Does Topical Heating Reduce Phrenic Nerve Injury and Lober Atelectasis During Cardiac Surgery?

Topikal Isıtma Kalp Cerrahisi Sırasındaki Frenik Sinir Hasarını ve Lober Atelektaziyi Azaltır mı?

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ABSTRACT Objective: Pulmonary complications are important causes of morbidity and fatalities among patients subject to cardiac surgery. The incidence of pulmonary complications after cardiac surgical procedures is high and includes pneumonitis,bronchospasm, or lobar collapse in 40%, prolonged mechanical ventilation in 5 to 10% and generalize respiratory dysfunction in most patients who undergo cardiopulmonary bypass. The use of cardiopulmonary bypass is the first of factors which contribute to development of pulmonary complications after cardiac surgery. Phrenic nerve palsy can occur secondary to hypothermia, induced by the use of topical cooling for myocardial protection. Diaphragm paralysis has been reported radiologically after cardiac surgery with an incidence ranging from 30% to 75% of patients. No method of prevention for this complication has been reported. The aim of this study is to evaluate the effect of topical warm solution on phrenic nerve injury and lobar atelectasis during cardiac surgery. **Material and Methods:** We routinely pour topical warm solution into the pericardium for heating the myocardium just before cross-clamp is removed. In the present study, we retrospectively reviewed the records of 233 patients undergoing cardiac surgery with cardiopulmonary bypass for evaluation of the effects of topical heating on the phrenic nerve. The topical heating was applied to first 120 patients (group 1), where as it wasn't applied to the next 113 patients (group 2). All 233 preoperative chest films were reviewed. None of the patients had elevation of the left diaphragm or atelectasis prior to surgery. **Results:** No significant differences were found for extubation time, elevation of the left diaphragma, and lober atelectasis. Only, the postoperative drainage was decreased. **Conclusion:** It was detected that the topical heating does not affect the cold injury of phrenic nerve.

Key Words: Phrenic nerve; thoracic surgery

ÖZET Amaç: Kalp cerrahisi hastalarında pulmoner komplikasyonlar oldukça önemli morbidite ve mortalite nedenidir. Kalp cerrahisi sonrası pulmoner komplikasyonların insidansı oldukça yüksektir ve %40 oranında pnömoni bronkospazm ve lober atelektazi, %5-10 uzamış ventilatör ihtiyacı ve birçok hastada jeneralize solunum disfonksiyonunu içerir. Kalp cerrahisinde kullanılan kardiyopulmoner bypass pulmoner komplikasyonların oluşumunda birinci etkendir. Miyokardial koruma amacıyla verilen topikal soğuk solüsyonun hipotermik etkisiyle frenik sinir felci ortaya çıkabilir. Kalp cerrahisi sonrası diyafram paralizisi radyolojik olarak %30 ile %75 lik bir aralıkta bildirilmiştir. Ancak bu komplikasyonun ortaya çıkmasını engellemek amacıyla herhangi bir yöntem bildirilmemiştir. Bu çalışmanın amacı kalp cerrahisi sırasında topikal ısıtmanın frenik sinir hasarı ve lober atelektazi üzerine etkilerini incelemektir. **Gereç ve Yöntemler:** Biz rutin olarak kalp cerrahi vakalarında kros klemp alınmadan hemen önce perikardium içerisine sıcak salin solüsyonu uyguluyoruz. Ocak 2006 ve Ekim 2013 arasında kalp cerrahisi uygulanan 233 hasta retrospektif olarak incelenmiştir. 120 hastalık birinci gruba (grup.1) topikal sıcak uygulanmış, 113 hastalık ikinci gruba (grup.2) ise uygulanmamıştır. 233 preoperatif akciğer filmi incelenmiş ve hiçbirinde diyafram elevasyonu veya atelektazi görülmemiştir. **Bulgular:** Gruplar arasında diyafram elevasyonu, lober atelektazi ve ekstubasyon süresi açısından anlamlı bir fark bulunamamıştır. Sadece postoperatif drenajın azaldığı görülmüştür. **Sonuç:** Topikal ısıtmanın, soğuk uygulama sonucu ortaya çıkan frenik sinir hasarı üzerine bir etkisinin olmadığı saptanmıştır.

Anahtar Kelimeler: Firenik sinir; torasik cerrahi

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Pulmonary complications are important causes of morbidity and fatalities among patients subject to cardiac surgery. The incidence of pulmonary complications after cardiac surgical procedures is high and includes pneumonitis, bronchospasm, or lobar collapse in 40%, prolonged mechanical ventilation in 5 to 10% and generalized respiratory dysfunction in most patients who undergo cardiopulmonary bypass.[1-3] The use of cardiopulmonary bypass is the first of factors which contribute to development of pulmonary complications after cardiac surgery.[4] The other factor that is the use of topical cooling to protect the myocardium, which results in phrenic nerve paralysis in 30% of patients compared with an incidence of 5% in patients in whom no topical cooling is used.[5,6] The use of cooling is also associated with an incidence of left lower lobe collapse of 80% compared with only 32% in patients in whom no cooling is used.[7] Left phrenic nerve paralysis or paresis, and resultant diaphragmatic elevation and left lower lobe atelectasis, following the use of topical cardiac hypothermia has been reported in the literature, but no method of prevention for these complications has been reported.[8]

In our department, we use topical cooled saline for myocardial protection, but we also routinely use topical warm saline to heat myocardium just before cross-clamp is removed. There are two goals of this application, heating the myocardium and neutralization the cold effects to phrenic nerve. The aim of the present study was to analyze the postoperative pulmonary effects of the use of topical heating on the myocardium in the patients undergoing cardiac surgery with cardiopulmonary bypass.

MATERIAL AND METHODS

The records of 233 patients who had undergone cardiac surgery with cardiopulmonary bypass were retrospectively reviewed between January 2006 and October 2013. Clinical characteristics of the patients such as age, smoking, obesity, sedanterism, pre-operative pulmonary function tests, cross-clamp time, type and time of surgery, duration of post-operative ventilatory support, elevation of the left diaphragma, and lober atelectasis were enrolled and compared among patients who were and were not poured topical warm solution into the pericardium for heating the myocardium. The topical heating was applied to first 120 patients (group 1), where as it wasn't applied to the next 113 patients (group 2). All 233 preoperative chest films were reviewed. None of the patients had elevation of the left diaphragm nor atelectasis prior to surgery. The patients who had severe chronic obstructive pulmonary disease were not included in this study.

SURGICAL TECHNIQUE

All operations were performed under fentanyl anaesthesia (1.5 mg/h fentanyl by infusion and 1% inhaled isoflurane) and neuromuscular blockade was achieved using 0.15 mg/kg pancuronium bromide. Intravenous heparin (300 IU/kg was administered before cannulation for cardiopulmonary bypass (CPB) and additional doses were given to maintain an activated clotting time of 480 s or faster. The aorta was cross-clamped and cold cardioplegic solution was injected into the root of the aorta while, simultaneously cold solution was poured over the heart externally. The cold solution was at near freezing temperature and frequently contained ice chips or was of a slushy consistency. In CPB, non-pulsatile flow rates of 2.4 l/min per m^2 with moderate hypothermia (28-32°C) were used. Cold crystalloid cardioplegia containing 16 mEq potassium (K+) (+4°C; plegisol, Abbott Laboratories, Abbott Park, IL, USA) was used for myocardial protection. The membrane oxygenator and standard synthetic circuits were used for CPB. In 113 patients (group 2), cross-clamp was removed without topical heating, while in the other (heating group), approximately 2000 mL of warm solution (about 42°C) was poured.

STATISTICAL ANALYSIS

Continuous variables were expressed as the mean ± standard deviation in the tables and values were compared using paired *t*-tests, Chi-Square and Mann-Whitney tests. A p values <0.05 was considered statistically significant.

RESULTS

The review of demographic and surgical data of the patients and case mix were summarized with table (Table 1). The clinical characteristics (age, obesity, smoking, pulmonary function tests) in the both groups were similar and there were no differences between the two groups with regard to case type, use of the internal mammary artery (IMA) and left or/and right pleurotomy. Aortic cross-clamp time was less in the control group compared with heating group, although this difference was not significant. Comparison of the postoperative records between the two groups showed that extubation time, elevation of the left diaphragma, and lober atelectasis were insignificant for statistically. Only, the pleural drainage was lower in the patients of the heating group (Table 2).

DISCUSSION

The left phrenic nerve passes cephalad through the thoracic cavity, lying between the lung and the mediastinal aspect of the pleura, in close association with the pericardium.[9,10] In 1957, Cross et al. used topical ice slush for myocardial protection.[11] Paralysis of the left side of the diaphragm, attributed to cold injury, was first described in 1963 by Scannel.[12] Hypothermia induced neuropathys well recognized with temperatures below 17 °C. Hypothermia is associated with steady decline in nerve conduction velocities with complete blockade occurring at 5 °C.[9] Myocardial oxygen demand decreases at lower temperatures, myocardial cooling confers cardiac protection intraoperatively. However application of the topical ice slush results in phrenic nerve paralysis and associated diaphragmatic dysfunction.[13,14] There is no definite evidence to suggest that topical ice slush provides better myocardial protection than cooled saline.[15] Moreover, left phrenic nerve damage is more frequent than right. Because, ice slush or/and topical cooled saline are applied around the left ventricle and into the left portion of the pericardial cavity. Thus, the right phrenic nerve is frequently preserved from cold injury.[14,16,17] Benjamin et al., attributed left lower lobe infiltrates to left hemidiaphragm dysfunction caused by left phrenic nerve paresis or paralysis.[18] They demonstrated a 65% frequency of left lower lobe atelectatic changes when topical myocardial cooling was used. Nevertheless, postoperative atelectasis is common typically being seen in the lung bases within 48 hours after surgery, and is generally multifactorial in nature.[13] The risk of atelectasis increases with longer cardiopulmonary bypass and operative times, entrance into the pleural cavity, lower core body temperature.[19] The occurrence of this complications is associated with significant morbidity and prolonged ventilator support.[20,21] There are several studies which local hyperthermia improved on the motor function of the nerves.[22,23]

TABLE 1: Demographic and surgical data of the patients and case mix.

Characteristics	Heating Group (n=120)	Control Group (n=113)
Sex (M/F)	79/41	75/38
Age (Years)	60.5±10.48	58.6 ±8.86
Weight (kg)	71.16±14.13	73.12±10.78
Body surface area m^2	1.73±0.19	1.78±0.15
Smoking	67 (55.7%)	82 (72.6%)
Pulmonary function test (FEV 1)(mL)	82.4±16.9	89.2±17.7
Coronary artery bypass grafting (CABG)	92 (77%)	95 (83.9)%
Mitral valve replacement (MVR)	18 (14.8%)	7 (6.5%)
Aorta valve replacement (AVR)	4 (3.3%)	2 (1.6%)
AVR+MVR	6 (4.9%)	9 (8.1%)
Use of LIMA (left internal mammary artery)	61 (63.9%)	74 (66.1%)
Pleurotomy	75 (62.3%)	85 (75.8%)
Cross clamp time (min)	76.67±26.34	63.5±23.7

There were no statistically significant differences between the groups.

TABLE 2: Post-operative records of the two groups.

Post-operative data	Heating Group (n=120)	Control Group (n=113)	p-value
Extubation time (h)	5.8±3.83	5.8±2.05	p>0.05
Oxygen pressure (PO_2)(mmHg)	139±48.3	154±42.8	p>0.05
Carbondioxide pressure (PCO_2)(mmHg)	34.7±4.8	36.7±5.1	p>0.05
O_2 Saturation (%)	96.29±2.3	96.27±2.80	p>0.05
Pleural drainage (mL)	641±227	797±362	*p<0.05
Elevation of diaphragma	16 (13.1%)	9 (8.1%)	p>0.05
Left lober atelectasis	59 (49.2%)	39 (35.5%)	p>0.05

One of the our goals of topical heating was neutralization of topical cooling for phrenic nerve. But, no significant difference was found between the two groups for elevation of the diaphragma, lober atelectasis and ventilator support. Elevation of the diaphragma and atelectasis were observed on chest radiograms for assessing phrenic nerve injury. We could have observed diaphragmatic motions on ultrasound. However, the best evaluation method is electrophysiological evaluation.[24,25]

Several technical points must be followed if topical hypothermia is to be used safely. First, a plastic foam insulating pad (DLP, Grand Rapids, MI) must be used and carefully positioned so that no ice comes into contact with the pericardium.[25,26] Bjork et al. were the first to describe the use of a cardiac insulating pad.[27] Esposito and Spencer performed this pad to protect the phrenic nerves from cold saline slush.[28] When the pad was used, the incidence of nerve injury was only 17% as compared to 73% in the control group.

The topical warm solution into pericardial cavity may provide fast heating for myocardium and hemostasis, but it does not reduce effect of topical cooling on the phrenic nerve. Nevertheless, we believe that larger serial and prospective studies electrophysiological evaluations are needed to investigate this method.

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