2-2022

Radial artery coronary bypass grafting: Surgical outcomes of an unexplored innovation in a developing country

Russell Seth Martins

Laiba Masood

Mabrooka Kazi

Mishal Gillani

Ayesha Sadiq

See next page for additional authors

Authors

Russell Seth Martins, Laiba Masood, Mabrooka Kazi, Mishal Gillani, Ayesha Sadiq, Hina Inam, and Saulat Fatimi

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 Fatimi[7]

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 procedures[6-8] 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

[1,2,4,5]Year 5 Medical Student, [3]Year 3 Medical Student, Medical College, Aga Khan University, Karachi, [6,7]Department of Cardiothoracic Surgery, Aga Khan University Hospital, Karachi, Pakistan.

Correspondence: Saulat Hasnain Fatimi. Email: saulat.fatimi@aku.edu

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 calculator[14] 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	
	97 (100)	23 (23.7)	74 (76.3)	
Age (Years)	58.33 ± 8.34	61.65 ± 8.13	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/m2)	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)	
Normal	12 (12.4)	1 (4.3)	11 (14.9)	
Overweight	18 (18.6)	3 (13.0)	15 (20.3)	0.182
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 Comorbids				
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)	
Triple Vessel	81 (83.5)	19 (82.6)	62 (83.8)	0.991
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±450.13ml 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±0.40mg/dL than those with EF >55% 1.04±0.19mg/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±1.62mg/dL than the rest 13.06±1.39mg/dL (p=0.027), higher pre-operative creatinine 1.09±0.27mg/dL than the rest 0.93±0.22mg/dL (p=0.005) and post-operative day 1 (POD-1) creatinine 1.54±0.31mg/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 Comorbids		
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±1.59g/dL than the rest 3.15±1.46g/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 arrhythmias[20] 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]

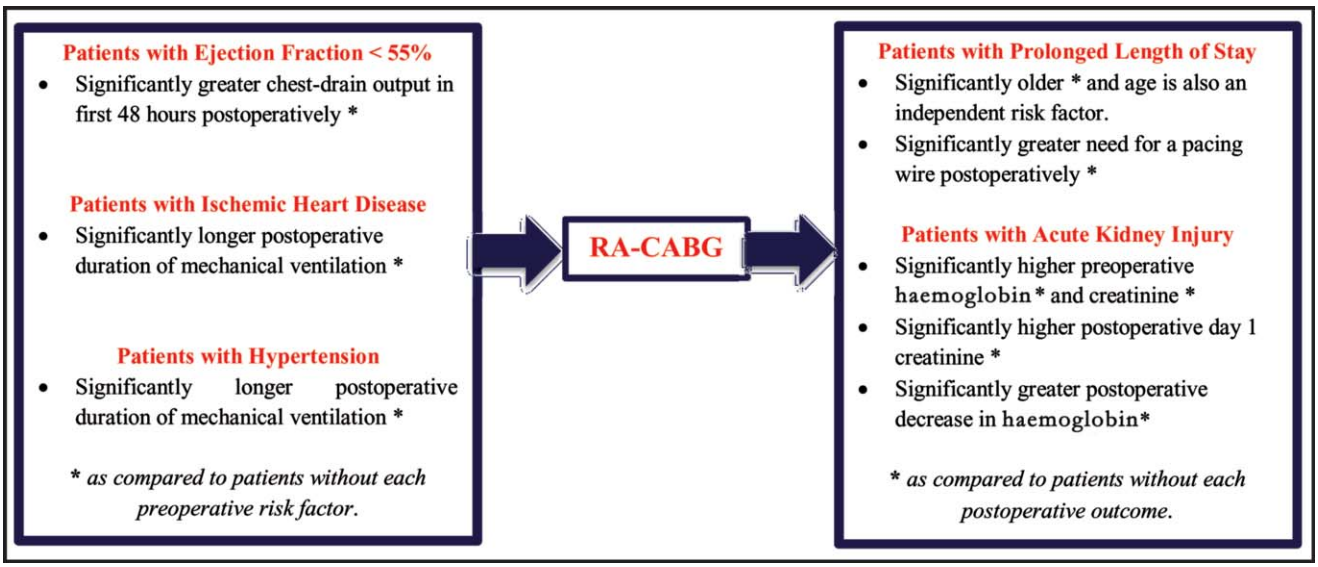

Figure: Pre-operative risk factors and post-operative outcomes.

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±1.46g/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 bleeding[30] 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 study[35] 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.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

References

1. Jannati M, Navaei MR, Ronizi LG. A comparative review of the outcomes of using arterial versus venous conduits in coronary artery bypass graft (CABG). J Family Med Prim Care 2019;8:2768-73. doi: 10.4103/jfmpc.jfmpc_367_19.
2. Shapira OM. Radial Artery as the Preferred Second Conduit for Coronary Bypass. N Engl J Med 2018;378:2134-5. doi: 10.1056/NEJMe1804750.
3. Hillis LD, Smith PK, Anderson JL, Bittl JA, Bridges CR, Byrne JG, et al. 2011 ACCF/AHA Guideline for Coronary Artery Bypass Graft Surgery: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation 2011;124:2610-42. doi: 10.1161/CIR.0b013e31823b5fee.
4. Carpentier A, Guermonprez JL, Deloche A, Frechette C, DuBost C. The aorta-to-coronary radial artery bypass graft. A technique avoiding pathological changes in grafts. Ann Thorac Surg 1973;16:111-21. doi: 10.1016/s0003-4975(10)65825-0.
5. Modine T, Al-Ruzzeh S, Mazrani W, Azeem F, Bustami M, Ilsley C, et al. Use of radial artery graft reduces the morbidity of coronary artery bypass graft surgery in patients aged 65 years and older. Ann Thorac Surg 2002;74:1144-7. doi: 10.1016/s0003-4975(02)03835-3.
6. Oliveira EK, Turquetto AL, Tauil PL, Junqueira LF Jr, Porto LG. Risk factors for prolonged hospital stay after isolated coronary artery bypass grafting. Rev Bras Cir Cardiovasc 2013;28:353-63. doi: 10.5935/1678-9741.20130055.
7. Weintraub WS, Jones EL, Craver J, Guyton R, Cohen C. Determinants of prolonged length of hospital stay after coronary bypass surgery. Circulation 1989;80:276-84. doi: 10.1161/01.cir.80.2.276.
8. Almashrafi A, Alsabti H, Mukaddirov M, Balan B, Aylin P. Factors associated with prolonged length of stay following cardiac surgery in a major referral hospital in Oman: a retrospective observational study. BMJ Open 2016;6:e010764. doi: 10.1136/bmjopen-2015-010764.
9. Ronald A, Patel A, Dunning J. Is the Allen's test adequate to safely confirm that a radial artery may be harvested for coronary arterial bypass grafting? Interact Cardiovasc Thorac Surg 2005;4:332-40. doi: 10.1510/icvts.2005.110247.

10. Ueda T, Kawakami R, Nishida T, Onoue K, Soeda T, Okayama S, et al. Left Ventricular Ejection Fraction (EF) of 55% as Cutoff for Late Transition From Heart Failure (HF) With Preserved EF to HF With Mildly Reduced EF. Circ J 2015;79:2209-15. doi: 10.1253/circj.CJ-15-0425.
11. Kellum JA, Lameire N, Aspelin P, Barsoum RS, Burdmann EA, Goldstein SL, et al. Kidney disease: Improving global outcomes (KDIGO) acute kidney injury work group. KDIGO clinical practice guideline for acute kidney injury. Kidney Int Suppl 2012;2:1-138. Doi:.10.1038/kisup.2012.1
12. World Health Organization. The Asia-Pacific perspective: redefining obesity and its treatment. Sydney, Australia: Health Communications Australia; 2000.
13. Martins RS, Dawood ZS, Memon MKY, Akhtar S. Prolonged length of stay after surgery for adult congenital heart disease: a single-centre study in a developing country. Cardiol Young 2020;30:1253-60. doi: 10.1017/S1047951120001936.
14. Dean AG, Sullivan KM, Soe MM. OpenEpi: Open Source Epidemiologic Statistics for Public Health, Version 3.01. [Online] 2013 [Cited 2021 December 25]. Available from URL: https://www.openepi.com/SampleSize/SSPropor.htm
15. Khairudin Z, Mohd N, Hamid H. Predictive models of prolonged stay after Coronary Artery Bypass surgery. In: 2012 International Conference on Statistics in Science, Business and Engineering (ICSSBE). Langkawi, Malaysia: IEEE, 2012; pp 257.
16. Eisenberg MJ, Filion KB, Azoulay A, Brox AC, Haider S, Pilote L. Outcomes and cost of coronary artery bypass graft surgery in the United States and Canada. Arch Intern Med 2005;165:1506-13. doi: 10.1001/archinte.165.13.1506.
17. Cowper PA, DeLong ER, Hannan EL, Muhlbaier LH, Lytle BL, Jones RH, et al. Trends in postoperative length of stay after bypass surgery. Am Heart J 2006;152:1194-200. doi: 10.1016/j.ahj.2006.07.017.
18. Terada T, Johnson JA, Norris C, Padwal R, Qiu W, Sharma AM, et al. Severe Obesity Is Associated With Increased Risk of Early Complications and Extended Length of Stay Following Coronary Artery Bypass Grafting Surgery. J Am Heart Assoc 2016;5:e003282. doi: 10.1161/JAHA.116.003282.
19. Bethea BT, Salazar JD, Grega MA, Doty JR, Fitton TP, Alejo DE, et al. Determining the utility of temporary pacing wires after coronary artery bypass surgery. Ann Thorac Surg 2005;79:104-7. doi: 10.1016/j.athoracsur.2004.06.087.
20. Asghar MI, Khan AA, Iqbal A, Arshad A, Afridi I. Placing epicardial pacing wires in isolated coronary artery bypass graft surgery--a procedure routinely done but rarely beneficial. J Ayub Med Coll Abbottabad 2009;21:86-90.
21. Levey AS, Coresh J. Chronic kidney disease. Lancet 2012;379:165-80. doi: 10.1016/S0140-6736(11)60178-5.
22. Hsu CY, Ordoñez JD, Chertow GM, Fan D, McCulloch CE, Go AS. The risk of acute renal failure in patients with chronic kidney disease. Kidney Int 2008;74:101-7. doi: 10.1038/ki.2008.107.
23. Lassnigg A, Schmidlin D, Mouhieddine M, Bachmann LM, Druml W, Bauer P, et al. Minimal changes of serum creatinine predict prognosis in patients after cardiothoracic surgery: a prospective cohort study. J Am Soc Nephrol 2004;15:1597-605. doi: 10.1097/01.asn.0000130340.93930.dd.
24. Kinnunen EM, Zanobini M, Onorati F, Brascia D, Mariscalco G, Franzese I, et al. The impact of minor blood transfusion on the outcome after coronary artery bypass grafting. J Crit Care 2017;40:207-12. doi: 10.1016/j.jcrc.2017.04.025.
25. Biancari F, Tauriainen T, Perrotti A, Dalén M, Faggian G, Franzese I, et al. Bleeding, transfusion and the risk of stroke after coronary surgery: A prospective cohort study of 2357 patients. Int J Surg 2016;32:50-7. doi: 10.1016/j.ijsu.2016.06.032.
26. Stone GW, Clayton TC, Mehran R, Dangas G, Parise H, Fahy M, et al. Impact of major bleeding and blood transfusions after cardiac surgery: analysis from the Acute Catheterization and Urgent Intervention Triage strategY (ACUITY) trial. Am Heart J 2012;163:522-9. doi: 10.1016/j.ahj.2011.11.016.
27. Walsh M, Garg AX, Devereaux PJ, Argalious M, Honar H, Sessler DI. The association between perioperative hemoglobin and acute kidney injury in patients having noncardiac surgery. Anesth Analg 2013;117:924-31. doi: 10.1213/ANE.0b013e3182a1ec84.
28. Na KY, Kim CW, Song YR, Chin HJ, Chae DW. The association between kidney function, coronary artery disease, and clinical outcome in patients undergoing coronary angiography. J Korean Med Sci 2009;24(Suppl 1):s87-94. doi: 10.3346/jkms.2009.24.S1.S87.
29. Dixon B, Reid D, Collins M, Newcomb AE, Rosalion A, Yap CH, et al. The operating surgeon is an independent predictor of chest tube drainage following cardiac surgery. J Cardiothorac Vasc Anesth 2014;28:242-6. doi: 10.1053/j.jvca.2013.09.010.
30. Lopes CT, Dos Santos TR, Brunori EH, Moorhead SA, Lopes Jde L, Barros AL. Excessive bleeding predictors after cardiac surgery in adults: integrative review. J Clin Nurs 2015;24:3046-62. doi: 10.1111/jocn.12936.
31. Topkara VK, Cheema FH, Kesavaramanujam S, Mercando ML, Cheema AF, Namerow PB, et al. Coronary artery bypass grafting in patients with low ejection fraction. Circulation 2005;112(Suppl 9):I344-50. doi: 10.1161/CIRCULATIONAHA.104.526277.
32. Mehta RH, Sheng S, O'Brien SM, Grover FL, Gammie JS, Ferguson TB, et al. Reoperation for bleeding in patients undergoing coronary artery bypass surgery: incidence, risk factors, time trends, and outcomes. Circ Cardiovasc Qual Outcomes 2009;2:583-90. doi: 10.1161/CIRCOUTCOMES.109.858811.
33. Nagendran J, Bozso SJ, Norris CM, McAlister FA, Appoo JJ, Moon MC, et al. Coronary Artery Bypass Surgery Improves Outcomes in Patients With Diabetes and Left Ventricular Dysfunction. J Am Coll Cardiol 2018;71:819-27. doi: 10.1016/j.jacc.2017.12.024.
34. Kogan A, Ram E, Levin S, Fisman EZ, Tenenbaum A, Raanani E, et al. Impact of type 2 diabetes mellitus on short- and long-term mortality after coronary artery bypass surgery. Cardiovasc Diabetol 2018;17:151. doi: 10.1186/s12933-018-0796-7.
35. Schwann TA, Al-Shaar L, Engoren M, Habib RH. Late effects of radial artery vs saphenous vein grafting for multivessel coronary bypass surgery in diabetics: a propensity-matched analysis. Eur J Cardiothorac Surg 2013;44:701-10. doi: 10.1093/ejcts/ezt061.