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ORIGINAL ARTICLE

Predictors of nasal bacterial culture rates in patients with chronic rhinosinusitis

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Abstract

All nontechnical factors were analyzed to predict nasal bacterial culture results in patients with chronic rhinosinusitis (CRS). Four hundred and ninety-six CRS patients, who underwent functional endoscopic sinus surgery (FESS), were enrolled. Prior to FESS, the severity of each patient's CRS was evaluated using a questionnaire, endoscopic examination, acoustic rhinometry, smell test, saccharine transit test, and CT scan. Nasal bacterial cultures were collected from both middle meati using a cotton-tipped stick. Our results showed that the symptom severity complained of by patients and their loss of smell function did not influence the bacterial culture rate. We discovered that the bacterial culture rate was significantly higher in nostrils with nasal polyps than those without polyps, along with nostrils experiencing thick, purulent discharge as opposed to those without discharge. Additionally, this result also occurred in nostrils with a saccharin transit time of more than 30 min than it did in those with a saccharin transit time of less than or equal to 30 min. Both the total endoscopic score and anterior group CT score were significantly higher in nostrils with positive culture than those with negative culture, while the second minimal cross-sectional area (MCA_2) of the nasal cavity was significantly lower in nostrils with positive culture than those with negative culture. Multiple logistic regression analysis showed that both nasal polyps and MCA_2 were the predictors for positive nasal bacterial culture results. It was concluded that nasal polyps and MCA_2 were the predictors for positive nasal bacterial culture results in CRS patients.

Keywords Acoustic rhinometry · Bacterial culture · Chronic rhinosinusitis · Nasal polyps · Predictor

Introduction

Bacterial infection or colonization has been considered as playing an important role in the pathogenesis of chronic rhinosinusitis (CRS) [1, 2]. It has also been shown that CRS patients with negative results from a nasal bacterial culture experienced better surgical outcomes than those with positive results [3]. Many technical factors including sterilizing methods, sampling techniques, and specimen type were found to influence the nasal bacterial culture results in CRS patients [4, 5]. Recently, 16S-sequencing technology has been used to study the microbiome of CRS, which offers the advantages of providing the most detailed information, along with the potential to reveal novel microorganisms in the paranasal sinuses [6, 7].

On the other hand, the interactions between the bacteria themselves, the bacteria and the mucosa, and any environmental changes have been considered as an influence toward the composition of the bacterial ecosystem [7]. Therefore, many other factors will influence the nasal bacterial culture results in CRS

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patients. In this study, we tried attempted to determine which nontechnical factors influenced the nasal bacterial culture results.

Material and methods

Subjects

CRS patients who had previously responded poorly to medical treatment, and subsequently underwent functional endoscopic sinus surgery (FESS), were enrolled in this study between July 2007 and November 2018. The diagnosis of CRS was made based on patient history, nasal endoscopy, and CT of the sinuses [8]. All patients had a history of rhinosinusitis for a period greater than 12 weeks and displayed endoscopic and radiological evidence of nasal inflammation. We excluded patients who were under the age of 20, had a history of immunodeficiency, had previous sinus surgery, or were under antibiotic treatment within a week prior to FESS. Patients with pathological reports indicating fungal sinusitis or a sinonasal tumor were also excluded from the study. This study was approved by the Ethics Committee of Taichung Veterans General Hospital. Written consent was obtained from each patient.

Evaluation of the CRS severity

The sinus CT scan of each patient was scored using the Lund-Mackay staging system [9]. Five sinus groups, the maxillary, anterior ethmoid, posterior ethmoid, sphenoid, and frontal sinuses, were individually graded between 0 and 2 (0, clear sinus; 1, partial opacification; 2, total opacification). The ostiomeatal complex was scored as either 0 (not obstructed) or 2 (obstructed). The CT score was classified into an anterior ethmoid score (range 0–2); an anterior group score which was the sum of the scores of maxillary, anterior ethmoid, and frontal sinuses and the score of ostiomeatal complex (range 0–8), and a total score which was the sum of all the scores of the unilateral sinuses (range 0–12).

Before FESS, all eligible patients completed a questionnaire – the Taiwanese version of the 20-item or 22-item sinonasal outcome test (SNOT) [10, 11]. They also received an endoscopic examination, acoustic rhinometry, smell test, and saccharine transit test, while also having a nasal bacterial culture taken.

The Taiwanese version of the 20-item SNOT is a validated instrument used to assess the rhinosinusitis-specific quality of life [10]. The patient grades each question from 0 to 5 (0 indicating “no problem” and 5 indicating “problem”). The total score will range from 0 to 100. In the later part of the study, the Taiwanese version of the 22-item SNOT was implemented. Two additional items were added to assess both the severity of nasal obstruction and loss of smell or taste. The severity of nasal obstruction and loss of smell or taste was graded by the patient from 0 to 5, as in the 20-item SNOT.

Endoscopic appearances were quantified on a 0–2-point scale according to the staging system of Lund and Mackay [12]. The features included the presence of polyps (0, no polyps; 1, polyps confined to the middle meatus; 2, polyps beyond the middle meatus), discharge (0, no discharge; 1, clear, thin discharge; 2, thick, purulent discharge), and edema. The patient’s total endoscopic score was determined by the sum of all the scores of the unilateral endoscopic findings (range 0–6). Based upon the endoscopic findings, the unilateral nasal cavities were classified into CRS as those with or without nasal polyps, and nostrils with thick, purulent discharge, those with clear, thin discharge, or those without discharge. The second minimal cross-sectional area (MCA_2) of the nasal cavity was measured using acoustic rhinometry. The smell function was evaluated by the birhinal phenyl ethyl alcohol (PEA) odor detection threshold test, along with a traditional Chinese version of the University of Pennsylvania smell identification test (UPSIT-TC) (Sensonics Inc., Haddon Heights, NJ) [13]. The saccharine transit test was performed by placing saccharine granules under the head of the inferior turbinate in the nostril which was experiencing more severe disease. The time was recorded from the placement of the particle to the first perception of a saccharine sweet taste. If patients did not perceive a sweet taste within 30 min after placement of the saccharin particle, the saccharin transit time was recorded as being more than 30 min.

Nasal bacterial culture

Bacterial cultures were collected from swab samples obtained from both middle meati using a cotton-tipped stick. The sticks were then placed in Thanswab tubes containing 5 ml of Amies charcoal medium used for culture of aerobes and anaerobes, prior to the tubes being sent to the clinical microbiology laboratory. On arrival at the laboratory, the swabs from the sticks in the Thanswab tubes were brushed on 5% sheep blood, eosin methylene blue, and chocolate agar plates. The plates were then incubated in a CO_2 (5%) incubator at 35 °C for 2 and 4 days. A Brucella anaerobic blood agar was inoculated for anaerobes and subsequently incubated in the Form anaerobic system for 2 and 4 days. The specimens were then placed into a thioglycolate broth tube for the enrichment of anaerobes and incubated at 35 °C for 2 days. All isolates were routinely examined and identified in the laboratory, including checking for aerobic and facultative bacteria and anaerobes. A culture result was reported as being positive if any aerobic and facultative bacterium or/and anaerobe grew and was considered negative if neither aerobic and facultative bacterium nor anaerobe grew. The bacterial culture rate was calculated as the number of specimens with positive culture divided by the number of all specimens.

Statistics

All data is presented as mean ± standard deviation. The bacterial culture rate was compared between males and females, between nostrils with and without nasal polyps, and between nostrils with a saccharin transit time less than or equal to 30 min, along with those with a saccharin transit time of more than 30 min using the Pearson's chi-squared test. The results of the bacterial cultures were compared among the age of patients, SNOT scores, nasal obstruction scores, smell threshold, UPSIT-TC score, and score for loss of smell or taste using the Kruskal Wallis test. The total endoscopic score, endoscopic score for discharge (0, no discharge; 1, clear, thin discharge; 2, thick, purulent discharge), MCA_2, and CT scores (anterior ethmoid score, anterior group score, total score) were compared between nostrils with positive culture and those with negative culture using the Mann-Whitney U test. The total endoscopic score, endoscopic score for discharge, MCA_2, and CT scores (anterior ethmoid score, anterior group score, total score) were compared between nostrils with and without nasal polyps using the Mann-Whitney U test. The MCA_2 was correlated using the total endoscopic score, endoscopic score for discharge, and anterior group CT score using Spearman's rank correlation coefficients. Logistic regression was used to analyze the predictors of nasal bacterial culture rates. Two-tailed p values < 0.05 were considered statistically significant. All analyses were performed using SPSS Version 17.0 (SPSS Inc., Chicago, IL, USA).

Results

Four hundred and ninety-six CRS patients were enrolled in the study, with 992 swab specimens collected from bilateral middle meati. There were 174 females and 322 males. The mean age was 45.6 years, with a range from 20 to 84 years of age. Among the 992 specimens, bacteria grew in 343 (34.58%), with 408 isolates of bacteria (Table 1).

When the predictors of nasal bacterial culture rates in patients were measured, the results of bacterial culture were classified into positive culture results in both nostrils, a positive culture result in either nostrils, or negative culture results in both nostrils for the purpose of comparison. Table 2 shows the comparison of age and gender, SNOT score, nasal obstruction score, smell threshold, UPSIT-TC score, and score of loss of smell or taste among these three groups of culture results. With the exception of the UPSIT-TC score, there was no significant difference among these three groups of culture for any other indicators. The UPSIT-TC score was significantly higher in patients with positive culture result in either nostril than it was for those with positive culture results in both nostrils ($p = 0.002$; Dunn-Bonferroni test).

Table 1 Bacteriology of chronic rhinosinusitis (992*)

Species	No. of isolates
Aerobic and facultative bacteria	
Gram-positive	
Staphylococcus aureus	86
Coagulase-negative staphylococci	78
Staphylococcus not aureus	2
Staphylococcus sciuri	1
Staphylococcus epidermidis	1
Corynebacterium spp.	19
Corynebacterium pseudodiphtheriticum	2
Streptococcus pneumoniae	12
Streptococcus viridans	1
Group B streptococcus	1
Moraxella catarrhalis	8
Gram-positive bacillus	2
Gram-positive coccus	1
Gram-negative	
Citrobacter koseri	30
Citrobacter freundii	4
Klebsiella pneumonia	17
Klebsiella oxytoca	2
Haemophilus influenza	14
Enterobacter aerogenes	12
Enterobacter cloacae	6
Escherichia coli	9
Escherichia vulneris	1
Pseudomonas aeruginosa	8
Pseudomonas oryzihabitans	1
Pseudomonas spp.	2
Shewanella algae	4
Proteus vulgaris	2
Proteus mirabilis	3
Bacillus spp.	2
Acinetobacter baumannii	2
Serratia marcescens	2
Pantoea agglomerans	2
Nonfermenting gram-negative bacillus	6
Flavobacterium spp.	1
Aeromonas hydrophila	1
Total aerobic and facultative bacteria	345
Anaerobic bacteria	
Gram-positive	
Propionibacterium acnes	18
Propionibacterium granulosum	2
Propionibacterium spp.	3
Peptostreptococcus magnus	9
Peptostreptococcus micros	6
Peptostreptococcus anaerobius	5
Clostridium sordellii	2
Streptococcus constellatus	1

Table 1 (continued)

Species	No. of isolates
Gemella morbillorum	1
Gram-negative	
Fusobacterium nucleatum	6
Fusobacterium varium	2
Fusobacterium necrophorum	1
Fusobacterium spp.	1
Prevotella intermedia	3
Prevotella spp.	1
Veillonella spp.	2
Total anaerobic bacteria	63
Total bacterial isolates	408

*number of specimens

When the predictors of nasal bacterial culture rates were measured unirhinally, the results of bacterial culture were classified into either positive culture or negative culture. Table 3 shows the comparison of the number of nostrils with or without nasal polyps, endoscopic score, CT score, MCA_2, and saccharin transit time between nostrils with positive culture and those with negative culture. The bacterial culture rate was significantly higher in nostrils with nasal polyps than those without; in nostrils with thick, purulent discharge than those without discharge ($p = 0.049$; chi-squared test); and in nostrils with a saccharin transit time of more than 30 min, but less than 31 min, than it was in those with a saccharin transit time less than or equal to30 min. Both the total endoscopic score and anterior group CT score were significantly higher in nostrils with positive culture than those with negative culture; however MCA_2 was significantly lower in nostrils with positive culture than those with negative culture. The total endoscopic score, endoscopic score for discharge, and CT scores (anterior ethmoid score, anterior group score, total score) were significantly higher for nostrils with nasal polyps than those without; however MCA_2 was not significantly different between nostrils with and without nasal polyps. Furthermore, the MCA_2 was not positively correlated with the total endoscopic score, endoscopic score for discharge, and anterior group CT score.

Logistic regression was used to further analyze the predictors for positive nasal bacterial culture results (Table 4). We found that nostrils with nasal polyps and less MCA_2 possessed the factors predicting a higher nasal bacterial culture rate.

Discussion

The etiology of CRS is multifactorial [14]. Bacterial infection or colonization has been considered as playing an important role in the pathogenesis of CRS [1, 2]. The bacteriology of CRS has been widely investigated. Recently, new techniques such as 16S-sequencing technology have been used to study the bacteriology of CRS [6, 7]. On the other hand, whether CRS itself influences the bacteriology of CRS has been less studied. Our previous studies have found that the bacterial culture rate of the maxillary sinus was not related to the sinoscopic appearance of the maxillary sinus in CPS patients [15]. These studies have also discovered that the bacterial culture rate of the middle meatus was moderately correlated with total CT score [16] and that the bacterial culture rate was higher when swab specimens were taken from the middle meatus where thick, purulent discharge or clear, thin discharge was present than it was from those taken from the middle meatus where no discharge was present [17].

Our present results show that the symptom severity complained of by patients and their loss of smell function did not influence the bacterial culture rate. This implies that a more severe CRS

Table 2 Comparison of the SNOT score, nasal obstruction score, smell threshold, UPSIT-TC score, and score of loss of smell or taste among these three groups regarding culture results

	Negative culture	Positive culture	Positive culture	*P* value
	(right or left)		(right and left)	
Age, years (496)	46.1 ± 13.1** (273)	43.3 ± 12.7 (103)	46.7 ± 14.4 (120)	0.132
Male/female (496*)	173/100	67/36	82/38	0.637
SNOT (407)	34.9 ± 19.9 (220)	35.8 ± 16.0 (86)	37.8 ± 19.7 (101)	0.425
Nasal obstruction (236)	2.9 ± 1.6 (145)	3.2 ± 1.5 (47)	3.3 ± 1.4 (44)	0.281
Smell threshold (477)	−3.5195 ± 2.8970 (257)	−4.04 ± 3.105 (100)	−3.4167 ± 2.8409 (120)	0.355
UPSIT-TC (407)	21.0 ± 8.9 (219)	23.6 ± 8.9 (86)	19.3 ± 8.8 (102)	0.003
Loss of smell or taste (236)	3.1 ± 1.9 (145)	2.7 ± 2.0 (47)	3.0 ± 2.0 (44)	0.608

*number of patients; **mean ± standard deviation; *SNOT* sinonasal outcome test; *UPSIT-TC* Traditional Chinese version of the University of Pennsylvania smell identification test

Table 3 Comparison of the evaluators of CRS severity between negative and positive cultures

	Negative culture (649*)	Positive culture (343)	*P* value
Nasal polyps			< 0.001
With nasal polyps (346)	33.8%**	66.2%	
Without nasal polyps (646)	82.4%	17.6%	
Total endoscopic score (992)	2.8 ± 1.2***	3.0 ± 1.2	0.005
Endoscopic score for discharge			0.042
Thick, purulent discharge (337)	60.8%	39.2%	
Clear, thin discharge (495)	66.5%	33.5%	
No discharge (160)	71.9%	28.1%	
Total CT score (992)	4.5 ± 3.4	4.9 ± 3.5	0.083
Anterior group CT score (992)	3.4 ± 2.5	3.8 ± 2.5	0.029
Anterior ethmoid CT score (992)	0.8 ± 0.7	0.8 ± 0.7	0.456
MCA_2 (992)	0.462 ± 0.272	0.411 ± 0.271	0.002
Saccharin transit time			0.010
≤ 30 min (187)	72.7%	27.3%	
> 30 min (48)	52.1%	47.9%	

*number of nostrils; **bacterial culture rate; ***mean ± standard deviation;

CRS chronic rhinosinusitis; *MCA_2* second minimal cross-sectional area of the nasal cavity

symptom or loss of smell did not mean there was a higher chance of getting bacteria recovered from the middle meatus, although the smell test was not performed unirhinally in this study.

On the other hand, when the CRS severity was evaluated using a nasal endoscopy, CT, acoustic rhinometry, or saccharin transit time, nostrils with positive culture results exhibited a higher endoscopic score, higher anterior group CT score, less MCA_2, and greater chances to accompany with nasal polyps or with thick, purulent discharge while also having a saccharin transit time of more than 30 min. Logistic regression analysis showed that both nasal polyps and MCA_2 were the predictors for positive nasal bacterial culture results.

Our results show that CPS with nasal polyps is a predictor for positive nasal bacterial culture results. Further analysis found that the endoscopic scores for discharge and CT scores were also significantly higher for nostrils with nasal polyps than they were for those without nasal polyps. It seems that CPS with nasal polyps was associated with a higher CRS severity in our patients. When 80% of nasal polyps are eosinophilic in the Western world, it has been reported that eosinophilic polyps are between 20 and 60% in Asia [18]. One study showed that non-eosinophilic CRS with nasal polyps constituted at least half of total Chinese CRS cases involving nasal polyps [19]. This may partly explain why our patients with nasal polyps had a higher nasal bacterial culture rate than those without nasal polyps; however the nasal polyps were not classified into either eosinophilic or non-eosinophilic in this study. Further investigation is still needed in order to clarify this assumption.

MCA_2, which indicates the second minimal cross-sectional area of the nasal cavity measured by acoustic rhinometry, was the other predictor for positive nasal bacterial culture results. Acoustic rhinometry can measure nasal geometry and is usually performed to evaluate the degree of nasal obstruction [20]. When the factor of the anatomic variation is controlled, it reflects the severity of nasal inflammation. In other words, the less MCA_2 there is, the more severe the nasal

Table 4 Logistic regression analyses of predictors of higher nasal bacterial culture rate predictors

	Univariate analysis			Multivariate analysis		
	OR	95% CI	*P* value	OR	95% CI	*P* value
Nasal polyps	9.13	(6.76–12.34)	< 0.001	9.19	(6.79–12.43)	< 0.001
Total endoscopic score	1.15	(1.04–1.28)	0.008			
Endoscopic score for discharge	1.28	(1.06–1.56)	0.012			
Total CT score	1.03	(1.00–1.07)	0.085			
Anterior group CT score	1.06	(1.01–1.12)	0.029			
Anterior ethmoid CT score	1.07	(0.89–1.28)	0.474			
MCA_2	0.49	(0.30–0.81)	0.005	0.47	(0.27–0.83)	0.009

MCA_2 second minimal cross-sectional area of the nasal cavity

inflammation will be. In this study, MCA_2 was not found to be significantly different between nostrils with or without nasal polyps. This indicates that nasal polyps themselves do not influence the severity of inflammation of nasal mucosa. Moreover, the MCA_2 was not positively correlated with a total endoscopic score, endoscopic score for discharge, or anterior group CT score either. This also implies that the severity of sinus inflammation did not correlate with that of nasal inflammation. Therefore, the more inflamed the nasal mucosa is in CRS patients, the higher the chance a patient has to recover bacteria from the middle meatus.

Conclusion

In this study, nontechnical factors were analyzed in order to predict nasal bacterial culture results in CRS patients. It was found that the bacterial culture rate was significantly higher in nostrils with nasal polyps than those without polyps; in nostrils with thick, purulent discharge than those without discharge; and finally in nostrils with a saccharin transit time of more than 30 min than it was in those with a saccharin transit time of less than or equal to 30 min. The total endoscopic score and anterior group CT score were significantly higher in nostrils with positive culture than those with negative culture; however MCA_2 was significantly lower in nostrils with positive culture than those with negative culture. Multiple logistic regression analysis showed that nasal polyps and MCA_2 were the predictors for positive nasal bacterial culture results.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval Ethical approval was achieved from the Ethics Committee of Taichung Veterans General Hospital, Taiwan, and the study was conducted in accordance with the Declaration of Helsinki.

Informed consent Written informed consent was obtained from each patient.

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