A NEW BASIS FOR AUTOMATIC FOETAL TOPOGRAM ANALYSIS

Carlos Hernández
Department of Electronic. Faculty of Physic. University of Santiago de Compostela. SPAIN.
Walter C. de Lima
Department of Electrical Engineering. U.F.S.C. BRAZIL.

ABSTRACT

During childbirth the state of the child is diagnosed on the basis of foetal heart rate (FHR) and maternal uterine pressure (UP) signals together with the obstetrical and general medical background of the mother. The foetal topogram and its associated display, which make up a screen-based interactive interface between the obstetrician and the automatic diagnostic systems new available, is designed to facilitate colaboration between medical staff and engineers in developing such systems. Consisting essentially in a two-dimensional figure produced by plotting FHR against UP for each contraction, analysis of the topogram to identify the type of each individual contraction constitutes the first step in most automatic diagnostic procedures. This article describes the analysis of topograms by the application of grid pattern techniques, which bring the machine's modus operandi into closer accord with that of human analysts.

INTRODUCTION

Diagnosis of the state of the foetus during labour is customarily carried out by visual analysis of cardiotocograph traces of foetal heart rate (FHR) and maternal uterine pressure (UP) (1) (2). Examination of these signals allows local diagnosis of the child's response to individual contractions and, together with the mother's obstetrical and general medical history, permits the obstetrician to estimate the child's progress. Such evaluations, which may be roughly quantified as predictions of the newborn child's Apgar rating, are essential for rapid diagnosis of foetal stress to allow surgical of pharmocological action to forestall possibly irreversible damage (3)(4)(5)(6). For some time, efforts have been made to automate these functions. Although reasonable success has been met with (up to 95% of predicted Apgar ratings correct to within ±1 point), it has become apparent that further advances require attention to be paid to the nature of the interface between the automatic system and the human obstetrician, both to facilitate communication between obstetrician and engineer and to allow the machine to make a positive contribution to the obstetrician's work even should he choose to ignore the actual diagnoses it produces.

With the above aims in view, we have based the user interface of our current automatic perinatal diagnostic systems on the foetal topogram, a two-dimensional figure which is characteristic of the contraction and is formed by plotting FHR against UP after filtering the signals. The topogram is displayed on a monitor screen and enables each contraction to be classified in one of the six categories customarily considered in obstetrics and which constitute the basis of the diagnostic procedures terminating in prediction of the newborn child's Apgar rating. Visual analysis of this simple figure is simpler for the obstetrician than that of twin cardiotocograph traces, and the system also automatically separates and presents other important information usually extracted by eye, notably the FHR pedestal (which should remain within certain limits) and the intensity of its rapid fluctuations (which reflect general neurological condition).

In earlier versions of the system we based the machine's automatic classification of individual topograms on their representation as strings of letters using the Freeman code. However, given the figures' origin in the FHR's response to increased UP during contractions, the human obstetrician almost certainly grants more importance to which areas of the FHR-UP plane the topogram passes through than to its shape as such. The present paper describes how, in keeping with our general philosophy of facilitating dialogue between medical staff and engineers, we have now brought the machine's modus operandi more into line with the obstetrician's by implementing a grid pattern approach to the automatic classification of topograms.

METHODS

The system is implemented on an HP-9827T with 64 Kbytes of memory. Foetal heart rate and maternal uterine pressure signals were obtained using and HP-8040A Doppler effect cardiotocograph with intrauterine catheters and subcutaneous electrodes.

The UP and FHR signals contain both low frequency components representing respectively the contraction of the uterus and the foetal heart's response to this aggression, and high frequency components due to straining, retching and foetal movements (in the case of the UP) or to the activity of the sympathetic-vagus system (in the case of the FHR). Only the low-frequency components are used in the classification of individual contractions, but the high frequencies also contain clinically important information. Once the FHR and UP signals have been digitalized at 1 Hz, the high and low frequency components are therefore separated by means of a second-order low-pass Butterworth filter and subtraction. The duration of each contraction is found using a derivator and a threshold detector (7), but relaxed periods are included at the beginning and end of the segment of signal used for classification, which is thus one and a half times as long as the contraction itself.

THE FOETAL TOPOGRAM

This two-dimensional character is formed by plotting the low-frequency FHR signal against the low-frequency UP signal ever a period one and a half times the duration of the contraction (although the topogram display usually shows the single topogram generated by the latest contraction, the user may also request accumulated display of the latest four topograms) (figure 1). The topogram display area is divided by FHR and UP thresholds into diagnostic regions corresponding to normal, tachycardial, sub-pathological and pathological responses, the latter two classes also being susceptible to subdivision into areas of moderate or severe bradicardia (figure 2). On the basis of the topogram the obstetrician can identify the type of each contraction according to the following classification of the foetal heart's responses to uterine pressure:

Healthy responses	Accelerations (A) No change (normal)(N) Early decelerations (E)
Sub-pathological responses	Variable dips (V)
Pathological responses	Late decelerations (L) Combined dips (e.g. la te deceleration with variable dip) (C)

Fig. 2 shows the areas of the screen typically intersected by the topograms of some of these types of contraction.

AUTOMATIC CLASSIFICATION, DIAGNOSIS AND PREDICTION

For the purposes of automatic topogram classification, the system uses a finer division of the FHR-UP plane than that shown in fig. 2, namely the 7x4 checkerboard arrangement of tables 2, which show the templates obtained for Variable and Late dips on the basis of 53 contractions of these types. When classifying a given topogram, the system first sets up a binary matrix showing which checkerboard squares it intersects, and then uses a grid point transformation algorithm to assign this input pattern to the class to whose template it is closest according to a weighted Chebychev distance function. The individual contraction type identification thus carried out is now passed to a set of syntactic pattern recognition procedures which use the string of identifications corresponding to successive contractions together whith other antenatal and perina:tal factors to obtain a final prediction of the newborn child's Apgar rating (8).

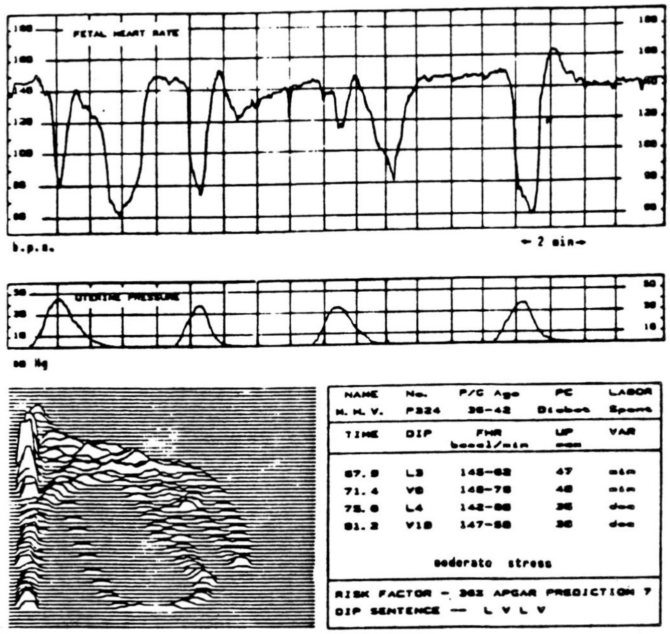
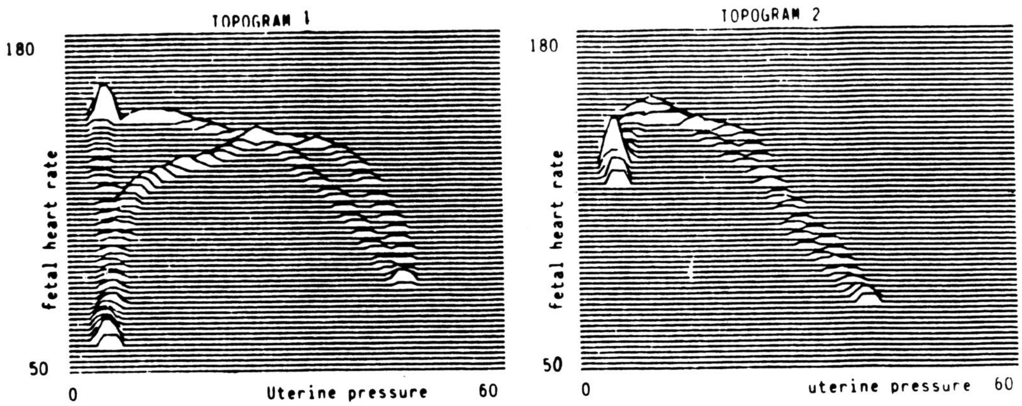


Fig. 1. Above: Cardiotocograph FHR and UP traces, showing 4 contractions. Below: The accumulated topogram of the 4 contractions, with the associated data display. Dip identifications are those made by the earlier system based on Freeman codings.

RESULTS AND DISCUSSION

By way of illustration, fig. 2 shows the topograms of the four contractions whose cardiotocograph traces are shown in fig. 1. In terms of the rough 6-area screen division considered suitable for human evaluation of the topograms, these four may be described as in table 3. It will be noted that whereas the earlier system based on Freeman codings classified contractions 1 and 3 as Late dips (fig. 1), the present algorithm classifies them as Combined dips. This is because the earlier scheme wighted the more patholofically significant component (see table 3 comment on



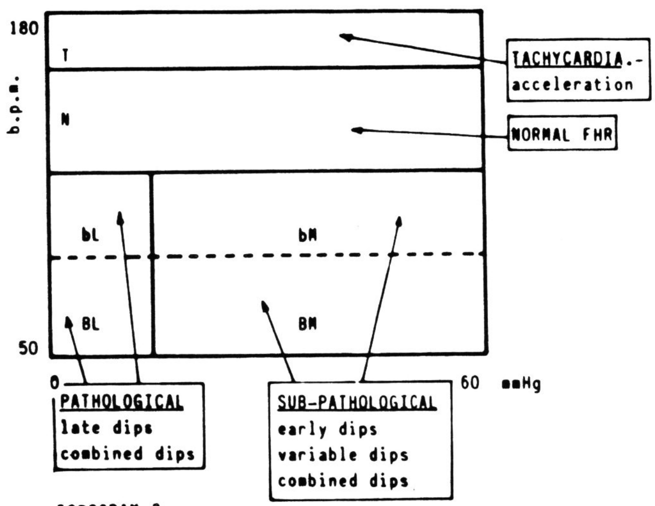
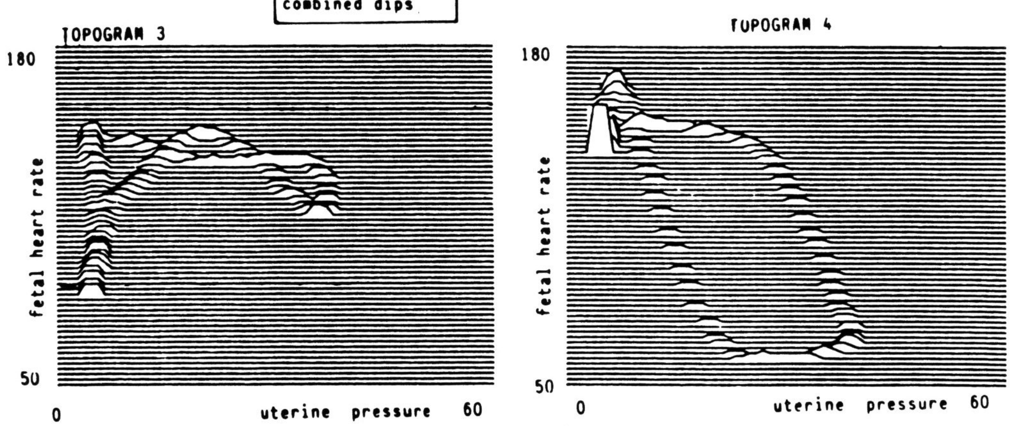


Fig.2
The four individual topograms of the contrations of fig.1 ,together with an explanation of the pathological significance of the various screen areas.



Topogram 3), whereas the grid pattern procedure reflects more closely the more phenomenological attitude underlying the customary classification scheme. These two approaches are nevertheless interchangeable with slight modifications of either set of algorithms.

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LATE DIP

T	0	0	0	0
N	78	100	100	92
	100	94	92	80
b	100	30	0	0
	100	0	0	0
B	80	0	0	0
	25	0	0	0
	L	M		

VARIABLE DIP

T	0	0	0	0
N	67	100	91	65
	98	100	100	30
b	0	96	100	20
	0	92	100	0
B	0	80	100	0
	0	73	81	0
	L	M		

Tabla 2. Screen area intersection percentages of 53 Late topograms corresponding to Varia ble or dips. Areas defined by continuous lines correspond to those of fig. 2.

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TOPOGRAM	T	N	bL	BL	bM	BM	CLASSIFICATION	COMMENTS
1	0	1	1	1	1	1	C	The intense bradicardia at low UP signals severe foetal stress
2	0	1	0	0	1	1	V	The hint of late deceleration at the left does not reach the bradicardial threshold
3	0	1	1	1	1	0	C	This combined dip is clearly dominated by the late dip component
4	1	1	0	0	1	1	V	The "compensatory" thachycardia registered is a common evershost effect on recovery from intense bradicardia

Table 3. Screen area pattern and classification of four contractions