Haemodynamic changes during beating heart coronary surgery with the ‘Bristol Technique’

Malcolm P.R. Watters, Raimondo Ascione, Ian G. Ryder, Franco Ciulli, Antonis A. Pitsis, Gianni D. Angelini*

Bristol Heart Institute, Bristol Royal Infirmary, Bristol, BS2 8HW, UK

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Abstract

Objectives: Optimal exposure and stabilization of the target coronary vessel is essential to allow the construction of a precise coronary anastomosis during off pump coronary surgery. However, this might be achieved at the expense of significant haemodynamic deterioration, particularly while grafting the circumflex and the posterior descending coronary arteries. The present study was designed to assess the haemodynamic changes with the beating heart positioned for grafting the three main coronaries. Methods: Twenty-nine consecutive patients (21 male, mean age 62.6 ± 7.1 years) undergoing off pump coronary surgery were enrolled in the study. Three different surgical settings of exposure and stabilization were used according to the site of anastomosis: left anterior descending (LAD ± set-up 1; n = 29), posterior descending (PDA ± set-up 2; n = 15), and circumflex (Cx ± set-up 3; n = 21) coronary arteries. Haemodynamic measurements were recorded before any cardiac manipulation (baseline) in set-ups 1, 2 and 3, and immediately after the completion of each distal anastomosis with the heart returned to its anatomical position. Results: There were no marked changes in heart rate (HR) and systemic mean arterial pressure during the construction of the anastomoses for any of the three surgical settings. Set-up 1 (LAD) showed a decrease of 15.5% in stroke volume (SV) and an increase of 9% in pulmonary capillary wedge pressure (PCWP) compared to baseline (both P < 0.05), with all the other haemodynamic parameters remaining unchanged. Set-up 2 (PDA) showed a marked decrease in SV and cardiac index (CI), and an increase in central venous pressure (CVP) when compared to baseline (all P < 0.05). The most extensive changes were observed in set-up 3 (Cx) with a considerable reduction in SV and CI, and an increase in central venous pressure (CVP) when compared to baseline (all P < 0.05). Most extensive changes were observed in set-up 3 (Cx) with a considerable reduction in SV and CI, and an increase in CVP, PCWP, pulmonary arterial pressure, and systemic vascular resistance index (all P < 0.05). These haemodynamic changes were transient and totally recovered after the heart was returned to its anatomical position. Conclusions: Exposure and stabilization of the three main coronary arteries during beating heart surgery does not produce any appreciable change in systemic blood pressure and HR. The haemodynamic deterioration observed during the construction of the circumflex and posterior descending coronary arteries distal anastomoses is transient and well tolerated with no adverse clinical events.

Keywords: Off pump coronary surgery; Haemodynamics; Monitoring; Cardiac output

1. Introduction

Off pump coronary artery bypass surgery (OPCAB) via a median sternotomy [1] is becoming increasingly popular with encouraging reports in the literature on clinical, angiographic and cost-effective outcomes [2–8]. However, concerns have been expressed regarding the haemodynamic deterioration observed when the beating heart is positioned and stabilized for grafting the circumflex (Cx) and the posterior descending (PDA) coronary arteries. A range of surgical strategies of exposure and stabilization of the beating heart have been developed both in animal experiments and in humans [9–14]. Furthermore, techniques of mechanical support of the left and right ventricles have been proposed during OPCAB surgery of the posterior wall to prevent haemodynamic deterioration [15,16].

The aim of the present study was to monitor the haemodynamic status during OPCAB, with the heart exposed and stabilized, while grafting the three main coronary artery systems.

2. Methods

2.1. Patient selection

Eligibility for surgery was based on the medical history and a recent coronary angiogram. Exclusion criteria
included: left ventricular ejection fraction of less than 40%, recent myocardial infarction (MI) (<1 month), re-operation, and single vessel coronary disease. No exclusion criteria were applied with relation to the anatomic position and size of the coronary vessel to be grafted.

The study was approved by the United Bristol Healthcare Trust Ethics Committee and all patients gave informed consent.

2.2. Anaesthetic technique

The anaesthetic technique consisted of premedication with benzodiazepine, and induction with intravenous infusion of propofol at 3 mg/kg/h combined with fentanyl (10–20 μg/kg). Neuromuscular blockade was achieved with 0.1–0.15 mg/kg pancuronium bromide or vecuronium, and the lungs were ventilated to normocapnia with air and oxygen (45–50%) without positive end expiratory pressure. After induction of anaesthesia, a quadruple lumen central venous catheter and pulmonary artery flotation catheter (PAC) (Ohmeda, Erlangen, Germany) were inserted into the right internal jugular vein. The PAC was then connected to the cardiac output module of the patient monitor (Solar 8000 Patient Monitor, Marquette Medic. Systems, Milwaukee, WI, USA). Cardiac output measurements were carried out using intermittent 10 ml boluses of iced dextrose 5% solution at a temperature of 4–8°C, as measured by the in-line-injectate sensor of the thermodilution injectate set.

End tidal CO₂ was maintained between 35 and 40 mmHg throughout. Heparin (100 IU/kg) was administered prior to the start of the first anastomosis to achieve an ACT of 250–350 s. On completion of all anastomoses, protamine sulphate was given to reverse the effect of heparin and return the ACT to less than 120 s.

2.3. Surgical technique

Following median sternotomy the pericardium is opened longitudinally. Traction sutures are not applied because they lift the whole pericardial cavity, reducing the freedom of movement of the heart, which is needed for subsequent manipulations. A half-folded swab (12 cm wide and 70 cm long) is snared to the posterior pericardium (using a single stitch 0-silk suture), halfway between the inferior vena cava and the left inferior pulmonary vein. Traction is applied on the two limbs of the swab and the snare. These are then fixed to the surgical drapes to facilitate exposure of the target coronary vessels which are then stabilized with a reusable stainless steel stabilizer (Abbey Surgical Limited, Mitcham, Surrey, UK) developed at our institution. This stabilizer can be applied to any flat-surfaced sternal retractor, and positioned depending on the coronary artery to be grafted. All anastomoses are performed with an intra-coronary shunt to ensure distal perfusion (Flothru Biovascular Inc., St. Paul, MN, USA). Visualization is enhanced by using a surgical blower-humidifier (Abbey Surgical Limited, Mitcham, Surrey, UK) with a quarter inch PVC gas line and fluid administration set connected to a regulated gas source (CO₂).

2.4. Surgical set-up of the beating heart according to the coronary vessel to be grafted

2.4.1. Set-up 1 – LAD (Fig. 1)

The operating table is kept in a flat position. Both limbs of the swab are pulled to the left towards the assistant side to rotate the heart anti-clockwise. The snare is pulled caudally to lift the pericardium and consequently the heart apex upward. The ends of both swab and snare are then clipped to the surgical towel. The stabilizer is fastened tightly to the caudal part of the left arm of the sternal retractor, and the foot is positioned on the target coronary site. Following temporary proximal occlusion of the vessel with a 4-0 Prolene and a soft plastic snugger, the arteriotomy incision is made, the appropriate sized intra-coronary shunt inserted, the snare released, and the anastomosis performed.

2.4.2. Set-up 2 – PDA (Fig. 2)

The operating table is positioned in Trendelenburg at about 20° and rotated towards the surgeon (10–20°) to increase venous return and facilitate the spontaneous anti-clockwise rotation of the beating heart to the right. The two limbs of the snared swab are positioned to hold the heart with its apex upward, and are fixed to the surgical drapes at the top end of the sternotomy incision. The plastic snare is pulled caudally and fixed to the left of the midline. The stabilizer is placed at the cranial end of the right arm of the sternal retractor, whilst its foot is directed downward to stabilize the exposed PDA.

2.4.3. Set-up 3 – Cx branches (Fig. 3)

The operating table is positioned at 20° Trendelenburg and rotated as far as possible towards the surgeon (30–40°) to increase the venous return and to assist the anti-clockwise spontaneous rotation of the heart towards the right. The two limbs of the snared swab are positioned distally to the branches of the Cx to be grafted and fixed to the towel on the side of the surgeon. The plastic snare is pulled caudally and fixed to the left of the midline. In this way the apex of the heart is rotated upwards and to the right, facing the surgeon. The stabilizer is then positioned on the cranial end of the right arm of the sternal retractor, while its foot is directed downward to stabilize the exposed branches of the Cx.

2.5. Haemodynamic and clinical monitoring

Heart rate (HR), mean systemic arterial pressure (MAP), central venous pressure (CVP), mean pulmonary arterial pressure (PAP), pulmonary capillary wedge pressure (PCWP), cardiac index (CI), stroke volume (SV), systemic vascular resistance index (SVRI), and pulmonary vascular resistance index (PVRI) were recorded. Each data set consisted of the average of three taken over approximately 3 min. To minimize the influence of variations of manual
injection on the accuracy of the thermodilution measure-
ments, the same anaesthetist always carried out the bolus
injections [17].

Haemodynamic monitoring was performed according to
the following timing:
(a) Baseline (heart in its natural position): 5 min before
any cardiac manipulation to expose and stabilize the target
vessel.
(b) Five minutes into the construction of each distal
coronary anastomosis, with the heart exposed and stabilized
for set-ups 1, 2 and 3, respectively.
(c) On completion of each coronary anastomosis, with the
heart back in its anatomical position.

Finally, intraoperative and postoperative data, including
complications and adverse events, were recorded. Clinical
diagnostic criteria for perioperative MI were new Q waves
of greater than 0.04 ms, and/or a reduction in R waves
greater than 25% in at least two leads. Chest infection was
deﬁned as the presence of purulent sputum associated with
fever and requiring antibiotic therapy according to positive
sputum culture.

2.6. Management of pre- and postoperative medications

Preoperative medications including β-blockers, diuretics,
anti-hypertensives, and calcium channel blockers were
routinely omitted on the day of surgery. On the ﬁrst post-
operative day, in accordance with the intensive care unit
protocol (HR > 55 beats/min, systolic blood pressure >
110 mmHg), β-blockers and anti-hypertensive drugs were
restarted.

2.7. Statistical analysis

Continuous data are presented as the mean ± SD for
baseline values and as the difference of the mean with
lower and upper 95% conﬁdence intervals for the
exposed-stabilized and released positions for each haemo-
dynamic variable. Paired Student’s t-test was used for the
analysis. A P value of <0.05 was considered a statistically
signiﬁcant difference. Analyses were performed using Stat-
view (SAS Institute Inc, Cary, NC, USA).

3. Results

Preoperative characteristics are shown in Table 1. All
patients completed the study without any technical difﬁculty
during the construction of the anastomoses and no need for
intraoperative inotropic support. All the preoperatively
intended grafts were performed. Construction of the anasto-
moses took a mean of 10 min (range 8–15 min). Haemody-
namic recordings were completed for 29 LAD, 15 PDA, and
21 Cx anastomoses. The haemodynamic changes of each
set-up are summarized in Tables 2–4, respectively. Overall,
the comparison between the haemodynamic status of the
beating heart at baseline and after release from set-ups 1,
2 and 3 did not show signiﬁcant differences for any of the

Fig. 1. Set-up 1 – LAD (as seen from the operating surgeon side). The two
limbs of the swab are clipped to the surgical drapes on the assistant side
whereas the plastic snare (*) is pulled caudally in the direction of the
abdominal midline.

Fig. 2. Set-up 2 – PDA (as seen from the operating surgeon side). The ends
of the swab are ﬁxed to the drapes at the top of the sternotomy incision
whereas the plastic snare (*) is ﬁxed to the left of the abdominal midline.

Fig. 3. Set-up 3 – Cx (as seen from the operating surgeon side). The ends
of the swabs are ﬁxed to the surgical drapes on the surgeon side whereas the
plastic snare (*) is positioned to the left of the abdominal midline.
investigated variables, with the exception of an increase in HR and PVRI in set-ups 1 and 2, respectively. No difference in HR and MAP were observed between the baseline and the exposed-stabilized position in any of the three set ups.

3.1. Set-up 1

During the exposure and stabilization of the LAD there was an increase in PCWP \((P = 0.009)\) and a decrease in SV \((P = 0.0002)\) when compared with baseline values (Table 2).

3.2. Set-up 2

Exposure and stabilization of the PDA produced a considerable increase in CVP \((P = 0.009)\), PAP \((P = 0.047)\), and PCWP \((P = 0.01)\) and a decrease of both CI \((P = 0.0001)\) and SV \((P = 0.0004)\) when compared with baseline values (Table 3).

4. Discussion

OPCAB through a median sternotomy [1–8] is gaining popularity because of its potential for complete multi-vessel revascularization [8]. Exposing posterior branches by displacing the beating heart has been reported to produce haemodynamic compromise both in animals [9,10] and humans [18], due to changes in ventricular geometry and valve competence [9]. Regional myocardial dysfunction has also been related to the temporary occlusion of the target coronary vessel [19,20] when this technique is used to perform the anastomosis.

Several strategies have been proposed to limit the haemodynamic deterioration observed during the construction of distal anastomoses on the posterior wall during OPCAB surgery. Some have advocated haemodynamic support including inotropes, volume loading, or increasing venous return [10,21]. Others have focused on improvements during surgical manipulation of the beating heart to facilitate the exposure of the coronary targets, while avoiding excessive compression and subsequent haemodynamic failure [9,10,12,13]. Finally, mechanical support of the left and right ventricles has been proposed to prevent haemodynamic deterioration while grafting the posterior wall on the beating heart [15,16].
In this study we describe our routine technique of positioning the heart and stabilizing the target coronary vessel for OPCAB, and present the haemodynamic changes observed while grafting the three coronary artery systems. Exposure and stabilization of the LAD seemed to have only minimal effects on the haemodynamics with a minor decrease in SV and an increase in PCWP. Exposure and stabilization of PDA and Cx produced more extensive haemodynamic changes, with a reduction in CI of 16.6 and 28%, respectively.

The increase of both SVRI and PVRI observed in set-ups 2 and 3 could be partially explained by the marked decrease in SV and increase in PCWP. Exposure and stabilization of PDA and Cx produced more extensive haemodynamic changes, with a reduction in CI of 16.6 and 28%, respectively.

It is difficult to interpret the clinical significance of the haemodynamic changes observed in the present study, as they were transient and completely reversed after the anastomoses, and no postoperative complications were observed in any of the patients. Previous studies undertaken at our institution have also demonstrated that this surgical technique is not associated with neurological, renal or myocardial injury as assessed by serum S-100 protein, N-acetyl-β-glucosaminidase and troponin I release, respectively [2,4,22].

Contrary to previous reports [9,10,14] we did not find any appreciable changes in MAP or HR during the construction of the anastomoses in any of the three settings. This could be ascribed to the improvements we have made over time to our surgical technique. The use of a swab snared to the posterior pericardium facilitates the lifting and the rotation of the heart while avoiding direct compression of the cardiac chambers. Opening of the right pleura might further reduce the compression of the right ventricle, although this was not required in any of the patients studied.

The routine use of an intra-coronary shunt has been of most value in avoiding temporary regional dysfunction [23] observed after the occlusion of the target coronary vessel.
Table 5
Postoperative outcome*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patient (n = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>0</td>
</tr>
<tr>
<td>MI</td>
<td>0</td>
</tr>
<tr>
<td>Low cardiac output</td>
<td>0</td>
</tr>
<tr>
<td>IABP</td>
<td>0</td>
</tr>
<tr>
<td>Neurological complication</td>
<td>0</td>
</tr>
<tr>
<td>Inotropic requirement</td>
<td>1</td>
</tr>
<tr>
<td>Supraventricular arrhythmias</td>
<td>3</td>
</tr>
<tr>
<td>Intubation time (h)</td>
<td>4.3 ± 1.3</td>
</tr>
<tr>
<td>Chest infection</td>
<td>2</td>
</tr>
<tr>
<td>Total blood loss (ml)</td>
<td>550 ± 332</td>
</tr>
<tr>
<td>ICU length of stay (h)</td>
<td>20.5 ± 8.6</td>
</tr>
<tr>
<td>Hospital length of stay (days)</td>
<td>5.1 ± 1.7</td>
</tr>
</tbody>
</table>

* Data are presented as the mean ± SD. MI, myocardial infarction; IABP, intra-aortic balloon pump; ICU, intensive care unit.

[19,20], and the potential injury related to the use of the sutures encircling and snaring the coronary vessel [24]. Furthermore, this has the added advantage of ensuring good visibility of the coronary edges and prevents catching the back wall of the coronary artery. The Trendelenburg manoeuvre and the rotation of the operating table facilitated blood redistribution by increasing venous return, and allowed the spontaneous anti-clockwise rotation of the beating heart [9,12]. Finally, the use of a sturdy stainless steel mechanical stabilizer, by providing a firm grip, reduced the need for excessive tension on the swab and in doing so minimized the compression of the heart.

The sequence of grafting might influence the haemodynamic status during the construction of the subsequent grafts. The results of the present study were obtained grafting first the LAD to optimize the perfusion to the most important coronary system, followed, when required, by PDA and Cx, respectively.

A limitation of the present study is that hearts with moderate to poor left ventricle (LV) function were excluded. This was done on purpose to investigate the exclusive effect of our technique of OPCAB on haemodynamics. However, more than 50 patients with impaired LV function have been operated on with OPCAB surgery at our institution over the last 2 years.

In conclusion, complete myocardial revascularization on the beating heart can be performed without changes in systemic blood pressure and HR. The haemodynamic deteriorations observed during construction of the distal anastomoses are transient and well tolerated with no adverse clinical events. Complete haemodynamic recovery is obtained on returning the heart to its anatomical position.

Acknowledgements

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References


