Fetal Doppler Hypoxic index for the prediction of abnormal fetal heart rate at delivery in chronic fetal distress

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Abstract

Objective: To design a Doppler Hypoxic index (HI), which takes into account both the duration and the intensity of fetal flow redistribution (i.e. hypoxia) for predicting the occurrence of abnormal fetal heart rate (FHR) at delivery.

Method: Sixty-six pregnancies with hypertension and/or growth retardation (IUGR) were investigated (age: 23 ± 5 years; primigravidas: 30%, CS 59%; hospitalisation: 10 ± 8 days, IUGR (<10 c) 82%, intensive care 23%, fetal death 1). Umbilical (URI) and cerebral (CRI) Doppler resistance indices, and the C/U ratio (CRI/URI) were measured every 2 days from admission to delivery. HI was calculated by summing the daily %C/U reduction (in % from normal cut-off limit 1.1) over the period of observation (or mean C/U reduction in % from $1.1 \times$ number of days of observation). Doppler C/U and HI were compared with fetal heart rate (FHR) traces, and perinatal data.

Results: HI > 160% was associated with abnormal FHR in 80% of the cases (PPV = 87%, NPV = 88%). HI > 160% predicted the occurrence of abnormal FHR 8 ± 6 days before they happened.

Conclusion: A combination of intensity and duration of the fetal flow redistribution (i.e. hypoxia) evaluated by Doppler is correlated with the occurrence of abnormal fetal heart rate.

1. Introduction

The alteration of placental function is generally responsible for a reduction in the nutritive supply leading to IUGR (intrauterine growth restriction) with or without hypovolemia and decreased fetal oxygen blood pressure (hypoxia). Fetal hypoxia can lead to poor perinatal outcome, perinatal brain damage and cerebral palsy. The physio-pathological mechanism of hypoxia is complex. The fetus reacts immediately to hypoxia by modifying heart rate, increasing arterial blood pressure and redistributing the cardiac output towards vital organs (heart, coronary, adrenal glands) [1–3]. This phenomenon, called the "brain-sparing effect", attempts to compensate for fetal hypoxia by providing more oxygen to the brain via a cerebral vasodilation but does not prevent the development of brain damage [4–8]. As a result, the question of the beneficial effect of fetal flow redistribution towards the brain must be raised. In pregnancies complicated by malaria the fetus is submitted to transient and reversible flow redistribution probably in relation to hypoxia. Nevertheless, when the crisis (and thus the exposure to flow redistribution or hypoxia) exceeds 1 week, abnormal fetal heart rate (FHR) patterns occur in 75% of the cases at delivery, several weeks after the crisis [9]. These observations suggest that the occurrence of functional (abnormal FHR) or organic fetal damage may depend both on the amplitude of the p_{O_2}

decrease, as has already been suggested, and on the duration of the exposure to the hypoxia. On the other hand several studies have suggested that decelerations in the fetal heart rate are a late sign of fetal deterioration, before which the fetus might be delivered [10–13]. Thus anticipation of FHR abnormality by Doppler monitoring of the fetal flow redistribution occurring before worsening hypoxia could provide an opportunity for early intervention [14–16].

The objective of the present study was to evaluate the predictive value of the Hypoxic index (HI), which integrates both the duration and the intensity of the hypoxia, as assessed by Doppler, in identifying fetal heart rate abnormalities in pregnancies complicated by hypertension or presenting IUGR.

2. Materials and methods

2.1. Population and protocol

The study was both a prospective and an observational one, and was carried out in the obstetric and fetal medicine department of the government hospital of the City of Tours in France. Sixty-six pregnant women with hypertension (pregnancy-induced hypertension; blood pressure > 140/ 90 mmHg), or presenting IUGR (below 10th percentile) were studied. None of them presented fetal malformation at the 23-week echographic control. Once the pregnant women were admitted to hospital, the fetus underwent Doppler every 2 days, and fetal well-being was assessed by at least two or three daily non-stress tests until delivery.

Delivery was not decided on the basis of the Doppler measurements but on the basis of the maternal and fetal clinical data and fetal heart rate pattern. Following delivery, the clinical data were collected and compared with the Doppler data. Doppler examination of the fetal blood vessels was used to confirm the existence of hemodynamic abnormalities at the placental level accompanying intra-uterine growth retardation, and to evaluate any cerebral vascular response to hypoxia.

2.2. Fetal hemodynamic parameter

Distribution of the fetal flows (between the placental and cerebral regions) was evaluated using the cerebral–umbilical resistance ratio (C/U), which is the ratio between the cerebral (CRI) and umbilical (URI) resistance indexes [1,3,17,18]. This parameter is always greater than 1.1 during normal pregnancy as CRI is always higher than URI. In the case of hypoxia URI increases (increase in placental resistance), CRI decreases (cerebral vasodilation) and C/U becomes lower than 1.1 [1]. The C/U ratio decreases proportionally with the fetal partial pressure of oxygen (p_{O_2}); it is not dependent on the fetal heart rate (as are the other CRI and URI Doppler indices), and its cut-off limit between the normal and pathological zones remains equal to 1.1 from 25 to 40 weeks of gestation [1,2,19–21].

Thus, the decrease in C/U from the cut-off value, expressed as a percentage in percent of this limit, is proportional to the reduction in p_{O_2} from the lower limit of the normal range (p_{O_2} relative deficit). Thus, by adding the decrease in C/U below the cut-off value (measured every day or 2 days) over the period of observation, we measured the cumulated relative deficit (or presumed) in p_{O_2}, to which the fetus was submitted during this period. The Hypoxic index is calculated by adding the percentage decrease of C/U (when C/U becomes lower than 1.1) at each measurement from admission to delivery. This number corresponds to the area between the %C/U curve and the time axis (days) (Fig. 1). A cut-off limit of 150% for HI, was found retrospectively in a study of pregnancies complicated by malaria [9] using ROC curves analysis. An HI of 150% can correspond, for example, to 3 days under a reduction of 50% in p_{O_2} (3 × 50), or to 15 days under a reduction of 10% of the fetal p_{O_2} (15 × 10). The HI takes into account the reduction in fetal p_{O_2} and the exposure duration to flow redistribution or hypoxia. ROC curves analysis was also used in the present study for determining the optimal HI cut-off value to be used for predicting the abnormal FHR. The product of the p_{O_2} value at delivery (Umbilical artery p_{O_2}) by the number of days with fetal flow redistribution (C/U < 1.1) was compared to the HI value (regression).

2.3. Data collection and processing

Doppler examinations were performed by two sonographers; the Doppler Hypoxic index was calculated after delivery. The obstetrician in charge of the pregnancy knew when there was flow redistribution (C/U < 1.1), but the flow redistribution was present in 70% of the whole population and in 94% of the fetuses below 32 weeks. The ultrasound system used was an ATL HDI 3000 (Philips, Paris, France) with either 3.5 or 5 MHz probes. At each Doppler examination, we measured the CRI, URI, C/U. Antenatal cardiotocography was performed as a non-stress test with conventional equipment (Hewlett Packard; Sonicaid), and was interpreted by visual assessment.

The protocol for Doppler measurements was approved by the Institute for Human Health Research (INSERM); each patient was informed of the protocol content and signed a formal consent document.

After delivery, the Doppler data were compared with the fetal and maternal clinical data: FHR monitoring preceding delivery, gestational age at delivery and route of delivery, Apgar score at 1 and 5 min, and fetal weight at delivery (centile). The FHR was considered as abnormal in the case of reduced baseline variability (less than 5 bpm for more than 40 min), or late decelerations. FHR traces were evaluated blind by two obstetricians. The Apgar score at 5 min was considered as pathological when lower than seven. Normal delivery was defined as at-term delivery, without signs of fetal distress or maternal complication. Cesarean section was decided for various reasons such as