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Hemodynamic disorders related to beating heart surgery using cardiac stabilizers: experimental study

Alterações hemodinâmicas devido ao uso de estabilizadores em revascularização do miocárdio: estudo experimental

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Abstract

Objective: **To study in swine the hemodynamic changes secondary to the use of stabilizers for off-pump coronary artery bypass graft surgeries by means of both a suction device "Octopus" and a compression device (Speroni).**

Methods: **Ten swine underwent median sternotomy. Monitoring of ECG, continuous cardiac output, mean arterial pressure, mean pulmonary artery pressure, mean right and left atrial pressures, and right and left ventricular diastolic pressure were performed. Stroke volume and systemic vascular resistance were calculated. Both stabilizers were studied placed on three vessels: anterior interventricular branch, posterior interventricular branch, and the left marginal artery of the circumflex branch. Each animal was randomly designed to application regarding the type of stabilizer and the target artery. The measurements were carried out 5 minutes before and after the stabilizer application.**

Results: **In the anterior interventricular branch changes have occurred only with the compression device, thus reducing cardiac output, stroke volume, and mean arterial pressure, but increasing the systemic vascular resistance. In the posterior interventricular branch changes have occurred with the compression device (Speroni), reducing cardiac output and stroke volume, but increasing the heart rate. With the suction device (octopus) there was an increase of both heart rate and systemic vascular resistance, but a decrease in stroke volume. In the left marginal artery of the circumflex branch there was a decrease of cardiac output, stroke volume, and mean arterial pressure with both stabilizers. Also, there was a decrease in the mean pulmonary artery pressure and an increase in the mean right atrial pressure with the compression device (Speroni).**

Conclusion: **Both stabilizers have caused hemodynamic changes. The compression device (Speroni) is more associated with changes than the suction device (Octous).**

Descriptors: **Myocardial revascularization, methods. Heart, physiopathology. Hemodynamics. Intraoperative period. Animal models.**

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Resumo

Objetivo: **Estudar, em suínos, as alterações hemodinâmicas secundárias ao uso de estabilizadores para operações de revascularização do miocárdio sem circulação extracorpórea, um por sucção (Octopus) e outro por compressão (Speroni).**

Métodos: **Dez suínos submetidos à esternotomia e monitorizados com eletrocardiograma, débito cardíaco contínuo e pressões: arterial média, pulmonar média, atriais médias direita e esquerda, ventriculares diastólicas direita e esquerda, calculando-se volume sistólico e resistência vascular sistêmica. Estudaram-se os estabilizadores posicionados em três artérias: interventricular anterior, interventricular posterior e ramo marginal da circunflexa. Para cada animal foi sorteada a ordem de aplicação do estabilizador com relação ao tipo e à artéria. As mensurações foram realizadas antes e após aplicar-se o estabilizador.**

Resultados: **Na artéria interventricular anterior, ocorreram alterações somente com o Speroni, havendo queda do débito cardíaco, do volume sistólico e da pressão arterial média, com aumento da resistência vascular sistêmica. Na artéria interventricular posterior, constatamos alterações com o Speroni, havendo queda do débito cardíaco e do volume sistólico, com aumento da freqüência cardíaca. Com o Octopus houve aumento da freqüência cardíaca e da resistência vascular sistêmica, com queda do volume sistólico. No ramo marginal da circunflexa, ocorreu queda do débito cardíaco, do volume sistólico e da pressão arterial média com os dois estabilizadores, havendo também queda na pressão arterial pulmonar média e aumento da pressão atrial direita média com o estabilizador por compressão.**

Conclusões: **Ambos os estabilizadores causaram alterações hemodinâmicas. O que atua por compressão provocou mais alterações do que o que atua por sucção.**

Descritores: **Revascularização miocárdica, métodos. Coração, fisiopatologia. Hemodinâmica. Período intra-operatório. Modelos animais.**

INTRODUCTION

In the beginning of coronary artery surgery, myocardial revascularization was performed without cardiopulmonary bypass (CPB) support. Kolessov was considered to be the precursor of this technique [1]. With the advent of CPB and the coronary artery bypass surgery, by grafting a section of saphenous vein, for myocardial revascularization, introduced by Favolaro, there had been a breakthrough in the disease treatment with patients' survival improvement and quality of life [2,3].

In the 1980s, Buffolo and Bennti groups systematized the off-pump cardiopulmonary bypass grafting using it on a daily basis for the purpose of avoiding the postoperative complications resulting from CPC, such as bleeding and late or early neurologic alterations [4-6]. However, due to the technical difficulty to perform anastomosis on a beating heart and the difficult access to the arteries of the posterior surface of heart, which caused severe hemodynamic disorders, the majority of the surgeons did not perform such a procedure.

In the 1990, devices to facilitate the approach of the coronary arteries on a beating heart were developed, such as intracoronary "shunts", which in addition to reducing myocardial ischemia during the procedure, act as a "model" for the anastomosis [7,8]. Lima et al. [9] introduced the use of a stripe attached to the posterior pericardium allowing anterior, right lateral, and cranial dislocation of the apex of heart, exposing lateral, posterior, and inferior surfaces, giving access to the left marginal artery of the circumflex branch of the left coronary artery and to the posterior interventricular branch of the right coronary artery [10, 11].

Other authors have described several devices of varying materials and functions, many of them barely reproducible, and for that very reason, they were not widely spread among the surgeons. However, mechanical stabilizers for off-pump coronary artery bypass graftsurgery have changed this situation. A suction device, referred as to "Octopus", which interposes the ventricular wall segment to be approached between two rows of suction cups stabilizing the segment and facilitating anastomosis performance [12,13]. Stabilizers compressing the area to be stabilized were also developed and several commercial models manufactured.

This present study aims at to study the hemodynamic changes resulting from using both types of stabilizers for off-pump coronary artery bypass graft surgery in porcine hearts considered to be normal.

METHODS

Ten Large-White female pigs, mean weight 40.7± 1.3 kg, 15 week-old, considered to be young adults, supplied by a specialized breeder (Granja Holambra) were used after the approval of UNICAMP Biology Institute Animal Experimentation Ethics Committee (Comissão de Ética em Experimentação Animal do Instituto de Biologia da UNICAMP).

Anesthetic technique

After a 6-hour fast, atropine, 1 mg and ketamine, 25 mg/kg were administered intramuscularly as preanesthetic. A

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venous access was punctured and an infusion of fentanyl hydrochloride, 12,5 µg/kg and pentobarbital, 15 mg/kg were administered. Proceeding to orotracheal intubation, curarization using pancuronium chloride (8 mg) and the animal was ventilated with a respirator; tidal volume of 10 mL/kg and fraction of inspired oxygen of 1.0. A dose of ketamine, 12.5 mg/kg, was repeated every 1 hour, and pancuronium chloride, 1 mg, as necessary [14].

Operation technique

With the animal placed in the horizontal supine position, through a right cervicotomy the internal jugular vein (for drugs and solution infusions) and the common carotid artery for mean arterial pressure measurements were catheterized. Sternotomy exposing the heart and great vessels was performed afterwards. In addition, right and left atrial appendices, both ventricle apices, besides the pulmonary trunk, were catheterized. Then, descending aorta was dissected and anular ultrasonic probe was settled for cardiac output measurements.

Hemodynamic monitoring

Measurements were performed at the end-expiratory artificial ventilation cycle. Electrocardiogram and the following pressure measurements were recorded by a polygraph (BESE - Belo Horizonte, MG, Brasil): Mean Arterial Pressure (MAP), Mean Pulmonary Artery Pressure (MPAP), Mean Right Atrial Pressure (MRAP), Mean Left Atrial Pressure (MLAP); Diastolic Right Ventricular Pressure (DRVP), and Diastolic Left Ventricular Pressure (DLVP). Cardiac output was continuously monitored by transomic flowmeter system (Transonic Systems, Ithaca, NY, USA) placed on the ascending aorta.

There were no deaths and blood transfusion, vasoactive drugs, calcium chloride, or any other methods were not employed to maintain hemodynamic stability.

Experimental protocol

Two stabilizers available in the market were used. The Octopus II (Medtronic Inc, Mineapollis, MN, USA), a suction device (its suction cups are connected to a vacuum system using pressures of approximately 400 mmHg) and the Speroni "One for all Retractor" (Geister Medizintechnik, Tuttlingen, Germany), a compression device.

The sequence of arteries to be stabilized (anterior interventricular branch of LCA, posterior interventricular branch of RCA, or the left marginal artery of the circumflex branch) and the stabilizers to be used were defined by random assortment.

Once the sequence was defined and with the animal in the horizontal supine position, baseline measurement was performed. The stabilizer was applied and five minutes later after hemodynamic stabilization, measurements were obtained. When this was accomplished, the stabilizer was removed and 10 minutes later a new baseline measurement was obtained. Administration of anesthetic drugs, when needed, was always performed after final measurements with the stabilizer.

Statistical analysis

Unpaired Student's *t* test was used to compare baseline status before and after applying the stabilizer. We considered *p* <.05 statistically significant.

RESULTS

There had been a decrease in cardiac output using Octopus when applied to the left marginal artery of the circumflex branch of LCA. In addition, a decreased cardiac output was noted when Speroni "One for all Retractor" was used to the following three arterial branches: anterior interventricular (LCA), posterior interventricular (RCA), and the left marginal artery from the circumflex branch of LCA (Figure 1).

Heart rate increased with the use of both stabilizers – Octopus and Speroni – in posterior interventricular branch of RCA (Figure 2).

Reduced systolic volume occurred when Octorpus device was used in posterior interventricular branch of RCA and in the left marginal artery of circumflex branch of LCA. When using Speroni device, a decrease was noted in three arterial branches: anterior interventricular branch of LCA, posterior interventricular branch of RCA, and left marginal artery of circumflex branch Figure 3).

Increased systemic vascular resistance was noted when both Octopus and Speroni were used in posterior interventricular branch of RCA and in anterior interventricular branch of LCA, respectively (Figure 4).

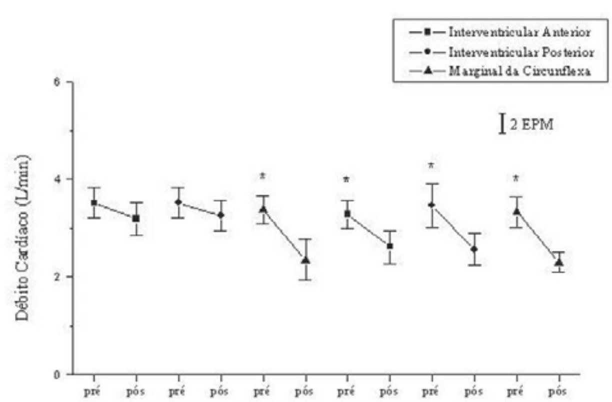

Fig. 1 – Pre- and poststabilization cardiac outputs using Octopus and Speroni devices. Mean values with two standard error of the mean (SEM). (*) difference with statistical significance (p<0.05)

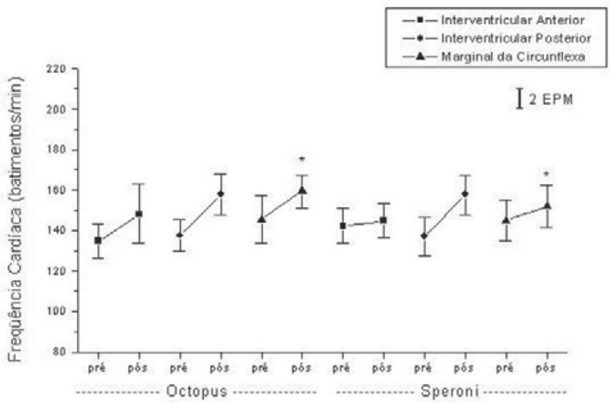

*Fig. 2 - Pre- and poststabilization cardiac outputs using Octopus and Speroni devices. Mean values with **two** standard error of the mean (SEM). (*) difference with statistical significance (p<0.05)*

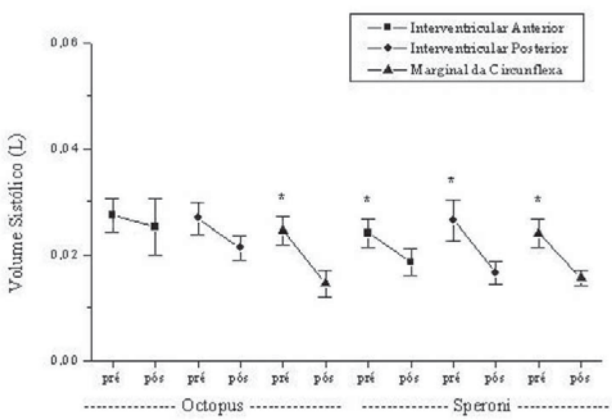

*Fig. 3 - Pre- and poststabilization sistolic volumes using Octopus and Speroni devices. Mean values with **two** standard error of the mean (SEM). (*) difference with statistical significance (p<0.05)*

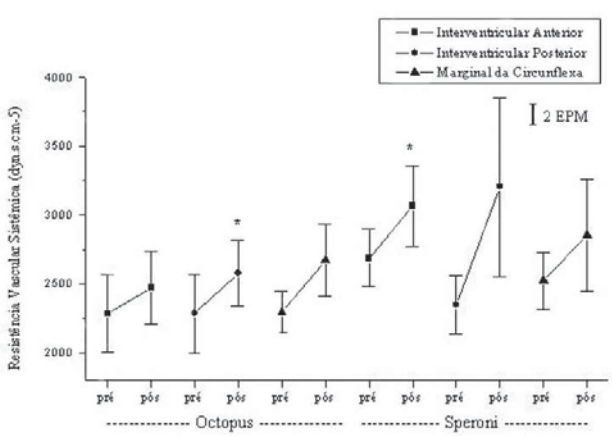

Fig. 4 – Pre- and poststabilization systemic vascular resistances using Octopus and Speroni devices. Mean values with two standard error of the mean (SEM). (*) difference with statistical significance (p<0.05)

A decreased mean arterial pressure was noted when both Octopus and Speroni were used in left marginal artery of circumflex branch and in both anterior and posterior interventricular branches, respectively.

Concerning to mean arterial pressure, the abovementioned event occurred only when Speroni device was used in the left marginal artery of circumflex branch (Tables 1 and 2).

There were no changes in right and left ventricular diastolic pressures in all the arteries regardless of the stabilizers used (Tables 1 and 2).

As to the mean atrial pressures, when Speroni device was used in the left marginal artery of circumflex branch, it was noted an alteration only in the right atrial pressure (Tables 1 and 2).

Table 1. Baseline pressures and after Octopus stabilizer application

Variable	Artery	Pre	Post	*p-value*
MAP	AIVB	101.2 (±21.98)	97.1 (±15.68)	0.3168
	PIVB	100.8 (±21.27)	105.8 (±18.21)	0.2861
	LMA	102.3 (±18.87)	79.1 (±24.55)	0.0036*
MPAP	AIVB	21.4 (±6.60)	20.3 (±5.69)	0.3888
	PIVB	21.3 (±6.70)	21.8 (±4.54)	0.7052
	LMA	22.3 (±7.81)	19.4 (±7.69)	0.0593
LVP	AIVB	8.2 (±12.10)	14.2 (±14.68)	0.0596
	PIVB	10.4 (±8.05)	6.5 (±5.54)	0.2430
	LMA	9.8 (±10.50)	8.3 (±4.54)	0.6201
RVDP	AIVB	2.6 (±1.83)	3.7 (±3.05)	0.3923
	PIVB	2.9 (±2.28)	3 (±2.31)	0.9221
	LMA	2.8 (±2.14)	4.3 (±3.46)	0.2443
MLAP	AIVB	17.8 (±12.29)	14.5 (±7.86)	0.1547
	PIVB	16.3 (±6.58)	17.4 (±9.37)	0.6875
	LMA	17.1(±8.08)	19.6 (±10.45)	0.4619
MRAP	AIVB	8.8 (±4.87)	6.7 (±4.02)	0.2877
	PIVB	7.9 (±5.78)	7.5 (±4.01)	0.8373
	LMA	8.5 (±5.96)	10.1 (±3.72)	0.2229

Mean values are expressed in mmHg (± standard deviation). Baseline premeasurement. Postmeasurement using stabilizer. AIVB – anterior interventricular branch. PIVB – posterior interventricular branch. LMA – left marginal artery of the circumflex branch. MAP – mean arterial pressure. MPAP – mean pulmonary artery pressure. LVP – left ventricular pressure. RVDP – right ventricular diastolic pressure. MLAP – mean left atrial pressure. MRAP – mean right atrial pressure. (*) Statistical significance (p <0.05)

Table 2. Baseline pressures and after Speroni stabilizer application

Variable	Artery	Pre	Post	*p-value*
MAP	AIVB	112.7(±15.76)	99.6 (±13.35)	0.0004*
	PIVB	99.7 (±13.28)	93.4 (±16.50)	0.1976
	LMA	106.5 (±13.79)	85 (±18.77)	0.0006*
MPAP	AIVB	22 (±4.80)	20.6 (±4.40)	0.1914
	PIVB	20.4 (±8.00)	22.5 (±6.32)	0.2804
	LMA	22.2 (±6.01)	16.7 (±5.73)	0.0049*
LVP	AIVB	13.7 (±13.65)	11.2 (±14.34)	0.6264
	PIVB	9.1 (±7.79)	11.7 (±14.81)	0.6279
	LMA	7.1 (±8.54)	14.1 (±11.31)	0.1888
RVDP	AIVB	5 (±4.42)	3.6 (±3.89)	0.1376
	PIVB	3.6 (±2.87)	3 (±1.69)	0.6075
	LMA	2.4 (±1.77)	3 (±2.21)	0.4151
MLAP	AIVB	16.1 (±6.33)	17.7 (±6.32)	0.2901
	PIVB	19.3 (±11.66)	17.7 (±10.28)	0.5940
	LMA	19.7 (±9.76)	25.9 (±19.8)	0.2609
MRAP	AIVB	7.6 (±4.88)	8.7 (±3.77)	0.4427
	PIVB	7.8 (±3.93)	8.3 (±3.71)	0.4402
	LMA	7.7 (±4.76)	10.6 (±4.62)	0.0469*

Mean values are expressed in mmHg (± standard deviation). Baseline premeasurement. Postmeasurement using stabilizer. AIVB – anterior interventricular branch. PIVB – posterior interventricular branch. LMA – left marginal artery of the circumflex branch. MAP – mean arterial pressure. MPAP – mean pulmonary artery pressure. LVP – left ventricular pressure. RVDP – right ventricular diastolic pressure. MLAP – mean left atrial pressure. MRAP – mean right atrial pressure. (*) Statistical significance (p <0.05)

DISCUSSION

Pigs were chosen to perform this study on account of their similarity with both human conducting system of heart and coronary anatomy [15]. There is a significant difference in pig heart anatomic position within the thoracic cavity: in comparison to the human anatomy, pig's apex is directed to the right if in comparison to the human heart; the inferences of this experimental study should be modified to be applied to the human heart [13].

Cardiac output

Cardiac output was measured continuously with a flowmeter placed in the aortic root, as described. As other authors did not detect changes in cardiac output using the thermodilution method, this was the method of choice [16]. Searching the literature, we could verify that the error rate associated to thermodilution, ranges between 10% and 20% and may not be responsive to small changes in cardiac output [17].

In our results, we have a decreased cardiac output when using Octopus device in left marginal artery of circumflex branch, but there was no statistical significance using Octopus device in other arteries. In a experiment using pigs, Jansen et al. [13] evaluated the hemodynamic changes using Octopus device applied to the left marginal artery of circumflex branch and reported a decreased cardiac output, which was reversed placing the animal in the Trendelenburg position, what was not done in our study.

Mathison et al. [18] in a study undertook in humans reported that during coronary artery bypass graft surgery using Octopus, there had been a decrease in cardiac output when the Octopus device was applied in the anterior interventricular branch of LCA, as well as in both posterior interventricular branch of RCA and circumflex branch of LCA. Do et al. [19], in an analogous study, described a cardiac output drop using the compression type stabilizer applied to the anterior interventricular branch of LCA, in its diagonal branch, and in the left marginal artery of circumflex branch. There were not changes in the posterior interventricular branch of RCA.

A decreased cardiac output established with both stabilizers can be explained by several factors, such as right ventricle impaired diastolic expansion [20], left ventricle outflow tract compression, impaired myocardial contractility, and decreased ventricular volume [17].

According to Nierich et al. [20] during off-pump coronary artery bypass graft surgeries using Octopus device, the right ventricle is constrained between the pericardium and left ventricle muscular mass, thus creating an acute low cardiac output situation, more marked when posterior and lateral walls are approached.

The obstruction of left ventricle outflow tract is caused by stabilizer direct compression. This can also constrain the branches of the artery stabilized obstructing its flow what leads to regional ischemia impairing myocardial contractility; however, Burfeind Jr. et al. [17] did not find any subsidies to confirm the hypothesis of ischemia.

In a study with pigs, Gründeman et al. [21] using the Octopus device applied to the anterior interventricular branch of LCA detected a decrease in cardiac output flow with the displacement of the heart. This situation was reversed by increasing preload by the maneuver of Trendelenburg, parallel to the recovery of cardiac output, thus concluding that coronary blood flow is not mechanically obstructed during displacement of the porcine beating heart. However, Mathison et al. [18] in off-pump coronary artery bypass graft surgery using Octopus device failed to achieve the recovery of cardiac output, regardless the Trendelenburg position, suspecting that myocardial ischemia might occur secondarily to the coronary blood flow drop caused by the decrease in the cardiac output.

For the reasons shown, we verified that the pathophysiology of the cardiac output drop when applying the stabilizer is multifactorial, thus resulting from factors such as compression of a given area and even from complex factors such as regional ischemia, blood flow obstruction, and deformations of the cavities.

Heart rate

There had been an increase in heart rate with both stabilizers applied to the posterior interventricular branch. There was not detected any other significant statistical changes. In an experimental study with pigs carried out by Gründeman et al. [22] also reported an increase in heart rate, however, the authors only used the Octopus device applied uniquely to the anterior interventricular branch. This resulted in an increase of this parameter by 121%±6% (p<0.05) in relation to the baseline. In a posterior study by the same authors, this parameter was fixed in 80 beats per minute with an infusion of propofol and using a pacemaker [21].

Evaluating the hemodynamic changes during off-pump coronary artery bypass graft surgeries, Nierich et al. [20] using the Octopus device described an increase of the heart rate in relation to the baseline regardless the artery studied. Mathison et al. [18] reported an increase of this variable only with the Octopus device applied to the circumflex branch. Other authors, such as Do and Cartier [23] and Do et al. [19] did not describe such a change, probably on account of that the patients were using beta-blockers.

The increase of heart rate is one of the compensatory mechanisms used by the organism attempting to maintain the cardiac output. It results from both sympathetic stimulation and catecholamines release by the suprarenal gland in response to the acute low cardiac output situation following heart displacement, deformation, and compression imposed by the stabilizers.

Systolic volume

A decrease in systolic volume was noted with both stabilizers in all the arteries, except when the Octopus device was applied to the anterior interventricular branch of LCA. According to Burfeind Jr. et al. [17] this results from several etiologies, such as mechanical deformation of mitral valve ring by the stabilizer or obstruction of right ventricle outflow tract as a consequence of direct stabilizer compression on the outflow tract and pulmonary artery, which function under a low pressure regimen.

Mathinson et al. [18] described changes to intraoperative transesophageal echocardiography in patients undergoing off-pump coronary artery bypass graft using the Octopus device. When the Octopus was applied to the anterior interventricular branch, it showed right ventricular compression in several cases; however, obstruction to the right ventricle outflow tract or mitral regurgitation was not noted. They reported a light-to-moderate left ventricle intensity, but when the Octopus was applied to the other arterial branches (posterior interventricular branch and circumflex branch) caused severe compression to both ventricles, leading to a poor ventricular filling with consequent decreased systolic volume [18].

Systemic ventricular resistance

An increased systemic ventricular resistance, when the Octopus and Speroni device were applied to both posterior interventricular branch and anterior interventricular branch, respectively, whereas other authors studying the Octopus device applied to the anterior interventricular branch did not detect any statistical significant changes regarding this variable [18,22]. The increase of systemic ventricular resistance is expected, since it is one of physiologic mechanisms used by the organism in an attempt to maintain circulatory homeostasis. Systemic ventricular resistance is increased in hypovolemic, obstructive, and cardiogenic shocks [24]. It is possible that other authors did not detected the increased systemic ventricular resistance as a consequence of differences on data collection or anesthetic technique, once anesthetic drugs are well-known to act in the periphery causing vasodilation, which could reduce the systemic vascular resistance.

Mean arterial pressure

When both stabilizers were applied to the left marginal artery of circumflex branch, a decreased mean arterial pressure was noted, as well as when Speroni device was applied to the anterior interventricular branch. Gründeman et al. [21,22] in an experimental Octopous study using the anterior interventricular branch also attained a decrease of this variable.

Mathison et al. [18] published their experiences with 44 patients undergoing off-pump CABG with Octopus device support. They reported a decrease in MAP with the same outcomes we achieved with the Speroni device, that is, when the stabilizer was applied to both anterior interventricular branch and circumflex branch territory. Do and Cartier [23] followed by Do et al. [19], reporting their series with 31 and 55 patients, respectively, and using a compression stabilizer device (Cor-vasc, CoroNéo Inc., Montreal, QC, Canadá) also described a decrease in the variable. The former authors just report when the stabilizer was applied to the anterior interventricular branch and left marginal artery of the circumflex branch, whereas the latter authors report when the device was applied to the anterior interventricular branch and its diagonal branch. A decrease in the MAP results from the low cardiac output situation, which is established by using the stabilizer.

Mean pulmonary arterial pressure

The drop in the mean pulmonary arterial pressure with the Speroni device applied to left marginal artery of the circumflex branch was the only change with statistical significance observed in this parameter. Unlike our experimental data, Do and Cartier [23] described an increase in pulmonary artery pressure when using a compression type device applied to the anterior interventricular branch and its diagonal branch and there were no changes when the device was applied to other territories. These data were obtained from the off-pump coronary artery bypass graft surgeries. Nierich et al. [20] using the Octopus device did not observed any changes in this variable. Do et al. [19] described an increase in this parameter when the compression stabilizer device was applied to the anterior interventricular branch, its diagonal branch, and posterior interventricular branch. There were not observed any changes when the device was applied to the left marginal artery of the circumflex branch. These authors report that what they observed during the manipulation of the anterior wall suggest a transitory status of the left ventricular restrictive diastolic dysfunction with the following outcomes: increase the mean pulmonary artery pressure, cardiac output and mean arterial pressure drop.

Left ventricular diastolic pressure

We did not observed any statistically significant changes, as well as Grundeman et al. [21,22]. Among the studies undertook using off-pump coronary artery bypass graft surgeries, Mathison et al. [18] studied this variable and described an increase when the Octopus device was applied to both the anterior interventricular branch and circumflex branch. These authors performed a transesophageal echocardiography during the stabilization of the heart using the Octopus device. They showed an important compression of both ventricles notably when it was applied in the circumflex branch territory. There was no left ventricular compression when the device was placed in the posterior interventricular branch. Do and Cartier [23] also suggested such a deformation when the compression type device was applied to the anterior interventricular branch.

Right ventricular diastolic pressure

There were no changes in the right ventricular diastolic pressure when both stabilizers were used regardless the artery to be stabilized. Gründeman et al. [21,22] report an increase of this pressure, reflecting that the right ventricle is more affected by the mechanical deformation set by the stabilizer than does the left ventricle, which did not present any changes in its diastolic pressure. Mathison et al. [18] in off-pump coronary artery bypass graft surgeries using the Octopus device described an increase of this pressure when the device was applied to both anterior and posterior interventricular branches and the circumflex branch. On transesophageal echocardiography, they observed right ventricular compression when the Octopus device was applied to the anterior interventricular branch; however, it was difficult to identify the changes in its conformation due to the echocardiographic window. When the stabilizer was applied to the circumflex branch territory there was a compression of both ventricles and when applied to the posterior interventricular branch, a considerable compression of the right ventricular cavity was observed [18].

Mean left atrial pressure

We did not observe an increase in mean left atrial pressure when both stabilizers were used, as well as Grundeman et al. [22]. Burfeind Jr et al. [17], using a compression type stabilizer device applied to the pigs' anterior interventricular branch, described an increase of this pressure, suggesting mitral regurgitation resulting from the deformity imposed by the stabilizer device. An increase of this pressure was highlighted by Mathison et al. [18] when the Octopus device was applied to human patients' anterior and posterior interventricular and circumflex branches. A transesophageal echocardiography was performed in part of a series of surgical patients. Mitral regurgitation was not observed, however, the left atrium was found to be distended, suggesting left ventricle filling difficulty caused by the stabilizer device.

Mean right atrial pressure

We observed an increase in this pressure only when the Speroni device was applied to the left marginal artery of the circumflex branch. An increased right atrial pressure was also achieved by other authors when studying the Octopus device applied to the anterior interventricular branch of pigs' heart [22]. Nierich et al. [20] reporting their consecutive series in patients using the Octopus device applied to anterior interventricular branch, its diagonal branch, right coronary artery, and left marginal artery of the circumflex branch, did not observed any changes in this parameter. However, Mathinson et al. [18] in off-pump coronary artery bypass graft surgeries using the Octopus device also described an increase in the right atrial pressure with the device applied to both anterior and posterior interventricular branches, and to the circumflex branch territory as well.

These authors reported that the increase was higher when the Octopus device was applied to the circumflex branch territory followed by the posterior interventricular branch, and finally by the anterior interventricular branch. They argued that the heart is displaced anteriorly directing the apex upward in order to allow the positioning of the stabilizer device in the regions of posterior interventricular and circumflex branches. Therewith, the heart is "bent", probably close to the atrioventricular valves possibly causing some degree of obstruction. Nevertheless, this degree of displacement is not necessary for the anterior interventricular branch exposure, which justifies the increase in the right atrial pressure as a reflex of the rise in the right ventricular diastolic pressure [18].

Final considerations

The discrepancy between the experimental data in both pigs and humans undergoing coronary artery bypass surgeries, as demonstrated by pulmonary artery pressure, and left atrial and ventricular pressures can be justified by the anatomic differences between both species, in addition to the singularities of both human myocardial pathology and anesthetic technique performed to normalize the patients' circulatory homeostasis [20].

Analyzing the hemodynamic data obtained all together with the experiments exposed in Table 3, we could verify that both stabilizers cause hemodynamic changes, what can occur in either positioning. However, the Speroni device triggered more systematically hemodynamic changes than the Octopus device, suggesting that mechanical stabilizers cause more interference with circulatory homeostasis than the suction stabilizers devices.

Table 3. Quantitative analysis of hemodynamic data obtained using the stabilizers

	Octopus			Speroni		
	AIVB	PIVB	LMA	AIVB	PIVB	LMA
CO	=	=	<	<	<	<
HT	=	>	=	=	>	=
SV	=	<	<	<	<	<
MAP	=	=	<	<	=	<
MPAP	=	=	=	=	=	<
LVP	=	=	=	=	=	=
RVDP	=	=	=	=	=	=
MLAP	=	=	=	=	=	=
MRAP	=	=	=	=	=	>
SVR	=	>	=	>	=	=

AIVB – anterior interventricular branch. PIVB – posterior interventricular branch. LMA – left marginal artery of the circumflex branch. CO – cardiac output. HR – heart rate. SV – systolic volume. MAP – mean arterial pressure. MPAP –mean pulmonary artery pressure. LVP – left ventricular pressure. RVDP – right ventricular diastolic pressure. MLAP – mean left atrial pressure. MRAP – mean right atrial pressure. SVR – systemic vascular resistance. (=) Unchanged. (>) Raise

We also verified that stabilizations of anterior and posterior wall arteries (left marginal artery of circumflex branch and posterior interventricular branch) were those which provoked more hemodynamic changes (Table 3). Probably, if the number of animals studied were larger, we could have obtained more statistically significant data.

In several studies searched and quoted in the present study, we verified that there is no homogeneity of data as well as in the explanations of the triggering mechanisms inducing the changes, with the authors' opinions being heterogenous. It is known that the mechanisms which induce the changes are multifactorial. Systolic performance is the most affected one. In this respect there is more agreement among the researchers being secondary to deformation and compression of the cavities with restriction to ventricular filling pressures and its hemodynamic outcomes. Systolic function is also impaired, however, the opinions regarding the mechanisms are varied and, sometimes, conflicting.

CONCLUSIONS

Hemodynamic changes have occurred when using both types of stabilizers for off-pump coronary artery bypass graft surgery. The compression type stabilizer provoked systematically more changes when compared to the suction type device.

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