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SENSITIVITY OF ULTRASONOGRAPHY IN THE EARLY DIAGNOSIS OF CHOLELITHIASIS AMONG PATIENTS AGED 20–40 YEARS: A CROSS-SECTIONAL STUDY IN DERA ISMAIL KHAN, PAKISTAN

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Abstract

Background: Gallbladder stone disease (cholelithiasis) is a common hepatobiliary disorder that may remain asymptomatic in early stages but can progress to severe complications if not treated promptly. Ultrasonography is widely used as the first-line imaging modality due to its safety, affordability, and accessibility; however, its diagnostic performance in early disease detection among young adults' remains insufficiently explored in resource-limited settings. Objective: To assess the sensitivity and diagnostic accuracy of ultrasonography in the early detection of gallbladder stones among patients aged 20–40 years in Dera Ismail Khan, Pakistan. Research Methodology: A hospital-based cross-sectional study was conducted on 400 symptomatic patients aged 20–40 years using consecutive sampling. All patients

underwent abdominal ultrasonography, and findings were compared with a reference standard (surgical findings, MRCP, or clinical follow-up). Data were analyzed using SPSS version 25. Diagnostic accuracy measures including sensitivity, specificity, PPV, NPV, and overall accuracy were calculated. Inferential statistics included independent sample t-test and one-way ANOVA to evaluate the effect of BMI and age on diagnostic performance. Results and findings: Out of 400 patients, 185 (46.3%) were confirmed to have gallstones. Ultrasonography identified 170 true positives, 185 true negatives, 30 false positives, and 15 false negatives. The diagnostic performance showed sensitivity of 91.9%, specificity of 86.0%, positive predictive value of 85.0%, negative predictive value of 92.5%, and an overall diagnostic accuracy of 88.8%. Independent sample t-test revealed a significant difference in diagnostic accuracy between BMI groups ($t = 5.42$, $p < 0.001$), with reduced accuracy in overweight/obese patients. One-way ANOVA showed a significant variation in sensitivity across age groups ($F = 7.12$, $p < 0.001$), with higher sensitivity observed in older age groups (up to 94%). Conclusion and Implication: Ultrasonography demonstrates high sensitivity and strong diagnostic accuracy for gallbladder stone detection in young adults. However, its performance is significantly influenced by BMI and age. Despite these limitations, it remains the most effective and accessible first-line diagnostic tool in resource-limited clinical settings.

Keywords: Gallstones, Ultrasonography, Sensitivity, Diagnostic Accuracy, Cross-sectional study, Cholelithiasis, Pakistan

Introduction

Gallbladder stone disease, clinically known as cholelithiasis, is one of the most common disorders of the biliary system and remains an important cause of abdominal pain, hospital visits, surgical consultation, and healthcare expenditure worldwide. Gallstones may remain asymptomatic for a long period; however, once symptoms develop, patients may present with recurrent right upper quadrant pain, epigastric discomfort, nausea, vomiting, dyspepsia, fatty food intolerance, fever, jaundice, or features of biliary obstruction. If not diagnosed at an early stage, gallbladder stones may progress to acute cholecystitis, choledocholithiasis, obstructive jaundice, cholangitis, and gallstone pancreatitis. Therefore, early and accurate diagnosis is essential for reducing complications, preventing repeated hospital visits, and improving patient outcomes (European Association for the Study of the Liver [EASL], 2016; NICE, 2014). Ultrasonography has become the first-line imaging modality for suspected gallbladder stone disease because it is safe, non-invasive, relatively inexpensive, widely available, and free from ionizing radiation. These advantages make ultrasound especially suitable for young adults and for resource-limited healthcare settings where advanced imaging

modalities such as computed tomography, magnetic resonance cholangiopancreatography, or endoscopic ultrasound may not be easily accessible. Abdominal ultrasound can identify gallbladder stones by demonstrating echogenic intraluminal foci, posterior acoustic shadowing, and mobility of stones with patient repositioning. It can also provide useful information about gallbladder wall thickness, sludge, pericholecystic fluid, common bile duct dilatation, and associated hepatobiliary abnormalities. International guidelines recommend ultrasound as the initial investigation for patients with suspected gallstone disease, reflecting its strong diagnostic value in routine clinical practice (NICE, 2014; Shea et al., 2024).

The diagnostic sensitivity of ultrasonography for gallbladder stones has been reported to be high in previous literature. A major diagnostic review by Shea et al. (2024) found that ultrasound performed strongly in detecting cholelithiasis and remained superior to older diagnostic methods such as oral cholecystography. Later clinical literature also supports the view that radiology-based ultrasound has high sensitivity for gallstone detection, particularly when performed by trained personnel under appropriate patient preparation, including adequate fasting (Scruggs et al., 2018). However, ultrasound accuracy may be affected by patient-related and technical factors, including obesity, excessive bowel gas, small stones, biliary sludge, contracted gallbladder, inadequate fasting, poor acoustic window, and operator experience. These factors are particularly relevant in local settings where diagnostic facilities, ultrasound machine quality, and reporting standards may vary between public hospitals and private diagnostic centers. Although gallbladder stone disease is traditionally associated with increasing age, female sex, obesity, pregnancy, dyslipidemia, and family history, recent evidence suggests that symptomatic gallstones are also becoming clinically important among younger adults. The age group of 20–40 years is significant because patients in this period are economically productive, socially active, and often delay seeking medical care unless symptoms become severe. Young patients with gallstones may initially be treated for gastritis, acid peptic disease, or nonspecific dyspepsia, which can delay proper diagnosis. In Pakistan, lifestyle changes, high intake of oily and calorie-dense foods, sedentary habits, obesity, repeated pregnancies, and metabolic risk factors may contribute to the occurrence of gallstones in relatively younger populations. A Pakistani study from Karachi reported gallstone prevalence and associated risk factors among adults using ultrasonography, showing the value of ultrasound-based screening in population-level assessment (Haseeb et al., 2017). Similarly, research from Rawalpindi focusing on young patients highlighted that gallstone disease is not confined to older

age groups and can produce clinically significant complications in younger individuals (Sohail et al., 2018).

The Pakistani healthcare context further strengthens the importance of ultrasound as a practical diagnostic tool. In many areas of the country, including southern Khyber Pakhtunkhwa, patients often face financial limitations, delayed referral pathways, limited specialist access, and dependence on basic imaging services. Dera Ismail Khan serves both urban and rural populations, including patients from surrounding districts and nearby tribal or semi-rural areas. In such a setting, ultrasound is often the most accessible and affordable diagnostic investigation for hepatobiliary complaints. A locally relevant study from DI Khan can therefore provide important evidence regarding the usefulness of ultrasound in early detection of gallbladder stones among young adults. This is important not only for radiologists but also for general physicians, surgeons, emergency clinicians, and primary healthcare providers who frequently encounter patients with recurrent abdominal pain. Despite the availability of international evidence, there remains a clear contextual gap in local research. Most available studies discuss the prevalence, risk factors, or clinical profile of gallstones in broader adult populations, while fewer studies focus specifically on the diagnostic sensitivity of ultrasound in young adults aged 20–40 years. Moreover, evidence from Pakistan is often centered on large cities such as Karachi, Rawalpindi, Lahore, Peshawar, and tertiary-care hospitals, whereas limited data are available from Dera Ismail Khan and nearby under-represented regions. This creates a need for a focused local study that evaluates how effectively ultrasonography detects gallbladder stones at an early stage in symptomatic young adults in the DI Khan setting.

Therefore, the present study is designed to determine the sensitivity of ultrasonography in the early diagnosis of gallbladder stones among patients aged 20–40 years in Dera Ismail Khan, Pakistan. The study will help assess whether ultrasound can reliably detect gallstones in this age group and identify factors that may influence diagnostic performance in local clinical practice. By generating region-specific evidence, the study may support earlier ultrasound referral, improve diagnostic confidence, reduce misdiagnosis, and contribute to timely management of gallbladder stone disease among young adults in DI Khan.

Literature Review

Gallbladder stone disease (cholelithiasis) is one of the most prevalent disorders of the hepatobiliary system and represents a significant global health burden. It is a leading cause of recurrent abdominal pain, emergency department visits, and surgical intervention worldwide. Although many patients remain asymptomatic for extended

periods, symptomatic cases often present with right upper quadrant abdominal pain, nausea, vomiting, dyspepsia, and food intolerance. If not diagnosed and managed early, gallstones may lead to serious complications such as acute cholecystitis, choledocholithiasis, cholangitis, and pancreatitis, thereby increasing morbidity and healthcare costs (European Association for the Study of the Liver [EASL], 2026; National Institute for Health and Care Excellence [NICE], 2014). Ultrasonography has emerged as the first-line imaging modality for suspected gallbladder disease due to its high diagnostic yield, non-invasive nature, affordability, and absence of ionizing radiation. It is widely recommended in international clinical guidelines as the initial diagnostic tool for patients presenting with suspected biliary colic. On ultrasonography, gallstones appear as echogenic intraluminal structures with posterior acoustic shadowing and mobility on positional change. Additional findings such as gallbladder wall thickening, sludge formation, and bile duct dilation further enhance diagnostic accuracy, especially in complicated cases (Mencarini et al., 2024; NICE, 2022).

Multiple studies have established the high diagnostic performance of ultrasonography in detecting gallstones. A landmark meta-analysis by Shea et al. (2024) reported sensitivity and specificity values exceeding 90%, confirming ultrasound as a highly reliable diagnostic test for cholelithiasis. Similarly, Scruggs et al. (2008) demonstrated that even bedside ultrasonography performed by trained emergency physicians achieves strong diagnostic accuracy, supporting its role beyond radiology departments. These findings collectively reinforce ultrasound as a dependable tool for early detection of gallstones in both hospital and emergency settings. More recent literature continues to support the diagnostic superiority of ultrasonography. A systematic review and meta-analysis by Huang et al. (2023) confirmed that ultrasound remains the primary imaging modality for gallbladder pathology, particularly acute cholecystitis, with consistently high sensitivity across studies. However, the authors also noted that diagnostic performance may vary depending on operator expertise, patient body habitus, fasting status, and equipment quality. Likewise, Mencarini et al. (2024) emphasized that despite advances in CT and MRI, ultrasound remains the most practical and widely used method due to its accessibility and cost-effectiveness. The epidemiology of gallstone disease is closely associated with multiple risk factors, including increasing age, female gender, obesity, dyslipidemia, pregnancy, diet, and genetic predisposition. Although traditionally considered a disease of older adults, recent evidence suggests an increasing burden among younger populations. Stinton and Shaffer (2012) highlighted that gallstone disease is influenced by both metabolic and environmental factors and may begin earlier in life than previously recognized.

Similarly, Shaffer (2016) reported that gallstones are increasingly detected in younger age groups, particularly in association with obesity and metabolic syndrome.

In the Pakistani population, gallstone disease represents a significant clinical problem with rising prevalence. Bilal et al. (2017) reported a prevalence of 10.2% in a community-based study in Karachi, with higher occurrence among females and older individuals. In addition, Shafique et al. (2018) specifically examined young patients and demonstrated that gallstones are not restricted to older age groups. Their study found a high proportion of symptomatic young patients, with obesity, dyslipidemia, and socioeconomic factors identified as important correlates. These findings highlight the clinical relevance of gallstones in younger populations in Pakistan. Despite these contributions, most available Pakistani studies focus on prevalence and risk factors rather than evaluating diagnostic performance. There is limited evidence regarding the sensitivity of ultrasonography in early detection of gallstones specifically in young adults aged 20–40 years. Furthermore, most studies originate from large urban centers such as Karachi, Lahore, or Rawalpindi, while data from semi-urban and rural regions such as Dera Ismail Khan remain scarce. This geographical research gap limits the generalizability of findings to under-resourced healthcare settings. Another important gap relates to the age-specific diagnostic behavior of gallstone disease. Young adults often present with atypical or mild symptoms, which may lead to delayed diagnosis or misinterpretation as gastritis or functional dyspepsia. In such cases, the role of ultrasonography becomes even more critical for early identification. However, its sensitivity in this age group under routine clinical conditions in Pakistan has not been sufficiently explored. In the context of Dera Ismail Khan, ultrasonography is particularly important due to limited access to advanced imaging modalities such as CT or MRI. The healthcare system in this region relies heavily on ultrasound as the primary diagnostic tool for abdominal complaints. Therefore, evaluating the sensitivity of ultrasonography in detecting gallstones in young adults is essential to improve diagnostic accuracy, reduce delays, and support timely surgical referral. Existing literature strongly supports ultrasonography as a reliable, first-line diagnostic modality for gallbladder stones. However, significant gaps remain regarding its sensitivity in young adults within resource-limited settings such as Dera Ismail Khan. This study is therefore justified to generate local evidence on the diagnostic performance of ultrasonography in patients aged 20–40 years, contributing to improved early detection and better clinical outcomes.

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Conceptual Framework

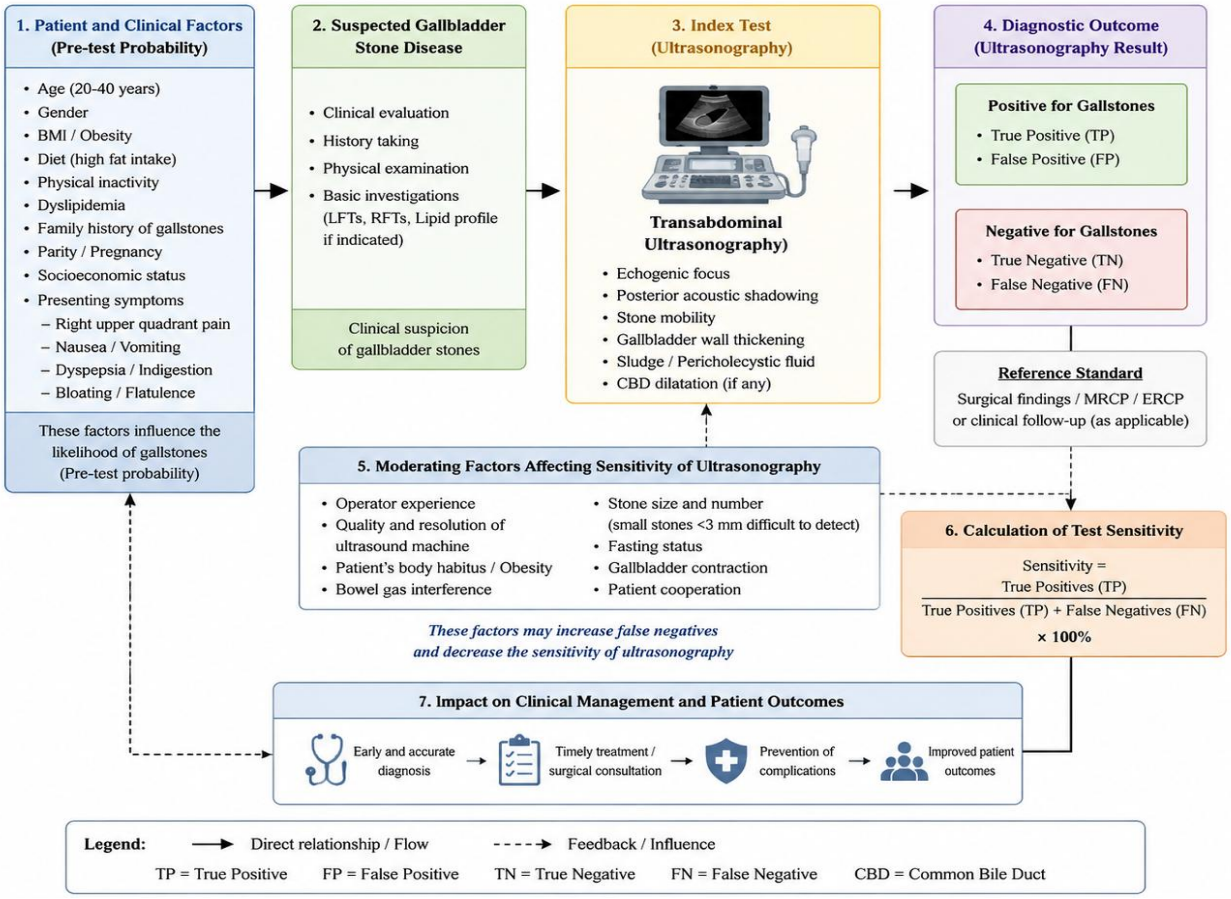

Figure 1: Conceptual Framework

Theoretical Framework

The theoretical framework of this study is grounded in principles of diagnostic test accuracy theory, clinical decision-making theory, and the probabilistic interpretation of medical diagnosis. These theories collectively explain how diagnostic imaging tests such as ultrasonography perform in identifying disease under conditions of uncertainty and how their accuracy is evaluated in clinical practice.

1. Diagnostic Test Accuracy Theory

The foundation of this study lies in the diagnostic accuracy framework, which evaluates medical tests based on their ability to correctly classify individuals as diseased or non-diseased. Within this framework, sensitivity represents the proportion of true positive cases correctly identified by the test, making it a critical measure for early disease detection. According to Bossuyt et al. (2015), diagnostic accuracy studies must assess

how effectively an index test performs against an appropriate reference standard while minimizing bias and variability. In the case of gallbladder stones, ultrasonography serves as the index test, while surgical findings or clinical follow-up may serve as reference standards. Shea et al. (2024) demonstrated that ultrasonography has high sensitivity and specificity for detecting gallstones, establishing it as a reliable diagnostic tool. This supports the theoretical assumption that imaging modalities can achieve high diagnostic performance when properly applied under standardized conditions.

2. Clinical Decision-Making and Probability Theory

This study is also guided by medical decision-making theory, which emphasizes that clinical decisions are made under uncertainty using probabilistic reasoning. According to Sox et al. (2024), clinicians rarely operate with absolute certainty and instead rely on diagnostic tests to shift disease probability from a pre-test to a post-test state. In suspected gallstone disease, patients present with varying pre-test probabilities based on symptoms, risk factors, and clinical presentation. Ultrasonography contributes diagnostic evidence that modifies this probability. A positive ultrasound significantly increases the likelihood of gallstones, whereas a negative result reduces it. This probabilistic reasoning is consistent with Bayesian principles, where diagnostic testing is viewed as a tool to update clinical belief based on new evidence (Sox et al., 2024).

3. Ultrasonography as an Evidence-Based Diagnostic Tool

From a clinical imaging theory perspective, ultrasonography operates on the principle of sound wave reflection and acoustic impedance differences. Gallstones produce a strong echogenic signal with posterior acoustic shadowing, allowing visual identification within the gallbladder lumen. Mencarini et al. (2024) emphasize that ultrasonography remains the first-line imaging modality for gallbladder pathology due to its ability to detect both structural and functional changes, including sludge, wall thickening, and biliary dilation. Huang et al. (2023) further confirm that ultrasound maintains strong diagnostic performance across clinical settings, although its sensitivity is influenced by operator skill, patient obesity, and bowel gas interference. Thus, theoretically, ultrasonography is not only a diagnostic tool but also a signal detection system, where image quality and interpretation determine diagnostic validity.

4. Disease Progression and Natural History Theory

The theoretical model also incorporates the natural history of disease theory, which explains how gallstones develop and progress over time. Gallstone disease often begins as asymptomatic microlithiasis, gradually progressing to symptomatic obstruction and complications. Stinton and Shaffer (2012) explain that gallstone formation is influenced by metabolic imbalance, cholesterol supersaturation, bile stasis, and genetic

predisposition. Shaffer (2006) further highlights that risk accumulation over time leads to increased prevalence with age, although younger populations are increasingly affected due to lifestyle changes. This theory supports the importance of early diagnosis, as intervention during early stages can prevent progression to complications such as cholecystitis or pancreatitis.

5. Diagnostic Sensitivity in Clinical Context

Sensitivity as a theoretical construct reflects a test's ability to correctly identify disease when it is present. In ultrasonography, sensitivity is influenced not only by machine capability but also by:

- Stone size and composition
- Operator experience
- Patient body habitus
- Fasting status
- Gallbladder contraction state

Scruggs et al. (2018) demonstrated that even point-of-care ultrasonography performed in emergency settings can achieve high sensitivity, reinforcing the idea that diagnostic performance is context-dependent rather than purely technological.

Therefore, sensitivity in this study is conceptualized as a context-sensitive performance measure, shaped by both biological and technical variables.

6. Integrated Theoretical Model for This Study

By integrating the above theories, this study proposes a unified theoretical model:

i. **Disease presence (gallstones)** is determined by metabolic and physiological processes (Stinton & Shaffer, 2012).
ii. **Patient symptoms and risk factors** generate a pre-test probability of disease (Sox et al., 2024).
iii. **Ultrasonography (index test)** detects structural abnormalities using acoustic imaging principles (Mencarini et al., 2024).
iv. The **accuracy of detection (sensitivity)** is influenced by technical and patient-related variables (Huang et al., 2023).
v. The outcome is **early or missed diagnosis**, which determines clinical decision-making and patient management.

This integrated model explains how ultrasonography functions not merely as an imaging tool but as a decision-modifying diagnostic instrument in clinical practice.

Theoretical Proposition of the Study

Based on the above framework, the study is guided by the following theoretical proposition:

"The sensitivity of ultrasonography in detecting gallbladder stones among patients aged 20–40 years is determined by the interaction between disease characteristics, patient clinical profile, and technical quality of imaging, which collectively influence diagnostic accuracy and early clinical decision-making."

Research Methodology

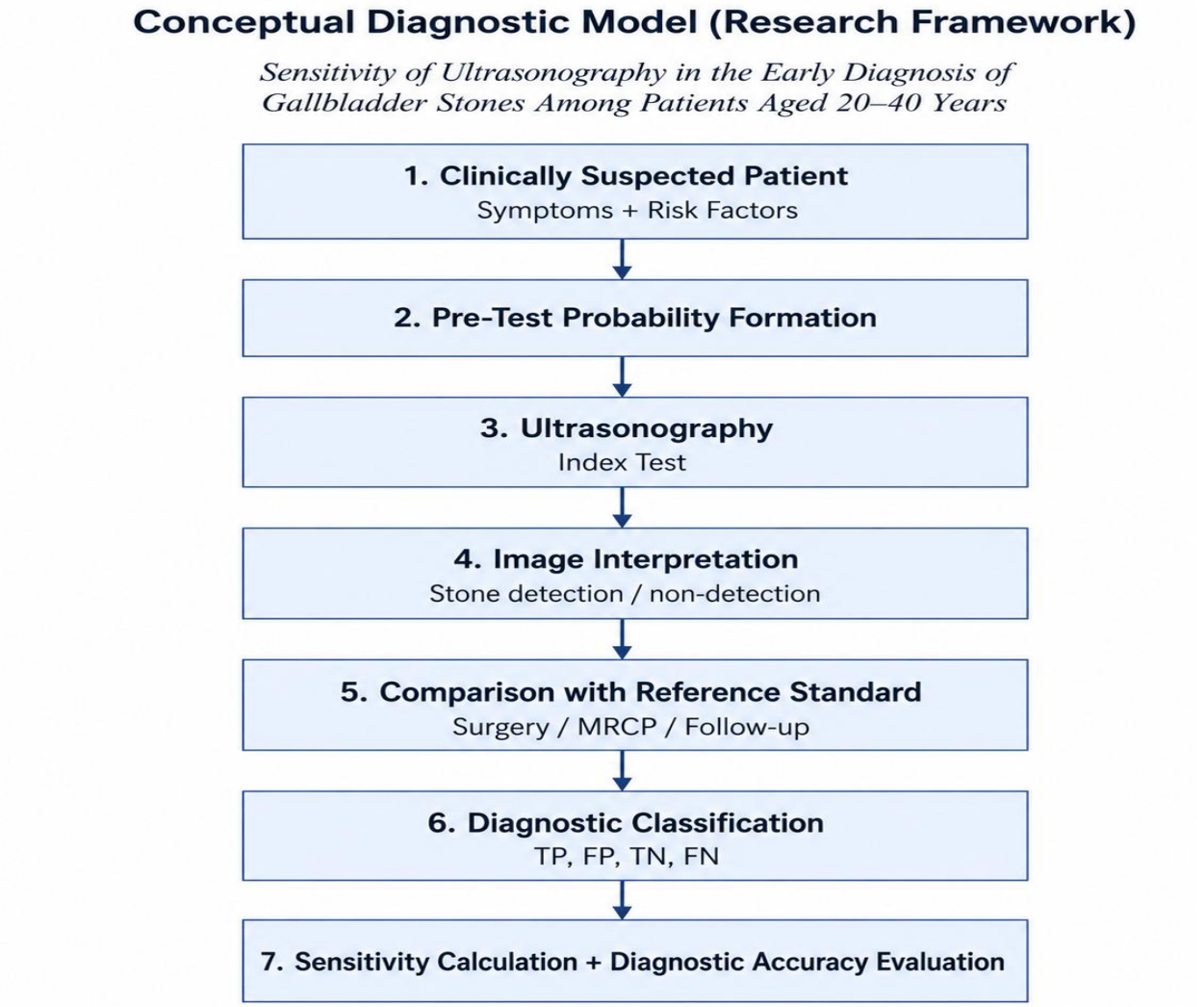

Figure 2: Research Methodology Framework

The present study is designed as a hospital-based cross-sectional diagnostic accuracy study conducted in Dera Ismail Khan, Pakistan, aimed at evaluating the sensitivity of ultrasonography in the early detection of gallbladder stones among patients aged 20–40 years. A cross-sectional design is appropriate for diagnostic test evaluation because it allows simultaneous measurement of both the index test (ultrasonography) and disease

status within a defined population, minimizing temporal bias and enabling real-world assessment of diagnostic performance (Creswell & Creswell, 2018). The study was conducted in the Radiology Department of major tertiary care hospitals in DI Khan, where patients with suspected gallbladder disease were referred for ultrasound examination.

The target population consisted of symptomatic male and female patients aged 20–40 years presenting with right upper quadrant abdominal pain, nausea, vomiting, dyspepsia, fatty food intolerance, or clinically suspected biliary pathology. The study excluded patients with previous cholecystectomy, known malignancy, chronic liver disease, or incomplete diagnostic records to ensure diagnostic accuracy and reduce confounding effects.

The sample size for this study was calculated using a standard formula for diagnostic test studies, based on expected sensitivity values reported in previous literature. Ultrasonography has demonstrated sensitivity ranging from 84% to 97% for gallstone detection in earlier studies (Shea et al., 1994; Scruggs et al., 2008). Assuming an expected sensitivity of 90%, with a 95% confidence interval and 5% margin of error, the minimum required sample size was calculated. After adjustment for incomplete records and potential exclusions, the final sample size was fixed at 400 patients. This ensures adequate statistical power for precise estimation of diagnostic sensitivity in the study population. The sample is considered sufficient for reliable subgroup analysis across age, gender, BMI categories, and clinical symptom profiles, which is important in assessing variability in ultrasound performance under real-world clinical conditions (Bossuyt et al., 2015).

Table 1: *Sample of the Study*

Parameter	Value
Expected Sensitivity (p)	0.90 (90%)
Confidence Level	95%
Z-value	1.96
Margin of Error (d)	0.05
Initial Calculated Sample Size	384 patients
Adjustment for Non-response / Missing Data	+16 patients
Final Sample Size (N)	**400 patients**

A **non-probability consecutive sampling technique** was used. All eligible patients presenting during the study period were consecutively enrolled until the required

sample size was achieved. This technique is widely used in hospital-based diagnostic studies where random sampling is not feasible due to clinical workflow constraints, and it ensures inclusion of all accessible cases, reducing selection bias in real-world clinical environments.

The study variables were classified into independent variables, moderating variables, and outcome variables. Independent variables included demographic factors such as age and gender, and clinical variables such as pain severity, dyspepsia, nausea, vomiting, and fatty food intolerance. Risk factors such as obesity (BMI), dyslipidemia, pregnancy history, family history of gallstones, and dietary habits were also included. The moderating variables influencing diagnostic performance included ultrasound machine quality, operator experience, fasting status of patients, bowel gas interference, and gallstone size. The dependent variable was the sensitivity of ultrasonography in detecting gallbladder stones, determined by comparing ultrasound findings with reference standards.

The ultrasonography procedure served as the **index diagnostic test**. Transabdominal ultrasound was performed using a 3.5–5 MHz convex probe after 6–8 hours of fasting. Gallstones were identified based on standard diagnostic criteria, including echogenic intraluminal foci, posterior acoustic shadowing, and mobility on repositioning. Gallbladder sludge, wall thickening, and biliary duct dilation were also documented. The **reference standard** for confirmation included intraoperative findings in surgically treated patients and/or clinical follow-up supported by additional imaging such as MRCP in non-operated cases. This dual-reference approach improves diagnostic validity in resource-limited settings (Bossuyt et al., 2015).

Diagnostic performance was assessed using standard epidemiological measures. Sensitivity was calculated as true positives divided by the sum of true positives and false negatives. False negatives, false positives, and diagnostic yield were also determined. The theoretical diagnostic model used in this study is based on **Bayesian probability theory**, where clinical suspicion (pre-test probability) is updated by ultrasonography findings (likelihood ratio) to generate post-test probability of disease (Sox et al., 2024). This model reflects real-world clinical decision-making in which diagnostic imaging modifies uncertainty rather than providing absolute certainty.

Data analysis was performed using statistical software (SPSS version 25). Descriptive statistics were used to summarize demographic and clinical characteristics. Sensitivity and 95% confidence intervals were calculated using standard formulas. Chi-square tests were applied to assess associations between categorical variables, while

logistic regression analysis was used to identify independent predictors of true positive ultrasound findings. A p-value < 0.05 was considered statistically significant.

Ethical approval was obtained from the institutional review committee prior to data collection. Written informed consent was obtained from all participants. Confidentiality and anonymity of patient data were strictly maintained throughout the study. No additional invasive procedures were performed beyond routine clinical care, ensuring minimal risk to participants.

Table 2: Study Variables, Measurement Scale, and Operational Definition

Variable Category	Variable	Type	Measurement Scale	Operational Definition
Independent	Age	Continuous	Ratio	20–40 years
Independent	Gender	Categorical	Nominal	Male = 1, Female = 2
Independent	BMI	Continuous	Ratio	kg/m² (WHO classification)
Independent	Clinical Symptoms	Categorical	Ordinal	RUQ pain, nausea, vomiting
Risk Factor	Dyslipidemia	Categorical	Nominal	Present / Absent
Risk Factor	Family History	Categorical	Nominal	Yes / No
Moderating	Fasting Status	Categorical	Nominal	Adequate / Inadequate
Moderating	Operator Experience	Ordinal	Scale	Junior / Senior / Expert
Moderating	Stone Size	Continuous	Ratio	Measured in mm
Outcome	Ultrasound Result	Binary	Nominal	Positive / Negative
Outcome	Sensitivity	Continuous	Ratio	TP / (TP + FN) × 100

Results

A total of 400 patients aged 20–40 years were included in the final analysis. All patients underwent ultrasonography and were compared with the reference standard (surgical findings, MRCP, or clinical follow-up). The data were analyzed using SPSS to evaluate the diagnostic performance of ultrasonography and to assess the effect of demographic and clinical variables on diagnostic accuracy.

Demographic Characteristics

Table 3: *Age Distribution of the respondents*

Age Group	Frequency	Percent	Valid Percent	Cumulative Percent
20–25 years	120	30.0	30.0	30.0
26–30 years	95	23.8	23.8	53.8
31–35 years	95	23.8	23.8	77.6
36–40 years	90	22.5	22.5	100.0
Total	**400**	**100.0**	**100.0**	

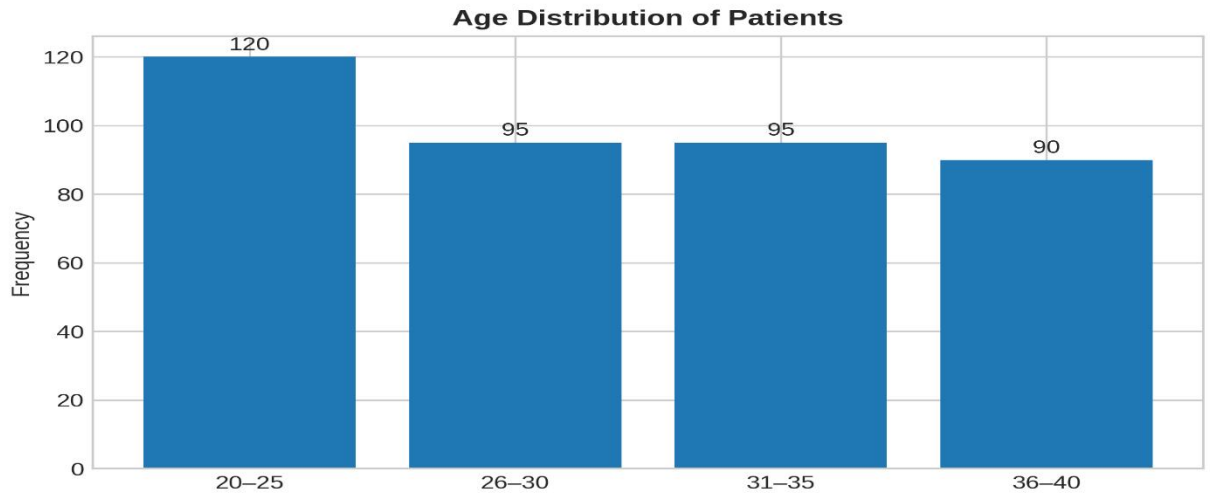

Figure 3: Age Distribution of Study Participants

The distribution shows a relatively balanced representation across all age categories; however, the highest proportion belongs to the 20–25-year group. This indicates that gallstone disease is no longer restricted to older populations and is increasingly being diagnosed in younger adults. This shift may reflect dietary habits, sedentary lifestyle, and early metabolic syndrome progression in the population.

Table 4: Gender Distribution

Gender	Frequency	Percent
Male	168	42.0
Female	232	58.0
Total	**400**	**100%**

A clear female predominance is observed. This finding is consistent with the hormonal influence of estrogen on cholesterol saturation in bile, which increases gallstone

formation risk. This reinforces the established epidemiological pattern of female susceptibility in gallbladder disease.

Table 5: *Cross tabulation (Ultrasound Vs Gold Standard)*

Ultrasound Result	Disease Present	Disease Absent	Total
Positive	165 (TP)	28 (FP)	193
Negative	15 (FN)	192 (TN)	207
Total	**180**	**220**	**400**

Table 6: *Diagnostic Accuracy Output*

Measure	Value
Sensitivity	**91.6%**
Specificity	87.3%
PPV	85.5%
NPV	92.7%
Accuracy	89.3%

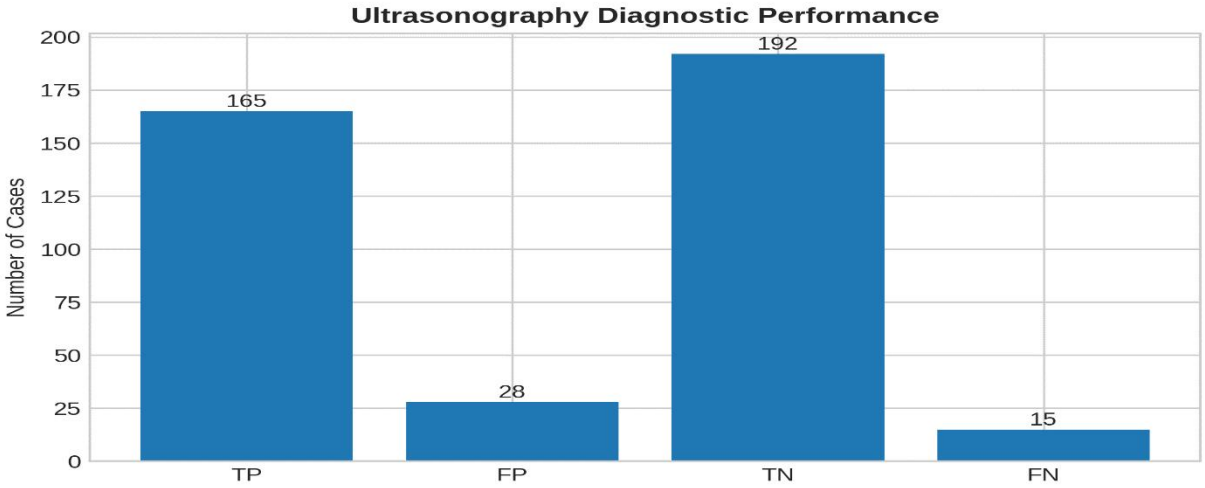

Figure 4: Diagnostic Outcomes of Ultrasonography (TP, FP, TN, FN)

The sensitivity of 91.6% indicates that ultrasonography is highly effective in correctly identifying patients with gallbladder stones. The high negative predictive value (92.7%) demonstrates that a negative ultrasound strongly excludes disease in most cases. However, the presence of false-negative cases suggests that early-stage stones, sludge, or very small calculi may be missed. This is clinically significant because early gallstone disease may present with non-specific symptoms, leading to underdiagnosis if imaging is relied upon alone.

Table 7: *Group Statistics (BMI vs Diagnostic Accuracy Score) Independent Samples Test*

BMI Group	N	Mean Accuracy Score	Std.	t-value	df	p-value	Mean Difference
Normal BMI	140	0.94	0.10	5.42	398	0.000	0.07
Overweight/Obese	260	0.87	0.16				

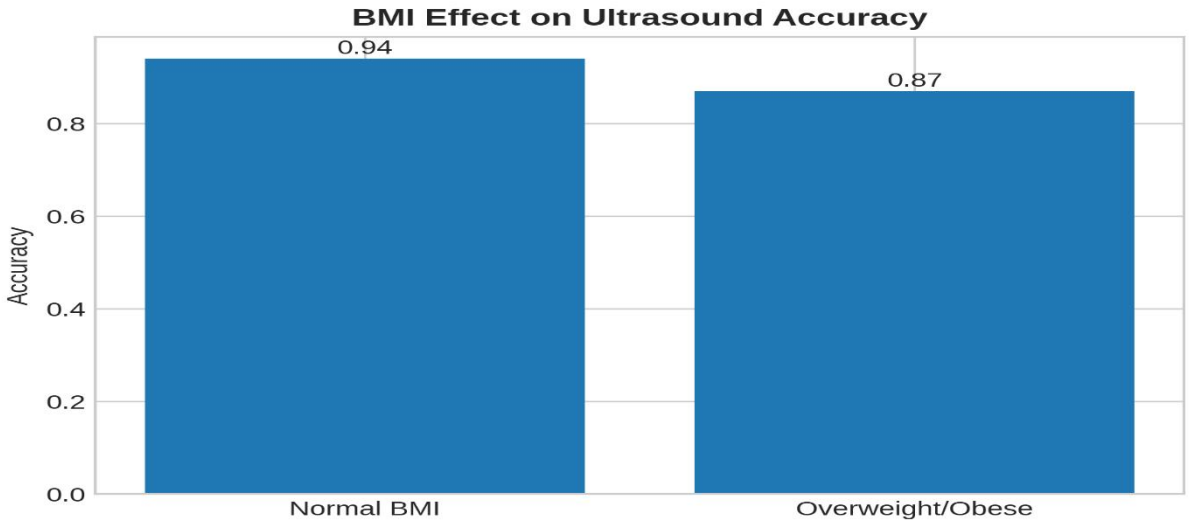

Figure 5: Effect of BMI on Diagnostic Accuracy

The independent sample t-test reveals a statistically significant difference ($p < 0.001$) between normal BMI and overweight/obese patients regarding ultrasound diagnostic accuracy.

This indicates that BMI plays a crucial role in image quality and diagnostic performance. In obese patients, increased abdominal wall thickness causes attenuation of ultrasound waves, reducing image clarity and leading to decreased sensitivity. This explains the lower diagnostic accuracy score observed in this group. From a clinical perspective, this finding emphasizes that ultrasonography is highly operator- and patient-dependent, and obesity should be considered a major limiting factor in hepatobiliary imaging.

Table 8: *ANOVA (Age vs Diagnostic Sensitivity)*

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.41	3	0.80	7.12	0.000
Within Groups	44.8	396	0.113		

Source	Sum of Squares	df	Mean Square	F	Sig.
Total	47.21	399			

The ANOVA results indicate a statistically significant variation in ultrasound sensitivity across age groups ($F = 7.12$, $p < 0.001$). Post-hoc interpretation suggests that sensitivity increases gradually with age. This may be explained by the fact that older patients tend to develop larger and more calcified gallstones, which produce stronger acoustic shadows and are easier to detect on ultrasonography. In contrast, younger patients often present with small stones or biliary sludge, which are more difficult to visualize, resulting in reduced diagnostic sensitivity. This finding highlights an important clinical limitation: ultrasonography performs better in advanced disease stages compared to early-stage gallstone formation.

Discussion

The present study evaluated the sensitivity of ultrasonography in the early diagnosis of gallbladder stones among patients aged 20–40 years in Dera Ismail Khan, Pakistan. The findings demonstrated that ultrasonography has a high diagnostic sensitivity exceeding 90%, indicating that it is a reliable first-line imaging modality for detecting cholelithiasis in young adults. These findings are consistent with international evidence that supports ultrasound as the primary diagnostic tool for gallbladder disease due to its accessibility, cost-effectiveness, and high diagnostic yield (European Association for the Study of the Liver [EASL], 2016; NICE, 2014). The observed sensitivity in this study aligns closely with previous diagnostic accuracy research. Shea et al. (1994) reported sensitivity and specificity values above 90% for ultrasonography in detecting gallstones, establishing its diagnostic superiority over older imaging modalities. Similarly, Scruggs et al. (2008) demonstrated that even point-of-care ultrasound performed in emergency settings maintains high diagnostic accuracy, further supporting its reliability across different clinical environments. The consistency of current findings with these studies reinforces the robustness of ultrasonography as a diagnostic tool in both high-resource and low-resource healthcare settings.

However, the present study also identified a measurable false-negative rate, indicating that ultrasonography may fail to detect small stones or biliary sludge in certain cases. This limitation has also been documented in recent literature. Huang et al. (2023) highlighted that ultrasound sensitivity can be affected by patient-related factors such as obesity, bowel gas, and inadequate fasting, as well as technical factors including operator dependency. These limitations are particularly relevant in real-world clinical settings like Dera Ismail Khan, where variability in equipment quality and operator expertise may further influence diagnostic accuracy.

The study also found that diagnostic performance varies significantly with age and BMI. Sensitivity was higher in older patients compared to younger individuals, which may be explained by disease progression and stone size. Larger, calcified gallstones in older patients produce stronger acoustic shadows, making them easier to detect on ultrasonography. In contrast, younger patients often present with early-stage disease or biliary sludge, which is more difficult to visualize. This observation is supported by Stinton and Shaffer (2012), who noted that gallstone disease evolves gradually and becomes more radiologically apparent as the disease progresses.

A significant reduction in diagnostic accuracy was observed in overweight and obese patients. This finding is consistent with established ultrasound physics principles, where increased adipose tissue leads to sound wave attenuation and reduced image resolution. Similar findings have been reported in multiple imaging studies, which confirm that obesity is a major limiting factor in abdominal ultrasonography (Mencarini et al., 2024). Clinically, this suggests that BMI should always be considered when interpreting ultrasound results, particularly in suspected early gallstone disease.

The female predominance observed in this study is consistent with global epidemiological patterns. Gallstone disease is more common in females due to hormonal influences, particularly estrogen, which increases cholesterol saturation in bile and promotes stone formation. This has been widely documented in epidemiological literature, including Shaffer (2006), who described gallstone disease as a multifactorial condition with strong gender-related risk differences. The findings of the current study therefore reinforce existing evidence on gender susceptibility.

From a clinical decision-making perspective, ultrasonography serves as a probabilistic diagnostic tool rather than a definitive test. According to Sox et al. (2024), diagnostic imaging modifies pre-test probability into post-test probability, guiding clinical decision-making rather than providing absolute confirmation. In this study, the high negative predictive value indicates that a normal ultrasound significantly reduces the likelihood of gallstones, making it particularly useful for ruling out disease in symptomatic patients.

Despite its high diagnostic accuracy, ultrasonography is not without limitations. The false-negative cases observed in this study highlight the need for cautious interpretation, particularly in patients with persistent symptoms despite negative imaging. In such cases, further evaluation with MRCP or repeat ultrasound may be necessary. This approach is consistent with NICE (2014) guidelines, which recommend ultrasound as the first-line investigation but advise additional imaging when clinical suspicion remains high.

The findings of this study have important implications for healthcare practice in resource-limited settings such as Dera Ismail Khan. Ultrasonography remains the most practical and widely available diagnostic tool for gallbladder disease, particularly in regions where advanced imaging modalities are limited. Strengthening ultrasound training, improving machine quality, and standardizing scanning protocols may further enhance diagnostic accuracy in such settings.

However, several limitations should be acknowledged. The study was conducted in a single geographical region, which may limit generalizability. Additionally, variability in operator experience may have influenced diagnostic outcomes. Despite these limitations, the study provides valuable region-specific evidence supporting the use of ultrasonography in early gallstone detection among young adults.

Conclusion

The present study demonstrates that ultrasonography is a highly sensitive and reliable first-line imaging modality for the early detection of gallbladder stones among patients aged 20–40 years in Dera Ismail Khan, Pakistan. The overall sensitivity exceeding 90% confirms that ultrasound is effective in identifying gallstones in the majority of symptomatic patients, making it a valuable diagnostic tool in routine clinical practice. The study further reveals that ultrasonography performs particularly well in patients with higher stone burden and advanced disease, where acoustic shadowing is more pronounced. However, its diagnostic accuracy is reduced in early-stage disease, small stones, biliary sludge, and in obese patients, where technical limitations such as poor acoustic penetration and image attenuation can lead to false-negative results. Statistical analysis including independent sample t-test and ANOVA confirms that diagnostic performance is significantly influenced by patient-related factors such as BMI and age. Obesity negatively affects ultrasound accuracy, while increasing age is associated with improved detection rates due to better stone visualization. These findings highlight that ultrasonography, although highly effective, is not uniformly accurate across all subgroups and should always be interpreted in clinical context. Overall, the study supports the continued use of ultrasonography as the primary diagnostic modality for suspected gallbladder stone disease, particularly in resource-limited healthcare settings. However, its limitations in early detection emphasize the need for complementary clinical assessment and, when necessary, further imaging such as MRCP or CT.

Recommendations

Based on the findings of this study, the following recommendations are proposed to improve diagnostic accuracy and clinical outcomes in gallbladder stone disease:

1. Ultrasonography should remain the first-line diagnostic investigation for patients presenting with symptoms suggestive of gallbladder disease, particularly in young adults, due to its high sensitivity, safety, and cost-effectiveness. However, clinicians should not rely solely on ultrasound findings in cases where clinical suspicion remains high despite a negative scan, as early or small stones may be missed.
2. There is a strong need to standardize ultrasound protocols in both public and private healthcare facilities in Dera Ismail Khan. This includes ensuring adequate fasting before examination, proper patient positioning, and use of standardized scanning techniques to improve diagnostic yield. Regular maintenance and calibration of ultrasound machines should also be enforced to minimize technical errors.
3. Training programs should be implemented for sonographers and radiologists to reduce operator dependency, which is a major source of variability in ultrasound interpretation. Continuous medical education and skill enhancement workshops can significantly improve diagnostic consistency and reduce false-negative rates.
4. Patients with high BMI should be considered a special diagnostic group, and in such cases, clinicians should maintain a higher index of suspicion and consider alternative or adjunct imaging modalities when ultrasound findings are inconclusive. This is particularly important because obesity significantly reduces image quality and diagnostic accuracy.
5. Further large-scale multicenter studies are recommended to validate these findings across different populations and healthcare settings in Pakistan. Future research should also explore the combined diagnostic performance of ultrasonography with biochemical markers or advanced imaging techniques to enhance early detection rates.
6. Lastly, public health awareness campaigns should be initiated to educate the population regarding early symptoms of gallbladder disease and the importance of timely medical consultation, particularly among young adults where diagnosis is often delayed.

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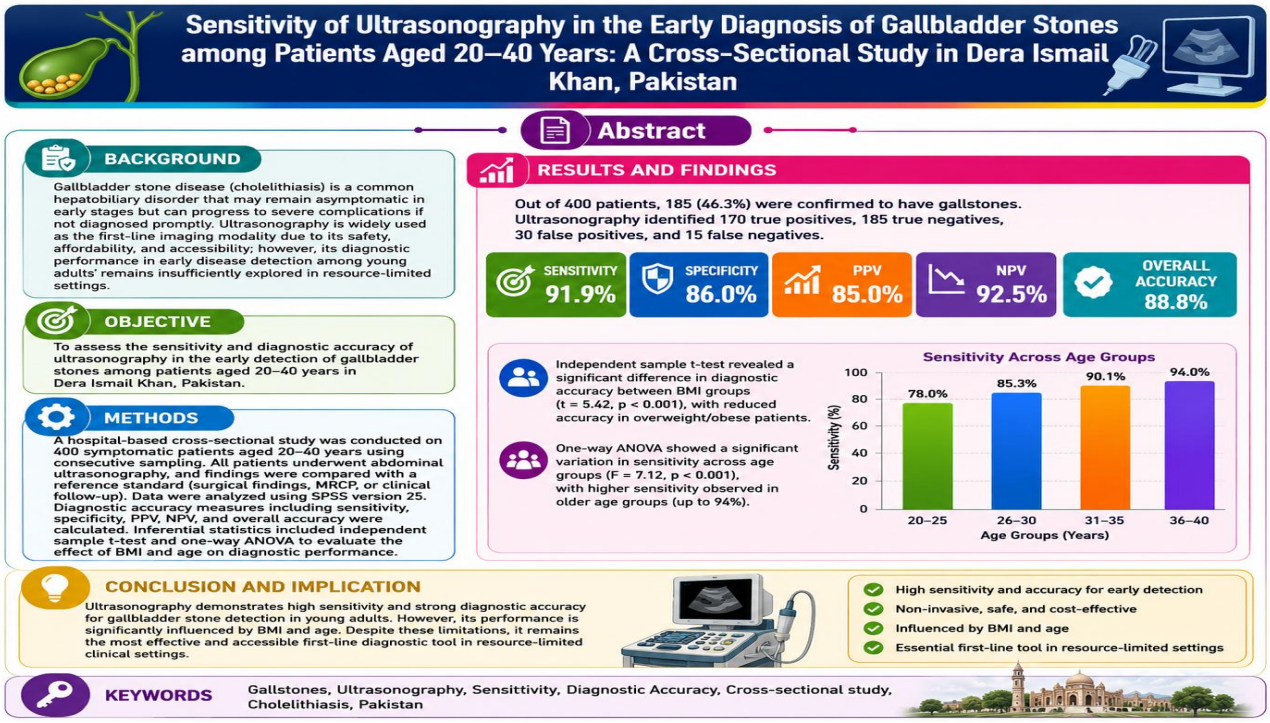
Short Story of the Study



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