ORIGINAL ARTICLE

Validity of Ultrasonography in Diagnosis of Acute Maxillary Sinusitis

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Background: Accurate diagnosis of maxillary sinusitis is difficult on the basis of clinical examination only because the signs and symptoms of sinusitis are nonspecific. A simple, rapid, and readily available method for diagnosing maxillary sinusitis in primary care would increase the accuracy of the diagnoses and thus reduce unnecessary antibiotic treatment.

Objective: To investigate the validity of ultrasonography compared with radiography and magnetic resonance imaging (MRI) in detection of maxillary sinusitis.

Design: Ultrasonography and plain-film radiography of the paranasal sinuses were performed on all patients and MRI was performed on 40 randomly selected patients on day 7 of the study.

Setting: Study office at the Department of Pediatrics of Turku University Hospital, Turku, Finland.

Patients: One hundred ninety-seven young adults who contacted the study office within 48 hours of the onset of symptoms of the common cold.

Main Outcome Measures: Detection rates of maxillary sinusitis by ultrasonography, radiography, and MRI.

Results: Acute maxillary sinusitis was diagnosed in 24% of the sinuses by radiography and in 28% by MRI. Compared with MRI findings, the sensitivity of ultrasonography for detection of maxillary sinusitis was 64% (specificity, 95%). Using a 2-step diagnostic approach in which radiological findings were additionally considered in cases of negative ultrasound findings, a sensitivity of 86% (specificity, 95%) was observed.

Conclusions: The high specificity of ultrasonography indicates that a positive ultrasound finding can be regarded as evidence of maxillary sinusitis. The addition of plain-film radiography in cases of negative ultrasound findings increases the diagnostic sensitivity to clinically acceptable levels without loss in specificity. Active use of ultrasonography would substantially decrease the need for radiological imaging of the sinuses and also help reduce unnecessary antibiotic treatment in primary care.

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ACUTE MAXILLARY sinusitis is one of the most common diseases diagnosed by primary care physicians and a leading cause of outpatient antimicrobial drug therapy.[1] Accurate diagnosis of sinusitis, however, is difficult on the basis of clinical examination only because the signs and symptoms of maxillary sinusitis are mostly nonspecific and similar to those of the common cold.[2-4] Plain-film radiography is traditionally used as the first diagnostic test to evaluate patients with suspected sinusitis, but it might not be available at all times in primary care settings, and it is time-consuming and costly and exposes the patient to radiation.

Ultrasonography is a rapid, inexpensive, convenient, and readily available method for evaluation of maxillary sinuses, and these features make it an optimal diagnostic method, especially in primary care. However, previous studies[5-10] on the sensitivity and specificity of ultrasonography have yielded extremely variable results, and hence the status of ultrasonography in the diagnosis of maxillary sinusitis has remained unestablished.

Magnetic resonance imaging (MRI) is currently considered the imaging modality of choice in the evaluation of inflammatory processes on the mucosal surfaces of the maxillary sinuses,[11,12] but no previous studies have assessed the accuracy of ultrasonography or plain-film radiography compared with MRI in acute maxillary sinusitis. We sought to determine the validity of ultrasonography compared with radiography and MRI for the diagnosis of acute maxillary sinusitis in adults.

PATIENTS AND METHODS

PATIENTS AND STUDY DESIGN

A total of 200 generally healthy young students at the University of Turku, Turku, Finland, were enrolled in a study of the treatment of the common cold.[13] The mean (SD) age of the patients was 24.0 (3.4) years. Participants were recruited through advertisements in local newspapers and student canteens. Patients were initially examined at the study office at the Department of Pediatrics of Turku University Hospital within 48 hours of the onset of symptoms of the common cold. The day of this first visit was defined as day 1 of the study. Ultrasonography and plain-film radiography of the paranasal sinuses were performed on all patients on days 1 and 7, and MRI was performed on 40 randomly selected patients on day 7. The present study consists of the findings obtained by the 3 different imaging methods on day 7. None of the patients received antibiotic drugs during the study week. The radiographs of 3 patients were unavailable for analysis, so the final study group consisted of 197 patients. All participants signed a written consent form, and the study was approved by the Ethics Committee of Turku University Hospital.

ULTRASONOGRAPHY

Ultrasonography of the maxillary sinuses was carried out using a portable Sinuscan 102 (Oriola, Helsinki, Finland) at a frequency of 3 MHz and with a transducer diameter of 8 mm. All patients were examined by the same physician (T.P.). The procedure was performed before radiography according to the method described by Revonta.[14] During the examination, the patient's head was in slight flexion so that an imaginary line from the auditory canal to the lower margin of the orbit was horizontal. Starting from the bottom of the maxillary sinus, the entire maxillary area was carefully examined by obtaining readings after every 0.5-cm vertical or horizontal move of the transducer. The ultrasound findings were printed out for documentation using Sinusprint (Oriola). Findings were classified into 4 categories: normal (echo at a distance of ≤1.0 cm), mucosal thickening (1.1-3.4 cm), fluid (≥3.5 cm), and cyst or polyp (dual peak echo). An ultrasound echo 1.0 cm from the skin was estimated to represent a mucosal thickening of approximately 5 mm. In the primary analysis, all echoes observed at 1.1 cm or more were considered to be proof of sinusitis. In a secondary analysis, only echoes indicative of the presence of fluid (≥3.5 cm) were regarded as sinusitis.

RADIOGRAPHY

Plain-film radiography of the sinuses (occipitomental view) was performed after ultrasonography. The radiographs were interpreted independently by 3 radiologists (A.A., T.K., and L.K.) who were unaware of the ultrasound findings. The radiological diagnosis of sinusitis was made if an air-fluid level, total opacity, or mucosal thickening exceeding 5 mm was detected.[15,16] All 3 radiologists agreed on the diagnosis of sinusitis or no sinusitis in 84% of the maxillary sinuses evaluated. In the remaining 16% of the sinuses, the interpretation of the 2 agreeing radiologists was chosen as the final diagnosis.

MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging of the sinuses was carried out by obtaining coronal T1-weighted (PS3D-50/20) and axial T2-weighted (SE-2100/120, 5-mm slices) images using a 0.1-T magnetic scanner. The MRIs were interpreted independently by 2 radiologists who had no knowledge of the ultrasound or radiographic findings. The radiologists compared their interpretations and resolved any disagreements through discussion. In accordance with the radiological criteria, maxillary sinusitis was defined as the presence of an air-fluid level or mucosal thickening exceeding 5 mm.[17]

STATISTICAL ANALYSIS

The Fisher exact test was used to compare frequencies between the groups.

RESULTS

ULTRASONOGRAPHY VS RADIOGRAPHY

A radiological diagnosis of maxillary sinusitis was made in 94 (24%) of 394 sinuses (**Table 1**). In 53 of these 94 sinuses, sinusitis was revealed by ultrasound, thus the sensitivity of ultrasonography for detection of maxillary sinusitis was 56% compared with radiography (**Table 2**). On the other hand, ultrasound findings were positive in 39 of the 300 sinuses without radiological evidence of sinusitis, ie, the false-positive rate of ultrasonography was 13%. The agreement between ultrasonography and radiography was 80% ($\kappa = 0.44$).

ULTRASONOGRAPHY VS MRI

Magnetic resonance imaging revealed an air-fluid level or mucosal thickening exceeding 5 mm in 22 (28%) of the 80 sinuses (**Table 3**). Ultrasonography provided an echo indicating sinusitis in 14 of these 22 sinuses, thus yielding a sensitivity of 64% compared with MRI (Table 2). Among the 13 sinuses in which an air-fluid level was detected by MRI, ultrasonography revealed fluid in 2 (50%) of 4 sinuses with air-fluid levels of 10 mm or more compared with 1 (11%) of 9 sinuses with air-fluid levels less than 10 mm ($P = .20$). Compared with MRI findings, 3 false-positive results were observed by ultrasonography (specificity, 95%). An example of the findings by the 3 different imaging methods is shown in the **Figure**.

RADIOGRAPHY VS MRI

Of 22 sinuses in which maxillary sinusitis was diagnosed by MRI, radiographic findings were positive in 16, yielding a sensitivity of 73% compared with MRI (Table 2 and **Table 4**). Detailed findings from the different imaging methods in the 6 MRI-positive sinuses with negative radiographic findings are presented in **Table 5**. All

Table 1. Comparison of Ultrasonography With Radiography (Occipitomental View) in Detection of Maxillary Sinusitis in 394 Sinuses

	Ultrasonographic Findings			
Radiographic Findings	Fluid	Mucosal Thickening	Cyst or Polyp	Normal
Sinusitis	**18**	**35**	**0**	**41**
Air-fluid level	3	6	0	10
Total opacity	1	2	0	2
Mucosal thickening >5 mm	14	27	0	29
No sinusitis	**8**	**31**	**1**	**260**
Mucosal thickening of 1-5 mm	4	6	0	27
Cyst or polyp	2	4	1	4
Normal	2	21	0	229

Table 2. Sensitivity, Specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV) of Ultrasonography and Radiography (Occipitomental View) in Detection of Maxillary Sinusitis*

	Sensitivity	Specificity	PPV	NPV
Ultrasonography vs radiography (394 sinuses)				
Echo ≥1.1 cm	56	87	56	86
Echo ≥3.5 cm	19	97	69	79
Ultrasonography vs MRI (80 sinuses)				
Echo ≥1.1 cm	64	95	82	87
Echo ≥3.5 cm	27	100	100	78
Radiography vs MRI (80 sinuses)	73	100	100	91

**Data are given as percentage. MRI indicates magnetic resonance imaging.*

cases of radiologically diagnosed sinusitis were also confirmed by MRI; thus, the specificity of radiography was 100% compared with MRI.

COMBINED ULTRASONOGRAPHY AND RADIOGRAPHY VS MRI

We further analyzed the sensitivity and specificity of a 2-step diagnostic approach for use in clinical practice. In this model, positive ultrasound findings were regarded as proof of sinusitis without further diagnostic tests. Only in cases in which ultrasonographic findings were negative, the results of plain-film radiography were considered to be an additional diagnostic tool. Findings indicative of sinusitis by either one of these methods were then compared with the MRI results. This 2-step method detected 19 of 22 sinuses in which sinusitis was diagnosed by MRI, thus yielding a sensitivity of 86% (**Table 6**). In 3 of 58 sinuses considered to be normal by MRI, either ultrasonography or radiography indicated the presence of sinusitis (specificity, 95%).

Table 3. Comparison of Ultrasonography With Magnetic Resonance Imaging in Detection of Maxillary Sinusitis in 80 Sinuses

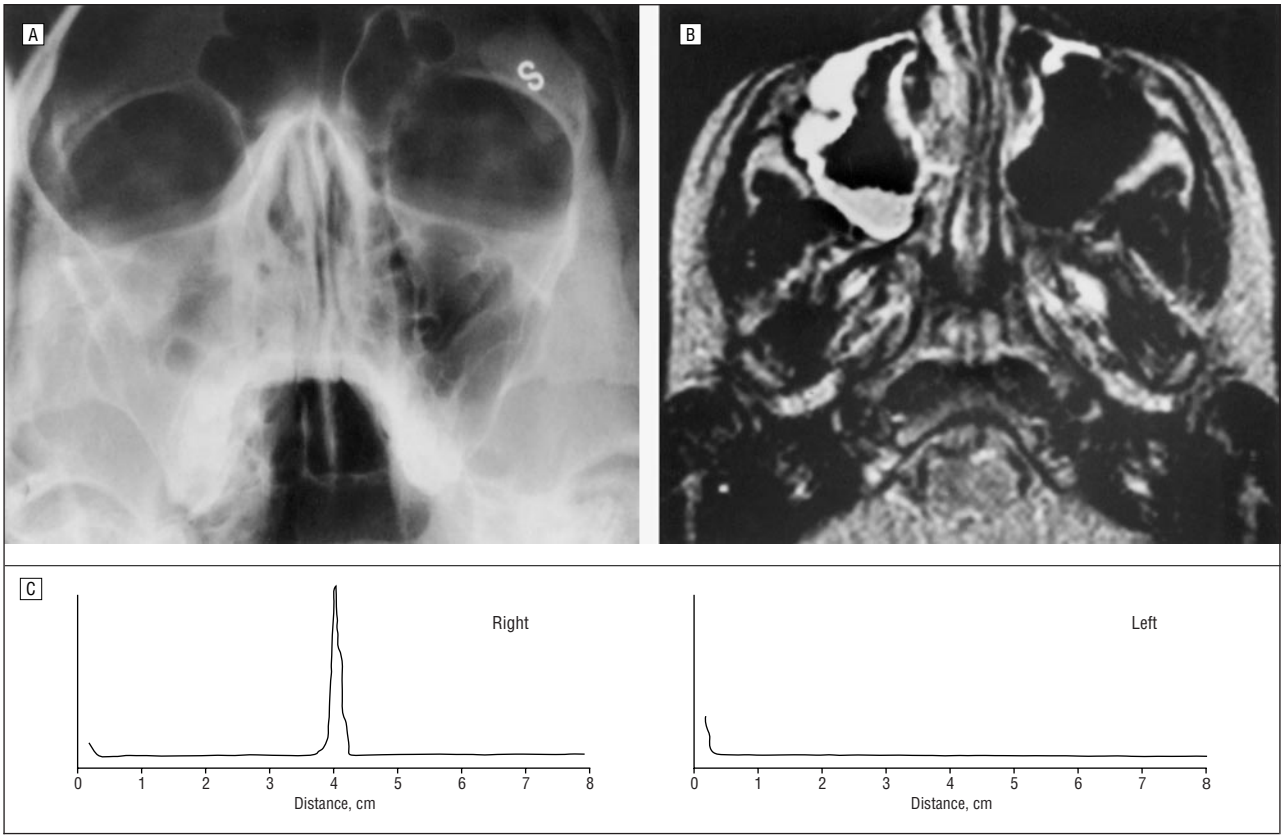
	Ultrasonographic Findings			
Magnetic Resonance Imaging Findings	Fluid	Mucosal Thickening	Cyst or Polyp	Normal
Sinusitis	**6**	**8**	**0**	**8**
Air-fluid level (height, mean ± SD, mm)	3 (15 ± 10)	6 (12 ± 9)	0	4 (7 ± 2)
Mucosal thickening >5 mm	3	2	0	4
No sinusitis	**0**	**3**	**0**	**55**
Mucosal thickening of 1-5 mm	0	1	0	20
Cyst or polyp	0	0	0	3
Normal	0	2	0	32

COMMENT

In everyday clinical practice, the diagnosis of acute maxillary sinusitis is usually based on the signs and symptoms of the patient, although these have been shown to be unreliable in differentiation between acute sinusitis and the common cold.[2-4] As a consequence, it is likely that a substantial proportion of patients with sinus complaints receive antibiotics for a simple viral respiratory tract infection. Considering the alarming global threat of increasing antimicrobial resistance of bacteria,[18] it is clear that any unnecessary use of antibiotics should be avoided. If sinusitis could be diagnosed using a simple, rapid, and readily available imaging method such as ultrasonography, unnecessary antibiotic treatment could be remarkably reduced.

The finding of infected secretions by direct sinus puncture is usually considered the gold standard for the diagnosis of maxillary sinusitis,[19] but obviously this is not feasible in primary care. Plain-film radiography is often used in the evaluation of patients with suspected sinusitis, but the limitations of this imaging method have also been demonstrated. Agreement between the rates of abnormalities in standard radiographs and the presence of secretions obtained by sinus aspiration has shown considerable variation in several clinical studies.[15,16,20] Furthermore, in addition to other disadvantages of radiography, the interpretation of sinus films might not always be simple. In our study, in 1 of 6 sinuses, the 3 radiologists disagreed about whether the radiological findings were indicative of sinusitis, and one could assume that the situation would not be any better among nonradiologists.

Although computed tomography visualizes the bony structures better than MRI and is thus mainly used in the preoperative evaluation of patients with chronic sinusitis, MRI is superior to computed tomography in determining mucosal changes because of the improved soft tissue contrast resolution and tissue characterization.[11,12] Because even mild abnormalities of the maxillary mucosa can be easily detected by MRI, indiscriminate interpretation of the images might lead to



Findings obtained using the 3 imaging methods on day 7 from a 23-year-old woman. A, Radiograph shows mucosal thickening exceeding 5 mm in the right maxillary sinus and no abnormalities in the left sinus. B, Magnetic resonance image shows a 6-mm mucosal thickening and an air-fluid level of 7 mm in the right sinus and minimal mucosal thickening on the left side. C, Ultrasound shows an echo at a distance of 4.0 cm in the right sinus and no echo on the left side.

Table 4. Comparison of Radiography With Magnetic Resonance Imaging in Detection of Maxillary Sinusitis in 80 Sinuses

	Radiographic Findings					
	Sinusitis			No Sinusitis		
Magnetic Resonance Imaging Findings	Air-Fluid Level	Total Opacity	Mucosal Thickening >5 mm	Mucosal Thickening of 1-5 mm	Cyst or Polyp	Normal
Sinusitis	**4**	**2**	**10**	**3**	**2**	**1**
Air-fluid level	1	2	6	2	2	0
Mucosal thickening >5 mm	3	0	4	1	0	1
No sinusitis	**0**	**0**	**0**	**5**	**0**	**53**
Mucosal thickening of 1-5 mm	0	0	0	4	0	17
Cyst or polyp	0	0	0	0	0	3
Normal	0	0	0	1	0	33

overdiagnosis of sinusitis.[17,21] Therefore, in the present study we only considered mucosal thickening exceeding 5 mm as an indication of sinusitis by MRI.

In previous studies[5-10] comparing ultrasonography with radiography in the detection of maxillary sinusitis, the sensitivity of ultrasound ranged from 32% to 99% and the specificity ranged from 61% to 100%. The comparability of these studies, however, is limited because of extensive methodological variation. In addition, the exact criteria used for diagnosing sinusitis by ultrasonography and radiography were reported in only 2 of these studies.[8,9]

Conventionally, only ultrasound findings indicative of the presence of fluid in the sinus (echo, >3.5-4.0 cm) have been interpreted as maxillary sinusitis.[8,9,14] In radiological imaging, however, considerable mucosal thickening even in the absence of an air-fluid level is generally regarded as evidence of sinusitis.[8,9,19,22] Because of this discrepancy, it is not surprising that most studies yielded low sensitivity of ultrasonography for detection of maxillary sinusitis. Although precise measurement of mucosal thickening is difficult using ultrasonography, the correlation between ultrasonographic and radiographic estimation of the degree of mucosal thickening has been documented.[14] In an attempt to make the diagnostic criteria similar for all imaging methods, we estimated that an ultrasound echo 1.0 cm from the skin would represent a mucosal thickening of approximately 5 mm. When

Table 5. Detailed Findings From the Different Imaging Methods in the 6 MRI-Positive Sinuses With Negative Radiographic Findings*

Sinus No.	MRI	Radiography	Ultrasonography
1	20-mm air-fluid level	Polyp	Mucosal thickening
2	5-mm air-fluid level and 18-mm mucosal thickening	Mucosal thickening of 1-5 mm	Mucosal thickening
3	10-mm mucosal thickening	Normal	Normal
4	8-mm mucosal thickening	Mucosal thickening of 1-5 mm	Normal
5	7-mm air-fluid level and 8-mm mucosal thickening	Polyp	Normal
6	7-mm air-fluid level and 7-mm mucosal thickening	Mucosal thickening of 1-5 mm	Mucosal thickening

*MRI indicates magnetic resonance imaging.

Table 6. Sensitivity and Specificity of Various Approaches Using Ultrasonography or Radiography in Detection of Maxillary Sinusitis Compared With Magnetic Resonance Imaging in 80 Sinuses

Imaging Method	Sensitivity, %	Specificity, %
Ultrasonography alone	64	95
Radiography alone	73	100
First ultrasonography, then radiography if ultrasound findings are negative	86	95
First radiography, then ultrasonography if radiographic findings are negative	86	95
Both ultrasonography and radiography in all cases	86	95

all ultrasound echoes observed at a distance of 1.1 cm or more were regarded as an indication of sinusitis, the sensitivity of ultrasonography increased considerably without a substantial loss in specificity compared with MRI findings.

Our results suggest a potentially significant role for ultrasonography in the diagnosis of maxillary sinusitis in the primary care setting. Because ultrasonography rarely yields false-positive results, a positive ultrasound finding (echo, ≥1.1 cm) can be regarded as evidence of maxillary sinusitis. In cases in which ultrasound findings remain negative but there is still a strong clinical suspicion of sinusitis, a single radiograph should suffice to confirm or rule out maxillary sinusitis. The results of the present study suggest that such a 2-step diagnostic approach is adequately sensitive and specific for detecting maxillary sinusitis in clinical practice. Use of this method would substantially reduce the need for radiography, with subsequent benefits in terms of time, costs, and the use of ionizing radiation. We conclude that ultrasonography seems to provide a simple, convenient, and useful method to aid in diagnosing maxillary sinusitis in primary care, and active use of this method could also prove valuable for reduction of unnecessary antibiotic treatment.

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