The Effect of Negative Pressure Applied on Chest Tubes in the Amount of Pleural Effusions in Postcoronary Artery Bypass Grafting Patients

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Abstract

Background: Application of negative pressure on chest tubes is one of the most common methods for management of chest tubes drainage after cardio-thoracic surgeries. However, the effect of this measure on long-term outcome of these patients and especially on postoperative pleural effusions is not thoroughly evaluated. For this reason, we designed a clinical randomized trial for the evaluation of the effect of negative pressure application on early and late pleural effusions after coronary artery bypass grafting (CABG) operations. **Methods**: A total of 440 patients entered in this study and divided into two groups: 220 patients, their chest tubes managed by application of −10–−20 cmH_2O negative pressure (negative pressure drainage group) and those who managed conventionally by simple under-water seal method (control group, $n = 220$). Evaluation for pleural effusion performed by signs and symptoms and chest X-rays at 3rd and 7th postoperative days and for those became symptomatic after 30th day of operation. **Results**: The occurrence of moderate and massive effusions at 3rd and 7th days after operation was the same in both groups. The most striking difference was in patients' required pleural tap or chest tube insertion, late after surgery due to pleural effusion. This was significantly more common in patients in control group ($P < 0.001$). **Conclusion**: Negative pressure application on chest tubes after CABG surgery is a safe and effective method for decreasing the occurrence of late pleural effusion.

Keywords: Chest tube, coronary artery bypass grafting, negative pressure, pleural effusion

Introduction

Accumulation of fluids in pleural space (pleural effusion) is one of the most common complications of open heart surgery, especially after coronary artery bypass grafting (CABG) surgery and in 10%–15% of cases is massive.[1] Rolla *et al*.[2] noted a 74% incidence of pleural effusion on the second postoperative day in coronary artery bypass graft surgery (CABG) patients in whom the pleural space had been entered, with 48% still present in the 6th postoperative day.

Significant effusion has also been detected by chest ultrasonography in 89% of patients on the 7th day after open heart surgery with a decline to 57% on the 30th postoperative day.[3] The occurrence of moderate and massive pleural effusions causes respiratory symptoms and needs invasive measures as chest tube insertion and/or tap and increases morbidity of these patients.[4] There are some risk factors of post-CABG pleural effusion such as early chest tube removal[5] and on-pump versus off-pump CABG.[6]

Despite, most of the cardiac surgery books advise to use low-negative pressure application to chest tubes (−10–−20 cmH_2O),[7] some surgeons prefer to manage chest tubes conventionally (as simple underwater seal). For example, Dunning *et al*. reported that the insertion of a Bellovac drain – that apply negative pressure – near to the harvested internal mammary artery during operation decreases the frequency of post-CABG pleural effusions.[8] Some surgeons consider the supplemental drain system with negative pressure

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after removal of all drains in second postoperative day and maintain them in place for 3 to 5 days; this approach reduces the risk of symptomatic pleural effusion.[9]

Although many years passes from the onset of chest tube insertion and management, the effect of negative pressure application on long-term outcome of patients and especially its effect on late pleural effusion is unknown. Hence, many surgeons manage chest tubes as institutional facilities or experience. Reducing the occurrence and severity of pleural effusion not only improves the recovery of patients after CABG operations but also reduces the costs and hospital stay time of these patients. This study was designed to evaluate the effect of negative pressure application on chest tubes on reducing moderate-to-severe pleural effusions.

Methods

Patients

We conducted an experimental study with enrolling consecutive patients who had undergone first time isolated and elective CABG. From January 2014 to March 2015, 440 consecutive patients who had undergone CABGs in a tertiary university heart hospital included in this study.

Patients with concomitant operations (such as valvular heart surgery) or those operated for second-time CABG (redo operations) and emergency operations were not enrolled. Patients were randomly assigned into two groups: those, their chest tubes managed with negative pressure drainage (NPD group, n = 220) with application of −10–−20 cmH_2O on chest tubes and patients that their chest tubes managed by conventional method (control group, n = 220) with simple under-water seal system in NPD group we used two chest battles that the negative pressure is dependent to height of fluid in the second bottle which is connected to central suction and we applied a continuous negative pressure.

Clinical data

At 3rd and 7th postoperation days, chest X-ray study performed and reviewed by on-call surgeons for estimation of the amount of fluid which were collected in hemithoraces. Echocardiography performed at the same days for the evaluation of concomitant pericardial effusion, too. In addition, during the Intensive Care Unit (ICU) stay, the amount of blood loss, drained by chest tubes was measured. When the chest tube drainage is below 100 ml/day or lower than 50 ml in 3 consecutive hours, we remove the chest tubes.

After discharge from hospital, all patients were followed and patients who developed dyspnea or any other respiratory symptoms, evaluated in clinic or emergency ward, for the development of pleural effusion and if they needed invasive intervention (tap or chest tube insertion), recorded in checklists.

Statistical analysis

The collected data were analyzed using IBM SPSS Statistics for Windows, Version 20.0 (Armonk, NY: IBM Corp.). The numerical variables are presented as mean ± standard deviation, and the categorical variables are summarized by raw numbers (%). The Kolmogorov–Smirnov test (K-S test) was used to evaluate the adaptation of continuous parameters with normal distribution curve. If there was statistically significant difference with normal distribution in K-S test for each variable, the nonparametric test, Mann–Whitney U was used for comparing the two study groups. The continuous variables were analyzed using the independent samples t-test. The categorical variables were compared using the Chi-square test (with Yates correction) or the Fisher exact test, as required. The independent predictors of the invasive intervention (pleural tap or chest tube insertion) for treatment of recurrent pleural effusion were determined using the logistic regression model. $P \leq 0.05$ was considered statistically significant.

Results

Demographic and operation data

All of 440 patients finished the study and entered to statistical analyses. The patients in both groups were the same in respect of age, sex, weight, the prevalence of hypertension, smoking, and diabetes. In addition, equal number of patients had received antiplatelet medication before operation [Table 1]. The median (interquartile range [IQR]) of chest tube drainage at 3rd postoperative day were 300 (150–500) ml in NPD and 250 (300–450) ml in control groups (P = 0.359). The median (IQR) of 7th postoperative day chest tube drainage was 450 (275–750) ml in NPD group and 500 (300–800) ml in control group and this difference was statistically significant (P = 0.156).

To keep the hemoglobin level at acceptable range (8–10 g/dl) during and after operation, blood transfusion was more in control group, than NPD group. 48.6% of the patients in "negative pressure darinage" group and 65.9% of patients in control group received "at least one unit" of packed red blood

Table 1: Demographic and clinical characteristics in the two study groups

	Negative pressure group (n=220) (%)	Control group (n=220) (%)	P
Age (years)	58.2±9.8	58.8±8.9	0.566
Sex			
Male	144 (65.5)	129 (58.6)	0.169
Female	76 (34.5)	91 (41.4)	
Weight (kg)	71.9±11.9	71.9±12.9	0.997
Hypertension	122 (55.5)	141 (64.1)	0.065
Cigarette smoking	70 (31.8)	84 (38.2)	0.162
Diabetes mellitus	85 (38.6)	81 (36.8)	0.694
History of MI	50 (22.7)	55 (25.0)	0.655
History of renal failure	8 (3.6)	15 (6.8)	0.199
Antiplatelet therapy	84 (38.2)	86 (39.1)	0.922
Preoperative LVEF	44.9±7.6	46.1±6.9	0.094
Preoperative hemoglobin (g/dl)	12.4±1.6	12.3±1.3	0.917

Values presented as mean±SD or n (%). LVEF: Left ventricular ejection fraction, MI: Myocardial infarction, SD: Standard deviation cell. The two study groups were the same regarding 3rd and 7th postoperative day chest tube drainage [Table 2].

Postoperative data

No differences were found in need to reexploration for the management of postoperative tamponade or excessive bleeding [Table 2]. The occurrence of moderate pleural effusion as estimated by chest X-ray at 3rd and 7th days after operation was not statistically different between the two groups [Table 3].

The most striking difference was in the percentage of patients, required invasive treatment (pleural tap) for drainage of pleural effusion, evidenced by moderate respiratory symptoms, and documented by chest X-ray (moderate pleural effusion). This was more common in patients in control group (14.5%) versus NPD group (2.7%; $P < 0.001$). In addition, 17 patients in control group (7.7%) underwent chest tube insertion, which was more than those in NPD group, who needed for this procedure (8 patients = 3.6%), but was not statistically different [$P = 0.099$; Table 2]. Seventy two patients (32.8%) in group control had abnormal pericardial effusion on echocardiography which was higher than NPD group (53 patients, 24.1%; $P = 0.028$).

Logistic regression analysis was used for assessing cofactors effecting on invasive treatment (pleural tap or chest tube placement) for pleural effusion during 30 days after CABG. This multivariate analysis revealed that the application of "negative pressure" on chest tube drainage and using left internal mammary artery as a bypass graft are "independent" factors of tap or chest tube placement for pleural effusion late after CABG [Table 4].

Discussion

Mid-term and long-term outcomes of CABG are very important to determining patients' quality of life[9,10]. Postoperative pleural effusion is one of the most common complications after CABG[1,4,7] and could be occurred in early postoperative period or in mid-term or even long-term follow-up period. Incidence of this complication is between 3.1% and 89%, variable in various studies.[4,8-14] This randomized trial is designed to evaluate the effect of one of the most popular methods for the management of chest tubes (negative pressure application) on reducing pleural effusions after CABG operation.

Table 2: Operative and postoperative variables of the patients in both study groups

	Negative pressure group (*n*=220) (%)	Control group (*n*=220) (%)	*P*
Graft type			
LIMA + vein	173 (78.6)	206 (93.6)	0.001
LIMA + radial + vein	36 (16.4)	4 (1.8)	
Only vein	7 (3.2)	7 (3.2)	
Radial + vein	4 (1.8)	3 (1.4)	
Bypass graft number	3.16±0.79	2.98±0.80	0.017
Aortic cross clamp time (min)	46.2±9.6	43.1±9.1	0.098
Cardiopulmonary bypass time (min)	66.4±12.8	63.7±13.1	0.179
Packed cell transfusion (at least 1 unit)	107 (48.6)	145 (65.9)	0.001
Fresh frozen plasma transfusion (at least 1 unit)	35 (15.9)	49 (22.3)	0.115
Platelet concentrate transfusion (at least 1 unit)	10 (4.5)	13 (5.9)	0.668
3rd postoperative day hemoglobin (g/dl)	9.4±1.1	10.0±1.3	0.001
7th postoperative day hemoglobin (g/dl)	9.8±1.2	10.5±1.4	0.001
3rd postoperative day drainage (ml)	300 (150-500)	250 (150-450)	0.359
7th postoperative day drainage (ml)	450 (275-750)	500 (300-800)	0.146
Postoperative LVEF (%)	40.7±6.8	42.01±6.9	0.019
Reexploration for tamponade	8 (3.6)	8 (3.6)	1.000
Reexploration for bleeding	6 (2.7)	2 (0.9)	0.285
Intubation time (h)	8 (6-9)	9 (6-10)	0.208
CT removal (day)	3 (2-3)	2 (2-3)	0.001
ICU stay (day)	3 (2-4)	3 (2-3)	0.096
Hospital stay (day)	7 (6-8)	8 (7-9)	0.001
Precordial window*	4 (1.8)	2 (0.9)	0.685
Pleural effusions tap in first postoperative month	6 (2.7)	32 (14.5)	0.001
CT insertion in first postoperative month	8 (3.6)	17 (7.7)	0.099
Invasive treatment (tap or CT insertion) (1 month)	14 (6.4)	49 (22.3)	0.001
Pericardial effusion on discharge			
Mild	45 (20.5)	68 (30.9)	0.028
Moderate	8 (3.6)	4 (1.8)	

Data presented as *n* (%), mean±SD or median (IQR), Pericardial window is an opening in pericardium after CABG in the depending part of the pericardium for preventing tamponade. LVEF: Left ventricular ejection fraction, SD: Standard deviation, IQR: Interquartile range, CT: Chest tube, LIMA: Left internal mammary artery, CABG: Coronary artery bypass grafting, ICU: Intensive Care Unit. *All *P* values <0.05 are statistically significant

Table 3: Comparison of severity of pleural effusion between the two groups in 3rd and 7th postoperative days

Date of evaluation	Group	Severity of pleural effusion				*P*
		No effusion (%)	Mild (%)	Moderate (%)	Massive (%)	
3rd day	NPD (*n*=220)	174 (79.1)	44 (20)	2 (0.9)	0	0.690
	Control (*n*=220)	181 (82.3)	37 (16.8)	2 (0.9)	0	
7th day	NPD (*n*=220)	186 (84.5)	33 (15)	1 (0.5)	0	0.096
	Control (*n*=220)	200 (90.9)	20 (9.1)	0	0	

NPD: Negative pressure drain group

Table 4: Logistic regression analysis of co-factors effecting on invasive treatment (pleural tap or chest tube placement) for pleural effusion during 30 days after coronary artery bypass grafting

	B	SE	*P*	Exp(B)	95% CI for Exp(B)	
					Lower	Upper
Negative pressure drain	1.610	0.346	0.001	5.004	2.541	9.852
Using LIMA as a graft or not	0.398	0.196	0.042	1.489	1.015	2.185
Postoperative LVEF (%)	0.006	0.022	0.781	1.006	0.963	1.051
Postoperative intubation time (h)	0.295	0.195	0.131	1.343	0.916	1.970
Constant	−5.552	1.174	0.001	0.004		

LIMA: Left internal mammary artery, LVEF: Left ventricular ejection fraction, CI: Confidence interval, SE: Standard deviation

Various methods of drainage system, including a package for accumulation of fluid and application of a low, negative pressure are available commercially.[13,15] In fact, the routine application of negative intrapleural pressure has not yet been proved as a standard method by surgeon despite numerous controlled trials and systematic reviews.[16] Recently, the electronic chest draining system – digital drainage system (DDS) – has a considerable influence on the progress of cardiothoracic surgery. The DDS apparatus is a portable device and supplied by a rechargeable battery with an adequately prolonged working time.[17]

A total of 440 patients enrolled in this study with the respect of inclusion and exclusion criteria (two patients excluded from the study due to developing mediastinitis, one due to deterioration and death and 7 patients were unavailable for follow-up and they replaced by other patients).

Of these 440 cases, 220 were assigned to manage by NPD and 220 managed conventionally by simple, underwater seal (as control group).We have used a system, consisted a source of controlled, low-negative pressure (−10–−20 cmH_2O) added to a conventionally underwater sealed chest drainage, for the application of negative pressure on chest tubes. The patients in both groups were the same in respect of age, sex, weight, and receiving antiplatelet agents and risk factors of coronary artery disease [Table 1].

One of the reasons of opponents for avoiding the negative pressure application on chest tubes after cardiac surgeries is that the negative pressure may stimulate excessive bleeding from operated areas or anastomosis and prevents hemostasis. In this study, we measured the amount of bleeding (chest tube drainage) and found, no statistically difference between two groups in 3rd (median amount of drainage 300 vs. 250 ml) and 7th (median amount of drainage 450 vs. 500 ml) postoperative days [Table 2].

We interestingly found that patients in control group, indeed, have needed more blood transfusion than NPD group to keep their hemoglobin in an acceptable range. Moreover, 65.9% in group control received at least one unit of blood, in comparison to 48.6% of patients in NPD group. We did not find any specified reason for more transfusion in control group. It may be due to some surgical bleeding that had not been evacuated, and remained in the patients' chest.

The most significant difference was in frequency of patients required tap of pleural effusion, late in the course of follow-up (usually associated with moderate pleural effusion present by respiratory symptoms and documented by chest X-ray).This was more common in patients in control group (14.5%) versus 2.7% in NPD group. Totally, more patients in control group (22.3%) required to be tapped or chest tube placement – invasive treatment – than NPD group (6.4%) in 30 days after CABG [$P = 0.001$; Table 2].

We have found that 32.7% of patients in group control had abnormal pericardial effusion, detected by echocardiography which was significantly higher than group NPD (24.1%; $P < 0.05$). This means that negative pressure application on chest tubes, may reduce the accumulation of fluid in mediastinum. More transfusion rate in control group may be related to the more bloody oozing that may explain the late pericardial effusion occurrence. Significance of these differences lead to conclude that the application of negative pressure on chest tubes reduces moderate to severe accumulation of fluid in hemithoraces, late after CABG operations.

The reason for this fact may be that, in NPD group, negative pressure, evacuates all clots and blood which is loosed in early postoperative period; but conventionally underwater seal drainage did not so, effectively.

We think: there are two theories that describe the effect of retained clot on late accumulation of fluid in pleural space. (1) It has been documented that retained clot is a powerful stimulus for fibrinolysis,[16] so, in addition to dissolving of the clot, itself (which produces some fluid), it may stimulate late oozing from dissected areas and bare surfaces in hemi-thoraces and pericardium. (2) The effect of oncotic pressure, produced by dissolved clot in accumulation of fluids in pleural spaces, remains to be studied in the future researches.

Limitations

The main limitations of this research were its small sample size and short-term follow-up period.

Conclusion

In this study, we found that the application of low-negative intrapleural pressure on chest tubes after CABG operation is a safe and effective method for the evacuation of fluids and clot from pleural space. This technique can reduce the frequency of late (30 days) moderate to massive pleural effusions and need for pleural tap or chest tube placement.

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Conflicts of interest

There are no conflicts of interest.

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