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Risk of Renal Dysfunction after Less Invasive Multi-Vessel CABG

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Abstract

OBJECTIVES—Several centers have established that off-pump, multivessel CABG performed via a small thoracotomy (MVST) is feasible. However, this procedure can be challenging when posterolateral coronary targets need to be grafted. We hypothesized that use of cardiopulmonary bypass via peripheral access (MVST-PA) would improve outcomes compared to a completely off-pump approach (OP-MVST).

METHODS—This was a prospective observational study of patients undergoing OP-MVST (n=46) vs. MVST-PA (n=45) using bilateral IMA grafts onto the LAD and Cx/RCA distribution. Hemostasis was quantified by measuring platelet function (aggregometry), chest tube output, TIMI bleeding score (%Hct change at 24hr), and transfusion requirements. The rate of mortality and major morbidity at 30d was defined according to STS criteria. Estimated GFR (normalized to baseline levels) was determined daily until discharge.

RESULTS—The OP-MVST vs. MVST-PA groups had similar risk factors at baseline and risks of composite morbidity/mortality at 30d. However, renal failure was significantly increased after OP-MVST (10.87 vs. 0%, p=0.05). MVST-PA affected hemostasis as evidenced by inhibition of platelet function (29.9 vs. 17.9 sec latency to response on aggregometry, p=0.04) and higher transfusion requirement (2.31 vs. 0.85 Units RBC/Patient, p=0.04; 55.6 vs. 34.8% transfused, p=0.059). However, 24hr chest-tube output was similar (645 vs. 750 cc, p=0.53).

CONCLUSIONS—In comparison to a completely off-pump strategy, use of cardiopulmonary bypass to assist MVST reduced the risk of renal dysfunction with only modest tradeoffs in other morbidities, e.g. altered coagulation and higher transfusion requirements. These data justify further study of the effect of MVST-PA on renal complications.

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INTRODUCTION

Coronary artery bypass grafting (CABG) via sternotomy is a procedure that is highly valued for its reliability and safety. Surgical robotics enables this procedure to be performed via small incisions without a sternal incision, providing a “less invasive” alternative to the traditional approach[1]. Potential advantages of multivessel CABG via a small thoracotomy (MVST) include decreased risk of sternal infection and a reduction in the length of time required for postoperative recovery. In appropriate candidates, the robot can be used to procure bilateral internal mammary arteries (BIMA) without the need for a sternotomy. Grafting these two IMA conduits onto two different regions of the heart then provides the long-term advantages of multiarterial grafting without the risks of sternal wound infection associated with BIMA harvest[2]. This procedure is currently performed at only a few expert centers, in part due to unanswered concerns about costs, safety and reproducibility.

Avoiding cardiopulmonary bypass (CPB) and its associated risks is another proposed advantage of MVST[3]. However, exposure and stabilization of coronary targets during MVST often poses unique challenges. The confines of a closed chest limit the working space needed for cardiac luxation compared to a full sternotomy. Excessive ventricular compression against the chest wall during these cases increases the risks for hypotension/vasopressor use, poor hemodynamics, reduced tissue perfusion, and renal dysfunction[4]. It is important to avoid this latter problem because even modest changes in renal function have demonstrated potent effects on morbidity and mortality after CABG[5–8]. Others[9,10] have suggested that CPB support (i.e. “pump assistance”) increases the feasibility and improves outcomes for beating heart CABG. We hypothesized that MVST using pump assistance (MVST-PA) would facilitate revascularization on posterior coronary targets and improve outcomes compared to a completely off-pump approach (OP-MVST).

METHODS

Patient Selection

The institutional review board approved this prospective, observational study of patients undergoing CABG at our institution. All patients enrolled in this study provided informed consent; informed consent was not waived for any patients enrolled. Inclusion criteria for this study were patients undergoing MVST using bilateral IMA conduits between 3/2008 and 3/2010 without pre-existing renal failure (defined by baseline creatinine >4.0 mg/dL or dialysis requirement). If all the coronary lesions that were present could not be addressed with this approach, they were evaluated by two staff cardiologists and deemed suitable for PCI/stenting. Patients treated during the study interval were excluded that underwent single vessel IMA grafting (n=73) or sternotomy CABG (n=82) or had pre-existing dialysis dependence prior to surgery or a baseline eGFR < 15 mL/min/1.73m^2 (n=3). Baseline data were acquired in all patients including whether CABG was performed within 5 days of preoperative cardiac catheterization or clopidogrel administration.

Surgical Procedure

After securing one-lung ventilation, both IMA were harvested using a skeletonized technique with robotic assistance (Intuitive Surgical, Mountain View, CA) and CO_2 insufflation at 8–10 mmHg. Distal anastomoses were completed manually via small thoracotomy without the use of shunts. All cases were completed on the beating heart using stabilizing devices (Medtronic, Inc, Minneapolis, MN) without aortic cross clamping. Patients underwent MVST-PA instead of OP-MVST based on anatomic considerations about how difficult it would be to expose the necessary coronary targets. Cardiopulmonary bypass (CPB) was initiated in these cases via peripheral access using femoral (or axillary) artery and vein cannulation. Site of peripheral access was based on surgeon preference using femoral (or axillary) artery and vein cannulation. Details of the perfusion strategy used by our group have been published previously[9]. No patient required an intraaortic balloon pump to be placed. If a hybrid strategy was used, PCI was performed in a separate setting using 6F guiding catheters with pre and post dilation of coronary lesions left to the discretion of the operator. Drug-eluting stents were implanted in all patients. All patients received aspirin and clopidogrel, which were given prior to PCI (300 mg followed by 75 mg daily thereafter). Serial assessments of temperature, arterial blood gas and hematocrit were prospectively collected for each case.

Management of Hemodynamics

Intraoperative hemodynamics were monitored by serial evaluation of cardiac function using transesophageal echocardiography, cerebral oximetry (INVOS, Somanetics), and invasive monitoring of arterial and central venous blood pressure with PA catheters used selectively as described[10]. Hypotension (defined as a 20% decrease from baseline mean arterial pressure (MAP), taken after iv. preload administration) was treated with phenylephrine boluses (10–50 μg) followed by an infusion (10 μg min^{-1}) in the presence of normal cardiac output. Evidence of low cardiac output with sufficient preload was treated with infusions of epinephrine and/or norepinephrine (0.1–1.0 μg/kg/min^{-1}). Transfusions were provided according to a previously published algorithm[11].

Renal Function Assessment

The estimated glomerular filtration rate (eGFR) was calculated from the standard serum creatinine level expressed in mg/dL (sCr) using Modification of Diet in Renal Disease (MDRD) formula[12]: (175) • ($sCr^{-1.154}$) • ($Age^{-0.203}$) • (1.212, if African American) • (0.724, if female) = GFR (in mL/min/1.73m^2); where sCr is expressed in mg/dL,. Urine output was monitored hourly in the first 24 hours and then daily for 4 days. Changes in eGFR during the postoperative period were quantified by the slope of eGFR change on a given postoperative day as compared with preoperative eGFR using the equation: [(GFR_{postop} - GFR_{preop})/ GFR_{preop})]. Preoperative renal dysfunction was classified as normal (GFR > 90 mL/min/1.73 m^2), mild (GFR of 60–89 mL/min/1.73 m^2), moderate (GFR of 30–59 mL/min/1.73 m^2), and severe (GFR of 15–29 mL/min/1.73 m^2). Preoperative renal failure was classified as GRF<15 mL/min/1.73 m^2 or creatinine > 4.0mg/dL (or otherwise requiring dialysis).

Adverse outcomes

The following prospectively defined outcomes were compared between cohorts:

1. Risk adjusted major and minor complications until 30 days, using the Society of Thoracic Surgeons (STS) National database definitions[13,14].
2. Major adverse cardiac and cerebrovascular events (MACCE) during the first year, using the ARTS 1 definition[15].
3. Renal insufficiency was defined using the RIFLE criteria[16]. This is defined as renal injury when postoperative eGFR less than 75% of baseline and renal failure when eGFR < 50% of baseline or < 75% combined with urine output less than 0.5 mL/kg/hour for > 6 hours.
4. Poor hemostasis and bleeding as quantified by mean 24-hour chest tube output measurements, mean TIMI bleeding score[17], and transfusion requirement defined by mean number units of blood transfused per patient and frequency of transfusions in each cohort.

Platelet Aggregometry

Whole blood aggregometry (Chronolog, Hawerton, PA) was performed using previously described techniques[11] and impedance change (Ω) was assessed in Platelet Rich Plasma (PRP) at 6 min after addition of a series of agonists: 1) ADP (5, 10mM), and 2) collagen (1, 5g/mL). Stimulation and complete blood counts were performed at baseline, immediately after surgery and on post-operative day 1 (POD1). Values obtained were total change in impedance (Δ Ω), area under the curve of Ω (AUC), slope of the curve of Ω vs. Time (i.e. rate of aggregation), and time between platelet stimulation and initial response (i.e. latency).

Statistical Analysis

Using renal failure as a sensitive indicator of compromised intraoperative perfusion, our power analysis demonstrated that a minimum sample size of 52 (26 patients per group) was required at a power level of 0.8 to determine hypothesized differences between groups. Comparisons were done by analysis of variance with subsequent pair-wise comparisons according to the Duncan multiple range test and correlations determined by calculating a Pearson's coefficient. Categorical data were compared using the Fischer exact test. Logistic regression was used to determine an interaction between study group assignment (i.e. OP-MVST vs. MVST-PA) and previously reported risk factors for renal failure. Variables with p less than 0.1 between groups with and without AKI were included in a stepwise fashion in the model. Analyses were performed with SPSS statistical software (SPSS version 13.0; SPSS, Chicago, IL) and SAS (SAS version 9.1; SAS, Cary, NC) with the assistance of a statistician.

RESULTS

Study Groups

A total of 91 MVST procedures utilizing BIMA grafts were performed by a single surgeon at our institution during the study interval. The distribution of cases was even between

MVST-PA (n=45) and OP-MVST (n=46) although group assignment was not randomized. One patient in each group required conversion to a sternotomy incision due to inability to tolerate single lung ventilation. A total of 3 patients that were in the OP-MVST group required pump assistance due to intraoperative hemodynamic instability. These cases were included in the OP-MVST group according to an intention to treat principle. The findings of our study were not altered when a separate analysis was performed after including these 3 patients in the MVST-PA group. Each was evaluated with the intention to treat principle. No patients required re-operation for revascularization. Baseline characteristics and preoperative use of medications were similar between the two groups (Table 1), except that diabetics had significantly higher mean hemoglobin A1c preoperatively in the MVST-PA cohort (7.26 vs. 6.46%, p=0.02). There was no difference in the proportion of patients having received cardiac catheterization within 5 days of CABG (19.1%vs. 17.7%, p=1.00) or were on angiotensin converting enzyme inhibitors/angiotensin-II receptor blockers (57.8% vs. 43.9%, p=0.280). There was no significant difference in either preoperative renal function or distribution of patients among classes of preoperative renal dysfunction between groups (data not shown).There was a similar incidence of chronic lung disease (15.2% vs. 14.3%, p=1.00), cerebrovascular disease (10.9% vs. 11.9%, p=1.00), congestive heart failure (28.3% vs. 28.6%, p=1.00), prior stroke or TIA (0.0% vs. 2.8%, =1.00), and atrial fibrillation (11.4% vs. 5.1%, p=0.439). There were no differences in pre-operative mean arterial pressures among groups (99.96 vs. 98.30mmHg, p=0.571). No patients had a prior intra-aortic balloon pump placed. The mean logistic EuroScore was similar between the MVST-PA group and the OP-MVST (7.18±8.47 vs. 6.39±6.25, p=0.616, respectively).

Intraoperative Variables

Including the period of CPB support for the MVST-PA cohort, this group showed lower mean systolic (80.6 vs. 111.3 mmHg, p<0.001 respectively) and diastolic (54.4 vs. 59.0mmHg, p=0.04) pressure than the OP-MVST group. This difference did not increase the need for vasopressors. On the contrary, the OP-MVST group showed a significantly greater intraoperative use of Phenylephrine and a trend towards increased use of Epinephrine/ Norepinephrine (Table 2), often triggered by hypotension after cardiac manipulation to expose coronary targets off-pump. Total OR time and the number of bypass grafts placed were similar between groups (Table 2). During MVST-PA, arterial pO_2 was significantly lower than OP-MVST at the completion of BIMA harvest (198.16 vs. 283.32 mmHg, P<0.001) and during the distal anastomoses (182.13 vs. 328.42 mmHg, p<0.001) but not by the end of the case. Mean pCO_2 and temperature were similar between groups at all three time-points. Although mean intraoperative CVP was similar between groups, peak CVP (often during periods of cardiac manipulation) was higher in the OP-MVST group (21.31±9.91 vs. 13.28±5.99, p<0.001).

Postoperative Clinical and Renal Outcomes

The risk of the composite endpoint of major morbidity and mortality within 30 days was similar between groups (8.9 vs. 13.0%, p=0.739) and consistent with the predicted risk according to the STS risk model (O/E ratio: 0.9 vs. 1.1, p=0.09). Over the first postop year, both groups had a similar risk of MACCE (8.7 vs. 8.9%, p=1.00) and need for repeat revascularization (4.3 vs. 4/4%, p=1.0). There was no significant difference in post-

operative length of stay between the two groups (5.89 vs. 6.19 days, p=0.787). Patients in the MVST-PA group had a significantly longer stay in the ICU (41.6 vs. 66.1 hours, p=0.004) and remained on ventilation longer (20.9 vs. 10.5 hours, p=0.019).

No patient required dialysis postoperatively. On post-operative day 2 (POD2) OP-MVST had a significantly higher instance renal failure (10.87 vs. 0%, p=0.055, Chi-square) and a trend towards significance in the risk of renal injury (15.91 vs. 6.98%, p=0.314). OP-MVST showed lower urine output intraoperatively (490.2 vs. 796.0 cc, p<0.001) and over the first 24 hours (2151.0 vs. 2719.0 cc, p<0.001). Although eGFR was similar between groups at baseline (72.3 vs. 73.2 ml $\cdot$ min^{-1} $\cdot$ 1.73 m^{-2}), it declined over the next two days after OP-MVST but not MVST-PA (change from baseline: −3.1 vs. +11.5%, p=0.028) (Figure 1). Neither postoperative renal injury nor failure showed any relationship to MACCE at 1 year in this cohort.

Compared to those without renal failure (n=80), patients with postoperative renal failure (n=4) had longer post-operative LOS (9.25 vs. 5.45 d, p<0.011), were more likely to be discharged to TCU/Rehab rather than home (75.0 vs. 21.8% discharged to TCU/rehab, p=0.043). Renal failure patients were more likely to be readmitted to the ICU (50.0% vs. 1.4%, p=0.006) but showed no increase readmission to the hospital after discharge (14.6% vs. 20.0%, p=0.564).

Predictors of Renal Function

Univariate predictors of eGFR on day 2 included baseline creatinine (R= −0.56, p<0.001), history of peripheral vascular disease (R=−0.352, p<0.001), pO_2 level at the completion of BIMA harvest (R=0.25, p=0.04), intraoperative use of any vasopressor (R= −0.22, p=0.05) or Epinephrine/Norepinephrine (R=−0.49, p<0.001). Predictors of developing postoperative renal injury include being assigned to OP-MVST instead of MVST-PA (RR 6.8, p=0.03) and cardiac catheterization (and administration of IV contrast) within five days of OP-MVST (R=0.776, p<0.001) but not MVST-PA.

Independent predictors of renal injury on POD2 in a multivariate model included preoperative peripheral vascular disease (p=0.02), active smoking (p=0.03), and the intraoperative use of Epinephrine/Norepinephrine (p=0.02) but not assignment to OP-MVST vs. MVST-PA.

Hemostasis/Bleeding

Intraoperatively, MVST-PA patients had a lower hemoglobin level at the completion of the case (9.82 vs. 11.58 g/dL, p<0.001) and received significantly more blood transfusions (0.89 vs. 0.23 Units RBC/patient, p=0.03). Over the first 24 hours after surgery, bleeding was similar between groups (chest tube output: 645 vs. 750cc, p=0.53, TIMI bleeding score: 10.0 vs. 8.7, p=0.31) but the total transfusion requirement was higher after R-CAGB-PA (2.31 vs. 0.85 Units RBC/Patient, p=0.04; 55.6 vs. 34.8% of cohort transfused, p=0.059). There was no significant difference in the number patients that underwent repeat operation for bleeding between the groups (2.2% vs. 6.7%, p=0.361) nor for revascularization (3.0% vs. 0.0%, p=1.00). On postoperative day 1, platelet counts declined in both groups (34.8 vs. 27.9% decline from baseline, p=0.06) although platelet function measured by aggregometry

appeared to be better preserved after OP-MVST (17.9 vs. 29.9 sec latency to response to ADP, p=0.04, 42% vs. 84% prolongation compared to baseline, p=0.03). The proportion of patients having undergone PCI within 5 days of surgery was similar between both groups (17.4% vs. 20.5%, p=0.791). There was no significant difference in the proportion of patients that received preoperative clopidogrel (17.4% vs. 24.4%, p=0.449). Those patients that received preoperative clopidogrel showed no significant difference in transfusion requirement, TIMI risk stratification, pre- or post-op platelet levels, and chest-tube output compared to those on active therapy.

DISCUSSION

Using the sternotomy approach, BIMA grafting involves a tradeoff between the short-term infection risks and long-term patency. MVST with BIMA grafts provides comparable results to traditional CABG in terms of patency and long-term outcomes while eliminating the risk of sternal infection[18,19]. This study analyzed outcomes after MVST that involved BIMA grafts placed onto inferior and posterior targets. The rates of complications, myocardial injury and most postoperative problems were acceptable in comparison to expected outcomes for traditional CABG. However, renal failure was an unanticipated problem after OP-MVST. This adverse event was associated with intraoperative hypoxia, the need for inotropes and/or vasopressors and/or intravenous contrast use (e.g. for heart catheterization) within 5 days of surgery. CPB assistance in these cases was associated with significantly reduced renal complications, perhaps by rapidly and effectively mitigating hypoxia and the need for inotropes and pressors during revascularization. There has been a strong association noted between even modest changes in postoperative renal function and the risks of mortality, and excessive resource utilization and costs after CABG[20]. CPB assistance might promote broader application of MVST despite tradeoffs of longer OR times, greater blood loss and more perioperative transfusions and we feel that these results warrant further study

In retrospect, it may seem obvious that prolonged cardiac luxation within the closed chest without the support of CPB would lead to problems with hemodynamics and renal perfusion. Our adoption of CPB in these cases reflects the “trial and error” process that accompanies procedures with limited acceptance and no “best practices” established *a priori* from which we could draw. We were initially reluctant to use CPB because prior data have suggested that off-pump CABG is renoprotective[21]. CPB is thought to injure kidney function by inducing hemodilution, activation of inflammatory and clotting cascades, non-pulsatile perfusion, hemolysis and release of nephrotoxic free hemoglobin[22]. It is possible that our strategy of using a miniaturized, heparin coated CPB circuit without cardiotomy suction, maintaining pulsatile blood flow during CPB support and avoiding the sternotomy helped mitigate these problems traditionally associated with CPB. In the absence of a third MVST group supported with a traditional CPB circuit for comparison, this point remains speculative and requires further study. Furthermore, hemodilution may be a mechanism by which serum creatinine levels may have been artificially lower in the MVST-PA group. However, we felt the differences in creatinine observed were too great to be explained by hemodilution alone. Additionally, differences in renal function were observed as far as two days post-operatively, including a decrease in urine output in the OP-MVST group.

It is not uncommon for patients requiring coronary revascularization to have pre-existing renal disease. Off-pump CABG via a sternotomy has been shown to reduce the risk of adverse outcomes and renal injury in these patients compared to percutaneous techniques (PCI)[23]. However, our findings illustrate that off-pump may not always be reno-protective. Variability in outcomes are often derived from unpredictable hemodynamics during OPCAB, particularly in the case of emergency conversion from off- to on-pump CABG. Several studies have demonstrated that on-pump conversion triggers a variety of complications including renal injury[24–29]. Initiating CPB during MVST requires peripheral cannulation, a procedure that takes longer than direct intracardiac cannulation through the open chest. Therefore, emergency conversion from off- to on-pump MVST can be associated with extended periods of poor tissue perfusion. Additional studies aimed at identifying those MVST cases most likely to derive benefit from CPB may help maintain the renoprotective advantages of surgery over PCI.

Renal function after MVST is influenced by anesthesia management, which can be highly challenging. These cases combine the more complex management issues associated with off-pump CABG (e.g. cardiac luxation and temporary coronary artery occlusion)[30] and thoracoscopic surgery (e.g. intrathoracic CO_2 insufflation and single-lung ventilation)[31,32]. Moreover, the time required for BIMA harvesting prolongs the period prior to revascularization in which these challenges are able to provoke cardiopulmonary problems if not effectively managed. In our patients, we noted that a low pO_2 level at the completion of BIMA harvest was a predictor of renal injury. A unique issue with BIMA harvest during MVST is that the right pleura is opened when procuring the right IMA, which exposes the univentilated right lung to CO_2 insufflation pressures (10–12 mmHg). Positive ventilator pressure after expiration (i.e. PEEP) was not routinely used in most of these cases. As a result, there was a risk of compressing the ventilated lung and compromising oxygenation during thoracic insufflation. Depending on their degree of pre-existing renal tolerance to hypoxia, we speculate that intraoperative hypoxia might help explain the high rate of postoperative renal injury seen in the OP-MVST group and believe this warrants further study.

An important limitation of this study is that it was not a randomized trial but reflects ongoing efforts at process improvement. Based on the intention to treat principle, the OP-MVST group included three patients that required emergent conversion to CPB support. Excluding these three patients from the analysis did not alter the main findings of our study. Because the study groups were treated with significantly different volumes of fluid in the OR, the use of serum creatinine to compare renal function is another methodological problem with this study. We normalized creatinine to baseline levels and to age, sex, body surface area by calculating eGFR in order minimize the influence of fluid management. In addition, abnormalities measured in eGRF were significantly associated with lower urine output, corroborating the pathologic significance of the creatinine differences between groups. Additionally, the sample size of our study was not adequate to assess differences of rare adverse outcomes (e.g. stroke). In order to determine differences in incidence of stroke, a minimum sample size of 788 (394 per group) would be required at the 0.8 power level. We feel this is an acceptable limitation as these outcomes were not primary endpoints of our

study; however, they do warrant further investigation. A final limitation of this study is that it was not sufficiently powered to establish long-term efficacy.

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Clinical Perspective

"Risk of Renal Dysfunction after Less Invasive Multi-vessel CABG" (Poston)

This is a prospective, observational study comparing 46 patients undergoing off-pump multi-vessel small thoracotomy coronary artery bypass grafting to 45 patients undergoing the same procedure using cardiopulmonary bypass (CPB) via peripheral access. In this small series, the use of CPB significantly reduce the incidence of renal failure from 11% to 0%. There was a modest tradeoff with a not unexpectedly higher transfusion requirement in the patients placed on CPB. The important limitations of this study are the groups were small and not randomized. Therefore, there may have been a significant selection bias. Moreover, the incidence of renal failure in the off-pump group was higher than in previous reports. In fact, some centers have advocated this approach in patients with renal dysfunction as being more friendly to the kidneys than going on CPB. This small study is underpowered to detect other differences in morbidity between the two techniques. However, this is an interesting report and suggests the need for larger, randomized studies comparing these two techniques.

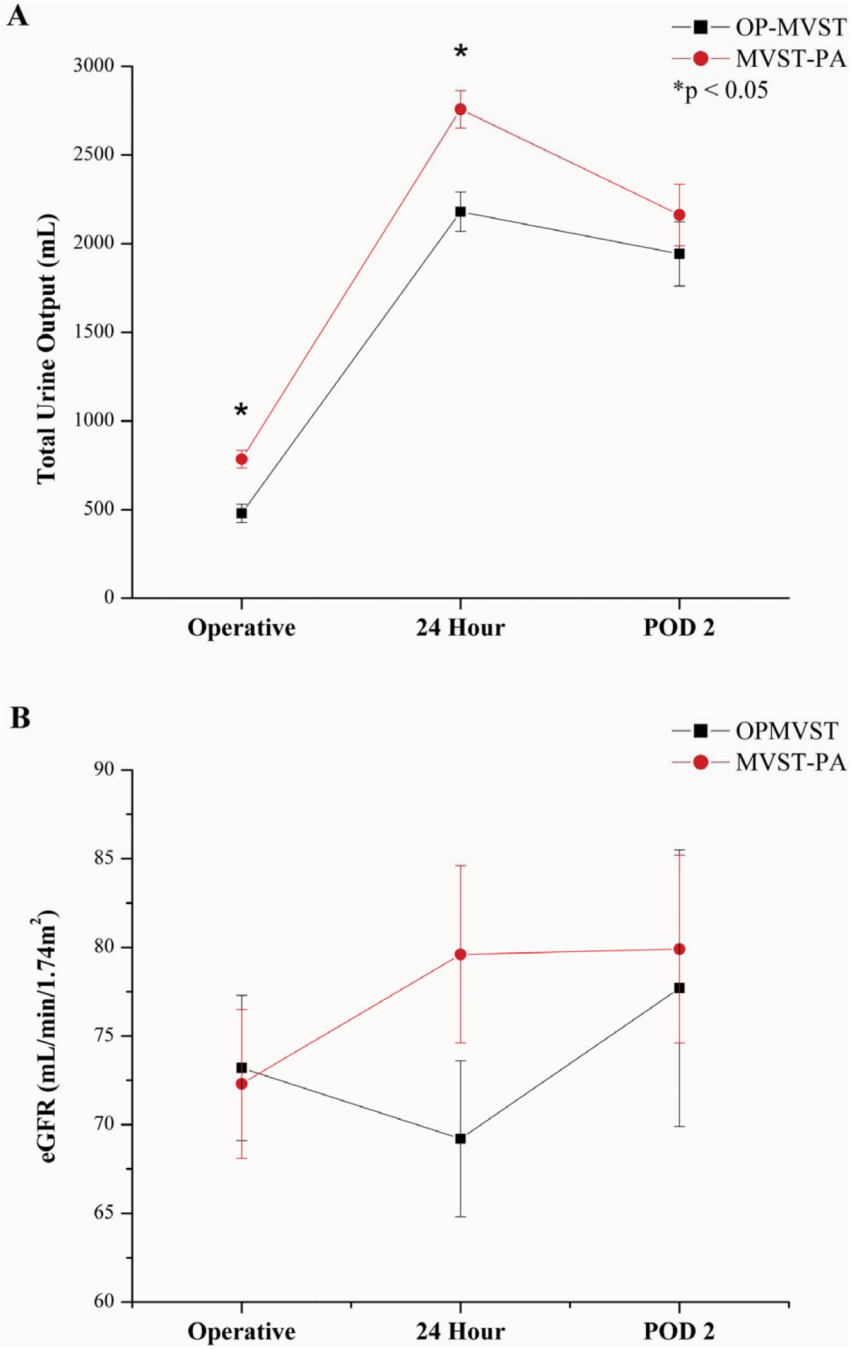

Figure 1. Comparison of Urine Output and eGFR vs. Time (OP-MVST vs. MVST-PA). Legend

Renal function was followed during hospitalization in terms of mean urine output **(A)** and mean eGFR **(B)** during and after the operative period. Urine output was significantly greater after MVST-PA at all time-points other than POD2. While the absolute eGFR was not different between groups, there was a significant difference in the change from baseline between groups on POD 2 (−3.1 vs. 11.5%, p=0.028). *POD2*= Post-Operative Day 2. Error bars represent standard error. *p<0.05.

Table 1

Baseline Characteristics

Parameter	MVST-PA (n=45)	OP-MVST (n=46)	P-Level
Age (years)	62.3	65.8	0.16
Male Sex	64.4	84.8	0.03
EuroScore	7.18±8.47	6.39±6.25	0.62
DM[a]	48.9	50	1
Unstable Angina	37	40.7	1
Poorly-controlled HTN[b]	42.2	60.9	0.08
Cerebrovascular Disease	11.9	10.9	1
Incidence of Peripheral Arterial Disease	15	11.4	0.75
Prior stroke/TIA	2.8	0	1
Atrial Fibrillation	5.1	11.4	0.44
Congestive Heart Failure	28.6	28.3	1
Chronic Lung Disease	14.3	15.2	1
Prior IABP Placement	0	0	1
Incidence of Left Main Disease (%)	26.2	44.4	0.12
Use of Statin	97.8	93.5	0.62
Use of ASA[c]	95.6	100	0.24
Use of ACEi/ARB[d]	43.9	57.8	0.28
Mean EFe (%)	53.6	51.2	0.46
EF < 35%	11.7	7.5	0.7
Baseline creatinine (mg%)	1.4	1.2	0.63
Total Cholesterol (mg/dL)	166.1	160.5	0.57
Triglycerides (mg/dL)	155.8	132.2	0.15
Troponin	1.1	3.3	0.07

Legend:

a) DM=Diabetes Mellitus;

b) HTN=Hypertension;

c) ASA = Aspirin;

d) ACEi/ARB=Angiotensin Converting Enzyme Inhibitors/Receptor Blockers.

Table 2

Operative Characteristics

Parameter	MVST-PA (n=45)	OP-MVST (n=46)	P-Level
Time on CPB[a] (min)	51	0	<0.001
Total Operative Time (min)	321.1	308.5	0.54
Number of bypass grafts (mean)	2.5	2.4	0.29
Intra-op use of Epi/NorEpi[b]	0	0.1	0.22
Intra-op use of Phenylephrine	0	0.5	<0.001

Legend:

a) CPB = Cardiopulmonary Bypass;

b) Epi/NorEpi = Epinephrine/Norepinephrine.

Table 3

Risk-adjusted major and minor complications

	MVST-PA (n=46)	OP-MVST (n=45)	P-value
Reoperation for Bleeding[a]	6.7%	2.2%	0.36
Prolonged Intubation[a]	2.2%	0.0%	0.50
Stroke[a]	0.0%	0.0%	1.00
Mediastinitis[a]	0.0%	0.0%	1.00
Mortality[a]	2.2%	2.2%	1.00
Renal Failure[ab]	0.0%	10.9%	0.06
Renal Injury[b]	6.9%	15.9%	0.31
MACCE[c] **at 1 Year**	8.7%	8.9%	1.00

Legend:

[a] STS Definition;

[b] On postoperative day 2;

[c] Major Adverse Cardiac and Cerebrovascular Events[15].