Hemodynamic Optimization in High-Risk Mitral Valve Repairs as a Key Component in Surgical Readiness

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ABSTRACT

Ensuring optimal readiness for surgery using a preoperative checklist has been shown to reduce perioperative morbidity and mortality in both elective and urgent surgeries. We recently introduced hemodynamic optimization as part of our preoperative preparedness strategy for cardiothoracic surgery. Here we describe the case of a patient with severe mitral regurgitation and suboptimal hemodynamics that was optimized preoperatively with nesiritide to reduce pulmonary hypertension. Postoperatively, the patient had an improvement of his heart failure from New York Heart Association functional class 3 to class 1. Without hemodynamic optimization the patient may have been considered too high-risk to undergo mitral valve repair. This case report illustrates the importance of a systemic approach with high-risk surgery, and the use of strategies that optimize key patient factors, including hemodynamics, prior to all elective and urgent procedures.

INTRODUCTION

Recognizing the value of surgery as an integral part of global health care and the need for standardized surgical practices to avoid unnecessary surgical complications, the World Health Organization[1] adopted a 19-item surgical safety checklist in 2009. The Safe Surgery Saves Lives Study Group[2] published data suggesting that implementation of this surgical safety checklist reduced the rates of deaths and complications in patients undergoing noncardiac surgery. Building on the idea of a general surgical readiness checklist, the Northern New England Cardiovascular Disease Study Group[3] bundled several evidence-based, preoperative strategies shown to improve outcomes for patients following coronary artery bypass surgery (CABG) and demonstrated that implementation of these strategies reduced time to extubation and length of stay after surgery.[4] Prior to cardiothoracic surgery, we use a “Readiness for Cardiac Surgery Checklist” based on the checklist developed by the Northern New England Cardiovascular Disease Study Group’s checklist for CABG[3] to optimize a patient’s surgical experience during any cardiac surgery (Table 1). Unique to our readiness checklist is the preoperative hemodynamic optimization bundle with a particular emphasis on pulmonary hypertension.

Patients with pulmonary hypertension undergoing mitral valve surgery are at increased risk for perioperative mortality.[5-7] As a result, strategies for effectively reducing pulmonary hypertension in the perioperative period have been developed. The majority of studies have focused on postoperative management with pulmonary vasodilators, but several preoperative interventions also have been explored, including inhaled nitric oxide and prostacyclin, phosphodiesterase inhibitors, and recombinant brain natriuretic peptide (BNP).[8] The addition of hemodynamic optimization to the cardiac surgery readiness checklist makes surgery safer for another group of patients that might otherwise be considered ineligible. Here we present a case of mitral valve repair (MVR) in a patient with pulmonary hypertension that clearly illustrates the value of preoperative hemodynamic optimization.

CASE PRESENTATION

A 72-year-old man who was followed in the heart failure clinic with stable heart failure symptoms developed progressive shortness of breath and dyspnea on exertion. These changes were associated with a marked reduction in exercise capacity over the previous 7 weeks. The patient also complained of fatigue, orthopnea, paroxysmal nocturnal dyspnea, new onset of bilateral lower extremity edema, ascites, and weight gain. His medical history was remarkable for an inferior wall myocardial infarction in 1987 with subsequent quadruple CABG surgery in 1993. At the time of surgery, bilateral internal thoracic arteries were used and configured as a composite Y-graft. The left internal mammary artery was left in situ and anastomosed as a sequential graft to the diago-

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Table 1. Readiness for Cardiac Surgery Checklist

Expectations	Yes	Fill in the interventions to be addressed	Initials
Patient taking ASA		Contraindicated:	
Creatinine at baseline: _______		Cr: _______ eGFR: _______	
Fasting glucose <125 mg/dl		Orders to address	
In diabetic patients, HgB A1c: _______			
Off clopidogrel 5 days		5th day: _______ (date)	
Greater than 3 days status post MI unless chest pain persists		MI: _______ (date)	
Hematocrit (HCT) greater than 30		Assess transfusion consent and GI consult for active bleeding or note contraindication: <30, epigen 500 units/kg, 200 mg IV iron- day before	
TRUST score: _______			
HR less than 80		Beta block orders to address	
LV function status assessed		EF% ___ by Echo. LV Gram or nuclear test (circle one)	
Eptifibatide off for 6 hours prior to surgery		Ordered off at: ________	
Carotid Doppler for history of PAD, bruit, or aortic stenosis if not done in last 6 months		❑ N/A ordered for: _______ last done: _______	
Vein mapping with marking if history of vein stripping, severe PAD, conduit assessment		❑ N/A	
Pre-op statins		Reason contraindicated:	
Lipitor 40-80 mg every day			
Bilateral arm blood pressure		Right: _________ Left: _________	
Pulmonary assessment		❑ N/A PFT ordered, smoking cessation. FEV-1 _____	
Chest pain free and/or no ECG changes		Notify both: Cardiologist Cardiac Surgeon	
Patient CHF managed BNP less than 500		❑ N/A	
Assess risk score on page 2[a]			
Standard prep			
Preoperative hemodynamic optimization			

[a]Refers to the Society for Thoracic Surgeons (STS) risk score available at http://riskcalc.sts.org/STSWebRIskCalc273/. Accessed March 11, 2013.
Abbreviations = ASA, aspirin (aceylated salicylate); Cr, creatinine; eGFR, estimated glomerular filtration rate; HgB A1c, hemoglobin A1c; MI, myocardial infarction; GI, gastroenterology; TRUST, transfusion risk understanding scoring tool; IV, intravenous; LV, left ventricular; EF, ejection fraction; Echo, echocardiogram; PAD, peripheral arterial disease; N/A, not applicable; PFT, pulmonary function test; FEV-1, force expiratory volume in 1 second; EKG, electrocardiogram; CHF, congestive heart failure; BNP, brain natriuretic peptide.

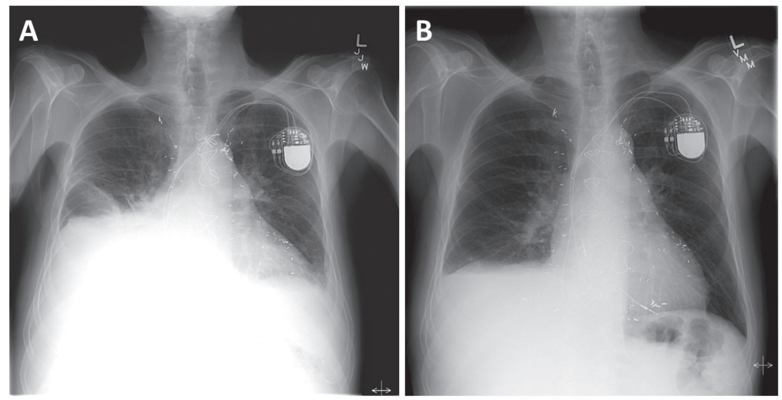
nal branch of the left anterior descending artery and to the left anterior descending artery proper. The right internal mammary artery was constructed as a Y-graft from the left internal mammary as a sequence graft to the obtuse marginal and the right posterior descending artery.

In 2010, the patient presented with a syncope episode and a non-ST elevation myocardial infarction. He underwent a left heart catheterization and was found to have a total occlusion of the right coronary artery, yet both left and right internal mammary arteries were patent. A dual-chamber pacemaker was placed for an intermittent high-grade atrioventricular block. The patient had ischemic cardiomyopathy with an ejection fraction (EF) of 30%. He underwent right thoracocentesis on multiple occasions for transudative effusion. Additional relevant medical issues included hypertension, type 2 diabetes mellitus, stage 3 chronic kidney disease, and benign prostatic hyperplasia. The patient's social history was remarkable for a remote history of tobacco use (quit 18 years prior) and a history of alcohol abuse. Medications at presentation included amlodipine (10 mg), aspirin (325 mg), diltiazem SR (180 mg), and furosemide (80 mg 3 times daily).

On examination, the patient was afebrile with a regular pulse of 79 beats per minute (BPM), respiratory rate of 24 breaths per minute, and blood pressure of 114/65 mmHg. Oxygen saturation was 84% on 3 liters nasal cannula. No jugular venous distention was noted. Cardiac exam revealed regular rhythm and the presence of 3/6 systolic murmur best heard at the left lower sternal border. Right basal lung sounds were decreased and bilateral lower extremity pitting edema was present. Other exams were unremarkable. A chest radiograph showed bilateral pleural effusion greater on the right than the left (Figure 1). An electrocardiogram (ECG) showed sinus rhythm at 80 bpm with a first degree atrioventricular (AV) block. On echocardiogram the patient's left ventricle and left and right atrium were enlarged (Figure 2A). His EF was 30%, left atrium diameter was 5.2 cm, left atrium volume/body surface area was 54 ml/m^2, and left ventricular end-diastolic diameter (LVED) was 5.8 cm. Mitral regurgitation (MR) was present, and quantitative analysis of MR with grading assessed by the proximal isovelocity surface area (PISA) and 2D volumetric methods showed severe MR based on standard criteria.[9] By the PISA method, regurgitant volume (RV) was 91 ml, regurgitant orifice area (ROA) was 57 mm^2, and regurgitant fraction (RF) was 54%. Similarly, by the 2D volumetric method, RV was 127 ml, ROA was 74 mm^2, and RF was 79%. Transesophageal echocardiogram revealed severe MR type 1 or central regurgitation. Laboratory values were as follows: hematocrit 31.4%, sodium 137 mmol/L, potassium 3.5 mmol/L, urea 30 mg/dL, creatinine 1.8 mg/dL, and BNP 2260 pg/mL. The patient underwent cardiac catheterization, and the findings were consistent with pulmonary hypertension and patent bypass grafts. He was referred for possible surgery.

The cardiothoracic surgeon deemed the patient to be a high-risk candidate for MVR. His Society of Thoracic Surgeons (STS) risk for mortality was 9.6%,[10] and his EuroScore perioperative mortality risk was 14.86%.[11] The decision was made to mitigate his perioperative hemodynamics with a series of strategies to optimize surgical readiness (see checklist, Table 1). He was admitted to an intensive care setting, and a pulmonary artery catheter was placed in order to effectively treat his pulmonary hypertension with the goal of reducing pulmonary artery pressures from near systemic to two-thirds systemic. A nesiritide infusion was started using the infusion protocol described and justified by Salzberg et al.[8] The patient received a loading dose of nesiritide of 2 μg/kg over 30 minutes and then 0.01 - 0.02 μg/kg/min for 42 hours before surgery. Nesiritide administration was continued postoperatively at 0.01 μg/kg/min for 24 hours. His pulmonary artery pressures successfully dropped from a systolic pressure of 70 mmHg to 45 mmHg, meeting the aforementioned goal. Other hemodynamic parameters measured by pulmonary artery catheter and values at baseline, during the nesiritide drip, and at the end of the nesiritide drip (postoperative stage) are shown in Table 2. Following the nesiritide drip, the patient's STS score decreased from 9.6% to 6.3%, and his EuroScore decreased from 14.86% to 10.16%, indicating a reduction in mortality risk. During the preoperative period of nesiritide infusion, the patient had a total fluid intake of 2371 ml and output of 3245 ml. Once optimized, the patient underwent surgery.

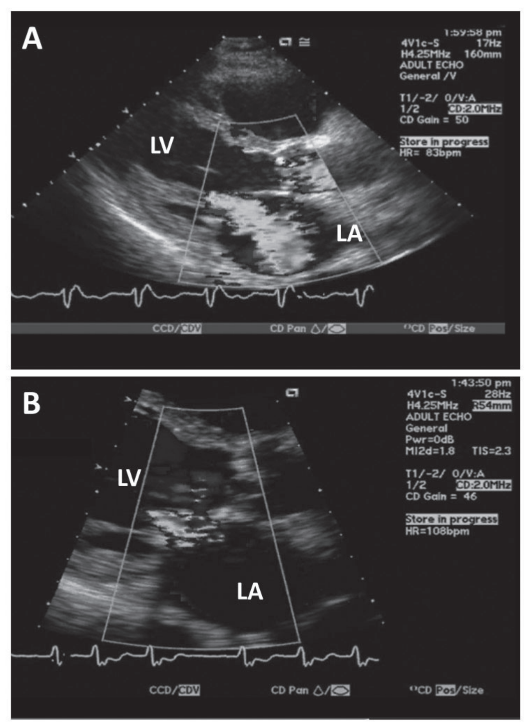
Figure 1. Pre- and Post-surgical Chest Radiograph.



A. Pre-surgical chest radiograph showing bilateral pleural effusion, greater on the right than on the left; B. Postoperative chest radiograph taken at four weeks follow-up showing decreased pleural effusion.

A re-do sternotomy was performed without difficulty, and an intraoperative echocardiogram confirmed severe MR with a central jet and EF of 30%. The patient's mitral leaflets were normal on direct inspection of the valve, and the mitral annulus was symmetrically dilated. MVR was performed using a 28 mm Life Science GeoForm ring. A postoperative transesophageal echocardiogram showed no MR and no gradient across the valve (Figure 2B). The postoperative course was uneventful. The patient's home dose of furosemide 80 mg 3 times per day was continued at discharge with the addition of spironolactone 25 mg once per day. On postoperative day 8, the patient was discharged home without oxygen. By the fourth week, the patient had lost more than 30 pounds and was able to perform his usual daily living activities without shortness of breath.

Figure 2. Transthoracic Echocardiogram, Parasternal Long Axis View Echocardiograms Showing Left Ventricle and Left Atrium.



A. Preoperative echocardiogram shows mitral regurgitation; B Postoperative echocardiogram shows no evidence of mitral regurgitation and no gradient across the valve.

DISCUSSION

Mitral valve regurgitation is classified into 3 functional types according to leaflet mobility. Type I MR has normal leaflet motion, type II is characterized by excessive leaflet motion, and type III by restricted leaflet motion.[12] The patient described here had severe type 1 MR caused by a dilated ventricle resulting in symmetrically dilated mitral valve annulus. The papillary muscles were displaced inferior and laterally resulting in central

Table 2. Hemodynamic Changes During Treatment With Nesiritide

	Baseline	During Nesiritide Drip	Postoperative[a]
PAS (mmHg)	70	45	42
PAD (mmHg)	30	37	27
CVP (mmHg)	20	8	10
CO (L/min)	4.4	5.2	7.5
CI (L/min/m2)	2.2	2.6	3.7
SVR (dynes•s/cm5)	1144	1040	597
HR (bpm)	75	80	90

[a]Following nesiritide drip in the postoperative stage, patient was on an epinephrine, norepinephrine, and dopamine drip (0.06 µg/kig/min norepinephrine, 0.03 µg/kg/min dopamine)
Abbreviations: PAS, pulmonary artery systolic pressure; PAD, pulmonary artery diastolic pressure; CVP, central venous pressure; CO, cardiac output; CI, cardiac index; SVR, systemic vascular resistance; HR, heart rate

severe MR. A successful MVR was performed using a Geoform ring, which remodeled the mitral valve annulus and provided a medium that helped to change the shape of annulus, thereby bringing the papillary muscles medial and superior. This patient's severe pulmonary hypertension in addition to other factors put him at particularly high risk for perioperative morbidity or mortality. The addition of hemodynamic optimization to our cardiac surgery readiness checklist and preoperative mitigation of his pulmonary hypertension made MVR surgery safer for this patient, who might otherwise be considered ineligible, although he clearly benefited from the procedure.

Nesiritide is a recombinant BNP that was FDA approved in 2001 for the treatment of heart failure.[13-15] Increased cardiac filling pressure is a potent stimulus for BNP release,[16,17] which then binds to the guanylate cyclase receptor on vascular smooth muscle and endothelial cells, increasing intracellular cyclic GMP and resulting in smooth muscle cell relaxation. The potent vasodilator effect of BNP results in a decrease in right and left ventricular filling pressures with a decrease in pulmonary capillary wedge pressure and an increase in cardiac output and diuresis without a reflex tachycardia.[13,14] Nesiritide use is controversial in the outpatient setting, where post market analysis has shown it to be associated with a higher mortality rate.[18] We have used nesiritide in the preoperative inpatient setting without incident.

As demonstrated by the Northern New England Cardiovascular Disease Study Group,[3,4] preoperative optimization of patient factors is important for surgical readiness and improved perioperative outcomes in cardiac surgery patients. Our patient was hemodynamically optimized preoperatively with nesiritide infusion. Hemodynamic optimization with nesiritide has been described in high-risk mitral valve repair/replacement patients.[8] The authors have adopted the above-described strategy to improve hemodynamic factors as a part of our bundle for preoperative readiness for cardiac surgery in elective and urgent patients. The above-described patient underwent MVR without any perioperative complications. Postoperatively, the patient's symptoms and exercise tolerance improved significantly, potentially due to correction of the underlying problem.

CONCLUSION

A systemic approach to preoperative patient optimization with a checklist and bundles is important for managing the perioperative risks of surgical procedures. Modifying patient factors prior to surgery can result in improved outcomes for high-risk patients as demonstrated in the case presented here where pulmonary hypertension was managed with perioperative nesiritide infusion to safely decrease pulmonary hypertension. Hemodynamic optimization is a key component for cardiothoracic surgical readiness.

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REFERENCES

1. World Health Organization. WHO guidelines for safe surgery: Safe Surgery Saves Lives. Geneva, Switzerland: WHO; 2009. Available at: http://whqlibdoc.who.int/publications/2009/9789241598552_eng.pdf Accessed February 26, 2012.

2. Haynes AB, Weiser TG, Berry WR, et al; Safe Surgery Saves Lives Study Group. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med.* 2009;360(5):491–499.

3. Northern New England Cardiovascular Disease Study Group. Develop a system to improve a patient's readiness for revascularization. Available at: http://www.nnecdsg.org/QI%20PDF/NNE%20Readiness%20Project.pdf. Accessed February 26, 2013.

4. Chaisson KM, Sanford M, Boss, RA, et al; The Northern New England Cardiovascular Disease Study Group. Improving a patient's readiness for coronary artery bypass graft surgery. Circulation. 2011;124:A10000. [Abstract] http://circ.ahajournals.org/cgi/content/meeting_abstract/124/21_MeetingAbstracts/A10000. Accessed February 26, 2013.

5. Bolling SF, Li S, O'Brien SM, Brennan JM, Prager RL, Gammie JS. Predictors of mitral valve repair: clinical and surgeon factors. *Ann Thorac Surg.* 2010;90(6):1904–1911; discussion 1912.

6. Bishay ES, McCarthy PM, Cosgrove DM, et al. Mitral valve surgery in patients with severe left ventricular dysfunction. *Eur J Cardiotharc Surg.* 2000;17(3):213–221.

7. Roques F, Nashef SA, Michel P, et al. Risk factors and outcome in European cardiac surgery: analysis of the EuroSCORE multinational database of 19030 patients. *Eur J Cardiothorac Surg.* 1999;15(6):816–822; discussion 822–823.

8. Salzberg SP, Filsoufi F, Anyanwu A, et al. High-risk mitral valve surgery: perioperative hemodynamic optimization with nesiritide (BNP). *Ann Thorac Surg.* 2005;80(2):502–506.

9. Dujardin KS, Enriquez-Sarano M, Bailey KR, Nishimura RA, Seward JB, Tajik AJ. Grading of mitral regurgitation by quantitative Doppler echocardiography: calibration by left ventricular angiography in routine clinical practice. *Circulation.* 1997;96(10):3409–3415.

10. Edwards FH, Clark RE, Schwartz M. Coronary artery bypass grafting: the society of thoracic surgeons national database experience. *Ann Thorac Surg.* 1994;57(1):12–19.

11. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). *Eur J Cardiothorac Surg.* 1999;16(1):9-13.

12. Carpentier A, Chauvaud S, Fabiani JN, et al. Reconstructive surgery of mitral valve incompetence: ten-year appraisal. *J Thorac Cardiovasc Surg.* 1980;79(3):338–348.

13. Colucci WS, Elkayam U, Horton DP, et al. Intravenous nesiritide, a natriuretic peptide, in the treatment of decompensated congestive heart failure. Nesiritude Study Group. *N Engl J Med.* 2000;343(4):246–253.

14. Publication Committee for the VMAC Investigators (Vasodilation in the Management of Acute CHF). Intravenous nesiritide vs nitroglycerin for treatment of decompensated congestive heart failure: a randomized controlled trial. *JAMA.* 2002;287(12):1531–1540.

15. Natrecor (nesiritide) injection, powder, lyophilized, for solution [package insert]. Fremont, CA: Scios Inc.; 2009. Also available at: http://dailymed.nlm.nih.gov/dailymed/archives/fdaDrugInfo.cfm?archiveid=6077. Accessed February 26, 2013.

16. Yasue H, Yoshimura M, Sumida H, et al. Localization and mechanism of secretion of B-type natriuretic peptide in comparison with those of A-type natriuretic peptide in normal subjects and patients with heart failure. *Circulation.* 1994;90(1):195–203.

17. Burnett JC Jr, Kao PC, Hu DC, et al. Atrial natriuretic peptide elevation in congestive heart failure in the human. *Science.* 1986;231(4742):1145–1147.

18. Yancy CW, Krum H, Massie BM, et al. Safety and efficacy of outpatient nesiritide in patients with advanced heart failure: results of the Second Follow-Up Serial Infusions of Nesiritide (FUSION II) trial. *Circ Heart Fail.* 2008;1(1):9–16.

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Quiz: Hemodynamic Optimization in High-Risk Mitral Valve Repairs as a Key Component in Surgical Readiness

EDUCATIONAL OBJECTIVES

Participants in this CME should be able:

1. Understand the strategies available for the preoperative management of pulmonary hypertension
2. Know the mechanisms of action of nesiritide
3. Describe the benefits of preoperative interventions prior to cardiac surgery

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QUESTIONS

1. Preoperative assessment and management of patients prior to cardiothoracic surgery has been shown to:
   - ❑ A. Reduce time to extubation
   - ❑ B. Reduce length of hospitalization
   - ❑ C. Reduces perioperative complications
   - ❑ D. All of the above

2. All of the following interventions have been used to improve preoperative readiness in patients with pulmonary hypertension except:
   - ❑ A.inhaled nitric oxide
   - ❑ B. beta-blockers
   - ❑ C. phosphodiesterase inhibitors
   - ❑ D. recombinant brain natriuretic peptide (BNP)

3. All of the following describes the mechanism of action of nesiritide except:
   - ❑ A. Decreases right and left ventricular filling pressure
   - ❑ B. Decrease pulmonary capillary wedge pressure
   - ❑ C. Increase stroke volume
   - ❑ D. Reflex tachycardia secondary to smooth muscle relaxation and vasodilation

4. The presence of pulmonary hypertension in patients undergoing mitral valve replacement portends a higher risk for perioperative mortality
   - ❑ A. True
   - ❑ B. False

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