THE EFFECT OF MATERNAL HYPOXIA ON THE HEART RATE OF THE FOETUS IN UTERO

BY

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SUMMARY

The effect on the foetal heart rate of induced maternal hypoxia is described. In the initial investigation, three out of five patients breathing a 10 per cent oxygen mixture showed changes in the foetal heart rate within 4 minutes and the five patients showed a foetal reaction within 4 minutes of breathing the 8 per cent oxygen mixture. A further study with the 10 per cent oxygen mixture showed that twenty out of twenty-eight patients showed foetal heart rate changes within 10 minutes of the start of administration and in ten of these patients the effect began within 5 minutes. The results are presented as further evidence of the potential dangers of gas-and-air analgesia in midwifery, and in support of the development of suitable gas-and-oxygen machines.

The administration of a 50 per cent mixture of nitrous oxide and air to patients in labour has become a widespread practice since the description of the original apparatus by Minnitt (1934). The safety of such machines was accepted until the reports of Cole and Nainby-Luxmoore (1962a, b) who showed that the majority of those which they tested delivered mixtures containing more than 50 per cent nitrous oxide and in some instances the proportion of nitrous oxide reached dangerous levels. Although the gas-and-air apparatus is used intermittently in labour, it is clear that foetal hypoxia may occur as a result of its use, especially if the placenta is not functioning adequately.

Experimental foetal hypoxia has been induced in animals by Bieniarz and Reynolds (1960) and in the human by Canon and Reinhold (1952) by decreasing the amount of oxygen inspired by the mother. Hellman and colleagues (1961) were able to induce an increase in foetal heart rate of about 20 beats per minute using a 12 per cent oxygen mixture and Hon (1963) showed that foetal tachycardia began about 10 minutes after the mother began breathing a 15 per cent oxygen mixture.

In view of these observed effects, the writer considered it worth assessing more fully the effect on the foetal heart rate of induced maternal hypoxia with a view to relating such effect to placental function as suggested by Duncan (1957). It was hoped that the production of a certain type of foetal reaction, or the time taken to produce a foetal reaction with various oxygen/nitrogen mixtures might prove to be a useful index of placental function.

The effect on the foetus in utero of induced maternal hypoxia will be of interest to all those who are giving thought to the redesigning of nitrous oxide and oxygen machines for use in labour.

METHOD OF INDUCING HYPOXIA

One of the difficulties in this study was the production of oxygen/nitrogen mixtures in varying proportions. Premixed cylinders could not be used because of their inaccuracy as well as the technical difficulty of disconnecting the apparatus and reconnecting to a different cylinder when the mixture needed to be changed.

Separate oxygen and nitrogen cylinders were used and to each was attached a Rotameter (Rotameter Manufacturing Company, Croydon). These gave an error of ±2.3 per cent of the indicated flow rate, which was sufficiently accurate for the investigation. The Rotameters were connected...
(fig. 1) to a non-rebreathing circuit consisting of a reservoir bag, breathing tube, valve mount and mouthpiece. The valve mount incorporated a one-way valve and an expiratory valve. The mouthpiece consisted of a short rubber tube with a flattened end which the patient gripped between her teeth, outside which was a flange fitting between the gums, lips and cheeks, so producing an airtight seal. A spring clip was applied to the nose to occlude the nares. A total flow rate of 20 l./min was maintained, the proportion of oxygen and nitrogen being varied to produce the required mixture.

The method of recording the foetal heart rate was by direct counting which has an error of less than 5 per cent (Lamkee, Huntington and Alvarez, 1962), the heart sounds being amplified by a cardiophone and amplifier of the type described by Wilson, Fothergill and Taylor (1956) and MacRae (1959, 1960, 1962). The foetal heart rate was recorded for 30 seconds of each minute for 15 minutes before the test and for 30 seconds of each minute during the test itself.

PRELIMINARY INVESTIGATION

It was realized that slight lowering of the oxygen concentration of the inspired mixture would be compensated for by overbreathing, but that if the percentage of oxygen was progressively reduced, a critical level would be reached at which compensation would be incomplete, and hypoxia would result. An initial study was undertaken to determine at what oxygen levels the foetal heart rate could be influenced.

Five normal patients (primigravidae, under the age of 30 years) at 36–38 weeks gestation were tested. The oxygen percentages used were 20 (twice), 15, 10 and 8 in each patient and each mixture was given for 4 minutes. In order that the reaction would not be influenced by the order in which the mixtures were administered, the sequence was different for each patient, the patients and gas mixtures being arranged in the form of a "Latin square" (table I). An assistant controlled the gas mixtures so that the observer recording the foetal heart rate was unaware of the actual mixture being given at any time.

<table>
<thead>
<tr>
<th>Patient number</th>
<th>Oxygen percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>20 20 15 8 10</td>
</tr>
<tr>
<td>II</td>
<td>10 15 8 20 20</td>
</tr>
<tr>
<td>III</td>
<td>8 10 15 20 20</td>
</tr>
<tr>
<td>IV</td>
<td>20 8 20 15 10</td>
</tr>
<tr>
<td>V</td>
<td>15 20 20 10 8</td>
</tr>
</tbody>
</table>

Results.

The results of preliminary investigations are shown in figure 2. As it takes time for the effect of any mixture to become evident, the foetal heart rate for the last minute of each mixture is plotted for each patient.

It is seen that very little change in the foetal heart rate occurred in any patient when given the 15 per cent oxygen mixture to breathe for 4 minutes. With the 10 per cent oxygen there

![Fig. 2](https://academic.oup.com/bja/article-abstract/37/7/515/266489/377515266469)
was a definite increase in foetal heart rate in three cases, the most marked being patient I with an increase of 30 beats/min. With 8 per cent oxygen four cases showed a foetal tachycardia above that which occurred with the 10 per cent mixture. The one exception was patient I who, having had a marked increase in foetal heart rate with 10 per cent oxygen, showed a slowing in foetal heart rate with the 8 per cent mixture. This latter reaction of tachycardia followed by bradycardia may well have represented the induction of true foetal distress, especially as in this case the administration of the 8 per cent followed directly on the 10 per cent mixture. In all cases the foetal heart rate had returned to the original level within 3 minutes of breathing 100 per cent oxygen.

FURTHER INVESTIGATION

The fact that with 8 per cent oxygen a foetal effect was observed within 4 minutes in the five normal cases indicated that this mixture was unlikely to be of much value as a test of placental function. Even with 10 per cent oxygen, three out of five cases showed a foetal tachycardia. On the other hand, no significant reaction occurred in any patient breathing 15 per cent oxygen. It seemed likely that the mixture which would prove most useful as a test of placental function would contain between 11 and 14 per cent oxygen. Further tests were carried out using 10 per cent or 12 per cent oxygen administered for 20 minutes.

As the Minnitt gas-and-air machine delivers to the patient approximately 10 per cent oxygen, the main purpose of this paper is to record the effects on the foetus obtained with the 10 per cent oxygen test. The method of administering the oxygen/nitrogen mixture was the same as that in the preliminary investigation. An initial period of 15 minutes, with the apparatus assembled, but with the patient breathing air, was allowed so that the apprehension of the patient resolved. The 10 per cent oxygen was then administered and the foetal heart rate recorded for 30 seconds of each minute for 20 minutes.

Results.

The foetal response to the administration of a 10 per cent oxygen mixture to the mother if it occurred appeared to take one of two forms:

1. After an initial period (usually 6–10 minutes) of no response, the foetal heart gradually increased in rate over the remainder of the test. This will be referred to as the "delayed response".

2. The foetal heart rate increased soon after the start of the test and, after reaching a peak, gradually fell back to or even below the pre-test rate. Since this foetal heart pattern of tachycardia followed by bradycardia is that associated with foetal distress, this will be referred to as the "distress response".

The test was carried out on twenty-eight patients of which eight showed no change in the foetal heart rate, nine gave the "delayed response" and eleven showed the "distress response". The nine patients giving the "delayed response" consisted of two who began reacting within 5 minutes of starting the test and seven who began between 6 and 10 minutes. The eleven cases showing the "distress response" consisted of eight who reacted within 5 minutes and three who began between 6 and 10 minutes after starting the test (table II).

<table>
<thead>
<tr>
<th>Type of reaction</th>
<th>Number of cases</th>
<th>Onset of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>8</td>
<td>0–5 minutes 6–10 minutes</td>
</tr>
<tr>
<td>&quot;Delayed&quot;</td>
<td>9</td>
<td>2 7</td>
</tr>
<tr>
<td>&quot;Distress&quot;</td>
<td>11</td>
<td>8 3</td>
</tr>
</tbody>
</table>

In the twenty cases showing some foetal reaction following the administration of a 10 per cent oxygen mixture to the mother, the degree of change in foetal heart rate ranged from 10 to 31 per cent of the pre-test level.

The group of cases investigated was a mixture of normal patients and those with suspected placental insufficiency. In fact only three out of the twenty-eight patients were subsequently found to have reduced placental function and they all gave the "delayed" response to the test. Thus seventeen patients who showed a change in foetal heart rate within 10 minutes of the mother breathing a 10 per cent oxygen mixture, had normal placental function.
DISCUSSION

This investigation has demonstrated that the induction of changes in foetal heart rate can be achieved without difficulty, by the administration of a 10 per cent oxygen mixture to the mother. Such changes were produced in twenty out of twenty-eight patients, the foetal reaction beginning within 10 minutes of starting in the twenty cases and within 5 minutes in ten of them. The Minnitt (gas-and-air) machine used in labour is meant to deliver a mixture containing 50 per cent air (10.4 per cent oxygen) but reference has already been made to the inaccuracies of such machines. It may be argued that, when used in labour, the gas mixtures are only given intermittently, during uterine contractions, for perhaps 1 out of every 3 minutes and that the cumulative effect described in this investigation is, therefore, unlikely to occur. However, it must be remembered that the changes in the foetal heart rate described occurred, in half of the cases, within 5 minutes of the administration of the 10 per cent oxygen mixture. Furthermore in the initial investigation, when the oxygen was reduced to 8 per cent, a foetal effect was observed in all cases within 4 minutes. Cole and Nainby-Luxmoore (1962a) showed that with the Minnitt machine the proportion of air breathed varied with the minute volume and that the latter ranged from 7 to 90 l./min in labour. With minute volumes of 5–9 l./min the mixture was equivalent to 12 per cent oxygen but with minute volumes of 40–50 litres the mixture was equivalent to only 8 per cent oxygen.

It might, therefore, be expected that, with the gas-and-air machines, hypoxia of the foetus in utero would occur for several reasons. First, the variation in oxygen concentration delivered to the patient, which is a serious criticism of the machine itself. Secondly, when used even intermittently for several hours, as it sometimes is, a cumulative effect would occur. Lastly, it must be remembered that as labour progresses the placental site becomes smaller and that with each uterine contraction there is marked slowing of the placental blood flow, both of which would aggravate any existing foetal hypoxia.

It is impossible to ignore the potential dangers of the conventional gas-and-air machines and attention is now being directed to the development of a gas-and-oxygen machine suitable for domiciliary and hospital midwifery. Trials have already been undertaken by the Medical Research Council (1963) into the use of nitrous oxide and oxygen instead of nitrous oxide and air, and the initial impression has been favourable. Some of the difficulties of premixing the gases have been overcome (Tunstall, 1961) and when the further difficulty of storage described by Gale, Tunstall and Wilton-Davies (1964) has been resolved, it is likely that gas-and-air analgesia will become obsolete. It could be suggested that the foetal effects observed in these studies were in fact due to hypocapnia rather than to the maternal hypoxia, but whatever the mechanism the effect must represent an indirect if not a direct effect of the hypoxia.

ACKNOWLEDGMENTS

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REFERENCES


MacRae, D. J. (1959). Monitoring the heart of the foetus and newborn. Lancet, 2, 266.


EFFECT OF MATERNAL HYPOXIA ON HEART RATE OF FOETUS


L'EFFET DE L'HYPOXIE MATERNELLE SUR LA FREQUENCE DES BRUITS DU COEUR DU FETUS IN UTERO

SOMMAIRE
L'effet de l'hypoxie maternelle induite sur la fréquence des bruits du coeur du fétus est décrit. Au cours des investigations précédentes 3 femmes sur 5 respirant un mélange d'oxygène à 10 pourcents présentaient des modifications des bruits du coeur après 4 minutes et les 10 femmes présentaient une réaction fétale après avoir respiré pendant 4 minutes un mélange d'oxygène de 8 pourcents. Une étude ultérieure avec le mélange d'oxygène à 10 pourcents montrait que 20 femmes sur 28 présentaient des bruits du coeur altérés après avoir respire ce mélange pendant 10 minutes et chez 10 de ces femmes ces phénomènes commençaient après 5 minutes. Ces résultats constituent une nouvelle preuve des dangers potentiels de l'analgésie par un mélange gaz-air au cours de l'accouchement et soulignent la nécessité de mettre au point des gaz et des débits d'oxygène convenables.

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