Computerized Analysis and Control of the Nonstress Test


Biomedical Engineering* and Obstetrics and Gynecology**

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We present a practical, inexpensive system which analyzes and documents fetal heart rate (FHR) baseline, long-term variability and episodic FHR events in real time and also controls a routine antenatal test protocol, archives and retrieves data, and transmits data between compatible computers.

The acquisition and analysis of FHR records is now possible with inexpensive microcomputers. Numerous techniques have been developed for conditioning and analyzing FHR data to compute basal rate, long- and short-term variability, acceleration and deceleration events, correlations to perceived fetal movements and contractions, rate alarm conditions, and classification of alarms and deceleration events. However, few systems successfully integrate their output into a standard clinical protocol. The system described in this report replaces manual analysis of FHR tracings obtained in an antenatal setting with an automated, objective, precise and comparative evaluation which is immediately available for clinical interpretation.

The system consists of a Hewlett Packard 8040A FHR monitor interfaced to an IBM PC/XT microcomputer equipped with a color monitor and a Texas Instruments TI-855 dot matrix printer. The monitored parameters, FHR, tocodynamometer (TOCO) and perceived fetal movement, are transmitted on demand to the microcomputer every 100ms and averaged for one second. The program offers a menu of commands which control the test protocol, archive the data and transmit or receive data from another system. As data is acquired, it is analyzed by routines which reject artifact, compute baseline FHR, identify accelerations and decelerations, and compute long-term variability. The test terminates at the first occurrence of three accelerations within a thirty minute window or when the elapsed time reaches 90 minutes. The program then prints a facsimile of the FHR and TOCO tracings which are annotated for acceleration and deceleration events and perceived fetal movements. Tables of maternal variables and statistical analyses may also be printed. Test data are saved on hard disk, compressed and archived on floppy disks. The data may be transmitted via telephone and high speed modem to another computer for analysis, display and voice consultation.

The analysis algorithms have been tested off-line on over 600 nonstress tests. A sample of 284 were chosen for comparative analysis by manual techniques on the basis of the test occurring within eight days of delivery. In determination of baseline mean FHR and recognition of acceleration and deceleration events, correlation values ranged from 0.80 to 0.98 with no significant difference between manual and computerized techniques.

References:
Signal Processing in a Local Area Network.

A Micro Controller System used for Processing of a.p. CTG

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Interfacing of Monitoring devices to a computer requires
- a normed and compatible serial interface in the Monitor or
- a short analog cabling or for longer distances
- a sophisticated analog wiring.

To eliminate or reduce this problems we introduce a multi-purpose
Micro Controller System for simple serial and long distance connec-
tion of any Monitor to the host computer as well as for pre-proces-
sing of the digital data (front-end). These front-end controllers
sample the analog signals directly from the sensor/monitor, process
the values and send messages to the host computer (Terminal Emula-
tion). Our system is based on the one-chip-microcontroller INTEL-
8052 AH-BASIC. The minimum System consists of this controller, which
includes already a BASIC-Interpreter, a 32 kB user Program (EPROM)
memory, a 32 kB Data (RAM) memory, ones serial interface for a Ter-

In our application example the system processes the antepartum CTG,
which is evaluated. At any time of day it can be connected to the
host computer for data transmission (Telephone or hardwired line).
The transmission of 30 minutes CTG-data (4 FHR-values/second, 1 IUP-
value/second) lasts about 90 seconds. The evaluated data are stored
in a Patient Data Base and the sampled CTG can be retrieved on a
matrix printer.

This system works since July 1985. The results of the evaluation
(1200 antepartum CTG s) is shown - especially the correlation to
gestational age.
Monitoring and controlling the diabetic expectant mothers' blood sugar levels are essentials to reduce the risks of maternal and neonatal complications; especially before conception and during the course of pregnancy.

A high risk diabetic pregnancy program was established at Sinai Hospital of Detroit. Ten to fifteen patients are monitored and followed up at any one time.

In order to aid the clinician with the management of diabetic pregnancies, a menu driven and interactive computer system was designed and implemented on an IBM-AT-PC, those programs were developed using dBase III Plus programming language. The system main menu includes the following options:

A. Initial and Follow up Data: Demographic, Clinical, Laboratory Tests and Investigations
B. Update Sugar Levels
C. Update Insulin Dose and Instructions
D. Search for Patients whose Sugar levels have not been Regularly Updated
E. Individual Case Review and Update of Results of Tests and Investigations
F. Generate Reports

In addition to the standard clinic visits and protocol of care, daily telephone interviews are conducted by the data entry personnel to obtain sugar levels. During the interview if the sugar levels are above certain tolerance levels, the system will alert the data entry personnel to notify the physician immediately.

Even though the system is functionally complex, it is easy to use by individuals without prior computer experience.

An important feature of the system is its contribution to the optimization of the physician and health care team members time. In addition, it permits organized and immediate access to the data necessary to manage these high risk pregnancies.

References
A COMPUTERIZED ON-LINE ANALYSIS OF ANTENATAL FETAL HEART RATE RECORDS

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The accurate recording and evaluation of human fetal heart rate (F.H.R.) is still now a matter of debate. To improve and compare the "eyeble" evaluation of F.H.R. records we chose to use a microprocessor system for on-line analysis of the F.H.R. detected by a conventional doppler system. The software was developed by Prof. G. Dawes from the Nuffield Institute of Medical Research of Oxford, recompiled and rewritten to be compatible with the new hardware. Autocorrelation can reduce signal loss and it is important to avoid these particular periods of time when the computerized analysis is performed. Beat to beat variation is distorted by doppler ultrasound detection so that it cannot be used as a useful measure, antenatally; for this reason we decided to use a software which evaluated the medium term variation.

The hardware consists of: a doppler ultrasound heart rate monitor with autocorrelation (Hewlett Packard 8040A) interfaced with the computer by a current-loop convertor (20-10 MA), a microprocessor Stride 440 dual floppy disc drive with keyboard, monitor Wyse 50, printer Epson LX-80 and a graphic videoprocessor VGP-64 (Digisolve). The women were given an event marker which was pressed when they identified a fetal movement. The computer receives the signal from the ultrasound monitor, examines fetal pulse intervals using an error algorithm and averages valid pulse intervals over 3.75 s. (1/16 min.). Pulse interval is recorded to the nearest msec., uterine pressure is calculated in Arbitrary Units and fetal movement as absent or present. Data analysis is undertaken after 10 min., every 5 min thereafter until 60 min. Recording is stopped after 60 min. but the nurse may interrupt the record at any time; a continuing display advises the operator to "continue" or to "stop".

Among 146 women with singleton pregnancies who were attending the antenatal clinic of our hospital we chose 68 of them belonging to the low risk group and these had F.H.R. records (cardiotocograph tracing with computerized analysis on-line) taken for variable periods of time from 28 week gestation and, every two weeks, until term. The assessment of gestational age was based on ultrasound measurement of the crown rump length before 12 week or of biparietal and abdominal diameter before 20 week. The numerical analysis and the parameters evaluated were described elsewhere (1,2).

The records were reviewed after delivery to determine survival, gestational age, weight, sex, evidence of fetal distress requiring instrumental delivery or section, Apgar at 5', admission to special care unit, final outcome. From the results it appears that medium term measure of fetal heart rate variation, as calculated by this software, was a better index of fetal well-being than long term measure.

References:


A PROSPECTIVE ANTEPARTUM MONITORING SYSTEM

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The University of Illinois, Department of Obstetrics/Gynecology and Section of Neonatology, Department of Pediatrics has implemented an electronic medical record (known locally as UNIPEN) which permits 24-hour surveillance of fetal well being from the first prenatal visit.

The methodology incorporated into the end-user system includes two 16-user Masscomp 5600 supermicro computers equipped with MC 68010 chip, 387 Mb disk drive, 8 mb memory, ethernet transceivers, C compiler and Unix operating systems. The Informix Version 3.30 was the selected relational software package because of its efficiency and compatibility with the hardware. It provides password protection with immediate shutdown for unauthorized access. Entry and retrieval to and from the system in the clinics, labor and delivery, admitting, postpartum and nursery is via alphanumeric terminals (Wyse 50), 1200-Baud modems (Robotics) and Radix 500 printers which generate medical-records, storage compatible, 8½" by 11" printouts.

The UNIPEN system incorporates six forms of the Hollister Maternal and Newborn Record, a Level I ultrasound system providing immediate printout of abnormalities and estimated fetal age by crown-rump length in the first 12 weeks, with graphic displays of gestational age by biparietal diameter, head and abdominal circumferences and femur length. Other prenatal graphics include a maternal mean arterial blood pressure chart and fundal height monitor depicting the adequacy of intrauterine growth by week of gestation. Additionally, the birth certificate is automatically generated in the nursery from UNIPEN insuring high-quality State data.

The UNIPEN system grew out of a main-frame based, retrospective monitoring system which currently incorporates data from 80,000+ obstetrics cases in 12 regional hospitals. While the initial objective in developing the system was to insure the availability of the medical record on demand at various locations, we have found many cost-effective benefits accruing to the hospital and our patients. UNIPEN is a constantly evolving system given the current needs of its users and the technology available to meet those needs. The startup costs of UNIPEN seemed high, but its maintenance and subsequent development costs have been extremely low and will not exceed the costs of the retrospective system which it will eventually replace.

The relation of automated fetal heart rate analysis and the regularity of fetal breathing movements

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Objectives: This study was undertaken to demonstrate the relation between automated fetal heart rate (FHR) analysis and the regularity of fetal breathing movements (FBM).

Methods: The study group consisted of 7 uncomplicated women whose gestational ages ranged from 35 to 39 weeks. The patients were kept in a semi-Fowler position. The non stress test (NST) was done by Doppler ultrasound device with a 1 MHz transducer (MT-320). The records were analysed with automated FHR analyser (MT-140) which printed out both baseline variability (V) and the number of accelerations (A) every 5 min. The ultrasound observation of FBM was made simultaneously with NST by means of a sector array real time ultrasound (SSD-880) and its B & M mode display was recorded on strip-charts and videotapes. In 3 cases, FBM rates (count/min) and sequential differences of FBM rates (absolute value) were measured and calculated from M mode records of FBM. Then the relation between automated FHR analysis and the regularity of FBM was described.

Results: The total length of time span in which FBM was present in 5 min period was 65 min. Fetal behavior was classified in 4 phases with automated FHR analysis. Phase 1: A was present and V > 10 beats/min (bpm), phase 2: A was present and V ≤ 10 bpm, phase 3: A was absent and V > 10 bpm, phase 4: A was absent and V ≤ 10 bpm. In each phase, the rates at which FBM were present were respectively 63.8% (FBM: 847 count), 44.1% (FBM: 591 count), 63.4% (FBM: 441 count) and 81.8% (FBM: 493 count). Mean and standard deviation (SD) of FBM rate was respectively 50.71 ± 11.2, 52.88 ± 9.94, 50.09 ± 10.88, 52.16 ± 8.61. Mean and SD of sequential differences of FBM rates were respectively 9.20 ± 9.88, 8.92 ± 8.73, 9.35 ± 9.37, 7.72 ± 7.77. Mean of FBM rate in phase 1 and 3 were significantly smaller than that in phase 2 and 4 (p < 0.005). Mean of sequential differences of FBM rate in phase 4 was significantly small (p < 0.01).

Comment: When automated FHR analysis shows no accelerations and small baseline variability, the FBM is significantly regular and that is observed during resting phases. Both accelerations and baseline variability on NST influence the regularity of FBM and in this two factors the latter has more influence than the former.

Reference
METABOLIC RATE ASSESSED BY A COMPUTER-ASSISTED THERMODYNAMIC MODEL IN ASPHYXIATED AND NON-ASPHYXIATED FETUSES

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Commonly used methods for fetal monitoring still result in a significant number of false positive and false negative interpretations concerning the metabolic condition of the fetus and thus operative deliveries without benefit to the infant. Alterations of fetal heart rate and/or scalp blood pH are only indirect indices of an decreased metabolic rate. We proposed a thermodynamic model of the fetus in utero which allows a more direct assessment of the metabolic rate considering metabolic heat loss via the (a)umbilical circulation and (b)body surface. In this model the metabolic rate is derived from measurements of scalp heat loss and fetal heart rate respectively, using these variables as continous input into a computer based model.

To test the validity of the computer model in comparison to clinical situations, we first determined the metabolic rate of non-asphyxiated fetuses as it was calculated in our model and compared it to values reported in the literature (Study A). Secondly, we compared the computer simulated metabolic rate of non-asphyxiated and asphyxiated fetuses as classified by umbilical artery pH, a metabolic index of the postpartum period (Study B).

In 26 normal deliveries of single fetuses showing no sign of distress and 10 deliveries of asphyxiated fetuses we measured continously their scalp heat loss and heart rate. Heat loss was measured by a heat flux transducer which was glued onto the fetal scalp after the cervix was dilated to more than 2 cm and the amniotic membranes were ruptured. The voltage signal was amplified and recorded on a polygraph together with the fetal heart rate obtained by a scalp electrode. Antepartum heat loss values, fetal heart rate and the post partum anthropometric measures of weight, lengths and surface area of the fetus were used as inputs into the thermodynamic model for computer-assisted simulations.

Results:
1. In Study A the mean values for heat loss of the unstressed fetuses were 13.2 watts/m², fetal heart rate 142 beats/min, body weight 3.3 kg and length 49.3 cm. Thus, the computer-assisted calculation of metabolic heat loss was 39.6 calories/kg/min and compared favorably with the value of 38.6 cal/kg/min cited in the literature (For details Lit. 2).
2. Surface heat conduction from the fetus accounted for 1/4 and umbilical heat convection for the remaining 3/4 of total heat loss.
3. In Study B metabolic rate of the asphyxiated fetuses with an postpartum umbilical artery pH 7.2 often fell below 33.6 cal/kg/min as determined by fetal heat loss and at times reached values of 5 cal/kg/min. Whereas in comparison, the non-asphyxiated fetuses had values higher than 33.6 cal/kg/min during almost all measurements in the last 30 minutes period before delivery.

Conclusion:
The thermodynamic model using fetal scalp heat loss and fetal heart rate as continuous inputs yields a metabolic rate allmost identical to the one reported in the literature for non-asphyxiated fetuses. In asphyxiated fetuses it yields a metabolic rate which is distinctly lower than the one of non-asphyxiated. The combination of clinical variables with a computer model seems to refine the clinical information in terms of fetal intrauterine metabolic rate.

References: