Glove Retractor for Left Circumflex Coronary Artery Bypass Grafting

(#2001-37356 … October 23, 2001)

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ABSTRACT

Background: During off-pump coronary artery bypass grafting (OPCAB), displacing the heart to expose the left circumflex artery (LCX) results in hemodynamic disturbance. The objective of this study was to evaluate, in a canine model, the hemodynamic impact on the beating heart of using a glove retractor instead of conventional retraction to expose the LCX.

Methods: Six mongrel dogs ranging in weight from 19.7 to 25 kg were used. Hemodynamic parameters were continuously monitored at a fixed rate of 80 beats/min. After the baseline data had been obtained, the LCX was exposed by applying an Octopus system. Each dog was then placed in the Trendelenburg position. Subsequently, the glove retractor was applied and its effects were examined both with and without the Trendelenburg position.

Results: LCX exposure decreased aortic flow to 35.2 ± 12.8% of the baseline value ($p < 0.001$ vs. baseline), and this decrease was not fully reversed even by the Trendelenburg position (67.6 ± 14.3%). Glove retractors tend not to interfere with right ventricular expansion so that hemodynamic disturbance is mild, and in the Trendelenburg position aortic flow (88.9 ± 9.9%) and mean aortic pressure (95.0 ± 5.1%) during LCX exposure were completely maintained with the glove retractor in place.

Conclusion: Glove retractors can be used to displace the canine heart to expose the LCX, minimizing hemodynamic impairment, with normalization of hemodynamic parameters by the Trendelenburg position. This technique may offer an alternative hemodynamic support method in some patients undergoing OPCAB.

INTRODUCTION

Cardiopulmonary bypass has long been recognized as having side effects such as complex systemic inflammatory responses [Wan 1997]. Recently, off-pump coronary artery bypass grafting (OPCAB) has become an acceptable technique for myocardial revascularization. This approach has advantages over conventional CABG for patients with poor ventricular function and/or risk factors for cardiopulmonary bypass [Pfister 1992, Jansen 1998]. Assistant devices, such as the Octopus Tissue Stabilization System (Medtronic Inc., Minneapolis, MN), have popularized this procedure and resulted in low mortality and morbidity [Borst 1996, Grundeman 1997, Jansen 1997, Jansen 1998]. However, displacement of the heart for visualization of the left circumflex artery (LCX) often leads to hemodynamic disturbance. Previously, we demonstrated that the main cause of hemodynamic disturbance by cardiac displacement involves right ventricular dysfunction [Suematsu 2000]. Therefore, we developed a glove retraction system (glove retractor) to permit flexible cardiac retraction. This system consists of a soft glove, which is widely available, and an extension tube. The shape of the glove can be altered by infusing a volume of hot water, at the surgeon's discretion (Figure 1,). The objective of this study was to evaluate, in a canine model, the hemodynamic impact on the beating heart of using a glove retractor instead of conventional retraction to expose the LCX.

MATERIALS AND METHODS

Six mongrel dogs ranging in weight from 19.7 to 25 kg were anesthetized with pentobarbital sodium (30 mg/kg). Respiration was maintained by a volume-controlled respirator, and the electrocardiograph was monitored continuously throughout the procedure. Arterial blood gases were sampled every 30 minutes, and bicarbonate was added as needed to maintain a physiologic pH between 7.35 and 7.45. Aortic blood pressure was monitored through the right femoral artery. The mean right atrial pressure was monitored through the right femoral vein, and mean left atrial pressure was monitored through the left atrial appendage. To reduce mechanical irritability of the heart, we administered intravenous propranolol to maintain the heart rate between 50 and 70 beats/min. as previously described [Suematsu 2000]. After median sternotomy, the heart was suspended in a pericardial cradle. The pericardial and right pleural spaces were not opened. A bipolar pacing lead was sutured onto the right atrial appendage, and the heart was thereafter paced at a fixed rate of 80 beats/min. An ultrasound transit time flow probe (Transonic Inc., Ithaca, NY) was placed around the aorta for on-line measurement of cardiac output. The surface temperature of the LCX was continuously

Submitted October 15, 2001; accepted October 23, 2001.

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Table 1. Hemodynamic values (% of the baseline values) in each animal (DIS = displacement of the heart, TR = Trendelenburg maneuver, GR = glove retraction, GR+TR = glove retraction plus Trendelenburg maneuver).

	Aortic Flow				Aortic Pressure			
	DIS	TR	GR	GR + TR	DIS	TR	GR	GR + TR
Dog 1	23.55	79.27	72.05	82.05	56.41	92.86	84.83	88.28
Dog 2	38.37	66.85	84.88	73.35	62.32	68.49	91.94	91.94
Dog 3	15.4	58.82	72.32	99.76	55.17	103.18	92.96	102.11
Dog 4	46.62	58.12	74.92	88.14	75.53	79.69	93.88	92.86
Dog 5	41.71	52.63	72.78	93.33	72.79	91.06	98.2	95.5
Dog 6	45.39	89.82	70.42	97.08	74.47	70.21	89.23	99.23

	Left Atrial Pressure				Right Atrial Pressure			
	DIS	TR	GR	GR + TR	DIS	TR	GR	GR + TR
Dog 1	75	88.89	88.89	100.11	144.44	185.71	93.33	166.67
Dog 2	78.18	92.73	100	100	155.56	197.14	112.5	167.5
Dog 3	72.73	97	90	102.86	163.64	200	109.09	158
Dog 4	87.5	83.33	99	92.31	120	200	100	180
Dog 5	80	98.89	100	100	150	166.67	122.22	191.11
Dog 6	83.33	77.78	100	83.33	166.67	183.33	114.29	170

monitored during the experiment. Baseline hemodynamic values were recorded after at least 15 minutes of pacing. An imaging probe (13 MHz) was connected to a commercially available scanner (SSD-5500, ALOKA Co., Tokyo, Japan).

The heart was displaced by 90 degrees with the Octopus system to expose the LCX, which was adequately visualized in the operative field without the aid of additional supportive tools (DIS (displacement) group). Five minutes later, each dog was placed in the Trendelenburg position (20 degrees head down) (TR group). A further five minutes after the Trendelenburg maneuver, the dog was returned to the horizontal position, and the surface temperature was returned to the initial value by active heating. After a 30-minute rest period, the heart was also displaced by 90 degrees, using the glove retractor and the Octopus system (GR group). Subsequently, each dog was placed in the Trendelenburg position in the same manner as above (GR+TR group). A further five minutes after the Trendelenburg maneuver, the dog was again returned to the horizontal position.

All hemodynamic values are expressed as means ± standard deviation of the mean (percentage of baseline values). The Student's t-test was used to assess the modifying effect of the Trendelenburg maneuver and/or glove retractor as compared with the control values, and statistical significance was accepted as $p < 0.05$. All animals received humane care in compliance with the "Guide for the Care and Use of Laboratory Animals" published by the National Institutes of Health (NIH publication 85-23, revised 1996).

RESULTS

All animals survived the entire procedure without the need for defibrillation or administration of inotropic drugs. The mean infused water volume needed for suitable LCX retraction was 406.7 ± 25.3 ml (range of 379-450 ml). The lowest temperature with the glove retractor in place was significantly higher than that without glove retraction (36.1ºC ± 0.5 vs. 34.9ºC ± 0.5; $p < 0.01$).

With LCX exposure using the glove retractor, there was no need to further displace the heart using the Octopus system, and therefore only the suction function of the Octopus system was required (Figure 2). Consequently, the right ventricular outflow tract was not compressed mechanically (Figure 3a). In the DIS group, on the other hand, the Octopus system functioned as both retractor and suction stabilizer, which resulted in significant compression of the right ventricular outflow tract (Figure 3b and Table 1). The results of hemodynamic measurements are shown in Figures 4-7. Exposure of the LCX in the DIS group resulted in a significant aortic flow decrease to 35.2 ± 12.8% ($p < 0.001$) of the baseline and a mean aortic pressure decrease to 66.1 ± 9.3% ($p < 0.001$) of the baseline. Mean left atrial pressure also decreased to 79.5 ± 5.4% of the baseline, a statistically significant drop. In the TR group, aortic flow and mean aortic pressure significantly recovered to 67.6 ± 14.3% and 84.2 ± 13.7% of the baseline, respectively. With the glove retractor, although aortic flow significantly decreased to 74.6 ± 5.3% of the baseline, there was no significant difference from the baseline in mean aortic pressure. Furthermore, use of the Trendelenburg maneuver with the glove retractor in place improved aortic flow (88.9 ± 9.9%) and mean aortic pressure (95.0 ± 5.1%), with neither value differing significantly from the baseline. Mean left atrial pressure increased significantly to 96.3 ± 5.3% ($p < 0.01$) and 96.4 ± 7.3% ($p < 0.01$) in the GR and GR+TR groups, respectively, as compared with the DIS group.

After repositioning the heart and releasing it from the Octopus system, hemodynamic status improved in a few minutes and all values returned to baseline in all dogs.

DISCUSSION

Recently, coronary artery bypass grafting without cardiopulmonary bypass (off-pump CABG) has become an alternative technique for myocardial revascularization in high risk patients [Pfister 1992]. This approach to the technique has many advantages, such as conserving blood products, avoiding global myocardial ischemia, and preserving interventricular septal function. Furthermore, it may avoid neuropsychological deficits caused by microemboli from cardiopulmonary bypass (CPB) and atheromatous emboli from manipulation of the aorta [Jansen 1998].

A logical next step would be for surgeons to apply OPCAB to multivessel disease and ultimately to achieve complete revascularization. However, displacement of the heart, particularly when the LCX is approached, leads to a significant arterial pressure drop. It may also induce more serious hemodynamic disturbances. We have previously shown that LCX exposure results in severe hemodynamic deterioration even when the Octopus system is used, and this deterioration is not fully reversed by the Trendelenburg maneuver [Suematsu 2000].

The main cause of hemodynamic deterioration after displacement of the heart is thought to be impairment of right heart function, which results in reduced venous return and, consequently, a decrease in left ventricular output. Grundeman and colleagues suggested that displacement primarily causes right ventricular dysfunction as a result of mechanical interference with diastolic expansion without concurrent valvular incompetence [Grundeman 1999]. Benetti and colleagues, based on clinical experience, advocated a technique in which deeply placed, large pericardial stay sutures are used to help rotate the apex [Benetti 1991]. Their technique preserved hemodynamic stability for revascularization in the LCX area, and 80% of their patients were successfully revascularized. However, the extent of rotation achieved with pericardial stay sutures is limited, and stay sutures may be inappropriate for patients with left ventricular impairment and cardiomegaly.

In the present study, glove retraction resulted in significantly better hemodynamic values than retraction with the Octopus system. Furthermore, complete hemodynamic stability was obtained by additional application of the Trendelenburg maneuver. The Octopus system, which displaces the heart by 90 degrees, tends to interfere mechanically with the right ventricular outflow tract. In contrast, LCX exposure using the glove retractor allows heart displacement without severe hemodynamic impairment because of the inherent flexibility of the retractor [Shennib 1999]. The hand shape of the glove retractor may also contribute to hemodynamic stability. Finger portions, which are located just below the lower pulmonary veins, elevate the heart slightly, and the palm portion, located at the apex of the left ventricle, displaces the heart more widely. As a result, the heart is effectively displaced without geometric disturbance.

Another important finding from this animal experiment is that cardiac temperature was favorably preserved by filling the glove retractor with warm water. Conventional full sternotomy tends to decrease cardiac temperature by exposing the heart to room temperature. Diseased hearts may be highly sensitive to temperature, which may result in ventricular fibrillation. The ability to use the glove retractor for maintaining cardiac temperature may therefore be an important advantage in addition to its hemodynamic support function.

Study Limitations

In our study we used normal, healthy dogs. Not only does the geometry of the human chest wall differ from that of dogs, but experimental results derived from healthy animal specimens must be applied with caution to patients with diseased or damaged cardiovascular systems. The effects of cardiac displacement in patients with ischemic heart disease who have cardiomegaly and left ventricular dysfunction remain unclear. Furthermore, we did not temporarily interrupt coronary blood flow in our study. In clinical situations, hemodynamic deterioration can be caused by coronary blood flow interruption during the anastomoses.

CONCLUSION

In a canine model, a glove retractor displaced the heart to expose the LCX through a median sternotomy with minimal hemodynamic impairment. Furthermore, the minimal impairment was eliminated by the Trendelenburg maneuver. This simple, low-cost technique may offer an alternative hemodynamic support method for some patients undergoing OPCAB.

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