipment in recent years, as you noticed from the CT and MRI topics.

Ultrasound is the 'little brother' compared to the other modalities, but nevertheless a very high tech modality with a comparable technical complexity. The technique looks less impressive because of the smaller machines, and the 'acceptance' is more difficult because it is less 'standardised, and the images are more difficult to read by the referring physician.

The diagnostic result is also more operator dependent than with other modalities, but the diagnostic potential is very high in experienced hands.

Ultrasound is not only an effective diagnostic method, but also economical. It is a relatively cheap method: machines, even the high end ones, are cheap compared to CT, cone beam CT, and MRI and even standard (digital) X-ray. They require less personnel, less preparation, no contrast media, and the power consumption (including often necessary cooling) is very low compared to other modalities. Less space is needed for installation, and the exams can be performed bedside if needed. It is not an old fashioned, but a very modern and 'green' technique, requiring not only less energy (CO2), but it has no adverse effects like X-ray or maybe high energy magnetic fields or radio-waves, or potential short and long term side effect of Iodine or Gadolinium contrast media. Maybe we should consider more a eco-fiendly use of medicine in general…

Ultrasound has a very good tissue contrast resolution without the use of contrast media. It is the first choice method for younger patients and for evaluation of a palpable lesion.

It is the most frequently used method for guiding interventional procedures.

Ultrasound is more and more used in the staging of lymph nodes, combined with FNA.

Increased computing power in High end *multichannel digital systems* (> 512 digital send-receive channels are common) and the development of high frequency *ceramic transducers* have dramatically improved image quality.

The transducer frequency we use is adapted to the field of interest; lower frequencies (e.g. for abdominal work) provide a deeper penetration but less spatial resolution. For superficial structures we use very high frequency probes, and nowadays frequencies over 10MHz are standard, and up to 18MHz is currently used in small parts. This improves the spatial resolution, and is capable of imaging fine detailed anatomic structures. The higher the frequency used the higher the spatial resolution, which is below 0.1 mm.

The technique is specifically suitable for soft tissue exams. For superficial applications like in the ENT area, we need a detailed resolution. Areas of interest are salivary glands, thyroid and parathyroid, lymph nodes, vascular structures.

Matrix probes, using multiple rows of crystals, can obtain a finer ultrasound beam enabling thinner slices, resulting in better contrast and lass partial volume effect due to slice thickness. Ultrasound is a tomographic technique providing us with a real time imaging in a infinite number of planes and orientations.

Harmonic imaging, difficult to obtain with higher frequencies, is certainly one of the major improvements in recent years. It improves the contrast resolution and reduces artifacts, which are the greatest cause of poor image quality.

Spatial and frequency *compounding* techniques also increase image resolution and decrease artifacts and image noise.

Color and Spectral Doppler techniques are very sensitive nowadays, and enable to study vascularisation of soft tissue lesions. Malignant tumors tend to be more vascularised than benign ones, and usually have a higher resistance flow than benign masses. These techniques also enables us to study the vascular structures in the neck; it is a standard technique for imaging carotids and asses stenosis.

Elastography is one of the most recent ultrasound development. With this technique it is possible to measure the differences in tissue elasticity or stiffness; as it is well know by palpation, malignant lesions tend to be harder than benign ones, and appear larger because of stromal reaction . This differences can be visualized by elastography. Elastography seems to increase the specifity of mass lesions, and reduces the need for biopsy.

Elastographic data can be obtained using tissue Doppler information, or through pixel by pixel correlation (strain imaging). A more recent method measures the (transversal) shear waves that are proportional to the tissue elasticity. High frame rates of over 20.000 images per second are needed for that. It is actually the only method capable of quantifying elasticity in kPa. Malignant tumors show significantly higher values than benign lesions.

Ultrasound contrast is a specific product containing microspheres filled with gas; the characteristics of these micro bubbles (smaller than red blood cells) can be altered by the acoustic energy waves, and let us study vascularity of lesions, not only degree of vascularity but also the wash in-wash out characteristics of a lesion.

3D-imaging has become a standard in obstetric ultrasound but is also finding his way in superficial imaging thanks to dedicated 3D probes. From these 3D data sets virtual reconstructions and fly-thru techniques are developed to provide an endoscopic-like visualization.

Endoscopic ultrasound techniques, like transoesophageal (TE) or endobronchial (EBUS) and even intravascular techniques with miniature probes have been developed. TE and EBUS can be used to stage mediastinal lymph nodes, and even provide possibilities for US guided cytological sampling.

Using magnets and GPS like techniques, *fusion imaging* is also under development, giving the possibility to have real time comparison with CT or MRI data.

Interventional techniques

Image guided biopsy techniques are standard procedures nowadays. Surgical open biopsy seems a thing of the past due to the use of very accurate, minimally invasive techniques, and can be virtually considered as malpractice. One area where there has been a lot of evolution in biopsy techniques is breast. Some of these techniques can also be applied in the field of ENT.

Frequently a preoperative histological diagnosis can easily be obtained using US guide needle biopsy.

More and more, staging of axillary lymph nodes is performed with ultrasound and guided needle aspiration or biopsy.

Hook wire localization can be used to guide surgical biopsy of lymph nodes, e.g. in case of suspicion of lymphoma.

Real time US guidance is a big advantage to assure accurate positioning of biopsy needles.

FNA is largely abandoned for the diagnosis of solid lesions, in favor of micro biopsy, which gives more histological material for a better and more confident diagnosis. FNA is still valuable for staging lymph nodes, where the retrieval of cellular material is easier. Vacuum biopsy is reserved for more complex lesions in the breast, but could also be used in ENT in some cases. The latest techniques enable multiple biopsies with a single needle insertion, and are safer because there is no forward throw of the needle during the procedure .

In conclusion we can say that there are tremendous technical improvements in the different diagnostic imaging procedures that increase the sensitivity and specifity in ENT exams. The value of Ultrasound should not be underestimated. It is also easily available and requires no special preparation. US guided minimally invasive diagnostic biopsy techniques make it possible to have a very reliable diagnostic work-up.

1. Department of Radiology, AZ Sint-Jan Brugge-Oostende av, Bruges, Belgium.

NEW CLINICAL HEAD & NECK APPLICATIONS

New CT applications and the value of perfusion CT

A. Trojanowska[1]

Computed tomography (CT) is routinely used for diagnosing and staging of head and neck malignancies. However, evaluation of sole anatomic images has some drawbacks, as early lesion detection remains difficult and benign processes can mimic malignancies. In many cases inflammatory response and oedema cannot be differentiated from tumour itself, what leads to over-interpretation and upstaging of the disease. On the other hand, pattern of infiltration not accompanied by visible anatomic distortion may result with lesion down-staging. Also, imaging post-surgical and post-RTG-therapy patients can be challenging due to anatomical alterations and post-treatment changes.

For better evaluation of tumour extent dynamic scanning with perfusion imaging (CTP) has been introduced. It quickly became an effective, simple and reliable method for the assessment of neo-angiogenesis, which is typical for tumour.

CTP during last years has been widely used to detect cancer, stage it, predict tumour behaviour and assess the response to radio- and chemotherapy. It specially holds promise in better delineation of the extent of tumour, more accurate staging and earlier depiction of squamous cell carcinoma recurrence.

Since recent studies have demonstrated that squamous cell carcinomas of head and neck, with increased blood volume/flow are more chemosensitive than other lesions with relative decreased perfusion parameters, perfusion techniques may be particularly useful in determining which patients would benefit from such medical treatment, as opposed to surgical therapies which may not always preserve organ function.

Knowledge about new powerful techniques of functional imaging, like CTP, its advantages and proper application, may help to improve the salvage rate and reduce the morbidity of treatment for recurrent head and neck squamous cell cancer, by earlier and more confident detection of both primary and residual/recurrent disease.

1. Department of Radiology, University Medical School of Lublin, Poland.

Value of PET CT and PET MR and their contemporary applications

M. Becker[1]

1. Geneva, Switzerland.

Clinical DWI applications: does it always work?

V. Vandecaveye[1]

Diffusion-weighted magnetic resonance imaging (DW-MRI) is a technique that characterizes tissue based on the random displacement of water molecules which is limited by the underlying tissue-specific microstructural barriers. This random water molecule movement is quantified by the apparent diffusion coefficient (ADC), while native high b-value images are used for lesion detection and initial qualitative characterization where possible.

ADC-values reflect the amount of signal loss on the DWI images with increasing b-value and show an inverse correlation with tissue cellularity.

Many technical improvements including the development of echo-planar imaging (EPI), increase of the main magnetic field, stronger high-quality gradients, improved coil-design and parallel imaging have enabled the use of DW-MRI with diagnostic quality in the head and neck.

The main (potential) applications of DW-MRI in the head and neck are oncologic (roughly to be subdivided into detection of unknown primary, nodal characterization and staging and treatment follow-up) and non-oncologic (mainly detection of cholesteatoma).

The aim of the presentation is to outline the potential applications and pitfalls (for instance nodal reactivity, abscess, fungal infection and granuloma) of DW-MRI in the head and neck. Furthermore, the indications will be discussed where DWI is already suitable for clinical use or requiring further development. Also possible solutions for recognizing potential pitfalls and increasing the accuracy of DWI in the head and neck by making image interpretation more straightforward and by adding anatomical imaging criteria or dynamic contrast enhanced MRI (DCE-MRI) as an adjunct tool will be discussed.

1. Department of Radiology, University Hospitals Leuven, Leuven, Belgium.

SINUSES: WHAT THE RADIOLOGIST AND SURGEON SHOULD TELL EACH OTHER

Surgical anatomy

R. Maroldi[1]

There are three main fields in which imaging provides critical anatomical data for planning endonasal surgery: untreated-inflammatory lesions and their revision, sinonasal neoplasms and skull base lesions.

The three fields share the fact that anatomical data are essential to identify variations that increase the risk of damaging *dangerous* sinusal walls, as the lamina papyracea, the cribriform plate, the sphenoid walls. In fact, inadvertent bone penetration may result in iatrogenic lesions of the orbital content, dura, brain, nerves and vascular intra-extracranial structures. CT is the technique of choice to detect and delineate these bone changes and to identify bone landmarks. The direct demonstration of cranial nerves branches is better accomplished by MR, both for the extracranial course (fissures, fossae, foramina) and the intracranial portion.

1. Which anatomical structures the radiologist should demonstrate and indicate in <u>planning endonasal surgery for untreated sinonasal inflammatory lesions</u>.
   a. In the last decade, several training plans have been developed for the acquisition of the surgical skills required to master the incremental technical difficulty of the different endonasal surgical procedures. Training programs include fundamentals (and more) of imaging techniques, where CT and MR anatomy is the backbone.
   b. PACS and imaging-based intraoperative navigation systems have directly pulled the surgeon into the volume-based imaging anatomy. There, multiplanar interaction with the MSCT volume greatly facilitates the surgeon in the identification of key anatomical structures. Of course, reconstructed <u>MPR sections in all 3 planes</u> should always been provided by the radiologist. Nowadays, though more experience and skill have been collected, frontal and sphenoid sinus approaches are still the most challenging.
   c. <u>Frontal sinus approach</u>. The frontal sinus has the most complex and variable drainage of any paranasal sinus. Its drainage pathway (or frontal recess) is a non-regular-space, funnel-shaped, crossing the anterior ethmoid complex down from the frontal sinus ostium. The ostium is identified on sagittal CT reconstructions as a *waist* in the hourglass configuration made by frontal sinus and upper frontal recess. The slope of the frontal recess, its bending and size greatly vary. In fact, the anterior outline of the upper recess is subjected to the anatomical variations of the agger nasi cell and frontal cells. Conversely, the posterior edge of the recess is mainly shaped by the ethmoid bulla and frontal bullar, suprabullar, and supraorbital ethmoid cells (if present). The inferior portion of the frontal recess is a narrower corridor formed by the ethmoid infundibulum if the upper uncinate process attaches medially to the skull base, or by the middle meatus if the upper uncinate attaches laterally onto the lamina papyracea. Access to the natural ostium of the frontal sinus is, therefore, quite variable as it is subjected to the changeable degree of pneumatization of the two cell-complexes lying in the sagittal plane: the agger nasi (anteriorly) and the bulla ethmoidalis (posteriorly), and to a structure on the coronal plane: the uncinate process.
      i. Confusing the roof of the frontal cells with the frontal sinus roof may lead to incomplete removal of the cells in the frontal recess (one of the commonest causes of failure of endoscopic sinus surgery) or – conversely – to intracranial penetration.
      ii. Sagittal and coronal planes are necessary for a detailed demonstration of the recess pathway and its emptying into the ethmoid infundibulum or, directly, into the middle meatus. Axial CT plane sections precise the relationships with the surrounding groups of fronto-ethmoidal cells.
      iii. The presence of a supraorbital ethmoid cell is a valuable anatomical finding as it alerts about the course of the anterior ethmoidal artery, which runs far from the etmoid roof in this variant. On coronal CT, the radiologist should look for a medial notch of the orbit (anterior ethmoidal foramen), the anterior ethmoidal sulcus on the lateral wall of the olfactory niche and the "mesentery" through the supraorbital ethmoid cell containing the artery. Dehiscences of the bone mesentery are observed in up to 40%.

d. Sphenoid sinus approach. The sphenoid sinus can be both a target for endonasal surgery (mostly because of fungal lesions or mucoceles) or a corridor to reach the sellar and suprasellar areas (in case of pituitary lesions, selected craniopharyngiomas and meningiomas), the middle skull base floor (laterally, mostly for CSF leak through the lateral cranio-pharyngeal canal) or the pre-pontine cistern (posteriorly, mostly to treat chordomas). On CT the radiologist should report about:
   i. the type of sphenoid pneumatization (Hamberger' classification), and the pattern of intrasphenoidal sepimentation.
   ii. the presence/extent of sphenoid sinus lateral recesses, possible dehiscence of recess roof.
   iii. the presence of abnormal pneumatization of a posterior ethmoidal cell projecting over the sphenoid sinus (Onodi cell). In this variant, the presence/extent of bone dehiscences of the optic and internal carotid artery canal should be carefully evaluated.
   iv. For inflammatory lesions the trans-ethmoidal approach is the one most frequently used. In this approach four primary bone lamellae must be crossed: the uncinate process, the anterior wall of the ethmoid bulla, the ground lamella of the middle turbinate and the anterior wall of the sphenoid sinus. All lamellae are mainly bent in the coronal plane. Therefore, axial and sagittal CT sections are best suited to demonstrate their tilt, shape, and attachment. Other endonasal approaches to the sphenoid sinus are the para-septal, trans-rostral and trans-ethmoid-pterygoid approaches.

2. Which anatomical structures the radiologist should demonstrate and indicate in planning revision surgery following previous FESS for inflammatory lesions.
   a. In revision surgery a detailed imaging assessment of the post-surgical changes is essential. CT should demonstrate which structures have been resected – and to which extent – and which structures are still present. Imaging should also report about the presence of scar tissue, bending of fragmented residual portions of the middle turbinate, impaired sinusal drainage, incomplete resection of cells. The surgical landmarks used in untreated patients may be useless because of partially or totally resected. In addition, when dealing with recurrent polyposis it may be very difficult on CT to identify residual bone lamellae, as often reabsorbed or distorted by the lesion itself. Therefore, on imaging it is easier to delineate structures as the maxillary sinus roof, the medial orbital wall or the skull base that should not have been changed/resected by previous surgery. Particular attention should be placed on the identification of dehiscent bone walls.
   b. Recurrent maxillary sinus impaired drainage post maxillary antrostomy may be caused by scar tissue, by a residual uncinate process or unresected large infraorbital ethmoid cells. Multiplanar CT analysis may demonstrate key anatomical findings as the lateral attachment of the uncinate on lacrimal duct medial wall and its superior insertion. As the revision surgery has to include the ethmoid complex, another landmark to look for on CT is the horizontal segment of the ground lamella of the middle turbinate. This segment is usually spared as it stabilizes the residual middle turbinate preventing its lateralization. Moreover, if the superior turbinate is still intact, and detectable by CT, it should be reported because this structure may act as a landmark to identify the sphenoethmoid recess.

3. Which anatomical structures the radiologist should demonstrate and indicate in planning endonasal, open or combined surgery for malignant neoplasms or skull base lesions.
   a. Once histology shows a sinonasal neoplasm amenable for surgery, key surgical anatomy includes the demonstration that the tumor does not/or extends through the bony walls of the sinuses. The most critical anatomical landmarks for treatment planning include:
      i. the orbital walls, where the most resistant structure is the inner periosteal layer; therefore imaging has to demonstrate that the periosteal lining is still containing the tumor or not;
      ii. the posterior and anterior maxillary sinus wall. Their involvement by a malignant tumor contraindicates an endonasal endoscopic resection (EER). Open or combined surgery is then required. Other contraindications to EER include extensive lacrimal pathway involvement, diffuse invasion of hard palate, nasal bones, anterior frontal sinus wall and lateral portion of the frontal sinus.
      iii. the pterygoid process, with its laminae, and the pterygopalatine fossa (PPF) content. The radiologist should look for signs suggesting invasion of the PPF and perineural spread (on CT and MR). Within the pterygoid process are two channels that lead to the intracranial surface of the skull base: the vidian canal and the foramen rotundum. Vidian canal is a critical structure to check as its posterior opening leads to the horizontal petrous portion of the ICA (and to the greater superficial petrosal nerve); the foramen rotundum and V2 conduct to the trigeminal ganglion and Meckel's cave;
      iv. the anterior cranial fossa (ACF) floor. Key anatomical structures are the bony laminae of the ACF floor (cribriform plate, fovea ethmoidalis, ethmoid and sphenoid planum) the dural layer, and the brain. If the tumor does not reach the nasal mucosa investing the ACF floor, endonasal endoscopic resection (EER) is feasible. Involvement of bone and focal infiltration of the dura can still be treated by EER with transnasal craniectomy. When the abnormal dura extends over the orbital roof, a combined cranio-endoscopic resection has to be planned;

4. Which anatomical structures the radiologist should demonstrate and indicate in planning endonasal for skull base lesions.
   a. In the last decade, endoscopic endonasal surgery has become a more widely accepted option to treat lesions of the skull base. Endonasal extended approaches (EEA) have been organized into different *corridors*, which lead to specific target areas. The corridors developed in the sagittal plane span from the frontal sinus down to the odontoid. They permit to enter the skull base through the cribriform plate(s), planum ethmoidale and sphenoidale, tuberculum, dorsum sellae, and clivus.
   b. Lesions that are treated by EEA include pituitary lesions (transellar approach), meningiomas of tuberculum sellae, selected craniopharyngiomas (transtuberculum, transplanum approaches), CSF leak repair, encephalo/meningoceles, olfactory groove meningiomas, sinonasal neoplasms (transcribriform approach), chordomas, chondrosarcomas and petroclival meningiomas (transclival approach).
   c. In addition to the anatomical data previously indicated in the endonasal surgical planning in sinonasal inflammatory and neoplastic lesions, several complex intracranial structures have to be demonstrated when planning EEA. They encompass the sella and pituitary gland, the cavernous sinus, cranial nerves, carotid branches and basilar, cisterns. This task requires integrating CT with MR sequences. In particular, high-resolution sequences are useful to detail nerves travelling through the CSF (3DFT-CISS, DRIVE) and to delineate small arterial branches or venous structures like clival venous plexus that run close to the skull base (VIBE, THRIVE).

1. Brescia, Italy.

Non-tumoral sinus pathology
V. Lund[1], N. Freling[2]

1. London, UK, 2. Amsterdam, The Netherlands.

Sinonasal tumours: what the radiologist and surgeon should tell each other
V. Lund[1], T. Beale[2]

1. London, UK, 2. London, UK.

MAXILLOFACIAL AND BRANCHIAL ARCH MALFORMATIONS

Neural crest in maxillofacial and branchial morphogenesis
S. Creuzet[1]

The maxillo-mandibular and branchial system is a composite assembly of interconnected skeletal tissues, that together, these structures fulfill multiple requirements. Those collectively embrace the formation of a feeder apparatus and anchorage of the uppermost parts of the digestive and respiratory tracts. These ontogenetic processes develop from varied morphogenetic strategies that subsequently become confluent and intricate. In spite of its complexity, the maxillo-mandibular and branchial system, as a whole, share the common feature of being an evolutionary novelty, which, to a large extent, depends on the advent of multipotent and invasive cell population, the neural crest (NC). Originating from the margin of the neural plate, NC cells delaminate from the neural primordium and deploy in the entire embryo. The NC durably impacts on cephalic morphogenesis owing to the wide-range of its derivatives: those include neurones, glial cells, endocrine cells, melanocytes, and myofibroblasts to cartilage and bone. The structural principles underlying the maxillo-mandibular and branchial moprhogenesis have been enlightened by embryonic studies. Investigations carried out by the mean of embryonic chimeras have documented the fate of the three germ layers in head ontogenesis, and enabled a tremendous stride in the understanding of the cell interactions involved in the maxillo-mandibular and branchial development. Furthermore, these studies led to emphasize the pivotal role played by the cephalic NC in this process. The notions that have been gained through embryological experiments have enriched our views on the origin of the vertebrate head and shed light on mechanisms responsible for the growth and patterning of these structures. The presentation reports on the NC contribution to the maxillo-mandibular and branchial development and overviews the major tissue interactions and the underlying molecular mechanisms that are involved in its morphogenesis.

1. Institut de Neurobiologie-Alfred Fessard, Laboratoire de Neurobiologie & Développement - CNRS - UPR3294, Gif-sur-Yvette, France.

Abnormal development: when and how it gows wrong
T. Naidich[1]

1. New York, USA.

Congenital lesions of the neck: US, CT and MR findings
J. Delanote[1]

1. Department of Radiology, University Hospitals Leuven, Leuven, Belgium.

Congenital neck lesions are an uncommon group of lesions usually diagnosed in infancy and childhood. They can be evaluated with ultrasonography,computed tomography and magnetic resonance imaging ,either alone or in combination.

Ultrasound should be considered first for studying suspected congenital lesions. It helps to define the primary nature of the lesion (cyst, solid, lymphadenopathy,..) and provides information about the extent of the mass in the neck. CT and MRI are best indicated for deep or extensive lesions and when ultrasound is inconclusive. They provide essential information on the location that allows preoperative planning. These examinations in young children necessitate general anaesthesia.Children are significantly more sensitive to radiation exposure(CTscan).

Congenital neck lesions are primarily benign. The most common congenital lesions in the neck are the thyroglossal duct cysts, the second branchial cleft cysts,the lymphangioma or cystic hygroma and the dermoid cyst.

Particular emphasis is applied to the embryological origin and anatomical site of the lesions to aid in differential diagnosis. We discuss the pathology of the different branchial arches: congenital cervical cystic masses among them thyroglossol duct cysts, cystic hygromas, branchial cleft cysts and thymic cysts. We include some external and middle ear anomalies arising from the first and second branchial arch. Further we look at the vascular –lymphatic spectrum and epidermoid-dermoid-teratoma lesions.

The clinical manifestations combined with knowledge of the embryology and spatial anatomy of the head and neck often provide clues for the correct diagnosis.

TEMPORAL BONE – WHAT THE RADIOLOGIST AND SURGEON SHOULD TELL EACH OTHER

Cholesteatoma imaging today
E. Offeciers[1], B. De Foer[2]

Diagnosis of a middle ear cholesteatoma is based on the clinical, audiological and otoscopical evaluation of the patient. Image evaluation of a middle ear cholesteatoma prior to first stage surgery is still performed mainly using CT scan. It will nicely demonstrate the erosion of the ossicles and the bony spur of the epitympanic space as well as its relation to Prussak's space. Delineation of the tegmen and the lateral semicircular canal can also be performed.

Different types of surgery exist. In the canal wall down tympanoplasty, the mastoid is opened with resection of the external auditory canal, eradication of disease and creation of a large resection cavity. The advantage is that this cavity can be monitored nicely. One of the disadvantages is that patients are no longer allowed to swim as contact with water may provoke sudden onset of vertigo due to contact of water with the lateral semicircular canal.

In the canal wall up tympanoplasty, the external auditory canal is left intact. This increases the risk of leaving residual cholesteatoma behind so there is the need to stage.

In the primary bony obliteration technique, the tympanoplasty cavity is subsequently filled up with a mixture of bone and bone pâté. Ossicular chain reconstruction can be performed in the same stage or during second look surgery. This type of surgery has a lower rate of residual and recurrent cholesteatoma.

MR imaging has gained increasing importance in the diagnosis and follow-up of middle ear cholesteatoma the past few years.

Whereas CT is regarded as the primary imaging tool in clinical clear-cut middle ear cholesteatoma to evaluate the extension of the cholesteatoma, MRI has its place in the clinically doubtfull cholesteatoma as well as in the evaluation of the pre second-look patient looking for residual and/or recurrent cholesteatoma.

Two types of MR imaging techniques have mainly been used. The delayed gadolinium-enhanced T1-weighted sequences and the non echo-planar diffusion-weighted MR sequences.

The rationale of the delayed-gadolinium enhanced T1-weighted sequences is based on the fact that scar tissue and inflammation require time to enhance and that early scanning might result in false positive results. The echo-planar diffusion-weighted MR sequences have been abandoned in favour of the non echo-planar diffusion-weighted due to the higher resolution, the thinner slice thickness and the complete lack of susceptibility artefacts of the latter sequences. On diffusion-weighted sequences, cholesteatoma lightens up as a hyperintense lesion on b-1000 images. It has been proven that the combination of delayed gadolinium-enhanced T1-weighted sequence and non echo-planar diffusion-weighted sequences yields no higher sensitivity, specificity, negative and positive predictive value than the non echo-planar diffusion-weighted sequences alone. Imaging of middle ear cholesteatoma can hence be performed using non echo-planar diffusion-weighted sequences alone. Association to T2-

weighted sequences will enhance the capability to locate any hyperintensity on diffusion-weighted sequences.

Exception should be made in case of an infected cholesteatoma and in case of suspicion of associated complications. In those cases, the combined protocol including delayed gadolinium-enhanced T1-weighted sequences and non echo-planar diffusion-weighted sequences should be used.

Imaging evaluation of patients prior to second-stage surgery should be performed by MRI using non echo-planar diffusion-weighted sequences alone. This inevitably will reduce the number of negative second-look surgery. By doing so, the number of useless CT scan will also diminish, reducing patient's irradiation.

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1. University Department of Otorhinolaryngology, AZ Sint-Augustinus Hospital, Wilrijk (Antwerpen), Belgium, 2. Department of Radiology, GZA Hospitals Sint-Augustinus, Wilrijk, Belgium.

Congenital inner ear malformations and cochlear implants

L. Sennaroglu[1], B. Ozgen[2]

This presentation will review the important aspects of imaging in the evaluation of the patients with congenital inner ear malformations with an emphasis on the imaging before cochlear implantation.

The different types of congenital inner ear malformations will be summarized and standard surgical implantation techniques will also be briefly described to familiarize the audience with these anomalies and treatment methods.

CT and MR imaging of the temporal bones before implantation will be reviewed with an interactive discussion between radiologist and surgeon, followed by real time movies during implant surgery. Contraindications for the cochlear implantation including cochlear nerve aplasia and absence of the cochlea will be highlighted. Additionally potential sites of surgical complication such as aberrant facial nerve, cases with increased CSF gusher risk will be pointed out.

For the assessment of congenital inner ear malformations and evaluation of the patients before cochlear implantation, the radiologists should be familiar with the surgical techniques and be able to identify clinically and surgically relevant findings that may contraindicate the implantation or alter the surgical methods.

1. Department of Otolaryngology-Head and Neck Surgery, Hacettepe University Medical Faculty, Ankara, Turkey, 2. Department of Radiology, Hacettepe University, Ankara, Turkey.

Conductive hearing loss with an intact tympanic membrane

J.W. Casselman[1,2,3] , E.F. Offeciers[4], B. De Foer[3]

The diagnostic methods available in patients with conductive hearing loss with an intact tympanic membrane are: personal and family history, otoscopy, audiology, imaging, surgical inspection and counselling. However, surgical inspection is only performed as a last resort, when all diagnostic efforts have failed to yield a plausible pre-operative diagnosis. The most important symptoms and personal history data that predict trouble are family history (e.g. otosclerosis), age and circumstances at onset of the hearing loss (e.g. childhood-LVA, trauma-luxation of the ossicles), fluctuating hearing loss and autophony (e.g. superior semicircular canal dehiscence-SCCD), recurrent vertigo/dizziness (e.g. fistula due to trauma), history of recurrent middle ear disease (e.g. incus lysis and tympanosclerotic fixation) or surgery. The most important clinical signs that predict trouble are: congenital facial abnormalities (congenital hearing loss) and otoscopic signs of EAC or ME disease (incus lysis or tympanosclerotic fixation, myringosclerosis or scarring of the TM, convexity or deep retraction of the pars flaccida due to cholesteatoma, pulsating drum or color change of the drum due to a dehiscent or aberrant vessel). The most important audiological signs that predict trouble are: fluctuating thresholds (LVA – imaging), unusual form of the audiogram (malleus fixation, LVA, SCCD – imaging), high impedant tympanogram (malleus fixation), stapedial reflex presence (posttraumatic ossicular luxation), tuning forks in contradiction with PTA and a phantom curve. CT can be used to detect the above mentioned causes like otosclerosis, tympanosclerosis, posttraumatic ossicular lesions, incus lysis, minor ear dysplasias and SCCD. MRI can be used to exclude schwannoma or is used when there is suspicion of congenital cholesteatoma or labyrinth dysplasia. Hence, the surgeon and radiologist should discuss whether a CT or MR has to be performed whenever something is "out of tune". The most important reasons to ask for imaging are: atypical history, cases suspect for congenital hearing loss, suspect otoscopic image, asymmetric BC thresholds, profound mixed loss and suspect tympanometry. The above mentioned clinical – radiological approach will be discussed and illustrated in this lecture.

1. Department of Radiology, AZ St-Jan Brugge AV, Brugge, Belgium, 2. University of Ghent, Gent, Belgium; 3. Department of Radiology, and 4. University department of ENT, St-Augustinus, Wilrijk, Belgium.

HEAD & NECK STRUCTURES AND THEIR CONNECTION WITH CRANIAL NERVES AND NUCLEI

Anatomy of the cranial nerves, cranial nerve nuclei and tracts

T. Naidich[1]

1. New York, USA.

Symptoms-guided imaging of the cranial nerves and nuclei

S. Kollias[1]

The brainstem (mesencephalon, pons, and medulla oblongata) contains the nuclei of the cranial nerves III to XII and their complex connectivity, serves as a conduit for many ascending and descending pathways and cerebellar connections, and is important for many key integrative functions (control of movement, modulation of pain, autonomic reflexes, arousal, and consciousness. In this presentation we will focus on a symptom-based diagnostic approach to lesions involving the cranial nerves (CN) III to XII and their nuclei in the brainstem (with the exception of CN VIII, which will be covered in the following presentation).

For tailoring the imaging approach the neuroradiologist needs to be familiar with how neuroanatomical functional units cluster in the brainstem. These units can be divided into cranial nerve nuclei, pigmented nuclei, and tracts. When two of these three anatomical units show impairment simultaneously (i.e., cranial nerve deficit and crossed corticospinal neurological signs), the first place to localize the lesion is within the brainstem. Furthermore, cranial nerve symptoms provide rostral-caudal localization and long tract related symptoms provide medial-lateral localization.

Specific clinical symptoms noticed by the neurologist or the ENT surgeon, or sometimes the neuroradiologist, should help in the potential localization of the lesion to specific CN nuclei within the brainstem or along the fibers of the specific CN.

The nuclei for CNs III, IV and part of V (sensory) are found in the midbrain. Affliction of the oculomotor n. (III) will manifest with ipsilateral eye deviation down and laterally, ptosis, and dilated pupil unresponsive to light. Lesion involvement of the trochlear n. (IV) may cause diplopia. Trigeminal n. (V) lesions will cause ipsilateral loss of sensation in the mandible (when the lesion is located in the midbrain), in the face (if the lesion is in the upper pons) and ipsilateral loss of pain and temperature in the face (when the lesion involves the pons and medulla oblongata).

The nuclei of CNs VI, VII, VIII and part of V (motor) are located in the pons. Involvement of the abducens (VI) will manifest with palsy of the lateral rectus muscle and medial deviation of the eye. Facial n. (VII) pathologies will manifest with lower motor neuron facial weakness ipsilaterally and loss of taste on the anterior 2/3 of the tongue. Vestibulocochlear involvement is manifested by deafness (indicating a lesion in the cohlear nuclear complex in lower pons) and vertigo, nystagmus and vomiting (when the lesion extends to involve the upper medulla oblongata).

The medulla contains the nuclei for the CNs IX, X, XI, XII and a portion of CN V. Symptoms of decreased gag response and loss of taste on the posterior 1/3 of the tongue should prompt examination of the medulla and the subarachnoid spaces along the course of the Glossopharyngeal n. (IX). Lesions of the Vagus n. (X) and Accessory n. (XI) will be indicated by ipsilateral paralysis of the larynx and soft palate, whereas ipsilateral flaccid tongue weakness should prompt examination of the Hypoglossal n. (XII).

Multiple brainstem syndromes, most known by eponym, manifest with symptoms related to a lesion involving the CN at the brainstem level. Thus the Weber, Claude, Benedict, Nothnagel and Perinaud syndromes, all resulting from midbrain lesions, have in common palsy of the CN III, causing diplopia on lateral gaze but it can also be disconjugate vertical gaze. Facial palsy (CN VII), and sometimes lateral rectus palsy (CN VI) is associated with Millard-Gubler and Foville syndromes and localize a lesion at the level of the pons. Oropharyngeal deficits arising from a lesion at the level of the medulla are seen with Avellis, Jackson, and Wallenberg syndromes and point towards a pathology of the CN and nuclei IX-XII.

The spectrum of pathology entering in the differential diagnosis of lesions involving the nuclei within the brainstem includes mainly focal lesions due to ischemia, neoplasm or demyelination . Less common etiologies include infectious diseases (rombencephalitis, tuberculosis etc), vascular malformation, trauma, hyponatremia, causing central pontine myelinolysis and other less common etiologies.

In summary, knowledge of brainstem anatomy and physiology, and the spectrum of clinical presentation are essential for the imaging assessment of patients with symptoms of cranial nerve deficits for tailoring the appropriate examination in high resolution to specific anatomical segments and for correct diagnosis.

Suggested reading:

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1. Institute of Neuroradiology and Magnetic Resonance Center, University Hospital of Zurich, Switzerland.

Auditory and vestibular pathways: in vivo anatomy-pathology

J.W. Casselman[1,2,3], M. Safronova[4], F. Craighero[5], B. De Foer[3]

Most often imaging is focused on the inner ear, internal auditory canal (IAC) or cerebellopontine angle (CPA) when patients present with sensorineural hearing loss (SNHL) or vertigo. In case of SNHL most of the pathology is indeed found in these anatomical areas, however some of the causes can also be located in the brainstem or higher along the auditory pathway or even in the auditory cortex. This is different in patients with vertigo in whom most of the pathology can be found along the afferent and efferent vestibular pathways in the brainstem, cerebellum and supratentorial vestibular pathways. MR is the method of choice to visualise these pathways and it is obvious that the radiologist must know this anatomy. The best MR sequences to show these structures are thin slice proton-density/T2 weighted SE/TSE images or sequences using different echo-times (TE) like the m-FFE or medic sequence. On these latter images the myelinated structures like the pathways have a low signal intensity and can be recognized. Also the auditory and vestiblar cortical areas must be imaged and patholgoy must be excluded. Many different lesions can affect the auditory or vestibular pathways. Infarctions are the most frekwent cause of vertigo at the level of the brainstem and cerebellum. Other lesions which can cause vertigo are tumors, multiple sclerosis, trauma, rhombencephalitis etc. However, similar lesions can also be found at the level of the vestibular cortex, although the clinical correlation is less understood and accepted. Similar lesions can also cause SNHL although this is rarely bilateral and profound. Posterior fossa infarctions are more frequently causing vertigo than deafness. Profound bilateral deafness is most frequently caused by trauma involving the brainstem, auditory pathways or auditory cortex although multiple sclerosis, brainstem tumors and rhombencephalitis can also cause bilateral hearing loss. The normal auditory and vestibular pathways, as they can be seen on MR, will be shown in this lecture and the most frequent lesions involving these pathways and the vestibular and auditory cortex will be illustrated.

1. Department of Radiology, AZ St-Jan Brugge AV, Brugge, Belgium, 2. University of Ghent, Gent, Belgium, 3. Department of Radiology, AZ St-Augustinus, Wilrijk, Antwerpen, Belgium, 4. Department of Neuroradiology, Hospital Pedro Hispano, Matosinhos Portugal, 5. Department of Radiology, CHU Marseille, France.

Imaging the anterior visual pathway

P. Demaerel[1]

This presentation reviews the lesions involving the anterior visual pathway in adults and children. In the majority of the pathological conditions, MR is the only imaging modality although CT may occasionally contribute to the diagnosis.

The sensitivity of the MR examination will depend on the quality of the examination, that should be tailored to image the anterior visual pathway adequately.

Optic nerve hypoplasia is a common cause of poor vision in childhood. Associated central nervous system malformations can be seen in up to 40%. Septo-optic dysplasia (formerly called de Morsier syndrome) consists of hypoplasia of the anterior visual pathway, absence of the septum pellucidum and thinning of the corpus callosum.

Optic nerve glioma can be seen in children and in adults but is more common in pediatric patients and is often associated with neurofibromatosis type 1. Involvement can be limited to the optic nerve(s) or can extend into the optic chiasm and optic tracts. Enhancement has been associated with a more aggressive behaviour but there have been reports on spontaneous disappearance of enhancement too. Imaging plays an important role in the follow up during chemotherapy.

Optic neuritis in young adults can be isolated but there is a strong association with multiple sclerosis (first manifestation in approximately 20% of the patients). Optic neuritis is a typical clinical diagnosis but MRI can be requested to exclude other pathology mimicking optic neuritis or as part of the diagnostic work-up for MS. The presence or absence of brain lesions offers prognostic information. Optic neuritis can easily be depicted on T2 weighted STIR images. Post contrast images are not necessary except when nonarteritic ischemic optic neuropathy is a possible differential diagnosis, because enhancement is absent in the latter.

Optic neuropathy can also be due to infectious, granulomatous and autoimmune disorders but it is ususally not possible to differentiate these entities from demyelinating optic neuritis.

Optic nerve sheath meningioma can be a primary tumour or can be due to extension of an intracranial meningioma into the orbital apex. CT can be useful to demonstrate hyperostosis or calcification.

Optic nerve contusion can be depicted by MRI. However CT should always first be performed to exclude ferromagnetic foreign bodies.

Common entities that can lead to compression of the anterior visual pathway will be briefly discussed too.

1. Department of Radiology, University Hospital K.U.Leuven, Belgium.

ORAL CAVITY

How medical imaging can influence the surgical decision making

J. Abeloos[1]

Today, almost every tumour in the oral cavity is resectable but the surgical dilemma on functional inoperability remains. The functional and cosmetic outcome after ablative surgery in the oral cavity can be enhanced by various types of immediate reconstruction.

Therefore medical imaging is besides the clinical inspection very important.

The depth of invasion and the extent of the tumour in the soft tissues such as tongue, floor of mouth and buccal mucosa gives an idea of the possible outcome. When lesions in the tongue and the floor of mouth cross the midline, they might need bilateral neck dissections.

The invasion of the mandible (cortex and medullar space) let decide about marginal or segmental resection. How far does the resection of the mandible need to be done? The reconstruction will be totally different. On demand fabricated reconstruction plates can facilitate the reconstructions, but an exact medical imaging is mandatory.

Different types of invasion and extent will demonstrate the importance of the imaging in planning the reconstructive possibilities and the functional outcome. This gives an idea of the preoperative assessment on the functional inoperability dilemma.

The different treatment possibilities are discussed with a multidisciplinary oncology experts group, including speech pathologists who are important for the re-education and play an important role in the decision making.

An exact knowledge of the tumour localisation and invasion is necessary in this assessment. In this way the imaging plays an important role and influences the surgical decision making on the treatment.

1. Department Maxillofacial Surgery, Bruges Oncological Head & Neck Centre, A.Z. Sint Jan Brugge, Bruges, Belgium.

Imaging of oral cavity cancer – What the surgeon needs to know

F. Dubrulle[1], F. Bidault[2]

The accuracy of pretherapeutic staging plays an important role in treatment planning of oral cavity tumors. The initial imaging assessment includes MR imaging with contrast and CT.

Both are necessary to provide the clinician with the crucial pretherapeutic information on deep tumor infiltration: MRI is necessary to appreciate the extension to the tongue, the oral floor but also to the retromolar trigone and the deep spaces. Perineural extension has also to be looked for carefully on MRI. CT is the modality of choice to look for cortical erosion or lyses, whereas MRI is useful to detect bone marrow involvement.

An evaluation of the entire upper aerodigestive tract and the cervical lymph nodes has to be realized during this pretherapeutic staging. A thoracic CT is also recommended at the same time.

All these findings can profoundly influence the staging and the management, in particular in case of surgery. Thus, it is necessary to know the potential most common routes of spread of squamous cell carcinomas of the oral cavity, and to be aware of the potential false-positive of imaging, in particular regarding the bone marrow signal on MRI, in order not to overestimate the staging.

We also shall review the sequences of diffusion and perfusion, particularly for the nodal staging and the evaluation before radio-chemotherapy.

1. Radiological Department, CHRU de Lille, Lille, France, 2. Department of Medical Imaging, Institut Gustave-Roussy, Villejuif, France.

What's new with Positron Emission Tomography in oral cavity cancer

G. Bonardel, E. Gontier, D. Metivier, C. Dechaud, M. Soret, H. Foehrenbach[1]

Since its introduction in clinical practice in the 1990's, positron emission tomography (PET), usually with ^{18}F-fluoro-2-deoxy-D-glucose (^{18}F-FDG), has become an important imaging modality in patients with cancer. PET, now systematically PET/CT, as metabolic and molecular imaging technique, is more and more involved in the management of head and neck squamous cell carcinoma (HNSCC). In particular, its clinical value in initial staging of neck lymph nodes, metastases or second cancers and in the evaluation of recurrent or residual disease is well established. The metabolic dimension of the technique provides additional prognostic information. FDG-PET is being used frequently on more advanced clinical applications. After chemoradiation, it is used for monitoring the response to therapy to accurately select patients for salvage surgery. The value of PET/CT for radiotherapy planning is still under investigation but it makes a significant difference by identifying malignant normal size nodes, extent of viable tumor and distant disease.

Technical innovation, such as hybrid positron emission tomography/magnetic resonance imaging (PET/MRI) provides also both anatomic and metabolic information in the same procedure but its place has still to be define in clinical practice. From the point of view of biological metabolism, new radiopharmaceutical probes are being developed. Those hold promise for future refinements in this field.

1. Department of Nuclear Medicine, HIA Val de Grâce, Paris, France.

How to differentiate recurrence or post therapeutic changes in the oral cavity

F. Bidault[1], G. Bonardel[2]

This course reviews the expected imaging findings after treatment of oral cavity squamous cell carcinoma (SCC), and how to differentiate these from complications, and from persistent or recurrent cancer. Follow-up for head and neck SCC is based on clinical, radiological and endoscopic survey. Radiologist must be aware of first location, TNM staging, date and type of treatment. Usual radiological post-radiotherapy changes are: increased enhancement followed by size reduction of salivary glands, oedema of retropharyngeal space and laryngeal soft tissue, thickening and increased enhancement of mucosal space, reticulation of subcutaneous fat, thickening of skin and platysma muscle, atrophy of lymphatic tissue. Changes after surgery depend on surgical resections, neck dissection, type of flap used to reconstruct oral cavity surgical defects. Principal complications are osteonecrosis of the jaw, soft tissue ulceration and fistula. Advanced T or N stage of disease, vascular or lymphatic involvement on pathology, unsatisfactory surgical margins, and long interval between surgery and radiotherapy are risk factors for local recurrence. Main recurrence signs are: growing mass with contrast enhancement (usually at the interface of the operative site and the flap), nodal recurrence (ipsi or contralateral to the primary), bone or cartilage destruction, perineural tumour spread. Authors generally agree about the usefulness of a 3 months imaging follow-up after SCC treatment. CT and MR are both useful and commonly performed. T2-weighted images are known to be helpful in distinguishing recurrent tumour from radiation fibrosis (fibrosis usually remained low in signal intensity on T2-weighted images, while tumour demonstrated higher signal intensity). Diffusion-weighted MR imaging with ADC measurement has promising results in some studies for differentiating residual or recurrent SCC from postoperative or postradiation changes. Localized single voxel magnetic resonance spectroscopy measurements were able to differentiate recurrent disease from post-therapeutic tissue changes in a study. FDG-PET/CT value in the evaluation of recurrent or residual disease is well established. Sonographic examination of radiotherapy treated lymph nodes offers a good sensitivity and NPV, but poor specificity and PPV.

1. Department of Medical Imaging, Institut Gustave-Roussy, Villejuif, France, 2. Department of Nuclear Medicine, HIA Val de Grâce, Paris, France.

THE MANCUSO GENERATION

"The hardest thing to do is call an imaging study negative": a critical thinking approach to image interpretation

A.A. Mancuso[1]

Dedication :This lecture is dedicated to Leo. G. Rigler, who taught me that "the hardest thing to do is call a chest x-ray negative", this concept serving as a guiding principle in my career and as the initial inspiration for this presentation.

And to Bill Hanafee for all of his wisdom, leadership and kindness and Paul Ward… who together, created a model of what can be accomplished for interdisciplinary patient care with a spirit of mutual respect and everlasting friendship.

And to my good friend and colleague Kathlyn Marsot-Dupuch whose wonderful spirit left us too soon.

"The hardest thing to do is call an imaging study negative". Assuming you believe this statement is true you must understand and accept this concept as rooted in habitual critical thinking and the development of fluid intelligence. Fluid intelligence directly relies of the application of critical thinking skills with those concepts in unison making it possible for one to determine patterns, make connections and solve new problems.

Critical thinking is about being both willing and able to evaluate one's thinking. The disposition toward of critical thinking is based on character. The traits of a critical thinker and a complete physician being the willingness to learn and develop the habitual intention to be truth-seeking, open-minded, systematic, analytical, inquisitive, confident in reasoning, and prudent in making judgments.

There is a reasonable level of consensus among experts that an individual or group engaged in strong critical thinking gives due consideration to:

- Evidence through observation
- Context of judgment
- Relevant criteria for making the judgment well
- Applicable methods or techniques for forming the judgment
- Applicable theoretical constructs for understanding the problem and the question at hand

This understanding of the interpretive process being best rooted in habitual critical thinking and fluid intelligence development, which then allows us to discard less orderly and potentially error burdened processes such as a primarily gestalt and DDX based educational and reporting/consulting methodologies. In essence the critical thinking model leads us to a fundamentally rules based approach to interpretation and reporting as the basis of our work product.

The building blocks of the critical thinking model in imaging include:

- A thorough knowledge of the normal anatomy
- And normal variants (based on a reliable normative data base when available)
- Having clinical information (context)
- A rules/structure by which to call study negative
- Rejecting interpreting studies only by "Gestalt" or other random processes

Following this model some of the goals for our reports become to:

- Avoid false negatives-which is a focus of this presentation
- Set reasonable expectations about what a negative imaging report means in a specific clinical context
- State a degree of confidence (whenever possible) of the negative interpretation for excluding specific pathologies (whether asked or not)

This presentation will identify specific clinical contexts with high error rates that are from the following categories:

- Interpretive
- Process (protocol application)
- Error poses unusually high risk to patients

As Examples-situations with high error rate for disease exclusion have been chosen

- Temporal bone- Anatomically a confined, complex (lots of small structures) region with numerous, diverse indications for study
- Invasive fungal sinus disease in immune compromised patients — a critical and usually high acuity situation, that requires exclusion of a specific condition with a high degree of confidence
- Facial pain and otalgia – "screening" of a relatively large anatomic area, requires numerous observations, diverse pathology – wherein the incidence of identifiable causative pathology is relatively low

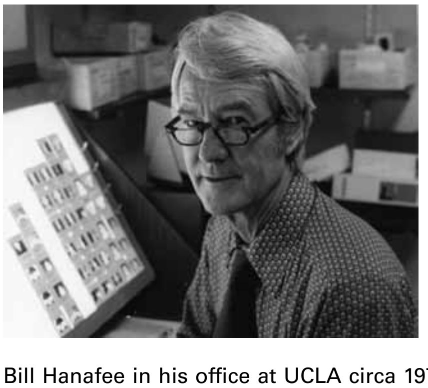
Our overall goals are to:

- Seek ways to make imaging relevant
- Ensure close cooperation with referring clinicians
- Understand what the clinicians really needed to know from imaging in a very specific clinical context and communicate that information clearly

The intended result of applying this continuum of the critical thinking, knowledge and resultant wisdom would be to produce the best possible diagnostic imaging process from acquisition to consulting and reporting. This would include assuring optimal resource utilization, which in turn leads to uniformly high quality images those images eventually facilitating the best possible timely consultations and written reports.

Realizing these goals requires access to the entire scope of core knowledge needed to plan, perform and interpret an imaging exam. This includes applied physics, anatomy and pathophysiology. Such core knowledge must then be expanded within the known specific clinical context. Core knowledge might also be applied to a clinical situation never before encountered and, with good fluid intelligence skills (wisdom and judgment), resulting in the correct decision making in what might otherwise be a confounding situation.

1. Department of Radiology, University of Florida College of Medicine, Gainesville FL, USA.



Bill Hanafee in his office at UCLA circa 1970's preparing teaching and in retirement in north San Diego County likely getting ready to shoot a round of golf with his long time friend and colleague Paul Ward.

Temporal bone imaging: from basics to benchmark (and beyond)

B.M. Verbist[1,2], M. Lemmerling[3]

Marc Lemmerling and Berit Verbist spent a visiting fellowship with Prof Dr A.A. Mancuso in 1996 and 2003 respectively. The vast and varied patient population at Shands at the University of Florida allowed them to immerse themselves in all aspects of Head and Neck radiology. Yet they both shared a special interest in the temporal bone. Thanks to the remarkable teaching skills of Tony Mancuso they rapidly increased their knowledge and insights into this fascinating topic. This has shaped their clinical work and teaching and it has laid the foundation to scientific work about middle and inner ear anatomy (Marc Lemmerling) and imaging evaluation of the inner ear in regard to cochlear implantation (Berit Verbist). This joint lecture will reflect on the evolution of temporal bone imaging in the past 2 decades.

1. Department of Radiology, LUMC, Leiden, The Netherlands, 2. Department of Radiology, UMCN, Nijmegen, The Netherlands, 3. Department Radiology, AZ Sint-Lucas, Gent, Belgium.

Imaging of the larynx and hypopharynx: The Gainesville Foundation
F.A. Pameijer[1]

Many reports in literature to date have recognised a positive correlation between tumor volume and prognosis for all subsites of the head and neck. Therefore, pre-treatment volumetric analysis may have predictive value for patient outcome (independently from the currently used TNM classification).

Treatment options for patients with squamous cell carcinomas of the larynx and hypopharynx include radical surgery, conservation surgery and definitive radiotherapy (RT). In recent years, chemoradiation therapy has become one of the main options for organ preservation therapy in these patients, with salvage surgery reserved for local recurrence. Even in advanced cancers, modern concomitant chemoradiotherapy can achieve relatively high locoregional control and survival rates. With all these different treatment strategies available, it is crucial to select individual patients for the right therapy.

In two reports, published as early as 1990 and 1993, from the University of Florida (UFL) raglottic carcinomas and T3 glottic carcinomas respectively, pre-treatment (volumetric) analysis of CT examinations has been shown to be potentially useful in this selection.

After an introduction in the principles of tumor volume determination, the value of (CT-determined) parameters as prognostic factors for treatment outcome of head and neck cancer patients after definitive radiation therapy will be presented. The focus will be on laryngeal and hypopharyngeal carcinomas, emphasizing tumor volume and cartilage sclerosis. Different combinations of these two parameters resulted in CT-bases pre-treatment risk profiles that were able to classify individual patients at low-, moderate- and high-risk for local failure after curative RT.

Post-RT CT studies can also predict local failure in patients with laryngeal carcinomas treated with definitive RT using a post-RT score, developed at UFL.

1. Department of Radiology, University Medical Center Utrecht, Utrecht, The Netherlands.

The larynx, hypopharynx and beyond: The Spin-Off
R. Hermans[1]

CT and MRI are well established methods in the initial diagnostic evaluation of head and neck malignancy, and are also widely used for treatment monitoring and follow-up. MRI is the preferred method for imaging certain tumour sites, such as the nasopharynx, skull base and sinonasal cavities.

As in other areas of the body, the results obtained with these anatomy-based imaging methods are not always optimal, because of difficulties to identify early disease or small volume lesions, as well as to differentiate tumour from inflammation and/or scar tissue.

The localisation and extent of primary squamous cell cancer, one of the most common types of malignant disease in this region, is usually well defined by CT or conventional MRI. However, the characterisation of small neck lymph nodes remains a difficult issue with anatomy-based imaging methods. The use of ultrasmall superparamagnetic iron oxide (USPIO) particles, a contrast agent accumulating in normal lymphoid tissue, has shown variable accuracy for nodal staging in the head and neck. Also, the routine use of USPIO-MRI is hampered due to limited availability and logistical problems concerning administration of this contrast agent.

Although diffusion-weighted MRI (DWI) is already a long time in use for evaluation of brain diseases, its potential utility for evaluating extracranial neoplastic disease is only recently recognized. For staging neck lymph nodes in squamous cell cancer, high sensitivities and specificities were reported, better than what is obtainable by CT or conventional MRI. This increased accuracy is mainly due to improved detection of subcentimetric nodal metastases. If these results are confirmed, this improved pretherapeutic nodal characterization may result in a closer conformity of the radiation target volume to the anatomical tumour extent, and reduce side effects of treatment when intensity modality radiotherapy is applied.

Differentiation of treatment induced tissue changes, especially after (chemo) radiotherapy, and persistent or recurrent cancer, is another topic in which DWI may be very helpful.

Studies investigating the role of DWI as prognostic tool during, and very early after treatment, are ongoing. Preliminary results are encouraging, and if confirmed, tailoring treatment according to the very early individual response, as seen on DWI, may become feasible.

For several of these possible applications of DWI in head and neck cancer, currently FDG-PET is being used or advocated. However, FDG is not an entirely specific cancer tracer, and false positive finding are not uncommon. The spatial resolution of PET is relatively low, potentially leading to false negative results. DWI is an interesting alternative, as correlation with anatomical MR images acquired during the same study is possible, allowing precise anatomical localisation of the observed abnormalities. DWI also appears to better discriminate between neoplastic disease and inflammatory changes than PET. DWI is a method that can be performed at a lower cost than PET, without the need for an external tracer, and without exposure of the patient to ionising radiation.

FDG-PET is, in general, not recommended for the routine diagnostic work-up of a head and neck neoplasm. However, FDG-PET should be performed in case of a clinically unknown cancer, if CT or MRI fail to reveal the primary tumor. Also, in case of evidence of extranodal tumour spread, or if adenopathies are present low in the neck (both factors increase the risk of metastasis), FDG-PET can be used to search for distant disease.

1. Department of Radiology, University Hospitals Leuven, Leuven, Belgium.

CONE BEAM CT

Radiation aspects of TMJ Imaging- An update on dose and risk
J. Ludlow[1]

This lecture will identify the risks from ionizing radiation that result from dental and maxillofacial CBCT examinations and discuss alternative ways for measuring exposure and calculating dose. Options in CBCT equipment and how these influence image and dose characteristics will be described. The importance of matching options to the objectives of imaging will be discussed. We will explore ways to reduce the risks from diagnostic imaging.

1. Radiology Section, Department of Diagnostic Sciences and General Dentistry, University of North Carolina, School of Dentistry, Chapel Hill, USA.

Dento-alveolar, implant & orthodontic indications for CBCT imaging
R. Jacobs[1]

During the last decade, there has been an upward trend in using 3D information as an aid to dentomaxillofacial diagnostics and surgical planning. This is further strengthened by the introduction of dental cone beam CT allowing volumetric jaw bone imaging at reasonable costs and doses. CBCT imaging may offer numerous diagnostic potentials and even change treatment strategies in oral health care. This definitely applies to orthodontics, implant surgery and other dentoalveolar diagnostic challenges. An exponential growth of the different CBCT machines available and fast evolutions with respect to dose and image quality have created an almost unbridgeable time gap between reporting of scientific evidence and the actual clinical use of CBCT. Recent studies in the framework of the SedentexCT Euratom project indicate crucial differences in radiation dose, image quality, dimensional accuracy and artefact expression depending on both equipment and patient factors. The impact of those variables to the resulting diagnostic requirements for orthodontics, implant and other dentoalveolar surgery will be discussed.

1. Oral Imaging Centre, K.U.Leuven, Leuven, Belgium.

Use of CBCT in dental implant treatment

T.A. Larheim[1]

Since it came available in the late 1990s, CBCT has rapidly and increasingly been used in dentistry. As judged from the literature and own experiences, the imaging modality has been particularly popular for examination of patients selected for implant treatment. The lecture will give an overview of the topic, focusing on pre-operative imaging of the alveolar ridge (size and shape evaluation) and anatomical structures to be avoided during surgery, software programs for treatment planning, as well as stent and ridge augmentation (sinus lift) procedures. Also postoperative imaging will be discussed, in particular related to complications.

1. Department of Maxillofacial Radiology, Faculty of Dentistry, University of Oslo, Norway.

Combination of CBCT imaging & 3D stereophotogrammetry in maxillo-facial deformity

S. Bergé[1]

The three important tissue groups in orthognathic surgery (facial soft tissues, facial skeleton and dentition) can be referred to as a triad. This triad plays a decisive role in planning orthognathic surgery. Technological developments have led to the development of different three-dimensional (3D) technologies such as multiplanar CT, cone beam CT and MRI scanning, 3D photography modalities and surface scanning. An objective method to predict surgical and orthodontic outcome should be established based on the integration of structural (soft tissue envelope, facial skeleton and dentition) and photographic 3D images. None of the craniofacial imaging techniques can capture the complete triad with optimal quality. This can only be achieved by 'image fusion' of different imaging techniques to create a 3D virtual head that can display all triad elements. An overview of current possibilities on image fusion in the craniofacial area will be presented. The focus will be on the value of stereophotogrammetry within this way of working.

Lit.:

Digital three-dimensional image fusion processes for planning and evaluating orthodontics and orthognathic surgery.
Plooij J.M., Maal T.J., Haers P., Borstlap W.A., Kuijpers-Jagtman A.M., Bergé S.J. A systematic review. Int J Oral Maxillofac Surg, 2011 Apr, 40(4): 341-52.

1. Department of Oral and Maxillofacial surgery of the Radboud University Nijmegen, Nijmegen, the Netherlands.

Other and new indications / quality

J.W. Casselman[1,3,4], G.R.J. Swennen[2], J. Abeloos[2], D. Volders[1], K. Mermuys[1], B. De Foer[4]

Many Cone Beam CT's (CBCTs) are bought to perform Dentascan and 3D-Face/Skull studies. However sinus imaging today became the major application, but other applications as face/nose trauma, TMJ, swallow studies and pharyngography, temporal bone imaging (and cochlear implants), dacryocystography, cervical spine etc. are possible. Newer systems can even replace conventional CT for imaging of the wrist-hand, elbow, ankle-foot and knee. In the MSK field CBCT can also be used to visualise structures around osteosynthetic materials (metal).

Most CBCT systems are not able to perform all these different studies and therefore one has to look for a system that is able to provide the locally needed studies. High resolution systems are needed to perform temporal bone studies using more powerful X-ray tubes and with a resolution of at least 0.100 mm or 100 μ. Some of the newer systems are even able to reach resolutions of 75 μ. This high resolution also opened possibilities for CBCT in "endodontology" and "periodontology". Double rotation systems are needed to perform 3D-Face/Skull studies (2 overlapping slabs, stitched together to cover the whole skull). Systems with a gantry are needed to perform studies of peripheral joints.

Immobilization is crucial and therefore the necessary time should be invested to position and immobilize the patients, as the slightest movements will destroy the high resolution ≤ 0.2 mm quality. Moreover nurses must perform enough studies per day to become experienced enough especially when they have to perform the whole spectrum of possible studies. Once high quality images are achieved, CBCT can start to replace MDCT in the above mentioned indications. In our institution CBCT even completely replaced conventional multidetector CT for imaging of the temporal bone because CBCT provides significantly higher resolution. The easy access to the system, the very low irradiation dose and the spatial resolution have guaranteed CBCT a strong place between the other imaging systems. Unfortunately, one drawback remains. Acquisition time is routinely between 20 and 40 seconds, too long to perform studies in moving children or elderly patients.

1. Department of Radiology, 2. Maxillo-Facial Surgery, AZ St-Jan Brugge AV, Brugge, Belgium, 3. University of Ghent, Gent, Belgium, 4. Department of Radiology St- Augustinus, Wilrijk, Belgium.

REFRESHER COURSE

PART 1

Anatomy of the skull base

H.B. Eggesbø[1]

The skull base is made up of five membranous bones: the frontal, ethmoid, sphenoid, temporal and occipital bone. From above, the skull base can be divided in the anterior, middle and posterior cranial fossae. From below, no clear boundaries are defined. The bony anatomy of the foramina and fissures is best evaluated using CT, while MR is superior for imaging the nerves and vessels passing through and the soft tissue on each side of the skull base.

The anterior cranial fossa extends from the posterior wall of the frontal sinus to the roof of the sphenoid sinus (planum sphenoidale and anterior pterygoid processes). The paired frontal bones form the lateral boundaries. The central ethmoid bone contains the deep olfactory fossa with the olfactory nerve (I) fibers passing the cribriform plate. The border between the olfactory fossa and the anterior ethmoid sinus is the thin and vulnerable lateral lamella that attaches superiorly to the roof of the ethmoid sinus (foveolae ethmoidale). Posterior in the anterior fossa, the sphenoid bone contains the optic canal with the optic nerve (II) and ophthalmic artery.

The anterior fossa contains the frontal lobes, while the orbits and paranasal sinuses are situated below the skull base.

The middle cranial fossa is formed by the basisphenoid, the lesser and greater sphenoid wings. The superior orbital fissure (SOF) is a slit-like opening between the greater and lesser wing, and the inferior orbital fissure (IOF) is the opening between the greater wing and the maxillary bone.

The basisphenoid contains the sella turcica limited by the tuberculum sella anteriorly, dorsum sella posteriorly, and cavernous sinus laterally. The oculomotor (III), trochlear (IV), abducens (VI), and ophthalmic nerve (V_1) pass through the cavernous sinus before entering SOF.

The maxillary nerve (V_2) also runs through the cavernous sinus, but leaves through the foramen rotundum into the pterygopalatine fossa. Before continuing through the IOF, the maxillary nerve exchanges nerve fibers in the sphenopalatine ganglion with the greater petrosal nerve that enters the pterygopalatine fossa from the bony Vidian canal.

The mandibular nerve (V_3) leaves the skull base through the foramen ovale in the base of the greater wing. Posterolateral is the foramen spinosum with the middle meningeal artery.

The carotid artery enters the petrous temporal bone from below and runs anteromedially in the carotid canal inside the skull base before entering the foramen lacerum and then the cavernous sinus.

The middle fossa contains the temporal lobes. The retropharyngeal, parapharyngeal, prevertebral, carotid and masticator spaces border the skull base below.

The posterior cranial fossa is the largest and deepest fossa formed by the occipital bone and petrous part of the temporal bone. The fossa contains the porus acusticus internus with the facial (VII) and vestibulocochlear (IX) nerves, the jugular foramen with the glossopharyngeal (IX), vagus (X), and accessory (XI) nerves, and the hypoglossal canal with the hypoglossal nerve (XII).

The jugular vein runs through the posterolateral part of the jugular foramen.

The posterior fossa contains the cerebellum, and the brainstem running through the foramen magnum.

1. Department of Radiology, Aker University Hospital, Oslo, Norway.

Pathology of the anterior and central skull base

R. Jacobs[1]

1. Department of Radiology, University Hospitals Leuven, Leuven, Belgium.

Temporal bone pathology

C. Czerny[1]

The incidence of imaging of the temporal bone in case of disease has been increasing over the past decades. Especially, imaging techniques such as Multi-Detector-Spiral-CT (MDCT) and Magnetic Resonance Imaging (MRI) provide substantial information for the correct diagnose of potential abnormalities/diseases.

MDCT is performed in the axial plane with coronal/sagittal reconstructed planes. The section thickness should be 2 x 0.6 mm/2 x 0.5 mm, the FOV ~20 cm, the matrix ≥ 512 x 512, the reconstructed section thickness 0.65-1.0, and a HRCT bone window level setting should be obtained. MRI is performed with a FLAIR or T2w FSE of the head, and a 3D T2w high-resolution thin-section sequence of the inner ear in the axial plane, and a T1w sequence before and after the intravenous application of contrast material in the axial plane and additionally (if necessary) in the coronal plane.

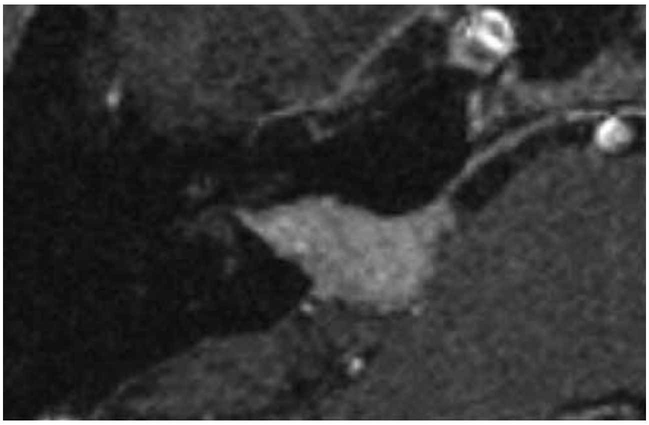
Apart from the normal anatomy of the structures of the temporal bone, there are also variants, which should be known.

The pathologic entities include congenital malformations of the external, middle, and inner ear. The acquired pathologies consist of inflammatory lesions, cholesteatomas, and tumors as well as posttraumatic changes.

In this refresher course the variants, the congenital malformations, and the acquired pathologies of the temporal bone especially of the middle and inner ear will be shown (see figs.).

1. Department of Radiology, University of Vienna, Austria.

Diffusion-weighted MR image of a cholesteatoma



CM-enhanced T1w MR image vestibular schwannoma

The parapharyngeal space
M.G. Mack[1]

The parapharyngeal space is a deep space in the neck in the shape of an inverted pyramid with its base attaching to the skull base and the apex reaching the level of the hyoid bone. It is bordered on its medial side by the naso- and oropharynx, on its anterolateral side by the masticator space, on its posterolateral side by the deep lobe of the parotid gland, and on its posteromedial side by the retropharyngeal space. Some authors devide the parapharyngeal space into two compartments on the basis of its relationship to the styloid process or, more precisely, to the tensor-vascular-styloid fascia and used terms such as "parapharyngeal space" that may sometimes be confusing. Some authors limit the parapharyngeal space to the fatty space anterior to the carotid space, while others consider the suprahyoid part of the carotid space to be part of the parapharyngeal space, then often called postyloid compartment of the parapharyngeal space.

The importance of the parapharyngeal space also lies in its relationship with the other spaces of the neck

The contents of the prestyloid compartment include the minor or ectopic salivary gland, branches of the mandibular division of the trigeminal nerve, internal maxillary artery, ascending pharyngeal artery, and pharyngeal venous plexus, whereas those of the poststyloid compartment (also called carotid space) include the internal carotid artery, internal jugular vein, cranial nerves IX-XII, cervical sympathetic chain, and glomus bodies.

Intrinsic and extrinsic parapharyngeal space pathology will be discussed.

1. Department of Diagnostic and Interventional Radiology, University of Frankfurt, Frankfurt Main, Germany.

PART 2

Cranial nerves I-VI
M. Lemmerling[1]

Imaging of the upper cranial nerves is mostly performed with axial and coronal standard T1- and T2-weighted images, in combination with thin sliced heavily T2-weighted images to visualize the cisternal nerve segment. Coronal images should always cover the complete peripheral course of the nerve as well as its origin in the brain stem. In selected cases additional sequences are an option (e.g. FLAIR if suspicion of demyelinating disease, DWI for ischemia in the elderly, …).

Olfactory nerve (N. I)

Coronal images can nicely demonstrate the olfactory bulb and tract. They also show the olfactory cortex in the frontal and temporal cerebral lobes. Trauma with hemosiderin deposits in this cortex is frequently seen in patients with anosmia. It is consequently interesting to perform a susceptibility-weighted sequence in such patients.

Optic nerve (N. II)

Coronal images are also very useful to image the second cranial nerve. Frequent indications for optic nerve imaging are suspicion of optic neuritis (mostly related to MS), or optic nerve tumor (most frequent glioma, and sometimes meningioma). Optic neuritis is best seen on coronal T2-weighted images performed with fat suppression techniques, and also on coronal postgadolinium fat suppressed T1-weighted images. Low grade optic nerve gliomas are most frequent in children (often with neurofibromatosis type I). More aggressive ones are seen in adults. Optic nerve sheath meningiomas are rare and most frequently occur in middle age females.

Oculomotor, trochlear and abducens nerve (N. III, IV, and VI)

These cranial nerves are responsible for eyeball motion. The trochlear and abducens nerve respectively innervate the superior oblique muscle and the lateral rectus muscle. All other eyeball muscles, as well as the levator palpebrae superioris muscle, are supplied by the oculomotor nerve. These 3 nerves run through the cavernous sinus and the superior orbital fissure towards the orbit. Imaging of these nerves is often done in non-diabetic patients with diplopia. Frequently seen anomalies are brain stem ischemia, infectious or malignant meningeal disease along the cisternal course of the nerves, or infectious or tumoral lesions in the cavernous sinus, superior orbital fissure, or orbit.

Trigeminal nerve (N. V)

The trigeminal nerve is the largest cranial nerve. It transmits sensory information from the face, and provides motor information to the muscles of mastication. Meckel 's cave contains the trigeminal ganglion and the trifurcation in the ophthalmic (N. V1), maxillary (N. V2), and mandibular (N. V3) nerves. In patients with trigeminal neuralgia a careful and systematic inspection of many skull base structures is mandatory (Meckel 's cave, the cavernous sinus, superior orbital fissure, pterygopalatine fossa, foramen rotundum, foramen ovale, Vidian canal, canals for the palatine nerves, canal for the infraorbital nerve, mandibular alveolar canal, …), as well as inspection of the more peripheral course of the different nerve divisions (masticator space, …). Frequent anomalies are meningiomas, schwannoma, infectious, and metastatic disease. Using a segmental approach based on locations (brain stem, cisternal segment, middle cranial fossa, peripheral course) can help to narrow the differential diagnosis.

1. Department Radiology, AZ Sint-Lucas, Gent, Belgium.

Cranial nerves VII-XII
F. Veillon[1]

1. Strasbourg, France.

The masticator space
M. Lemort[1]

The masticator space (MS) is part of the deep spaces of the supra-hyoid head and neck delimitated by the different components and reflection sheets of the deep cervical fascia. It includes the masticator muscles, ramus of the mandible and several vascular or nervous structures of interest. A careful examination of this space is of utmost importance for the staging and follow-up of facial and pharyngeal tumours. Access to foramen ovale is possible through the masticator space. Pterygo-palatine fossa, which is part of this space, is a major crossways between intracranial compartment, orbits, nose and oral cavity. Some lesions may also arise from the components of the MS such as schwannomas, bone or soft tissues tumours.

This course will covers in depth the anatomy and MR anatomy of the MS and its limits, using both anatomical documents and annotated high-resolution MR sections. It also will review the main primary and secondary pathologies affecting the MS.

1. Institut J. Bordet, Cancer Center of Université Libre de Bruxelles, Brussels, Belgium.

The oral cavity and oropharynx
S. Golding[1]

The area comprises: oral cavity (lips, buccal cavity, tongue, oral floor, alveolar ridge and retromolar trigone, and hard palate), and oropharynx (base of tongue, tonsil, soft palate and pharyngeal wall).
In imaging practice the most common lesions in practice are dental sepsis, carcinoma, lymphoma, ectopic salivary neoplasms and pharyngeal abscess. Others include benign lesions mimicking neoplasms, neoplasms of musculoskeletal, neurogenic and vascular origin, and thyroglossal remnants. Infection of the teeth or tonsils must always be considered and reactive lymph node hyperplasia is common. Dental radiographs must be obtained in suspected sepsis.

MRI may be regarded as the technique of choice in all focal disease of the oral cavity and oropharynx. PET/CT offers advantages, most especially in the detection of clinically occult cervical node metastases. Diagnosis is usually by clinical inspection and biopsy; imaging is rarely required for diagnosis. The major role of imaging is disease staging; this may include staging benign lesions for resection.

The internationally accepted staging criteria (TNM System) of this area are based on measurements of visible disease and do not provide good correlation with clinical management. The radiologist should report the extent of disease shown by imaging rather than stating a TNM stage. Other indications for imaging neoplasms are disease monitoring during treatment, and detection of recurrence.

90% of malignant neoplams are squamous carcinoma, the rest being Non-Hodgkin Lymphoma (5%), and adenoid-cystic or mucoepidermoid carcinoma of minor salivary glands in the buccal mucosa and floor of mouth, followed by rare tumours such as angiosarcoma, rhabdomyosarcoma and melanoma. Common sites in the mouth are lips, tongue, oral floor of mouth and alveolar ridge and retromolar trigone. Common sites in the oropharynx are tonsil (50%), base of tongue (20%) and soft palate (10%).

Disease in lymph nodes is shown by nodal enlargement. Metastatic nodes may show uniform or high central T2 signal. Breach in the capsule of the node is an indicator of a poor prognosis. Benign reactive lymphadenopathy is common in the face and neck and may produce false positive impressions of metastasis. MRI is very sensitive to bone marrow involvement and often can be used to evaluate spread into bone but if there is any doubt about cortical involvement high resolution CT should also be obtained.

Recurrent carcinoma tends to be detectable within two years after treatment and usually at the margin of the resected area. Interpretation may be difficult. The radiologist should have a high index of suspicion when there are symptoms, usually local pain. Active inflammation and scarring may mimic the signal characteristics of recurrent neoplasms within six months after treatment. Many recurrent tumours are more readily shown on enhanced images.

Common benign lesions, apart from infection, presenting to the radiologist are:

ranula; lingual thyroid; thyroglossal cysts; lymphangioma; branchial derivatives; arteriovenous malformations.

1. Department of Diagnostic Imaging, University of Oxford, UK.