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The role of ultrasonography in the evaluation of maxillary sinusitis in pediatrics

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Abstract

Sinusitis in children may sometimes present non-specific signs and symptoms. The imaging techniques used for its diagnosis are computed tomography and magnetic resonance imaging, the standard radiography being used less and less. Ultrasonography is seldom mentioned in literature as a diagnosis method of sinusitis. **Objective:** The purpose of this study is to evaluate the value of ultrasonography compared with the standard X-ray in the diagnosis of maxillary sinusitis in children. **Method:** The study was prospectively conducted. The study group included 76 patients who had an ultrasound of the maxillary sinuses. The including criteria were represented by uncontrolled or partially controlled asthma, symptomatology suggesting rhinosinusitis and age over 4. Patients with radiological anomalies of the maxillary sinuses were excluded from the study as well as the patients who were not examined through X-ray and the ultrasonography on the same day. The ultrasound was performed with a pediatric convex transducer with the patient in a sitting position. The ultrasonographic exam evaluated the presence of fluid collection and mucosal thickening within the maxillary sinuses. Signs evaluated by X-ray exam were: total opacity of the maxillary sinus, air-fluid level and mucosal thickening. The Wilcoxon matched-pairs tests was used in order correlate the results obtained through ultrasonography and radiograph. It was considered statistic significant $p < 0,05$. Using the ROC curve the sensitivity and the specificity of the ultrasound compared with the standard radiograph were determined. **Results:** Based on the excluding criteria a number of 67 patients (35 male) were selected from the study group. The patient's mean age ± standard deviation was 9 years 2 months ± 3 years 9 months. 134 maxillary sinuses were analyzed ultrasonographically and radiologically. There was a diagnosis agreement between the two techniques in 112 out of 134 sinuses (83,5%). Compared to the standard X-ray, ultrasonography had a 94.9 % sensitivity and a 98.4 % specificity. The error of the ultrasound exam compared to the standard X-ray evaluated in a divided interpretation was low for the normal aspect (1.58%) and for the fluid collection (5.12%), but the error for the thickening of the mucosa was high, over 50% (59.37%). In **conclusion**, ultrasonography may come to represent, on a larger scale, an accessible imaging alternative to the more invasive investigations used in the present in evaluating fluid collections in the maxillary sinus in pediatrics.

Keywords: maxillary sinusitis, ultrasound, child

Rezumat

Sinuzita la copil poate prezenta uneori semne şi simptome nespecifice. Tehnicile imagistice utilizate în diagnosticul acesteia sunt tomografia computerizată şi rezonanţa magnetică; radiografia standard este din ce în ce mai puţin mentionaţa. Ultrasonografia este citată rar în literatură ca şi metodă de diagnostic a sinuzitei. **Obiectiv:** Studiul îşi propune aprecierea valorii ultrasonografiei comparativ cu radiografia standard în diagnosticul sinuzitei maxilare la copil. **Metodologie:** Studiul a fost prospectiv. Lotul de studiu a inclus 76 pacienţi la care s-a efectuat ultrasonografie a sinusurilor maxilare. Criteriile de includere: astmul bronşic necontrolat/parţial controlat, simptomatologia sugestivă pentru sinuzită, vârsta peste 4 ani. Au fost excluşi pacienţii cu anomalii radiologice a sinusului maxilar sau la care radiografia nu s-a putut efectua în aceeaşi zi cu examinarea ultrasonografică. Ultrasonografia s-a efectuat cu un transductor convex pediatric cu pacientul în pozitie semişezandă. Au fost evaluate ultrasonografic colecţiile lichidiene din sinusul maxilar şi îngroşarea mucoasei sinusale. Radiologic s-au apreciat: opacifierea totală a sinusului maxilar, nivelul hidroaeric din sinus şi îngroşarea mucoasei sinusale. Analiza statistică: a fost aplicat testul Wilcoxon pentru perechi. S-a considerat rezultat statistic semnificativ $p<0,05$. Sensibilitatea şi specificitatea ultrasonografiei comparativ cu radiografia standard s-au evaluat utilizand curba ROC. **Rezultate:** Din lotul de studiu, pe baza crieriilor de excludere au fost selectaţi 67 pacienţi (35 băieţi), vârsta medie ± deviaţia standard de 9 ani şi 2 luni ± 3 ani şi 9 luni. Au fost 134 sinusuri maxilare. Concordanţa diagnostică între cele două tehnici imagistice a fost prezentă la 112/134 sinusuri (83,5%). Ultrasonografia comparativ cu radiografia standard a avut o sensibilitate de 94,9% şi o specificitate de 98,4%. Inadvertenţele raportate la examenul ultrasonografic comparativ cu radiografia standard evaluate diferentiat au fost reduse în cazul aspectului normal (1,58%) si colecţiei fluide (5,12%), dar eroarea în identificarea ultrasonografică a îngroşării mucoasei comparativ cu radiografia standard a fost mare, procentul fiind de peste 50% (59,37%). In **concluzie**, ultrasonografia ar putea reprezenta o alternativă accesibilă pe scară largă a investigaţiilor imagistice mai invazive utilizate în prezent în evaluarea colecţiilor fluide din sinusul maxilar la copil.

Cuvinte cheie: sinuzita maxilară, ultrasonografie, copil

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Introduction

Sinusitis represents a frequently encountered pathology in pediatrics. The symptoms of this condition are non-specific so the diagnosis is often difficult to establish.

The standard diagnosis method of bacterial sinusitis is the sinus puncture followed by a bacterial culture. Due

to its invasive character this technique is rarely used. Other diagnosis investigations used in sinusitis are: the standard radiography, computed tomography, magnetic resonance imaging and ultrasonography.

Objective

The aim of this study is to evaluate the role of B mode ultrasonography in the diagnosis of maxillary sinusitis in children compared to the standard X-ray.

Methods

The children included in this prospective study were between 4 and 16 years old. All patients underwent an ultrasonographic and radiographic exam of the maxillary sinuses. The including criteria were represented by uncontrolled or partially controlled asthma, symptomatology suggesting rhinosinusitis (rhinorrhea, cough, fever, nasal voice, headache, facial tenderness, postnasal drip) and age over 4. The excluding criteria were anomalies of the maxillary sinuses and the impossibility to perform both the X-ray and the ultrasonography on the same day.

The ultrasonographic exam was performed and interpreted by one investigator (F.O.) and the X-ray was interpreted by another observer (C.A.). Both imaging techniques were carried through on the same day, the ultrasound being the first investigation.

For the ultrasound, a Sonoace 8000 EX machine with a pediatric convex, multi frequency, 4-9 MHz transducer was used. The examination was executed with the patient in a sitting position with his head slightly bent forward. The transducer was placed in a transverse view, under the orbit and lateral to the nose (fig 1).

The ultrasonographic appearance of a normal maxillary sinus is given by the reverberation of the sound waves due to the presence of air in the sinuses (fig 2 a,b).

The detection of a hypoechoic/transonic, homogeneous or non-homogeneous image, with a well-defined contour and a triangular shape within the maxillary sinuses was interpreted as a fluid collection. An alteration of the normal pneumatization of the maxillary sinuses expressed through a hypoechoic/echoic image that did not have a triangular shape and well-defined margins was diagnosed as a thickening of the sinus mucosa.

The radiography was taken with the patient in orthostatism and obtaining a single projection, the occipitomental view. The plain film was acquired on the same day as the ultrasound, at a very short interval after the later. The X-ray, as it was previously mentioned, was interpreted by a different observer, under blinded conditions (without information regarding the result of the ultrasonogra-

Fig 1. The transducer position for maxillary sinus ultrasound examination.

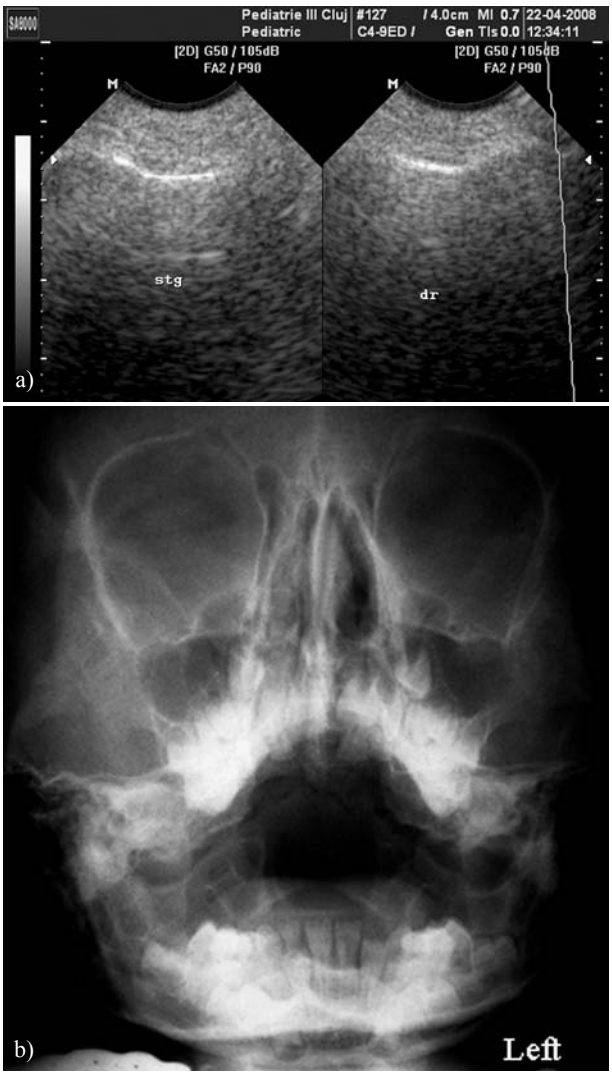


Fig 2. Ultrasonographic aspect of a normal maxillary sinus (2a) and normal X ray aspect - occipitomental view (2b) in patient P.D., boy, 7 years old (stg-left; dr-right).

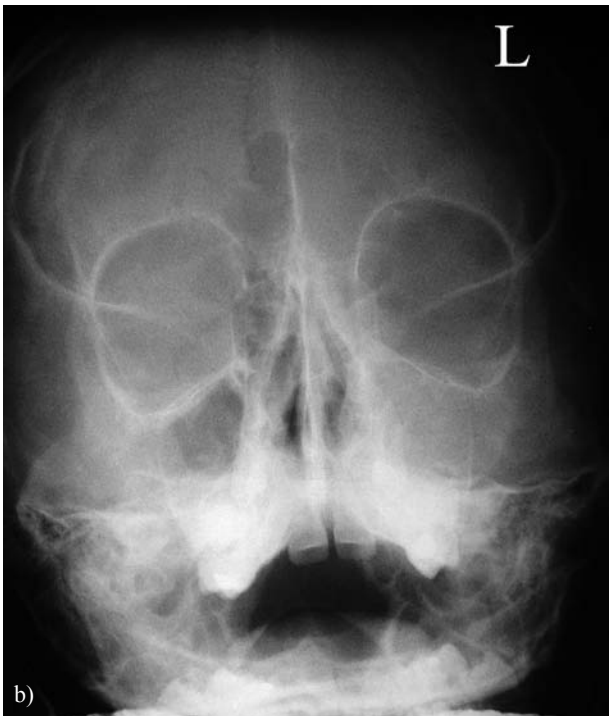


Fig 3. a) Ultrasonographic appearance of the maxillary sinus fluid collection (on the left side) and mucosal thickening (on the right side) in the patient MS, girl, 8 years old. b) X-ray exam confirms the ultrasound result and revealed also opacification of the frontal sinus and ethmoidal cells on the left side (stg-left; dr-right).

phy). A complete opacity of the maxillary sinuses or the presence of an air-fluid level were interpreted as a fluid collection, while a peripheral opacity of the sinus was regarded as mucosal thickening.

Figure 3a presents the ultrasonographic aspect of the fluid collection (in the left maxillary sinus) and the aspect of mucosal thickening (right maxillary sinus) in a girl with poor controlled asthma. The X ray exam in the same girl (fig 3b) revealed complete opacity of the left paranasal sinuses and right maxillary sinus mucosal thickening.

Statistic analysis: The study was prospectively conducted. The Wilcoxon matched-pairs test and correlation index r were used in order correlate the results obtained through ultrasonography and radiograph. It was considered statistic significant $p<0,05$. Using the ROC curve the sensitivity, specificity, positive predictive value and negative predictive value of the ultrasound compared with the standard radiograph were determined.

Before proceeding with the imaging investigations a consent from the legal guardians of the children included in the study group was obtained.

Results

In the study were enrolled 76 children (46 boys/36 girls). The age of the participants was between 4 and 16 years old (mean age ± standard deviation: 9 years and 4 months ± 3 years and 9 months). Based on the excluding criteria the selected study group consisted of 67 patients (35 boys/32 girls), with a mean age ± standard deviation of 9 years and 2 months ± 3 years and 9 months.

An ultrasound and a standard X-ray were performed for each of the 134 maxillary sinuses considered for the study.

The radiograph revealed a normal aspect in 63 maxillary sinuses, mucosal thickening in 32 and the presence of fluid collection in 39 sinuses. Ultrasonography showed a normal aspect in 80 maxillary sinuses, mucosal thickening of 14 sinuses and a fluid collection in 40. Table I presents the total number of normal and pathologic maxillary sinuses (right and left comparatively).

The standard X-ray depicted an equal number of left and right maxillary sinuses with mucosal thickening (16/134). The fluid collection was detected more frequently on the right side (23/134 sinuses) then on the left (16/134 sinuses).

A statistically significant agreement between the two imaging techniques was obtained (correlation index $r = 0.58$; $p<0.0001$). Consistent results between the two techniques were found in 112 (83,5%) of the 134 analyzed maxillary sinuses: normal appearance in 62/112 sinuses, mucosal thickening in 13/112 sinuses and fluid collection in 37/112 cases (Table II).

In figure 4 is presented the initial ultrasound exam and standard X ray in the patient V.B. with symptoms of sinusitis (purulent rhinorrhea, cough and headache). X ray exam revealed complete opacity of the right maxillary sinus and partial opacification with mucosal thickening on the left side (fig 4b). Ultrasound exam revealed also the presence of fluid in both maxillary sinuses (fig 4a). Figure 5 (a, b)

Table I. The number of normal and pathological maxillary sinuses examined through ultrasonography and standard X-ray; left/right aspects comparatively (134 maxillary sinuses).

	Normal aspect		Mucosal thickening		Sinus collection	
	Right	Left	Right	Left	Right	Left
Radiography (no of sinuses)	28	35	16	16	23	16
Total no of sinuses	**63**		**32**		**39**	
Ultrasonography (no of sinuses)	36	44	7	7	24	16
Total no of sinuses	**80**		**14**		**40**	

Table II. The number of maxillary sinuses for which consistent results (normal and pathologic) were found on both the ultrasound and the X-ray exam; left/right comparatively (112 maxillary sinuses).

	Normal aspect		Mucosal thickening		Sinus collection	
	Right	Left	Right	Left	Right	Left
Ultrasound/ Radiography (no of sinuses)	27	35	6	7	22	15
Total number of sinuses	62		13		37	

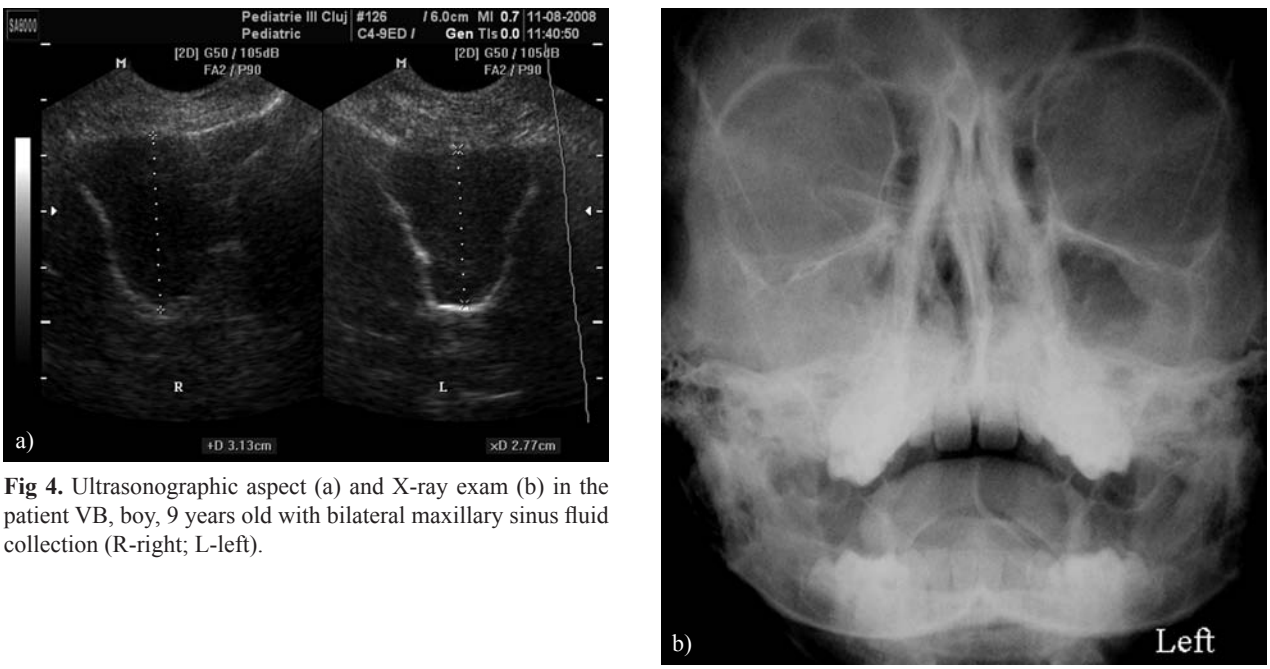


Fig 4. Ultrasonographic aspect (a) and X-ray exam (b) in the patient VB, boy, 9 years old with bilateral maxillary sinus fluid collection (R-right; L-left).

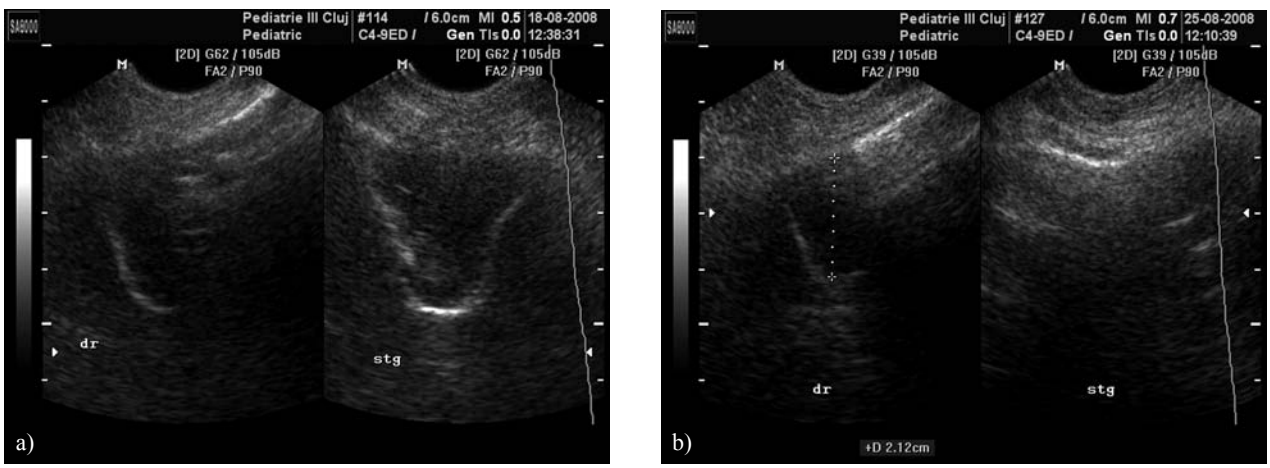


Fig 5. Ultrasonographic follow-up in the patient from fig 4 – one week later (a) and two weeks later (b) (stg-left; dr-right).

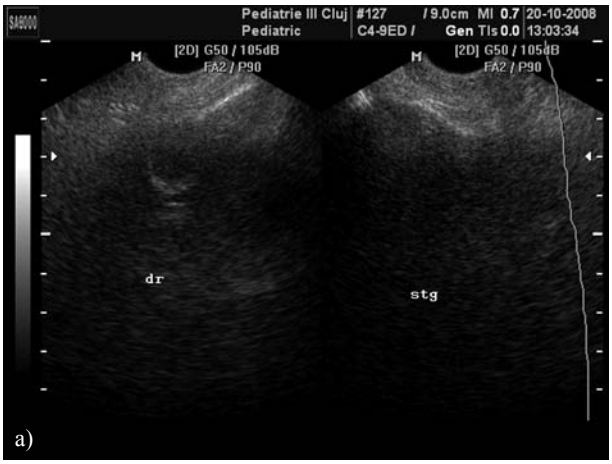


Fig 6. Maxillary sinus ultrasonographic aspect and magnetic resonance image in the same patient presented in fig 4 (performed 2 months later) (stg-left; dr-right).

and figure 6 a present the ultrasonographic follow-up in the same patient. There is the persistence of the fluid with cyst formation on the right side. At the last US exam (fig 6a), the left maxillary sinus appears normal, but MRI exam performed at the same time revealed persistence of a small amount of fluid within the left sinus and presence of a cyst within the right sinus (fig 6b).

In 22 out of the 134 examined maxillary sinuses the findings of the two imaging methods were inconsistent with each other. The most frequent inconsistency was the undiagnosed mucosal thickening by ultrasonography compared with the radiograph. Therefore, in 16 of the analyzed sinuses, the ultrasonographic aspect was considered normal while the radiograph showed mucosal thickening (fig 7). Other inconsistencies between ultrasonography and radiography were recognized: in 3 cases the radiograph revealed mucosal thickening while the ultrasound aspect was interpreted as fluid collection; in 2 of the examined maxillary sinuses the ultrasound did not identify the fluid collection found on the radiograph and in one radiologically normal sinus the ultrasonography report described mucosal thickening.

Figure 7a presents the normal ultrasonographic appearance of the maxillary sinuses in a patient (J.D, male, 8 years old) with headache and asthma. X-ray exam performed in the same patient revealed maxillary sinuses mucosal thickening (fig 7b).

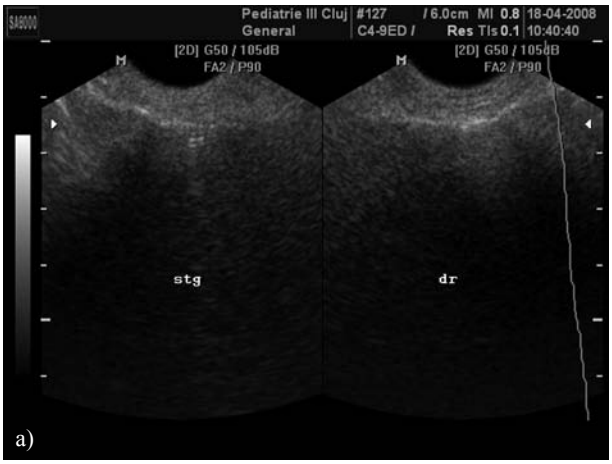
The ROC curve analysis was used to determine the diagnostic performance of ultrasonography compared with that of the standard X-ray in evaluating maxillary sinuses. The following data were obtained: a sensitivity of 94.9%, a specificity of 98.4 %, a positive predictive value of 97.4% and a negative predictive value of 96.9%.

The value of ultrasonograhy versus conventional radiograph was assessed applying the Wilcoxon matched pairs test to the entire study group. As shown in the table below (Table III), the test revealed strong correlations between the two imaging techniques. A non-parametric test was applied because categorical variables and not numerical variables were used in order to define the findings of the two methods (normal aspect, fluid collection, mucosal thickening).

Further the error of the ultrasound exam compared to the standard X-ray was evaluated in a divided interpretation for the normal aspect, the fluid collection and the mucosal thickening. The error was extremely low for the normal aspect (1.58%) and for the fluid collection (5.12%) results. But the error for the thickening of the mucosa found on the ultrasound turned out to be over 50% (59.37%). This result entitles for the conclusion that ultrasonography is not suitable in evaluating mucosal thickening (Table IV). The errors of ultrasonography in

Table III. The p-value obtained from the Wilcoxon matched-pairs used to assess the ultrasonography/conventional radiograph correlation.

Wilcoxon	Valid	T	Z	p-level
Var1&Var 2	134	14.00000	3.652386	0.000260



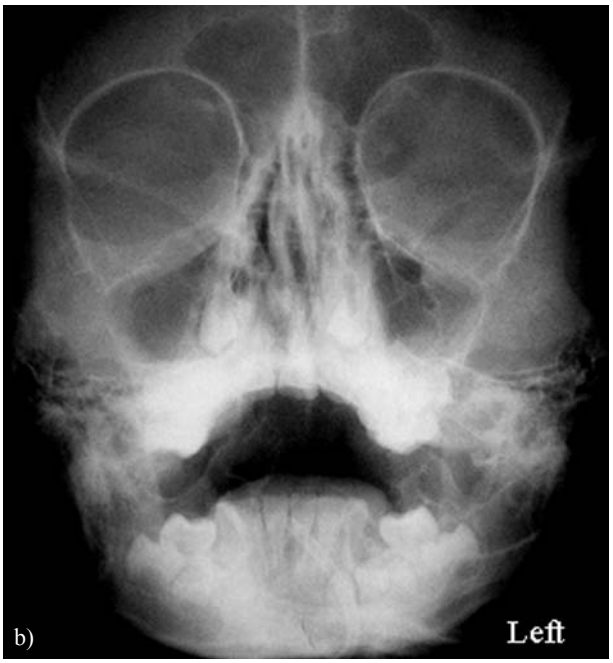


Fig 7. Normal ultrasonographic appearance in the patient J.D. 8 years old boy (a) and maxillary sinus mucosal thickening revealed by X-ray exam in the same patient (b) (stg-left; dr-right).

appreciating the thickening of the mucosa a lack of its visualization was observed in 16 of the 19 errors, that is 84.21% of the total number of identified errors.

Table IV. The error of the ultrasound exam compared to the standard X-ray regarding the interpretation of the normal aspect, the fluid collection and the mucosal thickening.

Ultrasonography	Number of maxillary sinuses	Number of inconsistencies of US versus X-ray	Inconsistencies %
Normal aspect	63	1	1.58%
Fluid collection	39	2	5.12%
Mucosal thickening	32	19	59.37%

Discussions

Maxillary sinusitis is defined as an inflammatory or infectious process of the maxillary sinuses mucosa with fluid retention in the sinus. The term used now is rhinosinusitis as the inflammation of the paranasal sinuses as almost always accompanied by the contiguous inflammation of the nasal mucosa [1]. Symptoms in sinusitis of children are sometimes unspecific: rhinorrhea, cough, fever, nasal voice, headache, inflammation of nasal mucosa, sinus tenderness, postnasal drip.

The sinus infection is diagnosed by puncture followed bacterial culture. But because this is an invasive technique, less invasive or non-invasive imaging methods may used in establishing the diagnosis. These are: the conventional radiograph, computed tomography, magnetic resonance imaging and ultrasonography. Yet these investigations may lead to a false positive diagnosis of infection when mucosal thickening, polyps, sinus cysts or anatomical anomalies are present [2].

Computed tomography is considered to be the gold standard in the diagnosis of sinusitis. But there are authors who consider that this radiation exposing imaging technique should be considered only in certain situations: recurrent sinusitis, chronic sinusitis and no response to therapy [3,4,5].

Radiologic exams to confirm the diagnosis of uncomplicated sinusitis are recommended by some authors just for children older than 6 years [6,7]. Others literature data suggest that imaging investigations are not necessary in uncomplicated acute rhinosinsitis [8,9].

Ultrasonography was used, for the first time, in the diagnosis of sinusitis by Mann in a study published in 1975 [10]. There are relatively few studies in literature evaluating the role of ultrasonography in the diagnosis of rhinosinusitis in adults or in children. One dimension A-mode or two dimensions B-mode were used to evaluate maxillary sinuses. Studies of ultrasound in pediatric maxillary sinusitis revealed conflicting results [11,12,13,14].

The use of ultrasonography compared with the standard radiograph in acute sinusitis was evaluated in a com-

parative study on 197 young adults showing common cold symptoms for 48 hours. From the initial study group a number of 40 patients were randomly selected and examined through MRI. In this study ultrasonography compared with MRI had a 64% sensitivity and 95 % specificity. If the radiograph was also evaluated (two steps diagnosis) the sensitivity increased up to 86% without a drop of the specificity (95%) [15].

Happaviemi et al detected a 77 % sensitivity and a 49% specificity of the ultrasound in study published in 2001 that evaluated 209 maxillary sinuses. The authors compared ultrasonography with maxillary antral lavage [16]. In a prospective study, realized in 1998, 100 maxillary sinuses were evaluated through ultrasound and radiograph. The author defined the term „sinusogram" (sinus ultrasound) this way: a „sinusogram" is complete when the internal, external and posterior walls of the sinus are visualized and incomplete when these walls are just partially visible. The „sinusogram" was correlated with the computed tomography's findings. Therefore, the sinusogram was present in 21 of the 21 opaque maxillary sinuses found on the computed tomography, in 2 of 21 sinuses with an air-fluid level, in 8/21 cases of mucosal thickening and in 1/1 giant nasal polyp. The author proposes ultrasonography as a first-line investigation for the diagnosis of radiologically detected maxillary sinusitis [17].

Another study, performed on adult population, assessed the accuracy of ultrasonography compared with conventional radiograph and maxillary sinuses sinoscopy in detecting acute or chronic inflammation. A number of 90 sinuses were evaluated in the study, a radiograph, an ultrasound and a sinoscopy being performed in each case. The value of ultrasonography was analyzed using McNemar's test for paired data. Compared with the radiograph the sensitivity of the ultrasound was 93 % and the specificity was 60 %. Compared with sinoscopy the ultrasound had a 93 % sensitivity and a 74 % specificity [18].

In a study performed on 56 adult patients, with a clinical and/or radiological diagnosis of acute maxillary sinusitis, a sensitivity of 66.7% and a specificity of 94.9 % of the ultrasound compared with computed tomography was detected [19].

Ionannidis & Lau carried out in 2001 a meta-analysis of the existing studies on rhinosinusitis imaging in literature until up that point. 2 out of 8 comparative studies evaluated ultrasonography as a rhinosinusitis diagnosis method. This meta-analysis showed that there is a moderate agreement between the results of the paranasal sinuses radiograph and the clinical diagnosis. The agreement between the two depended on the definition of the clinical diagnosis. Another conclusion they reached was that the results of the other imaging methods (including ultrasound) din not correlate with the clinical data [20].

Scheid and Hamm made a review of the comparative imaging studies in the diagnosis of rhinosinusitis in adults. Regarding ultrasonography with sinus puncture this review showed an 84% (with a range from 54% to 98%) sensitivity and a 69% (values between 30% and 94%) specificity [8].

In another review published in 2000 by Veronen 7 studies, assessing ultrasonography versus sinsus puncture, were analyzed, revealing an 85% sensitivity and 82% specificity of the ultrasound exam [2].

In our study the ultrasound exam of maxillary sinus was compared with conventional X ray exam performed in occipitomental view. The concordance between these two imaging methods was present in 83,5%. Regarding all situations (fluid collection in the maxillary sinus and mucosal thickening), the sensitivity of ultrasound was 94,8% with a specificity of 98%. If we evaluated in a divided interpretation for the normal aspect, the fluid collection and the mucosal thickening, the error was low for the fluid collection (5.12%), but the error for the thickening of the mucosa was high (59.37%). This result entitles for the conclusion that ultrasonography is not suitable in evaluating mucosal thickening. There are also studies in literature which revealed similar results about low accuracy of ultrasound in diagnosis of maxillary sinus mucosal thickening [21,22,23].

In **conclusion**, this study revealed that ultrasonography is not a suitable technique in the evaluation of maxillary sinus mucosal thickening. Ultrasonography may come to represent an accessible imaging alternative to the more invasive investigations used in the present in evaluating the presence of the fluid in the maxillary sinus in pediatrics.

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