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Original Article

Efficacy of sinus ultrasound in diagnosis of acute and subacute maxillary sinusitis

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Abstract

Background: The aim of this study was to evaluate the diagnostic efficacy of sinus ultrasound for acute and subacute maxillary sinusitis (ASMS) by investigating the agreement between different tools. We also proposed a confirmatory tool directed protocol for adult acute sinusitis, to enhance diagnostic accuracy.
Methods: This prospective cohort study enrolled patients who were older than 18 years, with a diagnosis of maxillary sinusitis. The duration of symptoms was confined to less than 12 weeks. Rigid nasal endoscopy, sinus ultrasound, and plain sinus film were performed for all patients on the same day to confirm the diagnosis. Kappa statistics were used to test interrater reliability.
Results: A total of 148 maxillary sinuses in 74 patients (38 men, 36 women) were evaluated. Sinus ultrasound and rigid nasal endoscopy disclosed the best agreement (agreement = 0.78, $\kappa = 0.556$). The agreement of rigid nasal endoscopy and plain sinus film was relatively poor (agreement = 0.72, $\kappa = 0.446$). Sinus ultrasound and plain sinus film had the poorest diagnostic consistency (agreement = 0.67, $\kappa = 0.338$).
Conclusion: Sinus ultrasound is a quick, safe, cost effective, and relatively easy-to-use technique for clinicians to evaluate the maxillary sinus. Sinus ultrasound and rigid nasal endoscopy are complementary tests to confirm the diagnosis of ASMS.

Keywords: Acute and subacute maxillary sinusitis; Plain sinus film; Rigid nasal endoscope; Sinus computed tomography; Sinus ultrasound

1. Introduction

Rhinosinusitis, one of the most common health concerns in the United States, results in over 30 million annual diagnoses.[1] In Taiwan, rhinosinusitis affects about 15%–20% of the population every year, creating cost-ineffective expenses for the National Health Insurance, and reducing job effectiveness and quality of life.[2]

According to the 2015 American Academy of Otolaryngology—Head and Neck Surgery Foundation (AAO-HNS) guidelines, rhinosinusitis is defined as symptomatic inflammation of the paranasal sinuses and nasal cavity.[1] Rhinosinusitis is classified by duration: acute rhinosinusitis (ARS) if lasting less than 4 weeks' or chronic rhinosinusitis (CRS) if lasting more than 12 weeks. Some authors classify rhinosinusitis lasting 4–12 weeks as subacute rhinosinusitis, while others define durations of up to 12 weeks as ARS. The most common type of ARS is acute viral rhinosinusitis (AVRS), a self-limited disease; however, initially, it may be indistinguishable from acute bacterial rhinosinusitis (ABRS). The difference between their clinical courses is that AVRS

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symptoms usually resolve within 10 days but ABRS symptoms persist for 10 days or more.[1]

Currently, the diagnosis of ARS is based on clinical presentation and duration according to the 2015 AAO-HNS guideline: purulent (not clear) nasal drainage accompanied with nasal obstruction, facial pain-pressure-fullness, or both within 4 weeks. This diagnosis can be supported by confirmatory physical findings and image examinations. In 2012, the European position paper on rhinosinusitis and nasal polyps (EPOS) stated that endoscopic signs of 1. mucopurulent discharge primarily from middle meatus and/or edema/mucosal obstruction primarily in the middle meatus and/or 2. computed tomography (CT) changes: mucosal changes within the ostiomeatal complex and/or sinuses can confirm the diagnosis of rhinosinusitis.[3]

Despite rhinosinusitis being one of the most common health concerns, an accurate and cost-effective method to diagnose ARS, especially the ASMS is yet to be established. Sinus puncture was thought to be the gold standard method for diagnosis,[4] but not every patient can tolerate the invasive procedure. Thus, serial studies were proposed to evaluate the diagnostic efficacy of clinical examination, rigid nasal endoscopy, ultrasound, plain sinus film, and computed tomography.[5–10] Rigid nasal endoscopy is a widely accepted minimally invasive procedure for the diagnosis of ASMS. It can also extract microbiological data from the middle meatus.[9,10]

Sinus ultrasound is also a readily available method for evaluation of the maxillary sinus.[7] However, previous studies showed extremely variable sensitivity (32%–99%) and specificity (61%–100%) for ultrasound compared to those of radiography or sinus puncture.[5,7]

Presently, no study exists that compares the use of sinus ultrasound with rigid nasal endoscopy in ASMS diagnosis. Our primary aim was to evaluate the diagnostic efficacy of sinus ultrasound by investigating the agreement between different diagnostic tools.

2. Methods

2.1. Patients

This prospective cohort study was approved by the Human Subjects Review Committee of Taipei Veterans General Hospital, Taiwan (2014-01-004CC). A prospective analysis was performed in the Otolaryngology Department of Taipei Veterans General Hospital between January 2013 and December 2014. Adults who were older than 18 years, diagnosed with maxillary sinusitis, and whose duration of symptoms were less than 12 weeks were enrolled in this study. Patients with "suspicious maxillary sinusitis" who at least met one of the three symptoms including purulent nasal drainage (anterior, posterior, or both), nasal obstruction, or facial pain-pressure-fullness were also enrolled.[1] On the same day, physicians conducted rigid nasal endoscopy, sinus ultrasound, and plain sinus film to evaluate each maxillary sinus and establish the definite diagnosis of ASMS. Patients with negative results for both maxillary sinuses by the above three diagnostic tools were excluded from the study. Our institutional review board approved this study and informed consent was obtained from each patient.

2.2. Sinus ultrasound

A-mode ultrasonography of the maxillary sinus was performed using the Sinus Echoscope DIGITAL 5 (Happersberg Otopront GmbH, Hohenstein, Germany) with a frequency of 4.25 MHz and a transducer diameter of 10 mm. The patient's head was positioned in slight flexion and the entire maxillary sinus area was examined by the transducer. The results were classified as fluid (back wall echo present with distance $\geq$ 3.5 cm) or normal (absent back wall echo).

2.3. Rigid nasal endoscopy

All patients underwent rigid nasal endoscopy with a 4 mm 0° telescope. Preparation with 2% xylocaine and 1:5000 parts epinephrine spray was applied for 10 min. During the examination, middle meatal purulent discharge was obtained under endoscopic guidance to minimize contamination, then sent for culture. The appearance, color, viscosity, and site of the nasal discharge were carefully noted. All the procedures were performed by the same experienced rhinolaryngologist.

2.4. Plain sinus film

The plain sinus film consisted of three standard projections (occipitofrontal, occipitomental, and lateral views). The radiographs were then interpreted by radiologists who were blinded to each patients' clinical condition or the results of the other exams. Diagnosis of maxillary sinusitis was concluded through total opacity or air-fluid level of the maxillary sinuses.

2.5. Statistical analysis

Descriptive statistics were performed on all variables of interest. The diagnostic tools were classified into three groups (A, sinus ultrasound and rigid nasal endoscopy; B, plain sinus film and rigid nasal endoscopy; C, sinus ultrasound and plain sinus film). The agreements of presence of sinusitis in each maxillary sinus were analyzed using Kappa statistics, which were then used to test interrater reliability. Statistical analysis was performed using SPSS 21.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Baseline characteristics

The characteristics of the study population are summarized in Table 1. A total of 74 patients, 38 men and 36 women, were enrolled in this study. A total of 148 sinuses (74 right maxillary sinuses and 74 left maxillary sinuses) were evaluated. The mean age of the patients was 49.3 $\pm$ 16.5 years (range, 18–84

Table 1
Clinical characteristics of the study population at diagnosis of acute and subacute maxillary sinusitis.

Characteristics		Overall (N = 148)[a]
Age, mean (standard deviation), y		49.3 (16.5)
Sex, No. (%)		
Male		72 (48.6)
Female		76 (51.4)
Duration, mean (standard deviation), d		17.9 (20.3)
Symptoms, No. (%)		
Ant. Rhinorrhea	Yes	126 (85.1)
	No	22 (14.9)
Nasal obstruction	Yes	72 (48.6)
	No	76 (51.4)
Postnasal drip	Yes	56 (37.8)
	No	92 (62.2)
Facial pressure	Yes	28 (18.9)
	No	120 (81.1)
Loss of smell	Yes	12 (8.1)
	No	136 (91.9)

[a] Include 74 patients with total 148 maxillary sinuses.

years). The mean duration of ASMS symptoms was 17.9 ± 20.3 days prior to visiting our hospital. The most common symptoms were anterior purulent nasal discharge in 63 patients (85.1%), nasal obstruction in 36 patients (48.6%), postnasal dripping in 28 patients (37.8%), facial pressure in 14 patients (18.9%), and loss of smell in 6 patients (8.1%). Among the 74 patients diagnosed with ASMS, 69 patients (93.2%) were diagnosed using rigid nasal endoscopy, 58 patients (78.4%) were diagnosed using sinus ultrasound, and 56 patients (75.6%) were diagnosed using sinus plain film (Table 2).

3.2. Data analysis

The agreement between sinus ultrasound and rigid nasal endoscopy in the diagnosis of sinusitis of each maxillary sinus was analyzed, resulting in a kappa value of 0.556 (agreement = 0.78, $\kappa = 0.556$, n = 148), indicating moderate agreement. On the other hand, the agreement between rigid nasal endoscopy and plain sinus film resulted in a kappa value of 0.446 (agreement = 0.72, $\kappa = 0.446$, n = 148), indicating relatively poor agreement. Sinus ultrasound and plain sinus film had the poorest agreement, with a kappa value of 0.338 (agreement = 0.67, $\kappa = 0.338$, n = 148). (Table 3).

Table 2
Acute and subacute maxillary sinusitis diagnostic rate by different tools.

Sinusitis characteristics	Diagnostic tool, No. (%)		
	Rigid nasal endoscopy	Sinus ultrasound	Plain film
Bilateral maxillary sinusitis	26 (17.6)	23 (15.5)	18 (12.2)
Left maxillary sinusitis	17 (11.5)	15 (10.1)	15 (11.1)
Right maxillary sinusitis	26 (17.6)	20 (13.5)	23 (15.5)
No maxillary sinusitis	5 (3.4)	16 (10.8)	18 (12.2)
Total maxillary sinusitis	69 (93.2)	58 (78.4)	56 (75.6)

Table 3
Kappa statistics between diagnostic tools.

Measures	Kappa (κ) statistic	
	Agreement	κ
Sinus ultrasound		
Rigid nasal endoscopy	0.78	0.556
Plain film		
Rigid nasal endoscopy	0.72	0.446
Sinus ultrasound		
Plain film	0.67	0.338

4. Discussion

Establishing accurate and prompt diagnoses of acute sinusitis is currently challenging. Misdiagnosis leads to suboptimal clinical outcomes such as chronic sinusitis and sinusitis complications. Therefore, reliable diagnostic tests are vital in allowing clinicians to provide more cost-effective treatments for patients.

Guidelines propose that the diagnosis of ARS should be based on purulent nasal drainage (anterior, posterior, or both) accompanied by nasal obstruction, facial pain-pressure-fullness, or both. Other nonspecific symptoms include headache, fever, fatigue, maxillary dental pain, cough, hyposmia or anosmia, and ear pressure or fullness. In diagnosing ARS by symptoms, purulent rhinorrhea has a sensitivity of 72% and a specificity of 52%; facial pressure has a sensitivity of 52% and a specificity of 48%; and nasal obstruction has a sensitivity of 41% and a specificity of 80%.[11] In cases when symptoms alone cannot effectively diagnose ARS, confirmatory diagnosis techniques such as sinus puncture, rigid nasal endoscopy, sinus ultrasound, or sinus CT can be used to establish a proper diagnosis.

In the past, sinus puncture and aspiration were thought to be the gold standard procedure in diagnosing maxillary sinusitis as purulent secretions can provide direct evidence for sinus inflammation. However, clinical use of sinus puncture and irrigation gradually decreased and was eventually replaced by other diagnostic tools because it was time consuming and invasive with risk of complications.[9,10] Some studies have investigated the appropriate diagnostic tests for maxillary sinusitis using sinus puncture or radiography as reference. 5–8 However, the lack of standard and accurate reference tests and methodological problems in these studies make it difficult to use a single modality to evaluate the maxillary sinus.

Rigid nasal endoscopy is a minimally invasive procedure that allows for direct examination of the sinus ostia. In diagnosing maxillary sinusitis, endoscopically directed middle meatal cultures provide an accurate representation of the microbiological pathogen. In a meta-analysis comparing the pooled data for known pathogenic bacteria using sinus puncture with endoscopically directed middle meatal culture, the latter recorded an overall accuracy of 87.0%, sensitivity of 80.9%, specificity of 90.5%, positive predictive value of 82.6%, and negative predictive value of 89.4%.[9] Our study also shows the highest diagnostic rate (93.2%) of ASMS using

rigid nasal endoscopy. The advantages of rigid nasal endoscopy include minimal invasiveness and a direct, detailed visualization of sinonasal conditions and yield more pathogenic organisms for culture. Therefore, rigid nasal endoscopy has become a reliable alternative to sinus puncture and a preferred method for identifying maxillary sinusitis microbiological information. However, it is not yet widely utilized by general practitioners and cannot be applied to specific populations (children, elderly, anxious patients and patients with severe deviated nasal septum or hypertrophic turbinate). In case of neoplastic or inflammatory diseases confined in the paranasal sinuses (odontogenic sinusitis, retention cyst, or polyp), ostiomeatal complex may reveal normal appearance, making it challenging to evaluate using nasal endoscope.

The plain sinus film is a simple radiographic tool that consists of three standard projections (occipitofrontal, occipitomental, and lateral projections) used to evaluate paranasal sinuses, specifically maxillary sinuses. Indications of sinusitis include complete opacification of the sinus or the presence of an air-fluid level. Mucosal thickening does not indicate sinusitis, because it can be observed in asymptomatic patients with viral upper respiratory tract infections.[12] According to the AAO-HNS guidelines, the plain sinus film is unnecessary for diagnosis in patients who already meet clinical diagnostic criteria for ARS.[1] In addition, the American College of Radiology (ACR) revealed a high percentage of inaccurate diagnosis of sinusitis using plain sinus film. A systematic review showed that in diagnosing ARS, sinus plain film has variable sensitivity and specificity compared to sinus puncture.[5] In our study, among the 74 patients with clinical diagnosis of ASMS, only 56 patients (75.6%) were diagnosed using sinus plain film. In addition, plain sinus film has weak diagnostic consistency with sinus ultrasound (agreement = 0.67, κ = 0.338) and rigid nasal endoscopy (agreement = 0.72, κ = 0.446). Due to its many limitations, plain sinus film is not recommended as a routine diagnostic tool. Plain sinus radiography is only utilized when signs or symptoms are unilateral or inconsistent among clinical symptoms, rigid nasal endoscopy, and sinus ultrasound.

Computed tomography has often been used as standard reference in studies for the diagnosis of rhinosinusitis because it can offer complete bony and soft tissue detail in all paranasal sinuses. The results of opacification and air-fluid level are correlated with ARS.[1] There are also a range of staging systems with varying complexity based on the CT scan findings.[1] The EPOS 2012 also suggested CT changes due to mucosal changes within the ostiomeatal complex and/or sinuses can suggest rhinosinusitis. False-positives, however are highly prevalent. Patients with the common cold or even nonsymptomatic patients may cause the CT scan to give abnormal results.[13] Incidental findings include mucosal thickening, polyp, and other anatomic anomalies. Sinus CT is taken only when acute sinusitis is observed with severe headache, facial swelling, cranial nerve palsies, or orbital swelling. In short, it should be reserved for cases of diagnostic doubt.

Sinus ultrasound is a simple, quick, readily available tool that is widely used clinically to diagnose maxillary sinusitis. In clinical interpretation of A-mode ultrasound, the air-mucosa echo (AME) is the first real echo. The front wall echo (FWE) is clearly detectable if there is no fluid in the maxillary sinus. The back-wall echo (BWE) is a single prominent echo at a distance of $\geq$3.5 cm in adults that represents fluid in the maxillary sinus. BWE is observed by an echo-free area of at least half or 1/3 of the distance from the initial echo to the BWE. The presence of a BWE is a sign of secretion accumulated in the maxillary sinus, which implies a diagnosis of maxillary sinusitis.[14,15] Some authors define the area of FWE 1.5–3.0 cm as mucosal swelling, but it is still controversial. Presently, there is no conclusive criteria or guideline for diagnosis of maxillary sinusitis using A-mode ultrasound due to heterogeneous results of various studies. A systematic review including studies from 1980 to 1998 assessing the efficacy of ultrasound in comparison to sinus puncture revealed that sensitivity ranged from 54% to 94%, and specificity ranged from 53% to 94%.[5] The sensitivity of ultrasonography compared to radiography varied from 32% to 99% and specificity varied from 61% to 100%.[7] The literature review offered inconclusive information about the accuracy of ultrasonography diagnosis in patients with maxillary sinusitis. The extremely large variability of accuracy in studies may arise from differences in patient populations, ultrasound techniques, methodological problems, untrained medical personnel, or different interpretation of ultrasound results by examiners.[8]

The lack of a good reference method is one of the major problems in evaluating the accuracy of a diagnostic tool. With the development of rigid nasal endoscopy, rhinosinusitis has become increasingly diagnosed according to the presence of mucopurulence from the sinus ostia. Moreover, previous studies show a strong correlation in microbiologic results between middle meatal culture and maxillary sinus puncture. Therefore, rigid nasal endoscopy is considered the confirmatory method for diagnosing maxillary sinusitis and may replace sinus puncture. As a result, we used rigid nasal endoscopy as reference to confirm the efficacy of the ultrasound and plain film in diagnosing ASMS. This is the first study to compare three diagnostic techniques using Kappa statistics in accordance with presence of sinusitis in each maxillary sinus. In our data, we found moderate agreement between rigid nasal endoscopy and sinus ultrasound (agreement = 0.78, κ = 0.556, n = 148). The ultrasound offers reliable data to support the diagnosis of ASMS. The A-mode ultrasound can be utilized in patients who cannot tolerate the rigid nasal endoscopy procedure (e.g., children or anxious, bed-ridden, or uncooperative patients with fear of invasive procedures). Ultrasound can also easily be used for follow-up treatment response. For patients with severe deviated nasal septum or hypertrophic turbinates, the scope may easily cause nasal mucosal trauma. Thus, we can choose ultrasound to evaluate their maxillary sinuses.

In a case with suspicious symptoms of ASMS, we can apply several tools to establish the diagnosis. We showed three representative cases, which were diagnosed by different

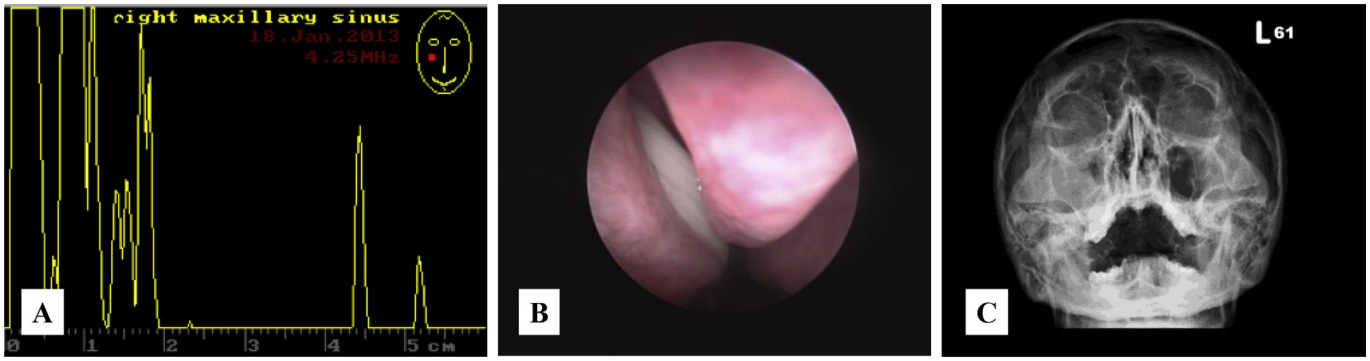

Fig. 1. A 39-year-old male presented with symptoms of rhinosinusitis for 4 days. (A) Sinus ultrasound detected fluid in right maxillary sinus, (B) rigid nasal endoscopy disclosed mucopus from right middle meatus, and (C) plain film found total opacity of right maxillary sinus. All exams supported the diagnosis of acute maxillary sinusitis.

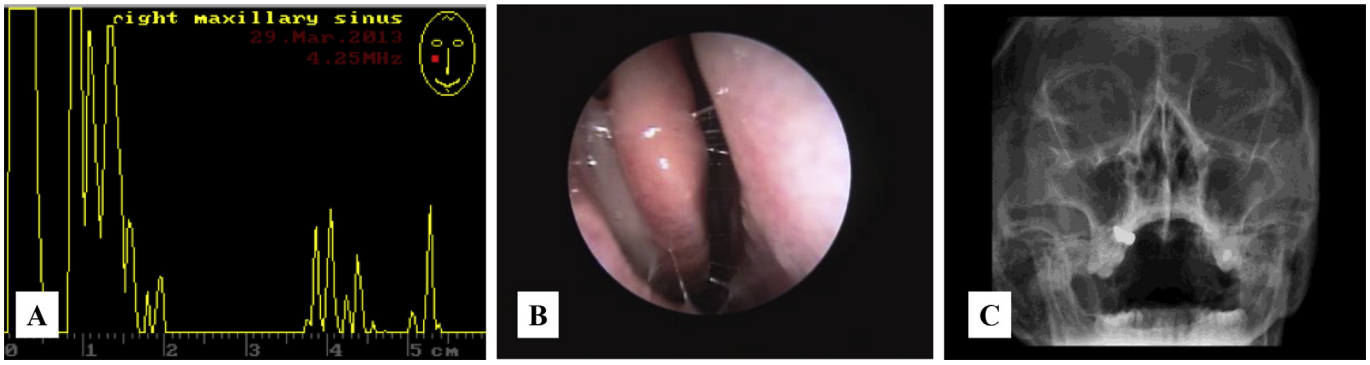

Fig. 2. A 74-year-old female had symptoms of rhinosinusitis lasting about 1 week. (A) Sinus ultrasound detected fluid in right maxillary sinus, (B) rigid nasal endoscopy showed mucopus from right middle meatus, but (C) plain film had no evidence of right maxillary sinusitis.

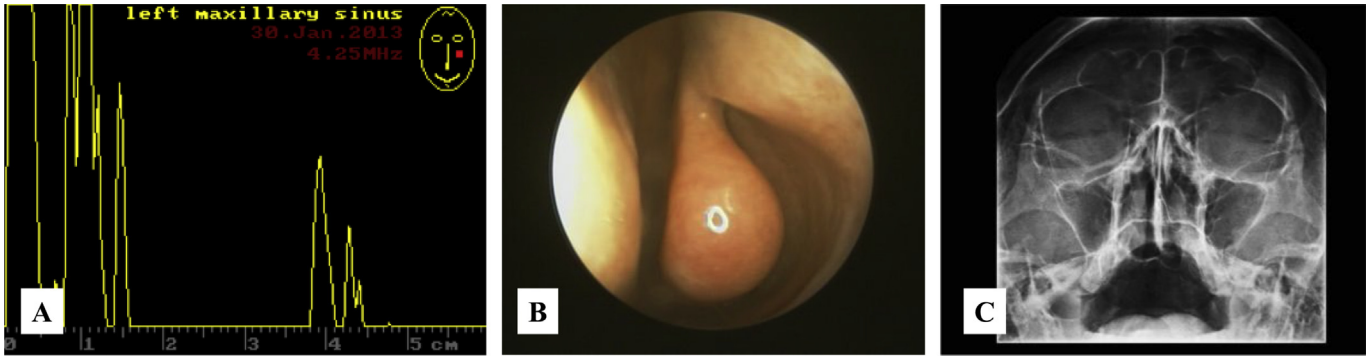

Fig. 3. A 77-year-old female patient with symptoms of rhinosinusitis for 1 day. (A) Sinus ultrasound detected fluid in left maxillary sinus, but (B) rigid nasal endoscope and (C) plain film had no evidence of maxillary sinusitis. Endoscope still has limitations and ultrasound could be a complementary tool for diagnosing acute maxillary sinusitis.

methods (Figs. 1–3). The results of the tests sometimes have no consistent explanation for maxillary sinus, which was because of strengths and limitations of each methods. Therefore, we proposed an algorithm using confirmatory exams to efficiently diagnose and manage ARS. The modified algorithm in accordance with AAO clinical practice guideline for adult sinusitis is illustrated in Fig. 4.[1] The initial evaluation for ARS is to distinguish between AVRS and ABRS after a patient meets the criteria for ARS. For a patient with symptoms or signs of ARS persisting for less than 10 days or with symptoms that are not worsening, AVRS should be considered. Sinus ultrasound or rigid nasal endoscopy can be used to confirm the maxillary sinusitis with good correlation and accuracy. Management of AVRS is directed primarily to symptomatic relief and avoiding unnecessary antibiotics. For patients with symptoms or signs persisting for at least 10 days

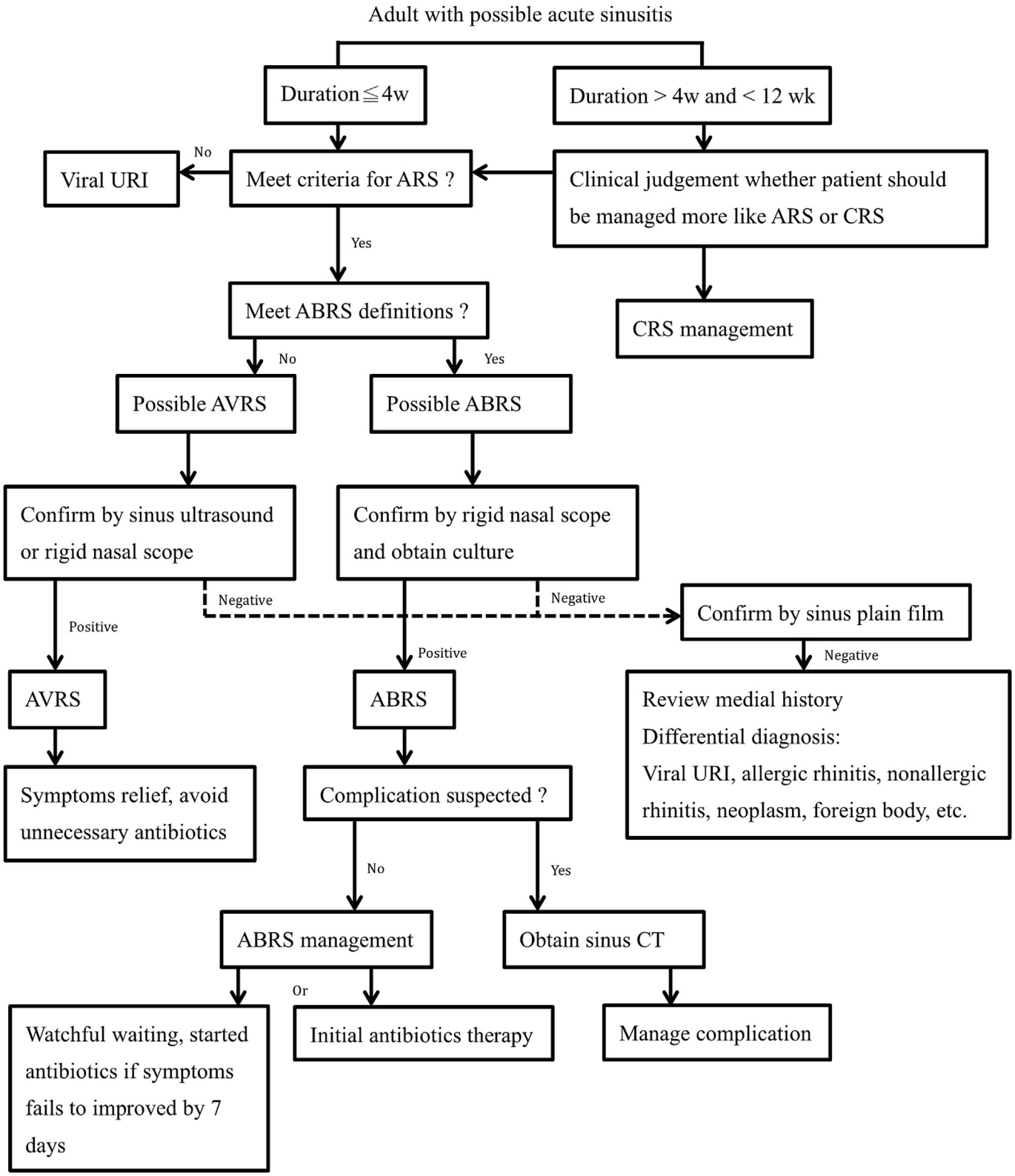

Fig. 4. Algorithm for the management of adult acute sinusitis using confirmatory methods. ARS = acute rhinosinusitis; ABRS = acute bacterial rhinosinusitis; AVRS = acute viral rhinosinusitis; CRS = chronic rhinosinusitis; URI = upper respiratory tract infection.

or with worsening symptoms within 10 days after an initial improvement (double worsening), ABRS should be highly suspected. Rigid nasal endoscopy should be performed to confirm the diagnosis and middle meatal culture should be obtained. According to the guideline, clinicians should offer watchful waiting or prescribe broad-spectrum antibiotics for adults with uncomplicated ABRS. Antibiotic treatment is required if the patient's condition fails to improve 7 days after diagnosis of ABRS.

In conclusion, sinus ultrasound is a quick, safe, cost effective, and easily performed technique that can be used by general practitioners after training. In our data, the information from sinus ultrasound and rigid nasal endoscopy is consistent in ASMS. Both methods are complementary tests to confirm the diagnosis.

Acknowledgments

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