Semi-skeletonized Internal Mammary Grafts and Phrenic Nerve Injury: Cause-and-effect analysis*

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Summary: Phrenic nerve injury after cardiac surgery increases postoperative pulmonary complications. The purpose of this study was to analyze the causes and effects of phrenic nerve injury after cardiac surgery. Prospectively collected data on 2084 consecutive patients who underwent cardiac surgery from Jan. 1995 to Feb. 2002 were analyzed. Twenty-eight preoperative and operation related variables were subjected to logistic analysis with the end point being phrenic nerve injury. Then phrenic nerve injury and 6 perioperative morbidities were included in the analysis as variables to determine their independent predictive value for perioperative pulmonary morbidity. An identical approach was used to identify the independent risk factors for perioperative mortality. There were 53 phrenic nerve injuries (2.5%). There was no phrenic nerve injury in non-coronary surgery or coronary surgery using conduits other than the internal mammary artery. The independent risk factors for phrenic nerve injury were the use of internal mammary artery (Odds ratio (OR)=14.5) and the presence of chronic obstructive pulmonary disease (OR=2.9). Phrenic nerve injury was an independent risk factor (OR=8.1) for perioperative pulmonary morbidities but not for perioperative mortality. Use of semi-skeletonized internal mammary artery harvesting technique and drawing attention to possible vascular or mechanical causes of phrenic nerve injury may reduce its occurrence. Unilateral phrenic nerve injury, although rarely life-threatening, is an independent risk factor for postoperative respiratory complications. When harvesting internal mammary arteries, it should be kept in mind avoiding stretching, compromising, or inadvertently dissecting phrenic nerve is as important as avoiding damage of internal mammary artery itself.

Key words: phrenic nerve injury; semi-skeletonized internal mammary artery; independent risk factor; pulmonary morbidity; mortality

DOI 10.1007/s11596-006-0420-z

The topic of phrenic nerve injury (PNI) after cardiac surgery has been discussed over many years with relatively inconclusive results. Many factors have been implicated as contributing to an increased incidence of PNI, including the use of left internal mammary artery (LIMA)[1, 2], devascularization of the periphreric nerve blood vessels[3], surgical manipulation[2, 4], cold injury[2, 5], the low preoperative myocardial performance[6], chronic obstructive pulmonary disease (COPD)[8], diabetes[9, 10], increased age[11], and patient variability.

PNI was a relatively minor problem in the past. In this era of managed care, and the prevalent use of right internal mammary artery (RIMA) with the clinical evidence demonstrating the benefits from bilateral internal mammary artery grafting (BIMA)[12, 13] will take on more importance because of the need to demonstrate improved clinical outcomes. Whereas left PNI usually results in minimal morbidity, right PNI is more likely to be symptomatic with respiratory dysfunction.

The most important issue in the clinical importance of PNI is the patient’s underlying pulmonary reserve and the pulmonary morbidity. This study reviews our 8 years’ experience of cardiac surgery and attempts to identify the causes and effects of PNI. The results are used as guidelines to modify surgical procedure or clinical management to improve clinical outcomes.

1 PATIENTS AND METHODS

1.1 Patients and Operation

Prospectively collected data on 2084 consecutive patients who underwent cardiac surgery under from Jan. 1, 1995 to Feb. 28, 2002 were analyzed. Procedures were performed through a median sternotomy with cardiopulmonary bypass established with right atrial and ascending aortic cannulation. Intermittent cold cardioplegia was used in the initial 952 patients (before Dec. 1, 1997) and tepid blood cardioplegia thereafter. Topical iced slush or cold saline was not used as an adjunct to cardioplegia in this series. In no case were adjuncts used to...
protect the phrenic nerve. Distal anastomoses of free RIMA were performed first, then its proximal was anastomosed end-to-side to the in situ LIMA, then the later was anastomosed (side-to-side to the diagonal arteries then) end-to-side to the left anterior descending artery whenever possible.

1.2 Harvesting of Semi-skeletonized Internal Mammary Artery

Following sternotomy, the parietal pleura were brushed off the endothoracic fascia over the internal mammary artery (IMA). A single diathermy incision in the fascia was made immediately medial to the vascular bundle and the fascia reflected to expose the IMA and venae concomitants. Using the veins for retraction, the vascular bundle was detached from the chest wall with diathermy in the intercostal spaces. The intercostal fat pads were harvested with the IMAs as this is the natural plane of dissection which reduces the requirement for dissection and diathermy\(^{[14]}\).

1.3 Definition of Phrenic Nerve Injury

PNI was considered present in patients in whom all the following radiographic criteria were met, on an inspiratory radiograph, for paralysed diaphragm: (1) the right hemidiaphragm was located over the left hemidiaphragm as seen at the normal posteroanterior chest radiography preoperatively; (2) the hemidiaphragm was at least two intercostal spaces higher than preoperative level, and is confirmed by fluoroscopy as the presence of diaphragmatic paradox or the absence, or both, or marked reduction in diaphragmatic spontaneous movement (less than one intercostal space, about 2 cm); (3) the hemidiaphragm either returned to its normal location on a late follow-up or was confirmed by ultrasound to be paralyzed at that time or was confirmed at plication.

1.4 Management of Phrenic Nerve Injury

All patients who were defined as having a paralyzed diaphragm had their diaphragms examined by repeated radiographies and at the last follow-up visit to determine diaphragmatic function. Respiratory function tests were performed on all patients before the operation and on all survivors at the last follow-up visit.

PNI was treated medically or surgically depending on the severity of impairment of respiratory function. Right hemidiaphragm plication was performed during the operation if right phrenic nerve transaction was recognized at operation. Otherwise the patients were treated first by medicine, then at some stages right hemidiaphragm plication were offered then performed if accepted by the patients. The decision to offer surgical intervention was made by the consensus between the referring respiratory physician and the cardiothoracic surgeon. The essential considerations were that the patient had effort dyspnea that interfered with his or her activities and orthopnea as well as respiratory function test results typical of diaphragmatic paralysis of the diaphragm, that is, the postoperative FEV\(_1\) or FVC had deteriorated 20 % from the preoperative value or from sitting to supine position postoperatively.

Recovery was documented by serial roentgengraphy, fluoroscopic evaluation of diaphragmatic motion, pulmonary function testing, and clinical resolution of profound orthopnea.

1.5 Data Collection and Statistical Analysis

All patients were studied prospectively. Perioperative data were collected and entered into the cardiothoracic clinical research database and the serial follow-up data thereafter. For each patient, preoperative data, including respiratory function test and radiographic results, were recorded. Operation related and postoperative data, including morbidity, mortality and length of ICU and hospital stay, were recorded.

Analyses were performed using the SPSS 10.0 statistical software package. A significance level of 5 % was used throughout. Three dichotomous outcome variables, namely, PNI, perioperative pulmonary morbidity and mortality, were considered separately. Logistic regression analysis was used to quantify the degree of association between each outcome variable and its possible risk factors.

The possible risk factors considered in the logistic regression analysis of PNI were age, sex, hypertension, hyperlipidemia, diabetes mellitus, chronic obstructive pulmonary disease, stroke, peripheral vascular disease, systemic steroids, chronic renal failure, New York Heart Association function class, Left ventricular ejection fraction (% , 70-50, 50-30, 30-20, 20-10, < 10), ECG (left ventricular hypertrophy), procedure (coronary surgery, non coronary surgery), type of operation (isolated, combined), urgency of operation (elective, semi-elective, urgent, emergency), redo surgery, conduit selection (nec conduit, LIMA, RIMA, BIMA other than IMA), cardio-pulmonary bypass time (min), cross-clamp time (min), the body temperature (°C), cardio-pulmonary arrest, open sternotomy in ICU, sternal reopening in ICU, reexploration, intrope support, and the use of intra aortic balloon support.

Pulmonary morbidity was considered to be present if any of perioperative pneumonia, prolonged ventilation or re-intubation for respiratory failure were seen. The possible risk factors used in the analysis of pulmonary morbidity included all those above together with PNI and the perioperative morbidities of myocardial infarction, stroke, dialysis, pleural effusion, sternal wound infection and ventricular arrhythmia. The same set of possible risk factors was used in the logistic regression analysis of perioperative mortality.

2 RESULTS

The overall rate of PNI was 2.5 %. There was no significant difference between either total (2.6 % vs 2.5 %, \(P=0.9\)) or left (1.6 % vs 1.9 %, \(P=0.6\)) right (0.9 % vs 0.6 %, \(P=0.6\)) PNI rates in the cold or tepid cardioplegia groups.

Multivariate logistic regression analysis identified 4 independent predictors of PNI amongst the 28 preoperative and operation related variables (table 1). The age effect is a consequence of the fact that BIMA were harvested for coronary surgery only when patients were under 66. Aside from this artifact of patient selection, the use of IMA, the presence of COPD and non-hyperlipidemia were significant independent predictors of PNI. When left and right PNI were considered