

STUDENTS' CORNER
PILOT STUDY**Radial artery coronary bypass grafting: Surgical outcomes of an unexplored innovation in a developing country**Russell Seth Martins,¹ Laiba Masood,² Mabrooka Kazi,³ Mishal Gillani,⁴ Ayesha Sadiq,⁵ Hina Inam,⁶ Saulat Hasnain Fatimi⁷**Abstract****Objective:** To explore postoperative outcomes, particularly prolonged length of hospital stay, in radial artery coronary artery bypass graft patients in a tertiary-care setting.**Methods:** The pilot prospective cohort study was conducted at the Aga Khan University Hospital, Karachi, from September 2019 to September 2020, and comprised adult patients of either gender due to undergo coronary artery bypass grafting for coronary artery disease involving two or more vessels. The subjects were approached for the use of their radial artery as a conduit. Prolonged length of hospital stay was defined as postoperative stay >9 days. Multivariable logistic regression was used to identify independent predictors of the length of hospital stay. Data was analysed using SPSS 21.**Results:** Of the 97 patients, 84(86.6%) were males. The overall mean age of the sample was 58.33±8.34 years. Mean length of hospital stay was 8.10±2.37 days, and 23(23.7%) patients had prolonged stay. Higher age was a significant predictor of prolonged hospital stay ($p<0.05$). Besides, 23(23.7%) patients developed acute kidney injury. There was no incidence of wound, infection or deep venous thrombosis, while 1(1.03%) patient had to be reopened due to excessive postoperative bleeding, and it represented the lone mortality.**Conclusion:** Patient age was found to be a significant predictor of prolonged hospital stay in patients undergoing radial artery coronary artery bypass graft, while almost a quarter of the sample was affected by acute kidney injury.**Keywords:** Coronary artery bypass graft, Radial artery, Prolonged length of stay, Acute kidney injury, Ejection fraction. (JPMA 72: S-106 [Suppl. 1]; 2022)**DOI:**<https://doi.org/10.47391/JPMA.AKU-22>**Introduction**

The bypass vessel conduits most frequently used in coronary artery bypass grafting (CABG) are the left internal mammary artery (LIMA) and the greater saphenous vein (SVG), with the graft of LIMA to the left anterior descending (LAD) artery acknowledged as the gold standard.¹ However, grafts from the right internal mammary artery (RIMA) and the radial artery (RA) have also been used. Moreover, both arterial grafts have been found to have better long-term clinical benefit compared to the SVG, leading to recommendations in favour of RA as the preferred second conduit after LIMA in multi-vessel CABG.^{2,3}

Despite the first use of a RA graft in 1973,⁴ its use as the second-choice conduit has been limited in Pakistan in favour of the more conventional SVG. As such, scarce information is available on the surgical outcomes and risk factors associated with RA grafts in the Pakistani

population. The use of RA as the second conduit is associated with shorter post-operative length of hospital stay (LOS) possibly due to the lower risk of harvest-site infection compared to the SVG.⁵

Prolonged length of post-operative hospital stay (PLOS) has been recognised as an important outcome, as it incurs increased hospital resource utilisation and higher patient costs. Although PLOS has been studied extensively in CABG procedures⁶⁻⁸ overall, where the SVG is the most commonly chosen second conduit after LIMA, there is little research regarding PLOS in CABG procedures where the RA serves as the second-choice conduit. This is particularly the case in developing countries, such as Pakistan, where the additional cost and expenditure resulting from PLOS adds further burden to an already resource-constrained healthcare system.

The current study was planned to explore post-operative outcomes, in particular PLOS, and associated factors amongst patients undergoing CABG with RA grafting in a tertiary-care setting.

Patients and Methods

The pilot prospective cohort study was conducted at the

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Department of Cardiothoracic Surgery, Aga Khan University Hospital (AKUH), Karachi, from September 2019 to September 2020. After approval from the institutional ethics review board, all adult patients, both male and female, undergoing CABG for coronary artery disease involving two or more vessels were approached. Informed consent was taken from all patients whereby they agreed to the use of the RA as the second conduit along with LIMA in their CABG surgery. Patients who refused consent to RA harvest and those with an abnormal modified Allen's Test, with capillary refill taking >12 seconds, were excluded.⁹ The RA graft was anastomosed to the right side of the coronary vasculature when the lesion in the right was >90% occlusive, and on the left side when the lesion in the left was >70% occlusive.

Data was collected from patients' charts and medical records through the online patient data system using a structured proforma which included patients' pre-operative, intra-operative and post-operative characteristics.

Ejection fraction (EF) was defined as the proportion of blood pumped out of the ventricles with each contraction, and the cut-off value was taken as 55%.¹⁰

Acute kidney injury (AKI) was diagnosed if any one of the three criteria were fulfilled: rise >0.3mg/dl in serum creatinine levels within 48 hours, or 1.5-fold rise in serum creatinine levels from baseline within seven days, and a reduction in urine output <0.5ml/kg/day for at least 6 hours.¹¹

Body mass index (BMI) was categorised according to the World Health Organisation (WHO) ranges for adult Asians.¹²

There is no universally-prescribed cut-off value for PLOS has been described in literature. Thus, PLOS was defined as any post-operative hospital stay longer than the 75th percentile of the overall sample which was the equivalent of >9 days in our sample. The selection of this cut-off was agreed upon by the cardiothoracic surgeons and is consistent with other studies which use the 75th percentile to define PLOS after cardiac surgery.^{8,13}

In terms of sample size calculation, it was hypothesised that 30% patients would experience PLOS. The hypothesis was made in the absence of previous studies exploring the incidence of PLOS after CABG using RA. The minimum sample size was calculated using OpenEpi calculator¹⁴ with a finite population size of 300 cases, which is the annual volume of CABG procedures at AKUH, and 95% confidence level. As the current study was a pilot

research, at least 50% of the required sample size of 156 was considered sufficient.

Data was analyzed using SPSS 21. For the comparison of data, independent sample t-tests and chi-squared tests were used, as appropriate. Subsets of the sample according to pre-existing hypertension (HTN) were also analysed. Univariable and multivariable regression analyses were performed. Factors with $p < 0.25$ on univariate analysis were included in multivariable analysis. Odds ratios (OR) with 95% confidence interval (CI) were worked out. All possible associations of PLOS with pre-operative, intra-operative and post-operative independent variables were assessed. $P < 0.05$ was considered statistically significant in all cases.

Results

Of the 97 patients, 84(86.6%) were males. The overall mean age of the sample was 58.33 ± 8.34 years. There were 66(68%) patients categorised as obese. The most common co-morbid was HTN 72(74.2%). There were 81(83.5%) cases of triple-vessel CABG. In addition to RA and LIMA, the most commonly used vessel was SVG 93(95.9%). The most common sites of distal anastomosis of the RA graft were the posterior descending artery (PDA) 47(48.5%) and the obtuse marginal artery (OMA) 26 (26.8%).

Pacing wires (PWs) were used in 26(26.8%) cases. The mean length of stay in the cardiac intensive care unit (CICU) was 1.2 ± 0.54 days, or 28.8 ± 12.96 hours. There was no incidence of wound infection, chest infection, urinary tract infection (UTI) or deep venous thrombosis (DVT) in the sample. There was 1(1.03%) case that needed to be reopened due to excessive post-operative bleeding and it was the lone mortality in the cohort. Pre-operative, intra-operative, and postoperative characteristics are summarized in Table-1.

Mean LOS was 8.10 ± 2.37 days, and 23(23.7%) patients had PLOS. The PLOS group had a significantly greater age at surgery 61.65 ± 8.13 years compared to 57.30 ± 8.18 years in 74(76.3%) patients who did not have PLOS ($p = 0.028$). In addition, a significant association was also found between PLOS and the use of PWs, with 10(43.5%) of the PLOS patients having a PW compared to 16(21.6%) of non-PLOS patients ($p = 0.039$).

Among the 72(74.2%) patients with HTN, the duration of mechanical ventilation was shorter in the PLOS group 6.13 ± 4.88 hours compared to the non-PLOS group 9.48 ± 7.69 hours ($p = 0.042$).

There were 48(49.5%) patients with EF <55%. T2DM was

Table-1: Patient pre-operative, intra-operative and post-operative characteristics.

Variables N (%)	Total	Prolonged Length of Stay		P-Value
		Yes	No	
Age (Years)	97 (100) 58.33 ± 8.34	23 (23.7) 61.65 ± 8.13	74 (76.3) 57.30 ± 8.18	0.028
Gender				
Male	84 (86.6)	19 (82.6)	65 (87.8)	0.5
Female	13 (13.4)	4 (17.4)	9 (12.2)	
BMI (kg/m ²)	27.81 ± 4.93	27.91 ± 4.56	27.77 ± 5.07	0.909
BMI Class				
Underweight	1 (1.0)	1 (4.3)	0 (0)	0.182
Normal	12 (12.4)	1 (4.3)	11 (14.9)	
Overweight	18 (18.6)	3 (13.0)	15 (20.3)	
Obesity I	36 (37.1)	11 (47.8)	25 (33.8)	
Obesity II	30 (30.9)	7 (30.4)	23 (31.1)	
EF < 55%	48 (49.5)	13 (56.5)	35 (47.3)	0.44
Present Comorbidities				
HTN	72 (74.2)	16 (69.6)	56 (75.7)	0.558
T2DM	49 (50.5)	12 (52.2)	37 (50.0)	0.885
IHD	61 (62.9)	13 (56.5)	48 (64.9)	0.469
Smoker	23 (23.7)	6 (26.1)	17 (23.0)	0.759
COPD	3 (3.1)	2 (8.7)	1 (1.4)	0.139
Others	16 (16.5)	6 (26.1)	10 (13.5)	0.198
IABP				
Yes	2 (2.1)	2 (8.7)	0 (0)	0.054
No	95 (97.9)	21 (91.3)	74 (100)	
Surgery Duration (mins)	227.69 ± 61.97	251.87 ± 91.23	220.18 ± 47.96	0.112
Bypass				
Double Vessel	4 (4.1)	1 (4.3)	3 (4.1)	0.991
Triple Vessel	81 (83.5)	19 (82.6)	62 (83.8)	
Quadruple Vessel	12 (12.4)	3 (13.0)	9 (12.2)	
XCT (mins)	58.68 ± 16.39	63.39 ± 17.27	57.22 ± 15.95	0.115
CPBT (mins)	106.55 ± 28.69	110.87 ± 28.95	105.20 ± 28.68	0.411
Pacing Wire				
Yes	26 (26.8)	10 (43.5)	16 (21.6)	0.039
No	71 (73.2)	13 (56.5)	58 (78.4)	
Duration of Ventilation (Hours)	8.09 ± 6.62	6.87 ± 5.49	8.47 ± 6.93	0.313
CICU Stay (Days)	1.20 ± 0.54	1.41 ± 0.91	1.14 ± 0.34	0.161
Acute Kidney Injury (AKI)	23 (23.7)	8 (34.8)	15 (20.3)	0.153
Chest Tube Day 1 (ml)	542.00 ± 287.59	565.67 ± 164.16	536.08 ± 311.71	0.724
Chest Tube Day 2 (ml)	357.05 ± 242.20	487.35 ± 366.90	310.90 ± 160.43	0.071

BMI: Body mass index, EF: Ejection fraction, HTN: Hypertension, T2DM: Type 2 diabetes mellitus, IHD: ischaemic heart disease, COPD: Chronic obstructive pulmonary disease, XCT: Cross-clamp time. CPBT: Cardiopulmonary bypass time, CICU: Cardiac intensive care unit.

significantly more common (30/48 or 62.5% vs. 19/49 or 38.8%; $p=0.019$) and chest drain output in the first 48 post-operative hours was significantly higher (1038.53 ± 450.13 ml vs. 818.37 ± 197.00 ml; $p=0.007$) in such patients.

Patients with ischaemic heart disease (IHD) had a significantly longer duration of ventilation 9.03 ± 7.5 hours than those without IHD 6.50 ± 4.4 hours ($p=0.039$). Patients with HTN had a significantly longer duration of ventilation 8.74 ± 7.3 hours than those not having HTN 6.24 ± 3.8 hours ($p=0.032$). Among the HTN group, patients with EF <55%

had a significantly higher post-operative creatinine 1.20 ± 0.40 mg/dL than those with EF >55% 1.04 ± 0.19 mg/dL ($p=0.043$).

Of the entire sample, 23(23.7%) patients developed AKI. The AKI group had a significantly higher pre-operative haemoglobin (Hb) 13.83 ± 1.62 mg/dL than the rest 13.06 ± 1.39 mg/dL ($p=0.027$), higher pre-operative creatinine 1.09 ± 0.27 mg/dL than the rest 0.93 ± 0.22 mg/dL ($p=0.005$) and post-operative day 1 (POD-1) creatinine 1.54 ± 0.31 mg/dL than the rest 0.98 ± 0.19 ($p<0.001$). Patients in the AKI group also had a greater decrease in

Table-2: Univariable and multivariable regression analysis.

Variables	cOR (95% CI)	aOR (95% CI)
Age	1.076 (1.007-1.151) **	1.129 (1.010-1.263) **
Gender		
Male	0.658 (0.182-2.375)	
Female	Reference	
BMI (kg/m ²)	1.006 (0.915-1.106)	
Present Comorbid		
HTN	0.735 (0.261-2.068)	
T2DM	1.091 (0.428-2.783)	
IHD	0.704 (0.272-1.825)	
Ejection Fraction		
Normal	Reference	
Borderline	0.480 (0.98-2.342)	
Reduced	1.559 (0.417-5.828)	
Surgery Duration (mins)	1.008 (0.999-1.016) *	1.129 (0.989-1.015)
XCT (mins)	1.022 (0.994-1.051)	
CPBT (mins)	1.007 (0.991-1.024)	
Pacing Wire		
Yes	2.788 (1.033-7.527) **	2.901 (0.632-13.309)
No	Reference	Reference
Duration of Ventilation (Hours)	0.957 (0.878-1.043)	
CICU Stay (Days)	2.358 (0.906-6.144) *	2.134 (0.732-6.223)
Chest Tube Day 1 (ml)	1.000 (0.998-1.002)	
Chest Tube Day 2 (ml)	1.003 (1.0002-1.006) **	1.003 (0.999-1.006)

* p < 0.25. ** p < 0.05.

cOR: Crude odds ratio, aOR: Adjusted odds ratio, CI: Confidence interval, BMI: Body mass index, HTN: Hypertension, T2DM: Type 2 diabetes mellitus, IHD: ischaemic heart disease, COPD: Chronic obstructive pulmonary disease, XCT: Cross-clamp time, CPBT: Cardiopulmonary bypass time, CICU: Cardiac intensive care unit.

Hb post-operatively 3.82 ± 1.59 g/dL than the rest 3.15 ± 1.46 g/dL (p=0.063).

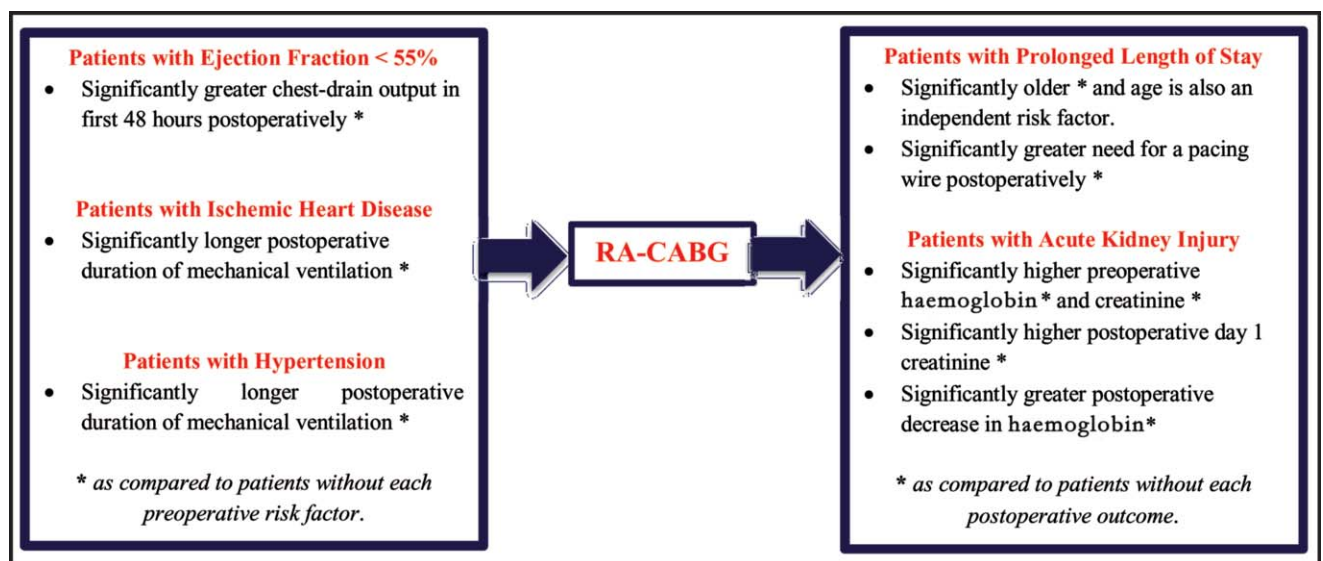
On univariate regression analysis with PLOS as the

outcome, age, PW, and chest drain output on POD-2 were found to be significant predictors of development of PLOS along with surgery duration and duration of CICU stay (p<0.25). Only age remained a significant predictor of PLOS on multivariable analysis (p<0.05) (Figure). Older patients were significantly more likely to have PLOS (Table-2).

Discussion

The current study revealed overall favourable outcomes with the use of RA as a conduit in CABG. The incidence of PLOS and AKI (both 23.7%) represented the main sources of post-operative morbidity. Age was found to independently predict PLOS, while PW and chest drain output on POD-2 were significant predictors on univariable analysis.

Higher age has been found to be a predictor of PLOS post-CABG earlier as well.^{7,15} The mean post-operative LOS in the current study was similar to an earlier study.¹⁶ The mean age in the current study was lower than that what has been reported in most earlier studies,^{17,18} while it matched the finding of a study conducted at AKUH in 2016. As age increases in adults, there is an increase in frailty and a decrease in physiological reserves, which comparatively retards their ability to recover post-operatively. The use of a PW has also been shown to lead to longer post-operative LOS.¹⁹ Patients requiring a PW have been found to have a higher age, and a greater incidence of preoperative arrhythmias²⁰ and T2DM.¹⁹ The percentage of patients in the current cohort requiring a PW was 26.8%, which is considerably higher than earlier reports.^{8,18}

**Figure:** Pre-operative risk factors and post-operative outcomes.

The current results showed that patients who developed post-operative AKI had higher pre-operative serum creatinine and POD-1 creatinine along with higher pre-operative Hb. A raised pre-operative creatinine level may indicate a worse pre-operative renal function, or possibly background pre-existing chronic kidney disease (CKD).²¹ Thus, developing AKI after CABG may be an exacerbation of it in the form of 'acute-on-chronic' kidney disease.²² The POD-1 creatinine levels were also significantly higher in the group of patients who developed AKI. Even a minimal increase in creatinine early in the post-operative period can increase the risk of post-operative mortality.²³ Patients who developed AKI lost on average 3.82 ± 1.59 g/dL of Hb compared to 3.15 ± 1.46 g/dL lost by patients who did not develop AKI. There are numerous studies having shown that increased peri-operative bleeding increases the risk of post-operative complications, including AKI.²⁴⁻²⁶ Moreover, early post-operative decreases in Hb concentration are also strongly associated with AKI development.²⁷ Early identification and management of patients can help reduce the burden of AKI after RA-CABG. This includes pre-operative imaging of the genitourinary tract and the glomerular filtration rate (GFR) measurement, given the association of coronary artery disease (CAD) and CKD,²⁸ as well as optimising surgical techniques to decrease surgery duration and intra-operative blood-loss, and judicious use of nephrotoxic drugs, such as vancomycin, post-operatively.

Lower pre-operative EF (<55%) was associated with greater chest drain output over the first two PODs. This association has been demonstrated in a few prior studies where lower EF was associated with increased chest drain output,²⁹ excessive bleeding³⁰ and a higher risk of reoperation for excessive bleeding from the chest.^{31,32} There was a significantly higher percentage of patients with T2DM in the EF <55% group compared to the EF >55% group. Patients with pre-existing T2DM and reduced EF represent a challenging population for CABG surgery due to the greater risk of post-operative complications,³³ including long-term mortality.³⁴ A study³⁵ showed that use of RA as the second-choice conduit instead of SVG conferred a late-survival advantage in diabetics undergoing CABG, supporting the use of the arterial conduit in this patient population.

A major limitation of the current study was its small sample size, resulting from a high rate of patient refusal for RA harvesting. Furthermore, this was a single-centre study, thereby its findings may not be generalisable. However, there is an absolute lack of research in developing countries regarding indicators, such as

reduced pre-operative EF along with post-operative adverse outcomes, including PLOS and development of AKI associated with patients undergoing RA-CABG. Thus, the study can serve as the basis for future studies on the subject.

Conclusion

Although outcomes of RA-CABG were generally favourable, there were a few important associations, including patient age which was found to be a significant predictor of PLOS. Moreover, reduced EF was associated with greater post-operative chest tube drainage. Higher pre-operative creatinine and greater post-operative change in Hb were associated with AKI development.

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