Digital Volume Tomography of the paranasal sinuses

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Learning Objectives

To illustrate relevant technical principles of digital volume tomography (DVT) and present an overview of applications for radiological diagnosis of the paranasal sinuses.
Background

DVT is increasingly applied in rhinology, laryngology and otology as well as dental surgery for the purpose of radiological assessment, surgical planning and intraoperative navigation due to the reasonable price and the easy handling. The technique allows high-resolution data acquisition of high-contrast structures. Projections of the object depicting the attenuation are obtained using image intensifiers or flat panel detectors. Reconstruction algorithms taking the cone beam geometry into consideration are used to generate cross-sectional images [1-2].

Different technical DVT setups exist allowing examination of the patient in supine, sitting or standing position. The desired scan volume is positioned using a laser coordinate system. Usually predefined scan protocols exist, that allow only limited variation of data acquisition and reconstruction parameters. Tube voltage values in the literature range from 80 - 120 kV. CTDI$_{w}$ averages approximately 3 mGy. Some clinical studies especially from non-radiological subspecialties reported increased high-contrast resolution and simultaneous decreased dose values compared to multi-slice CT [2]. However, extensive comparative examinations of objective image quality criteria could not confirm the finding [1]. A reduced susceptibility to artifacts has been reported for DVT imaging of metallic implants. Due to isotropic data use of post-processing techniques established for post-processing of multi-slice CT data and surgical navigation is usually feasible. Data acquisition time (approximately 20-60 s) is increased compared to multi-slice CT resulting in susceptibility to motion artifacts.
Imaging Findings OR Procedure Details

Radiological assessment of the paranasal sinuses using DVT does not differ considerably for high-contrast structures compared to multi-slice CT. Indications for imaging are related to pre- and post-operative diagnosis in chronic sinusitis and mid-facial trauma. Other indications such as the evaluation of bony structures in tumors of the paranasal sinuses are infrequent.

Acute / chronic sinusitis

Radiological assessment should include description of the extent of the pathological findings, anatomical variants and accompanying complications [3-6]. Air-fluid levels indicate acute inflammation, that should be first treated conservatively before evaluating the remaining chronic inflammatory changes. Special attention should be paid to the description of the routes of mucociliary drainage of the individual compartments of the paranasal sinuses. Involvement of the ostiomeatal unit should be surveyed [4]. Precise localization of the affected ethmoidal sections is important as the surgical accessibility differs. Anatomical variants have to be reported as they contribute to the multifactorial origin of chronic sinusitis and can cause surgical complications. As opposed to multi-slice CT or MRI only limited assessment of the rare intracranial and orbital complications of rhinosinusitis (such as epi- or subdural abscesses, meningitis, cavernous sinus thrombosis) is possible using DVT [7].

Reporting of post-operative findings should discriminate between non-functional (Apart from special indications nowadays abandoned. Fenestration of a non-natural ostium and complete excision of the mucosa) and functional surgical techniques (Fenestration of natural ostium, often "functional endoscopic sinus surgery" (FESS), improved mucociliary drainage can initiate healing process) [8]. Imaging is obtained to evaluate inflammatory changes and assess the altered anatomy with respect to findings that could limit ventilation and drainage again [9].

Trauma

Sufficient imaging is required to choose the appropriate treatment regime (conservative / semi-surgical / osteosynthetic) and is further necessary for post-surgical control [10]. For the assessment of localized fractures DVT allows reformation of the images in arbitrary orientations and 3D-post-processing, that facilitates a spatial comprehension [11]. However, in complex or transfacial cases it has the limitation that potentially injured regions of the facial skeleton are not included. Furthermore, assessment of accompanying injuries of the skull base and intracranial trauma is restricted. In these cases MS-CT is the modality of choice. In the cases of an isolated midface trauma DVT allows the detailed pre-surgical visualization of small fragments for the planning of...
osteosynthesis using miniplate systems. Precise post-surgical evaluation of the implants is possible. It has been reported that the technique is less susceptible to artifacts.

**Neoplastic and non-neoplastic lesions**

Imaging is mainly performed for staging and post-therapeutic follow-up. Due to limited low-contrast assessability DVT is of subordinate value as compared to MS-CT or MRI for the assessment of tumor extent into adjacent spaces or infiltration of anatomical structures. However, tumors can present as incidental findings in DVT. Unilateral space-occupying osseous changes are suspicious. Expansive growth patterns and smooth bony contours are mainly seen in benign disease. Bony destruction and fragmentation is seen in neoplastic lesions. However, aggressive inflammatory disease such as fungal infection can show coexistence of lytic and sclerotic changes [12].

Primary osseous lesion of the paranasal sinuses include osteoma (probably the most frequent lesion, consists of compact, spongiotic or both osseous components), fibrous dysplasia ("ground glass" appearance, cystic changes), chondrosarcoma (invasive bone changes, destruction, chondroid calcifications in tumor matrix, nonsclerotic transition zone to adjacent bone) and metastatic lesions [12].
Fig. 1: Anatomy of the paranasal sinuses. Axial (A-C), coronal (D, E) and sagittal (F) DVT-MPR. 1 Superior orbital fissure, 2 Christa galli, 3 Anterior ethmoid foramen, 4 optic canal, 5 Ostium of sphenoid sinus, 6 Third Basal lamella, divides anterior and posterior ethmoid complex, 7 Inferior orbital fissure, 8 Nasolacrimal duct, 9 Infraorbital canal, 10 Lamina papyracea, 11 Uncinate process, 12 Cribiform plate, 13 Ostiomeatal complex (Hiatus semilunaris (O), Maxillary infundibulum (dotted line), Ethmoid bulla (BE) and Ostium of maxillary sinus (\*), 14 Ostium of frontal sinus.

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**Fig. 2:** Anatomic Variants. Septal deviation and bony spur, hyperplasia of the left inferior turbinate (A), Concha bullosa (*) and type III frontal cell (arrow) resulting in an impaired drainage of the frontal sinus (B). Bifurcated uncinate process and Haller cell (C).

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**Fig. 3:** Sinusitis. Chronic sinusitis of the right sphenoid sinus, soft tissue opacification with thickening and sclerosis of sinus bony walls (A). Chronic pansinusitis with distinct bony changes (B). Air-fluid level in right maxillary sinus in an acute exacerbation of chronic sinusitis (C).

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**Fig. 4:** Imaging post-surgery. Tamponades in a patient with epistaxis (A). Following Caldwell-Luc surgery, bony defect in the anterior wall of right maxillary sinus and volume reduction (B). Following bilateral endoscopic infundibulotomy and anterior ethmoidectomy (C).

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**Fig. 5:** Trauma. Nasal fracture with dislocated fragment (A). Dislocated septal fracture and septal hematoma (B).

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**Fig. 6:** Neoplastic and non-neoplastic lesions. Osteoma in left ethmoid sinus (A). Fibrous dysplasia of sphenoid sinus, typical "ground glass" appearance (B). Chordoma of the posterior sphenoid wall, bony destruction of clivus (C), hyperintense appearance in T2-Flair MR sequence (D).

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Conclusion

DVT allows imaging of the high-contrast structures of the paranasal sinuses. It should be applied especially for pre- and post-surgical evaluation and minor trauma. Using MS-CT similar information can be obtained at a comparable CTDI$_w$. 
Personal Information
References


