How to Do It

The Use of Skin Plethysmography to Monitor Counter-Pulsation by the Intra-Aortic Balloon Pump

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Abstract

Skin plethysmography was used to monitor counter-pulsation by the intra-aortic balloon pump in 30 patients, 19 of whom came to coronary artery bypass grafting for pre-infarction angina.

Skin plethysmography provided a reliable display of the arterial waveform and permitted correct adjustment of the timing and rate of balloon inflation and exhaust to produce maximum augmentation of the systolic peak pressure and a controlled drop in the end-diastolic pressure. The technique proved simple, safe and without the risks that may be associated with long-term arterial cannulation.

Introduction

Counter-pulsation by the intra-aortic balloon pump (IABP) is now widely used in the management of patients with the preinfarction syndrome (1) and of early cardiogenic shock refractory to medical measures (2), as well as in the post-operative support of high-risk patients after cardiopulmonary bypass (3). Counter-pulsation permits unhurried investigation of the patient with acute coronary insufficiency, enabling surgery to be undertaken as a planned rather than emergency procedure. In patients with myocardial infarction complicated by mitral regurgitation, an acquired ventricular septal defect or the development of a cardiac aneurysm, counter-pulsation permits recovery from the effects of compromised myocardial function so that the patient can await surgery in a healthier state with greater expectation of recovery. For these reasons some patients are now supported by IABP counter-pulsation for several days or weeks, and at the Charing Cross Hospital the mean number of hours that patients spend on the balloon pump has increased dramatically since the device was first used at this hospital (Table 1).

A non-invasive means of monitoring the effects of the balloon pump is therefore desirable to minimize the complications (4) associated with arterial cannulation for such long periods. We have recently used skin plethysmography to monitor the arterial waveform in 30 patients on the balloon pump, and have found that a simple digital plethysmograph enables effective counter-pulsation to be obtained and checked regularly by the nursing staff. As a result of this initial experience, digital plethysmography is now our standard technique for monitoring the arterial waveform in patients on IABP assist in whom an arterial cannula is not required for other reasons, such as the continuous display of the calibrated arterial pressure.

Method

Thirty patients referred by the Cardiology Depart-
TABLE 1
Annual number of patients, mean number of hours and early survival on the balloon pump at the Charing Cross Hospital 1974-1979

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of patients</th>
<th>Mean number of hours</th>
<th>Survival number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>7</td>
<td>60</td>
<td>1 (14%)</td>
</tr>
<tr>
<td>1975</td>
<td>14</td>
<td>108</td>
<td>5 (36%)</td>
</tr>
<tr>
<td>1976</td>
<td>22</td>
<td>168</td>
<td>11 (50%)</td>
</tr>
<tr>
<td>1977</td>
<td>18</td>
<td>276</td>
<td>10 (56%)</td>
</tr>
<tr>
<td>1978</td>
<td>35</td>
<td>168</td>
<td>20 (57%)</td>
</tr>
<tr>
<td>1979</td>
<td>30</td>
<td>312</td>
<td>21 (70%)</td>
</tr>
</tbody>
</table>

ment at the Charing Cross Hospital for IABP counter-pulsation had their arterial waveform monitored by skin plethysmography using one of three devices marketed by Datascope which are respectively strapped to the wrist, clipped on the ear-lobe or lightly clamped on the thumb (Figure 1). Each device contains a diode emitting infra-red light, and this is reflected within the skin and detected by a sensor beside the diode. The mechanism is shielded from external interference (by the main power supply to room lighting, for instance) by a small rubber cuff around the sensor and by the bulk of the device itself. It is electrically isolated and therefore safe for the patient.

On referral for balloon-pumping, each patient was transferred to the Intensive Care Unit where precordial electrocardiograph leads were applied and a peripheral intravenous cannula inserted for clear fluid infusion and the injection of drugs. The patient received 100 i.u. heparin/kg body weight, intravenously. Under local anesthetic the common femoral artery was exposed through a vertical groin incision. A Datascope 35 cc intra-aortic double-chambered balloon catheter was inserted through an 8 mm Dacron sleeve sutured to a vertical arteriotomy in the common femoral artery, and connected in tandem to a Datascope slave chamber containing a balloon which was then primed with 52 cc carbon dioxide. The slave chamber was compressed within its safety chamber by pulses of compressed air from a modified Kantrowitz pressure console (5) activated by the R wave of the patient’s electrocardiogram. The position of the balloon catheter in the descending aorta was confirmed by a penetrated antero-posterior chest X-Ray.

The skin plethysmograph was applied to the patient’s thumb, wrist or ear-lobe according to the device under study and connected to the input of a Datascope 862 oscilloscope which displayed both the arterial waveform and the patient’s electrocardiogram. A calibrated reference trace from a Datascope Type P2 pressure module was also available for direct monitoring of the arterial pressure when arterial cannulation had been performed (during cardiac surgery, for instance).

The timing, duration, volume and rate of filling of the safety chamber were controlled by manual settings on the balloon pump console which was operated by the nursing staff to produce an arterial waveform illustrated in Figure 2. Special care was taken to augment

FIGURE 1. The digital skin plethysmograph.

FIGURE 2. The arterial waveform in a patient on the intra-aortic balloon pump, obtained by (a) arterial cannulation and (b) digital skin plethysmography. The upper trace is the simultaneous electrocardiogram.

TABLE 2
Analysis of 30 patients managed by IABP monitored with skin plethysmography

<table>
<thead>
<tr>
<th></th>
<th>(20 patients)</th>
<th>(10 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-INFARCTION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cardiac surgery</td>
<td>19</td>
<td>9</td>
</tr>
<tr>
<td>normal coronary arteriography</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>POST-INFARCTION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cardiogenic shock</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>persistent pain</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
the peak systolic arterial pressure by a presumptive 30 mm Hg and to produce a sharp drop in end-diastolic arterial pressure of about 10 mm Hg, as confirmed on tracings obtained by arterial cannulation. The plethysmograph was removed when a satisfactory waveform was obtained, and replaced at half-hourly intervals to check the waveform throughout the period of balloon-pump assist.

Results

Of the thirty patients referred for balloon-pumping, 20 had persistent chest pain with electrocardiographic changes suggestive of impending myocardial infarction. Nine patients were in early cardiogenic shock resistant to medical treatment, and one patient had severe chest pain following myocardial infarction (Table 2).

Of the 20 patients with presumptive pre-infarction syndrome, 19 had severe coronary arterial disease on coronary arteriography and eventually came to aorto-coronary bypass grafting with autogenous long saphenous vein. Fifteen of these patients survived to leave the hospital.

Of the 10 patients requiring balloon-pump assist after established myocardial infarction, four died despite this support, and six survived removal of the balloon-pump, two then being transferred back to the original referring hospital. The remaining four survivors are currently being followed up, having been discharged from the hospital during the first six months of 1979.

In all 30 patients, skin plethysmography proved a satisfactory technique of monitoring the arterial waveform and thus the effects of counter-pulsation which were independently confirmed by the relief of chest pain and the restoration of normal mental function, peripheral tissue perfusion and blood pressure. Arterial cannulation was used to monitor the arterial blood pressure in all patients during cardio-pulmonary bypass and in those patients in shock in whom poor peripheral tissue perfusion produced an inadequate initial record with the skin plethysmograph, though this was satisfactory as soon as effective counter-pulsation was established. In five patients, simultaneous records of the waveform obtained by arterial cannulation and by skin plethysmography were compared, and in each case could only be distinguished by mild damping of the peaks and troughs on the plethysmographic trace (Figure 2). If the dicrotic notch was evident on the normal arterial waveform, adequate counter-pulsation could be produced and monitored by timing the inflation of the balloon to augment the systolic peak at the moment the aortic valve closed; the balloon exhaust cycle was adjusted to produce a sharp fall in end-diastolic pressure followed by a rapid increase in arterial pressure as spontaneous systolic ejection occurred.

Discussion

The increasing period of time many patients now spend on the balloon pump (Table 1) warrants a non-invasive technique of monitoring the arterial waveform because arterial cannulation carries the risks of arterial injury, occlusion and embolism as well as local infection and the possibility of the cannula being dislodged. A flushing system is necessary and requires a pressurized bag, tubing and support stand and frequent attention by trained personnel. Arterial cannulation must usually be performed by a doctor and if it is used to obtain blood samples cannula may become plugged with fibrin. These risks are avoided by the use of finger plethysmography.

Skin plethysmography is not quantitative, does not provide a continuous record of the arterial pressure and cannot be used in severe shock or in very thin patients where the waveform is inadequate to monitor the effects of the balloon pump. The device must be removed between recordings to reduce the risk of pressure necrosis in sedated patients or those in whom there is poor tissue perfusion. Although generally satisfactory, the waveform is occasionally affected by low cycle interference from other sources (such as fluorescent-lighting) and several minutes must be allowed at each reading for the trace to stabilize.

Skin plethysmography is easy to perform and can be used by nursing staff at frequent intervals (half-hourly, for instance) as easily as taking the blood pressure. There is minimal risk to the patient, and the device is

| Time spent on intra-aortic balloon pump counter-pulsation, and period monitored by skin plethysmography, in 30 patients |
|---|---|---|---|---|---|---|
| | Less than 24 hrs | 1-3 | 4-7 | 8-14 | 15-21 | 22+ |
| BALLOON PUMP | 2 | 1 | 7 | 7 | 7 | 6 |
| PLETHYSMOGRAPHY | 5 | 2 | 11 | 6 | 3 | 3 |
simple and takes up little room in an area where space
is at a premium. Our experience indicates that it can
be a satisfactory and safe means of monitoring the ef-
fect of balloon pump counter-pulsation on the arterial
waveform, especially in patients requiring this form of
cardiac assist for long periods (Table 3).

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