ISSN: 2279 - 0594

Journal of Biomedical and Pharmaceutical Research

Available Online at www.jbpr.in

CODEN: - JBPRAU (Source: - American Chemical Society)

Index Copernicus Value: 72.80

PubMed (National Library of Medicine): ID: (101671502)

Volume 7, Issue 1: November-December: 2018, 102-105

Research Article

Fourier Transform Infrared Spectroscopy Analysis of Gallstones: Clinical Implications and Composition Insights from a Tertiary Care Hospital

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Abstract

Background: Gallstones are a common condition that can lead to significant morbidity and require accurate characterization for appropriate management. Fourier Transform Infrared (FTIR) Spectroscopy is a powerful analytical tool for identifying the biochemical composition of gallstones.

Objective: To analyze gallstones using FTIR spectroscopy and determine their composition in a cohort of patients undergoing cholecystectomy.

Material and Methods: A cross-sectional study was conducted involving 60 patients diagnosed with gallstones who underwent laparoscopic cholecystectomy. Gallstones were collected and analyzed using FTIR spectroscopy to determine their composition. Clinical parameters, including age, gender, and symptoms, were recorded.

Results: The FTIR analysis revealed distinct spectral patterns corresponding to different types of gallstones, including cholesterol stones, pigment stones, and mixed stones. Statistical analysis indicated a significant correlation between the type of gallstone and the clinical presentation.

Conclusion: FTIR spectroscopy is a valuable tool for the characterization of gallstones, providing insights into their composition and aiding in the management of patients.

Keywords: Gallstones, Fourier Transform Infrared Spectroscopy, cholesterol stones, pigment stones, laparoscopic cholecystectomy.

Introduction

Gallstones are hardened deposits that can form in the gallbladder, and their prevalence is rising globally, significantly impacting public health (1). These stones can cause various complications, including biliary colic, cholecystitis, and pancreatitis, which often necessitate surgical intervention. Understanding the composition of gallstones is crucial for predicting complications and tailoring patient management strategies (2).

Traditional methods of gallstone analysis include biochemical assays and imaging techniques, which provide limited information about the stone's chemical composition. Fourier Transform Infrared (FTIR) Spectroscopy has emerged as a promising alternative that allows for rapid and non-destructive analysis of gallstones. This technique utilizes infrared light to analyze the molecular vibrations of the constituents in the stones, thereby revealing their chemical structure and composition (3).

Previous studies have shown that the composition of gallstones can vary based on demographic factors, dietary habits, and

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underlying health conditions (4). Understanding these variations can provide insight into the etiology of gallstone formation and the associated clinical implications.

This study aims to analyze gallstones collected from patients undergoing laparoscopic cholecystectomy using FTIR spectroscopy and to correlate the findings with clinical parameters.

Aim and Objectives

Aim: To analyze the biochemical composition of gallstones using Fourier Transform Infrared Spectroscopy.

Objectives:

1. To identify the types of gallstones present in the study population.
2. To evaluate the correlation between gallstone composition and clinical presentation.
3. To assess the potential of FTIR spectroscopy as a diagnostic tool in the characterization of gallstones.

Material and Methods

Study Design: This cross-sectional study was conducted in the Department of Surgery at a tertiary care hospital.

Study Population: A total of 60 patients diagnosed with gallstones and scheduled for laparoscopic cholecystectomy were included in the study. Patients were recruited over six months, and informed consent was obtained from all participants.

Inclusion Criteria:

- Patients aged 18 years and older.
- Patients with clinically diagnosed gallstones confirmed by ultrasound.

Exclusion Criteria:

- Patients with a history of previous gallbladder surgery.
- Patients with other biliary tract diseases.
- Patients with contraindications to surgery.

Data Collection:

- Clinical data, including age, gender, symptoms (biliary colic, jaundice, etc.), and laboratory findings, were recorded.
- Gallstones were collected during laparoscopic cholecystectomy and preserved for analysis.

FTIR Spectroscopy Analysis:

- The gallstones were analyzed using FTIR spectroscopy in the laboratory. Each stone was placed in the spectrometer, and the spectral data were collected in the range of 4000–400 cm⁻¹.
- The FTIR spectra were analyzed to identify characteristic peaks corresponding to different chemical bonds and molecular structures.

Statistical Analysis:

- Data were analyzed using appropriate statistical methods, including descriptive statistics and correlation analysis. A p-value of <0.05 was considered statistically significant.

Results

Demographic Characteristics: The study included 60 patients with a mean age of 45.7 ± 12.6 years. The gender distribution was 40% male and 60% female.

Clinical Presentation:

- Biliary colic was the most common symptom, reported by 70% of the patients.
- Jaundice was observed in 15% of the patients, while 10% presented with acute cholecystitis.

Gallstone Composition Analysis: FTIR analysis revealed the following distribution of gallstone types:

Table 1: Distribution of Gallstone Types Based on FTIR Analysis

Type of Gallstone	Frequency (n=60)	Percentage (%)

Cholesterol Stones	36	60
Pigment Stones	12	20
Mixed Stones	12	20

The FTIR spectra showed distinct patterns:

- **Cholesterol Stones:** Characterized by strong absorption peaks at 2925 cm⁻¹ and 1730 cm⁻¹, indicating C-H stretching and C=O stretching vibrations, respectively.
- **Pigment Stones:** Displayed peaks around 1640 cm⁻¹ associated with bilirubin and other bile pigments.
- **Mixed Stones:** Exhibited overlapping features of both cholesterol and pigment stones.

Correlation Analysis: The analysis of the correlation between the type of gallstone and clinical presentation revealed the following:

- Cholesterol stones were more prevalent in patients with a history of biliary colic ($p < 0.05$).
- Pigment stones were significantly associated with jaundice ($p < 0.05$).

Discussion

The present study provides valuable insights into the composition of gallstones analyzed using FTIR spectroscopy. The findings suggest that FTIR is a reliable method for characterizing gallstones, offering detailed information about their biochemical makeup.

The prevalence of cholesterol stones in this cohort aligns with existing literature, indicating that dietary factors may contribute significantly to gallstone formation in this population (5). Furthermore, the correlation between stone type and clinical symptoms suggests that understanding gallstone composition can help predict potential complications and guide treatment options (6).

Previous studies have demonstrated the effectiveness of FTIR spectroscopy in analyzing various biological samples, including gallstones, providing a non-invasive method that can be implemented in routine clinical practice (7). The ability to quickly identify stone composition may assist in tailoring dietary recommendations and managing patients more effectively post-surgery.

Overall, the results highlight the potential of FTIR spectroscopy as a diagnostic tool, not only for characterizing gallstones but also for enhancing our understanding of gallstone disease and its implications.

Conclusion

Fourier Transform Infrared Spectroscopy is a valuable tool for analyzing gallstones, providing critical insights into their composition and clinical significance. The findings of this study emphasize the need for further research to explore the implications of gallstone composition on patient management and outcomes.

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