Coronary grafts flow and cardiac pacing modalities: how to improve perioperative myocardial perfusion

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Abstract

Objective: Aim of this study was to investigate modifications of coronary grafts flow during different pacing modalities after CABG.

Materials and methods: Two separate prospective studies were conducted in patients undergoing CABG and requiring intraoperative epicardial pacing. In a first study (22 patients) coronary grafts flows were measured during dual chamber pacing (DDD) and during ventricular pacing (VVI). In a second study (10 patients) flows were measured during DDD pacing at different atrio-ventricular (A-V) delay periods. A-V delay was adjusted in 25 ms increments from 25 to 250 ms and flow measurements were performed for each A-V delay increment. A transit time flowmeter was used for the measurements.

Results: An average of 3.4 grafts/patient were performed. In the first study, average coronary graft flow was 47.4 ± 20.8 ml/min during DDD pacing and 41.8 ± 18.2 ml/min during VVI pacing (P = 0.0004). Furthermore, average systolic pressure was 94.3 ± 10.1 mmHg during DDD pacing and 89.6 ± 12.2 mmHg during VVV pacing (P = 0.0007). No significant differences in diastolic pressure were recorded during the two different pacing modalities. In the second study, maximal flows were achieved during DDD pacing with an A-V delay of 175 ms (54 ± 9.6 ml/min) and minimal flows were detected at 25 ms A-V delay (38.1 ± 4.7 ml/min) (P = ns). No significant differences in systolic or diastolic blood pressure were noticed during the different A-V delays.

Conclusion: Grafts flowmetry provides an extra tool to direct supportive measures such as cardiac pacing after CABG. DDD mode with A-V delay around 175 ms should be preferred to allow for maximal myocardial perfusion via the grafts.

Keywords: Cardiac pacing; Coronary flow; Transit time flow measurement

1. Introduction

The main aim of coronary artery bypass grafting (CABG) is to increase blood flow to ischemic myocardium. Although this procedure is successfully performed in more than several hundred thousand patients per year in Europe, intraoperative graft patency verification is still considered optional in most of the cardiac surgery centers. Grafts are assumed to be patent at the end of the operation, especially if the patient has no hemodynamic compromise and if weaning from cardiopulmonary bypass (CPB) is successful. After an initial attempt to expand graft flowmetry in standard cardiac surgery practice, in the early 1960s measurement of coronary graft flow has been almost abandoned due to the many limitations of the obsolete electromagnetic flowmeters adopted at that time [1].

The recent popularization of off-pump CABG, together with the amelioration of the technology available for accurate graft flow measurement, have revived interests and concerns about the focal importance of intraoperative graft patency verification and documentation [2]. The introduction of ultrasound-based flow meters such as Doppler and Transit Time Flow Measurement (TTFM) systems, is presently giving a tremendous scientific and technological impact in the field of rheology and flow measurement.

In our experience intraoperative graft patency verification, if properly performed, may not only inform the surgeon about the status of the newly constructed coronary anastomoses, but could also guide him in modifying his perioperative conduct and strategy to achieve an ideal...
hemodynamic performance and, consequently, a maximal myocardial perfusion through the bypass conduits [3].

In the present manuscript we summarize our experience with intraoperative cardiac pacing and simultaneous coronary graft flow measurement trying to identify which are the pacing strategies that allow for an optimal coronary graft rheology.

2. Material and methods

Over a one-year period, two separate prospective studies were conducted at the Cork University Hospital in order to evaluate coronary grafts flow modifications in patients requiring epicardial pacing following primary CABG.

Patients were enrolled following preoperative informed consent.

All patients were operated on CPB and cardiac arrest was achieved via antegrade intermittent crystalloid cold cardioplegia. Distal anastomoses were performed with 7-0 polypropylene running sutures. Proximal anastomoses were constructed on partial aortic clamping with 5-0 polypropylene running sutures.

After aortic declamping, epicardial pacing was initiated due to nodal rhythm, atrio-ventricular dissociation, or sinus bradycardia.

Two epicardial atrial and two ventricular pacing wires were placed in each patient.

In a first study including 22 patients, coronary grafts flows were measured after weaning from CPB initially during dual chamber pacing (DDD) and secondly during ventricular pacing (VVI).

In a second study including 10 patients, flows were measured during DDD pacing at different atrio-ventricular (A-V) delay periods. A-V delay was adjusted in 25 milliseconds increments from 25 to 250 ms and flow measurements were performed for each A-V delay increment.

Although cardiac indexes were not routinely recorded, flow in the new pacing modality was detected only after allowing two minutes of hemodynamic stabilization aiming at systolic arterial blood pressure of 100 mmHg and diastolic of 60 mmHg to standardize measurements. Measurements were performed twice per each graft in the same pacing modality and averages were calculated.

A TTFM device was used to test the grafts. Flow probes have a size ranging from 2.5 to 3 mm and can be easily placed around the constructed grafts. A small amount of aqueous gel is placed between the probe and the conduit to increase the contact. The probe consists of two small piezo-electric crystals, one upstream and one downstream, mounted on the same side of the vessel. Opposite to the crystals, there is a small metallic reflector. Each crystal produces a wide pulsed ultrasound beam covering the entire vessel width. Both the amount of time necessary for an ultrasound beam emitted from the upstream crystal to arrive at the downstream crystal after being reflected, and for a signal from the down-stream crystal to reach the upstream crystal are measured. Since ultrasound travels faster if transmitted in the same direction as flow, a small time difference between the two beams is calculated as the transit time of flow and thus, the actual flow is proportional to the transit time [5]. All calculations are made automatically by the flow meter and are displayed as ml/min.

Flow findings were recorded together with hemodynamic values. No pulsatility indexes were recorded. Data were stored in a database and differences were statistically tested with the paired Student t-test (DDD-VVI and A-V delay study), and with the one-way ANOVA test (A-V delay study).

Differences in mean flows between arterial and venous conduits at different pacing modalities, correlations between mean flow changes and conduits size, flow variations for grafts to different myocardial areas and after use of different myocardial protection techniques were not investigated in the present study and are object of analysis in two further ongoing larger studies.

3. Results

3.1. Study 1

An average of 3.4 grafts/patient were performed. All 22 patients received a LIMA graft to the LAD. No further arterial grafts were adopted. Average coronary graft flow as measured in the 22 patients included in the study was 47.4 ± 20.8 ml/min during DDD pacing and 41.8 ± 18.2 ml/min during VVI pacing (P = 0.0004). Furthermore average systolic pressure was 94.3 ± 10.1 mmHg during DDD pacing and 89.6 ± 12.2 mmHg during VV pacing (P = 0.0007). No significant differences in diastolic pressure were recorded during the 2 different pacing modalities.

3.2. Study 2

An average of 3.4 grafts/patient were performed. All 10 patients received a LIMA graft to the LAD. No further arterial grafts were adopted. Although maximal coronary grafts flows were achieved during DDD pacing with an A-V delay of 175 ms (mean 54 ± 9.6 ml/min) and minimal flows were detected at 25 ms A-V delay (mean 38.1 ± 4.7 ml/min), no statistically significant differences were reported (P = ns). Furthermore, no significant differences in systolic or diastolic blood pressure were noticed during the different A-V delays. Mean flow values as recorded for each patient at different A-V delays are reported in Fig. 1.

All patients involved in study 1 and 2 remained hemodynamically stable during the procedure, and upon transfer to the ICU. No perioperative AMIs were reported.
4. Discussion

Intraoperative graft patency verification should be considered as a precious technology to include in the armamentarium already available to the modern cardiac surgeon.

Unfortunately skepticism and misinformation persist in the surgical community and the large majority of cardiac surgeons are still reliant on the tactile sense of their fingertips to evaluate quality and flow of their grafting [6].

Although performed in a limited group of patients, our study has emphasized the importance of intraoperative flow measurement not only in testing patency of coronary anastomosis but also in correctly guiding perioperative management (i.e. cardiac pacing) to achieve ideal hemodynamics and consequently maximal graft flows.

Electrical conduction disturbances may frequently occur after CABG as a result of mechanical problems or ischemic/reperfusion injury. To optimize hemodynamics, epicardial pacing may be required following CABG. Bicameral pacing has been proved to be the most physiological pacing mode [7]. Although it has been demonstrated that A-V sequential pacing may increase atrial priming of the left ventricular end diastolic pressure and consequently allow for an increase in cardiac output up to 25% [8], benefits in terms of increased bypass grafts performance have never been investigated.

As shown in our first study, improvement in systemic hemodynamics during DDD versus VVV pacing does also permit to achieve optimal myocardial perfusion via the newly constructed grafts. Increment in graft flow averages 6 ml/min and can arrive to a maximum of 20 ml/min.

On the basis of these findings, DDD mode should be preferred in patients requiring pacing immediately after CABG in order to allow for maximal reperfusion of the previously ischemic myocardium via the grafts.

Moreover, an ideal or optimal A-V delay during perioperative DDD pacing has never been proposed. In our second study we have tried to define the most appropriate A-V delay by using conduit flow as a hemodynamic index in patients requiring sequential pacing post CABG.

Interestingly, although systemic hemodynamics do not seem to be influenced by the A-V delay value, coronary grafts flows achieve an optimal level at 175 ms. of A-V delay and a minimum level towards 25 ms. of A-V delay. Although these findings are limited to a small number of patients and differences did not achieve statistical significance, it could be suggested that, in patients requiring DDD pacing, maximal coronary grafts flow may be obtained when maintaining an A-V delay in the 175 ms range.

As already emphasized, the importance of intraoperative coronary grafts flows findings is continuously increasing as a result of the technological improvements in the flow measurement technology. The introduction of ultrasound-based systems has revolutionized the flow measurement field. The term ultrasound has a generic definition that includes two different methods: Doppler and TTFM. The two systems rely on different properties of the ultrasound waves and, although the Doppler methods have shown good reliability both in vivo and in vitro [4], the TTFM technology offers many important advantages and is the most accurate system for intraoperative verification of coronary graft patency [9–11]. In the present studies we have adopted a TTFM device whose principles of functioning have been already described above. In our experience, the TTFM device is very easy to use and requires no more than 30 s per measurement. No complications resulted from the use of this flowmeter device. The flowmeter provides not only an absolute value expressed as ml/min but gives also a flow curve that summarizes the variations of graft flow during the different phases of the cardiac cycle. Because coronary graft flow is mainly diastolic, it is important to adopt an adequate modality of pacing that could allow for good diastolic filling and pressure without compromising the systolic performance.

5. Conclusion

Intraoperative graft patency verification and coronary grafts flow detection should be used to testify for a successful intraoperative myocardial revascularization and to guide a safe perioperative hemodynamic performance. Graft flow findings are not solely an anastomosis status indicator, but also a useful index for the patient...
hemodynamic condition. Appropriate intraoperative evaluation of coronary grafts flows may provide an extra tool to correctly direct supportive measures such as cardiac pacing modalities after CABG.

References