

HEART STABILISATION DURING CABG: AN IN VIVO STUDY

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INTRODUCTION

Despite improved clinical care, heightened public awareness and widespread use of health innovations, coronary heart disease remains the leading cause of death in the Western World. Cardiovascular-related risk factors are high blood pressure, high cholesterol, diabetes, arteriosclerosis, cigarette smoking, physical inactivity and stress. Sabiston and De Bakey introduced the surgical by-pass on the beating heart in the 60's [1], while the use of cardiopulmonary by-pass has been using since the end of the 60's [2]. However starting from the 80's, there has been a revival of interest in performing coronary artery bypass grafting on the beating heart [3] [4], in the attempt to decrease the morbidity associated with cardiopulmonary bypass procedures. In beating heart coronary bypass grafting, invasiveness is reduced, but anastomosis suturing is jeopardized by cardiac motion. Therefore, the use of stabilizers has been introduced in practical clinics in order to achieve an effective local cardiac wall stabilization. The stabilizers allow exposure and immobilization of all the coronary vessels through compression or aspiration, thus improving the surgical technique minimally interfering with the normal beating heart. In literature two studies [5, 6] have been focused on the evaluation of the extent of the residual motility of the coronary following the application of the stabilizer. In these studies, a marker was located on the cardiac wall surface and traced during its motion with a single camera; consequently, the marker motion is attained in a bidimensional plane. The present study was designed to assess the three-dimensional motion of the main coronaries by means of a stereo acquisition system. Contemporary, the haemodynamic changes after local stabilization were also evaluated. The performance of three stabilizers were compared: Genzyme OPCAB Immobilizer, Medtronic Octopus 2⁺ and CTS Axisus Guidant.

MATERIALS AND METHODS

Surgical protocol and experimental set-up

The experiments were conducted within the national animal welfare regulations and guidelines. Ten pigs underwent surgical chest opening after anaesthetisation. Atrial and aortic pressures and ECG

were monitored throughout the experiments. Each stabiliser was applied to three coronary branches of cardio-surgical interest: the inter-ventricular left anterior descending coronary artery, LDA, the inter-ventricular right posterior descending coronary artery, LDP, and the obtuse marginal branch of the circumflex left coronary, MB. A polypropylene marker was placed on the investigated branch between the two arms of the stabiliser; and its motion was recorded for 10 seconds with two TV-digital-cameras Sony PC2E, one located at the bottom of the operating table, and the second laterally close to the surgeon. Before performing a new stabilisation, the pressures and heart frequency were monitored until the pre-stabilisation values were recovered. A total of 9 recordings were performed for each heart. The sequence of the stabilisers and the coronary sites investigated were changed for each pig. Pigs were sacrificed at the end of the surgery.

Data extraction and analysis

The camera system was calibrated using an array of partially known point [7, 8], with an estimated precision of 50 μm within the region of interest (approximately 10x10x10 cm). The absolute reference co-ordinate system was placed at the optical centre of the first TV-camera. The images were in RGB format; only the red channel was selected and converted in grey scale. For each camera image array, the location of the marker was estimated by selecting the marker pixel with a threshold filter and calculating the average values of the x, y pixel locations in the local reference frame. Through the calibration parameters, the three-dimensional co-ordinates of the marker were calculated from the two-dimensional data arrays collected with the two TV-cameras. To allow the comparison of the residual motility after the application of the three stabilisers, the marker displacement was calculated with respect to its average position. Further, the marker motion was triggered with respect to the respiratory frequency and only data relative to three respiratory cycles were considered. One index was extracted from the row data: the systolic to diastolic motion (*SDI*), defined as the average distance between the systolic (diastolic) marker location and the subsequent diastolic (systolic) marker location. Together with the study of the

marker motion, haemodynamic changes induced by the use of the stabilisers were also evaluated. The cardiac frequency, and the mean pressure in the right and left atrium, in the aorta and in the pulmonary artery were recorded. Motion and haemodynamics data were analysed with the t-test for data with normal distributions and with the Wilcoxon signed rank test and the Mann-Whitney rank sum test for non-normal distributions.

RESULTS AND DISCUSSION

Three-dimensional motion analysis

The comparison with the free beating heart data shows that the stabilisers reduce the wall motion of about 80%. The obtained results confirm the reliability of stabilisers in reducing the heart motion and allow the quantitative comparison of the reduction obtained with different stabilisers. In turn, the method allows only the qualitative analysis of the direction of the residual motility, since the heart surface orientation is not known. Merely assuming that LDA, LDP and MB lay in the xz, xy and yz planes, respectively, the largest residual motility occurred in the direction perpendicular to the coronary plane; in all the cases, the perpendicular displacement within a heart beat was about twice the displacement in the coronary plane. Although an accurate analysis would be possible only through the exact estimation of the coronary plane orientation with respect to the camera reference frame, this preliminary result suggest that the 3-D analysis is essential for the correct estimation of the effective residual motility.

The quantitative analysis of the wall motion performed using the SDI index suggests that the CTS and Medtronic stabiliser would provide the best immobilisation for LDA and LDP, while Genzyme stabiliser would be slightly better in the case of MB.

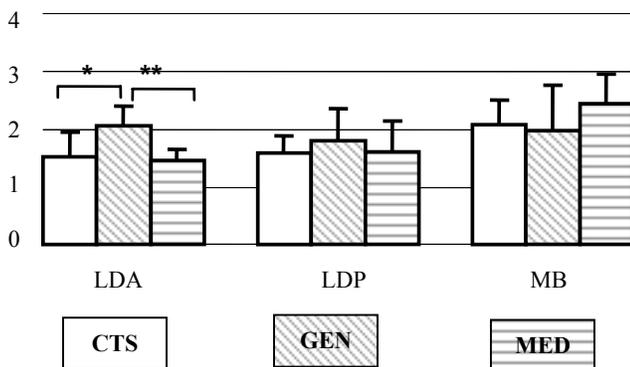


Figure 1. SDI index [mm]

SDI values were significantly lower for CTS and Medtronic stabilisers than those obtained with the Genzyme stabiliser ($p = 0.0036$ and $p = 0.0043$, respectively) in the case of LDA. In all the other cases differences were not statistically significant ($p > 0.05$). Two acquisitions, performed with the Genzyme stabiliser, were not considered in the analysis since the stabiliser moved accidentally away from the cardiac surface, probably due to a decrease of the cardiac pressure.

Haemodynamics analysis

The analysis of the haemodynamic changes showed the interference on ventricular diastolic filling by direct ventricular compression of the stabiliser. In comparison with the baseline values (before the application of the stabiliser), the cardiac frequency (CF) and the right atrium mean pressure (RAMP) significantly increased and

the aortic mean pressure (AMP) significantly decreased ($p < 0.05$); the left atrium mean pressure (LAMP) and the pulmonary artery mean pressure (PAMP) were not significantly affected ($p > 0.05$). The most extensive haemodynamics changes were induced when the stabilisers were applied to the LDP and MB coronaries. The CTS stabiliser showed the lowest influence on the mean left atrium pressure (when it was applied to the LDA,) and on the mean right atrium pressure (when it was applied to LDP), with statistically significant differences from the Genzyme stabiliser ($p = 0.0234$ and $p = 0.0156$, respectively). The Medtronic stabiliser showed the lowest influence on the mean left atrium pressure (when it was applied to MB), with statistically significant differences from the CTS ($p = 0.0165$) and Genzyme stabilisers (when it was applied to LDA, $p = 0.0322$). These results suggest that the most extensive haemodynamics changes were caused by the compression of the Genzyme stabiliser, with a considerable increase in the atrium pressure. In fact, the compression Genzyme stabiliser caused in some cases variations 30% greater than those obtained with the suction stabilisers.

However, the hemodynamic changes induced by the use of the stabilisers were temporary, in fact the values became physiological again, taking the heart back to its natural position.

REFERENCES

- Westaby S, Benetti FJ. Less invasive coronary surgery: consensus from the Oxford meeting. *Ann Thorac Surg* 1996;62:924-31.
- Favaloro RG. *Critical analysis of coronary artery bypass graft surgery: a 30-year journey*. *J Am Coll Cardiol*. 1998;31(Suppl B):1B-63B.
- Buffolo E, Andrade JCS, Succi J, Leao LEV, Gallucci L. *Direct myocardial revascularization without cardiopulmonary bypass*. *Thorac Cardiovasc Surg*. 1985;33:26-9.
- Benetti FJ, Naselli G, Wood M, Geffner L. *Direct myocardial revascularization without extracorporeal circulation. Experience in 700 patients*. *Chest*. 1991;100:312-316.
- Borst C, Jansen EWL, Tulleken CAF, Grundeman PF, Mansvelt Beck HJ. *Coronary artery bypass grafting without cardiopulmonary bypass and without interruption of native coronary flow using a novel anastomosis site restraining device ("Octopus")*. *J Am Coll Cardiol*. 1996;27:1356-1364.
- Shennib H, Lee AGL, Akin J. *Safe and effective method of stabilization for coronary artery bypass grafting on the beating heart*. *Ann Thorac Surg*. 1997;63:988-92.
- Janne Heikkilä Geometric camera calibration using circular control points. *IEEE Transactions on Pattern analysis and machine intelligence*. Vol.22, No.10, October 2000.
- Lenz R.K., Tsai R.Y. Techniques for calibration of the scale factor and image centre for high accuracy 3D machine vision metrology. *IEEE Transactions on Pattern analysis and machine intelligence*, 10(5), 731-720, 1988.