Published in final edited form as:

Ann Thorac Surg. 2010 November ; 90(5): 1418–1424. doi:10.1016/j.athoracsur.2010.04.029.

Same Admission Cardiac Catheterization And Cardiac Surgery: Is There An Increased Incidence Of Acute Kidney Injury?

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Abstract

Background: Acute kidney injury (AKI) is predictive of increased long-term mortality following cardiac surgery. Patients often undergo surgery following cardiac catheterization during the same admission for reasons of instability and threatening anatomy as well as non-urgent reasons such as patient convenience. We hypothesized that patients undergoing cardiac catheterization and cardiac surgery during the same admission are more likely to develop AKI after cardiac surgery than patients for whom surgery is performed on a later admission.

Methods: We prospectively enrolled 668 non-emergent adult cardiac surgical cases. Patients having heart catheterization were divided into two groups: cardiac catheterization followed by cardiac surgery during the same hospital admission (same admission) or catheterization followed by surgery during a later admission (later admission). AKI was defined by an increase in serum creatinine from baseline by 50% or 0.3 (mg/dL). Univariable and multivariable logistic regression and propensity-matched analyses were conducted.

Results: The incidence of AKI was significantly higher in the patients who had same admission cardiac catheterization and surgery (50.2%) compared to patients who had surgery on a later admission (33.7%, $p=0.009$). The adjusted odds ratio for surgery on a later admission was 1.54 (95% CI: 1.11–2.13) suggesting a 54% increased risk of AKI. Propensity matched results were similar with 1.58 (95% CI: 1.13–2.22).

Conclusion: When cardiac catheterization and cardiac surgery occur during the same hospitalization, there is an increased risk for postoperative acute kidney injury. After cardiac catheterization, discharge and readmission for non-urgent surgery should be considered as such an approach might reduce the risk of AKI.

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Meeting Presentation: Society of Thoracic Surgeons 46th Annual Meeting, Fort Lauderdale, Florida, January 26, 2010

Disclosures: None.

Keywords

Cardiac surgery; cardiac catheterization; acute kidney injury

Introduction

It is common practice to provide same admission diagnostic and surgical services for patients undergoing cardiac surgery. In the absence of compelling reasons for surgery such as instability or life-threatening anatomy, discharge and subsequent readmission may be indicated. However, patients often undergo surgery following cardiac catheterization during the same admission for non-urgent reasons. The practice of operating on patients with a same-admission cardiac catheterization may induce a higher risk for acute kidney injury (AKI) and therefore an increased likelihood of morbidity and mortality.[1–8]

Cardiopulmonary bypass (CPB) and other intra-operative practices may contribute or be responsible for AKI through a variety of mechanisms such as hemodynamic alterations, ischemic injury secondary to generation of macroscopic and microscopic emboli, exposure of patient's blood components to the bypass circuit inducing a systemic inflammatory response syndrome, activation of neutrophils and free hemoglobin released from injured erythrocytes causing oxidative injury, and ischemia-reperfusion injury.[9]

In addition to the intraoperative events noted above, there are pre and post-operative events that contribute to AKI in the cardiac surgical patient. A potentially modifiable risk for AKI could be the timing of cardiac surgery after cardiac catheterization. AKI due to radiocontrast exposure is a well known complication of cardiac catheterization and is associated with increased mortality.[10] Heart catheterization and heart surgery in close proximity may pose additive risks for AKI when performed during the same admission. Ranucci (2008) and Medalion (2009) have shown the influence of timing of cardiac catheterization on the incidence of acute renal failure after cardiac surgery.[5, 7] Medalion concluded that coronary artery bypass grafting should be delayed for at least 5 days in patients who receive a high contrast dose.[5] Ranucci concluded that delaying cardiac surgery beyond 24 hours of exposure to contrast has the potential to decrease the incidence of acute renal failure in elective cardiac surgery.[7] However, it is not known whether cardiac surgery conducted on a later admission, compared to surgery during the same admission as for cardiac catheterization, is associated with a lower incidence of postoperative AKI.

Therefore, we prospectively collected catheterization and surgery data during 2008 at a single center and retrospectively analyzed it to assess if same admission surgery is associated with increased risk for AKI when compared to later admission surgery.

Materials and Methods

The Northern New England Cardiovascular Disease Study Group (NNECDSG) was founded in 1987 as a regional voluntary consortium capturing 100% of the coronary revascularizations and valve procedures in northern New England including eight medical centers in Vermont, New Hampshire, and Maine. The group consists of clinicians, hospital

administrators, and health care research personnel who seek to improve continually the quality, safety, effectiveness, and cost of medical interventions in cardiovascular disease. The Maine Medical Center Institutional Review Board has approved this study and waived the need for patient consent. The authors had full access to the data and take full responsibility for its integrity. All authors have read and agree to the manuscript as written.

We prospectively enrolled 722 consecutive adult cardiac surgical cases at a single NNECDSG center between January 2008 and December 2008. Patients without a preoperative catheterization (N=8), with a history of dialysis treatment prior to surgery (N=5), or undergoing emergent cardiac surgery (N=41) were excluded from the analysis. The final cohort included 668 non-emergent patients. Patients undergoing cardiac catheterization were divided into two groups: catheterization followed by surgery during the same hospital admission (same admission) or on a later admission (later admission). Patients undergoing catheterization as an in-patient at an outside hospital and transferred during that admission to the surgical facility were considered same admission surgery. Patients undergoing catheterization at the surgical facility on a previous admission or if the catheterization was conducted at an outside hospital on a previous admission (not transferred) were considered a previous admission catheterization.

The most recent preoperative serum creatinine was measured at baseline prior to cardiac surgery, and 100% capture of daily postoperative serum creatinine up to 48 hours, then per clinician judgment until discharge. AKI was defined prior to discharge from cardiac surgery by a 50% or 0.3 (mg/dL) increase in serum creatinine from baseline during the post-surgical hospitalization.[11]

Statistical Analysis

Univariable and multivariable logistic regression was used to evaluate the relationship between same admission catheterization and previous admission catheterization. A non-parsimonious logistic regression model was used to identify significant baseline covariates to be used in the final adjustment using a backwards step approach and p-value 0.10. The final multivariate logistic regression model adjusted for age, presence of coronary artery disease, baseline serum creatinine (mg/dL), pumptime (minutes), and pre-operative hematocrit. All other variables were not significant (P-value >0.1) and were not included in the final model, including timing between cardiac catheterization and surgery (in days), pre-operative IABP, surgery type, prior surgery, prior percutaneous coronary intervention, and ejection fraction <40%. A propensity-matched analysis was conducted using a predictive model for the exposure (same admission cardiac catheterization), including gender, body mass index, ejection fraction <40%, pre-operative white blood cell count >12,000, urgent priority, type of surgery resulting in 550 matched patients. Conditional logistic regression was used to conduct the propensity-matched analysis. Multivariable modeling was conducted on the full cohort (N=668) with 100% complete data with the following exceptions: forty-one patients who did undergo cardiopulmonary bypass were missing recorded pump times (minutes). To correct for this missing data, we set the pumptime to the mean time. Nine patients had missing ejection fraction and for the indicator variable ejection

fraction <40% were set to the null. *A priori* sub-group analyses were conducted on important sub-groups of patients. All analyses were conducted using Stata 11.0 (College Station, TX).

Results

Patient and procedural characteristics are reported in Table 1. The overall incidence of AKI was 45%. AKI was associated with an increased risk of in-hospital mortality (OR: 2.62; 95%CI: 1.04–6.58), low cardiac output failure (OR: 3.34; 95%CI: 1.63–6.85), and pneumonia (OR: 3.94; 95%CI: 1.26–12.33). We found that the incidence of AKI (Table 2) was significantly higher in the patients who had same admission cardiac catheterization and surgery (50.2%) compared to patients who had cardiac catheterization during a prior admission (33.7%, $p = 0.001$). The adjusted odds ratio for patients having a catheterization during a previous admission was 1.54 (95% CI: 1.11–2.13) suggesting a significant 54% increased risk of AKI (Table 3). Propensity matched results were similar with odds ratio 1.58 (95% CI: 1.13–2.22). *A priori* subgroup analyses are reported in Table 3.

Comment

Our study shows that patients undergoing their cardiac catheterization procedure during a previous admission had a 45% reduction in AKI prior to discharge from cardiac surgery when compared to patients who experienced same stay cardiac catheterization and surgery. Therefore, this analysis suggests that all patients who undergo cardiac catheterization and cardiac surgery in close proximity in time, in this instance, during the same hospitalization, have a significantly greater risk of AKI than they would have if they were eligible to be discharged and operated on during a subsequent admission.

Several studies have demonstrated an association between AKI after cardiac surgery and increased morbidity, short-and long-term mortality, ICU and hospital lengths of stay, and utilization of resources.[4, 8, 12–14] Other studies have also that demonstrated postoperative increases in serum creatinine by 25% or 0.5 (mg/dL) are predictive of short-and long-term mortality.[4, 13]

Our study is unique in that it compares the association between same admission cardiac catheterization and cardiac surgery with separate admissions.[5, 7] The implication is that it is safe, and possibly beneficial in terms of renal protection, to send patients home after cardiac catheterization with plans for surgery during a subsequent admission. Others have demonstrated the harmful renal effects from radio-contrast dye, maligning the kidney through acute tubular necrosis and renal tubular cell apoptosis.[15] It is likely through this mechanism and necessity of time for renal cell recovery prior to inducing new insults from surgery that we begin to understand the association between a same admission catheterization and post-surgical AKI. A second explanation could be found in the aggressive medical management of the patient during single hospital stay between catheterization and surgery may subject the patient to pharmacological overload of the kidneys or other hospital acquired adverse events. In addition to the intra-operative events, there are pre and post-operative events that play a role in contributing to AKI in the cardiac surgical patient (Table 4).

The optimal time between cardiac catheterization and surgery was not revealed in our data as the addition of the timing between cardiac catheterization and surgery provided no additional value in our modeling of post-surgical AKI when the same admission versus later admission catheterization variable is included in the model. However, Ranucci and Medalion have both published papers regarding patients who had high volumes of contrast media during their heart catheterization.[5, 7] Their data suggested waiting between two and five days. Since AKI could be an epiphenomenon there may be resolution over time of other organ injuries we have yet to identify. In addition, anemia, drugs, and inflammation could be addressed by increasing the benefit from waiting. We are advocating for separate admissions, not only to mitigate the potential for acute kidney injury but to potentially address other issues. Based on the available literature and our observations, we suggest that at this time, waiting two weeks in the non-urgent patient and 5 days if the patient is urgent cannot leave the hospital.

There are limitations of this analysis. First, it was generated from a single-center database and while collected prospectively, was evaluated retrospectively. The prospective data collection was conducted using a veteran quality improvement registry, which undergoes validation. However, the analysis was conducted retrospectively and is limited to unmeasured confounding. Second, despite adjusting for significant baseline covariates, there may be other confounding covariates that would mark the urgent group for both increased mortality and incidence of AKI. In spite of these limitations, this analysis moves us in the direction of separating the catheterization and surgical admission in time when safe, thereby mitigating the potential for AKI and increased short-and long-term mortality.[1, 16, 17]

There are several strengths to this study. The cohort was created via consecutive enrollment of over 700 patients with a broad mix of comorbidities and gender, which permits adequate generalizability of our findings. The serum creatinines were collected prospectively and were determined frequently on all subjects as a standard of care. Consequently, there is no ascertainment bias for AKI in patients who were sicker or hospitalized for a longer duration. Finally, this is a modern prospective cohort where many evidence-based strategies such as blood and glucose management are the standard of care, adding further to the generalizability of the data when compared to other centers using evidence based protocols.

There is no question that the urgent group is going to have higher risk patients and comorbidities that would more likely be risk factors for AKI as demonstrated in our analyses. Embedded in the urgent group may be patients who are subjectively urgent and could safely be managed during a readmission. Furthermore, there may also be patients in the mix who are there for scheduling convenience. Those patients who cannot be managed as outpatients and be readmitted would be well served to wait a few days in the hospital before surgery.

It appears that there is an increased risk of renal injury when cardiac catheterization and cardiac surgery occur during the same hospitalization. Clearly, there are many patients admitted for unstable, life-threatening or disabling conditions that require surgical management during the same admission as their cardiac catheterization. The risk of AKI in

that group of patients is a component of the overall risk in the urgent patient population which is defined as patients that cannot leave the hospital prior to surgery.

The NNECDSG database has shown us that most of the mortalities in the isolated CABG cohort occur in the urgent population. This information may present the opportunity to operate on patients in an elective timeframe. Some of the patients that have surgery and cardiac catheterization during the same hospitalization who may be characterized as having a reason to be operated upon urgently, may truly belong in the elective (non-urgent) group. For example, some of the patients, especially those who are far from home, appreciate the convenience of having their diagnostic catheterization and surgery during the same hospital admission. When they are grouped with patients who are truly urgent, it appears that they may be at increased risk for AKI, with its attendant increase in long-and short-term mortality.

In conclusion, this prospective observational analysis presents the opportunity to compare future urgent and non-urgent patients using a protocol that would clearly state indications for cardiac surgery during the same admission as cardiac catheterization, for example, such as acute coronary syndrome or some other unstable pattern, critical left main trunk stenosis, life-threatening anatomy, or critical aortic stenosis. Patients admitted for cardiac catheterization and cardiac surgery during the same admission for purposes of convenience, or less compelling reasons, could be discharged and readmitted at a future date.

Our findings suggest there is an opportunity to decrease the incidence of AKI, along with its long-term mortality by separating the truly urgent patients from elective or non-urgent patients. The *a priori* sub-group analysis (Table 3) generates the hypothesis that conducting cardiac catheterization during a previous admission is renoprotective among elective patients, patients without a recent myocardial infarction (within 7 days of surgery), and among patients without unstable angina regardless of the type of surgery, congestive heart failure or left main disease. Increasing the time interval between the heart catheterization by sending patients home after a cardiac catheterization may allow resolution of some of the predisposing factors contributing to AKI in the post operative cardiac surgical patient and reduce overall morbidity and mortality for cardiac surgery patients.

Acknowledgements:

Susan Seekins, RN and Debra Kramlich, RN, Cardiac Surgery Database Coordinators, Maine Medical Center, Portland, Maine.

Sources of Funding: This project was supported by grant number K01 HS018443 (Dr. Brown) from the Agency for Healthcare Research and Quality. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

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Table 1.**Patient and Procedural Characteristics**

	Cath Prior Admit	Cath Same Admit	P-value
N	301	367	
Patient characteristics			
Age (years)	67±11	68±11	0.253
Female	24.2	27.6	0.348
BMI	29±5	29±6	0.469
Patient comorbidities			
Diabetes	33.7	30.0	0.341
COPD	14.7	17.9	0.297
Coronary artery disease	74.9	83.2	0.012
Hypertension	81.0	79.2	0.584
Cardiac profile			
Prior myocardial infarction 7 days	1.0	24.5	<0.001
Number of diseased vessels			
Two vessel disease	24.5	28.2	0.327
Three vessel disease	26.0	36.5	0.008
Ejection fraction <40%	8.1	14.0	0.029
Prior CABG	2.4	2.2	0.540
Prior PCI	8.1	11.4	0.149
NYHA			
I	2.6	0.6	0.426
II	36.8	35.1	
III	50.0	49.4	
IV	10.5	14.9	
Baseline laboratory values			
Baseline serum creatinine (mg/dL)	1.0±0.3	1.0±0.4	0.129
White blood cell count >12,000	2.4	6.6	0.024
Procedural characteristics			
Pre-operative use of intra-aortic balloon pump (IABP)	0.5	2.8	0.035
Priority of surgery			
Elective	85.8	12.7	<0.001
Urgent	14.2	87.3	
Type of surgery			
Coronary artery bypass graft (CABG)	52.6	60.2	0.049
CABG/Valve	18.0	19.0	
Valve	29.4	20.8	

	Cath Prior Admit	Cath Same Admit	P-value
Duration of cardiopulmonary bypass (min)	111±43	120±46	0.020
Time from cath to surgery (days)	39±40	3±5	<0.001

Table 2.**In-hospital outcomes**

	Cath Prior Admit	Cath This Admit	P-value
Acute kidney injury	33.7	50.2	<0.001
Acute dialysis	1.9	1.5	0.477
Low cardiac output failure	3.8	6.6	0.150
Transient ischemic attack (TIA)	1.0	0.4	0.376
Cerebral vascular accident (CVA)	1.9	2.8	0.333
Pneumonia	1.4	2.8	0.202
Q-wave myocardial infarction	0.0	0.2	0.684
Mortality	1.9	3.7	0.154
Length of post-operative stay (days)	8±8	9±7	0.393

Table 3.**Acute Kidney Injury**

	N	OR	95%CI	P-value
Cath during prior admission				
Crude	668	1.66	(1.22, 2.26)	0.001
Adjusted	668	1.54	(1.11, 2.13)	0.010
Propensity matched pairs	550	1.58	(1.13, 2.22)	0.008
Subgroup Analysis for Cath during prior admission				
Elective surgery	239	1.97	(1.08, 3.62)	0.028
Urgent surgery	429	1.16	(0.76, 1.78)	0.483
Isolated CABG	386	1.74	(1.15, 2.64)	0.009
CABG/Valve	125	1.38	(0.68, 2.80)	0.374
Valve	157	1.73	(0.91, 3.28)	0.095
No previous MI	463	1.81	(1.24, 2.63)	0.002
Prior MI	205	1.14	(0.65, 2.08)	0.620
No unstable angina	380	1.78	(1.18, 2.72)	0.007
Unstable angina	288	1.39	(0.87, 2.24)	0.173
No congestive heart failure	508	1.61	(1.13, 2.30)	0.009
Congestive heart failure	160	1.58	(0.82, 3.01)	0.170
Left main disease <50%	499	1.47	(1.03, 2.10)	0.035
Left main disease ≥50%	169	2.27	(1.20, 4.31)	0.012

Table 4.

Development of Acute Kidney Injury: Pre-operative Events

<ul style="list-style-type: none">• Intrinsic factors: poor renal reserve, renovascular disease• Prerenal azotemia: recent diuresis, NPO status, impaired LV function)• ACE Inhibitors and ARB's• Nephrotoxins: IV contrast, meds (e.g.NSAIDS)• Endotoxemia• Inflammation
Development of Acute Kidney Injury: Intra-operative Events
<ul style="list-style-type: none">• Decreased renal perfusion (hypotension, lack of pulsatile flow, vasoactive agents, anesthetic effects)• Embolic events• CPB-induced inflammation• Nephrotoxins (e.g. free hemoglobin)
Development of Acute Kidney Injury: Post-operative Events
<ul style="list-style-type: none">• Systemic inflammation• Reduced left ventricular function• Vasoactive agents• Hemodynamic instability• Nephrotoxins• Volume depletion• Sepsis