1. Headache

Headache (*cephalgia*, *cephalea*) is a symptom caused by a number of conditions. Headache can be divided according to etiology into *primary* or *secondary*, and according to duration into *acute* or *chronic*.

- Primary headaches do not have a known underlying organic basis for the disorder. Imaging methods are used to rule out other causes.
- Secondary headaches appear as a manifestation of an underlying condition (i.e. organic disease). Diagnostic imaging methods can be used in differential diagnosis.

Imaging methods should always be used if the headache is new in onset and progressively worsening, if the headache is sudden and severe in intensity, if manifesting in older patients, or if the headache is accompanied by neurological symptoms (e.g., changes in mental status, decreased level of consciousness/alertness, etc.).

In acute headaches, native CT of the brain is performed initially to rule out bleeding[1] or expansile lesions. If a subarachnoid hemorrhage of non-traumatic etiology is found on CT, CT angiography (CTA) of the cerebral arteries should follow to determine the source of the hemorrhage (usually an aneurysm, less commonly an AV malformation).

MRI of the brain is the modality of choice in chronic headaches. MRI is also used to investigate ambiguous findings or expansions on CT, and is particularly sensitive in discerning different types of tumors, abscesses, ischemia, etc.

Primary headaches

Primary headache disorders include migraine headache, tension headache, and cluster headache. Neuroimaging methods typically yield **normal findings**, and thus only serve to exclude underlying primary causes for the pain. Imaging is not necessary for chronic primary headaches or for acute headaches typical of migraine or tension headaches without neurological deficits. However, if a chronic headache begins to exhibit a fundamental change or progression in presentation, with "red flags" such as new accompanying symptoms or increasing frequency of the symptoms, MR imaging of the brain is warranted.

Migraine is a chronic disease manifested by recurrent headaches. Episodes are usually unilateral and may present with or without aura[2]. Accompanying symptoms include nausea, vomiting, anorexia, phonophobia, photophobia, and osmophobia. Migraines are usually self-limiting, lasting 4-72 hours.

Tension headaches are commonly dull, pressing/tightening, diffuse, and long-lasting in character, with a tendency to wax and wane in intensity. The onset of pain is usually gradual, with episodes lasting from hours to days. Vomiting and nausea are absent. Depression, anxiety, and sleep disorders are common comorbidities.

Cluster headaches[3] are uncommon primary headaches, described as a syndrome of recurrent bouts (clusters) of headaches - accumulated in the localization (always around one eye), or accumulation of bouts of pain over time. The pain has a different length of time, most often from 4 to 8 weeks, then the pain disappears, the condition calms down and the patient is completely without problems.

[1] CT without contrast is indicated because acute bleeding and IV contrast both appear hyperdense on CT.
[2] aura – a complex of reversible visual, sensory, or speech disturbances
[3] Cluster headaches have been reported among the most painful conditions known to humans, and thus are sometimes referred to as “suicide headaches”.

Secondary headaches

Sinusitis refers to inflammation of the paranasal sinuses. The (ethmoid and) maxillary sinuses are most commonly involved. Sinusitis rarely occurs in the absence of antecedent infection; it is a commonly associated complication of rhinitis, and may arise occasionally due to contiguous spread of periapical infection. The most common symptom is headache or facial pain/pressure, followed by purulent rhinorrhea and fever.

Imaging algorithm – A plain frontal X-ray image of the skull in semi-axial projection[4] is used to evaluate the paranasal sinuses[5] for sinusitis. A typical finding confirming the diagnosis is the presence of air-fluid levels[6] in the sinuses (Fig. A). In young patients, the imaging modality of choice is MR.

Orbital cellulitis is a potential complication of sinusitis in which the infection spreads to the orbital wall. Signs of orbital involvement begin with an inflamed, swollen eyelid and periocular pain, then progresses to ophthalmoplegia and visual impairment (e.g., disturbances, reduced acuity, etc.).

Imaging algorithm - MRI is a useful modality in assessing complications of sinusitis. **Contrast-enhanced MR imaging of the paranasal sinuses and orbit can be used to demonstrate abscess in the orbit**, indicated by an organized/focal collection of fluid with a peripherally contrast-enhanced rim. Edema of the intraorbital fat and extraocular soft tissues is also present (Fig. B).

Intracranial mass lesions manifest as headaches in about 50% of tumors (primary and metastatic) due to increased intracranial pressure (ICP). The quality of the headache is most often tension-like (less often migrainous). Patients also commonly present with other signs of increased ICP such as nausea, vomiting, and neurological deficits.

Intracranial mass lesions can be systematically described according to various criteria. One of the most important distinctions is the location of the lesion relative to the brain parenchyma: **extra-axial**[7] or **intra-axial**. Extra-axial lesions are most common for meningioma (more rarely metastases, e.g. melanoma), while intra-axial lesions are typical for most primary brain tumors and most metastatic tumors. Lesions may also be described according to the number of lesions as **solitary** (most primary tumors) or **multifocal** (typically metastases, possibly meningiomas or schwannomas in neurofibromatosis type II), and according to localization as **supratentorial** (adults: metastases, glial tumors – astrocytoma, oligodendroglioma, glioblastoma; children: astrocytoma, ganglioglioma, DNET, PNET) or **infratentorial** (adults: metastases, hemangioblastoma; children: medulloblastoma, ependymoma, juvenile pilocytic astrocytoma).

The presence of structural changes such as calcifications and a cystic or fatty component helps to differentiate some tumors.

Presence of calcifications (high density on CT = hyperdense) may occur in intra-axial tumors such as oligodendroglioma (90%), astrocytoma (20%), ependymoma (50%), ganglioglioma (40%). Among the extra-axial tumors, calcifications occur in meningioma (25%), craniopharyngeoma (90%), chordoma, chondrosarcoma.

Cystic lesions (low density on CT = hypodense) may be found in craniopharyngeoma, pilocytic astrocytoma, hemangioblastoma. Fat-containing lesions (negative densities on CT = markedly hypodense) are typical for lipoma, dermoid cyst, possibly teratoma.

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[4] Semi-axial (also Waters', occipitomental) view of the skull is an angled PA radiograph in which the head is tilted back 45° and the mouth is kept open.

[5] It is inappropriate to order imaging of sinuses in young children, as the sinuses are not well developed or well pneumatized until around age 7.

[6] An air-fluid (also gas-fluid) level refers to the interface between free air and fluid (pus) found in the cavity.

[7] Extra-axial – i.e., extraparenchymal (skull, meningeal, dural, subarachnoid, epidural, intraventricular) location

Imaging algorithm – initially usually native CT to exclude bleeding and to assess expansive manifestations (in cases where expansion is not known or MRI is not available , e.g. within 24 hours, in the case of known expansion), then MRI to investigate unclear findings, exclusion or characterization of tumors – contrast enhancement, edema, relationship to structures (Fig. C, D, E).

Advanced imaging methods, such as MR spectroscopy or MR perfusion, serve to further characterize the tumor (distinguishing between low-grade and high-grade tumors).

Headaches associated with cerebrovascular disease

Subarachnoid hemorrhage, e.g., due to rupture of an intracranial aneurysm, manifests as an abrupt onset, severe, sharp pain from full health (described by the patient as the worst pain they have experienced). The headache may be accompanied by vomiting, loss of consciousness. The diagnosis is made by native CT of the brain (hyperdense material – blood – in the subarachnoid space). The source of bleed is demonstrated by subsequent CT angiography (aneurysm or arteriovenous malformation). See also Stroke (CVA) see question 2.

Cerebral venous sinus thrombosis (CVST) occurs in hypercoagulable states in various etiologies (bacteremia, sepsis, cancer, during pregnancy and puerperium, disseminated intravascular coagulopathy, collagenosis, trauma, …), or as a complication of local infection (sinusitis, otitis media, meningitis). The most commonly affected dural sinuses are the superior sagittal sinus, the transverse sinus, and the cavernous sinus. CVST manifests with headache in combination with neurological symptoms.

Imaging algorithm - native CT of the brain to exclude bleeding (possible finding of hyperdense sinus - similar significance as dense artery sign in CVA - see question 2) + demonstration of thrombosis on MR venography (usually native, contrast agent is applied only to unclear findings; Fig. H), CT venography only when MR is unavailable.

Cervicogenic pain is caused by a dysfunction of the cervical spine (cervicocranial syndrome). It is caused by long-term static strain in a number of sedentary professions or some movements of the cervical spine. The pain usually starts in the neck or back of the head and can shoot or stab areas of the head. There is also increased tension in the neck muscles and trapezoids and the pain of the occipital nerve outlets during palpation.

Imaging algorithm - X-ray of the cervical spine (AP and lateral projection) + functional views (i.e., specialized projections showcasing flexion and extension of the cervical spine to assess spinal development and spinal stability, specifically displacement or shifting of vertebral bodies), MRI of the cervical spine.

Neurovascular conflict syndrome arises from compression of a cranial nerve (e.g., V, VII, XI) by a vessel at the site where the nerve is most sensitive: at the area of central (glial) myelination, which extends into the periphery of the cerebral nerve a few millimeters from the brainstem. Compression of the centrally myelinated segment of the facial nerve is clinically manifested by hemifacial spasm.

Trigeminal neuralgia is described as one of the most intense and mentally distressing pains that can be encountered. Impairment of cranial nerve VIII innervating the inner ear, where both the center of hearing and balance are located, causes chronic tinnitus or impaired balance with dizziness and falling to the affected side (vertigo); both components can present simultaneously.

Imaging Algorithm – high-resolution MRI to elucidate the neurovascular conflict.

Note: There is often suspicion of neurovascular conflict on MRI in a large proportion of asymptomatic patients (low specificity?), therefore findings on imaging should always be correlated with the clinical picture.

Temporal arteritis is a chronic systemic vasculitis affecting lamina elastica interna of medium-sized and large vessels. Clinical manifestations usually develop slowly, beginning with typical general symptoms (fever, fatigue, loss of appetite, headaches, weight loss), and later followed by symptoms specific to the affected vessels: pain on palpation in the area of a. temporalis, jaw claudication, diplopia, loss of vision, etc...

Imaging algorithm - ultrasound of the temporal region – wall thickening of the temporal artery (Fig. J).

Headaches related to head injuries - *see question 3 – Head and Neck trauma.*

Imaging algorithm:

Skull X-ray does not assess intracranial bleeding; only bony changes with very limited sensitivity can be evaluated, therefore it **is not indicated**

CT brain, without contrast – to demonstrate/exclude bleeding (epidural, subdural, or subarachnoid hemorrhage, contusion lesions, possibly diffuse axonal injury), hairline fractures.

MRI brain, without contrast – significant in suspected diffuse axonal injury, indicated minimally (Fig. K)

Note: Diffuse axonal injury (DAI) is usually completed by the clinical picture, i.e., a relatively insignificant/subtle finding on CT of the brain does not correlate with the patient's low level of consciousness (usually found out after several days in the ICU, when the originally subdued patient "does not wake up" from the induced coma, has normal laboratory findings, normal intracranial pressure, and cardiopulmonary compensation).

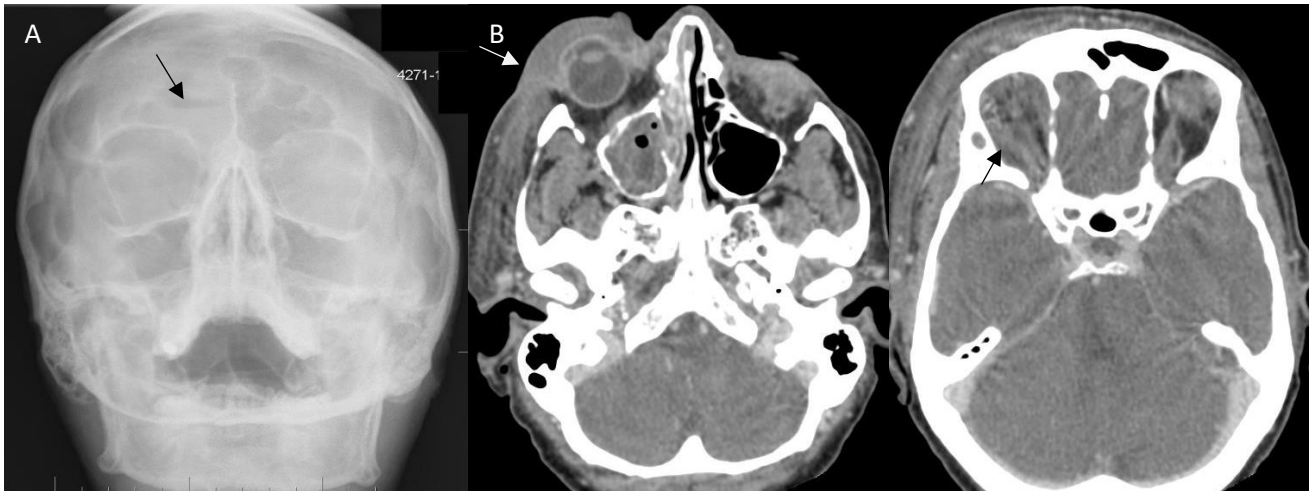

Fig. A – X-ray, semi-axial view, fluid-gas level in the right frontal sinus (**black arrow**), image of acute sinusitis

Fig. B - **CT** of the orbit after contrast administration, extensive periorbital edema right (white arrow), swelling of intraorbital fat on the right (dense structures intraorbitally; black arrow) and swelling of orbital muscles – orbital cellulitis and maxillary sinusitis on the right

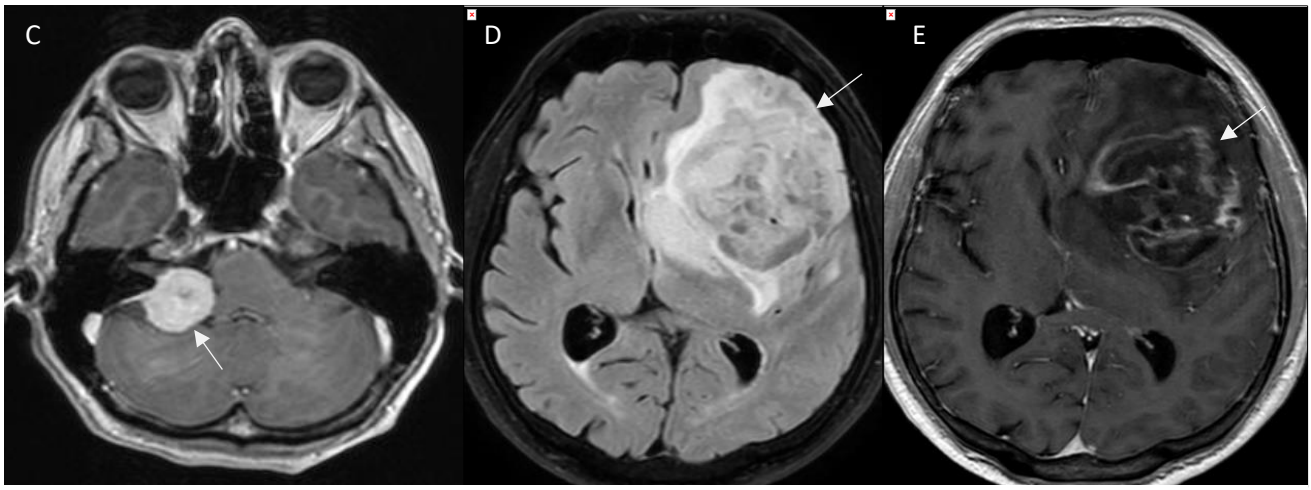

Fig. C - **MRI**, T1 weighted image after contrast adminitration, meningioma in posterior cranial fossa near petrous part of temporal bone (**white arrow**), homogenoust contrast enhancement, enhancement of adjacent dura mater

Fig. D - **MRI** T2 flair – inhomogenous tumor surrounded with vasogenic oedema in the left frontal lobe (hypersignal – white) causing contralateral shift of midline structures (histologically confirmed glioblastoma)

Fig. E - **MRI** T1 after contrast administration – central necrosis and enhancing peripheral parts of a tumor, typical for high-grade gliomas, identical patient as in Fig. D