G. Leo[1], C. Incorvaia[2], S. Masieri[3], F. Triulzi[4]

# Imaging criteria for diagnosis of chronic rhinosinusitis in children

[1]Pediatric Allergy and Respiratory Pathophysiology Unit, Buzzi Children's Hospital, Milan, Italy -
E-mail: gualtiero.leo@icp.mi.it
[2]Allergy/Pulmonary rehabilitation Unit, ICP Hospital, Milan, Italy
[3]ENT Clinic, University La Sapienza, Rome, Italy
[4]Department of Radiology and Neuroradiology, Buzzi Children's Hospital, Milan, Italy

**Key words**

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**Corresponding author**
Gualtiero Leo
Pediatric Allergy and Respiratory Pathophysiology Unit
Buzzi Children's Hospital
Via Castelvetro 32
20154 Milan, Italy
Tel: +390257995156
Fax +390257995741
E-mail: gualtiero.leo@icp.mi.it

**Summary**

*Symptoms of chronic rhinosinusitis (CRS) are nasal blockage, nasal discharge, post-nasal drip, facial pain, headache, and reduction or loss of smell, but they are often subtle and make it difficult to obtain a firm diagnosis based only on clinical data, and especially to distinguish CRS from persistent rhinitis. A diagnosis of certainty of CRS relies upon either direct observation by nasal fibroendoscopy of nasal turbinates, middle meatus, and rhinopharynx, detecting mucopurulent discharge from the middle meatus, and/or oedema or mucosal obstruction, or by imaging of the rhinosinusal cavities. Imaging techniques such as computed tomography (CT) scanning and magnetic resonance (MR) are currently recommended in consensus documents, while plain radiography is considered of poor diagnostic value. However, recent studies indicated that radiography by the Waters' projection had a sensitivity of 84.2% and a specificity of 76.6%, which suggests to use it routinely in suspected CRS, limiting the number of more expensive imaging investigations. This seems important in the current economic landscape that requires a cost-effectiveness evaluation in each diagnostic procedure.*

## Introduction

Chronic rhinosinusitis (CRS), as defined by a duration of more than 12 weeks (1), in children often presents with symptoms such as nasal blockage, nasal discharge, post-nasal drip, facial pain, headache, and a reduction or loss of smell (1). However, these symptoms are often subtle and make it difficult to obtain a firm diagnosis based only on clinical data, and especially to distinguish CRS from persistent rhinitis (2).

A diagnosis of certainty of CRS relies upon either direct observation by nasal fibroendoscopy of nasal turbinates, middle meatus, and rhinopharynx, detecting mucopurulent discharge from the middle meatus, and/or oedema or mucosal obstruction (3), or by imaging of the rhinosinusal cavities. Imaging for a long time was based only on plain radiography, but more advanced techniques such as computed tomography (CT) scanning and nuclear magnetic resonance (NMR) (4) are currently recommended. Due to valid results in diagnosis of acute sinusitis (5), a possible role for ultrasonography was also suggested, but thus far there is insufficient evidence to indicate it as a feasible option in diagnosis of CRS.

This article reviews advantages and drawbacks of each imaging procedure in the diagnostic work-up of CRS, also taking into account the cost-effectiveness issue.

## Plain radiography

Radiography has been for a long time the only available technique for paranasal sinus imaging (6), including chronic rhinosinusitis (7). The advantages offered in terms of resolution and quality of view by CT scanning and MR progressively reduced the space for radiography. According to the recent European Position Paper on Rhinosinusitis and Nasal Polyps, among the imaging criteria for diagnosis of CRS, plain sinus x-rays are stated as, "insensitive and of limited usefulness due to the number of false positive and negative results", while CT scanning is, "the imaging modality of choice confirming the extent of pathology and the anatomy", even though, "it should not be regarded as the primary step in the diagnosis of the condition" (1).
However, there are studies indicating that using the Waters' projection (figure 1), that is recommended for an optimal view of paranasal sinuses, radiography may be compared with CT scanning. In a study performing Waters' view radiography, and high resolution CT, in the same day in 134 patients, and using CT findings as the gold standard, plain radiography had a sensitivity of 68% and a specificity of 87% (8). In another study on 40 patients with suspected chronic maxillary sinusitis undergoing Waters' projection, and CT as reference standard, the former had a sensitivity of 83.3%, and a specificity of 69.2% (9), and in a survey on 91 children with clinically significant chronic sinusitis, a sensitivity and a specificity against CT of 76% and 81%, respectively, were observed (7).
The most recent study was conducted on the same kind of population: plain radiograph by Waters' view had a sensitivity of 84.2% (95% confidence interval 78.8 to 88.8), and a specificity of 76.6% (95% confidence interval 62.0 to 87.7). These values were obtained using as reference standard nasal endoscopy, and indicate that diagnostic performances of Waters' projection are able to maintain a role for radiography in the diagnosis of CRS (10). However, it has to be noted that plain radiography is inadequate to assess the anterior ethmoid, and the infundibular, middle meatus and frontal recess air passages (6).

*Figure 1* - Conventional X ray Waters projection in a 6 years old boy allows to demonstrate maxillary sinuses and the still hypopneumatizated frontal sinuses

## Computed tomography scanning

CT scanning is currently considered the gold standard of diagnosis of CRS by imaging, because it provides superior resolution of bone and soft tissue and removes superimposed overlapping structures that are present in conventional radiography (11). The standard protocol for modern multidetector CT imaging of the paranasal sinuses consists of a volumetric acquisition acquired in an axial position and covering all paranasal sinuses. Reformatted axial, coronal, sagittal, oblique or multiple oblique view can be subsequently obtained from the acquired volume. Also 3D images with virtual endoscopy can be obtained by modern reconstruction softwares (12,13). Scan enhancing by radiocontrast media is generally unnecessary in the diagnosis of CRS, since it is mainly required when complications of acute sinusitis are suspected (14).
Sinus obstruction, opacification, mucoperiosteal thickening, and osteitis can be easily seen (figure 2). Concerning mucoceles, CT has the advantage of a more precise evaluation of sinus expansion, dehiscence, and bony remodelling (14). CT imaging is of particular importance when endoscopic sinus surgery is planned, because it accurately assesses the anatomic variants and the key structures of the ostiomeatal complex, such as the ethmoid infundibulum, the uncinal process, the perpendicular plate, and the basal lamella of bulla ethmoidalis, fovea ethmoidalis, frontal recess, and sphenoethmoidal recess (12).
In 1991 five different patterns of inflammatory paranasal sinus disease were identified (15). The most common patterns are the infundibular and the ostiomeatal complex patterns in which an obstruction of the maxillary ostium

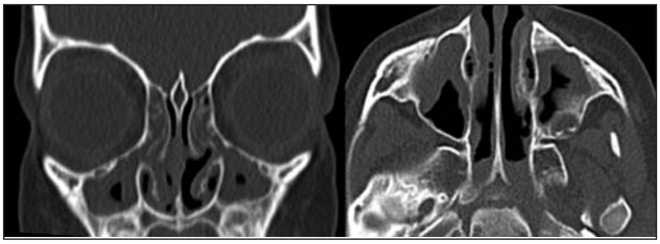
and/or ethmoid infundibulum in the first one or an involvement of ipsilateral maxillary, frontal and ethmoidal sinuses in the latter are usually present. Less frequent patterns are the sphenoethmoidal recess pattern in which an obstruction of such recess can cause an opacification of the sphenoid sinus, the sinonasal polyposis pattern in which the opacification of the paranasal sinuses is predominantly due to the presence of multiple polyps and the unclassificable pattern that comprises all the forms that can not be classified in the previous four patterns.

In 1993 Lund and Mackay introduced a sinus CT scans staging score attributing 0 to no opacification, 1 to partial opacification, and 2 to complete opacification for each sinus, and 0 for no occlusion and 2 for occlusion of the ostiomeatal complex: left and right sides are staged separately, and the scores may range from 0 to 24 (16).

A multicenter prospective study of 1840 patients undergoing surgery for chronic rhinosinusitis in the UK (17) showed that the Lund-Mackay score measures a different aspect of disease to "subjective" symptom scores, but, though with some limitations (18), correlates well with other markers of disease severity, such as complication rates and surgical parameters.

Concerning safety, it is known that CT exposes to higher radiation dose than plain radiography. Data from a large radiology department showed that CT accounted for 15% of the procedures but 75% of the radiation dose (19). This aspect is particularly important in children, and the American Academy of Pediatric Section on Radiology stated that “Pediatric health care professionals' roles in the use of computed tomography on children include deciding when a CT scan is necessary and discussing the risk with patients and families” (20). Both the current (in mA) and the duration of exposure concur to the effective radiation dose, that for paranasal sinus procedures may vary from 0.03 to 0.55 milliSievert (21). Of particular concern for the head and neck region are the crystalline lenses and the thyroid gland, but it is generally accepted that the risk of cataract or thyroid cancer is very low (22), especially with the newest generation of CT scanners (13).

***Figure 2*** - Multidetector CT, coronal and axial reformatted views in a 4 years old boy demonstrated an occlusion of the ostiomeatal complex with a bilateral mucosal thickening of maxillary sinuses.

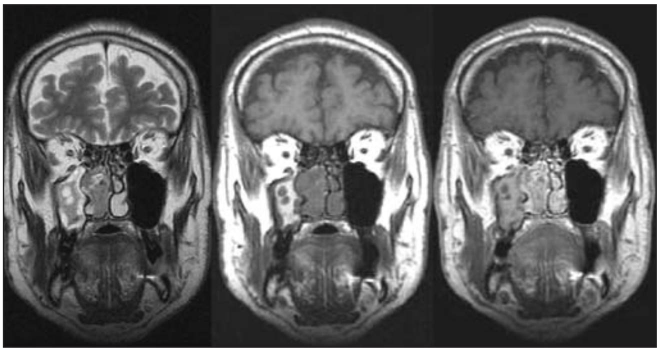


**Magnetic resonance imaging**

Magnetic resonance imaging (MRI) is commonly considered as the best anatomic imaging technology available, because it evaluates not only the tissues, as CT does by the absorption of x-rays, but also their properties, by showing the location and behaviour of nuclei emitting MR signals (12). In fact, while CT distinguishes two structures by spatial resolution, MR has a better contrast resolution, distinguishing the differences between two arbitrarily similar but not identical tissues by their different relaxation times (T1 and T2) and by their different proton density (figure 3). When needed, contrast-enhanced T-1 weighted images can be obtained by Gadolinium, a chelate contrast agent whose 7 unpaired electrons give a very high magnetic moment, thus improving the detection of local disease extent and its diffusion beyond the paranasal sinuses (23).

These abilities of MR provide a very detailed assessment of soft tissues, of their differentiation and composition in fluids, which is of great help in defining the characteristics and the extent of inflammation, as it occurs in CRS. MR is very useful in chronic fungal sinusitis (24) based on the detection of a decreased signal intensity on T1-weighted images and a markedly decreased signal intensity on T2-weighted images (25). Another advantage of MR over CT is the capacity to differentiate sinus opacification caused by inflammation or neoplasms by distin-

***Figure 3*** - MR imaging of the paranasal sinuses, T2 weighted, T1 weighted and T1 weighted post contrast coronal images demonstrate a different contrast behaviour of the right maxillary mucosal thickening and of the right nasal cavity polyp.



guishing soft tissue from dense secretions (26). This is attained by T2-weighted images detecting the high signal of secretions compared with the intermediate signal of neoplasms (14). Moreover, MR may also assess physiologic processes in the nose and sinuses, but has a limitation in the absence of MR signal by cortical bone, that prevents the precise definition of the fine bony anatomy, which is instead optimally depicted by CT scanning.

## Ultrasonography

Ultrasonography has in general several advantages, namely the easiness of performance, the directly accessible results, the absence of ionizing radiations, and the low cost, that favour its unlimited applicability and its use also in office settings (27). In its application to sinusitis, ultrasonography reliably evaluates mucosal thickening and presence of fluid level, but cannot adequately visualize sinus opacification. The two basic types include the mode A-scan, that modulates 1-dimension amplitude, and the mode B-scan, that modulates brightness in a 2-dimension method (28). In a recent study, 71 patients with chronic maxillary sinusitis were evaluated by concomitant radiography and ultrasonography, with a significant correlation between the findings from the two imaging techniques (29). However, studies comparing ultrasonography either to reference imaging as CT scanning or MR or to nasal endoscopy are not yet available, thus ultrasonography in diagnosis of CRS is currently not recommended.

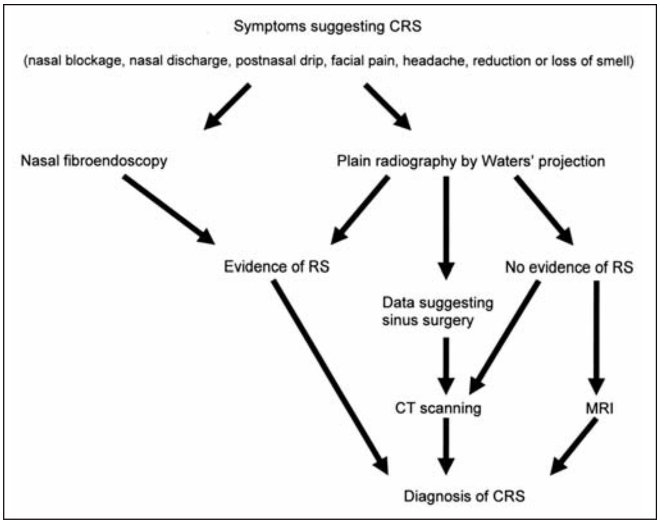
## Imaging in complications

Paranasal sinusitis is rarely associated with complications, that follow the spread of infection into adjacent structures. Consequently, serious complications include intracranial and orbital infections, and the latter are the most common type of complication in children (30). Children with these complications may experience severe consequences, including visual impairment, neurological deficits, and death (30). Chandler's classification lists 5 types of orbital complications: inflammatory edema (preseptal cellulitis), orbital cellulitis, subperiosteal abscess, orbital abscess, and cavernous sinus thrombosis (31). Intracranial complications include meningitis, cerebritis, epidural empyema, subdural empyema, cerebral abscess, and thrombosis of the cavernous sinus or other venous sinuses (32,33). Although the CT scan and MRI are the best diagnostic tools for these complications, there is controversy regarding the selection of appropriate imaging (34). Contrast-enhanced axial CT (with coronal reconstructions) is more rapid and diffuse than MR and is still the modality of choice for the diagnosis of the orbital complications in an emergency setting (35,36). However, in children with orbital cellulitis, MRI is more accurate not only for the evaluation of the orbital apex (37) but also in the assessment of abscess or inflammation location, in particular using diffusion-weighted imaging techniques (38). If an intracranial process is suspected, contrast-enhanced MRI is recommended in addition to a CT scan of the orbits and paranasal sinuses (36). MRI with gadolinium contrast provides excellent evaluation of soft tissues, and consequently it is the diagnostic tool of choice for intracranial infection (39).

## Economics of imaging in CRS

In Italy, the cost of a single imaging technique performance on paranasal sinuses is 24.95 euros for plain radiography, 106.62 euros for CT scanning, and 153.05 euros for MRI, respectively. Concerning CT and MRI, the cost increases when contrast media are used. Of course, also the cost of the equipment must be considered. For example, in the US the cost for MRI equipment is between 1 and 1.5 million USD for 1.5 tesla scanners and between 2 and 2.3 million USD for 3.0 tesla scanners, with the cost of construction of MR suites – that is around 500,000 USD – to be added. However, MR scanners have been significant sources of revenue for healthcare providers in the US, because of favorable reimbursement rates from insurers and federal government programs. Insurance reimbursement is provided in two components, an equipment charge for the performance of the MR scan and professional charge for the radiologist's review of the images and data. In the US, the 2007 Deficit Reduction Act (DRA) significantly reduced reimbursement rates paid by federal insurance programs for the equipment component of scans. Therefore, in the current economic landscape, it is hardly possible not to take into account the cost-effectiveness of each diagnostic procedure. Concerning diagnosis of CRS, a cost-effective diagnostic work-up should reappraise the role of plain radiography and limit the more expensive CT scanning and MRI to a smaller number of patients than generally done.

*Figure 4* - A flow-chart for diagnosing chronic rhinosinusitis with consideration of cost-effectiveness of single imaging techniques.




## Conclusions

On the basis of diagnostic performances and costs of the different imaging techniques in CRS, a flow-chart as depicted in figure 4 may be proposed. Clinical diagnosis, as performed by the indications from consensus documents (1) cannot give the certainty of disease because no symptom is pathognomonic (40) and this warrants the use of imaging. The recent report that a plain radiography by Waters' projection is able to identify about 85% of patients with CRS indicate Water's projection radiography as the first step to achieve a diagnosis by imaging in subjects with clinical symptoms suggesting CRS. CT scanning or MRI should thus be reserved to about 15% of patients or to those who show radiographic pictures of surgical interest or images requiring more accurate definitions.

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