Single lead atrial synchronised pacing in patients with cardiogenic shock after acute myocardial infarction

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Summary A pacing system requiring only a single lead was used to establish atrial synchronised pacing in eight patients with complete atroventricular block and cardiogenic shock following acute myocardial infarction. Spontaneous atrial activity was sensed through electrodes positioned on the pacing lead and used to trigger ventricular demand pacing. A normal atroventricular relation could be established in each of these critically ill patients without the complexity of inserting and finding a stable position for an additional atrial sensing lead.

Atrial synchronised pacing at the spontaneous sinus rate had distinct haemodynamic advantages compared with conventional ventricular pacing at 100 beats/min. Mean cardiac output for the group was 3.3 l/min with atrial synchronised pacing compared with 2.6 l/min with conventional pacing, a significant difference of 27%. Peak systolic pressure averaged respectively 91 and 73 mm Hg in the two pacing modes. With conventional ventricular pacing a pronounced phasic alteration in blood pressure was observed, dependent on the altering relation of the paced beats to spontaneous atrial activity. Atrial synchronised pacing abolished this effect and resulted in a stable blood pressure at or above the peak pressure achieved with conventional pacing.

Atrial synchronised pacing with a single lead system can be established rapidly. This mode of pacing has appreciable and significant haemodynamic superiority over conventional ventricular pacing in patients with cardiogenic shock and atroventricular block following acute myocardial infarction.

Most patients who develop complete atroventricular block following prolonged myocardial ischaemia have inferior infarction associated with failure of conduction at the level of the atroventricular node. The escape rhythm, commonly of junctional origin, is reliable, and ventricular pacing is not usually required. In contrast, the majority of patients with anterior infarction (and only a few with inferior infarction) complicated by complete atroventricular block have unreliable escape foci of ventricular origin, having sustained extensive myocardial necrosis. Pacing is mandatory, but the prognosis remains poor because of associated cardiogenic shock.

Under these circumstances the haemodynamic advantages of re-establishing atroventricular synchronisation may be particularly important. But the difficulty of inserting and finding a stable position for a second (atrial) lead under emergency conditions has been a major factor in hindering the widespread adoption of this “physiological” mode of pacing. Moreover, the value of an atrial contribution to cardiac output in patients with raised left ventricular filling pressure is controversial. Small haemodynamic benefit may be thought not to justify the complexity of the procedure.

We report the use of a pacing system (prototype Telectronics Sussex AV pacemaker), initially developed at Sussex University, which requires only a single lead to achieve atrial synchronised ventricular pacing. The potential advantages of this form of pac-
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ing for patients with complete heart block and card-
diogenic shock have been assessed by comparing
haemodynamic variables during conventional and
atrial synchronised pacing.

Patients and methods

Measurements were made in eight patients during
emergency pacing following acute myocardial infar-
tion. All had cardiogenic shock with peripheral vaso-
constriction, a systolic blood pressure of less than 90
mm Hg, and anuria. The ages of the men and two
women ranged from 57 to 76 (mean 63) years. The site
of infarction was inferior in four, anterior in two, and
indeterminate in two. The indication for pacing was
asystole in three patients or complete atrioventricular
block with a heart rate of less than 50 beats/min in the
remaining five (four of whom had had ventricular
fibrillation).

In six of the patients a 6 French quadropolar tem-
porary pacing lead (USCI) was inserted percutane-
ously via a subclavian vein with the tip positioned
near the apex of the right ventricle. The lead has a
distal pole and three others 10, 15, and 20 cm from
the tip. The indifferent pole for both pacing and sens-
ing was the most proximal and lay in the superior vena
cava. Electrograms were recorded from both poles
which lay within the atrium: the pole detecting the
larger atrial signal was selected for unipolar atrial
sensing. In the remaining two patients a pacing wire
with a choice of four atrial poles was used.

A prototype Teletronics Sussex AV synchronous
pacemaker was connected to the common indifferent,
the ventricular, and the selected atrial pole. The
pacemaker functions as a unipolar or bipolar atrial
synchronised ventricular inhibited unit. The stimulus
frequency is governed by atrial depolarisation signals
in the atrial electrogram (corresponding to the P
waves of the surface electrocardiogram), but provision
is made for continued safe pacing if the atrial rate
should become unacceptably slow or fast. The unit
functions as a ventricular demand pacemaker if atrial
sensing is switched off. In this mode, stimulus fre-
quency is determined by the “standby rate” setting,
which also provides the “escape” rate during unex-
pected sinus slowing or failed atrial sensing. The
upper rate limit is adjustable to a maximum of 150
beats/min. Above the upper rate limit each atrial
depolarisation will cause ventricular pacing with
increasing delay until eventually the stimulus follow-
ing a P wave is blocked mimicking spontaneous
Wenckebach periods.

A triple lumen thermodilution Swan-Ganz catheter
(Edwards Laboratories Inc) was inserted through the
same subclavian vein. Cardiac output was measured
by the thermodilution technique (Edwards
Laboratories Inc, cardiac output computer number
9520) using an OMP injector gun to inject 10 ml of 5%
dextrose at room temperature. Five readings were
recorded at each setting. Solitary aberrant readings
were rejected. In one patient cardiac output mea-
surements were not available because of a computer
fault.

A short Teflon cannula inserted into the radial
artery was used to record blood pressure. All pres-
ures were measured with reference to the sternal
angle using Statham P23Db transducers and were
recorded together with an electrocardiogram on a
fibrooptic medical recorder (Cambridge Scientific
Instruments Ltd). If phasic variation was consid-
erable an average was taken of peak and trough mea-
surements.

Atrial synchronised pacing, with heart rate control-
led by sinus activity, was established in all the
patients, and haemodynamic measurements were
recorded once these had stabilised. The patients were
then paced in conventional demand mode at 100
beats/min for at least five minutes, and the
haemodynamic measurements were repeated.

The procedure was fully explained to all the
patients, but signed formal consent was not sought
because haemodynamic monitoring is performed
routinely in our unit for patients who are critically ill
with cardiogenic shock. Student’s t test for paired
data was used for statistical comparisons.

Results

The Table summarises the principal haemodynamic
effects of conventional ventricular pacing at 100
beats/min and atrial synchronised pacing at the spone-
taneous heart rate. Fig. 1 shows the change in cardiac
output and stroke volume in the seven patients from
whom measurements were obtained. In every case
cardiac output was higher with atrial synchronised
pacing, the mean increment for the group being 27% (p < 0.005). In two patients the synchronised pacing
rate rose to 130 beats/min, and consequently their
stroke volumes fell slightly.

Conventional pacing caused a pronounced phasic
variation in systemic blood pressure (Fig. 2) depen-
dent on the altering relation between atrial contrac-
tion and paced beats. We also noticed a tendency for
the arterial pressure to continue to fall during the
period of conventional pacing. Atrial synchronised
pacing abolished the phasic variation and resulted in a
stable pressure at or above the peak reading recorded
during conventional pacing. Systolic pressure was
augmented more (73–91 mm Hg) than diastolic press-
ure (47–54 mm Hg), and consequently pulse pres-
sure was increased (26–37 mm Hg).

Mean right atrial pressure fell significantly from 10
Table  Comparison of haemodynamic variables during standard ventricular pacing (VVI) at 100 beats per minute and atrial synchronised pacing (VDD). Values are means ± SEM.

<table>
<thead>
<tr>
<th>Haemodynamic variables</th>
<th>VVI</th>
<th>VDD</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>73±6</td>
<td>91±8</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>47±3</td>
<td>54±3</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Systemic vascular resistance (units)</td>
<td>23.9±2.0</td>
<td>21.9±1.4</td>
<td>NS</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>100±0</td>
<td>105±13</td>
<td>NS</td>
</tr>
<tr>
<td>Cardiac output (l/min)</td>
<td>2.6±0.8</td>
<td>3.3±0.8</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Stroke volume (ml)</td>
<td>26±3</td>
<td>33±4</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Right atrial pressure (mm Hg)</td>
<td>10±2</td>
<td>5±1</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Pulmonary artery systolic pressure (mm Hg)</td>
<td>28±4.0</td>
<td>32±3.0</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Pulmonary artery diastolic pressure (mm Hg)</td>
<td>19±2</td>
<td>19±2</td>
<td>NS</td>
</tr>
</tbody>
</table>

Pressure was recorded with reference to the sternal angle. (Reference to the mid-chest would require the addition of about 5 mm Hg.)

Discussion

The patients whom we studied were characterised by having cardiogenic shock. Seven of the eight had been resuscitated from ventricular fibrillation or prolonged asystole before pacing was established, and all remained in a critical condition during ventricular pacing. We could not determine the optimal ventricu-
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lar pacing rate in individual patients as prolonged observation in this mode would have caused further haemodynamic deterioration. We chose a rate of 100 beats/min as a standard for comparison with atrial synchronised pacing because this has been shown previously to provide optimal haemodynamic benefit in most patients in heart block following myocardial infarction.13

Our results show that restoration of a normal physiological relation between atrial and ventricular contraction has significant haemodynamic advantages over conventional ventricular pacing in patients with cardiogenic shock following acute myocardial infarction. In every case the haemodynamic benefit was matched by obvious clinical improvement with evidence of better peripheral perfusion and sometimes an improved level of consciousness. Conventional ventricular pacing was associated with a pronounced phasic variation in systolic blood pressure, which was abolished by the restoration of normal atrioventricular relations during atrial synchronised pacing. The improvement in systolic blood pressure was matched by a concomitant increase in cardiac output. The only haemodynamic variable that did not improve consistently during physiological pacing was the raised left ventricular filling pressure (measured indirectly as pulmonary artery end diastolic pressure). A prompt fall would not be expected, however, if the output of both ventricles improved equally.

Unfortunately, despite the demonstrable haemodynamic advantage of atrial synchronised pacing none of the patients in this study regained spontaneous atrioventricular conduction. Their condition remained critical and all the patients subsequently deteriorated and died after periods of atrial synchronised pacing ranging from four hours to six days. In other patients with atrioventricular block complicating anterior infarction, paced before cardiogenic shock had supervened, atrial synchronisation produced similar haemodynamic benefits associated with recovery of conduction and prolonged survival. These patients did not meet the criterion for inclusion in the present report.

The single lead system overcomes important disadvantages of physiological pacing. It is particularly suited for use in patients who are critically ill and least able to tolerate the delay caused by insertion of a second lead. Indeed atrial synchronised pacing was successfully initiated in three patients during cardiopulmonary resuscitation for ventricular standstill. No special skills are required above those necessary for conventional pacing.

The prototype Telectronics Sussex AV synchronous external pacemaker employs sensing circuits using timing, filtering, and signal comparison to separate the atrial and ventricular electrograms. It was possible to sense atrial electrograms down to a nominal 0.1 mV. Because of unstable electrograms, there were occasional instances of failed atrial tracking seen in every patient. The pacemaker then functioned correctly as a conventional pacing unit at the set standby rate. In none of the patients were these failed sensing periods prolonged.

Our experience with the prototype unit has strengthened our belief that atrial synchronised pacing is the most suitable mode for patients with initially impaired myocardial function. The single lead system has shown that the haemodynamic benefits of atrial synchronisation can be achieved without sacrificing simplicity of lead insertion or the speed with which pacing can be initiated.

References

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