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Effect of nuchal cord on fetal cerebral haemodynamics and oxygenation measured by near infrared spectroscopy during labour

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Abstract

Objective: To test the hypothesis that a nuchal cord has a significant effect upon fetal cerebral haemodynamics and oxygenation during labour. *Study design*: A specially designed optical probe was inserted through the dilated cervix and placed against the scalp of 37 fetuses during labour in a teaching hospital obstetric unit. Changes in total cerebral haemoglobin concentration were measured continuously together with fetal heart rate and uterine contraction frequency during the first and second stages. *Results*: At birth 11 fetuses (30%) were noted to have a nuchal cord (cord around the neck). For these, significantly more contractions were associated with an increase in total cerebral haemoglobin concentration when compared with the control fetuses without a nuchal cord (40.2% (S.D.19.5) vs 5.9% (S.D.7.1), $P < 0.001$). A significantly greater number of variable decelerations was found in the nuchal cord group (4 per 30 min vs. 2 per 30 min in the controls) ($P < 0.01$). There was no significant difference between mean cerebral oxygen saturation determined at the end of the first stage of labour, which was 47.0% (S.D.13.3) and 50.1% (S.D.11.8) for the nuchal cord and control groups, respectively. *Conclusion*: A nuchal cord was associated with a significant increase in cerebral blood volume during uterine contractions, without any significant effect upon cerebral oxygenation.

Keywords: Near infrared spectroscopy; Fetal; Nuchal cord

1. Introduction

A nuchal cord (umbilical cord around the fetal neck) is present at birth in approximately 20–30% of fetuses [1], and although its clinical importance remains controversial it has been considered by most obstetricians to be of no consequence [2]. However, some authors have described an association with abnormal fetal heart rate (FHR) patterns [3,4], which may occur both before and during labour. An association between nuchal cord and acidaemia at birth has also been reported [5]. More recently neonatal anaemia [6] and hypovolaemic shock [7] have been associated with the presence of a nuchal cord. No information about the effects of a nuchal cord on the fetal cerebral circulation is currently available. The purpose of this study was to determine the effect of a nuchal cord on cerebral haemodynamics and oxygenation during the first and second stages of labour using the newly developed technique of fetal near infrared spectroscopy (NIRS) [8–10].

2. Materials and methods

Thirty-seven women (24 primigravid, 13 multiparous), aged between 20 and 41 (median 30) years were recruited for the study. All were in established labour at a median of 40 (range 34–42) weeks of gestation. Each had a singleton fetus with a cephalic presentation and ruptured amniotic membranes. Twenty five women had effective epidural analgesia (0.25%-0.50% bupivacaine),

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nine were receiving Entonox (50:50 nitrous oxide and oxygen) and/or had received pethidine (50–150 mg pethidine i.m.) and three had no analgesia. Twenty two of the labours were augmented with intravenous oxytocin infusions (4–30 milliunits/min) and regular uterine contractions were present in all cases. The fetal heart rate and uterine contractions were monitored continuously using cardiotocography (Hewlett Packard 80300A, Hewlett Packard, Mass, USA.). The study was approved by the local committee on the ethics of human research and informed written consent was obtained from each woman prior to entry into the study.

A specially designed fetal optical probe [8] was inserted through the dilated cervix (median 7 cm, range 3 to 10 cm) and applied against the side of the fetal head during a routine vaginal examination. The probe incorporated the ends (optodes) of two flexible fibreoptic bundles mounted at a fixed distance of 3.5 cm apart. It was applied to the fetal scalp, care being taken to avoid the face and ears, and was maintained in position by maternal tissue forces and controlled continuous negative pressure (150 mmHg) provided by a modified wall suction apparatus. One fibre bundle conveyed near infrared light at four different wavelengths between 777 and 913 nm from a portable spectrophotometer (NIR0500, Hamamatsu Photonics KK, Hamamatsu City, Japan) to the probe. Light emerging from the head was returned via another optode and fibre bundle back to the spectrophotometer. Changes in attenuation at each wavelength were detected continuously and converted into cerebral concentration changes in oxyhaemoglobin [HbO_2] and deoxyhaemoglobin [Hb] using a previously established algorithm [11–13]. Changes in total cerebral haemoglobin [Hb_{tot}] were obtained, using the expression [Hb_{tot}] = [HbO_2]+[Hb] [14–15]. Data were averaged over consecutive 10-second periods and the NIRS data together with the cardiotocography data were recorded onto a portable computer for subsequent analysis.

After application of the NIRS probe, all the women were helped into a comfortable position and monitoring was commenced and, where possible, continued up to the end of the second stage. At delivery blood was taken from the umbilical artery for acid-base analysis and estimation of haemoglobin concentration. Apgar scores at 1 and 5 min were recorded for each fetus.

Overall changes in [Hb_{tot}] during each uterine contraction were assessed (Onmain vs. 1.32a, Hamamatsu Photonics KK) and classified as demonstrating an increase or no change or a decrease from the baseline established before the onset of the contraction. Significant changes were judged to have occurred when there had been an increase of more than 2 S.D. from the baseline and this was confirmed by visual inspection. Data were further divided between the first and second stages of labour. For each patient the number of contractions with an increase in [Hb_{tot}] was then expressed as a percentage of the total number of contractions during each stage of labour.

During a uterine contraction where both [HbO_2] and [Hb] demonstrated a change in the same direction estimates of the mean cerebral oxygen saturation ($SmcO_2$) were determined as previously described [8], using the formula:

$$SmcO_2 = \frac{100 \times \Delta[HbO_2]}{\Delta[HbO_2+Hb]}$$

For each fetus the mean value for $SmcO_2$ was calculated over a 15 min period (2–5 contractions), within 30 min of the diagnosis of full dilatation (a period common to all studies).

The incidence of variable FHR decelerations for each fetus, occurring during first and second stages, was assessed using the continuous cardiotocograph recordings by one author (CJA) who was unaware of the presence or absence of nuchal cord. This was expressed as the mean number of variable decelerations per 30 min of CTG trace.

3. Results

No difficulty was experienced in positioning the probe satisfactorily on the fetal scalp and none of the mothers found monitoring with NIRS uncomfortable. Satisfactory data were obtained from all 37 fetuses. At birth 11 of the 37 fetuses had a nuchal cord (29.7%) and this was either slipped over the baby's head ($n = 6$) or required clamping and cutting ($n = 5$), before delivery of the trunk. In the group with nuchal cord, three women had a spontaneous vaginal delivery and eight had operative deliveries (three ventouse, three forceps and two lower segment caesarean section (LSCS)), for either fetal distress ($n = 2$) or delay in the second stage ($n = 6$). In the control group of 26 infants, 14 were born by spontaneous vaginal delivery and 12 had operative deliveries (six ventouse, four forceps and two LSCS) performed either for fetal distress ($n = 2$) or delay in the second stage ($n = 10$). The median birthweight of the nuchal cord group was 3291 g (S.D. 506) which was not significantly different from the median in the control infants, 3408 g (S.D.606). There was no significant difference in the umbilical artery pH between the nuchal cord and control groups 7.23 (S.D. 0.08) vs. 7.27 (S.D. 0.09). Two infants (one with a nuchal cord and one without) had an Apgar score less than 6 at 1 min and required intubation and intermittent positive pressure ventilation. The Apgar score at 5 min was greater than 9 in all infants and none required admission to the neonatal unit.

The changes in [HbO_2], [Hb], FHR and uterine contractions in two fetuses, one with a nuchal cord (a) and the other without (b) are illustrated in Fig. 1. A total of

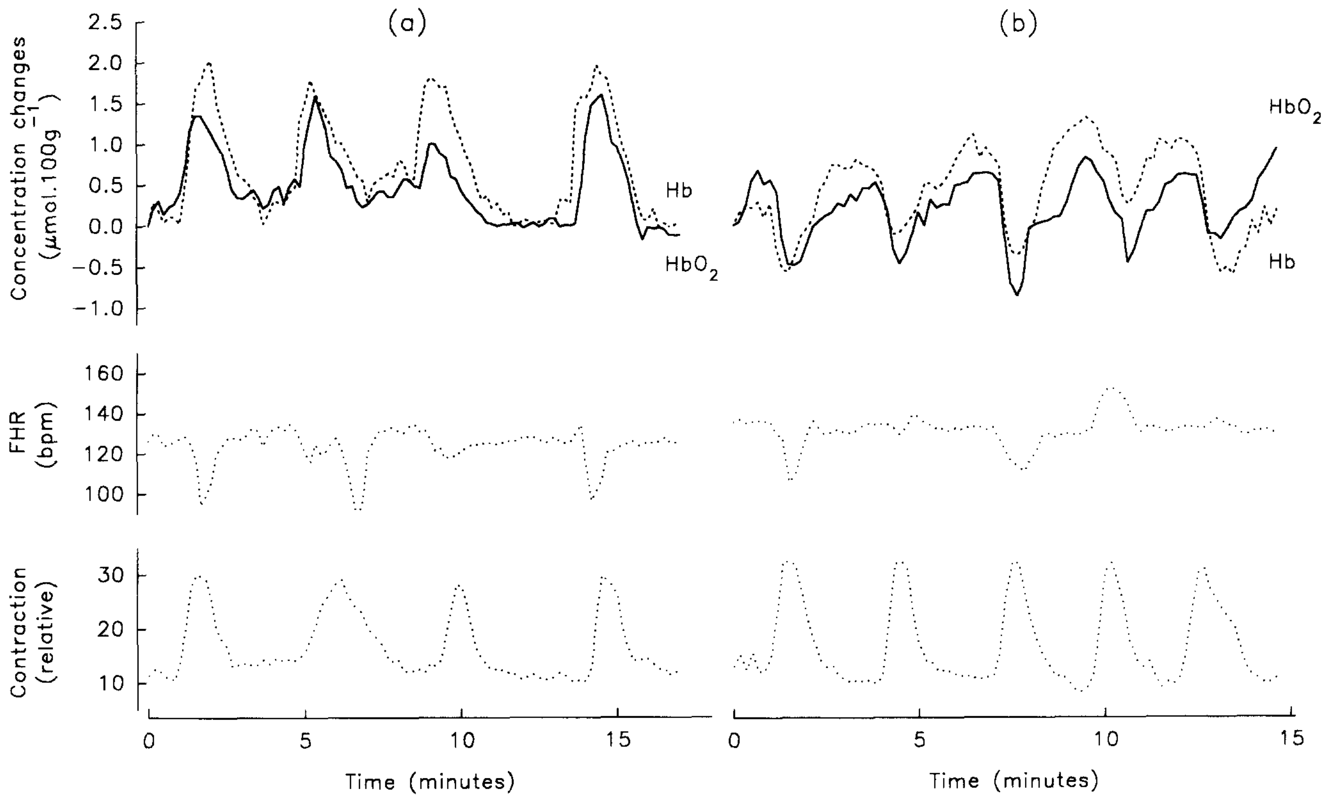

Fig. 1. Representative changes in [HbO_2], [Hb], FHR and uterine contractions in a fetus with a nuchal cord (a) and in a control fetus (b).

1984 contractions were analysed and of these 373 were associated with a significant increase in [Hbtot]. For the fetuses in the nuchal cord group a mean of 40.2% (S.D. 19.5) of uterine contractions was associated with an increase in [Hbtot] which was significantly greater than in control fetuses, 5.9% (S.D. 7.1) (unpaired students t test and Mann-Whitney U test $P < 0.001$) (Fig. 2). Within the nuchal cord group there was no significant difference in the percentage of uterine contractions that were associated with an increase in [Hb_{tot}] between the 1st and 2nd stages, 44.59% (S.D. 26.1) and 36.1% (S.D. 21.8), respectively.

The mean $SmcO_2$ for the nuchal cord group was 47.0% (S.D. 13.3) compared with 50.1% (S.D. 11.8) for the control group (no significant difference). The mean number of variable decelerations observed within a 30 min period was significantly greater in the nuchal cord group (4.0 (S.D. 2.5)) when compared with the control fetuses (2.0 (S.D. 1.7)) (unpaired t test $P < 0.01$); in the nuchal cord group, 34.6% (S.D. 23.5) of the contractions showing an increase in [Hb_{tot}] were associated with variable decelerations.

4. Discussion

During labour the fetal head is subjected to considerable compression [16] and we have previously reported that uterine contractions are associated with significant changes in [Hb_{tot}] and cerebral blood volume (CBV) [9]. The pattern that we have most frequently observed is one of a transient reduction in CBV synchronous with each uterine contraction but we have previously noted that a minority of fetuses demonstrated a rise in CBV with uterine contractions [8,9]. In this study we have shown that this unusual pattern of changes in fetal cerebral haemodynamics during uterine contractions is strongly associated with the presence of a nuchal cord.

During a uterine contraction a pressure gradient exists between the fetal head and thorax [17] and we have previously suggested that this results in blood being mechanically squeezed from the cerebral venous compartment with a consequent reduction in CBV [9]. The presence of a nuchal cord appears to interfere with this process. One possible explanation for this observation is transient compression of the jugular veins of the neck by the umbilical cord [18,19] during uterine contractions. If the arterial blood supply to the brain was maintained during the uterine contraction the cerebral blood volume would increase as long as the venous drainage of the head was obstructed.

The overall changes in [Hb_{tot}] we observed during contractions are the sum of changes in the arterial and venous compartments of the head. If it is assumed that

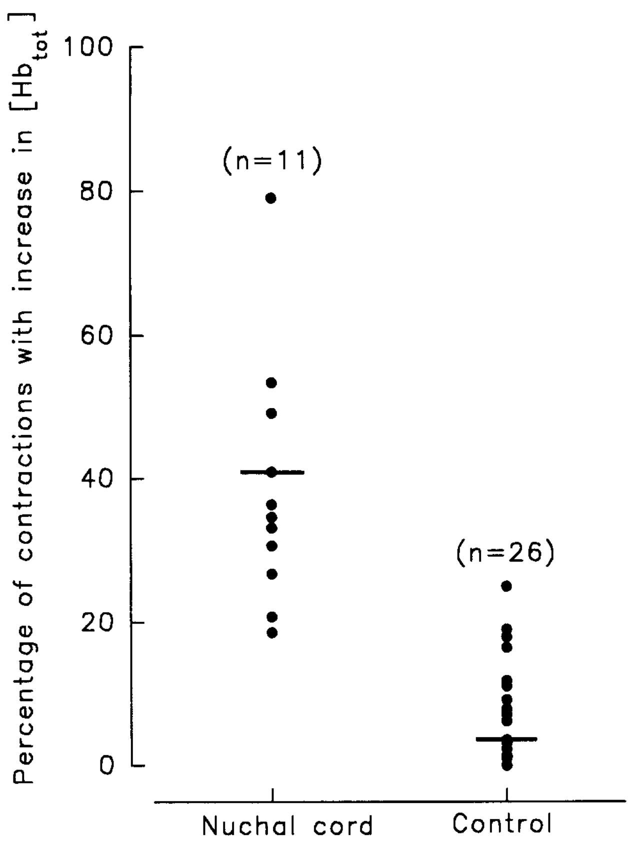

Fig. 2. Percentage of uterine contractions associated with an increase in [Hb_{tot}], for fetuses with a nuchal cord and control fetuses.

an increase in [Hb_{tot}] in the nuchal cord group was associated with total occlusion of the cerebral venous outflow, it is possible to obtain an estimate of cerebral blood flow (CBF), since the rate of increase in CBV is equal to the CBF. This is analogous to the method of estimating CBF in newborn infants by transient jugular venous compression [20]. Changes in [Hb_{tot}] may be converted into changes in CBV using the haemoglobin concentration, obtained from the umbilical artery at birth, and assuming a cerebral large vessel haematocrit of 0.69 [15]. Estimates for CBF, made in this way, were determined for each fetus with a nuchal cord over a 30 min period and a mean value of 15.0 (S.D. 14.9) ml/100g/min was obtained, very similar to values found by NIRS in newborn infants [21,22]. Since it is possible that only partial venous occlusion occurred in some cases, values for CBF during labour are likely to be underestimated when calculated in this way.

Although increases in CBV during contractions were strongly associated with the presence of a nuchal cord, this pattern also occurred occasionally in the control fetuses. It is possible to speculate that this may have occurred for other mechanical reasons such as a greater pressure on the thorax than on the head during a uterine contraction, resulting in an increase in central venous pressure [23], or transient compression of the jugular veins caused for example by rotation of the head [18]. The changes in CBV during uterine contractions depend on the balance of forces between the head and the neck and thorax and it is obvious that many complex factors will influence this balance.

Although it might be expected that the effect of a nuchal cord would become more pronounced with descent of the fetus down the birth canal and potential tightening of the cord, we observed no significant differences between the first and second stages of labour. During the second stage intrauterine pressure increases, especially with the onset of pushing. This may result in an increase in the pressure exerted directly on the fetal head [24] and this may counteract the effect of a tighter nuchal cord compressing the jugular veins.

In the nuchal cord group we observed a greater incidence of variable fetal heart rate decelerations. This may be explained by compression of the umbilical artery and vein in the segment of cord round the neck, during contractions [25]. Compression of the jugular veins would also cause a significant reduction in venous return to the right side of the heart [20] and this may be associated with alterations in fetal heart rate. Although variable decelerations have been associated with a poor fetal outcome the association is not strong [26].

Values for $SmcO_2$ calculated during labour, and for umbilical artery pH measured at birth, were slightly lower in the nuchal cord group compared with the controls. This difference did not reach statistical significance and a much larger study would be required to prove a genuine effect.

In conclusion, this study has demonstrated that uterine contractions during labour are more likely to result in a transient increase in fetal CBV if the umbilical cord is around the fetal neck. No significant adverse effects of nuchal cord on cerebral oxygenation or neonatal outcome were detected.

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References

[1] Paul RH, Suidan AK, Yeh SY, Schifr BS, Hon EH. Clinical fetal monitoring. V. The evaluation and significancy of intrapartum baseline FHR variability. Am J Obstet Gynecol 1975; 123: 206–10.

[2] Pritchard JA, MacDonald PC, Gant NF. Conduct of normal labour and delivery. In: William Obstet, 17th ed. Norwalk: Appleton-Century Crofts, 1985; 340–64.

[3] Paul RH, Krosnick G. Fetal heart rate in excessive cord encirclement. Obstet Gynecol 1966; 28: 646–9.

[4] Goldkrant JW, Speinchninger JP. "Mixed cord compression", fetal heart patterns, and its relation to abnormal cord position. Am J Obstet Gynecol 1975; 122: 144–50.

[5] Stembera ZK, Horska S. The influence of coiling of the umbilical cord around the neck of the fetus on its gas metabolism and acid-base balance. Biol Neonate 1972; 20: 214–9.

[6] Shepherd AJ, Richardson CJ, Brown JP. Nuchal Cord as a Cause of Neonatal Anemia. Am J Dis Child 1985; 139: 71–3.

[7] Vanhaesebrouck P, Vanneste K, De Prater C, Van Trappen Y, Tiery M. Tight nuchal cord and neonatal hypovolemic shock. Arch Dis Child 1987; 62: 1276–7.

[8] Peebles DM, Edwards AD, Wyatt JS et al. Changes in human fetal cerebral hemoglobin concentration and oxygenation during labour measured by near infrared spectroscopy. Am J Obstet Gynaecol 1992; 166: 1369–73.

[9] Peebles DM, Wyatt JS. Near infrared spectroscopy and intrapartum fetal monitoring. Contemp Rev Obstet Gynaecol 1993; 5: 124–9.

[10] O'Brien PMS, Doyle PM, Rolfe P. Near infrared spectroscopy in fetal monitoring. Br J Hosp Med 1993; 49: 483–7

[11] Essenpreis M, Elwell CE, Cope M, van der Zee P, Arridge SR, Delpy DT. Spectral dependence of temporal point spread functions in human tissues. Appl Opt 1993; 32: 418–25.

[12] van der Zee P, Cope M, Arridge SR et al . Experimentally measured optical pathlengths for the adult head, calf and forearm and the head of the newborn infant as a function of interoptode spacing. Adv Exp Med and Biol 1992; 316: 143–53.

[13] Wray S, Cope M, Delpy DT, Wyatt JS, Reynolds EOR. Characterisation of near infrared absorption spectra of cytochrome aa_3 and haemoglobin for the noninvasive monitoring of cerebral oxygenation. Biochim Biophys Acta 1988; 933: 184–92

[14] Wyatt JS, Cope M, Delpy DT, Wray S, Reynolds EOR. Quantification of cerebral oxygenation and haemodynamics in sick newborns infants by near infrared spectroscopy. Lancet 1986; ii: 1063–6.

[15] Wyatt JS, Cope M, Delpy DT et al. Quantification of cerebral blood volume in human infants by near infrared spectroscopy. J Appl Physiol 1990; 68: 1086–91.

[16] Mann LI, Carmichael A, Duchin S. The effect of head compression on FHR brain metabolism and funtcion. Obstet Gynecol 1972; 39: 721–6.

[17] Furya H, Hashimoto T, Kokuho K, Kino H, Fukumauchi K. Pressures on the human fetus during labor — intrauterine and on the fetal head. Nippon Sanka Fujinka Gakkai Zasshi 1981; 33: 2173–81.

[18] Cowan F, Thoresen M. The effect of interruption of the cranial venous drainage on cerebral haemodynamics in the new born infant. In: Rolfe P, ed. Neonatal physiology measurements, proceedings of the second conference on fetal and neonatal physiological measurements. London: Butterworths, 1986; 86–96.

[19] Williams J, Chir B, Katzman GH, Kripke SS. Neck Compression by nuchal cord. Am J Obstet Gynecol 1981; 140: 345–6.

[20] Cross KW, Dear PRF, Hathorn MKS et al. An estimation of intracranial blood flow in the new born infant. J Physiol 1979; 289: 329–45.

[21] Edwards AD, Wyatt JS, Richardson EC, Delpy DT, Cope M, Reynolds EOR. Cotside measurement of cerebral blood flow in ill newborn infants by near infrared spectroscopy. Lancet 1988; ii: 701–2.

[22] Meek JH, Kirkbride V, Edwards AD, Wyatt JS, Reynolds EOR. Changes in cerebral blood flow in very preterm babies measured over the first three days of life by near infrared spectroscopy (abstract). Early Human Devel 1994; 36(3).

[23] Hibino H, Matsuura M. Cerebral venous sinus pressure in seated dogs: impact of PEEP, cervical venous compression, and abdominal compression. Anesth 1985; 63: 184–9.

[24] Rempen A, Kraus M. Pressure on the fetal head during normal labor. J Perinat Med 1991; 19: 199–206.

[25] Ingemarsson I, Ingemarsson E, Spencer JAD. Maternal and fetal acid-base balance. In: Ingemarsson I, Ingemarsson E, Spencer JAD, eds. Fetal heart rate monitoring — a practical guide. Oxford: Oxford University Press, 1992; 153–81.

[26] Cibils LA. Clinical significance of fetal heart rate patterns during labor.V.Variable decelerations. Am J Obstet Gynecol 1978; 132: 791–803.