# Imaging in chronic rhinosinusitis: A systematic review of MRI and CT diagnostic accuracy and reliability in severity staging

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**Abstract**

***Background:*** Computerized tomography (CT) severity scores are frequently used as an objective staging tool in chronic rhinosinusitis (CRS). Magnetic resonance imaging (MRI) has also been proposed as a valid option in CRS imaging. ***Purpose***: The aim of this systematic review was to briefly present the recent developments on sinus imaging utilized in clinical practice with regard to diagnostic accuracy of imaging and severity staging in CRS according to evidence-based medicine (EBM) principles. ***Material and Methods:*** This review paper has been assembled following PRISMA guidelines. A PubMed and Scopus (EMBASE) search using CRS, „severity staging", „diagnostic accuracy" and „imaging" resulted with 80 results. Of these, only 12 (59%) contained original data, constituting the synthesis of best-quality available evidence. ***Results:*** CT is the most commonly used imaging technique for the severity staging of CRS, but a question of higher cumulative radiation dose should be taken into consideration when repeating CT examinations in evaluating treatment efficacy. MRI may be a complementary diagnostic and staging tool, especially when repeated examinations are required, or when paediatric CRS patients are evaluated. The severity staging system may be improved to better correlate with subjective scores. ***Conclusions:*** MRI may be utilized as a staging tool with comparable diagnostic accuracy, using the same staging systems as with CT examinations.

**Keywords**: CT scan; Magnetic Resonance; Tomography, Cone-Beam Computed; Nasal Sinuses; Transnasal Endoscopic Surgery

## 1. Introduction

Several imaging modalities have been utilized for the diagnosis and management of chronic rhinosinusitis (CRS). Although special and explicit evidence-based recommendations on their use are not directly provided in current consensus/positional papers, firm evidence on their value as diagnostic and staging tools still has to be extrapolated. By elaborating more on the related studies, the evidence-based value of the various imaging modalities can thus be described. At the same time, possible unmet needs, resulting from the ongoing evolution of both imaging technology and diagnostic methods in CRS, can also be identified.

In particular, computerized tomography (CT) is commonly used as an objective diagnostic tool in CRS to establish the differential diagnosis between inflammatory and other sinus disorders, and in the staging of the severity of chronic rhinosinusitis with and without nasal polyps (CRSwNP and CRSsNP respectively). Computerized tomography (CT) and magnetic resonance imaging (MRI) may also provide substantial information both on the anatomy of paranasal sinuses and on the anatomical variants associated with recurrent rhinosinusitis (RS) or severe symptoms which cannot be explained by endoscopy. Sinus CT scan is regarded as an obligatory diagnostic tool before endoscopic sinus surgery, and it is used as a "road map" during such procedures, whether these use navigation systems or not. The diagnosis of CRS is based on the presence of characteristic clinical symptoms confirmed by endoscopic signs and eventually by imaging. (1) In the majority of CRS cases, symptoms-based diagnosis is confirmed by endoscopy, and may be established without the use of imaging. (1) However, CRS symptoms, and, in some cases, endoscopic findings, may overlap with the symptoms of rhinitis or neoplasmatic disease of the nose and sinuses. (2) In such cases, imaging may be necessary to support the suspected diagnosis. (3) CT, and MRI, unlike standard x-ray and ultrasonography (USG), provide objective information on the extent of sinus disease. These are, indeed, the most common objective tools for the staging of the disease (with the exception of endoscopic staging of the polyp size). (4,5) The aim of this study was to present

the recent developments on sinus imaging utilized in clinical practice with regard to diagnostic accuracy of imaging in CRS, and severity staging in CRS according to EBM principles.

## 2. Material and Methods

This review paper has been assembled following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A cross-referenced PubMed and Scopus (EMBASE) search was performed and relevant data were extracted accordingly. Initially searching was performed using the following key-words: CRS, imaging, CT, MRI, sensitivity, specificity, diagnostic accuracy, severity staging. A second search included the following key words: test protocol, standardization, recommendation, diagnostic criteria. The first and second searches were then combined using the Boolean operator AND.

The inital search using combinations of key-words concerning CRS and „severity staging“ resulted with 166 results. When adding „imaging“, the search resulted with 28 hits. The second search concerning CRS related key-words and „diagnostic accuracy“ resulted with 173 results. When adding „imaging“, the search yielded 52 results.

We included papers which correlated imaging scores or validity with the other diagnostic criteria, like symptoms, HRQL questionnnaires, histopathology, endoscopy. Every study discussing imaging related diagnostic accuracy and severity staging was compared to the golden standard – histopathologic staging.

Exclusion criteria were: publication before 2000 (7 records), case reports (7 records), full text available (10 records), papers concerning other topics (35). Thus, 21 records were included in this review. Of these, only 12 (59%) contained original data, constituting the synthesis of best-quality available evidence. (Table 1) The others were reviews, editorials, letters, comments etc.

## 3. Results

This review is concerned with a clinical question whether CT or MRI imaging should be used in clinical practice with regard to diagnostic accuracy and severity staging in CRS according to EBM principles. It is of great clinical importance for general medical practitioners and otolaryngologists and radiologists alike, especially considering its associated cost and time consumption.

### Imaging methods currently in practice

Although low-dose MSCT protocol is considered imaging method of choice in diagnosing CRS, a potentially higher cumulative doses of radiation from repeated CT examination must be taken into account. An additional concern are high doses of radiation exposure for eye lenses considering the acquisition field for paranasal sinuses. (6,7,8,9) Cone beam computed tomography (CBCT) was relatively recently developed as imaging technique for dental use which compared to conventional CT, deliver a smaller radiation dose. CBCT scanning of the maxillofacial region can be obtained with effective dose in the broad range of 30 to 80 microsieverts (μSv), and conventional MSCT imaging of the paranasal sinuses delivers approximately 860 μSv. (10) The main advantages of CBCT are lower radiation dose, lower costs, 3D reconstruction algorithms and potential applications in temporal bone, skull base and sinus imaging. Several studies suggest that CBCT may be suitable for intraoperative and postoperative bony structural evaluation including intraoperative navigation but evidence concerning clinical utility of CBCT with respect to diagnosing or staging CRS is insufficient due to lack of studies. (11,12)

MRI constitutes a useful tool in CRS imaging, as well. The fact that it is not based on ionizing radiation is of importance, especially in cases involving children or in cases where repeated examinations are required. However, the need for sedation and its potential risks may be

reduced through combining the optimization of the MRI environment and the use of advanced MRI sequences and techniques, fast sequences, and approaches including radial k-space sampling and compressed sensing can overcome potential motion artifacts to acquire diagnostic-quality images in the shortest time possible to minimize the time in the scanner for both awake and sedated children. (13,14) The most significant characteristic of MRI is the fact that it has a better soft tissue resolution than CT. MRI of the paranasal sinuses using standard imaging sequences such as T1-weighted, T2-weighted and STIR (short tau inversion recovery) images in axial, sagittal and coronal planes, enables better distinction between both fat and soft tissue interfaces and mucosal lining and entrapped secretion. (15) Thus, it is recommended for complicated cases, as, for example, with patients having an intracranially extended inflammatory sinus disease or a suspected neoplastic disease, because it can better distinguish solid mass from retained secretion. (13) Nevertheless, MRI cannot be utilized in patients who have specific metal prosthesis. Additionally, it is more time-consuming, costly and inferior to CT in defining bony structures. MRI and CT can be regarded as complementary techniques for imaging of the paranasal sinuses. (15)

**Diagnostic accuracy of MRI and CT**

The diagnosis of rhinosinusitis, as well its differentiation into acute and chronic one, cannot be based solely on imaging, since a significant portion of asymptomatic patients show abnormalities on CT or MRI scans. (14,15) Consequently, the validation of their diagnostic accuracy depends on the reliability of their clinical history and the related examinations (endoscopy, histopathology). (16,17)

It has been found that in chronic rhinosinusitis, the correlation between endoscopy and CT findings was 65% for positive and 71% for negative results. (18) To increase the diagnostic and prognostic values of CT, various staging systems have thus been employed. Among these, the Lund Mackay system, which is based on scoring each sinus with 0 - 2 points (0 - no

pathology, 1 point - any opacity, 2 points - total opacity) and ostiomeatal complex with 0 or 2, with range from 0 - 12 per side, seems to better quantify the severity of the disease in relation to the other systems, namely, the Kennedy, the Levine and May, the Friedman and the Harvard. (18,19,20) The accuracy of the Lund Mackay score in the diagnosis of CRS was tested in normal and diseased people using explicit clinical and histopathological criteria. ROC analyses revealed a sensitivity of 94% and a specificity of 41% when using a Lund score cut-off value greater than 2, whereas specificity was increased to 59% for a cut-off value >4. (18,21) In the paediatric population the same author calculated sensitivity at 86% and specificity at 85% using a Lund score cut-off value of 5. It has also been ascertained that Lund scores of 2 or less have an excellent negative predictive value, while Lund scores of 5 or more have an excellent positive predictive value, strongly indicating true disease. (21)

CT scores correlate with the histopathologic severity of inflammation in CRS with and without nasal polyps. (20,22,23) A number of studies have found association between severity of mucosal inflammation as measured with Lund-Mackay score and osteitis, but a widely accepted osteitis grading system still has to be found. (24) Correlation between density of eosinophilic tissue infiltration and serum eosinophilia is significant, and these results are rather consistent across studies. The same holds true also for osteitis scores. (25) CT scores correlate significantly with Th-2 profile cytokines. (26) However, these results are influenced by selection of patients regarding phenotype and comorbidities. Even in CRSwNP, more severe asthmatic patients, due to higher dose steroid treatments may have less eosinophil tissue infiltration than CRSwNP patients with mild asthma. (27) If imaging scores are taken as a surrogate marker for the sinus mucosal inflammation, the results should be adjusted for phenotype and comorbidities which increase local inflammation and treatment like steroids, which modifies inflammation. We currently do not have a reliable biomarker to test the response to anti IL-5 or anti IgE treatment for CRSwNP. (28)

**Severity staging issues when using MRI and CT**

Many studies have failed to show a significant correlation between CT scores and disease specific HRQL (health-related quality of life) questionnaires, such as SNOT-20, Chronic Sinusitis Survey (CSS) and SNOT-22 questionnaire. (29,30,31,32) Some others, however, seem to identify some correlations especially in relation to symptoms scores. For example, nasal symptoms, fatigue and sleep disturbance on a Likert scale correlate with the severity of the disease on CT scan, while headache and facial pain/pressure had no correlation at all. (33) In a cohort of patients that underwent endoscopic sinus surgery, Ryan et al. found that the correlations between subjective and objective findings in CRS patients are as equally poor after surgery as they were before surgery. Based on SNOT-20 scores, symptoms had poor correlation with endoscopy and CT scores. Based on VAS ratings, most individual symptoms had poor correlation with the endoscopy and CT scan scores. (29,33)

On the other hand, although MRI sinus imaging is better than CT in differential diagnosis of sinusitis, polyps and neoplastic disease, it is often believed to overrate hyperplastic sinus disease when compared to CT. This belief, however, was not confirmed in a recent study which was carried out using the Lund Mackay scoring system. (26) The mean scores for CT-based staging and MRI-based staging did not differ significantly, moreover, they were closely correlated with a likelihood of true sinus disease revealed by both CT- and MRI-based scoring agreeing in 85.4% of cases. (34)

At the same time, regarding the ultrasonography of the sinuses, sensitivities in relation to MRI and CT scans have been reported from 29% to 100% and specificities from 55% to 99%, but these are limited to an analysis of maxillary and frontal sinuses. (35) Nevertheless, the use of ultrasonography in the studies of acute maxillary sinus should be validated in high quality trials due to the absence of irradiation, and the fact that it is easily applied and costs much less than MRI.

## 4. Discussion

In general, CT findings show statistically significant correlations with various objective findings, such as comorbid conditions, CRS complications, FESS revision rates or medication use. (29,30) Several studies also reported that asthma has had a significant impact on sinus disease extension on CT scans whereas the evaluation of 37 studies on the role of atopy in CRS failed to show its significant role in CT scan severity. (36,37,38,39,40) Medication taken for CRS may also be associated with positive CT scores. (41) This is not the case, however, with subjective outcomes, such as symptoms severity scores, where contradictory results can be found in the literature.

Several limitations, methodological and other issues can, however, be mentioned in relation to these studies. Firstly, explicit inclusion criteria are not always utilized. Some studies included acute rhinosinusitis patients, while very few studies differentiate CRS patients into CRSwNP and CRSsNP ones, based on the existence of nasal polyposis. Previous studies have also indicated that CRSwNP phenotype has different demographic characteristics and comorbidities, a higher CT score and a different nasal symptoms profile with lower facial pain when they are compared to CRSsNP phenotype. (42,43,44,45) Moreover, Zheng *et al.,* reported a significant but weak correlation between Lund Mackay score and SNOT-20 ($r = 0.31$) only in the CRSwNP subgroup and not in the total cohort of patients. (46) A recent study by Sedaghat also revealed an association only of the nasal subset score of SNOT-22 with Lund Mackay score. (47) Statistical corrections for controlling the covariates which may influence the severity of the disease, or statistical corrections for multiple comparisons were not performed in the majority of these studies. Recent studies, after controlling for comorbidities, found differences in clinical symptom profile between CRSwNP and CRSsNP with independent association between nasal symptoms and disease severity on CT scans only in patients with nasal polyps. (47,48,49) In general, CT scores - and this includes even the modified Lund Mackay scores - which are based on newer CT developments and methods

such as 3D reconstructions, have a poor correlation with most of the subjective outcomes, especially with the health-related questionnaires on the quality of patients' lives. However, some newer methods as volumetric scoring exhibited higher degree of correlation then Lund-Mackay scoring when comparing improvement in CT score with improvement in symptom score, but future studies are needed to find optimal tool for assessing objective disease improvement. (49) For ethical reasons, CT score improvement should not be used as an outcome measure due to the irradiation involved with sinus CT scans. Other imaging modalities such as MRI should be sought to complement CT both in clinical and research settings, if we consider its poor capacity to distinguish between microbial inflammatory disease, fungal concretions, other inflammatory diseases, vascular disease and tumors. (13)

In the forthcoming era of expensive biological treatment targeting specific inflammatory response for uncontrolled CRS, imaging may be considered as an outcome measure of objective improvement rate. So far, CT was used as an outcome measure after medical treatment in several studies regarding oral and topical steroids, amphotericin B, capsaicin. (50) To increase sensitivity of mucosal response some of the studies used mucosal thickness or nasal/sinus air volume before and after the treatment. Objective improvement after biological treatment (omalizumab, mepolizumab, dupilumab) for CRS was also evaluated using Lund-Mackay score before and 8 to 24 weeks after the treatment. Sensitivity in detecting improvement rate was confirmed in studies regarding CRSwNP. (51)

There are very few prospective, well-controlled studies that test the diagnostic value of different imaging tools in CRS coupled with the other diagnostic procedures considered to have the highest level of evidence for the diagnosis, like histopathology or microbiology. (52) There are also very few prospective and controlled studies that validate symptoms based diagnosis with imaging techniques in order to establish sensitivity and specificity of imaging technique and different staging systems. (53) Improvements in the staging systems and new image analysis tools are constantly being developed. In addition, the side effects of different

imaging techniques, such as the irradiation dose in CT, the complications with metals on MRI, the artefacts caused by implanted metals on CT and so on, which interfere with their accuracy, have been improved lately. It is important to provide information for the selection of patients to be used as negative or healthy control groups for future studies. Indeed, we may use the imaging of non-ENT patients as negative control group based only on their pre-scanning history, but this does not necessarily mean that those patients are with no CRS symptoms. Justification of the severity of individual nasal/CRS symptoms (i.e. type of headache, hyposmia, anosmia, parosmia – localization of CT or MRI changes that are related to the symptoms) through the use of imaging is still to be investigated.

## 5. Conclusion

Ionizing radiation, cost and availability should be taken into account when deciding between low-dose CT, cone beam CT and MRI, when imaging is used as an outcome measure after medical treatment. Adequate imaging severity scoring system for mucosal disease and osteitis, which would correlate best with the inflammation should yet be defined, and current literature suggests that both methods may be used with success.

## Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

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