



Does Ice Slush Placed Inside Pericardial Well During Mitral Valve Replacement Cause Injury to Phrenic Nerve?

Sharjeel Abbas¹, Saira Gul¹, Sumbal Memon¹

Department of Cardiothoracic Surgery LUMHS, Hyderabad¹

CORRESPONDING AUTHOR:

Dr Sharjeel Abbas (MRCSEd,
FCPS) Assistant
Professor/Incharge Department
Contact No: 0300-
9379750 and 0310-
9379750
Email: sharjeel.abbas@lumhs.edu.pk

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ABSTRACT

This study was conducted to determine frequency of phrenic nerve injury during mitral valve replacement, with application of Ice Slush, and compare it with international data. This study was performed at Punjab Institute of Cardiology Pakistan from January 2010 to December 2015. A total of 931 patients with only primary rheumatic mitral valve disease were prospectively observed. A pre-designed proforma was used, that recorded phrenic nerve injury. Out of 931 patients who underwent mitral valve repair or replacement, 466 (50.1%) were males. Time spent on CPB ranged from 40 to 120 min; in 58.1% patients the time remained less than 80 minutes. Post-operative chest X-ray remained normal in 97.5% patients whereas it showed atelectasis in 2.3% and elevated left hemidiaphragm in 0.2% of the patients. The total in-hospital mortality was 3.2% during study period. No patient was found to have phrenic nerve injury, unilateral or bilateral, during the study period. Topical cooling of heart, during mitral valve replacement, with Ice slush per se is not responsible for Phrenic nerve injury.

Key Words: Cardiopulmonary Bypass, Mitral Valve, Phrenic Nerve, Ice Slush

INTRODUCTION

Phrenic nerve is the principal innervation of the diaphragm. It is formed in the neck, from cervical nerve roots C3, C4 and C5. It runs vertically downwards on the anterior surface of scalenus anterior, behind the prevertebral fascia. It leaves the medial side of the muscle near its lower end and enters the thorax between the main arterial and venous structures lateral to the vagus nerve. The nerve is related to the mediastinal pleura and passes in front of the hilum as it descends across the pericardium.

This nerve on each side supply ipsilateral sensory fibres to the fibrous pericardium, the parietal serous pericardium and the mediastinal pleura, before terminating in diaphragm.¹ During Mitral valve repair or replacement procedures, the Cardiopulmonary Bypass (CPB) with hypothermia is used.^{2,3} After cross clamping and cardioplegia, the surface of the heart is further cooled down to reduce the local Basal Metabolic Rate (BMR), especially over the left ventricle, in order to reduce myocardial damage.^{2,3} This makes left phrenic nerve at risk of paresis or paralysis; this may be short term or long term.^{1,2,3} Once phrenic nerve injury occurs it can result into abnormal diaphragmatic movements & transitory diaphragmatic paralysis. This then results into higher rates of prolonged mechanical ventilation, failure of extubation, nosocomial pneumonia, pleural effusions & thoracentesis, prolonged ICU stay, increased treatment cost and may be mortality.^{3,4} Thus, this study was conducted to sort out issue of phrenic nerve injury, whether unilateral or bilateral, with application of Ice Slush, and compare it with international data.

METHODOLOGY

This study was performed at Department of Cardiothoracic Surgery, Punjab Institute of Cardiology, Lahore, Pakistan, from 1st January 2010 to 31st December 2015. A total of 1105 patients with only primary rheumatic Mitral valve disease, both stenosis and regurgitation, were prospectively observed, without coming into knowledge of primary surgeons who were either doing repair or replacement. Both men and women aged 20-50 years, undergoing elective Mitral valve repair or replacement were included in the study. However, patients for emergency Mitral valve replacement, calcified mitral valve disease, Redo Mitral valve Surgery, & combined valve surgery, those patients with associated additional cardiac pathologies (Coronary artery disease, aortic aneurysm and congenital heart disease, detected preoperatively on echocardiogram and angiography), those patients with chronic obstructive pulmonary disease, chronic cough, diabetes mellitus, obesity (BMI (body mass index, ≥ 30) and neurological disorders, were excluded from the study. This left us with only 931 patients, suitable for study.

All cases were operated at the same Institute. Patients were preoperatively assessed as per routine. As the left phrenic nerve injury is more common, we performed central venous catheter placement through the internal jugular vein of right side, for all cardiac operations. All operations were performed with sternotomy under cardiopulmonary bypass with double venous cannulation, and after cooling to 28-32°C, with cardiac diastolic arrest by antegrade blood cardioplegia with potassium. Ice slush was applied all the time during repair or replacement of the mitral valve, either directly into the pericardial well or Ice slush wrapped inside gauze and then applied directly over the left anterolateral surface of heart. Once the mitral procedure was over, the Left atriotomy was closed with deairing. Cross clamp was made off from the ascending aorta, CPB was disconnected along with its connections. Patient was normothermized (37°C). Hemostasis maintained and drains along with pericardial pacing wires placed. After the procedure Stainless-steel no.5 wire were used in all cases for sternum closure. Following sternal closure pre-sternal fascia, subcutaneous tissue and the skin closure was performed as per standard.

A pre-designed proforma was used, that recorded demographic data of patients, type of valvular pathology, type of procedure performed, the size of the valve used, whether pleura was opened, cardiopulmonary bypass time, cross clamp time, degree of hypothermia, total time of hypothermia, total operation time, time on mechanical ventilation, delayed extubation, re-intubation, total ICU stay, pleural effusion, nosocomial pneumonia, reciprocal or paradoxical diaphragmatic / abdominal movement, total hospital stay, Chest x-ray findings (elevation of diaphragm, pleural effusion, no movement of diaphragm in expiration and inspiration) and ultrasonological detection of diaphragmatic movements, before operation during hospital stay and after 6 weeks of operation, need for chest intubation, Echocardiographic Findings (LVESD, LVEDD, EF, LA diameter), whether pericardial patch was taken, whether pericardium was closed before sternal closure, time to diagnosis of phrenic nerve injury, and mortality. Statistical Package for Social Sciences (SPSS) for Windows version 21 was used for the analysis of data. All qualitative variables, like diaphragmatic paralysis and gender, were presented in the form of frequency tables, percentages, graphs and pie charts. All quantitative variables were presented in the form of mean \pm standard deviation and bar charts. Frequency of sternal wound dehiscence was compared in both groups by using Pearson chi-square test, Fischer Exact Test. A p-value of ≤ 0.05 was taken as significant.

RESULTS

Out of 931 patients who underwent Mitral valve repair or replacement, 466 (50.1%) were males. In 243 cases the primary pathology was stenosis, whereas regurgitation was found in 388 cases and mixed valvular disease in 300 patients. The preoperative echocardiography showed that the End systolic dimensions of left ventricle were less than 45 mm in 89 % patients (829) while End diastolic dimensions were between 56-60mm in 67.7% patients (630). The ejection fraction was more than 51% in 77.8% (725). The left atrial diameter was more than 56mm in 47.6% patients (419). Mitral valve repair was performed in 10 patients, whereas the major treatment remained the valve replacement (921 patients, 98.9%). Valve size of St Jude mechanical prosthesis varied between 27-33, where valve size 29 was most used (502 patients) followed by size 27 (326 patients). The time on CPB varied from as little as 40 min to as high as 120 min. but in 58.1% patients the time remained less than 80 minutes.

As far as the Ascending aortic cross clamp time was concerned 83.1% patients had less than 40 minutes of cross clamp time. Pericardial closure was performed in 7.7% patients. Pleura remain intact in 27.1% patients. The right pleura was most common to open, either willingly or inadvertently, in 36.8% patients, left pleura opened in 17.6% patients, while both pleura were found opened in 18.5 % patients. Total ICU stay was 2 days in 85.7% patients while the total hospital stay was 6-7 days in 75.5% patients. 93% patients remained on mechanical ventilation for 1 day or less. Post-operative chest X ray remained normal in 97.5% patients, showed atelectasis in 2.3% and elevated left hemidiaphragm in 0.2% patients. The total in-hospital mortality was 3.2% (30 patients) during study period. No patient was found to have phrenic nerve, unilateral or bilateral, injury during the study period.

Table 1. Various study variables in comparison with immediate postoperative x-ray chest findings			
	Normal Chest X-Ray	Atelectasis (n=21)	Elevated left hemidiaphragm (n=2)
Age			
• Mean	33.10	37.33	45
• Minimum	20	21	45
• Maximum	50	49	45
• SD	7.719	8.575	0.000
Gender			
• Male	457	8	1
• Female	451	13	1
Valve Pathology			
• Stenosis	238	4	1
• Regurgitation	379	8	1
• Mixed disease	291	9	0
CPB Time			
• 40-60 min	251	5	-
• 61-80 min	366	10	2
• 81-100 min	194	4	-
• 100-120 min	97	2	-
Cross Clamp Time			
• 20-30 min	559	14	1
• 31-40 min	194	4	1
• 41-50 min	155	3	-
Hypothermia			
• 28°C	274	4	2
• 30 °C	282	9	-
• 32 °C	312	7	-
• 34 °C	40	1	-
Hypothermia Time			
• 20-30 min	559	14	1
• 31-40 min	194	4	1
• 41-50 min	155	3	-
Pleura			
Intact	252	0	-
Right pleura opened	343	6	-
Left pleura opened	158	0	-
Both pleurae opened	155	15	2
Pericardial Closure	70	2	0
Total ICU Stay			
• 1 Day	519	12	1
• 2 Days	259	6	1
• 3 Days	95	3	-
• 4 Days	35	0	-
Mechanical Ventilation			
<1 Day	740	17	2
1 Day	103	4	-
2 Days	43	-	-
3 Days	21	-	-
> 3Days	1	-	-
Nosocomial Pneumonia	3	0	0
Mortality	30	0	0

DISCUSSION

Topical hypothermia over Heart into pericardial well is clinically applicable for myocardial preservation during heart operations, because during temporary individual coronary artery occlusion it protects regional myocardium detected as early return of function and decreased necrosis. This is the reason, an ice slush is used as topical cooling agent for conventional heart tissue preservation during open heart surgery.¹⁻⁴

Diaphragmatic dysfunction results from damage to phrenic nerve, a well-recognized complication observed in cardiac surgery. Myriad of mechanism for phrenic nerve injury are proposed e.g. decreased body temperature, mechanical trauma and probably decreased blood flow. Hypothermia, especially Topical cooling with ice slush decreases cell membrane integrity during ischemia.²⁻⁵ Canbaz et al found 5 cases from a total of 78 patients, who developed left phrenic nerve dysfunction, all in the hypothermic cardiopulmonary bypass groups and were of the opinion that hypothermic CPB and topical ice-slush application may be related to phrenic nerve dysfunction.⁶ Similar results were shown by four studies by Efthimiou, & Dimopoulou, & Mazzoni, & Mills GH et al. ⁷⁻¹⁰ However, Canbaz S et al also suggested that as both left and right phrenic nerves have been equally exposed to CPB and systemic hypothermia, hypothermic cardiopulmonary bypass is not itself the cause of the damage.⁶ They explained phrenic nerve injury caused by topical cardiac cooling.

Sarnowski W et al gave their impression that ice/saline slush used addition to cold cardioplegia for heart arrest during cardiac surgery can cause hypothermic injury of phrenic nerve. Paralysis, partial or complete, of Phrenic nerve results in raised ipsilateral diaphragm and delayed recovery of the patients.² Alassar A et al in their randomized study of patients undergoing elective cardiac surgery found significant phrenic nerve injury ($P = 0.009$) and failure of extubation ($P = 0.034$) with the use of with iced slush.¹¹ Efthimiou J7 found Twenty (36%) patients developed unilateral diaphragm paralysis when topical hypothermia was used in open heart surgeries. Similarly, Cassese et al found that phrenic nerve injury and failure of extubation occurred more frequently with the use of iced slush ($P = 0.009$ and $P = 0.034$, respectively).¹² Additionally, Maccherini et al in their study titled “Warm heart surgery eliminates diaphragmatic paralysis”, found that topical hypothermia causes transitory diaphragmatic paralysis, pleural effusions, and thoracentesis.¹³ The opponents of Topical cooling with ice- slush suggested that such maneuver does not provide additional cardioprotective effects, and is an unnecessary adjunct to myocardial protection in patients undergoing cardiac surgery.^{2,14,15}

Fortunately, we have found no Phrenic nerve injury during the study period. This study does not compass the whole cardiac surgical procedures and was performed only on those patients who underwent mitral valve surgical procedure, whether repair or replacement. In this group of patients iced slush was used whether covered in gauge and then applied over the anterolateral surface of heart or applied directly. The slush that turned water was immediately suctioned back. Secondly, due to shorter cross clamp time, the ice slush remains for a short time in pericardial well. It is also our routine practice to lift the left and right leaves of pericardiotomy and hitch them with the skin or with the self-retaining sternal spreader.

This does not allow the spilling over of the ice or water slush into the pleural space, once found open, thus reducing direct contact of hypothermic solution with ipsilateral phrenic nerve. It is also our routine practice just to drift a little hypothermia (mostly to 32-34oC. All these factors may have contributed to No phrenic nerve injury noted in any of the cases in the study group during specified period. The main limitation of this study was the inability to conduct electrophysiological studies to detect phrenic nerve injury perioperatively.

CONCLUSION

Once ice slush stays in pericardial well, for a shorter period of time, in cases of mitral valve surgeries, this remarkably reduces the chances of Phrenic Nerve injury. Thus topical cooling of heart with Ice slush per see is not responsible for Phrenic nerve injury.

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