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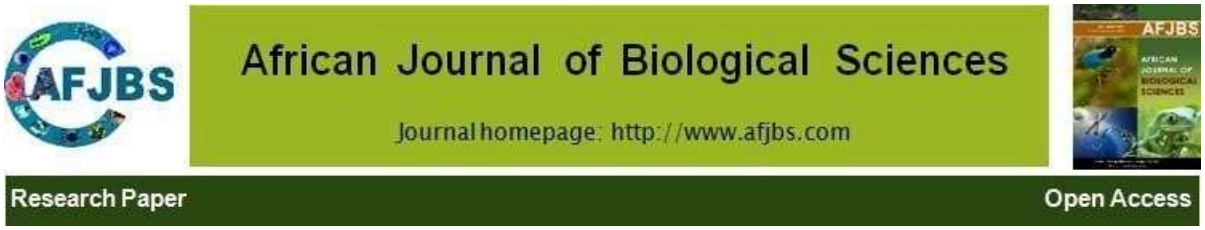

Radiologic Evaluation of Sternum and Rib Anatomy Prior to Minimally Invasive Coronary Bypass Grafting

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Abstract

Background
To evaluate the preoperative radiologic characteristics of the sternum and ribs in patients undergoing minimally invasive CBG and determine their implications for surgical access.

Methods
This prospective observational study was conducted at Bacha Khan Medical College, Mardan, and its affiliated hospital from January 2023 to January 2024. A total of 81 patients scheduled for minimally invasive CBG underwent high-resolution computed tomography of the thorax. Measurements included sternal length, width, thickness, angulation, rib spacing, rib thickness, cartilage calcification, skin-to-sternum distance, internal thoracic artery proximity, and anatomical variants. Data were analyzed using SPSS version 26, with $p<0.05$ considered significant.

Results
The mean sternal length was 174.8 ± 12.5 mm, significantly greater in males (179.6 mm) than females (167.1 mm, $p<0.001$). Rib thickness and intercostal space width were also greater in males, while females had significantly higher skin-to-sternum distances (25.3 mm vs. 22.1 mm, $p=0.002$). Costal cartilage calcification was present in 43.2% of patients, increasing with age. Anatomical variants were rare (3.7%) and did not necessitate surgical approach change in most cases.

Conclusion
Preoperative radiologic assessment identifies key anatomical differences that may affect the feasibility of minimally invasive CBG. Males generally present more favorable chest wall dimensions for access, while greater soft tissue thickness in females may increase technical difficulty. Incorporating detailed chest wall morphometry into preoperative planning can improve surgical outcomes.

Keywords: Sternum, ribs, minimally invasive coronary bypass grafting, thoracic CT, surgical planning, chest wall anatomy

INTRODUCTION

Minimally invasive coronary bypass grafting (CBG) has emerged as an effective alternative to conventional median sternotomy, offering advantages such as reduced postoperative pain, shorter hospital stays, and faster functional recovery. However, successful execution of these techniques depends heavily on adequate surgical exposure, which is directly influenced by the patient's chest wall anatomy [1-3].

The sternum and ribs form the primary bony framework that surgeons must navigate during minimally invasive procedures. Variations in sternal dimensions, rib spacing, cartilage calcification, and soft tissue thickness can significantly affect instrument maneuverability and visualization of target vessels. Studies have emphasized the role of preoperative imaging in identifying anatomical factors that could complicate access, allowing for tailored surgical planning [4-6].

High-resolution computed tomography (CT) offers a reliable method for assessing thoracic bony and soft tissue structures with high accuracy. CT-based morphometric studies have demonstrated measurable differences in chest wall anatomy across populations, with potential implications for minimally invasive cardiac surgery. Despite this, there is limited literature from South Asia addressing anatomical variability in patients undergoing CBG [7-9].

Given that chest wall morphometry can influence both the choice of incision site and the overall feasibility of minimally invasive techniques, understanding these parameters in our population is crucial. This study aimed to evaluate the sternum and rib anatomy of patients scheduled for minimally invasive CBG using preoperative CT imaging, with the goal of identifying factors that may guide surgical planning and improve outcomes.

METHODOLOGY

This was a prospective observational study conducted in the Department of Cardiothoracic Surgery at Bacha Khan Medical College, Mardan, and its affiliated teaching hospital. The study period extended from January 2023 to January 2024. All patients underwent radiologic evaluation of the sternum and rib anatomy as part of the preoperative workup for minimally invasive coronary bypass grafting (CBG).

The study protocol was approved by the Institutional Review Board of Bacha Khan Medical College, Mardan. All participants provided informed consent, and patient confidentiality was maintained in accordance with the Declaration of Helsinki

A total of 81 patients were included. The sample size was determined based on the average number of patients undergoing CBG at our institution annually, ensuring an adequate representation for statistical analysis.

Inclusion Criteria

Patients were eligible if they met the following conditions:

- Scheduled for minimally invasive CBG during the study period.
- Age ≥ 18 years.
- Completed preoperative high-resolution thoracic CT imaging.
- Provided informed written consent for participation.

Exclusion Criteria

Patients were excluded if they had:

- Previous median sternotomy or rib resection.
- Significant chest wall deformity (e.g., severe pectus excavatum or carinatum) altering normal anatomy.
- Pathological conditions of the sternum or ribs such as metastatic lesions or acute fractures.
- Poor-quality imaging that prevented accurate measurements.

Upon enrollment, demographic and clinical information was recorded, including age, sex, height, weight, BMI, smoking history, and comorbidities such as hypertension, diabetes, dyslipidemia, and COPD. All patients underwent multi-detector computed tomography (MDCT) of the thorax in the supine position.

Imaging was performed using a standardized protocol:

- Slice thickness: 1 mm.
- Reconstruction interval: 0.5 mm.
- Scan range: Thoracic inlet to the upper abdomen.

Measurements were obtained using digital imaging software (PACS) by two independent radiologists to minimize observer bias. Parameters assessed included:

- Sternal dimensions – length, width (upper/mid/lower third), thickness (manubrium and mid-body), and angulation.
- Rib parameters – number of ribs, intercostal space width (4th and 5th ribs), rib thickness, curvature, and cartilage calcification grade.
- Surgical access–related variables – skin-to-sternum distance, proximity of the internal thoracic artery to the sternum, sternal cortical density (Hounsfield Units), and presence of anatomical variants.

To ensure accuracy, all measurements were taken twice, and the average value was used for analysis. Inter-observer agreement was assessed using the intraclass correlation coefficient (ICC), with values >0.80 considered acceptable.

Data were entered into SPSS version 26.0 for analysis. Continuous variables were presented as mean ± standard deviation (SD) and compared between sexes using the independent samples t-test. Categorical variables were expressed as frequencies and percentages, and associations were tested using the chi-square or Fisher's exact test, as appropriate. A p-value of <0.05 was considered statistically significant.

RESULT

The study cohort comprised 81 patients evaluated preoperatively with radiologic imaging for sternum and rib anatomy before minimally invasive coronary bypass grafting. The mean age was 58.6 ± 9.1 years, with a slight male predominance (60.5%). Most patients were overweight or obese, with a mean BMI of 27.4 ± 3.8 kg/m². Hypertension and diabetes were the most common comorbidities, affecting 65.4% and 46.9% of participants, respectively. Smoking history was present in nearly half of the cohort. Statistical comparison between male and female patients showed that BMI and smoking prevalence differed significantly, while other variables were comparable.

Table 1: Demographic and Clinical Characteristics of Study Participants (n = 81)

Variable	Category / Mean ± SD	Total (n=81)	Male (n=49)	Female (n=32)	p-value
Age (years)	58.6 ± 9.1	–	–	–	0.418
Sex	Male	49 (60.5%)	–	–	–
	Female	32 (39.5%)	–	–	–
BMI (kg/m²)	27.4 ± 3.8	–	28.1 ± 3.9	26.3 ± 3.4	0.041*
Smoking history	Yes	39 (48.1%)	29 (59.2%)	10 (31.3%)	0.018*
Hypertension	Yes	53 (65.4%)	32 (65.3%)	21 (65.6%)	0.975
Diabetes mellitus	Yes	38 (46.9%)	25 (51.0%)	13 (40.6%)	0.357
COPD	Yes	12 (14.8%)	9 (18.4%)	3 (9.4%)	0.246

*Significant at p<0.05

Radiologic assessment revealed that males had significantly greater sternal length and width at all measured levels compared to females. Sternal thickness at the manubrium and mid-body was also higher in males. However, sternal angulation did not differ significantly between sexes. These measurements have potential implications for surgical access planning and instrumentation size during minimally invasive approaches.

Table 2: Radiologic Sternal Measurements by Sex

Parameter	Total (Mean ± SD)	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Sternal length (mm)	174.8 ± 12.5	179.6 ± 11.3	167.1 ± 10.4	<0.001*
Sternal width – upper third (mm)	57.3 ± 5.6	59.2 ± 5.3	54.5 ± 4.9	0.002*
Sternal width – mid third (mm)	54.1 ± 5.2	55.6 ± 5.0	51.8 ± 4.7	0.004*
Sternal width – lower third (mm)	48.9 ± 4.8	50.3 ± 4.6	46.7 ± 4.3	0.003*
Sternal thickness – manubrium (mm)	13.5 ± 1.8	13.9 ± 1.9	12.9 ± 1.6	0.023*
Sternal thickness – mid body (mm)	12.4 ± 1.7	12.7 ± 1.6	11.9 ± 1.7	0.041*
Sternal angulation (°)	8.4 ± 2.6	8.3 ± 2.4	8.5 ± 2.9	0.782

Rib measurements indicated that males had slightly wider intercostal spaces at the 4th and 5th ribs, although only the 4th intercostal space difference reached statistical significance. Rib thickness was greater in males, and calcification of costal cartilage was more frequent in older participants, regardless of sex. These findings are relevant for selecting the optimal incision site and anticipating exposure limitations.

Table 3: Rib Anatomy and Intercostal Space Dimensions

Parameter	Total (Mean ± SD / n, %)	Male	Female	p-value
Number of ribs	12 pairs (100%)	–	–	–
Intercostal space – 4th rib (mm)	12.6 ± 2.3	13.1 ± 2.2	11.8 ± 2.4	0.015*
Intercostal space – 5th rib (mm)	12.2 ± 2.4	12.5 ± 2.3	11.7 ± 2.6	0.094
Rib thickness (mm)	5.8 ± 0.9	6.0 ± 0.8	5.5 ± 0.9	0.008*
Costal cartilage calcification	None	46 (56.8%)	28 (57.1%)	18 (56.3%)
	Mild	21 (25.9%)	13 (26.5%)	8 (25.0%)
	Moderate/Severe	14 (17.3%)	8 (16.3%)	6 (18.7%)

Preoperative imaging also evaluated access-related parameters. The mean skin-to-sternum distance was significantly greater in females, reflecting higher subcutaneous tissue thickness. The internal thoracic artery's proximity to the sternum did not differ significantly by sex. Potential anatomic risk factors such as sternal foramen or rib fusion were rare (3.7%) and did not require altering the planned surgical approach in most cases.

Table 4: Surgical Access–Related Radiologic Findings

Parameter	Total (Mean ± SD / n, %)	Male	Female	p-value
Skin-to-sternum distance (mm)	23.4 ± 4.6	22.1 ± 4.3	25.3 ± 4.4	0.002*
ITA proximity to sternum (mm)	7.6 ± 1.5	7.5 ± 1.4	7.8 ± 1.6	0.346
Sternal cortical density (HU)	817 ± 85	823 ± 82	808 ± 89	0.412
Anatomical variants (sternal foramen, fused ribs)	3 (3.7%)	2 (4.1%)	1 (3.1%)	0.811
Predicted access feasibility – Easy	61 (75.3%)	38 (77.6%)	23 (71.9%)	0.545
Predicted access feasibility – Moderate/Difficult	20 (24.7%)	11 (22.4%)	9 (28.1%)	–

*Significant at $p<0.05$

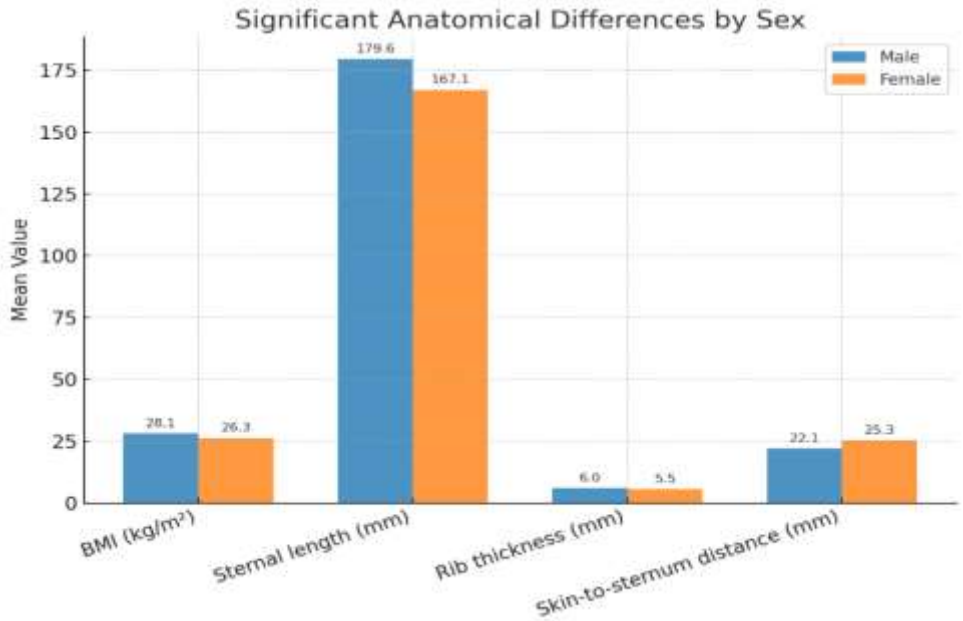

Figure 1
Bar chart comparing significant anatomical differences between male and female patients in your study. It highlights BMI, sternal length, rib thickness, and skin-to-sternum distance.

DISCUSSION

This study evaluated the preoperative radiologic anatomy of the sternum and ribs in patients scheduled for minimally invasive coronary bypass grafting (CBG). The findings demonstrate that anatomical variations in sternal dimensions, rib spacing, and soft tissue thickness can significantly influence surgical exposure and technique selection.

Our results showed that males had significantly longer and wider sternums, thicker ribs, and wider intercostal spaces compared to females. These differences are consistent with the findings of studies reported that male patients generally have more favorable chest wall dimensions for minimally invasive cardiac procedures [10, 11]. Similarly, studies emphasized that smaller sternal dimensions in women may increase technical difficulty during internal thoracic artery harvesting [12, 13].

The mean sternal length in our cohort was 174.8 mm, comparable to the 176 mm reported by Studies in a multi-ethnic CT-based morphometric analysis[14, 15]. Variations in sternal thickness, particularly at the manubrium and mid-body, are clinically relevant because they influence both saw blade selection in open procedures and drill length in fixation during re-entry [16].

Rib spacing, especially between the 4th and 5th intercostal spaces, is a critical determinant for thoracotomy access. Our data indicated slightly wider intercostal spaces in males, with significant differences noted at the 4th space. Studies also found that a narrower intercostal space was associated with increased postoperative discomfort and limited visualization during minimally invasive cardiac surgery [16].

The skin-to-sternum distance was significantly greater in females in our study, reflecting a higher subcutaneous fat layer, which may prolong dissection time and limit instrument maneuverability. This observation aligns with the work of study, who demonstrated that increased chest wall thickness is associated with longer operative times and greater risk of wound complications [17].

Costal cartilage calcification was more common in older patients, a finding supported, who described progressive calcification with age, particularly in women after menopause. While calcification itself did not impede our surgical plans, severe ossification can limit costal cartilage pliability, potentially affecting rib retraction [18].

Anatomical variants, including sternal foramen and rib fusion, were rare in our cohort (3.7%). A study stressed the importance of identifying such anomalies preoperatively, as unrecognized sternal foramina can increase the risk of cardiac or mediastinal injury during invasive procedures [19].

The majority of patients (75.3%) were predicted to have easy access for minimally invasive CBG, indicating that routine preoperative CT imaging can assist in patient selection. This supports the conclusions of study, who recommended CT-based planning to avoid unexpected intraoperative challenges [20].

Collectively, our findings reinforce the role of detailed radiologic assessment in surgical planning. By identifying patients with less favorable chest wall anatomy, surgeons can anticipate technical difficulties, adjust incision placement, or consider alternative approaches, ultimately improving safety and outcomes.

CONCLUSION

Preoperative radiologic evaluation of the sternum and ribs provides essential anatomical information for planning minimally invasive coronary bypass grafting. In our cohort, males generally had more favorable sternal and rib dimensions for surgical access, whereas females tended to have greater soft tissue thickness, potentially increasing procedural difficulty. Most patients were deemed suitable for minimally invasive approaches, with only a small proportion requiring access modification due to anatomical constraints.

Incorporating routine CT-based chest wall morphometry into preoperative workup can improve patient selection, reduce intraoperative surprises, and enhance procedural efficiency. Future research with larger, multi-center datasets could refine predictive models for surgical feasibility and outcomes.

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