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The Impact of Common Comorbidities on the Cardiopulmonary Rehabilitation Outcomes and Cost of Care for Post-CABG Surgery Patients

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Abstract: Background: The incidence of coronary Heart Disease (CHD) has increased globally, including in Saudi Arabia. Consequently, the use of coronary artery bypass graft (CABG) surgery, one of the most valuable solutions, has also increased. Common comorbidities (CMs) such as diabetes mellitus (DM), hypertension (HTN), peripheral vascular disease (PVD), chronic obstructive pulmonary disease (COPD), peptic ulcer disease, dialysis-dependent renal failure, and obesity have been reported to adversely affect rehabilitation outcomes, increase hospital length of stay (LOS), and increase the cost of care for post-CABG surgery patients. Despite these facts, no previous studies have assessed the effect of comorbidities on Cardiac Rehabilitation outcomes, cost of care, and length of hospital stay in post-CABG surgery patients in the Saudi Population. Objective: To assess the effect of cardiac comorbidities on the outcomes of CR intervention in CABG patients and examine how these comorbidities affect the length of stay in the intensive care unit (ICU) and hospital, as well as the cost of care. Methods: A retrospective cohort study was conducted to follow-up post-CABG patients over two years, from 2020 to 2022. A total of 62 male and female patients who met the inclusion criteria were included in this study. The subjects were divided into two groups based on the CM size. Group I consisted of patients with (> 4 CMs), whereas Group II consisted of patients with (<3 CMs). Results: Group I had a higher mean score of comorbidities (CMs) at 5.09 ± 2.43, which resulted in longer stays in the ICU at 4.34 + 2.24 and in the hospital at 9.16 + 4.63 compared to Group II at 3.43 ± 1.48 and 7.2 ± 1.47, respectively. Group II had higher total cost of care. Conclusions: This study found that patients with multiple comorbidities such as DM, HTN, and dyslipidemia had longer hospital and ICU stays and higher care costs.

Keywords: CABG, Cardiac Rehabilitation, Comorbidity, Length of Stay, Cost of Care

1. Background

The Kingdom of Saudi Arabia (KSA) is experiencing a significant increase in deaths caused by cardiovascular diseases [1], particularly coronary heart disease, which is the leading cause of death in many countries, including the KSA and Gulf Cooperation Council region [2, 3]. This disease is caused by atherosclerosis in the coronary arteries, [4] and is responsible for over 7.2 million deaths worldwide each year [5]. While the mortality rate of coronary heart disease (CHD) is decreasing in the West, it continues to rise in Saudi Arabia and other developing countries [6 −9] due to the adoption of Western lifestyle habits, such as smoking, high dietary fat intake, and lack of physical activity. These habits increase the risk of developing cardiac-related diseases, such as hypertension and diabetes mellitus, which in turn increases the risk of CHD [10]. The prevalence of CHD in the Saudi population has been increasing owing to rapid economic growth [11] and has resulted in an increased demand for cardiac care and rehabilitation [12]. One of the most common solutions for patients with CHD in the KSA is the Coronary Artery Bypass Graft surgery [13], but

comorbidities such as diabetes mellitus (DM), hypertension (HTN) peripheral vascular disease (PVD), chronic obstructive pulmonary disease (COPD), peptic ulcer disease, dialysis-dependent renal failure, obesity, and dementia are common among patients undergoing this surgery and can adversely affect their outcome [14, 15]. The focus of coronary artery bypass (CABG) research has been shifted from investigating mortality and morbidity to investigating patients' physical and mental health [16, 17] including their health-related quality of life [18, 19]. Despite the impact of comorbidities on health outcomes, such as hospital stay, mortality, long-term disability, hospital costs, and readmission [20], no previous studies in the Kingdom of Saudi Arabia have assessed their influence on cardiac rehabilitation (CR) outcomes and length of hospital stay for post-CABG surgery patients. This study aimed to evaluate the effect of common cardiac comorbidities on CR intervention outcomes and assess their influence on intensive care unit (ICU) length of stay as well as the cost-effectiveness in the KSA.

2. Methods

Study Design: A retrospective cohort study was conducted over two years to analyze how comorbidities affected the outcomes of patients who had undergone coronary artery disease (CABG) surgery at King Faisal Specialist Hospital and Research Center over a period of two years, from 2020 to 2022.

Ethical Approval: This study was approved by the Research Advisory Council of the King Faisal Specialist Hospital and Research Center (KFSH&RC), Riyadh, Saudi Arabia. The patient and demographic data were retrieved from the KFSHRC database [21].

Sample size: In this retrospective study, 62 patients (12 females and 51 males) were divided into two groups: Group I (n=32) with more comorbidities ($\geq$ 4) and Group II (n=30) with fewer comorbidities (< 3).

Intervention: Patients were randomly assigned to groups based on the number of comorbidities and received identical CR interventions. This intervention included aerobic and endurance exercises, breathing exercises using an incentive spirometer, active range of motion exercises, functional training, gait training, and education. The CR program followed the guidelines of the American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) [24] and the British Association of Cardiovascular Prevention and Rehabilitation (BACVPR) [25], Table 1.

Table 1. *The CR intervention program (Phase 1) [22, 23].*

Intervention Parameters	Phase I CR Exercise Program (Inpatient Phase)
Frequency	Daily 5 days a week including the weekends.
Intensity	Low – Moderate Intensity depending on pre-exercise screening results. Building up to 3 sets of 10 for each exercise). RPE, 12–14, 60%–75% HRmax, Borg scale <15
Types of Exercises Day 1 – 5	Breathing Exercise; Active Cycle of Breathing Technique (ACBT) exercise consists of breathing control, deep breaths to be repeated 3 or 4 times, and Forced expiration techniques (Huff) to be repeated 1-2 times, using of incentive spirometer (500 – 1000) ml. Range of motion Exercises: Active ROM exercises on the bed, for both upper limbs, circulatory or ankle pumping exercises, Hip/knee flexion, and extension 10 repetitions for each limb. Out-of-bed mobility; Sitting at the edge of bed and out to the chair for 30 – 60 min. Aerobic and endurance exercises: Sit to stand, Marching on the spot 5 -10 repetitions. Gait Training: Walking with or without walking aids, starting with 100 – 300 meters. Stairs: Going up and down stairs of 10 steps. Education: Patient instruction and precautions about his surgery, home exercise program, and walking after discharge.
Time	30 - 45 min (5 min warm-up, 20 min of bed exercises, breathing, aerobic, strengthening, functional activities, balance exercises, gait training, and up and down stairs & education). Depending on the patient's ability.
Sitting	King Faisal Heart Institute (KFHI) of KFSH&RC. Inpatient Units; Cardiac Intensive Care Unit, Cardiovascular Step-down, Cardiovascular Telemetry Unit.

Inclusion criteria:

1) Age group 30 – 50 years old.
2) Male and female participants
3) Participant diagnosed with CHD/CAD
4) Underwent CABG surgery at KFSH&RC
5) Same surgical technique (Med-sternum/on-pump using extracorporeal circulation.
6) Hemodynamic stable (Stable vital signs, normal temperature, etc.).

Exclusion criteria:

1) Ejection Fraction < 35%
2) Any other surgery within the last 3-6 months
3) High-risk postoperative complications (history of open chest, extracorporeal membrane oxygenation (ECMO) insertion, bleeding, etc.)
4) Mental health disorders

Outcome measures:

1) In this study, four outcome measures were used as follows:
2) The length of stay in the surgical ICU was determined by calculating the number of hours between admission and discharge.
3) To determine the Length of Hospital, Stay, we calculated the total number of days between the surgery date and discharge date.
4) The cost-effectiveness of each patient's stay in the ICU and hospital was evaluated. The daily cost of being in the hospital varies depending on whether the patient is in the ICU or the hospital unit. Therefore, the cost of each day in the ICU and/or hospital unit was

determined, and the total number of days was calculated based on the cost for each individual patient.

5) The Charlson Comorbidity Index (CCI) was used to measure comorbidities. This index is based on the diagnostic codes of the International Classification of Diseases (ICD) [24, 25].

Data collection and analysis

The clinical data of the twenty-five patients were prospectively collected and analyzed using SPSS® Statistics V22.0 (version 22 (IBM, Armonk, NY, USA). Outcome variables were expressed as proportions of the total (percentage), and continuous variables as means with standard deviation (SD). The chi-square test was used to compare categorical variables between the groups. The demographic characteristics of the participants were explored by comparing means using paired-sample t-tests. One-way analysis of variance (ANOVA) was used to compare means. The significance level was set at 90%, and an alpha level of $P<0.05$ was considered significant.

3. Results

This study included 62 patients who underwent coronary artery bypass grafting (CABG). Table 1 shows the patients' demographic and clinical characteristics. The mean age and body mass index (BMI) were similar in both groups, and both groups had similar preoperative characteristics. However, more patients in Group I (with higher comorbidities) were female and, had a history of Diabetes Mellitus, hypertension, dyslipidemia, peripheral vascular diseases, kidney disease, and other cardiac-related problems. Table 1 shows the patients' demographic and clinical characteristics. In this cohort study, the mean age and body mass index (BMI) were similar; (59.07 $\pm$ 9.13 VS. 59.06 $\pm$ 6.48, $P = 0.07$), and (28.91 $\pm$ 6.10 vs 28.16 $\pm$ 6.48, $P = 0.09$). However, both groups had similar preoperative characteristics. This study showed that patients in (Group I) were found to have more females than (Group II); ((n=12), 75% vs (n=9), 25%, $P = 0.001$), and had more diabetes mellitus (71.88% vs 60%, $P = 0.032$), hypertension (81.25% vs 56.7%, $P = 0.001$), dislepedimia (46.87% vs 20%, $P = 0.021$), peripheral vascular diseases (18% vs 3.33%, $P =0.033$), kidney disease (25% vs 6.7%, $P =0.001$), Stroke (9.37% vs 3.33, $P =0.020$), in addition to other cardiac related problems such as myocardial infarction (34.38% vs 6.0%, $P = 0.001$). The results also showed that the mean of CCI score for group I was higher than that of group II (12 vs. 7), and group II had a longer length of stay (LOS) in the ICU and hospital (4.34 + 2.24 and 9.16 + 4.63, $P = 0.031$) days compared to group II (3.43 + 1.48 and 7.2 + 1.47, $P = 0.001$) days. (Table 2 and Figure 2). This study revealed that the total cost of care in the ICU and Hospital length of stay for Group I was higher than in Group II ($P = 0.001$) (Table 3).

Table 2. *Demographic characteristic Data of the patients.*

	Group I: High CM Mean (±SD)	Group II: Low CM Mean (±SD)	*P* Value
Gender (Female/Male Ratio)	9:23	3:27	< 0.05
Age (years)	61.65 (5.83)	56.48 (8.80)	> 0.05
BMI cm/kg	28.33 (5.21)	28.72 (5.59)	> 0.05
# Comorbedities (CM)	5.09 (2.43)	2.57 (0.63)	< 0.05
# Medications (MED)	11.38 (3.89)	10.97 (2.04)	> 0.05
ICU length of stay	4.34 (2.24)	3.43 (1.48)	< 0.05
Hospital length of stay	9.16 (4.63)	7.2 (1.47)	< 0.05
CCI)	12	7	< 0.05

Charlson Comorbidity Index (CCI), Standard Deviation (SD)

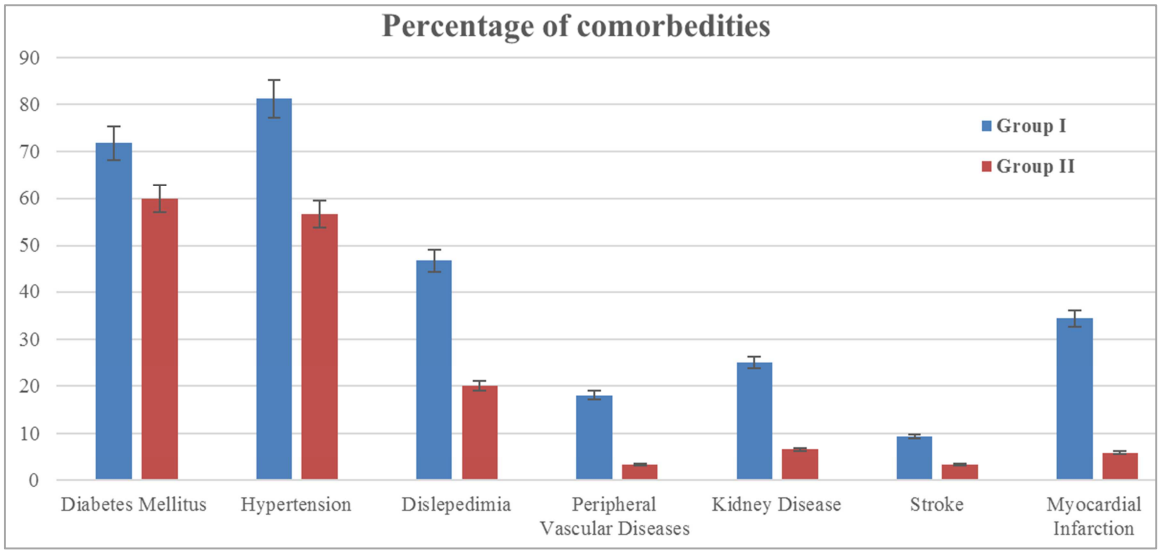

Figure 1. *Percentage of comorbidities "Group I versus Group II".*

Table 3. *Total cost of ICU and Hospital length of stay.*

Groups/Cost per LOS	Group I (Saudi Riyal) US $	Group II (Saudi Riyal) US $
ICU Cost of care	(20,241.66) 75, 907	(15997,62) 59,991
Hospital Cost of Care.	(15,691.08) 58,841.55	(12,333.6) 46,251

US $: United States of America dollars

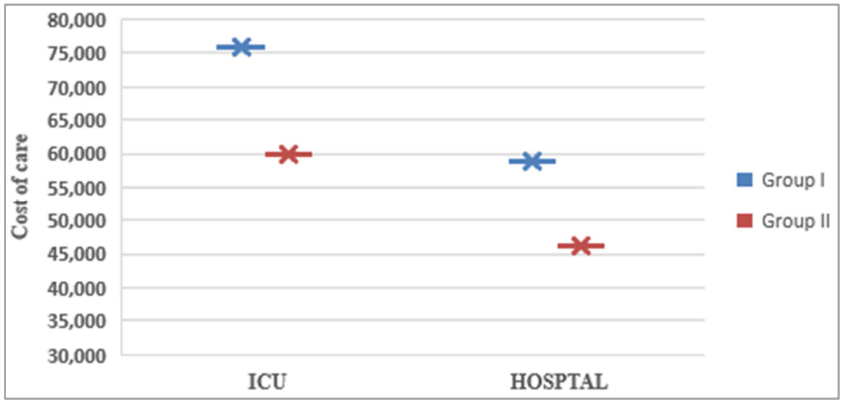

Figure 2. *Cost of care in the ICU and Hospital, Group I versus Group II.*

4. Discussion

Currently, there are no accurate statistics available regarding CABG surgery in KSA. [14, 16, 17] However, the King Faisal Specialist Hospital and Research Center (KFSH&RC) reported that over 500 CABG surgeries are performed annually [21]. It is assumed that all post-CABG patients in the KSA are offered an early intervention inpatient program (phase I) of Cardiac Rehabilitation post-surgery, as KFSH&RC. The available programs for post-CABG patients differ from hospital to hospital and there are no unified or structured CR programs for those patients [26]. It has been proven that early CR intervention is safe, effective, and has a remarkable influence on the length of ICU stay, reducing the overall length of hospital stay, improving patient outcomes, including quality of life, and decreasing the financial burden of care [13, 26]. However, the results of the current study correspond with those of existing studies, which reported that an increased number of comorbidities may affect health outcomes including hospital stay, readmission, mortality, and long-term disability. The Charlson Comorbidity Index (CCI) is a valid and reliable assessment tool that assesses comorbidity levels by considering both the number and severity of predefined comorbid conditions [24, 25]. It provides a weighted score of a client's comorbidities that can be used to predict short- and long-term outcomes, such as function, hospital length of stay, and mortality rates [18−20]. The Charlson Comorbidity Index is a method of categorizing patient comorbidities based on the International Classification of Diseases (ICD) diagnosis codes found in administrative data, such as hospital abstract data [27]. It has been reported that the original index was developed with 19 categories; however, it was modified into 17 categories [24, 27]. Comorbidity and age were both independent significant predictors of the length of hospitalization beyond that expected based on injury severity [18]. Patients with a higher mean score of comorbidities had a higher CCI score and longer ICU and hospital stays than those with lower mean scores of comorbidities, indicating that the former had a higher predicted mortality rate [28]. In this study, both groups had similar BMI scores that fell within the overweight range, which is a comorbidity factor associated with a higher incidence of longer hospitalization [29]. Patients with more comorbidities reported a higher cost of care than those with fewer comorbidities did. The results of this study showed that patients in group I, who had a higher mean score of comorbidities (> 4), had a higher CCI score of 12, and stayed longer in the ICU and hospital than group II patients, who had lower mean scores of comorbidities and lower CCI scores of 7. This indicates that group I patients had a higher predicted mortality rate than group II patients. Both groups had similar BMI scores (> 28 cm/kg), which falls in the overweight range and is a comorbidity factor that contributes to longer hospitalization [29]. Furthermore, it has been reported that high BMI in elderly individuals may reduce life expectancy and increase the risk of mortality, cardiovascular diseases, and metabolic syndrome [30-33]. The Healthcare Cost and Utilization Project (HCUP) Statistical Brief presents statistics on thirty-eight comorbidities, with obesity contributing to 17.0% of all hospital stays [34]. The study also found that group II patients had a higher mean score for comorbidities, such as DM, HTN, dyslipidemia, peripheral vascular diseases, kidney disease, and stroke. These results were verified by a study conducted by Hamza et al [35], which concluded that the severity of illness and mortality rates were significant among smokers and patients with diabetes mellitus, hypertension, and thyroid disease. Other studies have reported that higher healthcare costs and longer hospital stays are associated with

increasing age and the presence of cardiovascular diseases, chronic kidney disease, and foot ulcerations [36]. Patients with comorbid diabetes also have a more severe profile and higher direct hospitalization costs [37]. Patients with more than one chronic condition also have higher healthcare costs than the sum of the costs of the individual diseases [38]. Therefore, the conclusions of these studies are compatible with the results of the current study, which confirmed that patients with more comorbidities reported a higher cost of care than those with fewer comorbidities.

5. Conclusion

This study further supports the existing evidence that cardiovascular diseases in Saudi Arabia are still a major concern, and that coronary artery bypass graft surgery is one of the most performed procedures at King Faisal Specialist Hospital & Research Centre and across the country. The study results also showed that patients with more comorbidities, such as diabetes, hypertension, kidney and liver diseases, and strokes, tend to experience delayed cardiac rehabilitation intervention and unexpected outcomes, which can result in longer stays in the ICU and hospital as well as higher healthcare costs.

6. Implications

Previous studies conducted by Mao et al. [37], Hong et al. [39], and Parappil et al. [40] have shown that comorbidities, such as obesity, age, DM, and cognitive impairment, are linked to poor HRQoL. Therefore, it is important for therapists to have sufficient knowledge about the impact of these comorbidities on post-surgery patients and be aware of potential complications and expected outcomes before designing treatment programs. Additionally, if cardiac rehabilitation intervention is not initiated early, therapists should anticipate a longer ICU and hospital stay.

7. Strengths and Limitations

This is the first retrospective study in the Kingdom of Saudi Arabia that focuses on the impact of common comorbidities among post-CABG patients. This study highlights how comorbidities affect the outcomes of CR intervention in the post-CABG population and highlights the potential risks associated with the delay in the CR treatment program for these populations. However, the study has two main limitations: first, the inability to generalize the results since it was conducted in only one center; and second, the cost of care, which may vary from one healthcare facility to another.

8. What Is New

This is the first retrospective study in the Kingdom of Saudi Arabia that focuses on the impact of common comorbidities among post-CABG patients. The study highlights how comorbidities affect the outcomes of CR intervention in the post-CABG population and the potential risks associated with the delay in the CR treatment program for these populations. Despite the impact of comorbidities on health outcomes such as hospital stay, mortality, long-term disability, hospital costs, and readmission, no previous studies in the KSA have assessed their influence on cardiac rehabilitation outcomes and the length of hospital stay for post-CABG surgery patients.

Author Contributions

Mohammed Takroni, Nargis Mirza, Collins Ogbeivor, Mohammed Al-Subaie, and Mohammed Al-Zahrani, all of whom contributed equally to these tasks, wrote the original draft, conceptualization, and methodology of the manuscript. Mohammed Takroni, Collins Ogbeivor, and Nargis Mirza performed the formal analysis, data curation, and review and editing. All the authors have read and agreed to the published version of the manuscript.

Conflict of Interest and Funding

There are no potential conflicts of interest to disclose for any of the authors listed in the article. In addition, this study did not require any funding.

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