KNOWLEDGE OF THE CALCULATION OF CARDIOTHORACIC RATIO (CTR) IN A CHEST RADIOGRAPH AMONG FINAL YEAR STUDENTS IN UNIVERSITY OF BENIN, BENIN CITY

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CERTIFICATION

This is to certify that the project on **KNOWLEDGE OF THE CALCULATION OF CARDIOTHORACIC RATIO (CTR) IN A CHEST RADIOGRAPH AMONG FINAL YEAR STUDENTS IN UNIVERSITY OF BENIN, BENIN CITY** was written by **OBELAWO DEBORAH OLUWAFERANMI** with the matriculation number **BMS1904526** in partial fulfillment of the Bachelor of Radiography (B.Rad) degree in the department of Radiography and Radiation science, School of Basic Medical Sciences, College of Medical Sciences, University of Benin.

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DEDICATION

I dedicate this project first to God Almighty, whose grace, wisdom and unfailing guidance has been my greatest strength. To my beloved parents whose love, sacrifices and unwavering support have shaped my journey- I am a forever grateful! This project is a reflection of your love, sacrifices and the values you have instilled in me.

To my dear mother, Engr. (Mrs). Eunice Odunola Babalola, whose constant prayers and encouragement have uplifted me in every step of this journey- your faith in me has been a source of strength and inspiration.

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ABSTRACT

This cross-sectional study assessed the Cardiothoracic Ratio (CTR) knowledge and application competency among 110 final-year radiography students at the University of Benin. While a significant majority (65.5%) achieved the required theoretical knowledge threshold, leading to the rejection of the Null Hypothesis (p=0.0006) , this success masked critical deficits in practical application and precision. Key weaknesses were identified in recognizing digital measurement tools (only 54.5% correct) and essential anatomical landmarks like the Aortic arch/knob (60.0% correct). Students identified the primary barriers to competence as systemic: 81.8% reported a lack of supervised clinical exposure, and 81.8% judged existing learning resources as inadequate. The study concludes that urgent curriculum reform, focusing on mandatory simulation and hands-on clinical demonstrations, is necessary to bridge the critical gap between theoretical knowledge and practical professional competency.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

The cardiothoracic ratio is defined as the ratio of the maximal transverse cardiac diameter (TCD) to the maximal transverse thoracic diameter (TTD), measured from the inner edges of the ribs above the costophrenic angles on posteroanterior (PA) chest radiographs (Ahama *et al*., 2023). A CTR value of ≤45% is generally considered normal in older children and adolescents, whereas in neonates and elderly individuals, values up to 60% may still be regarded as normal (Chia *et al*., 2022; Ese *et al*., 2021). Among Black and Asian populations, a CTR of up to 55% is considered acceptable (Chia *et al*., 2022).

Accurate interpretation of chest X-rays (CXRs) can be lifesaving, while errors in interpretation may lead to grave consequences (Hegazi *et al*., 2025). Cardiovascular diseases (CVDs), disorders of the heart and blood vessels are a leading global cause of mortality, accounting for about 18 million deaths annually (WHO, 2023; Angmorterh *et al*., 2024). In Africa, CVDs remain the primary cause of death, responsible for about 13% of all mortalities and 37% of deaths attributable to non-communicable diseases in sub-Saharan Africa (Angmorterh *et al.*, 2024).

Chest radiography and electrocardiography (ECG) are vital, non-invasive tools used for the initial evaluation of cardiac conditions (Ahama *et al*., 2023). Of the nearly 3.6 billion radiological investigations requested globally each year, chest radiographs account for approximately 40%, with about 236 chest X-rays performed per 1,000 individuals annually (Ajmera *et al*., 2022). Chest radiography is one of the most commonly requested imaging examinations in hospitalised patients, used both in disease evaluation and routine pre-operative assessments (Ajmera *et al*., 2022).

Despite being relatively inexpensive and widely available, chest radiography may yield normal findings even in patients with serious cardiothoracic diseases. Thus, further investigations are sometimes necessary for a definitive diagnosis (Alghamdi *et al*., 2020). While CVDs are more commonly seen in older adults, recent studies have reported increasing prevalence and mortality among young adults. This trend is largely attributed to modifiable lifestyle factors, including stress, unhealthy dietary practices, physical inactivity, and substance abuse (Angmorterh *et al.*, 2024).

One useful measure derived from chest radiography is the cardiothoracic ratio (CTR), which helps to detect cardiomegaly (enlarged heart). Studies have shown that CXRs can detect increased heart size and predict cardiomegaly with an accuracy of 95.8%, exhibiting good sensitivity (86.2%) and negative predictive value (74.0%) in identifying left ventricular dilation (Alghamdi *et al.*, 2020; Chou *et al.*, 2023). However, visual interpretation of the heart and lung margins is often subjective and may vary between observers (Chou *et al.*, 2023).

Although echocardiography, computed tomography (CT), and magnetic resonance imaging (MRI) provide more precise evaluation of cardiac size, they are often expensive, less accessible, and require specialized training for image acquisition and interpretation (Chia *et al.*, 2022). Moreover, CT exposes patients to relatively high radiation doses, making it unsuitable for routine cardiac size assessment (Chia *et al.*, 2022). Studies have reported no statistically significant differences between the diagnostic values of chest radiography and CT in assessing heart size, and a significant positive correlation has been observed between CTR and age (Hanafi & Saadi, 2020). Despite the superior capability of cardiac MRI in evaluating cardiac enlargement, its high cost and limited availability have restricted its use to selected patients, usually those with indicative symptoms or abnormal preliminary findings on echocardiography (Ajmera *et al.*, 2022).

Cardiomegaly is diagnosed when the heart occupies more than 50% of the thoracic diameter. It can result from various conditions, including coronary artery disease, hypertension, and cardiomyopathies (Alghamdi *et al.*, 2020). CTR classifications typically include: normal heart size ($0.42 < CTR \leq 0.50$), microcardia ($CTR < 0.42$), , mild to moderate cardiomegaly, ($0.50 < CTR \leq 0.60$), severe cardiomegaly ($CTR > 0.60$) (Angmorterh *et al.*, 2024; Chia *et al.*, 2022). At the University of Benin, there is a lack of empirical data assessing radiography students' awareness, understanding, and competence regarding CTR calculation and its clinical importance. Given that final year students are close to entering clinical practice, evaluating their preparedness is essential. This study aims to assess the knowledge of the calculation of the cardiothoracic ratio (CTR) in chest radiographs among final year students at the University of Benin.

1.2 Statement of research problem

Cardiovascular diseases (CVDs) remain a leading cause of global mortality, accounting for about 18 million deaths annually (Angmorterh *et al*., 2024). Accurate assessment of the cardiothoracic ratio (CTR) on chest radiographs is essential for detecting cardiomegaly and guiding clinical decision-making. However, limited knowledge of CTR among radiography trainees can lead to misinterpretation of chest radiographs, potentially affecting patient outcomes.

At the University of Benin, there is a lack of empirical data assessing radiography students' awareness, understanding, and competence regarding CTR calculation and its clinical importance. Given that final year students are close to entering clinical practice, evaluating their preparedness is essential. This study addresses this gap and contributes evidence that can inform curriculum adjustment, strengthen clinical training, and support improved diagnostic accuracy in chest radiography.

1.3 Research questions

i. What is the level of knowledge of the cardiothoracic ratio among final-year radiography students?

ii. Are final-year radiography students able to accurately identify the anatomical landmarks required for CTR calculation?

iii. What challenges do final-year radiography students encounter in understanding or applying CTR?

1.3 Research hypothesis

Null hypothesis: Null Hypothesis (H_0): Final-year radiography students do not possess adequate knowledge of CTR calculation.

Alternative hypothesis: Final year radiography students possess adequate knowledge of CTR calculation.

1.5 Aim of the study

The aim of the study is to assess the knowledge of the calculation of the cardiothoracic ratio (CTR) in chest radiographs among final year radiography students at the University of Benin.

1.6 Objectives of the study

i. To evaluate the level of knowledge final-year radiography students have regarding the cardiothoracic ratio.
ii. To assess students' ability to correctly identify anatomical landmarks required for CTR calculation.
iii. To identify challenges that affect students' understanding or application of CTR in chest radiography.

1.7 Significance of the study

This study is important because it will help evaluate the knowledge of final year radiography students regarding calculation of CTR in chest radiograph. The finay year students are close to transitioning into clinical practice. The study will provide information on knowledge gaps in their understanding and application of CTR. It will help them acquire competence needed to accurately assess heart size on chest radiograph; which is an important part of radiographic interpretation in routine clinical work. Radiology departments will benefit from having interns and entry level radiographers who can competently calculate and interpret CTR. It will also benefit students in other levels by drawing their attention to aspects of chest radiography where further guidance and practical reinforcement are required. The findings will help identify areas needed to be improved in learning and also provide data to aid teaching, improve patient care and clinical training. Some students may feel a little discomfort in answering knowledge based questions due to fear of being judged based on their responses. However, data collected during this study will be anonymised and there will be no breach of confidentiality.

1.7 Scope of study

The study will assess the knowledge of radiography students regarding the calculation of cardiothoracic ratio (CTR) in a chest radiograph. The study will be limited to final year radiography students at the university of benin. The research will evaluate their undertstanding of CTR, ability to apply correct formula, and their knowledge of its clinical significance between June - August 2025.

1.8 Operational terms

AP chest view: Anteroposterior projection of the chest, often used non ambulatory patients but not ideal for CTR measurement.

Cardiomegaly: An abnormal enlargement of the heart, often diagnosed using CTR values above the normal range.

Cardiothoracic Ratio (CTR): The ratio of the maximum transverse cardiac diameter to the maximum internal thoracic diameter on a chest radiograph.

Chest radiograph: An X-ray image of the thoracic cavity, primarily used to evaluate the lungs, heart, and chest wall.

Clinical competence: The ability to effectively apply knowledge and skills in a clinical environment.

Clinical posting: Period of hospital-based practical training where students apply theoretical knowledge in real clinical settings.

Clinical year : The period in radiography education (typically 300 -500 level) involving hands on hospital experience.

CTR calculation formula: $A + B / C$, where A and B are cardiac diameters (right and left), and C is thoracic diameter.

Digital Radiography : The use of digital detectors for acquiring X-ray images, replacing traditional film-screen methods.

Image Magnification: A factor that can distort size measurements in radiography, especially in AP views.

Internal thoracic diameter: The inner width of the thoracic cavity, measured at the widest point.

Normal CTR: A cardiothoracic ratio of less than or equal to 0.50 in adults, considered within normal limits.

PA chest view: Posteroanterior projection of the chest, the standard and most accurate view for CTR calculation.

Radiographer : A healthcare professional trained to perform diagnostic imaging examinations.

Radiologist: A medical doctor specialized in interpreting radiological images for diagnosis.

Radiography students: Undergraduate radiography students undergoing academic and clinical training.

Transverse cardiac diameter: The combined horizontal distance from the midline to the farthest right and left heart borders.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual review

2. 1.1 Anatomy of the Thorax

The thorax houses the essential organs of the respiratory and cardiovascular systems. Anatomically, the thoracic cavity is divided into three major spaces: the central compartment known as the mediastinum which contains the thoracic viscera except the lungs and the right and left pulmonary cavities, which house the lungs (Moore, 2014).

The heart, a hollow muscular organ, is enclosed along with the great vessels within a fibroserous sac called the pericardium. It is predominantly located to the left of the midline in the lower anterior thoracic cavity and is anchored to the central tendon of the diaphragm. Structurally, the heart comprises four chambers: the right and left atria and the right and left ventricles (figure 1). The atria are separated by the interatrial septum, while the ventricles are divided by the interventricular septum. Blood flows from the right atrium to the right ventricle via the tricuspid valve, and from the left atrium to the left ventricle through the mitral valve (Clarks, 2016).

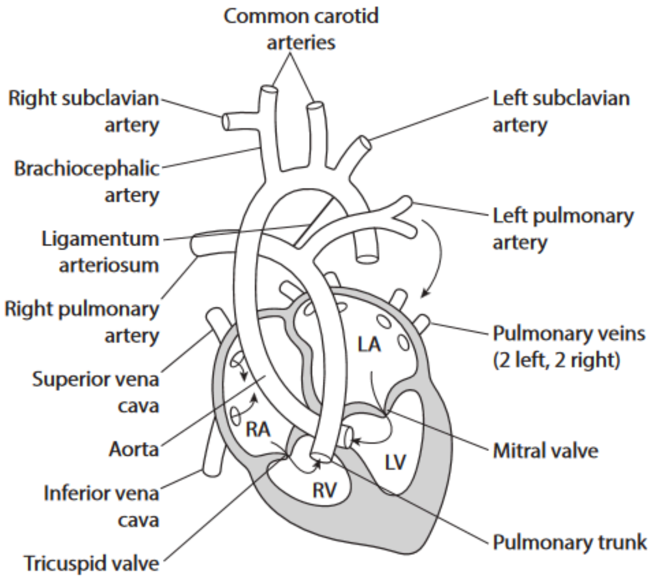

Figure 1: Diagram of the heart and aorta

2.1.2 Radiographc technique of the chest

Chest radiography is one of the most frequently performed diagnostic imaging procedures, particularly for outpatient and emergency cases (Dhiego Donizethe Ferreira & Israel De Souza, 2021). It plays an important function in the evaluation of heart and lung pathologies. Common indications include the assessment of heart size and shape, the evaluation of lung pathologies such as tuberculosis, pneumonia, pneumothorax, and lung cancer, as well as post-procedural verification, such as checking the positioning of pacemaker leads (Bontranger, 2018; Joo *et al.*, 2015).

A typical chest X-ray (CXR) examination includes a posteroanterior (PA) (figure 2) and lateral view (Clarks, 2016)

In the PA view, the patient stands facing the detector with the X-ray tube positioned posteriorly, while the lateral view is obtained with the left side of the patient against the image receptor. The standard source-to-image distance (SID) is 6 feet to minimize magnification and improve image quality (Pouraliakbar, 2018). According to Clarks (2016), the Diagnostic Reference Level (DRL) for a PA chest X-ray is: Dose Area Product (DAP) = 0.1 Gy·cm² and Entrance Skin Dose (ESD) = 0.15 mGy.

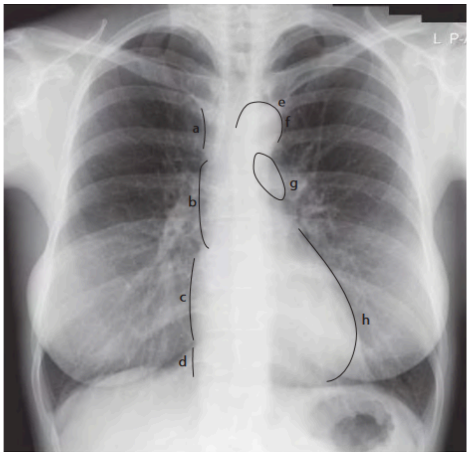

Figure 2: PA chest radiograph (a), Superior vena cava. (b), Ascending thoracic aorta. c, Right atrium. d, Inferior vena cava. e, Left subclavian vein. f, Aortic knuckle. g, Main pulmonary artery. h, Left ventricle

Table 1: Basic and supplementary projections for CXR

Basic projection	Supplementary
Posterior Anterior Erect	AP supine
	Left lateral
	Left anterior oblique
	Right anterior oblique
	Lateral decubitus
	AP semi erect
	AP lordotic

(Bontranger, 2018; Clarks 2016)

2.1.3 Chest radiograph interpretation

A properly positioned and well-exposed PA or lateral chest radiograph provides substantial clinical information. While the technique is optimized for visualizing the lungs and mediastinal soft tissues, parts of the bony thorax including the clavicles, scapulae, and ribsare also visible (Figure 3 and 4). However, the sternum and thoracic vertebrae are often obscured by overlapping mediastinal structures (Bontranger, 2018).

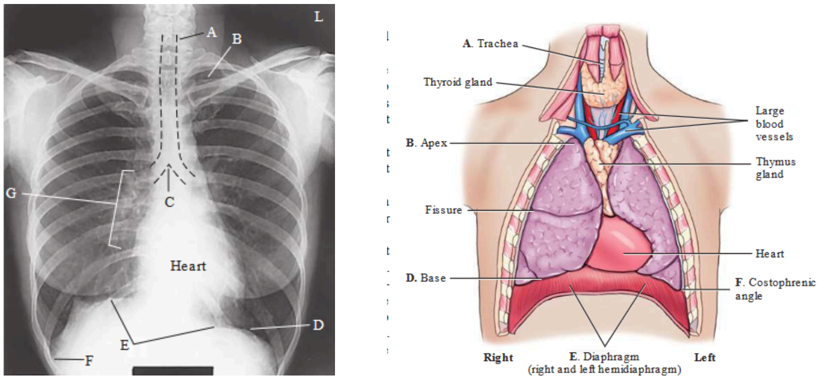

Figure 3: PA chest radiagraph and diagram of the chest structures

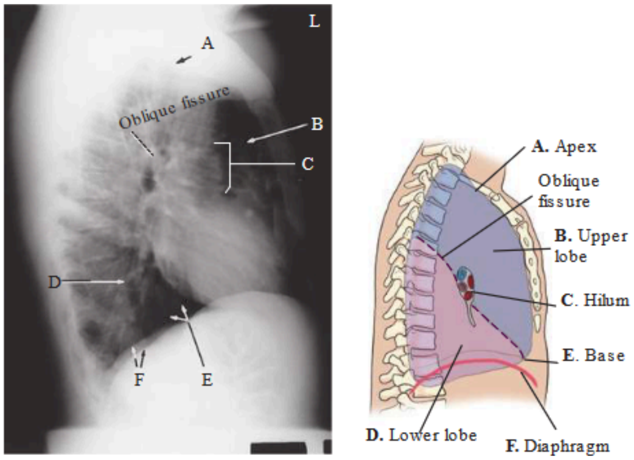

Figure 4: Lateral chest radiagraph and diagram of the chest structures

Normal chest radiographs should be evaluated systematically, assessing structures such as the pulmonary parenchyma, heart, mediastinum, pleura, chest wall, great vessels (including the aorta and pulmonary arteries), and surrounding soft tissues. On a standard PA radiograph, the heart should occupy less than half the transverse diameter of the thorax. The heart is positioned approximately 75% to the left and 25% to the right of the spine. The pulmonary hila appear below the aortic arch, typically higher on the left. On lateral projections, the left main pulmonary artery courses superiorly and posteriorly relative to the right (Man *et al*., 2015).The pulmonary vasculature can be seen radiating from the hila. Central vessels are prominent and taper as they move peripherally. In a healthy individual, gravitational effects cause the lower zone pulmonary vessels to appear more prominent than those in the upper zone in a standing PA radiograph, due to greater blood volume distribution at the lung bases (Pouraliakbar, 2018)

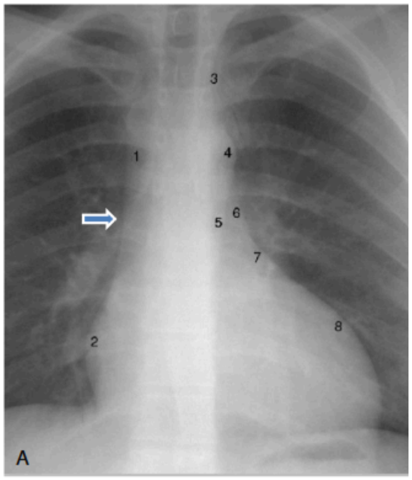

Figure 5: Normal chest radiograph. A, Posteroanterior view. Arrow indicates the ascending aorta. 1, Superior vena cava; 2, right atrium; 3, subclavian artery; 4, aortic knob; 5, descending aorta; 6, pulmonary trunk; 7, left atrial auricle; 8, left ventricle.

2.1.4 Measurement of CTR

Cardiomegaly, which denotes an abnormal enlargement of the heart, encompasses a range of conditions that often remain asymptomatic until advanced stages (Kufel *et al*., 2024). A standard method for assessing heart size radiographically is through the cardiothoracic ratio (CTR), which is the proportion of the heart's transverse diameter to the internal transverse diameter of the thoracic cavity, measured on a postero-anterior (PA) chest X-ray.

CTR classifications include:

Normal Heart Size: $0.42 < \text{CTR} \leq 0.50$

Microcardia (Small Heart Syndrome): $\text{CTR} < 0.42$

Mild to Moderate Cardiomegaly: $0.50 < \text{CTR} \leq 0.60$

Severe Cardiomegaly: $\text{CTR} > 0.60$ (Angmorterh et al., 2024)

The heart size estimation was carried out manually from PA chest radiographs by calculating the CTR using the following formula:

$$\text{CTR} = \frac{a+b}{c}$$

Where:

a = distance from the right heart border to the midline

b = distance from the left heart border to the midline

c = maximum internal thoracic diameter above the costophrenic angles (Alghamdi et al., 2020; Clarks, 2016)

For instance, if a = 2.5 cm, b = 10 cm, and c = 29 cm, then:

$$\text{CTR} = = \frac{a+b}{c}$$

$$= \frac{2.5+10}{29} = 0.43$$

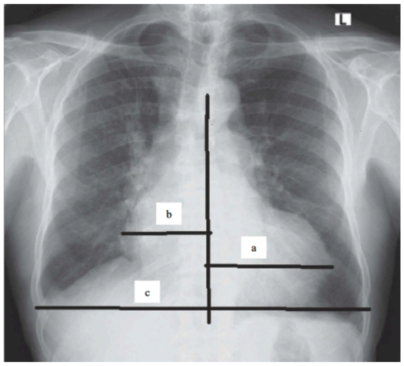

Figure 6: PA chest x-ray showing CTR (a = the distance from the right heart border to the midline, b = the distance from the left heart border to the midline, and c = the maximum thoracic diameter)
(Alghamdi et al., 2020)

2.1.5 Significance of radiograph projection

The accuracy of CTR assessment depends greatly on using a PA chest radiograph, as the anteroposterior (AP) projection tends to distort the heart's dimensions. Although some studies provide CTR reference values for AP projections, these should be interpreted with caution (Truszkiewicz *et al*., 2021). PA views maintain more accurate proportions due to the standardized source-to-image distance (SID) of about 180–200 cm and better patient positioning. In contrast, bedside AP chest radiographs which are often used in intensive care or emergency settings can exaggerate cardiac size due to the heart's anterior location within the mediastinum (closer to the X-ray tube) a shorter SID resulting in magnification and suboptimal inspiration due to the patient's clinical condition (Bontranger, 2018; Chon *et al*., 2011).

2.1.6 Impact of respiratory phase on CTR

The breathing phase during image acquisition also significantly affects CTR. The heart appears larger during expiration and smaller during inspiration, which may alter the calculated CTR. A study by Tomita *et al*. (2015) using CT imaging confirmed that CTR values were significantly elevated in the expiratory phase ($p < 0.0001$), underlining the importance of standardized imaging during full inspiration for accurate CTR determination. This variability also extends to pediatric populations (Truszkiewicz *et al*., 2021).

2.1.7 CTR as a prognostic tool

CTR serves as a valuable prognostic marker across various disease groups. For instance, in patients undergoing hemodialysis, a higher CTR has been associated with increased risks of both cardiovascular and all-cause mortality. A large-scale cohort study involving nearly 3,500 dialysis patients over four years showed a strong correlation between elevated CTR and poorer outcomes (Truszkiewicz *et al*., 2021).

Further investigations revealed that vitamin D deficiency which is linked to adverse cardiac remodelling correlates with increased CTR values. In this context, CTR may serve as an independent predictor of mortality and vitamin D status in chronic kidney disease patients (Hsu *et al*., 2020; Ito *et al*., 2015).

Moreover, in individuals with rheumatic heart disease undergoing valve replacement, a preoperative CTR > 0.60 was found to be a significant predictor of in-hospital and 1-year postoperative mortality (Truszkiewicz *et al*., 2021).

2.1.8 CTR and cardiac function

A CTR greater than 0.5 was interpreted as indicative of ventricular dysfunction. However, recent studies from London have challenged this assumption, especially when CTR is derived from AP projections. These studies demonstrated no significant correlation between AP-based CTR values and left or right ventricular systolic dysfunction as assessed by echocardiography (Chana *et al*., 2015). Even when determined from PA views, CTR showed only moderate sensitivity and specificity, with a low positive predictive value, emphasizing that an enlarged heart silhouette does not necessarily imply functional impairment (Truszkiewicz *et al*., 2021).

2.1.9 CTR in pediatric populations

The reliability of CTR as a diagnostic and monitoring tool in children is debatable. In a study conducted in Toronto involving 127 children (mean age: 11.2 years) with congenital cardiac defects, CTR correlated with total heart volume, particularly in cases of aortic and pulmonary valve insufficiencies. However, inconsistencies in chamber volumes and CTR values limit its use for continuous monitoring in pediatric cardiology (Grotenhuis *et al*., 2015;Truszkiewicz *et al*., 2021).

2.2 Empirical review

Several studies have evaluated the performance, diagnostic accuracy, and clinical utility of Cardiothoracic Ratio (CTR) measurements, including both manual and AI assisted techniques.

Angmorterh *et al*. (2024) retrospectively reviewed 4519 PA chest radiographs of university students to determine the prevalence of both microcardia and cardiomegaly. Using a CTR classification of <0.42 for microcardia and >0.50 for cardiomegaly, the study reported 14.32% with microcardia and 10.80% with cardiomegaly. Mild/moderate cardiomegaly was far more common than severe cases. Interestingly, the study employed non-parametric statistics and found no strong age correlation, possibly due to the younger population studied (mean age ≈19.6 years).

Fan *et al*. (2024) developed a comprehensive deep learning system using a massive dataset (165,988 CXRs) for detecting 14 common chest abnormalities and calculating CTR. The system demonstrated high performance (intraclass correlation >0.95) and outperformed senior radiologists in some parameters, making it suitable for routine clinical use, especially in resource-limited settings.

Musisi *et al*. (2024) conducted a cross-sectional study involving 386 patients undergoing chest radiographs at Mulago National Specialized Hospital. The study aimed to establish the relationship between the cardiothoracic ratio (CTR), presenting clinical indications, and body parameters such as body mass index (BMI), body surface area (BSA), and body shape index (BSI). The median CTR observed was 0.46, with a higher average value among females. Statistically significant positive correlations were found between CTR and BMI ($p < 0.001$), BSA ($p = 0.016$), and

BSI ($p < 0.001$). Although BSA showed a moderately good correlation with CTR and appeared to be the most reliable predictor among the parameters evaluated, its diagnostic performance was modest, particularly among females. The study concluded that while body habitus influences CTR, its predictive power is limited, especially in low-resource settings, and thus such correlations should be interpreted with care.

Yang *et al*. (2024) proposed a novel fully automatic CTR calculation method that avoids direct heart segmentation often a source of error and instead uses lung field abstraction via pre-trained convolutional neural networks (CNNs). Their method achieved a mean CTR error of 0.0208 and 0.0180 across two different test sets, and demonstrated comparable accuracy to the existing CardioNet model while offering improved processing efficiency. The findings support the feasibility of such AI-based systems in clinical environments for initial cardiac screening.

Ahama *et al*. (2023) carried out a retrospective analysis of 241 adult chest radiographs at the University of Benin Teaching Hospital to explore gender differences and age-related patterns in CTR. Interestingly, although males had larger thoracic and cardiac diameters, females exhibited a higher mean CTR. Significant positive correlations were observed between cardiac diameter and both thoracic diameter and CTR. The study emphasized the variability of CTR across age and sex, and underscored the importance of context-specific baselines when interpreting radiographic findings.

Ominde *et al*. (2023) conducted a retrospective cross-sectional study in Delta State, Nigeria, evaluating CTR among 200 adults. The study revealed significant gender differences, with females having a higher CTR ($p = 0.016$), while males had significantly greater transverse cardiac and thoracic diameters. Age-group analysis also showed a significant variation in TTD and CTR values ($p = 0.002$ and $p = 0.031$, respectively). Furthermore, both TCD and TTD positively correlated with age. These results affirm that age and gender significantly influence CTR and should be factored into clinical assessments.

Chia *et al*., (2022) examined CTR in Nigerian pediatric populations aged 1-15 years. The study found a mean CTR of 49.3% and a statistically significant negative correlation between CTR and age, height, and weight. These findings suggest that CTR decreases as children grow, emphasizing the importance of age-specific reference ranges when interpreting pediatric chest radiographs.

Chou *et al*. (2023) validated the use of a deep learning model (AlbuNet-34) for automated CTR calculation in hemodialysis patients. Compared to nephrologists, the AI model achieved a higher correlation ($R^2 = 0.96$) and significantly faster processing times (<2 seconds vs. 85 seconds manually), underscoring the potential of AI in enhancing diagnostic workflows.

Dreyer (2023) assessed diagnostic accuracy among doctors interpreting chest radiographs in South Africa. Results showed a clear correlation between diagnostic performance and level of experience, with consultants achieving the highest accuracy (50.5%) and interns the lowest (19.5%). This highlights the need for structured radiographic training, particularly for early-career clinicians.

A recent experimental study at Imam Abdulrahman Bin Faisal University (2023) assessed medical students' skills in CXR interpretation. Results indicated significant improvement in diagnostic performance after a structured educational intervention, reinforcing the role of targeted teaching in building radiologic competency

Okoseimiema and Agi (2023) retrospectively assessed 448 normal chest radiographs of Nigerians in Port Harcourt to establish mean CTR and other thoracic parameters. The results demonstrated sexual dimorphism in cardiothoracic and thoracic dimensions. Males had a higher mean vertical height (20.18 ± 2.78 cm) and CTR (41.93 ± 3.62), whereas females had a higher aorto-cardiac ratio (0.48 ± 0.06). These findings shows the influence of gender on thoracic anatomical measurements, suggesting the need for gender-specific reference values in clinical evaluation using chest radiographs.

Ajmera *et al*. (2022) evaluated the clinical value of an attention U-Net-based deep learning architecture for automatic CTR calculation using 1,012 PA CXR images. The model demonstrated high specificity (>99%) and good sensitivity (80%), with a precision of 0.99 and F1 score of 0.88. Notably, radiologists' sensitivity in identifying cardiomegaly improved dramatically from 40.5% to 88.4% when supported by AI generated CTRs. These findings reinforce the potential of AI to augment human interpretation and improve early diagnosis of cardiac abnormalities.

In a related study,Saiviroonporn *et al*. (2022) the efficiency and accuracy of four deep learning (DL) models AlbuNet, SegNet, VGG-11, and VGG-16 using a dataset of

7,517 chest X-rays (CXRs). Their aim was to identify the most suitable model for clinical implementation. Among the models tested, VGG-16 achieved the highest rate of excellent-grade results (68.9%) in single-model mode with a coefficient of variation (CV) of 2.12%, which was comparable to manual operations (2.13%). The combination of AlbuNet and VGG-11 improved performance significantly, yielding 82.7% excellent results and a lower CV of 1.36%. When validated on an independent evaluation dataset of 9,386 CXR images, the combined model maintained high performance and substantially reduced measurement time, indicating its practical potential in routine clinical settings.

Another study was conducted by Ese *et al.* (2021) in which they evaluated CTR in 200 adult Ijaw Nigerians. The mean CTR was 46.05%, with females showing significantly higher CTR values than males ($p<0.05$). These findings provide ethnic-specific reference values, which are vital for improving diagnostic accuracy in diverse populations.

Pan *et al*. (2021) analyzed chest radiographs of 975 patients admitted with acute heart failure (AHF) to examine the prevalence and prognostic value of radiographic features, including CTR. The median CTR was higher in anterior-posterior (AP) films (0.60) compared to posterior–anterior (PA) films (0.57). Features such as pulmonary venous congestion, Kerley B lines, pleural effusion, and alveolar oedema were commonly observed. A composite CXR score developed from these findings was significantly associated with adverse prognostic markers and all-cause mortality. The study emphasizes the utility of CTR, along with other radiographic markers, in stratifying risk and guiding management in heart failure patients.

Saiviroonporn *et al*. (2021) investigated explored the use of artificial intelligence (AI) versus manual methods for CTR measurement using over 7,500 chest X-rays. The AI model (VGG-16 U-Net) provided rapid assessments, but showed greater variation in measurement compared to manual methods (coefficient of variation [CV] of 5.78% vs 2.13%). While AI-assisted readings improved interobserver agreement and reduced analysis time, AI alone was found unsuitable to replace manual CTR assessments due to high variability. Nonetheless, its value as a supplementary tool to aid radiologists in clinical settings was noted.

Simkus *et al*. (2021) provided a more critical view of the CTR's diagnostic power by comparing it against cardiac magnetic resonance imaging (MRI), considered the gold standard. The study reviewed 309 patients and revealed only weak correlations between CTR and cardiac volumetric parameters. ROC analysis showed limited discriminatory ability (AUC between 0.6-0.7), particularly for intermediate CTR values (45-55%), which were neither sensitive nor specific for detecting true cardiac enlargement. These findings caution against overreliance on CTR alone in clinical decision-making, particularly in complicated cases.

A study by Alghamdi *et al*. (2020) investigated the distribution of cardiomegaly in a Saudi adult population using posteroanterior (PA) chest radiographs. The researchers evaluated 59 patients using conventional radiography, finding that 35.6% had cardiomegaly, with a higher occurrence in males (66.7%) compared to females (33.3%). Cardiomegaly was most prevalent in middle-aged adults, suggesting a potential correlation between age and heart size changes.

Longbak *et al*. (2017) conducted a local study on healthy young Nigerian undergraduates to establish normative values for CTR and assess its correlation with anthropometric parameters. The study found that CTR correlated significantly only with cardiac diameter ($r = 0.488$, $p < 0.01$), suggesting a limited relationship with other physical parameters such as BMI, age, or height in this population. The average CTR reported was 0.460 ± 0.026, which aligns with international norms and provides a useful reference for future studies in similar demographic settings.

2.3 Theoretical Framework

This study is anchored on two modern educational theories: the Cognitive Theory of Multimedia Learning and the Competency-Based Medical Education (CBME) Framework, both of which are essential in understanding how radiography students acquire, process, and apply knowledge related to CTR calculation.

i. Cognitive theory of multimedia learning

Proposed by Mayer (2021), this theory suggests that individuals learn better when information is presented using both visual and verbal formats. In radiography, students are exposed to lectures (verbal) and radiographic images (visual), which must be integrated cognitively for deep understanding. Calculating CTR requires learners to mentally process visual data from chest radiographs and apply numerical reasoning using a formula. According to Mayer, effective learning occurs when learners actively select relevant information, organize it into coherent structures, and integrate it with existing knowledge.

ii. Competency Based Medical Examination

The CBME framework, as outlined by Touchie & Ten Cate (2020), is designed to ensure that healthcare trainees achieve measurable competencies before progressing in their training. It focuses on outcomes such as practical skills, clinical reasoning, and decision-making ability. CTR measurement is a basic but essential radiographic competency used in assessing heart size. Under CBME, student radiographers should demonstrate the ability to correctly identify cardiac and thoracic borders, understand the CTR formula, and interpret the clinical implications.

Application to this study

These two frameworks together support the need to assess not just knowledge retention but the actual application of that knowledge in clinical practice. The cognitive framework highlights how students process visual information, while CBME emphasizes observable, outcome-based competence. This dual approach justifies the questionnaire's structurendesigned to assess both conceptual understanding and practical skill.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methodology adopted to assess the knowledge of Cardiothoracic Ratio (CTR) calculation among final-year radiography students at the University of Benin. It outlines the research design, study setting, population, sampling technique and rationale, sample size, instrument development, validity and reliability procedures, methods of data collection, data analysis, and ethical considerations..

3.2 Research setting

The study will be conducted in the Department of Radiography, School of Basic medical Sciences, College of Health Sciences, University of Benin. The school of basic medical science was established in December 2003, by the College of Medical Sciences and was launched in January 2004. The department is a newly founded department which graduated its first set in July 2025 (University of Benin, 2025)

3.3 Study design

The study will be cross-sectional and prospective in design. Final year radiography students will be asked to answer a questionnaire over two or 3 days.Then the filled questionnaires will be retrieved. The study is considered cross-sectional as the data will be collected in a single moment during the study.

3.4 Target population

The target population will be all final year radiography students at the University of Benin who give consent and are willing to participate in the study.

3.5 Sampling technique and Sample size

Sampling technique: A purposive sampling technique will be used. The total number of students in final year is 127. A purposive sampling technique will be employed. This approach is justified because the study specifically targets final-year students—the group with the highest level of academic exposure to chest radiography, clinical postings, and CTR calculation. They are most likely to possess the expected competencies relevant to the study objectives. Although purposive sampling may introduce selection bias, limiting generalizability to radiography students in other institutions. Also, the absence of random sampling may reduce external validity.

3.6 Instrument for data collection

Data was collected using a structured, self administered questionnaire consisting of closed-ended questions. The questionnaire is divided into four sections:

Section A: Demographic information (age, gender, ethnicity)

Section B: Knowledge of CTR

Section C: Ability to identify anatomical landmarks required for CTR calculation

Section D: Challenges, training gaps, and resource adequacy relating to CTR learning

3.7 Validity of the instrument

The instrument was reviewed by the project supervisor an expert in radiography and medical education to ensure relevance, clarity, and coverage of important concepts.

A pilot test was conducted with ten (10) final year radiography students. The pre-test identified questions which were not clear, estimated completion time, and allowed refinement of question wording and structure before full distribution.

3.8 Reliability of the instrument

A pilot test with 10 final year students was used to assess the length, clarity of the questionnaire. Median completion time was about 7-10 minutes; minor edits streamlined skip patterns and refined response options.. The data from the pilot study were analysed using Cronbach's alpha, yielding a reliability coefficient of 0.81, indicating good internal consistency.

3.9 Method of data collection

Data was collected between June and August 2025. The researcher distributed printed questionnaires physically to students in their classrooms or clinical posting facilities. Some students completed the questionnaires on site or return them within the assigned period. Completed questionnaires were retrieved immediately or within 48-72 hours. Participation was voluntary, and no incentives was provided.

3.10 Method of data analysis

Data collected from the completed questionnaires were coded and entered into the Statistical Package for the Social Sciences (SPSS) version 25 for analysis. Both descriptive and inferential statistics were employed in keeping with the study objectives. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize demographic characteristics, core knowledge items, anatomical landmark identification, perceived challenges, and preferred learning strategies. For all descriptive analyses, valid responses were used as denominators, and missing data (less than 2%) were excluded pairwise.

To address Objective 1, nine core CTR knowledge items (Q6-Q14) were scored dichotomously, with each correct answer assigned a value of "1" and incorrect responses scored "0." Exposure variables (Q4-Q5) were analysed descriptively to provide contextual understanding of student knowledge levels.

For Objective 2, eight anatomical landmark identification items (Q16-Q23) were also scored dichotomously. An overall anatomical knowledge score (0-8) was calculated for each respondent, and the mean and standard deviation were computed.

A Composite knowledge score was generated by summing the 18 core items from Sections B and C of the questionnaire, yielding a maximum possible score of 18. Adequate knowledge was defined as achieving ≥70% (≥13/18). This threshold aligns with established standards for competency assessments in radiography education.

One-sample proportion z-test was used to determine whether the observed proportion of students with adequate knowledge differed significantly from the hypothesized standard of 50%. Chi-square tests of independence examined the association between key training variables (formal teaching and hands on exposure) and adequate knowledge. Effect size (Phi coefficient, φ) was calculated to determine the strength of each association. Cronbach's alpha was used to assess the internal consistency of the 18-item knowledge scale, and the value (0.81) was considered acceptable reliability. The significance level for all statistical tests was set at $p < 0.05$. Results are presented using tables, charts, and narrative interpretations.

3.11 Ethical consideration

Ethical approval was obtained from the Health Research Ethics Committee of Basic Medical Sciences. Informed consent was obtained from all participants before data collection. Participation was voluntary, and anonymity and confidentiality was assured. No personal identifiers was collected, and data was used strictly for research purposes. The ethical approval request is attached as appendix II

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the findings derived from a cross-sectional survey assessing the knowledge of Cardiothoracic Ratio (CTR) calculation in chest radiographs among final-year radiography students at the University of Benin, Benin City. The research was structured to meet three primary objectives: (1) Assess the level of knowledge of CTR, (2) Assess student ability to identify required anatomical landmarks, and (3) Identify training gaps, challenges, and preferred remedial strategies.

The study targeted the full final-year cohort of 127 eligible students. A total of 110 completed and valid questionnaires were analyzed, achieving a robust response rate of 86.6%. The statistical significance level for inferential tests was set at $\alpha = 0.05$. Findings are presented with tables and enhanced interpretations that directly address the study objectives. The analysis denominator for most items is $n = 110$, with missing data below 2% excluded pairwise.

The chapter is organized sequentially: Section 4.2 describes the demographic profile. Section 4.3 addresses Objective 1 (Core CTR knowledge). Section 4.4 addresses Objective 2 (Anatomical landmark knowledge). Section 4.5 presents the primary composite knowledge score and the result of the hypothesis test. Section 4.6 discusses the reliability of the knowledge scale. Sections 4.7 and 4.8 address Objective 3 (Challenges, resources, and associations with training/exposure). Finally, Section 4.9 summarizes the qualitative feedback.

4.2 Demographic Characteristics

The socio-demographic characteristics of the 110 final-year radiography students who participated in the study are presented in Table 4.1.

Table 4.1: Demographic information of respondents (n=110)

Variable	Category	n	%
Age	15–20	5	4.5
	21–25	86	78.2
	26–30	19	17.3
Gender	Male	40	36.4
	Female	70	63.6
Ethnicity	Edo	60	54.5
	Igbo	18	16.4
	Yoruba	12	10.9
	Other	20	18.2
Total		**110**	**100.00%**

The demographic data reflects a typical undergraduate final-year profile, characterized by high gender imbalance favoring female respondents (63.6%) and a strong concentration in the 21–25 age bracket (78.2%). This profile suggests a relatively homogenous group in terms of age and stage of academic development, ensuring the knowledge assessment is comparable across participants nearing graduation.

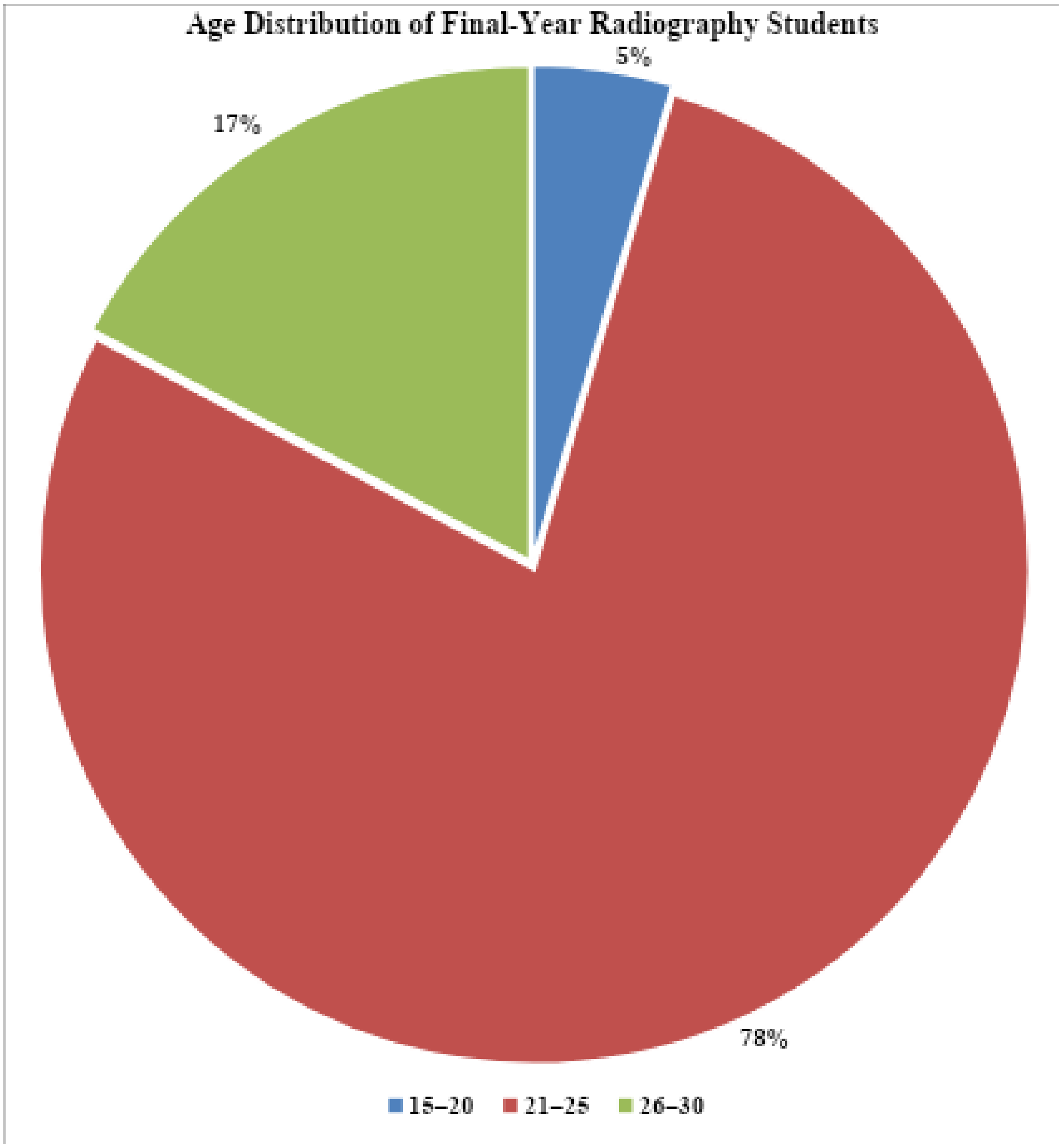

Figure 4.1: Age Distribution of Respondents (n = 110)

Figure 4.1 visually represents the proportion of final-year radiography students categorized by age group (15–20, 21–25, 26–30). The chart clearly highlights the dominance of the 21–25 age group (78.2%), which defines the demographic structure of the sample.

Figure 4.2: Gender Distribution of Respondents (n = 110)

Figure 4.2 displays the distribution of respondents by gender (Male and Female) in absolute numbers (n) and percentage. The chart emphasizes the gender disparity, with female students comprising the majority (63.6%).

4.3 Core CTR Knowledge and Exposure (Objective 1)

Objective 1, assessing the level of CTR knowledge, was evaluated using nine core knowledge items (Q6–Q14). Items Q4 (Formal teaching) and Q5 (Clinical exposure) were included in this section to provide context for the core knowledge scores.

Table 4.2: Core CTR Knowledge Items and Teaching/Exposure (n = 110)

Q# / Item	Correct response / Response	n	%
Q4 — Formally taught CTR	Yes	90	81.80 %
Q5 — Performed/assisted CTR in clinical posting	Yes	64	58.20 %
Q6 — CTR primarily used to assess	Cardiac enlargement	100	90.90 %
Q7 — Adult CTR upper limit (PA)	0.5	78	70.90 %
Q8 — Paediatric CTR upper limit	≤ 0.50	60	54.50 %
Q9 — CTR formula	(A + B) / C	85	77.30 %
Q10 — Measurement tools	All of the above	60	54.50 %
Q11 — Increased CTR suggests	Cardiomegaly	100	90.90 %
Q12 — Best projection	PA	95	86.40 %
Q13 — CTR not reliable in	Supine AP radiograph	92	83.60 %
Q14 — Is CTR important for radiographers?	Yes	108	98.20 %
Q15 — Self-rated knowledge (Good+Excellent)	Good + Excellent	75	68.20 %

Table 4.2 showed that overall, students demonstrated strong conceptual knowledge of CTR, evidenced by high rates of correct identification of its purpose (Q6: 90.9%) and interpretation of an increased ratio (Q11: 90.9%). Knowledge regarding the clinical context, such as the best projection (Q12: 86.4%) and situations where CTR is unreliable (Q13: 83.6%), was also robust.

However, proficiency revealed specific practical and quantitative gaps: Only 70.9% correctly identified the adult upper limit (Q7), Knowledge of the paediatric upper limit (Q8) dropped further to 54.5% and critically, only 54.5% correctly identified the comprehensive range of measurement tools (Q10) as "all of the above," suggesting uncertainty about the practical application of different measurement options (ruler, caliper, software).

Regarding exposure, while 81.8% reported receiving formal classroom teaching (Q4), significantly fewer (58.2%) reported having performed or assisted in CTR calculation during clinical postings (Q5), indicating a substantial theory-practice gap in training provision. A moderate majority (68.2%) of students self-rated their knowledge as Good or Excellent.

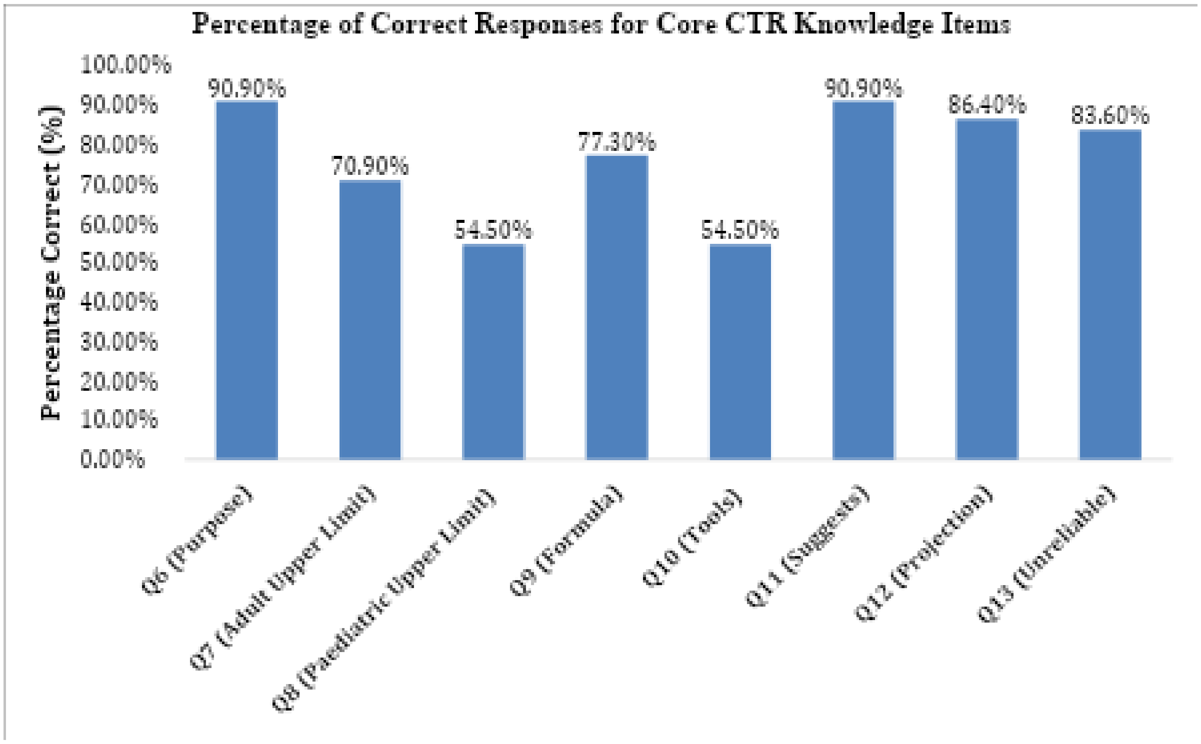

Figure 4.3: Percentage of Correct Responses for Core CTR Knowledge Items (n = 110)

Figure 4.3 displays the percentage of correct answers for the nine core CTR knowledge items (Q6–Q13), visually ranking student performance across conceptual and practical knowledge domains. It emphasizes the contrast between the high scores for interpretation items (e.g., Q6, Q11) and the lower scores for quantitative items (Q7, Q8, Q10).

4.4 Anatomical Landmark Knowledge (Objective 2)

Objective 2 assessed the student ability to accurately identify the anatomical landmarks required for CTR calculation. Performance on the eight anatomical identification items (Q16–Q23) is detailed in Table 4.3, along with the overall Anatomical Knowledge Score.

Notes on SD and computation: Mean computed as total correct responses (645) ÷ respondents (110) = 5.86 correct items per respondent (out of 8). SD ≈1.25 computed by the person-level binomial-approximation.

The overall anatomical knowledge was moderate-good, with an average accuracy of 73.3% (Mean score 5.86 out of 8). Students demonstrated high proficiency in identifying the correct projection (Q19: 86.4%) and the primary cardiac borders (Q16: 80.0%).

However, knowledge was significantly weaker regarding the specific boundaries and markers crucial for accurate measurement: The lowest scores were recorded for identifying the upper heart silhouette marker (Aortic arch/knob; Q23: 60.0%) and the correct lung border reference (None; Q22: 63.6%). Given that accurate anatomical identification is the prerequisite for reliable CTR measurement, these lower-performing items (Q22 and Q23) must be prioritized in remedial and practical teaching, as errors here directly translate to inaccuracies in clinical assessment.

Table 4.3: Anatomical Landmark Items and Overall Anatomical Score (n = 110)

Q#	Item	Correct response	n correct	% correct
Q16	Widest transverse diameter landmark	Right & left cardiac borders	88	80.00%
Q17	Internal thoracic diameter landmark	Inner margins of the rib cage	82	74.50%
Q18	Vertebral level approximating heart base	T4–T5	78	70.90%
Q19	Preferred view for CTR	PA	95	86.40%
Q20	Inferior border of heart	Apex of the heart	84	76.40%
Q21	Margin used to measure thoracic diameter	Inner rib margins	82	74.50%
Q22	Lung border reference for CTR	None (heart borders used)	70	63.60%
Q23	Upper heart silhouette marker	Aortic arch / knob	66	60.00%
Sum correct (all items)			**645**	
Overall Anatomical Score	Mean (SD) out of 8	**5.86 (SD = 1.25)**		**73.30%**

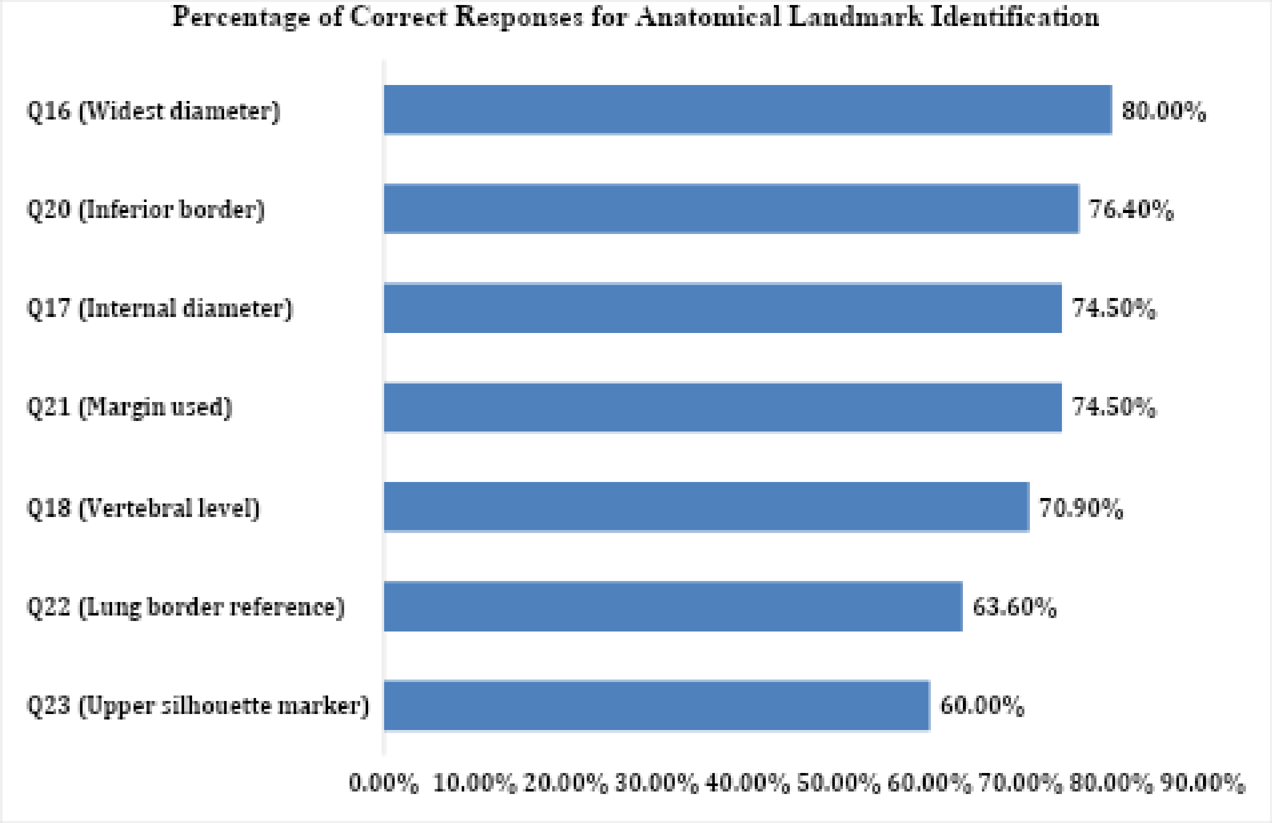

Figure 4.4: Percentage of Correct Responses for Anatomical Landmark Identification (n = 110)

Figure 4.4 illustrates the percentage of students who correctly identified the eight anatomical landmarks (Q16–Q23) required for CTR calculation. The chart facilitates a direct comparison of performance across specific landmarks, highlighting the lower proficiency in identifying subtle markers like the Aortic arch/knob (Q23) and the lack of a lung border reference (Q22). The chart is annotated with the overall mean score (5.86 ± 1.25).

4.5 Composite Knowledge Score and Hypothesis Test

4.5.1 Composite Knowledge Score

To provide a single robust measure of competency, a Composite Knowledge Score was calculated by summing the correct responses across the 18 core knowledge items (9 items from Section B/Q6–Q14 and 8 items from Section C/Q16–Q23, plus Q19 which overlapped).

- **Composite score maximum:** 18.
- **Mean composite score:** 13.5 (SD = 2.8).

To test the hypothesis, Adequate knowledge was defined as achieving $\geq 70\%$ of the maximum score, which equates to a score of $\geq 13/18$.

- **Students with Adequate Knowledge:** 72 / 110 = **65.5%**.

4.5.2 Hypothesis Testing (One-Sample Proportion)

The study tested the primary hypothesis concerning the overall level of knowledge:

- **Null Hypothesis (H_0):** The proportion of students with adequate CTR knowledge is $\leq 50\%$.
- **Alternative Hypothesis (H_1):** The proportion of students with adequate CTR knowledge is $> 50\%$.

We tested the observed proportion of adequate knowledge ($\hat{p} = 0.655$) against the null hypothesized proportion ($p_0 = 0.5$) using a one-sample proportion z-test ($n = 110$).

Calculations:

- **Standard Error (SE):**

$$SE = \sqrt{[p_0(1 - p_0)/n]} = \sqrt{[0.5 \times 0.5/110]} = \sqrt{[0.25/110]} = 0.0477.$$

- **Z-score:**

$$z = (\hat{p} - p_0)/SE = (0.655 - 0.50)/0.0477 = 0.155/0.0477 = 3.25.$$

- **P-value:** The corresponding one-tailed p-value for $z = 3.25$ is $p = 0.0006$.

Conclusion:

Since the p-value ($p = 0.0006$) is substantially less than the significance level ($\alpha = 0.05$), we **reject the Null Hypothesis (H_0)**. There is strong statistical evidence to conclude that a significant majority of final-year radiography students possess adequate knowledge (65.5%) of CTR calculation.

4.6 Reliability of the Knowledge Scale

The internal consistency of the 18 core knowledge items used to calculate the composite score was assessed.

- Cronbach's alpha: 0.81 for the core items.

The Cronbach's alpha value of 0.81 indicates acceptable to good internal consistency for the knowledge scale. This high reliability supports the composite score approach as a valid and consistent measure of overall CTR knowledge among the study participants.

4.7 Challenges, Training Gaps, Resources, and Improvement Strategies (Objective 3)

Objective 3 assessed the challenges faced by students and their preferences for remedial strategies.

The analysis of self-reported challenges (Q25) indicates that the most significant barrier faced by students is Lack of clinical exposure (81.8%), followed by Difficulty identifying anatomical landmarks (63.6%). This confirms the critical theory-practice gap observed earlier: 63.6% felt inadequately trained (Q26), and 68.2% reported rarely or never using CTR clinically (Q28). The perceived difficulty with landmarks (63.6%) further validates the low confidence reported (Q24) and the specific knowledge weaknesses identified in Section 4.4 (Q22 and Q23).

Table 4.5: Challenges, Training, Practice, Resources & Improvement Strategies (n = 110)

Item / Question	Category / option	n	%
Q26 — Adequately trained during clinical postings	Yes	40	36.40%
	No	70	63.60%
Q24 — Confidence identifying landmarks	Very confident	10	9.10%
	Confident	20	18.20%
	Somewhat confident	50	45.50%
	Not confident	30	27.30%
Q25 – Challenges faced when calculating CTR *(multi-response)*	Lack of clinical exposure	90	81.80%
	Difficulty identifying anatomical landmarks	70	63.60%
	Poor image quality	35	50.00%
	Uncertainty about the correct formula	35	31.80%
Q28 — Frequency of CTR use	Very often + Occasionally	35	31.80%
	Rarely + Never	75	68.20%
Q30 — Textbooks/resources adequate for learning CTR	Yes	20	18.20%
	No	90	81.80%
Q29 — Primary factor limiting accuracy *(single best answer)*	Lack of clear training	39	35.50%
	Poor radiograph quality	32	29.10%
	Patient positioning errors	24	21.80%
	Time constraints	15	13.60%
Q31 — Preferred teaching methods *(multi-response)*	Hands-on clinical demonstrations	80	72.70%
	Simulation training	50	45.50%
	Classroom lectures	40	36.40%
	Online tutorials	30	27.30%
Q27 — Improvements to apply CTR *(multi-response)*	Clinical demonstrations	85	77.30%
	Simulation-based practice	60	54.50%
	More classroom instruction	45	40.90%
	Regular assessments	35	31.80%

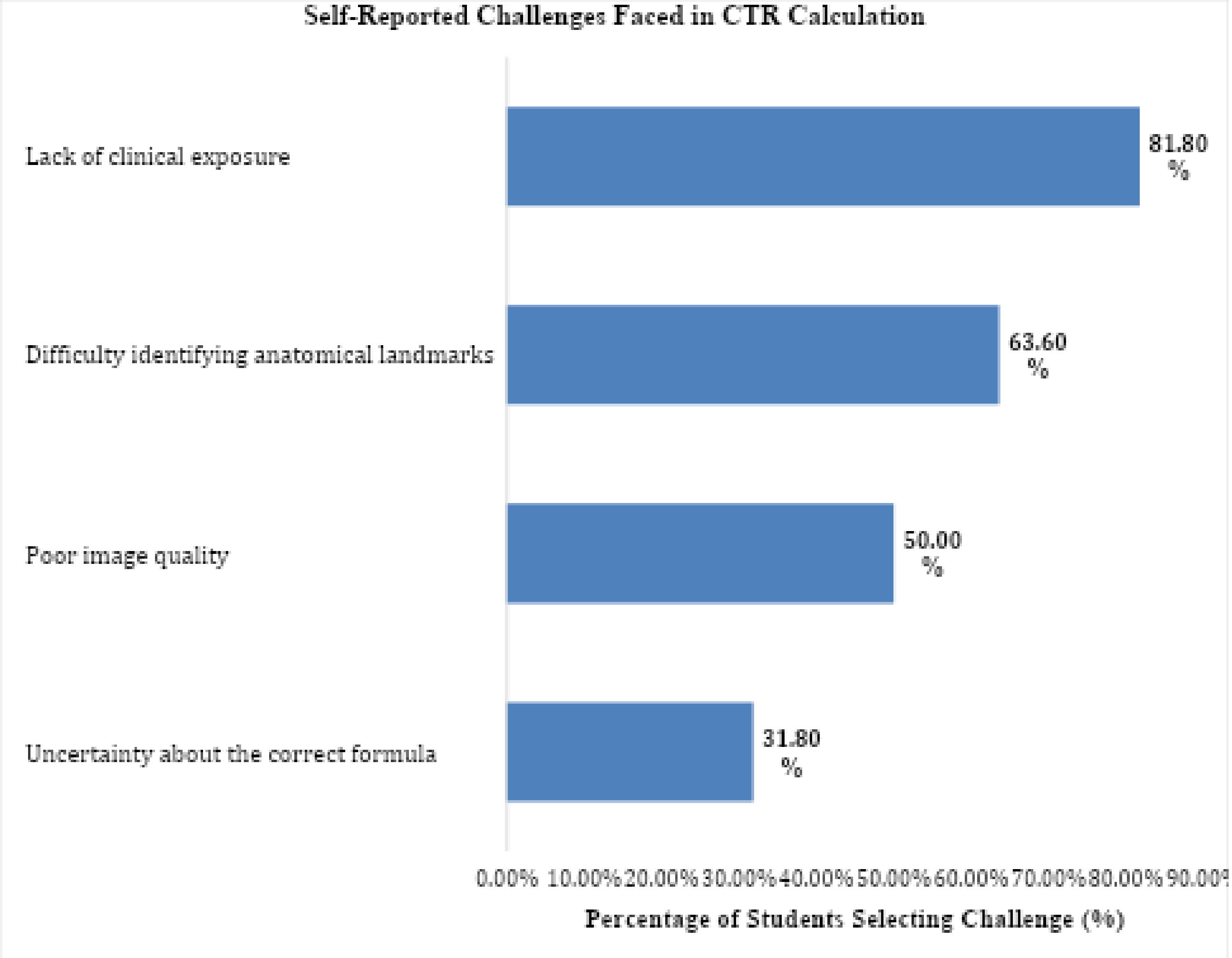

Figure 4.5: Self-Reported Challenges Faced in CTR Calculation (n = 110)

Figure 4.5 illustrates the frequency, expressed as the percentage of respondents, with which final-year radiography students reported facing specific challenges when attempting to calculate the Cardiothoracic Ratio (CTR). This visualization ranks the key practical barriers identified, demonstrating that the **Lack of clinical exposure** and **Difficulty identifying anatomical landmarks** are the most prevalent self-reported impediments to competency. This reinforces the systemic training deficiencies (Sections 4.3 and 4.7) and the specific anatomical knowledge gaps (Section 4.4) that restrict students' ability to apply CTR measurement accurately.

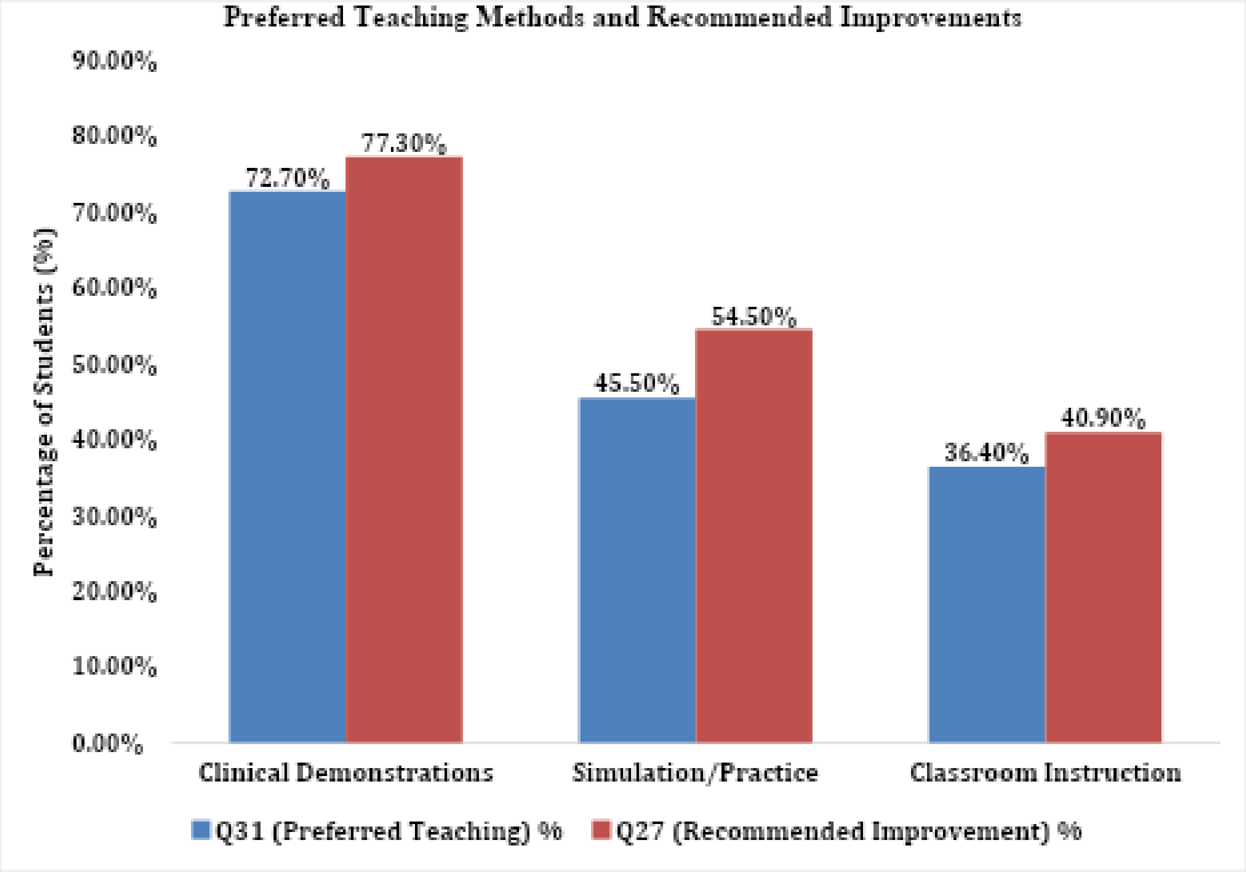

Figure 4.6: Preferred Teaching Methods and Recommended Improvements (n = 110)

Figure 4.6 compares student preferences for key teaching methods (Q31) against their recommendations for application improvements (Q27). The chart visually underscores the dominant and consistent preference for practical, experiential learning methods, such as clinical demonstrations and simulation, over traditional classroom instruction, linking pedagogical desire to perceived training gaps.

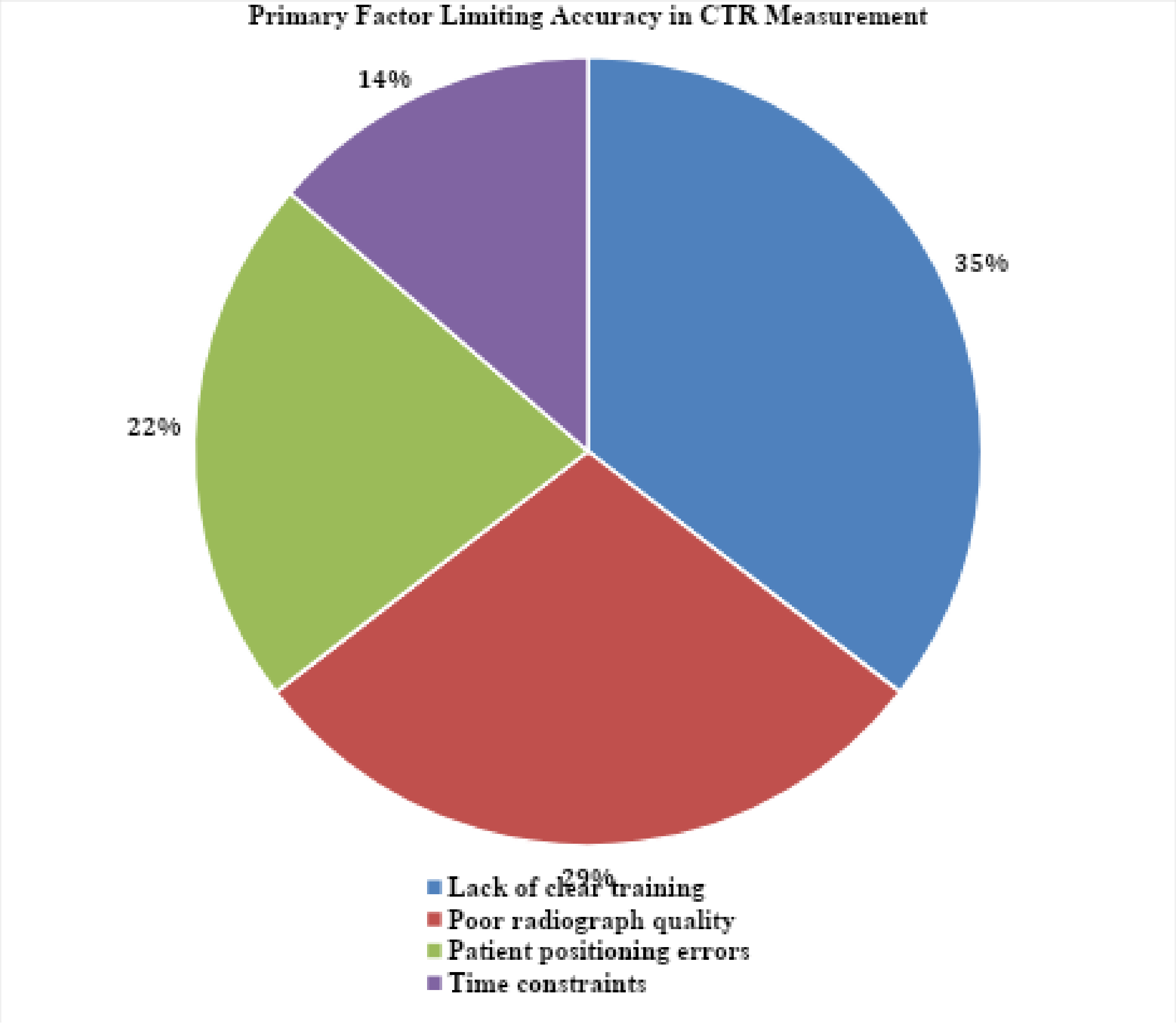

Figure 4.7: Primary Factor Limiting Accuracy in CTR Measurement (n = 110)

Figure 4.7 visualizes the distribution of the "single best answer" chosen by students for the primary factor limiting CTR measurement accuracy (Q29). The largest segment represents "Lack of clear training," reinforcing the interpretation that training deficits are perceived by students as the most significant systemic barrier to achieving practical competence.

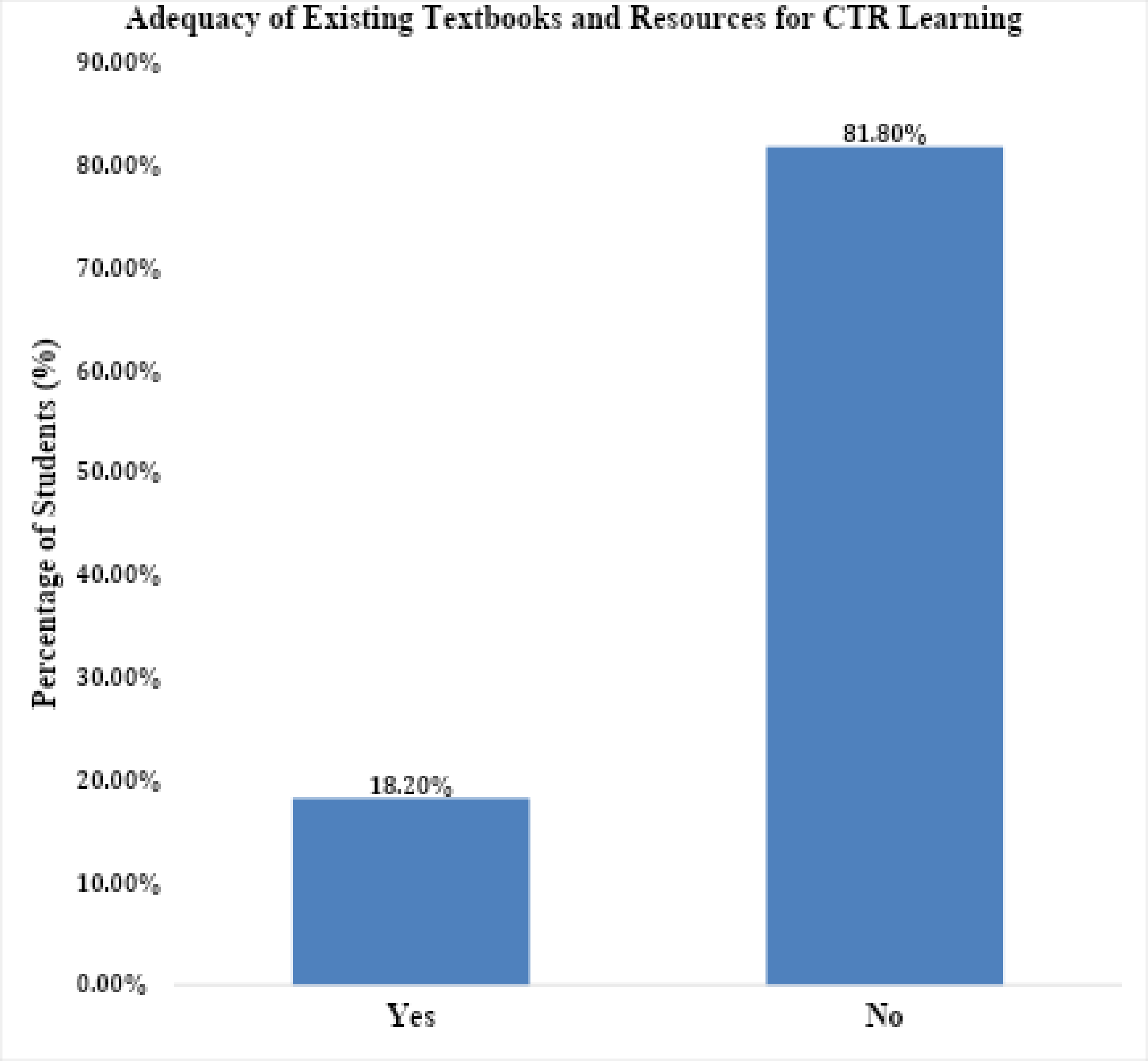

Figure 4.8: Adequacy of Existing Textbooks and Resources for CTR Learning (n=110)

Figure 4.8 illustrates the reported adequacy of existing textbooks and resources for learning CTR measurement (Q30) by displaying the percentage of students who answered 'Yes' or 'No'. The chart visually underscores the substantial resource deficiency, revealing that an overwhelming majority of students (81.8%) deemed the available learning materials as inadequate. This severe lack of appropriate resources is highlighted as a fundamental, systemic factor contributing significantly to the theoretical and practical knowledge gaps identified in the study.

4.8 Associations: Training/Exposure with Adequate Knowledge

Two inferential analyses were performed to test the association between the key independent variables (formal teaching and hands-on exposure) and the primary dependent outcome (Adequate knowledge ≥70%).

4.8.1 Q4 (Formally taught CTR) × Adequate knowledge

Observed contingency	**Adequate (≥70%)**	**Not adequate (<70%)**	**Row total**
Formally taught (Q4 = Yes)	68	22	90
Not formally taught (Q4 = No)	4	16	20
Column total	**72**	**38**	**110**

- **Chi-square (χ^2) = 22.33**, df = 1, **p < 0.001**.
- **Effect size (ϕ)** = $\sqrt{(\chi^2/N)} = \sqrt{(22.33/110)} = 0.45$ (moderate–large association).

The association between formal classroom instruction and adequate knowledge is highly statistically significant ($p < 0.001$), with a moderate-to-large effect size ($\phi = 0.45$). Students who reported receiving formal teaching were substantially more likely to achieve adequate knowledge (75.6%) compared to those who did not

(20.0%). This robust finding emphatically underscores the indispensable role of structured theoretical instruction in establishing foundational competency.

4.8.2 Q5 (Performed/assisted CTR during clinical posting) × Adequate knowledge

Observed contingency	**Adequate (≥70%)**	**Not adequate (<70%)**	**Row total**
Performed / assisted (Q5 = Yes)	50	14	64
Not performed (Q5 = No)	22	24	46
Column total	**72**	**38**	**110**

- **Chi-square (χ^2) = 10.87**, $df = 1, p = 0.001$.
- **Effect size (ϕ)** = $\sqrt{(10.87/110)} = 0.31$ (moderate association).

Hands-on clinical exposure is also significantly associated with better knowledge ($p = 0.00$), demonstrating a moderate effect size ($\phi = 0.31$). Students with clinical experience were markedly more likely to achieve adequate knowledge (78.1%) than those without (47.8%). This result reinforces pedagogical principles emphasizing the necessity of experiential learning to bridge the gap between theoretical knowledge and practical competence in CTR calculation.

4.9 Qualitative Comments – Thematic Summary

Thematic coding of the ≈ 60 free-text comments provided by respondents highlighted four consistent priority areas that reinforce the quantitative findings:

1. **Need for Supervised Hands-on Practice:** Students repeatedly requested more structured clinical exposure and direct supervision, linking their low confidence directly to insufficient practice.

2. **Desire for Simulation/Digital Demonstrations:** There was a strong demand for innovative teaching tools, such as digital software training and simulation, to practice CTR calculation accurately without reliance on physical clinical resources.

3. **Concerns about Radiograph Quality and Positioning:** Students noted that difficulty identifying landmarks often stemmed from poor image quality or suboptimal patient positioning in the clinical environment, emphasizing a limiting factor beyond their core knowledge.

4. **Requests for Regular Assessments and Structured Feedback:** Students requested more frequent, formalized assessments and prompt feedback mechanisms to gauge and correct their understanding and application of CTR.

4.10 Summary of Findings

The study involved 110 final-year radiography students, most of whom were female and between 21 and 25 years of age, reflecting a typical undergraduate demographic profile. Students demonstrated strong conceptual understanding of the Cardiothoracic Ratio (CTR), particularly regarding its purpose, interpretation, and appropriate projection. However, practical and quantitative knowledge was weaker, especially in identifying paediatric limits and selecting correct measurement tools. Although

81.8% of students received formal classroom teaching, only 58.2% had hands-on clinical exposure, indicating a significant theory–practice gap.

Anatomical landmark knowledge was moderately strong, with an overall accuracy of 73.3%, but notable deficits existed in identifying subtle anatomical markers such as the aortic arch and the absence of a lung border reference. The composite knowledge score averaged 13.5 out of 18, and 65.5% of students achieved adequate knowledge. Statistical testing confirmed that this proportion was significantly higher than the hypothesized threshold ($p < 0.001$), and the reliability of the knowledge scale was supported by a Cronbach's alpha of 0.81.

Students reported major challenges, primarily lack of clinical exposure (81.8%) and difficulty identifying anatomical landmarks (63.6%). Most felt inadequately trained during clinical postings, rarely used CTR in practice, and judged the available learning resources as insufficient. Preferred improvements centred on hands-on demonstrations, simulation training, and more structured instructional support.

Inferential analyses showed that both formal teaching and clinical exposure were significantly associated with adequate knowledge, with formal instruction showing the strongest effect. Qualitative comments reinforced the need for supervised practice, digital/simulation tools, better radiograph quality, and regular assessments with feedback.

CHAPTER FIVE
DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the key findings from the cross-sectional survey of 110 final-year radiography students regarding their knowledge and application of the Cardiothoracic Ratio (CTR) calculation. The discussion is structured according to the three primary study objectives, linking statistical results to the theoretical frameworks, particularly the need for demonstrable competency emphasized by the Competency-Based Medical Education (CBME) model and the learning demands highlighted by the Cognitive Theory of Multimedia Learning (Mayer, 2021). Following the discussion, the chapter presents the implications for education and practice, the study conclusion, identified limitations, and specific recommendations for curriculum enhancement and future research.

5.2 Discussion of Findings

The findings of this study aligns closely with our study's three research objectives and demonstrates how each aspect of students' knowledge, skills, and challenges contributes to their overall competency in using the cardiothoracic ratio (CTR). In addressing the first objective, which sought to evaluate the level of knowledge final-year radiography students have regarding the CTR, the discussion shows that a majority of students (65.5%) possessed adequate understanding of CTR concepts. Their strong performance on theoretical items—such as identifying the purpose and interpretation of CTR, both answered correctly by 90.9%—indicates that classroom instruction has effectively conveyed the foundational principles of CTR. This led to the rejection of the null hypothesis that students lack sufficient knowledge of the subject. However, the analysis also revealed important gaps: only slightly more than half of the respondents (54.5%) correctly identified all the measurement tools required for CTR calculation, suggesting that although theoretical comprehension is strong, students struggle with its numerical and applied components. These shortcomings imply that the achievement of the first objective is only partial, as deeper, clinically oriented knowledge remains weak. The findings therefore point to the need for improved quantitative training and better integration of numerical and visual material in teaching—an approach supported by established multimedia learning theories.

The second objective, which focused on evaluating students' ability to correctly identify anatomical landmarks essential for CTR calculation, was also addressed directly by the discussion. The findings demonstrated a moderate level of competence, with an overall anatomical knowledge score of 73.3%, indicating that students recognize many of the major structures required for accurate CTR measurement. Yet, this level of performance also exposed persistent weaknesses. Students had particular difficulty identifying the aortic arch or knob (60%) and struggled to recognize when a lung border reference was absent (63.6%). Because these subtle features are critical in determining measurement accuracy on chest radiographs, their misidentification suggests that students have not fully developed the perceptual and interpretive skills necessary for clinical competence. These shortcomings show that while the second objective was addressed, it was not fully met, and they further underscore the importance of enhancing training methods through simulation, hands-on radiograph interpretation sessions, and other experiential learning activities that strengthen visual diagnostic skills.

The discussion also addressed the third objective, which sought to identify challenges that affect students' understanding or application of CTR in chest radiography. The findings revealed significant systemic and instructional barriers. Students reported limited clinical exposure (81.8%), inadequate training during clinical postings (63.6%), and insufficient learning resources (81.8%) as major obstacles to mastering CTR. Additionally, because CTR is not frequently used in day-to-day clinical practice (68.2%), students often lack opportunities to reinforce theoretical knowledge through real-world application. Other challenges, such as poor radiograph quality, confusion about the measurement formula, and difficulty identifying anatomical landmarks, further demonstrate that both environmental and pedagogical factors impede learning. Importantly, the study also captured students' preferred strategies for overcoming these obstacles, with most calling for hands-on demonstrations (72.7%), simulation-based training (54.5%), and stronger classroom support. These insights show that the third objective was fully achieved, as the study clearly identified the factors limiting CTR competency and provided a pathway for targeted improvement.

Taken together, the discussion integrates all three objectives by demonstrating that while students possess a reasonable level of theoretical understanding and moderate anatomical knowledge, their clinical application of CTR is compromised by gaps in practical training, insufficient exposure to relevant radiographic cases, and limited access to essential learning resources. These combined findings offer a strong foundation for the recommendations presented in the subsequent section, emphasizing the need for enhanced practical instruction, better clinical integration, and improved resource availability to ensure that theoretical knowledge can be effectively translated into clinical competence..

5.4 Summary

The study confirmed that final-year radiography students possess adequate foundational knowledge of CTR, successfully rejecting the null hypothesis. However, the analysis exposed severe weaknesses in the practical application of this knowledge, rooted in poor resource availability (81.8% inadequacy), limited hands-on clinical exposure, and low confidence in identifying precise anatomical landmarks. Students strongly advocated for the increased use of clinical demonstrations and simulation. These gaps demonstrate a current pedagogical model that fails to meet the practical competency standards essential for entry-level practice, as emphasized by the CBME framework.

5.5 Conclusion

Final-year radiography students at the University of Benin demonstrate satisfactory theoretical knowledge of the Cardiothoracic Ratio but exhibit critical gaps in the clinical integration and accurate application of measurement techniques. The key limiting factors are structural, stemming from inadequate resources and insufficient supervised clinical training opportunities. To ensure students transition into competent entry-level radiographers, the curriculum must undergo reform focused on experiential learning, mandatory simulation, and targeted reinforcement of critical anatomical visual interpretation skills.

5.6 Limitations of the Study

1. **Cross-Sectional Nature:** The study provides a snapshot of knowledge at one point in time and cannot determine if knowledge deficits observed persist into professional practice or track improvements from remediation.
2. **Self-Reported Application:** Data on clinical exposure and challenges relied on student self-report, which may be subject to recall bias or a tendency to attribute errors to external factors (e.g., training lack) rather than internal ability.
3. **No Practical Skills Testing:** The study assessed *knowledge* of landmark identification and formula, but not the *practical skill* of actual measurement on a radiographic image (i.e., psychomotor skill demonstration), which represents the ultimate CBME outcome.

5.7 Recommendations

5.7.1 For the Radiography Department, University of Benin

1. The department should integrate digital simulation into student training by acquiring CTR measurement software and incorporating it into routine laboratory sessions. This should include structured weekly practicals where students complete a set number of digital CTR measurements, thereby ensuring consistent, repeatable practice that aligns with student preferences for simulation-based learning.
2. Curriculum time should be reallocated from predominantly lecture-based delivery to mandatory hands-on clinical demonstrations. These demonstrations should focus specifically on areas where students

demonstrated the greatest weaknesses—such as pediatric CTR limits, the correct use of measurement tools, and the identification of subtle anatomical markers. This shift will ensure that theoretical content is reinforced through supervised practical application.

3. The department should conduct an immediate audit of existing learning resources to determine which materials are outdated, insufficient, or misaligned with students' clinical needs. Updated textbooks, digital radiograph libraries, and annotated chest imaging resources should be procured to improve students' access to high-quality visual learning materials and enhance their anatomical recognition skills.

5.7.2 For Clinical Training Coordinators

1. Clinical coordinators should mandate the routine application of CTR during student postings by requiring each student to complete and document a minimum number of supervised CTR calculations. These should be recorded in a standardized clinical logbook, reviewed and signed by supervisors to ensure proper technique. This approach will eliminate the current issue where many students report "rarely" or "never" applying CTR in clinical practice..

5.8 Suggestions for Further Study

1. **Skills-Based Assessment:** Future research should employ an objective structured clinical examination (OSCE) or simulation task to directly measure students' *ability* to physically perform CTR calculation, validating the self-reported knowledge and skill gaps found in this study.

2. **Longitudinal Study of Intervention Impact:** Conduct an experimental study to evaluate the effectiveness of simulation-based training versus traditional methods on CTR knowledge and retention over time.
3. **Multi-institutional Comparison:** Replicate this study across other Nigerian radiography institutions to identify whether the training and resource gaps observed are systemic across the country.

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APPENDICES

Appendix I: Questionnaire

My name Obelawo Deborah Oluwaferanmi a final year student in the Department of Radiography, School of Basic Medical Science, University of Benin with matriculation number BMS1904526 conducting a research study on “Knowledge of the calculation of CTR in a chest radiograph among final year students of university of benin, Benin city under the supervision of my lecturer Mrs Okeh E.O.

Kindly help complete this questionnaire.

SECTION A: Demographic Information

1. Age: 15-20yrs ☐ 21-25yrs ☐ 26-30yrs ☐
2. Gender: ☐ Male ☐ Female
3. Ethinicity: ☐ Edo ☐ Yoruba ☐ Hausa ☐ Hausa ☐ Igbo ☐ Others

SECTION B: Knowledge of Cardiothoracic Ratio (CTR)

1. Have you been formally taught how to calculate CTR in chest radiographs?
   ☐ Yes ☐ No
2. Have you ever performed or assisted in calculating CTR during clinical posting?
   ☐ Yes ☐ No
3. The cardiothoracic ratio is primarily used to assess:
   ☐ Lung volume
   ☐ Cardiac enlargement
   ☐ Thoracic curvature
   ☐ Pleural effusion
4. What is the normal upper limit of CTR in adults on a PA chest radiograph?
   ☐ 0.25
   ☐ 0.40
   ☐ 0.50
   ☐ 0.70
5. What is the normal upper limit of CTR in pediatric on a chest radiograph?
   ☐ ≤ 0.40
   ☐ ≤ 0.45
   ☐ ≤ 0.50
   ☐ ≤ 0.60
6. How is CTR calculated on a PA chest radiograph?
   ☐ A + B / C
   ☐ B – A / C

☐ A × B
☐ A + B × C

7. Which measurement tools are used for CTR assessment on digital radiographs?
☐ Ruler
☐ Caliper
☐ Digital software tools
☐ All of the above

8. What does an increased CTR suggest?
☐ Pleural thickening
☐ Cardiomegaly
☐ Atelectasis
☐ Pneumothorax

9. The best projection for accurate CTR measurement is:
☐ AP
☐ Lateral
☐ PA
☐ Oblique

10. CTR calculation is not reliable in which of the following?
☐ Supine AP chest radiograph
☐ Erect PA chest radiograph
☐ Chest CT
☐ None of the above

11. Do you think it's important for radiographers to understand CTR?
☐ Yes
☐ No

12. Rate your knowledge of CTR calculation:
☐ Poor
☐ Fair
☐ Good
☐ Excellent

Section C: Anatomical markers relating to CTR

13. Which anatomical landmark is used to measure the widest transverse diameter of the heart on a chest radiograph?
☐ Carina
☐ Apex of the lung
☐ Right and left cardiac borders
☐ Clavicle

14. Which part of the thoracic cavity is used to determine the internal thoracic diameter for CTR calculation?
☐ Posterior ribs

☐ Inner margins of the rib cage
☐ Costophrenic angles
☐ Lateral scapular margins

15. On a properly centered posteroanterior (PA) chest radiograph, which vertebral level approximately corresponds to the position of the heart's base?

☐ T1
☐ T4 - T5
☐ T7
☐ T10

16. What is the preferred chest radiograph view to accurately calculate the CTR?

☐ Anteroposterior (AP)
☐ Posteroanterior (PA)
☐ Lateral
☐ Oblique

17. Which anatomical landmark represents the inferior border of the heart on a PA chest radiograph?

☐ Carina
☐ Aortic knob
☐ Apex of the heart
☐ Diaphragm

18. Which margin is used to measure the thoracic diameter in CTR calculation?

☐ Outer rib margins
☐ Inner rib margins
☐ Scapular margins
☐ Clavicle margins

19. In CTR measurement, which lung border is considered a reference landmark?

☐ Anterior lung border
☐ Posterior lung border
☐ Apex of the lung
☐ None (heart borders are used)

20. What anatomical feature marks the upper limit of the heart silhouette on a PA chest radiograph?

☐ Diaphragm
☐ Aortic arch (knob)
☐ Carina
☐ Sternum

Section D: Challenges faced in CTR application

21. How confident are you in identifying the anatomical landmarks needed for CTR calculation on a PA chest radiograph?

☐ Very confident
☐ Confident
☐ Somewhat confident
☐ Not confident

22. Which of the following challenges do you face most when calculating the CTR?

☐ Difficulty identifying anatomical landmarks
☐ Uncertainty about the correct formula
☐ Poor image quality
☐ Lack of clinical exposure

23. Do you feel adequately trained during clinical postings on how to calculate CTR in chest radiographs?

☐ Yes
☐ No

24. Which of the following do you believe would improve your ability to apply CTR calculation in practice?

☐ More classroom instruction
☐ Clinical demonstrations
☐ Simulation-based practice
☐ Regular assessments

25. How often do you use CTR measurement in your clinical practice or studies?

☐ Very often
☐ Occasionally
☐ Rarely
☐ Never

26. What factor most limits your accuracy in measuring the CTR?

☐ Patient positioning errors
☐ Poor radiograph quality
☐ Lack of clear training
☐ Time constraints

27. Do you find existing textbooks or resources adequate for learning CTR measurement?

☐ Yes
☐ No

28. What teaching method do you prefer to improve your skills in CTR application?

☐ Class room lectures
☐ Hands on clinical demonstrations
☐ Simulation training
☐ Online tutorials

APPENDIX II: Ethical approval request

Department of Radiography,
School of Basic Medical Sciences,
University of Benin,
Edo State.
June 2025.

The Chairman,
Health Research and Ethics Committee
College of Basic Medical Sciences,
Edo State.

Dear Sir/ma,

APPLICATION FOR ETHICAL APPROVAL TO CONDUCT A RESEARCH STUDY

My name Obelawo Deborah Oluwaferanmi a final year student in the Department of Radiography, School of Basic Medical Science, University of Benin with matriculation number BMS1904526 conducting a research study on “Knowledge of the calculation of CTR in a chest radiograph among radiography clinical year students of university of benin, under the supervision of my lecturer Mrs Okeh E.O. I write to kindly request for ethical approval to conduct this research study.

Attached is a copy of my research project proposal. I hope my request will be considered.

Yours Faithfully,

Obelawo Deborah Oluwaferanmi

Phone number: 09086138683