CEREBRAL VASODILATATION BY HALOTHANE ANAESTHESIA IN MAN AND ITS POTENTIATION BY HYPOTENSION AND HYPERCAPNIA

BY

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SUMMARY

In ten young normal adults the cerebral blood flow and oxygen uptake during normotensive and normocapnic halothane anaesthesia (1 per cent) were studied by means of the $^{85}$Kr inhalation method. Compared with a similar group studied when awake, a significant increase of 27 per cent in cerebral blood flow was found during anaesthesia while the oxygen uptake was reduced by 26 per cent. After discussing previous conflicting reports, it is concluded that halothane per se acts as a cerebral vasodilator. Ten patients from the neurological service with and without cerebrovascular disease were studied when awake and during hypotensive hypercapnic halothane anaesthesia (1 per cent). In five cases a third study was made during either hypotension (three cases) or hypercapnia (two cases) alone. Cerebral blood flow was measured by the $^{133}$Xe injection method. The results suggested a potentiation of the cerebral vasodilatation of halothane by hypotension and/or hypercapnia even in patients with cerebrovascular disease. The very high blood flows found during normotensive, moderately hypercapnic halothane anaesthesia indicated a sort of controlled cerebral hyperoxygenation, the application of which is discussed.

The published evidence concerning the effect of halothane (Fluothane) anaesthesia on cerebral blood flow is conflicting. A vasoconstrictor effect was deduced from animal studies by McDowall, Harper and Jacobson (1963) and McDowall and Harper (1965). However, in subsequent studies by the same group of investigators, in which the experimental conditions were more strictly controlled, cerebral vasodilatation was found to occur (McDowall, 1967). In man two studies have demonstrated vasodilatation (Wollman et al., 1964; McHenry et al., 1965), whereas preliminary studies from this laboratory failed to show evidence of either constriction or dilatation (Christensen, Høedt-Rasmussen and Lassen, 1965). As will be commented on further in the discussion, a closer analysis of these experimental and clinical studies indicated that secondary factors, notably variations in blood pressure and in arterial carbon dioxide tension, have an important influence. On this basis, and in view of the widespread use of halothane in anaesthesia, we decided to restudy the effect of this anaesthetic on the cerebral circulation in man, giving special attention to the influence of these secondary factors and of cerebrovascular disease.

I. EFFECT OF HALOTHANE DURING NORMOTENSION AND NORMOCAPNIA

MATERIAL AND METHODS

Ten young normal adults were studied in this group during anaesthesia with 1 per cent halothane before the start of minor surgical procedures (operations for varicose veins in most cases). The results obtained in ten young normal adults studied by means of the same technique by Lassen, Feinberg and Lane (1960) were available for comparison.

Anaesthesia was induced with 2 per cent halothane in nitrous oxide-oxygen (ratio 2:1) and was maintained for about 1 hour with 1 per cent halothane in oxygen before the study. Halothane was delivered from a Fluotec Mk. II vaporizer.
The same vaporizer was used for all patients in the study. No premedication was given. Endotracheal intubation was performed after production of muscle relaxation with tubocurarine (Tubarine) 20 mg i.v. When it was necessary to prevent the patient from resisting mechanical ventilation, this dose was supplemented (0–40 mg). Ventilation with oxygen was controlled by means of a time-cycled non-rebreathing ventilator (Barnet) and was adjusted to maintain an arterial carbon dioxide tension (\(P_{A}O_2\)) of about 40 mm Hg with the help of serial arterial blood samples; these were analyzed immediately with a teflon-covered glass electrode (Severinghaus and Bradley, 1958). A negative (subatmospheric) pressure of 3–8 cm \(H_2O\) was applied in the expiratory phase in order to minimize the circulatory effects of controlled ventilation. Normotension was maintained by keeping the mean arterial blood pressure close to the pre-anaesthetic level using elevation of the legs (keeping the body in the horizontal level and the head a little elevated) and, in some cases, by infusion of 5.5 per cent dextrose solution (approximately 1 l.) over a period of about 15 minutes.

Cerebral blood flow (c.b.f.) in ml/100 g/min was measured by the \(^{85}\text{Kr}\) inhalation method used by Lassen and Munck (1955) and Lassen, Feinberg and Lane (1960), the \(^{85}\text{Kr}\) being mixed with the oxygen driving the ventilator. The study lasted 15 minutes (fig. 1) and the \(^{85}\text{Kr}\) curves were extrapolated to full saturation of the brain. No correction was made for the time lag between the appearance of tracer in the artery and in the jugular vein (Lassen, Feinberg and Lane, 1960).

The arteriovenous oxygen deficit [(A-V)\(O_2\)] in volumes per cent was measured manometrically (van Slyke and Neill, 1924), and the cerebral metabolic rate of oxygen (c.m.r.o\(_3\)) in ml/100 g/min was calculated from the product of cerebral blood flow and arteriovenous oxygen difference. The mean arterial blood pressure (m.a.b.p.) in mm Hg was taken as the mean pressure as measured directly (using an electrically damped capacitance manometer), and corrected for the small pressure in the internal jugular vein of about 2–3 mm Hg. Cerebrovascular resistance (c.v.r.) in mm Hg/(ml/100 g/min), was calculated as the ratio of mean arterial blood pressure and cerebral blood flow.

The methods used in the non-anaesthetized control group reported by Lassen, Feinberg and Lane (1960) were the same as those here described with the exception of the \(P_{A}O_2\) analysis. In the control group the \(P_{A}O_2\) was calculated from the arterial pH and total carbon dioxide values.

### RESULTS

Table I lists the results obtained during halothane anaesthesia together with the average values obtained in the series of non-anaesthetized young adults and previously published by Lassen, Feinberg and Lane (1960).

It can be seen that normocapnia was maintained during anaesthesia, the \(P_{A}O_2\) averaging 41 mm Hg in both series. A slight decrease in mean arterial blood pressure of 3 mm Hg (from an average value of 76 to one of 73 mm Hg) was found in the anaesthetized group in comparison with the pre-anaesthetic level. Thus normotension was maintained. The average blood pressure was 11 per cent below that of the non-anaesthetized group studied previously, indicating some degree of blood pressure rise in the adults who were awake; this was probably provoked by the stress of the study.

The average value for cerebral blood flow was 54.4 ml/100 g/min during halothane anaesthesia as compared to 43.0 ml/100 g/min in the control group. This 27 per cent increase of cerebral blood flow...
flow was statistically significant (P<0.02). The validity of the control value is supported by the results of Wollman and his co-workers (1964), who found an average cerebral blood flow of 44.4 ml/100 g/min (SD 5.4) in normocapnic awake young adults studied by the **Kr saturation technique (including extrapolation to full saturation of the brain).

Cerebrovascular resistance was reduced to an average value of 1.42 mm Hg (ml/100 g/min) during halothane anaesthesia as compared to 1.93 in the control group. This decrease of 26 per cent was statistically significant (P<0.02). Even if the blood pressure had been exactly the same in the control group (73 mm Hg, not 82 mm Hg), cerebral vasodilatation during halothane anaesthesia would have been suggested by the data (in this case the average value for the control c.v.r. would have been 1.69 units, SD 0.25).

The arteriovenous oxygen difference and the oxygen uptake of the cerebral cortex were reduced during halothane anaesthesia by 40 and 26 per cent respectively (P<0.001 in both cases).

II. EFFECT OF HALOTHANE AND HYPOTENSION OR/AND HYPERCAPNIA

MATERIAL AND METHODS

The ten subjects in this group were selected from the neurological service, and the cerebral circulatory studies were made in conjunction with cerebral angiography. The ages ranged from 33 to 72 years and the series included four patients with a clinical diagnosis of cerebral arteriosclerosis (one had had a stroke some months previously) and two patients with hypertensive encephalopathy. This choice was made since maximal cerebrovascular dilatation was sought by the combined effect of halothane, hypotension and hypercapnia. We hoped to be able to disclose subnormal cerebrovascular relaxation.

### Table I

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>b.p. (mm Hg)</th>
<th>P\textsubscript{aO\textsubscript{2}}</th>
<th>(A-V)\textsubscript{O\textsubscript{2}}</th>
<th>c.b.f. (ml/100 g/min)</th>
<th>c.v.r. (mm Hg/ml/100 g/min)</th>
<th>c.m.r.o\textsubscript{O\textsubscript{2}} (ml/100 g/min)</th>
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<tbody>
<tr>
<td>1</td>
<td>23</td>
<td>F</td>
<td>80</td>
<td>43</td>
<td>2.90</td>
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<td>41</td>
<td>5.70</td>
<td>40.0</td>
<td>1.63</td>
<td>2.28</td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>F</td>
<td>72</td>
<td>48</td>
<td>3.33</td>
<td>56.4</td>
<td>1.30</td>
<td>1.87</td>
</tr>
<tr>
<td>4</td>
<td>33</td>
<td>F</td>
<td>80</td>
<td>41</td>
<td>3.89</td>
<td>58.0</td>
<td>1.38</td>
<td>2.25</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>M</td>
<td>82</td>
<td>36</td>
<td>7.41</td>
<td>33.9</td>
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<td>23</td>
<td>F</td>
<td>80</td>
<td>39</td>
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<td>1.49</td>
<td>2.26</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
<td>F</td>
<td>67</td>
<td>39</td>
<td>3.27</td>
<td>66.2</td>
<td>1.01</td>
<td>2.16</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>M</td>
<td>80</td>
<td>41</td>
<td>3.69</td>
<td>44.0</td>
<td>1.82</td>
<td>2.51</td>
</tr>
<tr>
<td>9</td>
<td>37</td>
<td>F</td>
<td>60</td>
<td>44</td>
<td>2.57</td>
<td>69.9</td>
<td>0.86</td>
<td>1.79</td>
</tr>
<tr>
<td>10</td>
<td>32</td>
<td>F</td>
<td>60</td>
<td>36</td>
<td>4.40</td>
<td>51.3</td>
<td>1.17</td>
<td>2.26</td>
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</table>

<table>
<thead>
<tr>
<th>Halothane</th>
<th>Mean</th>
<th>SD</th>
<th>Awake (6)</th>
<th>Mean</th>
<th>SD</th>
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<tr>
<td>Mean</td>
<td>27.9</td>
<td>5.3</td>
<td>22.6</td>
<td>3.7</td>
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<tr>
<td>SD</td>
<td>8.9</td>
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</tr>
</tbody>
</table>

**P<0.001**
Anaesthesia was the same as that described above. Moderate pulmonary hyperventilation was employed and maintained unaltered throughout and carbon dioxide in oxygen was added to give the desired Pa\textsubscript{\text{CO}}\textsubscript{2}. The blood pressure was allowed to fall spontaneously during halothane anaesthesia. In only two studies was normotension maintained by dextrose infusion and a small dose of metaraminol bitartrate (Aramine) (5 mg given intravenously over several minutes).

Cerebral blood flow was first measured in the awake state, after inserting the necessary needles under local anaesthesia, and was then restudied under moderate hypotension and hypercapnia. A third study was made in five patients in which either the Pa\textsubscript{\text{CO}}\textsubscript{2} was normal (three patients) or the blood pressure (two patients) was adjusted to the pre-anaesthetic level during continued halothane anaesthesia.

Successive measurements of cerebral blood flow were facilitated by the use of the \textsuperscript{133}Xe injection method (H\o edt-Rasmussen, Sveinsdottir and Lassen, 1966). \textsuperscript{133}Xe dissolved in saline was injected via the internal carotid artery and the cerebral blood flow calculated from the externally recorded clearance curve (fig. 2). By maintaining a constant, moderate hyperventilation in all studies the recirculation of \textsuperscript{133}Xe was kept at a low normal level.

The blood pressure was measured in this series as the mean arterial-jugular venous difference and used for calculating the cerebrovascular resistance. The arteriovenous oxygen difference and the cerebral oxygen uptake were not measured.

RESULTS
In all ten patients (case Nos. 11 to 20) the combined effects of 1 per cent halothane, hypotension (to 62 per cent of the conscious level) and moderate hypercapnia (to 57 mm Hg) were studied. As seen in table II, a slight increase in cerebral blood flow was noted but this increase was not statistically significant. The cerebrovascular resistance, expressed in per cent of the control value, decreased in all patients and a highly significant average decrease to 55 per cent (SD 17 per cent) was noted (P<0.001). There was no apparent difference in the cerebrovascular dilatation of patients with and without clinical evidence of cerebrovascular disease (in case No. 17 a rather moderate decrease of resistance was found but in this case the Pa\textsubscript{\text{CO}}\textsubscript{2} had only increased by 3 mm Hg).

In case Nos. 11, 13 and 15 the effect, during halothane anaesthesia, of hypotension alone was examined in an additional study made during normocapnia, before or after the combined study. In table III the control data are compared with those obtained during halothane anaesthesia when the arterial carbon dioxide tension was normal, but the blood pressure was allowed to fall. Maintenance of normocapnia did not alter the decrease in cerebrovascular resistance in case Nos. 13 and 15, while in case No. 11 a lesser decrease was found.

In case Nos. 19 and 20 the effect of hypercapnia alone during halothane anaesthesia was studied. As seen in table III maintenance of normotension during halothane anaesthesia and hypercapnia caused a marked increase in cerebral blood flow (to 192 per cent of the control level). The cerebrovascular resistance, however, was reduced to the same low level as when hypotension had been allowed to develop in the two subjects, both of whom had clinical evidence of cerebrovascular disease.

DISCUSSION
Halothane as a cerebral vasodilator in man.
In the present study an average increase of cerebral blood flow of 27 per cent was found.
CEREBRAL VASODILATATION BY HALOTHANE ANAESTHESIA IN MAN

Table II
Cerebral blood flow and vascular resistance in awake condition and during halothane anaesthesia, hypotension, and hypercapnia.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Neurological findings</th>
<th>b.p. (1)</th>
<th>PaCO₂ (mm Hg)</th>
<th>c.b.f. (2)</th>
<th>c.v.r. (3)</th>
<th>% of control</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>46</td>
<td>F</td>
<td>0</td>
<td>83</td>
<td>80</td>
<td>40</td>
<td>52</td>
<td>41</td>
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<td>12</td>
<td>56</td>
<td>M</td>
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<td>117</td>
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<td>54</td>
<td>46</td>
</tr>
<tr>
<td>13</td>
<td>33</td>
<td>F</td>
<td>Epilepsy</td>
<td>103</td>
<td>70</td>
<td>38</td>
<td>56</td>
<td>55</td>
</tr>
<tr>
<td>14</td>
<td>66</td>
<td>M</td>
<td>Cerebral atrophy</td>
<td>87</td>
<td>54</td>
<td>39</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>15</td>
<td>54</td>
<td>F</td>
<td>Hypertensive encephalopathy</td>
<td>137</td>
<td>72</td>
<td>41</td>
<td>50</td>
<td>37</td>
</tr>
<tr>
<td>16</td>
<td>72</td>
<td>M</td>
<td>Hypertensive encephalopathy</td>
<td>122</td>
<td>56</td>
<td>42</td>
<td>64</td>
<td>22</td>
</tr>
<tr>
<td>17</td>
<td>60</td>
<td>M</td>
<td>Arteriosclerosis</td>
<td>97</td>
<td>57</td>
<td>46</td>
<td>49</td>
<td>48</td>
</tr>
<tr>
<td>18</td>
<td>58</td>
<td>M</td>
<td>Arteriosclerosis</td>
<td>100</td>
<td>73</td>
<td>41</td>
<td>61</td>
<td>46</td>
</tr>
<tr>
<td>19</td>
<td>70</td>
<td>F</td>
<td>Arteriosclerosis</td>
<td>115</td>
<td>78</td>
<td>37</td>
<td>58</td>
<td>45</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
<td>M</td>
<td>Arteriosclerosis Apoplexy</td>
<td>92</td>
<td>49</td>
<td>43</td>
<td>65</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>105.3</td>
<td>65.6</td>
<td>41.2</td>
<td>57.4</td>
<td>40.5</td>
</tr>
<tr>
<td>Difference</td>
<td>Halothane - awake in % of awake</td>
<td>-38</td>
<td>+39</td>
<td>+22</td>
<td>-46</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

(1) b.p.=blood pressure=mean arterial-mean jugular pressure in mm Hg.
(2) c.b.f.=cerebral blood flow in ml/100 g/min, measured by the 133Xe intra-arterial injection method.
(3) c.v.r.=cerebral vascular resistance in mm Hg/(ml/100 g/min).

during halothane anaesthesia (1.0 per cent) in ten normotensive and normocapnic young adults (group I). In comparison, Wollman and his co-workers (1964) found an increase of only 14 per cent in six normocapnic normal young men anaesthetized with 1.2 per cent halothane. This less pronounced increase may be explained by the fact that the anaesthesia was associated with an average fall of 32 per cent in mean perfusion pressure, compared to a fall in the present study of only 4 per cent. This is supported by the present observations made in three patients from group II (cf. table III). In these patients a decrease in cerebral blood flow of about 18 per cent was found during normocapnic halothane anaesthesia when a pronounced hypotension was allowed to develop (a fall of almost 50 per cent).

McHenry and associates (1965) studied a group of eight young adults before and during halothane anaesthesia (1.0 per cent) in combination with 50 per cent nitrous oxide in oxygen. In this series normotension was maintained but moderate hypercapnia developed (average PaCO₂ 47.4 mm Hg), probably explaining the greater increase in cerebral blood flow of 55 per cent found by them. Correcting for the hypercapnia according to Reivich's data (1964) (3 per cent increase in cerebral blood flow per mm Hg increase of PaCO₂ above 40.0 mm Hg), the findings of McHenry and associates correspond closely with our data.

The results reported by McDowall, Harper and Jacobson (1963) and McDowall and Harper (1965) showing a moderate decrease in cortical blood flow during halothane anaesthesia in the dog, are in conflict with the present data. Induction of anaesthesia with thiopentone, the use of halothane in a concentration of 0.5 per cent, and failure to control the systemic blood pressure are important aspects in which these experiments differ from the present studies. In subsequent experimental studies by McDowall (1967) 0.5, 2, and 4 per cent halothane was used, a 2-hour period was allowed to elapse between the last dose of thiopentone and the start of the measurements, and the effect of blood pressure changes were taken into account. These studies showed that the fall in cerebrovascular resistance (as per cent of control; nitrous oxide-oxygen anaesthesia) during increasing concentrations of halothane is associated with a proportionally lesser fall in mean arterial blood pressure and it was concluded that halothane has a cerebral vasodilator effect.
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TABLE III
Cerebral blood flow and vascular resistance in awake condition and during halothane anaesthesia, combined with hypotension + normocapnia or with normotension + hypercapnia.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Neurological findings</th>
<th>b.p.(1)</th>
<th>P&lt;sub&gt;02&lt;/sub&gt; (mm Hg)</th>
<th>c.b.f.(2)</th>
<th>c.v.r.(3)</th>
<th>% of control</th>
</tr>
</thead>
<tbody>
<tr>
<td>11*</td>
<td>46</td>
<td>F</td>
<td>0</td>
<td>83</td>
<td>65</td>
<td>40</td>
<td>38</td>
<td>41 37</td>
</tr>
<tr>
<td>13*</td>
<td>33</td>
<td>F</td>
<td>Epilepsy</td>
<td>103</td>
<td>42</td>
<td>38</td>
<td>38</td>
<td>35 47</td>
</tr>
<tr>
<td>15*</td>
<td>54</td>
<td>F</td>
<td>Hypertensive encephalopathy</td>
<td>137</td>
<td>67</td>
<td>41</td>
<td>42</td>
<td>37 25</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
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<td>108</td>
<td>58</td>
<td>40</td>
<td>39</td>
<td>44 36</td>
</tr>
</tbody>
</table>

Difference
Hallothane—awake in % of awake
-46 -3 -18 -30

| 19 70 | F | Arteriosclerosis | 115   | 110               | 37       | 58        | 45 72       | 2.6 1.5 58 |
| 20 50 | M | Arteriosclerosis | 92    | 90                | 43       | 68        | 30 73       | 3.1 1.2 39 |
| Mean   |     | Apoplexy         | 104   | 100               | 40       | 63        | 38 73       | 2.8 1.4 49 |

Difference
Hallothane—awake in % of awake
-4 58 +92 -50

(1) b.p. = blood pressure = mean arterial—mean jugular pressure in mm Hg.
(2) c.b.f. = cerebral blood flow in ml/100 g/min, measured by the 133Xe intra-arterial injection method.
(3) c.v.r. = cerebral vascular resistance in mm Hg/(ml/100 g/min).

* In a previous report by Christensen, Høeet-Rasmussen and Lassen (1965) these patients were presented as case Nos. 1, 2 and 3; in that publication the c.b.f. values were not extrapolated to infinity but calculated to a clearance period of 10 minutes.

The evidence cited may be summarized to indicate clearly that halothane anaesthesia per se dilates the vessels of the brain in man as well as in the dog.

Effect of 1 per cent halothane on cerebral oxygen uptake.

In the present series a decrease of cerebral oxygen uptake to 74 per cent of the control value was observed. In comparison McHenry and associates (1965) using 1.0 per cent halothane and 50 per cent nitrous oxide in oxygen found a reduction in uptake to 72 per cent. Cohen and associates (1964) who used 1.2 per cent halothane noted a reduction to 85 per cent. The latter authors observed that the degree of reduction in cerebral oxygen uptake correlated with a moderate reduction in body temperature and expressed the opinion that the reduction was mainly a result of falls in body temperature and not of the anaesthetic itself. With this in mind we measured the rectal temperature in our subjects and found no falls in temperature (average 37.0°C). McDowall (1967) reported that increasing concentrations of halothane were followed by an increasing reduction in oxygen uptake by the cortex. Apparently in halothane anaesthesia, as in other types of anaesthesia, it is the depth of anaesthesia (i.e. the degree of cerebral depression) which determines the reduction in cerebral oxygen uptake.

From a comparison of the increase in cerebral blood flow with the decrease in cerebral oxygen uptake during halothane anaesthesia it appears that in these circumstances there is no metabolic control of cerebral blood flow, that is to say that the adjustment of flow in parallel with tissue oxygen uptake, as first proposed by Roy and Sherrington (1890), does not take place. In addition to halothane other volatile anaesthetic agents such as chloroform, trichloroethylene and ether cause cerebral vasodilatation and a reduction of cerebral oxygen uptake (McDowall and Harper, 1965). On the other hand, a reduction of cerebral blood flow in proportion to the reduction in oxygen uptake has been found during barbiturate anaesthesia in numerous studies in human subjects (cf. Sokoloff, 1959).
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is customarily taken as an example of the metabolic control referred to. In this context it may be said, therefore, that the volatile anaesthetics appear to "uncouple" the metabolic control of cerebral circulation, but the reactivity of the cerebral vessels to carbon dioxide ("chemical control") and to variations in blood pressure ("autoregulation"; Lassen, 1964) is preserved during halothane anaesthesia as will now be discussed.

Potentiation of vasodilatation by hypotension and hypercapnia.

In normal man such a potentiation is evident from the data already discussed in relation to the effect of halothane on cerebral blood flow. Perhaps the best method of demonstrating this combined action is to express the data in terms of the percentage reduction of cerebrovascular resistance; this decreased to 74 per cent of the control level in our normotensive and normocapnic normal patients. In the moderately hypotensive but normocapnic patients studied by Alexander and co-workers (1964) a reduction of cerebrovascular resistance to 58 per cent (potentiation by hypotension) was noted. McHenry and co-workers (1965) found a reduction to 57 per cent in normotensive but moderately hypercapnic normals (potentiation by hypercapnia). The combination of halothane anaesthesia with hypotension and/or hypercapnia (potentiation by hypercapnia). The combination of halothane anaesthesia with hypotension and hypercapnia may cause what appears to be the maximum degree of cerebral vasodilatation with values for cerebrovascular resistance as low as only 40 per cent of the control level in young normal adults (Alexander et al., 1964).

This pattern of additive effects apparently was present also in the aged patients (Group II) some of whom showed clinical evidence of cerebrovascular disease. The combined effect of halothane, hypotension and/or hypercapnia reduced cerebrovascular resistance to about 55 per cent of the control level when awake, i.e. to almost the same level as in the normal adults. This is evidence of a considerable vasodilator capacity, even in such aged patients, in agreement with earlier findings (Lassen, 1959). It strongly suggests that the above described potentiation also occurs in this type of patient. One important point must be stressed here: the vasodilator reserve here alluded to concerns that of the entire brain. But in patients with cerebrovascular disease one particular region may well be supplied through an already critically stenosed artery; hence that region might possess little or no vasodilator reserve even though the entire brain has such. As in all other forms of anaesthesia this possibility makes it inadvisable to rely on the cerebrovascular dilator capacity in elderly patients, that is arterial hypotension should be avoided whenever possible.

The very high values for cerebral blood flow induced by moderate hypercapnia during halothane anaesthesia when the blood pressure is normal deserve special comment. A high blood flow means a high oxygen delivery to the brain if the arterial blood is normally oxygenated. At the same time the oxygen demand is lowered as under all forms of anaesthesia. Thus the ratio of supply to demand is extremely favourable as is evident from the high oxygen saturation of cerebral venous blood. Fully arterialized cerebral venous blood results if 100 per cent oxygen breathing under halothane anaesthesia is combined with normotension and moderate hypercapnia. This form of anaesthesia consequently results in a state of controlled cerebral hyperoxygenation which has been used successfully during surgery for carotid artery stenosis (Lyons et al., 1964; Clauss, Hass and Ransohoff, 1965). Halothane anaesthesia alone can cause a marked rise in the intracranial pressure in patients with intracranial space occupying lesions (Jennett, McDowell and Barker, 1967). It is therefore likely to compromise rather than improve tissue oxygenation in such cases, and the potentiating effects here described might further accentuate the adverse effect. In many other situations, however, this type of anaesthesia might increase the safe time margin in face of sudden circulatory disturbances.

REFERENCES


SOMMAIRE
Chez 10 jeunes adultes normaux, le flux sanguin cérébral et la résorption d'oxygène ont été étudiés au moyen de la méthode d'inhalation de 85 Kr, durant une anesthésie à l'halothane (1 pourcent) normotensive et normocapnique. Comparativement à un groupe similaire, étudié à l'état réveillé, il y eut une augmentation de 27 pourcent du flux sanguin cérébral durant l'anesthésie, tandis que la résorption d'oxygène fut réduite de 26 pourcent. Après avoir passé en revue plusieurs rapports précédents contradictoires, les auteurs arrivent à la conclusion que l'halothane agit par le même mécanisme vasodilatateur cérébral. Dix patients du service neurologique, avec et sans maladie cérébrovasculaire, furent observés à l'état réveillé et durant une anesthésie hypotensive et hypercapnique à l'halothane (1 pourcent). Dans 5 cas, il y eut un troisième essai, soit avec hypotension seule (3 cas), soit avec hypercapnie seule (2 cas). Le flux sanguin cérébral fut mesuré par la méthode d'injection de 133 Xe. Les résultats suggèrent qu'il y a une potentialisation de la vasodilatation cérébrale causée par l'halothane, sous l'influence de l'hypotension et/ou l'hypercapnie, même chez les patients avec maladie cérébrovasculaire. Les flux sanguins très élevés, observés durant l'anesthésie normotensive, modérément hypercapnique à l'halothane, indiquent qu'il existe un genre d'hyperoxénisation cérébrale contrôlée, dont l'application possible est discutée.

Die Zerebrale Vasodilatation durch Halothan-Anästhesie beim Menschen und ihre Potenzierung durch Hypotonie und Hyperkapnie

ZUSAMMENFASSUNG

BRITISH JOURNAL OF ANAESTHESIA


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Vasodilatation Cérébrale par l'Anesthésie à l'Halothane Chez l'HOMME ET SA POTENZIALISATION PAR L'HYPOTENSION ET L'HYPERCAPNIE

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