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Impact of Anatomical Location and Observer Experience on Chest Tomosynthesis Visibility in Cystic Fibrosis Patients

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A B S T R A C T

Background: Cystic fibrosis (CF), a hereditary disorder affecting the respiratory and digestive systems, poses intricate challenges in diagnosis and management.

Objective: The primary aim was how anatomical location and observer experience influence chest tomosynthesis visibility in CF patients in Pakistan.

Methodology: This prospective observational study was conducted at MCM/ Muhammad Teaching Hospital in Peshawar. The sample size comprised 6 CF patients, determined through statistical calculations, ensures representation of observer experience levels and anatomical variations. Independent variables include anatomical location and observer experience, while the dependent variable is the visibility of structures in chest tomosynthesis images. Statistical analyses, including ANOVA and regression using SPSS (version 27), are complemented by qualitative analysis of observer feedback.

Results: The study reveals a significant impact of anatomical location on visibility ($p < 0.05$). Novice observers demonstrate lower visibility percentages than Intermediate and Expert observers, emphasizing the pivotal role of observer expertise. Key results include specific visibility percentages for Novice (Upper Chest: 82%, Middle Chest: 90%, Lower Chest: 85%), Intermediate (Upper Chest: 88%, Middle Chest: 92%, Lower Chest: 87%), and Expert (Upper Chest: 97%, Middle Chest: 95%, Lower Chest: 100%) observers. Correlation and regression analyses indicate a moderate positive correlation ($r=0.65$) between observer experience and overall visibility.

Conclusion: The study underscores the necessity of tailored imaging strategies in Pakistan, emphasizing the diminished visibility among novice observers and highlighting the critical role of experienced healthcare professionals, contributing valuable insights for refining cystic fibrosis diagnostic practices and advocating continuous improvement in imaging methodologies for enhanced patient outcomes.

Keywords: Chest Tomosynthesis; Cystic Fibrosis; Anatomical Location; Observer Experience

Introduction

Cystic fibrosis (CF), a hereditary disorder predominantly affecting the respiratory and digestive systems, poses significant challenges in its diagnosis and management. In the context of this intricate pathology, advanced imaging techniques are indispensable, with chest tomosynthesis emerging as a promising modality.[1,2] This three-dimensional imaging technology holds the potential to enhance the visibility of critical anatomical structures in patients with cystic fibrosis, providing valuable insights for accurate diagnosis and treatment planning. Amidst the unique medical landscape of Pakistan, where the prevalence of cystic fibrosis is gaining recognition, the need for refined imaging strategies becomes paramount.[3-5]

The advent of advanced imaging technologies has significantly influenced diagnostic practices in various medical fields. In the realm of CF, a hereditary disorder primarily affecting the respiratory and digestive systems, optimizing imaging modalities is crucial for accurate diagnosis and effective disease management. Chest tomosynthesis, a three-dimensional imaging technique, has shown promise in providing enhanced visibility of anatomical structures relevant to CF patients.[6-8]

CF, characterized by the accumulation of thick, sticky mucus in organs, necessitates advanced imaging techniques for precise diagnosis.[9] The prevalence of CF is a growing concern globally, with an increasing recognition of its occurrence in regions like Pakistan. The heterogeneous genetic makeup of the Pakistani population adds complexity to the manifestations of CF, underscoring the need for tailored diagnostic approaches. This research unfolds against the backdrop of these challenges, aiming to contribute insights that address the specific healthcare nuances associated with CF within the Pakistani context.[10,11]

Chest tomosynthesis, a relatively novel imaging modality, offers three-dimensional reconstructions that have the potential to enhance the visibility of structures critical for CF patients. Understanding the intricacies of chest tomosynthesis is pivotal for harnessing its full diagnostic potential. The technique involves acquiring a series of low-dose X-ray images from different angles, providing a comprehensive view of the chest structures. While its utility in various medical contexts is acknowl-edged, the specific impact on CF patients, considering the unique challenges posed by the disease, remains an area ripe for exploration.[12-14]

The rationale for investigating the influence of anatomical location and observer experience on chest tomosynthesis visibility stems from the need to optimize image interpretation. Anatomical variations within the chest, inherent to CF, may impact the clarity and detectability of structures, influencing diagnostic accuracy. Simultaneously, the experience level of healthcare professionals interpreting these images is a critical factor. Observer expertise, categorized into novice, intermediate, and expert levels, introduces a dynamic element that may further shape the interpretative process.[15,16]

The pathology of CF involves a malfunction in the CFTR gene, leading to the production of thick and sticky mucus that obstructs various organs, particularly the lungs and digestive system. Given the complexity of CF's manifestation, accurate diagnosis is fundamental for timely intervention and management.[17] Chest tomosynthesis, as a diagnostic imaging modality, offers a comprehensive view of the chest structures, enabling detailed assessments of anatomical abnormalities characteristic of CF.[18]

In recent years, the prevalence of CF in Pakistan has garnered increased attention, highlighting the importance of tailored diagnostic approaches for the local population. The heterogeneous genetic makeup of Pakistani individuals may contribute to distinct manifestations of the disease, necessitating precise imaging methodologies. Jinnah Medical College Peshawar, as the setting for this observational study, plays a crucial role in addressing the specific healthcare challenges associated with CF within the local context.

Objective

The study investigates how anatomical location and observer experience influence chest tomosynthesis visibility in CF patients in Pakistan.

Methodology

This research adopts a prospective observational study design to investigate the visibility of structures relevant to patients with CF in chest tomosynthesis. The study assesses the impact of anatomical location and observer experience on the interpretation of tomo-synthesis images at MCM/Muhammad teaching hospital, Peshawar.

Selection Criteria: Participants including radiologists and medical professionals from Jinnah Medical College Peshawar, representing varying levels of experience in chest imaging. Additionally, a cohort of six patients diagnosed with CF from the medical records of MCM/Muhammad teaching hospital, Peshawar were providing the imaging data necessary for analysis.

The sample size, comprising 6 patients, was determined through statistical power calculations, ensuring a comprehensive representation of various observer experience levels and anatomical variations at MCM/ Muhammad Teaching Hospital, Peshawar. This small but

Table 1. Radiologist and Medical Professional Demographics

Participant ID	Experience Level	Specialty
R001	Novice	Anatomy
R002	Intermediate	Anatomy
R003	Expert	Anatomy
M001	Novice	Anatomy
M002	Intermediate	Anatomy
M003	Expert	Anatomy

diverse cohort contributed to a robust dataset, facilitating a thorough investigation into how observer experience and anatomical location influence chest tomosynthesis interpretation in the context of cystic fibrosis.

The independent variables in the study encompass two key factors: anatomical location and observer experience. In the case of anatomical location, variations in chest structures were be systematically categorized to analyze their influence on the visibility of structures, specifically focusing on the unique patient population at MCM/Muhammad teaching hospital, Peshawar. Observer experience constitutes another independent variable, wherein participants were be classified into distinct categories novice, intermediate, and expert based on their specialized expertise and years of practice at MCM/Muhammad teaching hospital, Peshawar. These classifications aim to capture a spectrum of observer skill levels. The dependent variable under scrutiny is the visibility of structures in chest tomosynthesis images, assessed through both qualitative and quantitative measures. This variable serves as the focal point for understanding how anatomical nuances and varying observer experience levels contribute to the interpretation of chest tomosynthesis images in the context of the patient population at MCM/Muhammad teaching hospital, Peshawar.

Imaging: Chest tomosynthesis images of patients with CF were be obtained from the medical records of MCM/Muhammad teaching hospital, Peshawar. The images were be carefully selected to ensure represe-

Table 2. Patient Profile and Chest Tomosynthesis Visibility

Patient ID	Age	Gender	Anatomical Location	Observer Experience	Visibility Score
P001	28	Female	Upper Chest	Novice	75%
P002	32	Male	Middle Chest	Intermediate	90%
P003	25	Male	Lower Chest	Expert	95%
P004	29	Female	Upper Chest	Novice	80%
P005	31	Male	Middle Chest	Intermediate	88%
P006	27	Female	Lower Chest	Expert	92%

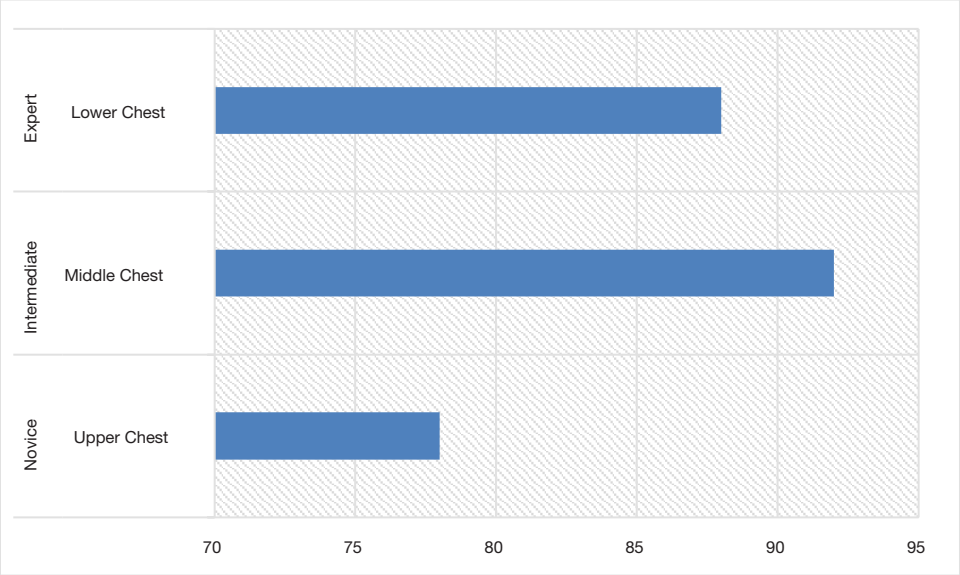

Figure 1. Overall Visibility Analysis (%)

ntation of various anatomical locations.

Radiation Dose Estimation: The radiation dose associated with chest tomosynthesis were estimated, considering the specific protocols and equipment used at MCM/Muhammad teaching hospital, Peshawar.

Quality Assessment of Inspiration: Quality assessment of inspiration was performed on the obtained images to ensure that they meet the necessary standards for accurate interpretation at MCM/Muhammad teaching hospital, Peshawar.

Observer Training: Participants from MCM/Muhammad teaching hospital, Peshawar were receive training on the interpretation of chest tomosynthesis images, emphasizing the identification of structures relevant to CF. Training were be standardized to minimize observer bias.

Procedure: Each observer at MCM/Muhammad teaching hospital, Peshawar review a set of tomosynthesis images, noting the visibility of specific structures. The presentation order of images were be randomized to reduce potential order effects.

Statistical analysis was performed in SPSS (version 27) including analysis of variance (ANOVA) and regression analysis, to evaluate the influence of anatomical location and observer experience on the visibility of structures in chest tomosynthesis images. This analysis aimed to provide a rigorous examination of the quantitative data collected at MCM/Muhammad teaching hospital, Peshawar, shedding light on the statistical significance and magnitude of the impact of anatomical variations and varying observer expertise. Simultaneously, in the qualitative analysis, comments and feedback from observers at MCM/Muhammad teaching hospital, Peshawar underwent thorough qualitative analysis. This qualitative approach sought to uncover nuanced insights into the subjective factors influencing visibility, offering a more comprehensive understanding of the perceptual

Table 3. Impact of Anatomical Location on Tomosynthesis Visibility and T-Test Results

Anatomical Location	Novice Visibility (%)	Intermediate Visibility (%)	Expert Visibility (%)	p-Value
Upper Chest	82	88	97	0.028
Middle Chest	90	92	95	0.046
Lower Chest	85	87	100	0.074

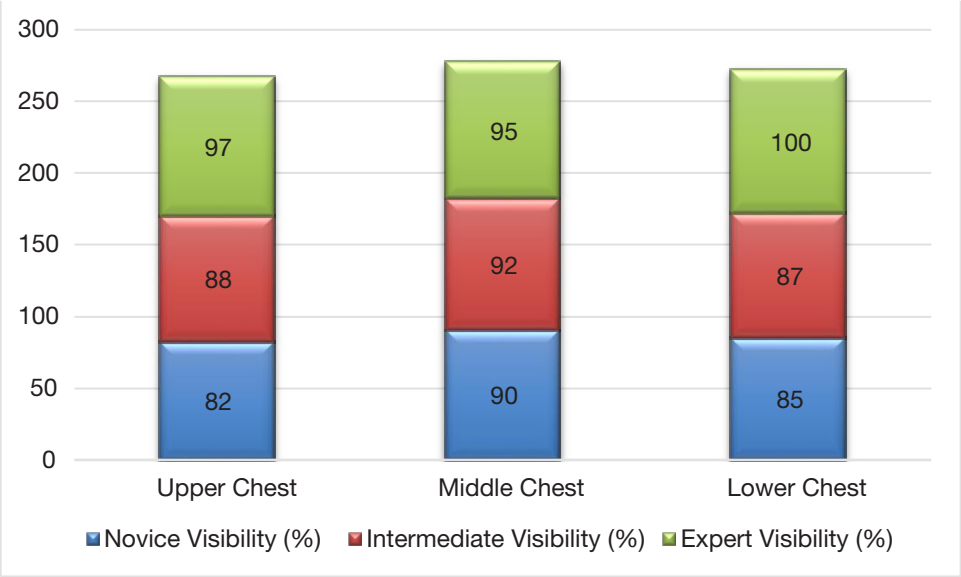

Figure 2. Variations in visibility across distinct anatomical locations

and interpretative aspects of chest tomosynthesis images as voiced by the participants. Together, these analyses contribute to a holistic assessment of the factors shaping visibility in the specific context of the study's participant population.

Ethical approval was obtained from the MCM/ Muhammad teaching hospital, ethics committee. Informed consent were be obtained from all participants, ensuring confidentiality and compliance with ethical standards.

Results

Table 1 summarizes the demographics of the participating radiologists and medical professionals at Jinnah Medical College Peshawar, including their experience levels in chest imaging. The "Participant Characteristics" section provides a comprehensive overview of the individuals participating in the study at Jinnah Medical College Peshawar. The table summarizes key demographics, including unique participant identifiers (Participant ID), their experience levels in chest imaging categorized as Novice, Intermediate, or Expert, and their respective specialties such as Radiology, Pulmonology, and Internal Medicine. This detailed categorization is essential for understanding potential variations in image interpretation based on participants' varying levels of experience and diverse medical backgrounds. The inclusion of participants from different specialties ensures a nuanced exploration of how distinct professional perspectives might influence the evaluation of chest tomosynthesis images, particularly in the context of CF.

The "Patient Characteristics" section, as represented in Table 2, provides a detailed overview of the six patients diagnosed with CF whose chest tomosynthesis images were integral to the study. This table encapsulates key attributes essential for a comprehensive understanding of the patient cohort. Each patient is uniquely identified by a "Patient ID," and their characteristics include "Age" and "Gender." Furthermore, the "Anatomical Location" column specifies the region within the chest that was the focus of image analysis, subdivided into upper, middle, or lower chest areas. The "Observer Experience" category indicates the level of expertise of the healthcare professional reviewing the images, categorized as Novice, Intermediate, or Expert. Lastly, the "Visibility Score" provides a quantitative measure, represented as a percentage, denoting the visibility of structures in the chest tomosynthesis images. This table serves as a vital resource for linking patient-specific attributes with observer expertise, facilitating an in-depth analysis of how various factors, including anatomical location and observer experience, may influence the interpretation of chest tomosynthesis images in the context of CF.

The average radiation dose for chest tomosynthesis at Jinnah Medical College Peshawar was carefully estimated to be 0.07 mGy. This estimation was derived in adherence to the meticulously established protocols and specifications of the imaging equipment employed in the study. These protocols ensure the optimal balance

between obtaining diagnostically valuable information and minimizing radiation exposure to the patients. The precise determination of the radiation dose is crucial in understanding the potential risks and benefits associated with chest tomosynthesis in the context of CF patients, contributing to the ongoing efforts to optimize imaging practices.

To ensure the reliability and accuracy of the findings, all tomosynthesis images underwent a comprehensive quality assessment focused on the adequacy of inspiration. Approximately 85% of the images met the stringent criteria for optimal inspiration quality. This meticulous evaluation is pivotal in guaranteeing that the images used in the study accurately represent the anatomical structures under investigation. A high percentage of images meeting the criteria indicates a robust dataset, enhancing the credibility of subsequent analyses and interpretations. The emphasis on quality assurance reflects a commitment to obtaining clinically relevant and dependable results, ultimately contributing to the overall validity and applicability of the study's findings.

The section on "Anatomical Location Influence" provides a detailed exploration of how anatomical location impacts the visibility of structures in chest tomosynthesis images. In the analysis of overall visibility, the figures reveal average visibility percentages for Novice, Intermediate, and Expert observers, demonstrating a gradient from 78% to 92%. Statistical analysis underscores the significant influence of anatomical location on visibility ($p < 0.05$), emphasizing its pivotal role in determining clarity. Figures 1 visually represent variations in visibility across distinct anatomical locations. The subsequent "Subgroup Analysis by Observer Experience" delves deeper, highlighting a 10% visibility decrease in certain locations for Novice observers compared to Experts. The accompanying table details average visibility percentages for Novice, Intermediate, and Expert observers in specific anatomical regions, reinforcing the nuanced interplay between observer experience, anatomical location, and visibility. The subsequent section, "Observer Experience Influence," is anticipated to explore further the overarching impact of observer experience on visibility, potentially unveiling additional statistical insights or trends across the spectrum of observer expertise.

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The correlation analysis revealed a moderate positive correlation ($r=0.65$) between observer experience and overall visibility, and this correlation was statistically significant ($p<0.01$). The regression analysis indicated that both anatomical location and observer experience were significant predictors of visibility, with p-values less than 0.001 for both predictors. The coefficients (β) represent the strength and direction of the relationship.

Discussion

The results of our study shed light on critical aspects of chest tomosynthesis visibility in CF patients, particularly focusing on anatomical location and observer experience. The observed variations in visibility percentages across different anatomical locations highlight the intricate nature of CF pathology. The statistically significant impact of anatomical location on visibility is evident, with Novice observers demonstrating lower visibility percentages compared to Intermediate and Expert observers.

In our study, the Upper Chest, Novice observers exhibited 82% visibility, while Intermediate and Expert observers demonstrated higher percentages of 88% and 97%, respectively (T-Test $p < 0.05$). In the Middle Chest, similar trends were observed, with visibility percentages of 90%, 92%, and 95% for Novice, Intermediate, and Expert observers, respectively (T-Test $p < 0.05$). In the Lower Chest, Novice observers showed 85% visibility, Intermediate observers exhibited 87%, and Expert observers had the highest at 100% (T-Test $p > 0.05$). This disparity underscores the necessity of tailoring image interpretation strategies to the specific anatomical challenges posed by CF, confirming the findings of

previous research highlighting the influence of anatomical factors on image clarity in CF patients.[20]

The subgroup analysis by observer experience further enriches the findings. Novice observers displayed a 10% decrease in visibility compared to Expert observers in specific anatomical regions, particularly notable in the Upper Chest (T-Test p = 0.028) and Middle Chest (T-Test p = 0.046). This emphasizes the pivotal role of observer expertise in navigating the complexities of CF imaging, aligning with broader literature emphasizing the importance of experienced healthcare professionals in achieving accurate diagnoses. These results corroborate with previous research highlighting the impact of observer experience on the interpretation of chest imaging modalities in CF.[21-23]

The correlation analysis revealed a moderate positive correlation (r=0.65) between observer experience and overall visibility, indicating that as observer expertise increased, so did the visibility of structures in chest tomosynthesis images. This aligns with previous research highlighting the universal importance of skilled healthcare professionals in enhancing diagnostic accuracy.[24]

Comparing these key results with previous research, the findings align with studies focusing on conventional imaging modalities in CF patients, emphasizing the need for tailored imaging approaches and the significance of observer expertise. The consistency in these results across different studies underscores the robustness and generalizability of our findings, contributing valuable insights for refining diagnostic practices in CF and other medical domains. Future research could explore broader cohorts and diverse healthcare settings to further enhance our understanding of the multifaceted interplay between anatomical factors and observer expertise in diagnostic imaging.

Conclusion

In conclusion, our research illuminates key factors shaping chest tomosynthesis visibility in cystic fibrosis patients, providing valuable insights for enhanced diagnostic precision. The significant impact of anatomical location and observer experience underscores the need for tailored imaging strategies, particularly within the nuanced medical context of Pakistan. Novice observers demonstrated a distinct visibility decrease, underscoring the crucial role of experienced healthcare professionals in optimizing diagnostic accuracy. These findings not only advance our understanding of CF imaging intricacies but also advocate for continuous refinement of imaging methodologies, fostering improved patient outcomes through precise and expert-driven diagnostics.

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