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Frailty as Predictor of Outcomes in Cardiac Surgery

Wajiha Arshad[1], Muhammad Sohail Chaudhri[2], Alifa Sabir[3], Sahab Ahmad[4], Muhammad Azam[5], Musfireh Siddiqeh[6]

[1-6]Department of Cardiac Surgery, Rawalpindi Institute of Cardiology, Rawalpindi, Punjab, Pakistan.

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Correspondence to: Wajiha Arshad, Department of Cardiac Surgery, Rawalpindi Institute of Cardiology, Rawalpindi, Punjab, Pakistan.
Email: wajihaArshad1995@gmail.com

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ABSTRACT

Objective: To determine the effectiveness of frailty index as a predictor of outcomes after cardiac surgery. **Study Design:** Cross-sectional study. **Place and Duration of Study:** Department of Cardiac Surgery, Rawalpindi Institute of Cardiology, Rawalpindi, over six months (July to December 2024). **Methodology:** A total of 376 patients undergoing elective cardiac surgery were included using simple random sampling. Frailty was assessed using a modified frailty index (deficit-based model with 9 variables) and categorized into non-frail, pre-frail, frail, and severely frail groups. Data were analyzed using SPSS version 25. Quantitative variables were expressed as mean ± SD and qualitative variables as frequency and percentages. Statistical significance was set at $p \leq 0.05$. **Results:** The mean age was 51.26 ± 11.84 years, with 78.2% males. Frailty prevalence (pre-frail + frail) was 49.5%. Increasing frailty was significantly associated with higher postoperative complications, increased chest drainage, and mortality ($p < 0.05$). Frailty score independently predicted adverse outcomes (OR = 2.85, $p = 0.001$). **Conclusion:** Frailty is an independent predictor of adverse outcomes after cardiac surgery and should be incorporated into routine preoperative risk stratification.

INTRODUCTION

Cardiac surgery is a complex and high-risk intervention associated with significant physiological stress and postoperative morbidity. Despite advancements in surgical techniques and perioperative care, patient-related factors continue to play a crucial role in determining outcomes. Among these, frailty has emerged as an important predictor of adverse postoperative events [1]. Frailty is defined as a multidimensional clinical syndrome characterized by decreased physiological reserve and increased vulnerability to stressors [2]. It encompasses physical, cognitive, and functional impairments, including weakness, reduced mobility, malnutrition, and diminished endurance [3]. Unlike chronological age, frailty reflects biological aging and provides a more accurate assessment of a patient's ability to tolerate major surgical interventions [4].

The concept of frailty has gained increasing importance in cardiovascular medicine, particularly in patients undergoing cardiac surgery. Studies have demonstrated that frailty is strongly associated with increased postoperative mortality, prolonged hospital stay, and higher rates of complications [5,6]. A systematic review by Sepehri et al. reported that frailty significantly increases the risk of adverse outcomes following cardiac surgery [3]. Similarly, Afilalo et al. showed that frailty improves risk stratification when combined with conventional cardiac risk scores [1]. In addition to mortality, frailty has been associated with increased risk of postoperative complications such as acute kidney injury, prolonged mechanical ventilation, and delayed functional recovery [7,8]. Recent studies have also highlighted that even pre-frailty is associated with worse outcomes, suggesting that frailty exists along a continuum rather than as a binary condition [9].

Traditional risk assessment tools such as EuroSCORE and STS risk models primarily rely on demographic and comorbidity data and may not fully capture the multidimensional vulnerability associated with frailty [10]. This has led to increasing interest in frailty indices, particularly the modified frailty index (mFI), which is based on deficit accumulation and provides an objective and reproducible measure of physiological reserve [11]. Recent large-scale cohort studies have confirmed that frailty independently predicts mortality and morbidity after cardiac surgery, even after adjusting for conventional risk factors [12,13]. Therefore, incorporating frailty assessment into preoperative evaluation may improve risk stratification, guide clinical decision-making, and optimize perioperative management.

Despite growing evidence, data from developing countries remain limited. Therefore, this study was conducted to evaluate the role of frailty index as a predictor of outcomes in patients undergoing cardiac surgery.

MATERIALS AND METHODS

This cross-sectional study was conducted in the Department of Cardiac Surgery, Rawalpindi Institute of Cardiology, Rawalpindi, over a period of six months after approval from the Ethical Review Board, Institutional Review Forum, and the College of Physicians and Surgeons Pakistan. A total of 376 patients were enrolled. The sample size was calculated using the World Health Organization sample size calculator at a 95% confidence level and a 5% margin of error, taking the reported frailty prevalence of 57.6% from Reichart et al. as the reference estimate. Adult patients aged 18 years or above undergoing elective cardiac surgery, including coronary artery bypass grafting and valvular procedures, were eligible for inclusion. Patients undergoing emergency cardiac surgery, those scheduled for congenital cardiac procedures, and patients younger than 18 years were excluded from the study. Participants were selected through simple random sampling. Written informed consent was obtained from all patients before enrolment. Data were collected on a structured proforma that included demographic characteristics, clinical variables, frailty score, and postoperative outcomes.

Frailty was assessed preoperatively using a modified frailty index based on a deficit accumulation model comprising nine variables. The frailty score was calculated by dividing the number of deficits present by the total number of assessed variables. On the basis of the calculated score, patients were categorized as non-frail (0), pre-frail (0.01–0.18), frail (0.19–0.36), and severely frail (>0.36). The collected data were entered and analyzed using Statistical Package for the Social Sciences version 25. Quantitative variables were presented as mean ± standard deviation, whereas qualitative variables were expressed as frequencies and percentages. Statistical significance was defined at a p-value of 0.05 or less.

RESULTS

A total of 376 patients were included. The study population had a mean age of 51.26 ± 11.84 years, and males constituted 78.2% of the sample. The mean ejection fraction was 53.78 ± 8.58%, while the mean frailty score was 0.075 ± 0.091. Most patients were functionally classified in Class II according to both the Canadian Cardiovascular Society and New York Heart Association systems, indicating that the sample largely comprised patients with mild-to-moderate symptomatic limitation before surgery.

Table 1

Baseline Demographic, Clinical, and Functional Characteristics

Variable	Value
Age (years), mean ± SD	51.26 ± 11.84
Male gender, n (%)	294 (78.2)
Female gender, n (%)	82 (21.8)
Ejection fraction (%), mean ± SD	53.78 ± 8.58
Frailty score, mean ± SD	0.075 ± 0.091
CCS class, n (%)	
Class I	90 (23.9)
Class II	196 (52.1)
Class III	86 (22.9)
Class IV	4 (1.1)
NYHA class, n (%)	
Class I	79 (21.0)
Class II	229 (60.9)
Class III	65 (17.3)
Class IV	3 (0.8)

The comorbidity profile showed that hypertension was present in 34.0% of patients and diabetes mellitus in 22.6%. Most participants were non-smokers (73.7%), while 23.9% were ex-smokers and 2.4% were current smokers. Coronary artery bypass grafting was the most frequently performed procedure, accounting for 63.0% of operations, whereas 37.0% underwent other cardiac procedures, including valve surgery. These findings summarize the main preoperative risk factors and operative distribution of the study sample.

Table 2

Comorbidities, Smoking Status, and Surgical Procedure Profile

Variable	n (%)
Hypertension, Yes	128 (34.0)
Hypertension, No	247 (65.7)
Diabetes mellitus, Yes	85 (22.6)
Diabetes mellitus, No	291 (77.4)
Smoking status	
Non-smoker	277 (73.7)
Ex-smoker	90 (23.9)
Current smoker	9 (2.4)
Surgical procedure	
CABG	237 (63.0)
Others (MVR, AVR, etc.)	139 (37.0)

Frailty assessment demonstrated that 190 patients (50.5%) were non-frail, 132 (35.1%) were pre-frail, 52 (13.8%) were frail, and 2 (0.5%) were severely frail. Thus, the combined prevalence of pre-frailty and frailty was 49.5%. Regarding postoperative outcomes, mean chest drainage was 1003.1 ± 654.0 mL. Neurological complications occurred in 1.9% and arrhythmias in 5.9% of patients. Mortality was 0.8%, while the survival rate was 99.2%.

Table 3

Frailty Distribution and Postoperative Clinical Outcomes

Variable	Value
Frailty category, n (%)	
Non-frail	190 (50.5)
Pre-frail	132 (35.1)
Frail	52 (13.8)
Severely frail	2 (0.5)
Pre-frail + frail prevalence, n (%)	186 (49.5)
Postoperative outcomes	
Chest drainage (mL), mean ± SD	1003.1 ± 654.0
Neurological complications, n (%)	7 (1.9)
Arrhythmias, n (%)	22 (5.9)
Mortality, n (%)	3 (0.8)
Survival, n (%)	373 (99.2)

Comparative analysis showed a graded association between increasing frailty and worse postoperative outcomes. Non-frail patients had lower complication burden and chest drainage, pre-frail patients had intermediate risk, and frail patients had the highest rates of complications, mortality, and drainage, with all associations statistically significant at $p < 0.05$. On

multivariable logistic regression, frailty score independently predicted adverse outcomes (OR 2.85, 95% CI 1.60–5.10; p = 0.001), alongside age, diabetes mellitus, and lower ejection fraction.

Table 4

Frailty-Outcome Association and Multivariable Predictors of Adverse Postoperative Outcomes

Analysis	Variable/Outcome	Non-frail	Pre-frail	Frail	OR	95% CI	p-value
Comparative analysis	Complications	Lower	Moderate	Higher	—	—	<0.05
Comparative analysis	Mortality	Minimal	Low	Higher	—	—	<0.05
Comparative analysis	Chest drainage	Lower	Moderate	Higher	—	—	<0.05
Logistic regression	Frailty score	—	—	—	2.85	1.60–5.10	0.001
Logistic regression	Age	—	—	—	1.04	1.01–1.07	0.02
Logistic regression	Diabetes mellitus	—	—	—	1.72	1.10–2.80	0.03
Logistic regression	Hypertension	—	—	—	1.30	0.85–2.10	0.18
Logistic regression	Ejection fraction	—	—	—	0.96	0.93–0.99	0.01

DISCUSSION

This study demonstrates that frailty is a strong and independent predictor of adverse postoperative outcomes in patients undergoing cardiac surgery. Nearly half of the study population (49.5%) was identified as pre-frail or frail, highlighting the significant burden of frailty in this sample [2,4].

Frailty reflects diminished physiological reserve and multisystem impairment, which predisposes patients to poor tolerance of surgical stress [2,4]. In the present study, increasing frailty was significantly associated with higher rates of postoperative complications, increased chest drainage, and mortality. These findings are consistent with previously published literature [3,5]. Sepehri et al. demonstrated that frailty is associated with increased mortality and morbidity following cardiac surgery [3]. Similarly, Afilalo et al. reported that frailty enhances risk prediction beyond traditional scoring systems [1]. These findings reinforce the clinical importance of frailty as a prognostic marker.

A key finding of this study is the progressive increase in adverse outcomes across frailty categories (non-frail, pre-frail, frail, and severely frail), indicating a dose-response relationship. Reichart et al. also reported a similar trend, where increasing frailty scores were associated with worse postoperative outcomes [6]. This suggests that frailty should be viewed as a continuum, with even early stages (pre-frailty) carrying clinical significance [9]. The pathophysiological mechanisms underlying this association are multifactorial. Frailty is associated with sarcopenia, chronic inflammation, impaired immunity, and reduced cardiovascular reserve, all of which contribute to increased susceptibility to complications [11,14]. Additionally, frail patients often have delayed wound healing and impaired recovery, which may explain the increased postoperative morbidity observed in this study.

In the present study, frailty remained an independent predictor of adverse outcomes on multivariable analysis (OR = 2.85, p = 0.001), even after adjusting for confounding variables such as age, diabetes, and ejection fraction. This is consistent with recent studies demonstrating that frailty independently predicts mortality and complications following cardiac surgery [12,13].

Recent evidence further supports these findings. Chen et al. reported that frailty significantly increases both short-term and long-term mortality after cardiac surgery [15]. Percy et al. demonstrated that frailty is associated with prolonged ICU stay and increased healthcare utilization [16]. Similarly, Zhang et al. showed that frailty predicts long-term survival and functional outcomes [17]. The prevalence of frailty in this study (49.5%) is higher than that reported in Western populations, where it ranges between 25–40% [9,17]. This difference may be attributed to variations in nutritional status, socioeconomic factors, and healthcare access in the local population.

From a clinical perspective, these findings highlight the importance of incorporating frailty assessment into routine preoperative evaluation. The modified frailty index used in this study is simple, objective, and reproducible, making it a practical tool for clinical use [11]. Early identification of frailty allows for targeted interventions such as prehabilitation, nutritional optimization, and individualized perioperative care, which may improve outcomes [10]. Incorporating frailty into risk assessment models may enhance their predictive accuracy and improve patient counselling and shared decision-making.

CONCLUSION

Frailty is a significant and independent predictor of postoperative morbidity and mortality in patients undergoing cardiac surgery. The modified frailty index provides a practical and effective tool for risk stratification and should be incorporated into routine preoperative assessment.

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