CARDIAC OUTPUT DURING HALOTHANE ANAESTHESIA

BY
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The study to be described represents an attempt to demonstrate the effect of halothane anaesthesia on the cardiac output of twelve healthy volunteers who were about to undergo surgery.

The estimation of cardiac output in man is based either on the Fick principle (Cournand and Ranges, 1941) or on the dilution curve (Kinsman, Moore and Hamilton, 1929). The use of the Fick Principle during general anaesthesia is complicated by the fact that the measurement of oxygen consumption during the administration of an inhalational agent is an extremely tedious and difficult procedure; indeed, there is some doubt whether oxygen consumption can ever be measured accurately under such circumstances. It was obvious, therefore, that a dilution curve technique would be preferable and, in practice, the choice lay between the injection of a radio-active isotope such as I$^{131}$ labelled serum albumin (Pritchard et al., 1952), or the use of T-1824 (Evans Blue) dye (Werko, et al., 1949). The main advantage of the radio-active isotope method is the simplicity of procedure, but this is outweighed by the absence of established criteria and by the expense of the equipment required. It was decided, therefore, to use the Evans blue dye dilution technique.

PROCEDURE

Two hours before the patient was due in the operating theatre, 3 grains (200 mg) pentobarbitone was given by mouth, and an hour later 1/100 grain (0.65 mg) of atropine was injected intramuscularly.

On arrival in the anaesthetic room e.c.g. leads were connected to the patient for continuous monitoring throughout the procedure. A stethoscope was placed over the right brachial artery and a sphygmomanometer cuff applied. A superficial vein in the left antecubital fossa was exposed under local anaesthesia (2 per cent lignocaine), through a small incision along the longitudinal axis of the vein. The vein was ligated distally and opened. A small bore polythene catheter was threaded through until its tip was judged to be in the superior vena cava in the vicinity of the right atrium. A slow infusion of normal saline maintained the patency of the catheter. An oximeter was applied firmly to the right ear and the patient given 100 per cent oxygen to breathe through a Magill (Mapleson “A”) attachment, at a flow rate of 6 litres per minute. At this stage a 10-ml blood sample was taken to provide a plasma blank. Ten minutes later the first injection of 10 mg of Evans blue dye was made. The concentration of dye in the arterial blood led to a change in the absorption of light by that blood. This was measured by the ear-oximeter and, after amplification by means of a Cambridge amplifier, was charted by an Evershed-Vignoles pen recorder (Shillingford, 1958). Once the dye dilution curve had settled and a constant tail had been established, the recording was discontinued. The residue of the dye was then withdrawn from the catheter together with a further 15 ml of blood to ensure adequate cleansing. Two further samples, each of 10 ml, were taken; one at 7 minutes and the other at 10 minutes after the dye injection.

Induction with halothane was begun by diverting part of the oxygen flow through a B.O.C. halothane bottle attached to a Boyle’s machine. The concentration of halothane was gradually increased until anaesthesia was adequate. At no time was the concentration of halothane greater than 5 per cent. Induction took approximately 5 minutes and was usually uneventful. Ten minutes later when the patient was stabilized in the second plane of surgical anaesthesia and was breathing a concentration of approximately 2 per cent halothane in oxygen, the next injection of dye was
made. The procedure after the second injection of dye followed exactly that described for the first injection.

The estimation of Evans blue concentration in plasma was based on the modification (Murray and Shillingford, 1958) of the cellulose-absorption, acetone-elution method of Allen (1951). The extraction method is preferred to the direct estimation of the dye in plasma because it eliminates the inaccuracies introduced by the presence of lipaemia or haemolysis (Gregersen, 1938). When the dye level in the tail of the curve has been estimated, the dye concentration throughout its course can be calculated at regular intervals, and the results plotted on semilogarithmic graph paper. The cardiac output can then be calculated according to the formula:

\[
CO = \frac{60 \times I \times 100}{SC \times (100 - Htc)}
\]

Where
- \( CO \) = Cardiac output in litres/minute.
- \( I \) = Quantity of dye injected in mg.
- \( SC \) = Sum of concentrations at 1-second intervals under area of curve.
- \( \frac{100}{(100 - Htc)} \) = Blood/plasma ratio.
- \( Htc \) = Haematocrit, corrected for trapped plasma and total body haematocrit.

**RESULTS**

Cardiac outputs and blood volumes were estimated before and after the induction of halothane anaesthesia in twelve healthy male patients undergoing herniorrhaphy or interval appendicectomy. In seven patients the cardiac output was raised after the induction of halothane anaesthesia. In the remaining five it was lowered. The mean of the control cardiac outputs was 5.79 litres, and this rose to 6.10 litres after the induction of anaesthesia. The range of the twelve cases was 8.79 litres for the control period and 4.74 litres under anaesthesia. The standard deviation for the control was 2.77, and for anaesthesia 1.44.

The blood volume was increased in nine of the twelve patients and in the remaining three it was reduced. The mean blood volume in the pre-induction series was 4.9 litres with a standard deviation of 0.61. Once anaesthesia was established it rose to 5.6 litres, standard deviation 0.64.

There was no significant difference in the circulation time as judged by the appearance time.

Blood pressure records are available for eleven of the twelve patients. In ten of these patients the blood pressure fell after the induction of anaesthesia, and in the remaining patient it was unaltered. There was no evidence to show that the extent of the fall in blood pressure was directly related to a change in cardiac output.

The results obtained are set out quantitatively in tables I and II.

**DISCUSSION**

The method used to induce anaesthesia with halothane was deliberately chosen to avoid any possible confusion in the interpretation of the results. Other workers, notably Severinghaus and Cullen (1958), have reported falls in cardiac output during halothane anaesthesia, but with their techniques it is difficult to exclude the possibility that the lowered outputs were due to factors unconnected with the halothane anaesthesia.

The use of halothane alone has another advantage: the pattern of central depression follows closely that described by Guedel (1937) for ether, and the depth of anaesthesia is easy to assess. The patient advances rapidly through the various stages once induction has begun, and the specific planes of surgical anaesthesia are readily identified.

It is well recognized that without heavy premedication it is virtually impossible to obtain a basal resting state in patients about to undergo surgery. The emotional stress involved usually leads to a metabolic rate considerably higher than the anticipated value. In five separate groups of patients awaiting surgery Johnson (1951) found oxygen consumption rates between 14 and 27 per cent above the calculated levels. Similarly in this series, the wide range of the cardiac output figures estimated before anaesthesia implied a varying degree of nervousness, which might have been overcome by more liberal use of premedication. The reduction in the range after anaesthesia was induced would appear to support this interpretation. It was decided, however, that the premedication employed should follow the pattern normally prescribed in our routine practice.
CARDIAC OUTPUT DURING HALOTHANE ANAESTHESIA

Details of haemodynamic changes induced in twelve patients by halothane anaesthesia.

<table>
<thead>
<tr>
<th>PATIENTS</th>
<th>AGE</th>
<th>BLOOD PRESSURE</th>
<th>CARDIAC OUTPUT</th>
<th>APPEARANCE TIME</th>
<th>BLOOD VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>INITIALS</td>
<td></td>
<td>BEFORE</td>
<td>AFTER</td>
<td>BEFORE</td>
<td>AFTER</td>
</tr>
<tr>
<td>A A.</td>
<td>50</td>
<td></td>
<td>4.095</td>
<td>7.07</td>
<td>11</td>
</tr>
<tr>
<td>T.C.</td>
<td>36</td>
<td>120/70</td>
<td>90/60</td>
<td>6.56</td>
<td>7.99</td>
</tr>
<tr>
<td>M.C.</td>
<td>35</td>
<td>120/100</td>
<td>110/80</td>
<td>10.59</td>
<td>6.0</td>
</tr>
<tr>
<td>F.C.</td>
<td>32</td>
<td>120/90</td>
<td>110/80</td>
<td>2.025</td>
<td>5.12</td>
</tr>
<tr>
<td>J. F.</td>
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<td>110/60</td>
<td>4.68</td>
<td>6.725</td>
</tr>
<tr>
<td>W J.</td>
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<td>110/70</td>
<td>9.06</td>
<td>7.21</td>
</tr>
<tr>
<td>H. K.</td>
<td>61</td>
<td>110/70</td>
<td>65/40</td>
<td>2.97</td>
<td>3.71</td>
</tr>
<tr>
<td>O. K.</td>
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<td>100/70</td>
<td>10.82</td>
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<td>H. L.</td>
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<td>E. P.</td>
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<td>105/70</td>
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<td>3.245</td>
</tr>
<tr>
<td>W. R.</td>
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<td>100/70</td>
<td>3.45</td>
<td>7.28</td>
</tr>
<tr>
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<td>120/80</td>
<td>120/80</td>
<td>4.50</td>
<td>7.38</td>
</tr>
</tbody>
</table>

Table II
Analysis of cardiac output and blood volume figures before and after the induction of halothane anaesthesia.

<table>
<thead>
<tr>
<th>CARDIAC OUTPUT</th>
<th>BLOOD VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>LITRES/ MINUTE</td>
<td>LITRES</td>
</tr>
<tr>
<td>BEFORE</td>
<td>AFTER</td>
</tr>
<tr>
<td>MEAN</td>
<td>5.79</td>
</tr>
<tr>
<td>STANDARD DEVIATION</td>
<td>2.77</td>
</tr>
</tbody>
</table>

From table I it can be seen that the tendency is for high cardiac outputs to fall once anaesthesia is established, and for low outputs to rise. Although in the majority of patients the outputs have increased, and the average output during anaesthesia is slightly higher than before induction, on applying Student's "t" test the figures are not found to be statistically significant (P>0.05). It can be concluded, therefore, that halothane has no significant action on the output of the heart during short anaesthetics in man.

Some degree of hypotension is a fairly constant feature of halothane anaesthesia, and Raventós (1956) postulated that this was due to a selective action of the agent on mesenteric ganglia. This explanation was rejected by Burn (1957) and his colleagues, who demonstrated that in the eviscerated cat the hypotensive response to halothane was just as marked in the absence of the mesenteric blood flow. They suggested that the fall in blood pressure was due to a depression of central vasomotor centres combined with diminished cardiac output, but it is obvious from a consideration of the data presented here that there
is no direct relationship between the fall in blood pressure and the cardiac output in man.

Depression of the central vasomotor centres by general anaesthetics has previously been evoked by Lynn and Shackman (1951) to explain the rapid onset of vasodilatation after the induction of anaesthesia. From a clinical standpoint, vasomotor paralysis could certainly explain, not only the hypotension, but also the warm dry skin and markedly dilated superficial veins, which are such a feature of anaesthesia with halothane.

Of the twelve patients studied, three showed a diminished blood volume as well as a reduced cardiac output after the induction of anaesthesia, and it is probably no coincidence that these patients had the highest pre-induction outputs recorded in the series. The remaining nine patients showed a considerable increase in blood volume once anaesthesia was established, and the average increase of 0.7 litres for the whole series, on statistical analysis by applying Student's "t" test, was found to be probably significant (P<0.05). In view of this it is planned to carry out a more detailed study of blood volume changes induced by halothane anaesthesia. If this observation can be confirmed then it ought to be possible to demonstrate the source from which this additional blood is mobilized, and the mechanism by which the mobilization is achieved.

SUMMARY

Both before and after the induction of anaesthesia with halothane, cardiac outputs and blood volumes were measured in twelve patients about to undergo surgery.

Although there was a slight rise in the mean cardiac output after induction, statistical analysis showed that this increase was not significant.

The mean blood volume was also raised, and in this instance the increase is probably significant.

ACKNOWLEDGMENTS

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REFERENCES


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