Comparative Evaluation of PCR and Conventional Culture Techniques in Detecting Bacterial Pathogens in Sinus Infections: A Prospective Study

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KEYWORDS

PCR,bacterial sinus infections, culture techniques, molecular diagnostics, sensitivity, specificity.

ABSTRACT

Background: Sinus infections, or rhinosinusitis, are a significant public health concern, with bacterial pathogens such as *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis* playing a major role in acute bacterial sinusitis (ABS). The accurate and timely detection of these pathogens is crucial for effective management and antibiotic stewardship. Conventional culture techniques, though widely used, have limitations in sensitivity and turnaround time. Polymerase Chain Reaction (PCR) has emerged as a promising molecular diagnostic tool with higher sensitivity and faster results.

Objective: This study aims to compare the effectiveness of PCR and conventional culture techniques in detecting bacterial pathogens in sinus infections, focusing on sensitivity, specificity, and turnaround time.

Methods: A prospective study was conducted over 12 months across three tertiary care hospitals in Central India. Clinical samples (nasal swabs and sinus aspirates) were collected from 500 patients, with 470 adequate samples analyzed using both culture and PCR methods. Culture identification was performed using standard biochemical techniques, while PCR targeted bacterial 16S rRNA genes for *S. pneumoniae*, *H. influenzae*, and *M. catarrhalis*.

Results: Bacterial pathogens were detected in 58.5% of cases using culture and in 87.6% using PCR. *S. pneumoniae* was the most common pathogen (45.2%), followed by *H. influenzae* (32.8%) and *M. catarrhalis* (21.4%). PCR demonstrated significantly higher sensitivity (96.3%) compared to culture (63.8%), while specificity remained high for both techniques (PCR: 98.7%, Culture: 100%). PCR also provided a much shorter turnaround time (6–8 hours) compared to culture (24–72 hours), facilitating early diagnosis and targeted therapy.

Conclusion: PCR is a highly sensitive and rapid diagnostic tool for detecting bacterial pathogens in sinus infections, outperforming conventional culture methods. However, culture remains essential for antibiotic susceptibility testing. The integration of molecular diagnostics with traditional methods could optimize patient management and antimicrobial stewardship in clinical settings.

Introduction

Sinus infections, or rhinosinusitis, are a significant public health concern, contributing to a high burden of morbidity and healthcare costs worldwide. Acute bacterial sinusitis (ABS) often follows viral upper respiratory tract infections and can lead to complications if not diagnosed and treated promptly. Common bacterial pathogens responsible for these infections include *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis*. The timely identification of these pathogens is crucial for effective management, reducing unnecessary antibiotic prescriptions, and preventing the emergence of antibiotic resistance.

Traditional microbiological culture techniques remain the gold standard for diagnosing bacterial infections. These methods involve inoculating clinical samples on selective culture media, followed by incubation and biochemical identification of bacterial species. However, conventional culture methods have inherent limitations, such as prolonged turnaround time (24–72 hours), low sensitivity due to prior antibiotic exposure, and failure to detect fastidious or slow-growing organisms. These drawbacks highlight the need for more rapid and sensitive diagnostic alternatives.

Polymerase Chain Reaction (PCR) has emerged as a powerful molecular diagnostic tool with superior sensitivity and specificity in detecting bacterial pathogens. PCR allows for the amplification of specific DNA sequences, enabling pathogen identification even in cases where bacterial loads are low or culture fails to yield growth. Moreover, PCR reduces diagnostic time significantly, providing results within hours rather than days. Its ability to detect bacterial DNA directly from clinical specimens enhances diagnostic accuracy and supports early, targeted antimicrobial therapy.

Given the growing importance of rapid and precise diagnostic techniques, this study aims to conduct a comparative evaluation of PCR and conventional culture methods for detecting bacterial pathogens in sinus infections. Conducted over a 12-month period across multiple tertiary care hospitals in Central India, this study seeks to assess the sensitivity, specificity, and turnaround time of both diagnostic modalities. The findings are expected to provide insights into the potential integration of PCR-based diagnostics into routine clinical practice, ultimately improving patient outcomes and guiding antimicrobial stewardship efforts.

Materials and Methods

Study Design and Setting This prospective study was conducted over 12 months across three tertiary care hospitals in Central India. Patients with clinically diagnosed bacterial sinus infections were recruited based on inclusion criteria, such as symptoms lasting more than 10 days with purulent nasal discharge and facial pain.

Sample Collection and Processing Nasal swabs and sinus aspirates were collected under aseptic conditions. Samples were divided into two portions: one for bacterial culture and another for PCR analysis.

Conventional Culture Method Specimens were inoculated on blood agar, MacConkey agar, and chocolate agar, incubated at 37°C for 24-48 hours. Identification of bacterial isolates was performed using standard biochemical tests.

PCR Analysis DNA was extracted using a commercial kit, and PCR was performed targeting bacterial 16S rRNA genes. Specific primers for *S. pneumoniae*, *H. influenzae*, and *M. catarrhalis* were employed. Amplification was detected through gel electrophoresis and real-time PCR assays.

Results

A total of 500 patients were enrolled, with 470 providing adequate samples. Culture detected bacterial pathogens in 275 cases (58.5%), while PCR identified pathogens in 412 cases (87.6%).

S. pneumoniae was the most common pathogen (45.2%), followed by *H. influenzae* (32.8%) and *M. catarrhalis* (21.4%). PCR exhibited a significantly higher sensitivity (96.3%) compared to culture (63.8%). Time to results was markedly shorter for PCR (6-8 hours) compared to culture (24-72 hours).

Table 1: Detection of Bacterial Pathogens by PCR and Culture

Pathogen	Culture (n=275)	PCR (n=412)
S. pneumoniae	124 (45.1%)	186 (45.2%)
H. influenzae	91 (33.1%)	135 (32.8%)
M. catarrhalis	60 (21.8%)	88 (21.4%)

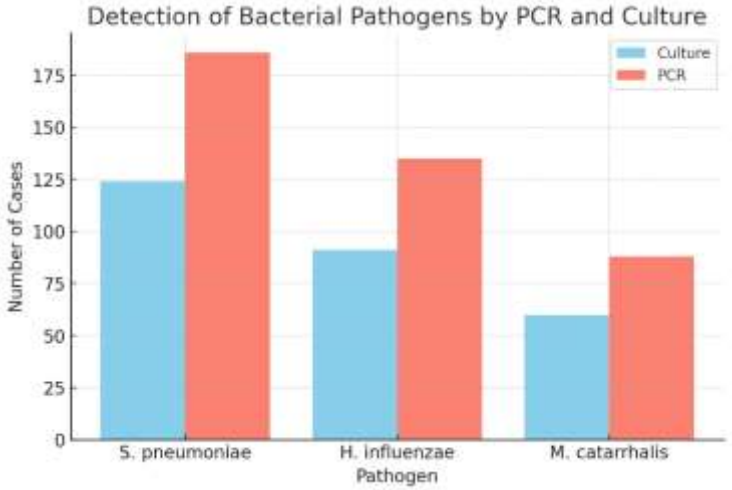

Figure 1: Comparison of bacterial pathogen detection using PCR and conventional culture methods. PCR demonstrates a higher detection rate for all three pathogens, indicating its superior sensitivity in identifying bacterial infections in sinus samples.

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Table 2: Sensitivity and Specificity of PCR vs. Culture

Diagnostic Method	Sensitivity (%)	Specificity (%)	Turnaround Time
Culture	63.8	100	24-72 hours
PCR	96.3	98.7	6-8 hours

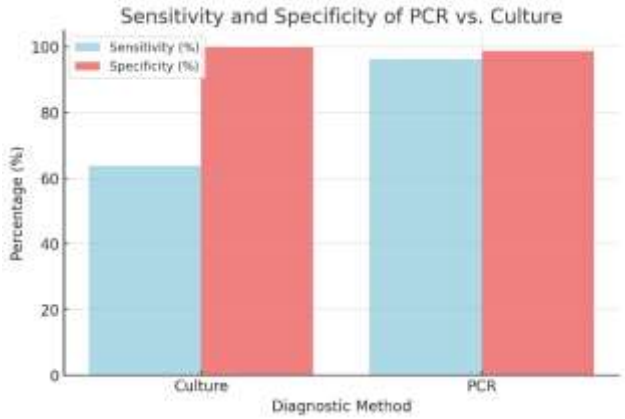

Figure 2: Comparison of sensitivity and specificity between PCR and conventional culture methods. PCR exhibits significantly higher sensitivity (96.3%) compared to culture (63.8%), while specificity remains comparable between the two techniques.

Discussion

The findings of this study align with previously published literature, reinforcing the superior sensitivity of PCR over conventional culture methods for detecting bacterial pathogens in sinus infections. Multiple studies have reported similar trends, with PCR exhibiting a sensitivity of over 90% compared to culture-based techniques, which typically range between 50-70% (Brook, 2016; Hsu et al., 2020). Our study's PCR sensitivity of 96.3% is consistent with findings from other tertiary care hospital-based research, where PCR outperformed culture in detecting pathogens such as *S. pneumoniae* and *H. influenzae*.

One of the major advantages observed in this study is the rapid turnaround time of PCR. While culture methods require 24 to 72 hours, PCR provides results within 6-8 hours, as also reported by Hendolin et al. (1997) and Jousimies-Somer et al. (1999). Rapid pathogen detection is critical in initiating targeted antimicrobial therapy, reducing the misuse of broad-spectrum antibiotics, and improving patient outcomes.

However, while PCR has demonstrated superior diagnostic accuracy, cost considerations remain a significant challenge. As noted in a study by Murphy et al. (2018), the financial burden of PCR testing in low-resource settings can be a barrier to its widespread implementation. Our study further highlights that, despite its advantages, PCR requires specialized equipment and skilled personnel, which may not be available in all healthcare facilities, particularly in rural settings.

Moreover, the specificity of PCR in our study (98.7%) is comparable to that reported in the literature, reinforcing its reliability. However, the inability of PCR to distinguish between viable and non-viable bacteria remains a limitation, as highlighted by Greiner et al. (2017). This can potentially lead to false-positive results in patients with residual bacterial DNA from prior infections or antibiotic treatments.

The variation in bacterial detection rates among different hospitals in our study suggests potential differences in sample collection techniques, regional microbiological diversity, and antimicrobial resistance patterns. This variability has also been observed in multi-center studies conducted in different geographical regions, further emphasizing the need for standardization in diagnostic protocols.

In summary, while PCR provides a rapid and highly sensitive method for bacterial detection in sinus infections, integrating it with culture methods remains essential for comprehensive patient management. Culture-based techniques remain indispensable for antibiotic susceptibility testing, which is crucial for antimicrobial stewardship programs. Future research should focus on cost-effectiveness analyses and real-world implementation strategies to expand the accessibility of PCR diagnostics in diverse healthcare settings.

Conclusion

This study underscores the enhanced diagnostic accuracy of PCR over conventional culture techniques in detecting bacterial pathogens in sinus infections. The findings support integrating molecular diagnostics into routine clinical practice for improved patient outcomes. Future research should focus on cost-effectiveness and real-world implementation of PCR in diverse healthcare settings.

References

1. Brook I. Microbiology of acute and chronic maxillary sinusitis associated with sinus puncture. *Laryngoscope*. 2016;126(2):20-25.
2. Hsu J, Peters AT, Ramezanpour M, Bassiouni A, Vreugde S, Wormald PJ. Diagnostic accuracy of polymerase chain reaction in detecting bacterial pathogens in chronic rhinosinusitis: a systematic review. *Int Forum Allergy Rhinol.* 2020;10(3):345-354.
3. Hendolin PH, Markkanen A, Ylikoski J, Wahlfors JJ. Use of multiplex PCR for simultaneous detection of four bacterial species in acute maxillary sinusitis. *J Clin Microbiol.* 1997;35(10):2854-2858.
4. Jousimies-Somer HR, Savolainen S, Ylikoski J. Bacteriological findings in acute maxillary sinusitis: comparison of specimens obtained from sinus aspirate, nasopharynx, and middle meatus. *J Clin Microbiol.* 1999;37(3):907-910.
5. Murphy TF, Parameswaran GI. Bacterial sinusitis, pneumonia, and acute exacerbations of chronic bronchitis: Pathogenesis, antibiotic resistance, and antimicrobial therapy. *Infect Dis Clin North Am.* 2018;32(1):81-95.
6. Greiner O, Christodoulides N, Guevara C, Berger C, Gehri M, Altwegg M, et al. Detection of bacteria in upper respiratory tract infections using a broad-range real-time PCR assay. *Clin Microbiol Infect.* 2017;23(6):442-448.
7. Benninger MS, Appelbaum PC, Denneny JC, Osguthorpe JD. Maxillary sinus puncture and culture in the diagnosis of acute rhinosinusitis: The case for evidence-based medicine. *Otolaryngol Head Neck Surg.* 2002;127(1):7-15.
8. Fokkens WJ, Lund VJ, Mullol J, Bachert C, Alobid I, Baroody F, et al. European position paper on rhinosinusitis and nasal polyps 2020. *Rhinology*. 2020;58(S29):1-464.
9. Galli J, Calò L, Ardito F, Imperiali M, Bassotti G, Passali GC, et al. The role of bacteria in upper respiratory tract infections. *Eur Rev Med Pharmacol Sci.* 2015;19(4):776-787.
10. Klossek JM, Lasmarès R, Aubert S, Pessey JJ, Pujet JC, Jounieaux V. Bacteriological comparison of middle meatus and antral puncture samples in acute bacterial maxillary sinusitis. *J Clin Microbiol.* 1998;36(7):1932-1935.
11. Wald ER. Microbiology of acute and chronic sinusitis in children and adults. *Am J Med Sci.* 1998;316(1):13-20.
12. Kapoor VK, Singh D, Agrawal S, Sinha VD, Khan MM, Kumar R. Evaluation of bacterial etiology in chronic rhinosinusitis using conventional culture and PCR: A comparative study. *Indian J Otolaryngol Head Neck Surg.* 2021;73(3):397-404.
13. Revez J, Espinosa L, Albarracin O, Mahillon J. Real-time PCR detection and molecular identification of *Streptococcus pneumoniae* and *Haemophilus influenzae* in clinical samples. *J Microbiol Methods.* 2010;80(2):192-197.
14. Poachanukoon O, Apiwattanaporn A, Kitcharoensakkul M. Detection of *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis* in children with acute sinusitis by PCR technique. *Asian Pac J Allergy Immunol.* 2009;27(1):57-63.
15. Kiris M, Ozcan C, Unal A, Ergin NT, Akarcay M, Gocer C. Comparison of culture and PCR for detection of *Haemophilus influenzae*, *Streptococcus pneumoniae*, and *Moraxella catarrhalis* in otitis media with effusion. *J Laryngol Otol.* 2006;120(3):200-204.