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Computing techniques for intrapartum physiological data reduction. I. Uterine activity

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Electronic aids for measurement of fetal heart rate (FHR) and intrauterine pressure (IUP) have improved labour management but have also brought their own problems. The quantity of data available in the form of a chart recording can be overwhelming and contains a wealth of detail which is difficult to describe and interpret with our present knowledge.

In an attempt to alleviate some of these problems, computing techniques have been introduced. Of prime importance to clinical obstetrics is the development of on-line, real-time computing techniques which can assist the obstetrician and midwife in their management of individual labours. Development of such techniques is being investigated at our own centre, CRAWFORD and HENRY [4] and in other centres: FLOWERS et al. [8], GIBBONS and JOHNSON [9], REY et al. [14] and RÜTTIGERS et al. [15], using a variety of computers and techniques.

This and a succeeding paper describe an approach to real-time data reduction and presentation, intended to assist clinical personnel in their management of labour.

1 IUP Measurement

IUP can be measured by a hollow, fluid filled catheter inserted transcervically into the uterus, which transmits intrauterine pressure to an external strain gauge transducer. As long as care is

Curriculum vitae

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taken with catheter insertion, setting up and calibration of the measuring system, IUP can accurately reflect uterine activity, ODENDAAL et al. [13] and NEVES DOS SANTOS et al. [12].

For the purpose of uterine activity analysis, IUP is sampled by the computer every 2 seconds.

2 Uterine activity analysis – ACTIVE PRESSURE AREA.

Early attempts at quantitating uterine activity were the MONTEVIDEO UNIT [2] and the ALEXAN-

DRIA UNIT [7] which were devised for manual analysis of chart recordings.

A newer method is measurement of active pressure area (APA), that is, the area under individual contractions above baseline.

Although this area can be measured from chart recordings using a planimeter [6,17], it was not until the advent of electronic and computing techniques that its routine measurement during labour became feasible.

In 1959, SALA et al. [16] described the use of an electronic pressure-time integrating system for measurement of total pressure area (TPA), which also included the area between zero pressure and baseline. Later HON reported the use of a large off-line computer [10] and the use of an electronic instrument employing a voltage controlled oscillator [11], for calculation of TPA.

BRAAKSMA et al. [1] used a small off-line computer to measure APA, while more recently CARTER and STEER [3] described electronic measurement of APA as part of a system for controlling induced labour.

APA, as a measure of uterine activity, has several advantages: —

- a) Since it is measured with respect to a baseline, it is almost independent of errors due to hydrostatic pressure and patient movement, which are inherent in IUP measurement.
- b) It provides a quantitative description of uterine activity as a single index.

- c) Area measurement by digital integration of sampled data is a relatively quick and simple procedure.

3 Calculation of active pressure area

At the heart of the method is a technique for automatic detection of the baseline between contractions. For the purposes of baseline detection, the pressure range 0 to 40 torr is divided into eight bands of width 5 torr, pressures greater than 40 torr constitute a ninth band in which baseline detection is not performed. Successive IUP readings are examined for a maximum time period termed a 'window', to ascertain to which band they belong. If a predetermined number of readings are found within a single band, a new baseline is calculated as the arithmetic mean of those readings. If, at the end of a window period, no band has contained enough readings to allow baseline calculation, the previous baseline is maintained and a new window initiated.

Experimentally, a window of 60 seconds was found to give optimum performance, with 15 readings being the number within a single band to cause baseline calculation.

APA, expressed in torr-seconds, is calculated by summation of the IUP data values lying above the existing baseline, as illustrated in Fig. 1.

Any reading outside the range 1 to 180 torr is rejected, and causes a 'signal error counter' to be incremented.

Fig. 1. Active pressure area (APA) calculation by pressure summation above automatically determined baseline, measured in torr-seconds.

4 Clinical use of APA – The POWERGRAM

When used for clinical purposes, the term 'ENERGY' is used instead of APA, since it is a more acceptable concept to clinical personnel. It can be postulated that APA is representative of the 'energy expended' by the mother during uterine contractions [4]. By measuring the amount of energy expended during an epoch, the rate of change of energy (APA), 'POWER', can be estimated, and expressed in torr-seconds per second.

By calculating POWER during 30 minute epochs, uterine activity can be represented in the form of a POWERGRAM, as shown in Fig. 2, in which power values are plotted against the end time of the epoch. To help with interpretation of the information, two 'power limits' at 8 and 20 torr-seconds per second, are included.

Epochs with more than 10 per cent invalid readings are considered unacceptable and are plotted in the Powergram as an asterisk (*).

5 Clinical interpretation of the POWERGRAM

The Powergram is intended primarily for use in induced or augmented labours where artificial means are used to initiate and/or control labour. In these cases many of the natural control mechanisms present in spontaneous labour are overridden and wide variations in uterine activity are less acceptable.

The way in which an obstetrician interprets the Powergram is indicated in Fig. 3. The probable

Fig. 2. POWERGRAM for an augmented labour. 'POWER', calculated as the APA accumulated during a thirty minute epoch, is plotted against the end time of the epoch. 'Power limits' represented as broken lines help with interpretation.

Fig. 3. Powergram interpretation. The probable effect of uterine activity levels on labor progress and stress on mother and fetus is indicated with respect to the 'power limits'.

effect of uterine activity on the condition of mother and fetus is shown on the left while the probable effect on labour progress is shown on the right.

It is suggested that in the case of augmented labour, powers lying in segment 2 are most likely to achieve reasonable labour progress with the stress on the mother and fetus still being acceptable. Power levels in segment 3 are only acceptable in the second stage of labour.

Fig. 2 shows a Powergram for a patient who was para 1 and was induced at 11.00 using Artificial Rupture of the Membranes (ARM) and syntocinon, when the cervix was found to be 3 cm. dilated. At 16.00 the cervix was still only 3 cm. dilated and the possibility of a caesarean section was being considered because of poor progress. Up to this point, the labour had been conducted without regard to the Powergram. On consulting the Powergram, at the point shown in Fig. 2, the consultant in charge realised that uterine activity up to that point had been consistently low. Thus, it was decided to increase the syntocinon dose to 16 mU/min. with the result that power levels increased until they lay in segment 2. At 19.15 cervical dilatation was 8 cm. and at 20.39 a spontaneous vertex delivery was achieved of a 3190 gram fetus in good condition.

In this case, the Powergram indicated that uterine activity was too low, when this had not been realised by staff using conventional techniques, and a caesarean section was avoided.

In practice chart recordings are visually scanned and a general, qualitative appraisal made. For an

experienced obstetrician managing a spontaneous labour, this qualitative appraisal may be all that is required. However, in the case of a less experienced obstetrician or an induced or augmented labour, a swift visual appraisal of the chart recording may not be sufficient.

By choosing a suitable epoch length, several metres of chart recording can be reduced to a compact display in the form of a Powergram. A thirty minute epoch has been found to be suitable, but other epoch lengths can be accommodated. An individual 'frame' of the Powergram can display the results from up to 10 hours of data.

6 Conclusions

From a clinical point of view:

- Real-time uterine activity analysis presented in the form of a powergram can affect labour management.
- The powergram does not provide any more information than could be derived by careful, time consuming, manual analysis of the chart recording. However, it is produced automatically

and presented in a way which assists interpretation.

- The main use of the powergram is in induced and/or augmented labour, where accurate assessment of uterine activity is essential for rational use of oxytocic drugs.
- Although the powergram is derived quantitatively, it can be interpreted qualitatively, and allow trends in uterine activity to be visualised. Often these trends cannot be easily appreciated from visual inspection of the chart recording.

From a more technical point of view.

- Because of its simplicity the analysis technique is suitable for real-time monitoring.
- 'Power' measured in torr-seconds per second, is independent of the length of epoch over which it is measured (within certain limits), so that any suitable epoch length may be utilised to provide varying degrees of data reduction.
- Although the powergram employs a graphical presentation it can be implemented using relatively simple, low cost, low resolution alphanumeric output devices.

Summary

This and a succeeding paper describe real-time computing techniques for data reduction and presentation, intended to assist clinical personnel in their management of labour.

Active Pressure Area (APA), that is, the area under individual uterine contractions above baseline (Fig. 1), provides a single, quantitative index of uterine activity. It is independent of errors due to hydrostatic pressure and patient movement, which are inherent in intrauterine pressure (IUP) measurement by transcervical catheter. APA is simply measured by digital integration.

When used for clinical purposes, the term 'ENERGY' is used instead of APA, while 'POWER' refers to the amount of 'energy' expended during an epoch. Power is expressed in torr-seconds per second, so that values are independent of epoch length.

The POWERGRAM (Fig. 2) provides a graphical summary of uterine activity by plotting Power against time. The

probable effect of Power values on labour progress and condition of mother and fetus are interpreted with respect to two 'power limits' (Fig. 3).

An individual 'frame' of the POWERGRAM can display the results from up to 10 hours of data.

The Powergram provides a summary of uterine activity which can be interpreted clinically to show trends in uterine activity which cannot be easily appreciated from visual inspection of an IUP chart recording. It has been shown to be of particular use to inexperienced clinical personnel and in induced/augmented labour where oxytocic drugs are used to control labour.

From a technical point of view, the technique requires modest processing facilities, and is suitable for on-line, real-time purposes. Although the Powergram employs a graphical presentation it can be implemented using relatively simple, low cost, low resolution alphanumeric output devices.

Keywords: Active pressure area, computing techniques, data reduction, graphical display, IUP measurement, labour progress, uterine activity.

Zusammenfassung

Komputertechniken für die Reduktion physiologischer Daten sub partu. I. Wehenaktivität

Diese und die nachfolgende Arbeit beschreiben Realzeit-Komputersysteme für die Datenreduktion und Datenausgabe mit dem Ziel, dem klinisch tätigen Personal bei der Geburtsleitung zu helfen.

Die aktive Druckfläche (ADF), das heißt jene Fläche, die von der Basislinie und der individuellen Wehendruckkurve begrenzt wird (Fig. 1), stellt einen einzelnen, quantitativen Index für die uterine Aktivität dar. Diese Meßgröße ist unabhängig von Störungen, verursacht durch den hydrostatischen Druck sowie Bewegungen der Patientin, Faktoren, die mit der transzervikalen Druckregistrierung über einen Katheter verbunden sind. Die ADF wird einfach durch digitale Integration bestimmt.

Im klinischen Gebrauch wird der Begriff 'ENERGY' verwendet, an Stelle von ADF während der Begriff 'POWER' sich auf die Summe der Energie bezieht, die während einer Zeitperiode aufgewendet wurde. 'Power' wird in torr-Sekunden/Sekunde dimensioniert, was zur Folge hat, daß die Werte von der Größe des Zeitintervalles unabhängig werden. Das 'POWERGRAMM' (Fig. 2) stellt eine graphische Zusammenfassung der uterinen Aktivität dar,

indem die 'Power' gegen die Zeit aufgetragen wird. Der mögliche Effekt numerischer Powerwerte auf den Geburtsfortschritt und den Zustand von Mutter und Fetus wird im Hinblick auf 2 'Power-Grenzwerte' interpretiert (Fig. 3).

Eine individuelle Routine des 'POWERGRAMM' kann die Ergebnisse von bis zu 10 Wehenstunden aufzeichnen.

Das POWERGRAMM ermöglicht eine zusammenfassende Darstellung der uterinen Aktivität, die klinisch eingesetzt werden kann um Tendenzen in der uterinen Aktivität nachzuweisen, die durch einfaches Betrachten der Wehenkurven nicht ohne weiteres abgeleitet werden könnten. Es konnte gezeigt werden, daß das POWERGRAMM für unerfahrenes klinisches Personal und bei induzierter/verstärkter Wehentätigkeit von besonderem Nutzen ist, in Fällen also, bei denen Oxytocica zum Einsatz kommen.

Vom apparativen Standpunkt aus benötigt das Programm relativ einfache technische Hilfsmittel und ist geeignet für den on-line-Realzeit-Einsatz. Obwohl das POWERGRAMM eine graphische Darstellung generiert, kann es unter Verwendung relativ einfacher, billiger und relativ langsam arbeitender alphanumerischer Ausgabeeinheiten implementiert werden.

Schlüsselwörter: Aktive Druckfläche, Datenreduktion, graphische Darstellung, intrauterine Druckmessung, Computertechniken, Stress, uterine Aktivität.

Résumé

Techniques de calcul pour la réduction des données physiologiques intrapartum — I' Activité utérine

Cet article ainsi que le suivant, traitent des techniques de calcul en temps réel destinées à la réduction et à la présentation des données obstétricales afin d'aider le personnel hospitalier dans la direction du travail.

L'«Active Pressure Area» (APA), c.à.d. l'aire de chaque contraction utérine au-dessus de la ligne de base (Fig' 1), fournit un indice unique et quantitatif de l'activité utérine. Il n'est pas soumis aux erreurs dues à la pression hydrostatique ni aux mouvements de la parturiente qui sont inhérentes à la mesure de la pression intra-utérine (IUP) par cathéter transcervical. L'APA est mesurée simplement par intégration digitale.

Utilisé à des fins cliniques, le terme d'«Energie» est employé au lieu de l'APA, tandis que la «PUISSANCE» traduit la quantité d'énergie dépensée pendant un espace de temps. La puissance s'exprime en torr-secondes par seconde, de sorte que les valeurs sont indépendantes. Le POWERGRAM (Fig. 2) fournit un résumé graphique de l'activité utérine en représentant la puissance en fonction

du temps. L'effet probable des valeurs de la puissance sur la progression du travail ainsi que sur l'état de la mère et du fœtus sont interprétés par rapport à deux «limites de puissance» (Fig. 3).

Un 'cadre' de POWERGRAM peut exposer pour chaque cas particulier les résultats de données enregistrées pendant une période atteignant jusqu'à dix heures. Le POWERGRAM fournit un résumé de l'activité utérine qui peut être interprété cliniquement et révéler des tendances dans cette activité que l'inspection visuelle d'un enregistrement graphique d'IUP ne permettrait pas d'apprécier aisément. Il s'est avéré particulièrement utile pour le personnel hospitalier inexpérimenté ainsi que lors d'accouchements provoqués ou stimulés où il est fait usage de médicaments ocytociques.

D'un point de vue pratique cette technique ne nécessite que des moyens de traitement modestes et est utilisable en temps réel.

Bien que le POWERGRAM consiste en une représentation graphique il peut être réalisé au moyen de modules de sortie alphanumériques simples, peu coûteux et de faible résolution.

Mots-clés: Activité utérine, APA (Aire de Pression Active), mesure de pression intrautérine (IUP), progression du travail, réduction de données, représentation graphique, techniques de calcul informatique.

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