

UTERINE ACTIVITY IN LABOUR

BY

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DECLARATION

This thesis is based on original work initiated by myself.
The manuscript is entirely my own work.

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ABSTRACT

Reproductive success, the birth of a healthy child, may be seen in mechanical terms as the uncomplicated filling, enlargement and subsequent emptying of the uterus: a quite remarkable organ. Much clinical activity by obstetricians concerns the need to prevent premature emptying of the uterus and in turn causing it to expel the fetus at the appropriate time. Many believe a successful conclusion preferably includes the expulsion of the fetus safely per via naturales. Currently concern is expressed in many countries about the increasing frequency of Caesarean birth.

An understanding of uterine activity is important for effective management of several pregnancy complications. However, this thesis is restricted to the birth process itself: the intra partum period. Several investigations have documented uterine activity at various times. However, detailed analysis correlated with the various phases of labour had not been undertaken. Previous workers had omitted to study normal events before abnormal ones effectively working without a normal range.

The progress of labour has to be understood within the context of the nature of its onset and subsequent

documentation of dilatation of the uterine cervix on a partogram: a graphic representation of labour. Preliminary work was undertaken to clarify types of labour progress

and subsequent outcome of the labour according to the cervical dilatation pattern (cervimetric progress). The next step complemented this with a study of intrauterine pressure changes and the evolution of contractions related to this process. This had never been adequately undertaken bearing in mind the important variables of parity and actual cervical dilatation at the time. Uterine activity profiles during labour were generated and significant differences shown according to parity. Induced labour was then studied documenting comparative profiles and the cumulative uterine activity as labour progressed. This led to the development of the concept of the total uterine activity in labour reflecting the resistance to the fetus passing through the birth canal: the cervical and pelvic tissue resistance.

These results may be applied in the rational management of difficult labours permitting the appropriate use of oxytocic drugs and providing the data to determine the appropriate use of Caesarean delivery.

1. HISTORICAL ASPECTS

1:1. Labour Documentation

The study of any subject must commence with clear and careful recording. With respect to labour this was facilitated in a revolutionary way by Friedman (1954, 1955) who proposed the graphico-statistical analysis of labour. This involved the pictorial representation of the labour process rather than a written account; normal labour was documented as a characteristic sigmoid curve. Thus originated the nomenclature for the phases of labour; the latent phase, active phase and deceleration phase. (fig 1)

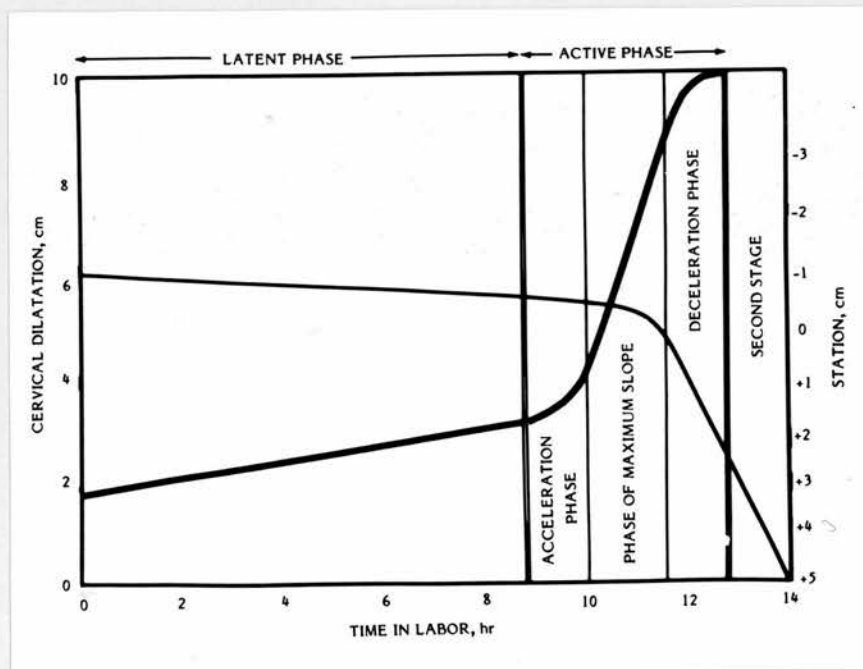


Figure 1: Friedman's Curve

Practical considerations limit the use of the Friedman curve because unlike spontaneous labour it starts at 0 centimetres. Hendricks et al (1970) stress the point that the time the attendant first sees the woman in labour on admission should be taken as the start of "observed" labour. Anything preceding that point has not been objectively established. Women may complain of experiencing pain for five days but clearly they have not been in labour for five days. Consequently, the length of observed labour is most obviously related to the dilatation of the uterine cervix on admission to the labour ward. Hendricks concept of prelabour is very useful. Philpott & Castle (1972a, 1972b) working in Africa developed the concept of the partogram in a rather different way. The motive was to detect abnormal labour progress in rural units by using alert and action lines on partograms thus facilitating transfer of such cases to bigger hospitals where facilities for intravenous therapy, anaesthesia, blood transfusion, operative delivery and expertise in neonatal care were available. Philpott's partogram, (fig 2) designed in Zimbabwe for the considerable problems of labour in that community gained increasing popularity in other parts of Africa where they ensured improved recording of management in a community with a high incidence of dystocia, with the problem compounded by inadequate medical resources and poor transport facilities.

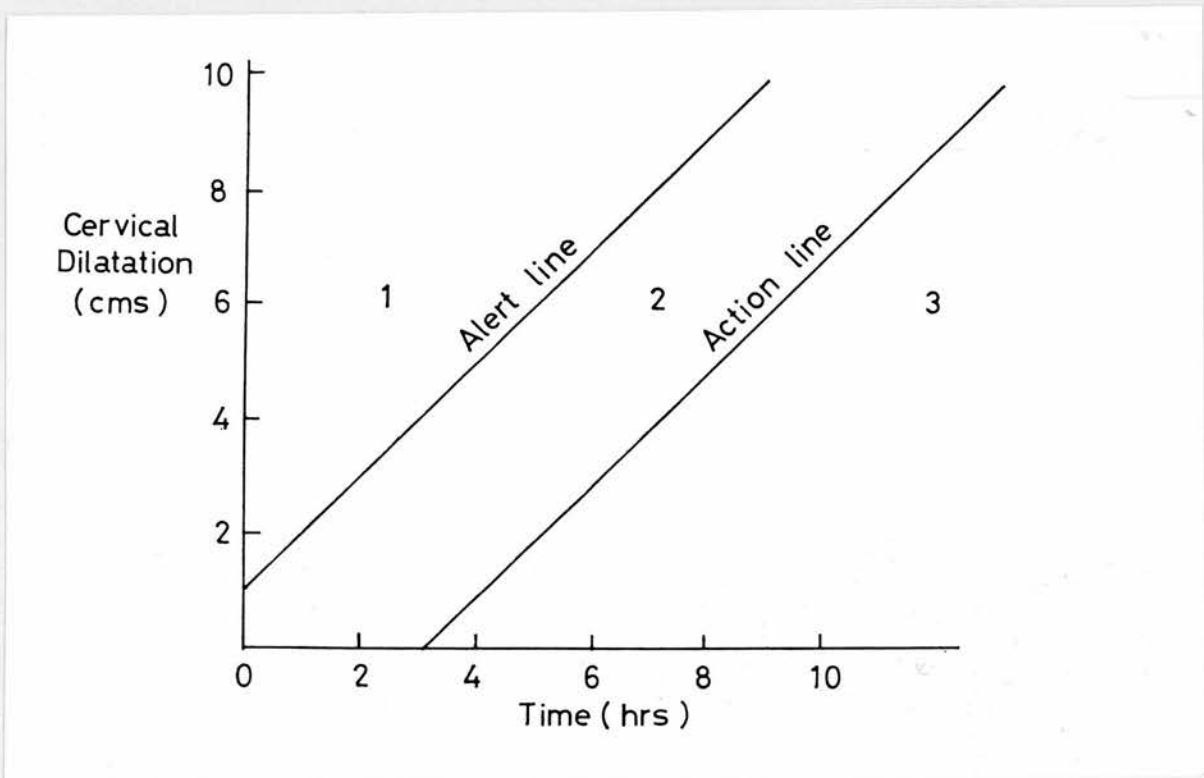


Figure 2: Philpotts Partogram

Partograms were introduced into the United Kingdom in 1972 at the Birmingham Maternity Hospital (Studd & Philpott, 1972; Studd 1973). Studd and Duignan (1972) complemented this with a nomogram, a series of curves commencing at the patients admission cervical dilatation and representing the mean progressive cervical dilatation of normal primigravidae. This prospective evaluation is the basis of the labour stencil now used in this country (fig 3).

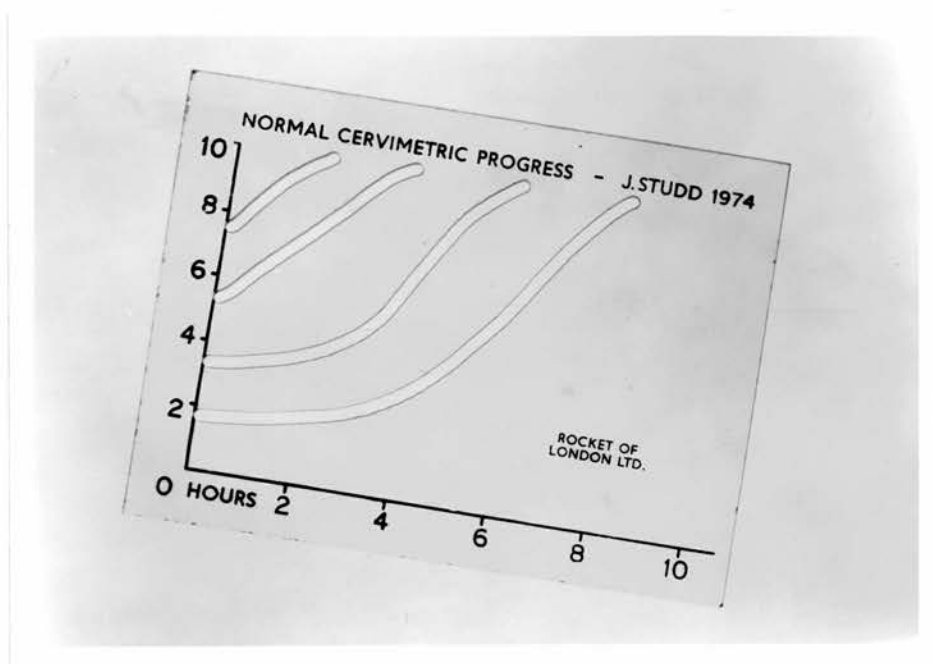


Figure 3: Studd stencil

Multigravid patients and those of different racial origin have been studied and it has been demonstrated that this curve of normal first stage progress is identical from a given cervical dilatation regardless of parity or racial group (Duignan et al, 1975). Thus the use of the labour stencil is appropriate for the prediction of first stage progress in all cases of spontaneous labour.

O'Driscoll and colleagues (1973) in their development of the Active Management of Labour utilised a simple square labour chart to document cervical dilatation with an expected labour progress along a diagonal line a 1 centimetre per hour. They did not comprehensively document all observations on this chart. (fig 4)

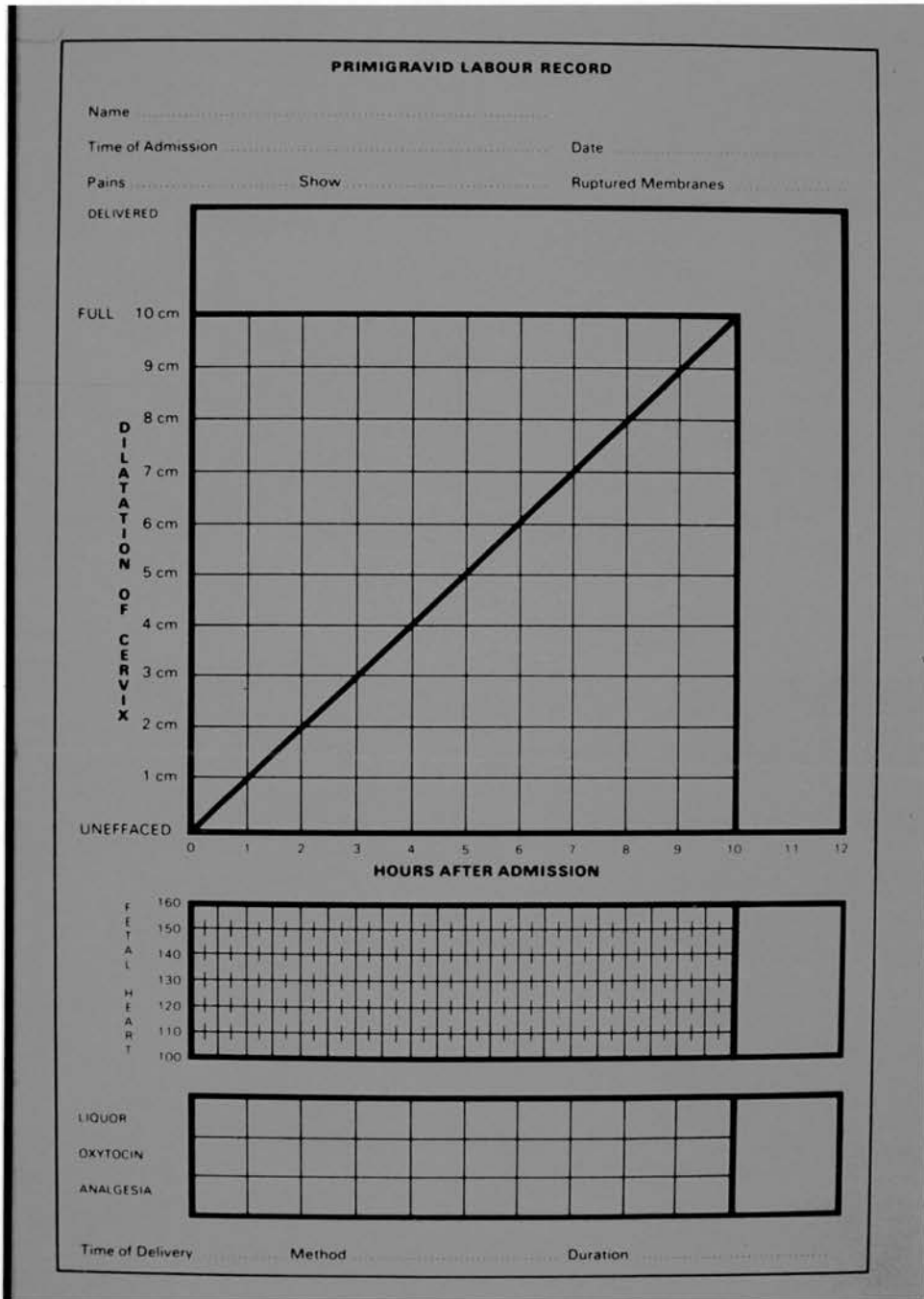


Figure 4: O'Driscoll's partogram

Partograms are essential in the structure of any research concerning the process of labour. These are now used throughout the United Kingdom for routine labour documentation: the version used by us is shown in Fig 5. It contains all the necessary information about mother and fetus obviating the need for a long-hand record altogether.

Date: _____	Surname: _____	On admission in labour:	Special instructions
Consultant: _____	First name: _____	Membranes intact Y/N	
Age: _____	EDD: _____ USS: _____	Date/time of rom _____	
Unit no: _____	Parity: _____	Show Y/N	
		Palpation:	lgl _____ Date/time
		SFH in CMS	Pg Press (1) (2) (3)
		Clinical est of fetal wt: _____	Arm Y/N
			Synto Y/N
			Cervical score:

Fetal Heart	190															
	180															
	170															
	160															
	150															
	140															
	130															
	120															
	110															
	100															
	90															
	80															
	70															
	60															
Maternal B/P																
Maternal pulse																
Maternal temp.																
	10															
	9															
	8															
	7															
	6															
	5															
	4															
	3															
	2															
	1															
	0															

C E R V I X	Dilatation 0-10 cm.	A B D O M I N A L	D E S C E N D I N G	Fifths palpable	
----------------------------	------------------------	---	--	-----------------	--

Times	
Vaginal examinations	
Signature	
Amniotic fluid	
Length of cervix	
Moulding/caput	
Station	
Position	
Cephalic/breech	
Oxytocin	
Contractions per 10 min	
IUC	
Drugs & IV fluids	
Unnalysis	
Test Amount	
Third stage	

Placenta/membranes	Placenta	Method	Drugs used	Baby:
Date: _____	Weight: _____	CCT <input type="checkbox"/> <input type="checkbox"/>	Drug: _____	Boy <input type="checkbox"/>
Times: _____	Cord insertion: _____	Maternal effort <input type="checkbox"/> <input type="checkbox"/>	Dose: _____	Girl <input type="checkbox"/>
Placenta Membranes	No. vessels 1 2 3	MRP: - GA <input type="checkbox"/> <input type="checkbox"/>	Route: IV IM	BW _____
Complete <input type="checkbox"/> <input type="checkbox"/>	Sent path lab yes no	- Epidural <input type="checkbox"/> <input type="checkbox"/>	Anterior shoulder <input type="checkbox"/> <input type="checkbox"/>	APGARS 1
Incomplete <input type="checkbox"/> <input type="checkbox"/>	Abnormality: _____		After birth <input type="checkbox"/> <input type="checkbox"/>	@ 5

Figure 5: Current King's Partogram

1:2 Oxytocin

The action of pituitary gland extract on uterine tissue in animal experiments was first recorded by Sir Henry Dale (1906). Blair Bell (1909) later to become the first President of the Royal College of Obstetricians and Gynaecologists, independently presumed this property and calling the substance "Infundibulin" conducted experimental and clinical trials. He recorded its effects in raising the blood pressure, causing uterine contractions and stimulating intestinal contractions. He was responsible for its introduction into clinical practice in 1909 recommending its use by the intravenous or intramuscular route but "that it ought but rarely to be given before delivery." Hofbauer was the first to suggest its use in established labour and Blair Bell (1925) later also recommended this.

Standardization of the preparation and dosage was a problem until 1926 when a committee of the League of Nations adopted a Standard Reference Powder as the international standard, 0.5 mg of this powder being equivalent to one international unit. There was much debate about whether posterior pituitary extract contained more than one active principle and it was not until 1928 that Kamm et al separated two active principles, antidiuretic hormone with its vaspressor effect and oxytocin.

Hofbauer (1927) dissatisfied with the unpredictability of the action of "Pituitrin", as he called it, by the intramuscular route recommended sublingual and then nasal administration. Theobald (1948) in Bradford subsequently reported the successful use of the "The Pitocin Drip" intravenously for the induction and augmentation of labour. He used a very dilute solution compared to those used subsequently.

Progress was also being made by biochemists, the structure of oxytocin being discovered by Du Vigneaud (1953) leading to its synthesis. (Du Vigneaud et al, 1954) One of its commercial trade names was to be Syntocinon manufactured by Sandoz.

Intravenous administration became the method of choice in the 1960s and many studies were performed to determine the correct usage of oxytocin in induction and augmentation of labour (Maxwell 1964, Whitfield 1964, Chalmers et al 1966, Bergsio & Jensson 1969) and in the prevention and treatment of postpartum haemorrhage (Gate & Noel, 1967, Mathie et al, 1967). Synthetic oxytocin became and remains one of the most widely used drugs in obstetrics. Regrettably, because of a lack of understanding of uterine activity it is sometimes misused.

1:3 Uterine Activity

Measurement forms the basis of all scientific work. Observations are quantified by measurement. Parameters such as height, weight and fetal heart rate are measured easily. Uterine contractions the clinical manifestation of uterine action are more difficult. Measurement requires methods of detection, recording and quantification. The human uterus contracts intermittently throughout reproductive life. This thesis is concerned primarily with this action during expulsion of the fetus at the end of pregnancy. At this stage the uterus is large, appearing like a balloon filled with fluid and solid parts consequently being more accessible to examination and observation. The contracting uterus is to a large extent autonomous with limited hormonal and neural control mechanisms. An electrical impulse spreads from cell to cell causing depolarisation of the membrane resulting in calcium ion flux which is an essential prerequisite for contraction of myofibrils. Calcium is transported into the cells as well as being passively released from sarcoplasmic reticulum, mitochondria, plasma membrane and surface vesicles. Contraction of segments of the uterus occurs which when coordinated results in rising intra uterine pressure and progressive expulsion of the fetus through the only exit from its confined space: the uterine cervix and the birth canal.

In clinical practice contractions are detected and recorded as the manifestation of uterine action. For research purposes several methods have been used for the detection of contractions: external and internal tocography are used in clinical practice. Tocometry is the measurement of a contraction and tocography permits sequential analysis and measurement of them. External tocography is generally adequate and used most frequently whilst internal tocography provides valuable additional information in difficult cases.

Terminology of Uterine Contractions

The elements of uterine contractions are shown in Fig. 6.

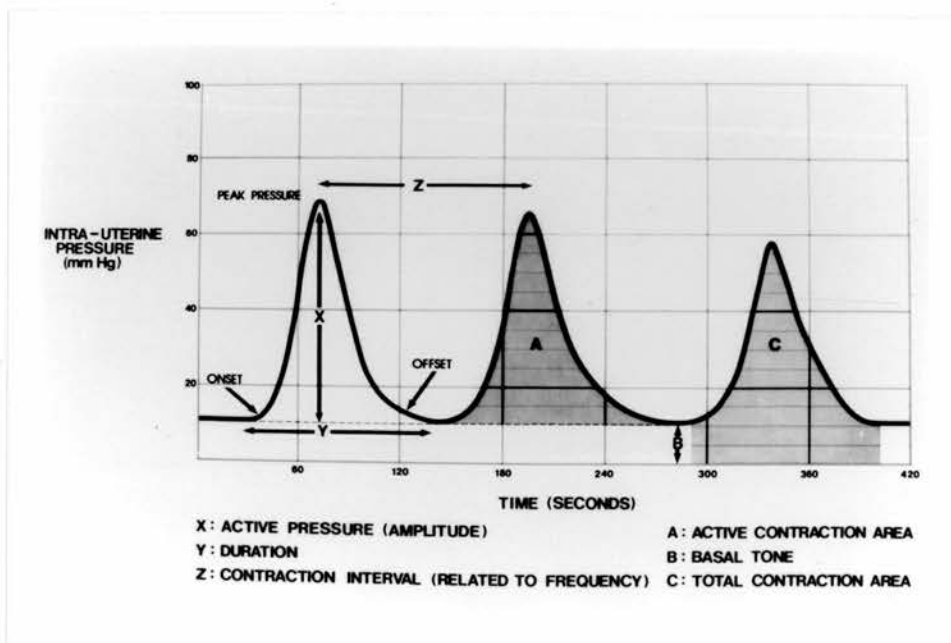


Figure 6: Terminology of uterine contractions

The duration measured depends on identification of the beginning (onset) and the end (offset). A sensitive device records a contraction for a longer duration than a palpating hand does. The amplitude (active pressure) is the difference between basal and peak pressure. The basal pressure (basal tone) is the resting pressure between contractions. The frequency is the number of contractions in a fixed time period usually ten minutes. This may vary because of irregularity of contractions. Irregularity of timing is reflected in changes in frequency but irregularity of shape is termed incoordination. There is no absolute definition of incoordination however significant changes in shape, varying amplitude, merging of contractions (coupling, tripling) and failure to return to basal pressure may all be seen.

External Methods

A hand placed between the umbilicus and uterine fundus is used most commonly to observe uterine contractions. A sensation of hardening and forward movement of the abdominal wall is felt. Braxton Hicks contractions are felt in this way and indeed he used observation of contractions early in pregnancy to confirm the diagnosis. (Braxton Hicks 1872) Palpation may provoke a reflex contraction making delineation of the fetal parts more

difficult. When this occurs the observer should desist from examining for a short time and then recommence. Such contractions should not be misinterpreted as meaning the patient is in labour. They are often painless and may be localised, non propagating, not leading to significant rises in intra uterine pressure. Palpation of contractions permits a crude estimate of their duration and frequency but reveals little information about amplitude. There is no permanent record but a shaded box method may be used on the labour record indicating the observer's subjective estimate of strength, duration and frequency.

Schaffer (1896) was the first person to employ an external method of recording uterine contractions. Ruebsamen (1920) used an instrument applied externally to the abdominal wall to observe uterine behaviour. The apparatus consisted of a device of known weight suspended from a frame by means of cord and pulleys so as to rest on the abdominal wall covering the uterus. This was connected mechanically to a recording drum. It was not very sensitive and was affected by gross artefacts due to movement of the patient. Most of his observations concerned the effects of drugs given after delivery and the method was unsuitable for use in the first and second stages of labour. Dodeck (1932) devised a system incorporating a plunger applied to the maternal abdomen

linked to a recording tambour by a pneumatic system. With this he studied the effects of twelve different drugs on the human uterus at term. Moir (1935) used a modification of the apparatus in which the method of recording was hydraulic. Mechanical and electromechanical recorders then appeared with Murphy (1947) popularising the Lorand tocograph which was a mechanical clockwork instrument in which the plunger projected a fixed distance from the base; this was placed directly on to the subject's anterior abdominal wall held in place by a belt.

The introduction of electromechanical devices simplified use of the previously cumbersome equipment. Reynolds, Hellmann & Bruns (1948) exploited this with the introduction of a multichannel, strain gauge tocodynamometer. They documented uterine activity in three separate zones of the uterus at the same time and related this to the progress of labour. Progress in labour was associated with strong intermittent contractions in the fundus rising quickly to a maximum and being of relatively long duration. In contrast the contractions in the mid portion of the uterus were less intense and shorter. They found the lower uterine segment to be inactive throughout the first stage of labour and proposed that cervical dilatation is the result of diminishing physiological activity from the fundus to the lower segment; the important concept of fundal dominance.

Embrey (1955) reported from Oxford on a new multichannel external tocograph. This was similar to Reynolds equipment except it depended on a hydraulic system to transmit the impulse. The aim was to produce a simple yet efficient, robust, easily operated machine requiring little supervision and capable of recording uterine contractions in all cases. This purpose was revolutionary because until that time all devices had been used for research purposes only and had not been employed clinically.

Smyth (1957) introduced the guard ring tocodynamometer. This instrument differed from previous devices being a flat disc with an outside ring and an inner circular pressure sensing area. The deflection of a spring mounted on the guard ring supporting the central measuring area was taken as a measure of force on the central area. This deflection was calibrated to measure intra amniotic pressure. The instrument must be applied to the patient over a fluid filled part of the uterus. The pressure must be sufficient to flatten the abdominal surface into contact with the guard ring. It requires quite a firm application with a tight band round the maternal abdomen. With very careful adjustment and placement it was claimed that this instrument actually measured intra uterine pressure accurately. It has since been used successfully by Bell (1981, 1983) in the assessment of patients at risk

of preterm labour. When the membranes are still intact a non invasive technique is required and this is appropriate. Prediction of preterm labour by quantifying uterine activity could form part of a comprehensive approach to reduce mortality and morbidity from preterm birth in high risk patients.

The technology for recording uterine contractions developed pari passu with that for recording the fetal heart. Gunn and Wood (1953) presented a paper to the Royal Society of Medicine on the amplification and recording of fetal heart sounds. Fetal heart rate monitors as we know them did not become commercially available until the late 1960s. Miniaturization of electronics permitted both cardio and toco recording equipment to be placed in a single mobile box and mass produced at reasonable cost. The recent generation of fetal monitors incorporate a tocograph of guard ring type. Telemetric internal and external tocography permitting assessment of contractions in a mobile patient is now available.

Lacroix (1968) described the use of the Parturiograph. This comprised a hollow gas-filled plastic-domed transducer applied to the maternal abdomen by adjustable straps. This was connected by a gas filled system transmitting pressure to a recording device. Comparison

of parturiographic and intrauterine pressure tracings revealed similar contraction patterns with respect to configuration, frequency and resting pressure. However, only 60-90 per cent of intrauterine pressure was measured. Nonetheless it was suggested that such continuous monitoring identified abnormal uterine contractility being a useful guide for regulation of oxytocin infusion and facilitating the management of abnormal labour. This method did not become widely used.

Clinical experience shows that external tocography does have its limitations. The guard ring tocograph requires a tight and somewhat uncomfortable application to the pregnant abdomen to permit its accurate use. A significant proportion of patients are restless or have a thick adipose anterior abdominal wall which precludes proper placement and adjustment. It is uncommon to find a technically perfect external tocographic tracing on patients in the labour ward: whether it is necessary is discussed elsewhere. An undesirable result of external tocography is undue attention paid by staff and patient alike to each contraction as it appears in late pre labour or early labour. Even regular contractions may be painless not resulting in cervical changes and should not be misinterpreted as diagnostic of the onset of labour. These should be described as pre labour contractions; the term false labour should be discarded.

Invasive Methods

More direct access to uterine function than that permitted by external methods has been attempted by many workers. Assessment of intrauterine pressure has been extensively studied. However, the preceding electrical events are of some interest. Csapo et al(1963,1965) placed separated electrodes in the myometrium of pregnant rabbits together with an intra amniotic probe to measure intrauterine pressure. During pregnancy before labour the electrical activity showed a lack of transmission, irregularity and lack of synchrony. The active pressure was low associated with a slow rise and a prolonged time of propagation from the activity at one electrode to another. During labour activity at each electrode occurred synchronously, active pressure being much higher with a more rapid rise of a quadratic nature. The potential propagation time and the time of pressure rise shortened at the same rate, the ratio remained constant, indicating that the rate of pressure rise was controlled by the rate of propagation. This work is consistent with the later work of Garfield and Hayashi,(1981) showing the formation of gap junctions seen under the electron microscope as gestation proceeds to the time of labour. Such gap junctions are thought to facilitate propagation of the electrical impulse. Csapo distinguished between the propagating synchronic activity and the asynchronic local activity. This also raises the possibility that some forms of external tocograph may

suggest good contractions when the area of the uterus under the sensor is active but this may be local non propagating activity. This work suggests that the intra-uterine pressure reflects the conduction characteristics of the uterus to a considerable degree. Dill and Maiden (1946) attempted to record changes in electrical potential with uterine contractions using external devices without success. External electromyography of the uterus is difficult because of the many possible sources of artifact such as movement of the patient, respiratory movement, abdominal wall muscle activity, abdominal organ activity, electrocardiogram of the mother and skin potentials. All these affect the signal to noise ratio adversely.

Access to the human uterus before or during labour is difficult but Sakaguchi and Nakajima (1970) inserted bipolar needle electrodes through the os 10 to 25 centimetres along the posterior wall of the gravid uterus. During labour they recorded bursts of action potentials initially poorly synchronized with contractions. With progression of labour good synchronization developed. Wolfs and Van Leeuwen (1979) confirmed these observations using a linear array of ten electrodes inserted on a wire 30 centimetres into the uterus between the membranes and myometrium. Such a device produces fascinating data for physiological studies but would not be acceptable in clinical practice.

Intrauterine pressure

There are two laws of physics governing the pressure within a closed spheroid: those of Laplace and Pascal.

The law of Laplace states that the pressure (P) is equal to twice the wall thickness (W) divided by the radius (R) multiplied by the wall tension (T).

$$P = \frac{(2W) T}{(R)}$$

P & T are in balance at all times and at a given T the size of P becomes a function of R. If this law were directly applicable to the uterus then if R is known then T and P may be calculated from each other. However, the Laplace theorem was originally aimed at the description of behaviour of non living matter. The tension (T) of living muscle increases with increasing radius because of increased excitability, conduction and contractility. The thickness of uterine wall also changes. The quantification of T & P cannot therefore be made by mathematical manipulation but it must be based on direct measurement. Direct measurement of wall tension is not feasible.

Is pressure measured at one point within the uterus representative of its overall function? The law of Pascal

states that pressure is equal and uniform at all points throughout a fluid filled space. The space must be continuous and closed. After membrane rupture it might be suspected that neither the law of Laplace nor Pascal apply on account of leakage from the space. During active leakage measurements are inaccurate but when the descending head completely prevents the leakage of amniotic fluid as is usually the case in the second half of labour then measurements are relevant. Does oligohydramnios lead to difficulties in measurement of IUP? It seems not to do so because if there is a space in which to insert a probe it must be filled with fluid however little and a pressure value is produced.

Internal Tocography; Recording & Measurement

The history of internal tocography is longer than that of external methods going back to the work of Schatz in the late nineteenth century (Schatz 1872). He inserted a balloon on the end of a catheter into the pregnant uterus. Polaillon (1880) passed a rubber air balloon just inside the cervix with less success. Westermarck (1893) measured pressures accurately but did not record the changes continuously. Bourne and Burn (1927) introduced a rubber bag into the uterus in the form of a hollow disc. This was attached to the end of a gum elastic catheter. Rubber tubing was attached to this and filled with water to transmit the impulse. The pressure was recorded by an ink

writing point on a revolving drum driven by clockwork. Prior to insertion the patient was anaesthetized, placed in the lithotomy position and the vagina prepared with iodine. Using a speculum to prevent contact between the bag and vaginal wall it was passed through the cervix and insinuated between the internal os and the membranes and gently pushed into the uterus to a distance of eight inches above the os! In no case did the membranes rupture or the placenta become detached. This was an extra-ovular balloon method and was used to study the effect of drugs on the uterus in labour. Incidentally the observation was made by Bourne and Burn that during the first 15 or 20 minutes after insertion there was usually an increase in contraction due to the stimulant effect of the bag and of the waning of the effects of the anaesthetic. This must be borne in mind after any manipulation of the lower segments during vaginal examination. In a well primed uterus this effect may in itself be enough to augment labour.

Caldeyro Barcia and colleagues in Uruguay undertook fundamental work on uterine activity from 1948 onwards. They passed intrauterine catheters through the anterior abdominal wall at all stages of pregnancy, sometimes sequentially in individual patients. Caldeyro Barcia and Poseiro (1960) documented the progressive development of contractions until delivery of the baby. They used a

transabdominal fluid filled catheter. A second catheter was passed into the urinary bladder to measure vesical pressure. The abdominal pressure is equal to the vesical pressure when the contents of the urinary bladder are less than 20 millilitres. Subtraction of abdominal pressure permits the assessment of true intrauterine pressure. Caldeyro Barcia et al (1950) used external receptors on the abdominal wall to record local contractility relating this information to intra amniotic pressure. This was taken a step further with the introduction of tiny rubber balloons into various parts of the interstitium of uterine muscle. (Caldeyro Barcia and Alvarez 1952) These balloons were compressed by contractions of the surrounding muscle and the pressure recorded by an electromanometer. The results were consistent with those of Reynolds et al (1948) showing lack of synchronization of the spread of contractions in abnormal labours. They also demonstrated the high resting basal pressure of a patient with polyhydramnios and the frequent contractions and high basal pressure of a patient suffering from placental abruption.

Few investigators could justify the degree of invasion necessitated by the techniques of the Montevideo group and certainly such studies are unlikely to be repeated today because of ethical constraints. Williams and Stallworthy (1952) working in Oxford described the use of a polythene

tube passed through the cervix into the amniotic sac. This intra amniotic open ended fluid filled catheter technique was reported as simple, accurate and safe. At that time such developments were stimulated by the increasing use of oxytocic drugs during prolonged labour.

Csapo (1970) considered the use of an extra ovular open catheter filled with fluid. He found this simple technique to be grossly inaccurate probably because of the entry of air into the open catheter and insufficient fluid transmission. Lack of a fluid pool around the catheter tip is also important: this can only be created and sustained with difficulty. This difficulty is resolved by a micro balloon placed on the end of the catheter (extra ovular microballoon method) Such a system generates tracings indistinguishable from a transabdominal intra amniotic device. There is no more than 0.7 ml fluid in the balloon. Placement of such a device requires skill and experience in the placement of the catheter, freeing of the system of air, control of fluid leakage and the avoidance of membrane rupture. Csapo and co-workers were well satisfied with this device not only in research but also for monitoring labour. They believed there was no interference with normal physiology, no placental detachment or infection and accidental rupture of the membranes during placement occurred in less than three per cent of subjects.

In 1970 Csapo et al reported preliminary work using a microtransducer mounted on the end of a catheter and placed in an extra amniotic position. This produced identical recordings to an extra ovular micro balloon. Until the 1970s intrauterine pressure recording was usually performed using the transcervical intra amniotic approach with a fluid filled catheter. (fig 7)

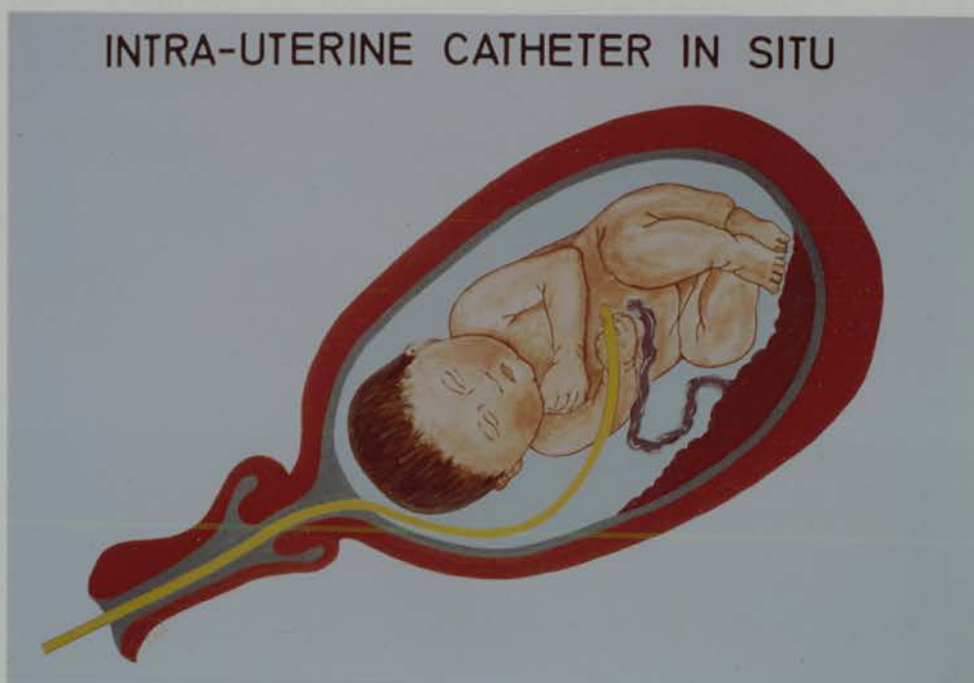


Figure 7: Intrauterine catheter in situ

(Turnbull 1957, Hon & Paul 1973, Huey et al 1976, Miller et al 1976) These devices had to be flushed to maintain continuity of the fluid column and were prone to blockage with vermix, blood clot or fetal parts. (Odendaal et al 1976) Such complications are dangerous because falsely low values in a subject requiring oxytocin augmentation might

lead to hyperstimulation. In the later 1970s a few reports appeared of fetal and placental damage associated with their use. (Nuttall (1978), Trudinger & Pryse Davies 1978) The incidence of such complications is not obvious for two reasons. They are probably under reported and the total number of intra uterine catheter insertions (the demoninator) is not known. Several institutions use such devices without problems. Only a minority of Obstetric units in the United Kingdom undertake intra uterine pressure monitoring.

In 1978 Steer introduced the Sonicaid Gaeltec catheter tip pressure transducer. (figs 8, 9, 10) (Steer et al 1978)

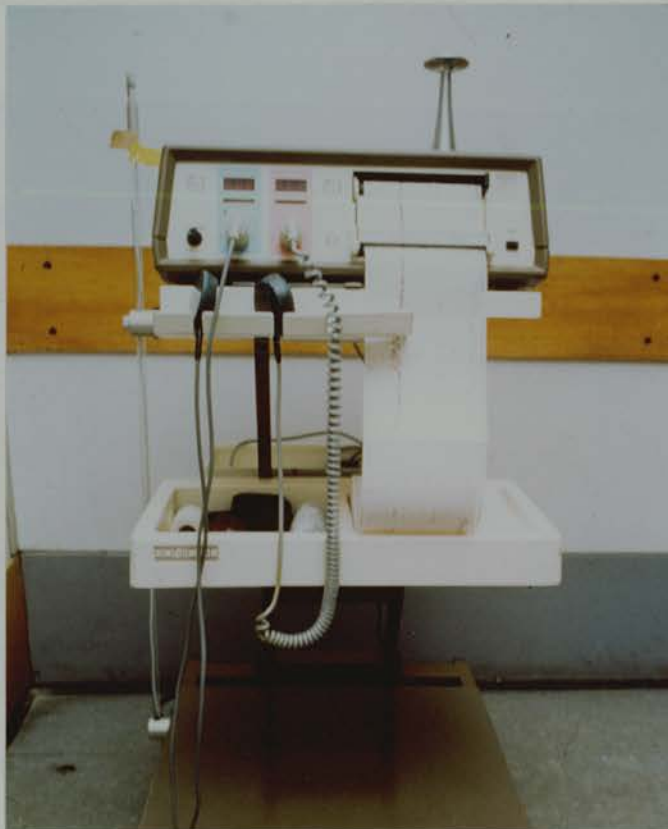


Figure 8: Gaeltec catheter in storage tube attached to monitor

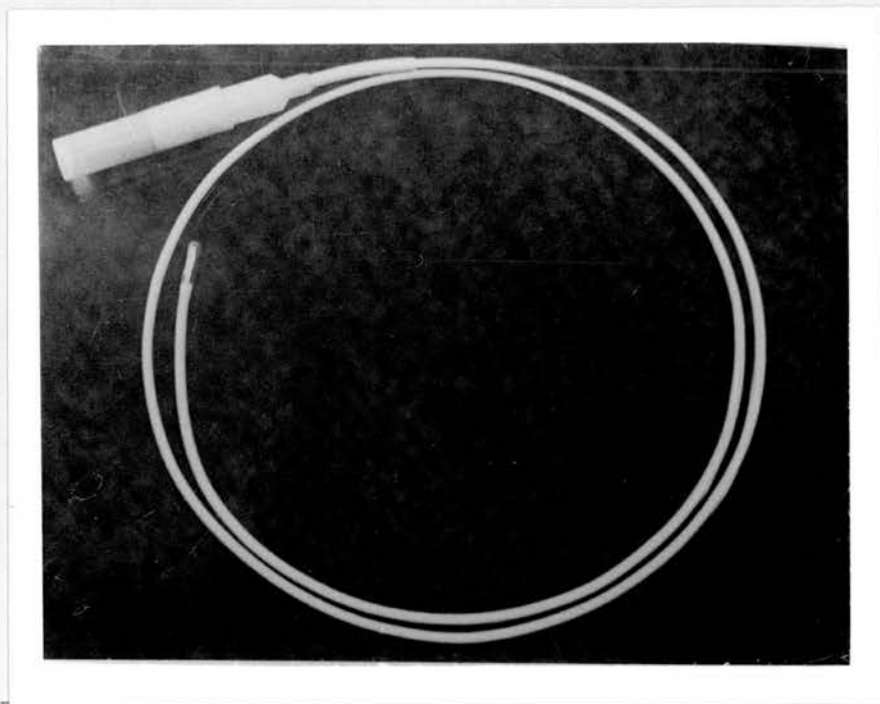


Figure 9: Gaeltec catheter

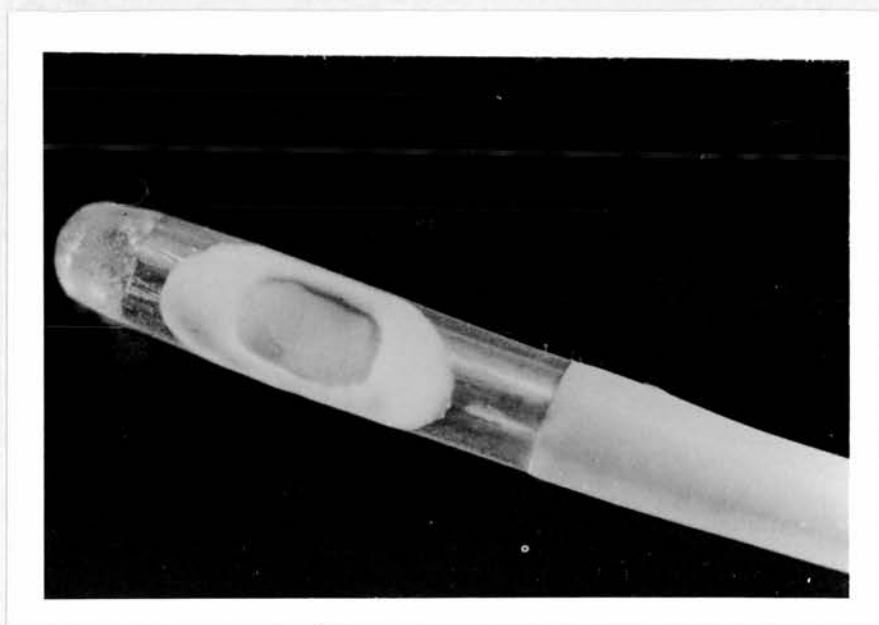


Figure 10: Transducer at catheter tip

This is an intra amniotic device and will not produce recordings from an extraamniotic site for reasons referred

to earlier. It is easy to use and after removal from its storage tube attached to the fetal monitor requires wiped, dried with a guaze swab and inserted through the ruptured membranes. Simple calibration is undertaken beforehand. It is compatible with modern fetal monitors. These devices are not associated with any increased risk of infection and there have been no reports of complications from their use. They are fragile and expensive but if properly handled should last for more than one hundred insertions and be as cost effective as a fluid filled system.

Svenningsen et al (1986) have reported the use of a fibre optic pressure transducer mounted on the end of a solid catheter. The principle of this device is that a light impulse is passed down the catheter to a pressure sensitive membrane from which it returns by a different channel having been altered by the pressure. This does produce reliable results but is in an early stage of development.

Internal Tocography; Measurement

Developments in the measurement of uterine activity have progressed at the same time as developments in recording techniques. Although Smyth (1957) claimed accuracy in recording actual intrauterine pressure with external techniques this generally only reveals duration of

contractions and frequency with a rather poor subjective impression of amplitude. The technical difficulties of obtaining clean tocographic recordings by this method have already been mentioned. Accurate measurements of uterine action especially in the labouring subject have only been made using intra uterine transducers.

Average intensity (active pressure, amplitude) of contractions has been most commonly used. Alvarez & Caldeyro (1950) considered the average intensity of contractions in the first stage of labour to range between 30 and 60 mm mercury. If the average intensity was below 25 mm mercury labour progressed slowly and if below 15 mm mercury it rarely progressed at all. They observed the frequency to be generally between 3 and 5 contractions per ten minutes and considered the normal range to be between 2 and 6. They did not document the duration of contractions. This may have been because of difficulties in identifying the end of a contraction. The upstroke of a contraction is rather steep and its beginning can be easily identified. The downstroke is less steep especially in its terminal part. Often in a trace of normal labour the subsequent contraction begins before the pressure has subsided to the precontraction baseline. A more major degree of this is coupling and a greater degree becomes incoordination. For the same reason it may be difficult to identify basal pressure (basal tone) and this

may be stated to be within a range (8 - 12 mm mercury)
The problems of recognising basal pressure exactly have
been referred to at the end of the preceding section.

The shape of contractions will vary according to the paper speed of the machine. In the United Kingdom cardiotocography is generally performed at a paper speed of one centimetre per minute but in the United States of America speeds of two or even three centimetres per minute are common. This results in contractions appearing to be of longer duration than they are. Pressure tends to rise more abruptly in the first part of a contraction and fall more slowly later. It becomes clear that referring to several elements of contractions sequentially makes comparison difficult. Caldeyro Barcia et al (1957) wished to relate overall activity to duration of pregnancy and labour. They therefore devised Montevideo units named after the city where they worked. Montevideo units are the product of average active pressure multiplied by frequency in a ten minute period. (Fig 11)

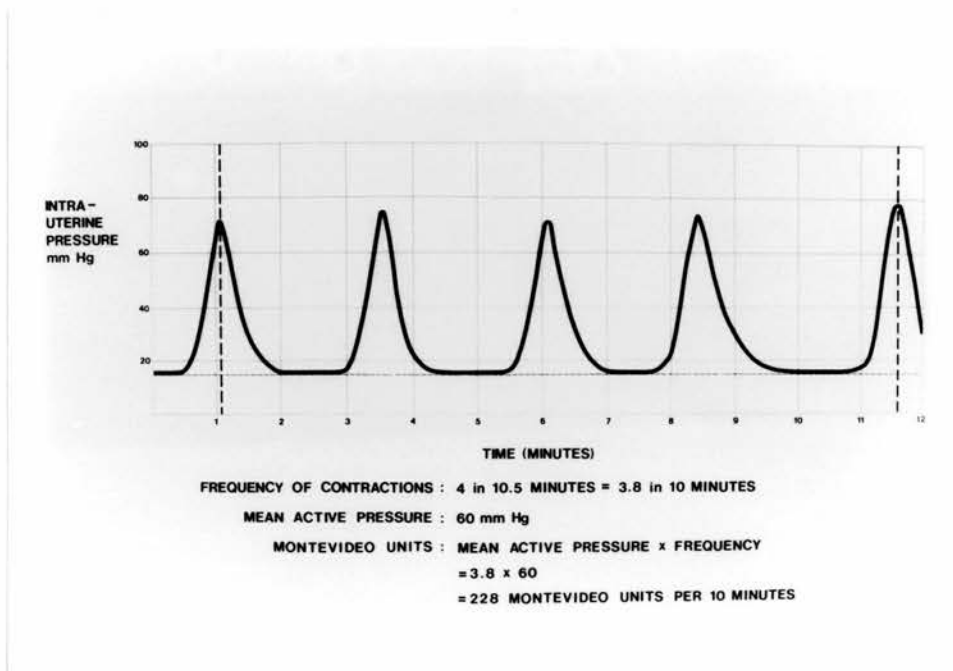


Figure 11: Montevideo Units

They produced a series of reference values for this during pregnancy and labour. At that time this could only be calculated retrospectively and the information was not available during labour when it would have been of diagnostic and therapeutic value. Dehart et al (1977) later devised an on line recording system. This system did not allow for duration of contractions. Montevideo units are only meaningful when one of the parameters is changing but less so when both are changing especially in opposite directions. El Sahwi (1967) added the mean duration of the contraction to the multiplication devising Alexandria units. This only increased the complexity further and did not find favour.

Bourne and Burn had suggested in 1927 that the area described by the writing point of the tocograph above the line of zero pressure was proportional to the work done by the uterus. This concept was used by Hon & Paul (1973) when they devised uterine activity units. The total contraction area (TCA Fig 6) is the area above zero enclosed by the contraction curve.

This had to be divided into units and they decided that one uterine activity unit (1UAU) would be the area enclosed by a pressure of one millimetre of mercury for one minute. This is also called one Torr minute. Advances in technology permitted this to be available on line whilst labour was in progress. It is evident that the area under basal pressure accounts for a substantial part of the total. Significant changes in active contractions might therefore be submerged by this large unchanging area. It might also be considered that in terms of the dynamic process of labour pressure below basal pressure may not play with such an active part.

Seitchik and Chatkoff (1975) and Seitchik et al (1977) opted to study the waveform of contractions. They digitised the waveform and derived its slope in millimetres of mercury per second. Each contraction was divided into four components. They observed that oxytocin stimulated contractions differed from prostaglandin

stimulated contractions or spontaneous contractions in that they showed a disproportionately rapid rise in pressure. They suggested that the ratio of amplitude to the rate of pressure rise identified the myometrial response to oxytocin earlier than amplitude or Montevideo units. This ratio is a more sensitive dose response indicator which changes little with increasing doses once a steady state is reached. These observations suggest that the ratio of amplitude to rate of intrauterine pressure rise may be a useful measure for monitoring oxytocin therapy.

In the trend towards *systeme international* (SI) units Steer (1977) used the SI unit of pressure the Pascal instead of millimetres of mercury (1 kilopascal = 7.52 mm Hg) One kilopascal of pressure existing over a duration of one second is 1 kilopascal second. This measure of active area under the pressure curve must be quantified over a period of time. The time intervals used are kilopascal seconds per 15 minutes (kPas/15 mins.) This quantity is termed the Uterine Activity Integral (UAI). As uterine activity units (UAU) are traditional units depending on mm Hg and kPas are SI units there is a direct relationship between them as shown in Fig 12 (1UAU = 7.8 kPas.) It should be emphasized that UAU are computed from total contraction area and kPas from active contraction area.

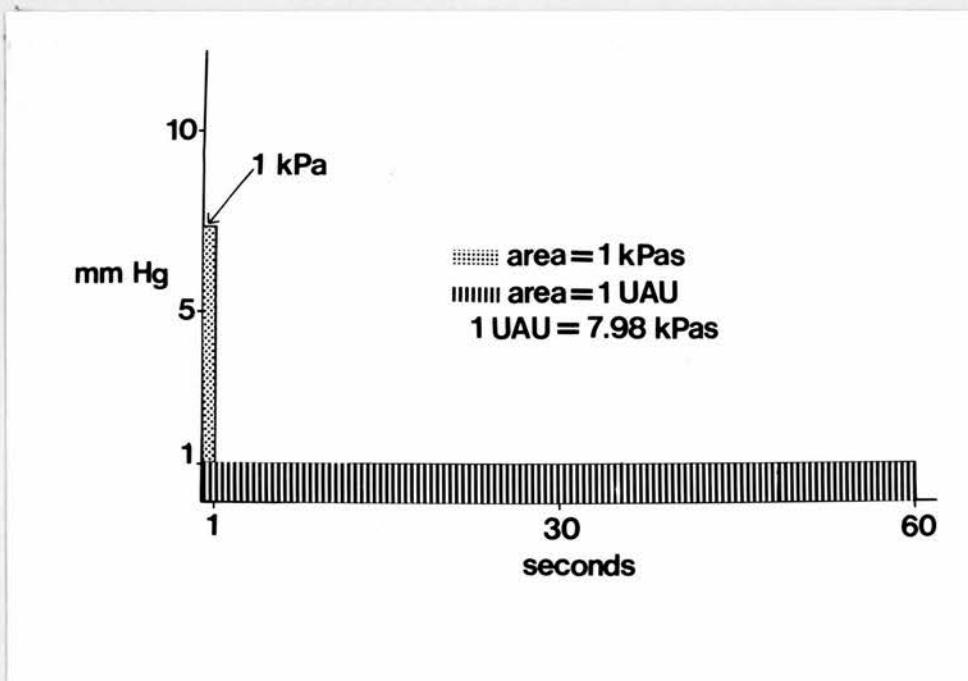


Figure 12: Relationship between uterine activity units and kilo Pascal Seconds

We have used the UA1 (kpas/15 minutes) system in all our work on uterine activity. Phillips & Calder (1987) has proposed a theoretically attractive system which may supercede this.

2. PRELIMINARY STUDIES: CERVIMETRIC ASPECTS OF LABOUR

Before embarking on studies of uterine pressure profiles two studies were conducted to further the understanding of progress in labour without the inclusion of uterine pressure measurement.

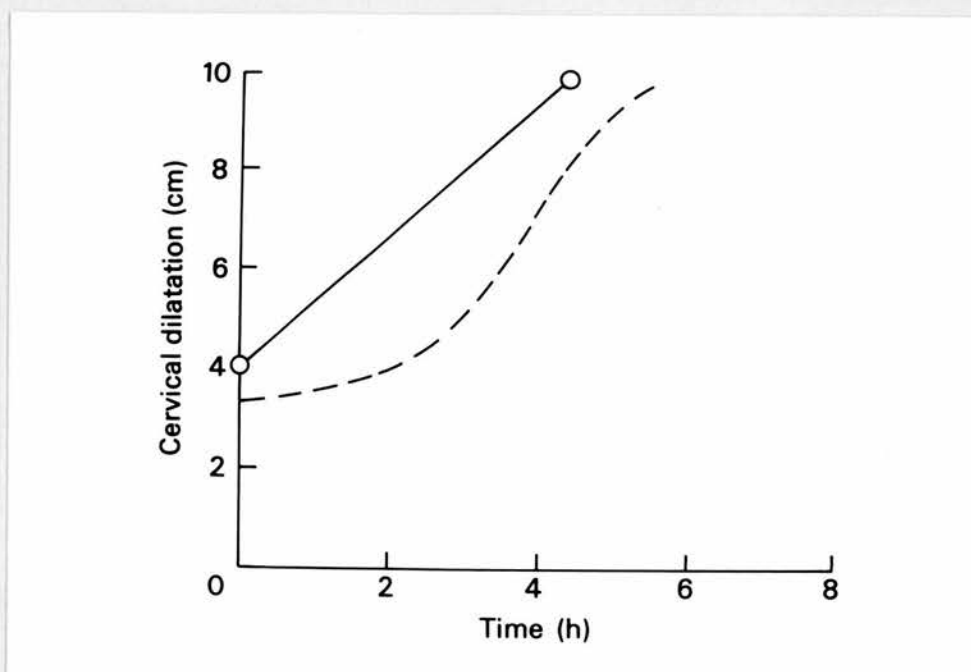
2:1 Nulliparae: cervimetric progress

Method

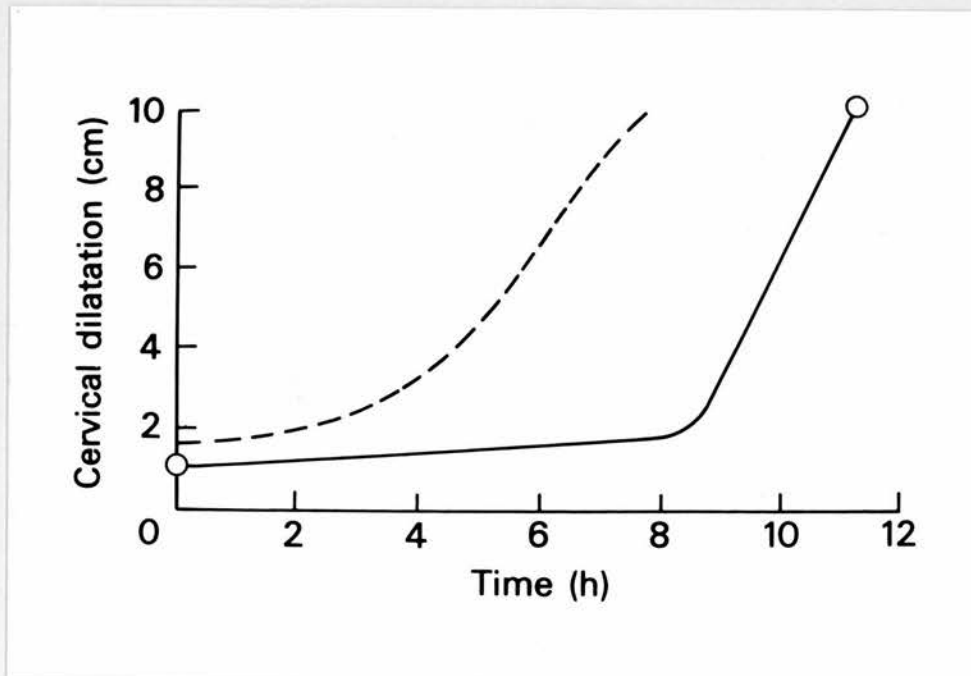
The labour progress of 684 nulliparae delivering in a district general hospital was reviewed. The management had been standardized. When admitted in labour all women were examined per vaginam and the cervical dilatation charted at zero time on the partogram. A nomogram of expected labour progress was drawn from the labour stencil. If labour progressed to the left of the nomogram or within 2 hours to the night it was judged to be normal.

Dysfunctional labour was identified if the cervimetric pattern deviated more than two hours to the right of the nomogram. Labour was then augmented with intravenous oxytocin after ensuring the membranes were ruptured and malpresentation had been excluded. Most women were monitored continuously by electronic means. Epidural anaesthesia was offered to patients requiring oxytocin.

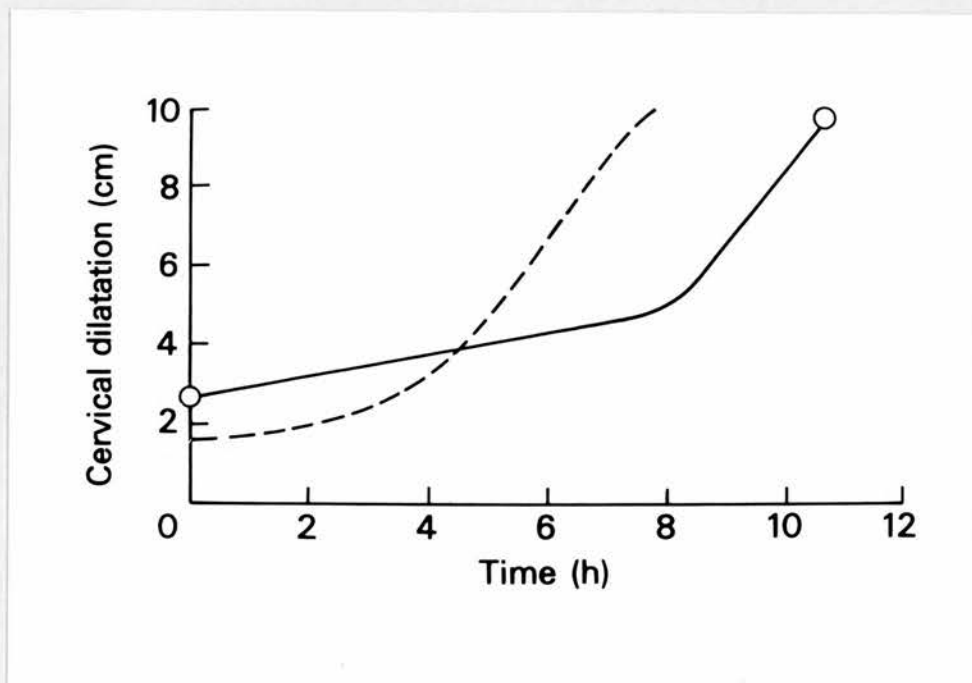
The information from the labours was coded and the type of cervimetric progress allotted to several categories.



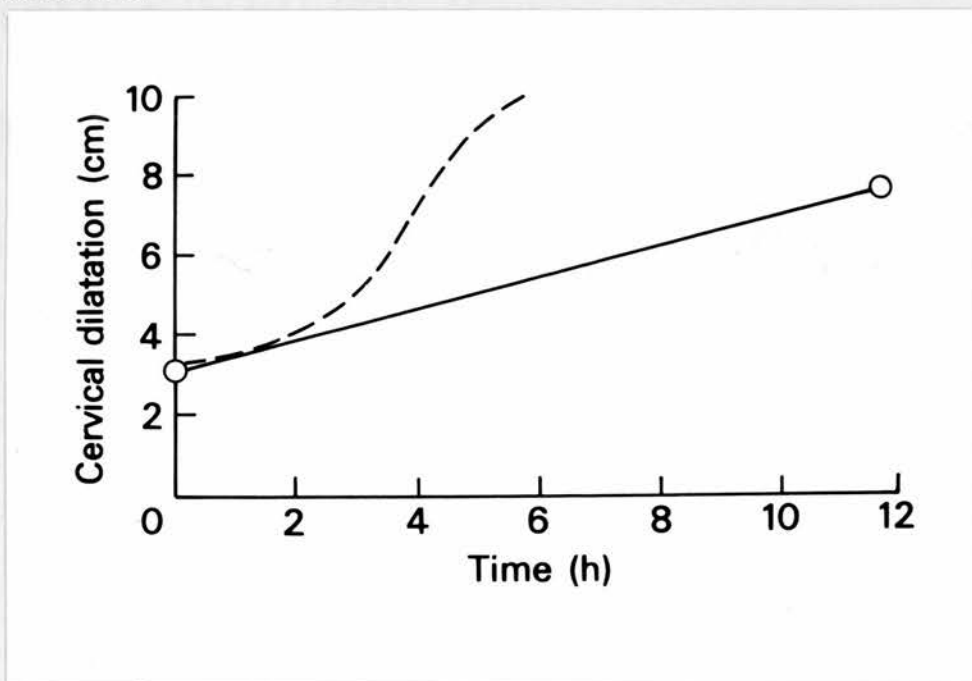
Group A (Fig 13) Normal. Labour which progressed to the left of the stencil nomogram or not more than 2 hours to its right.



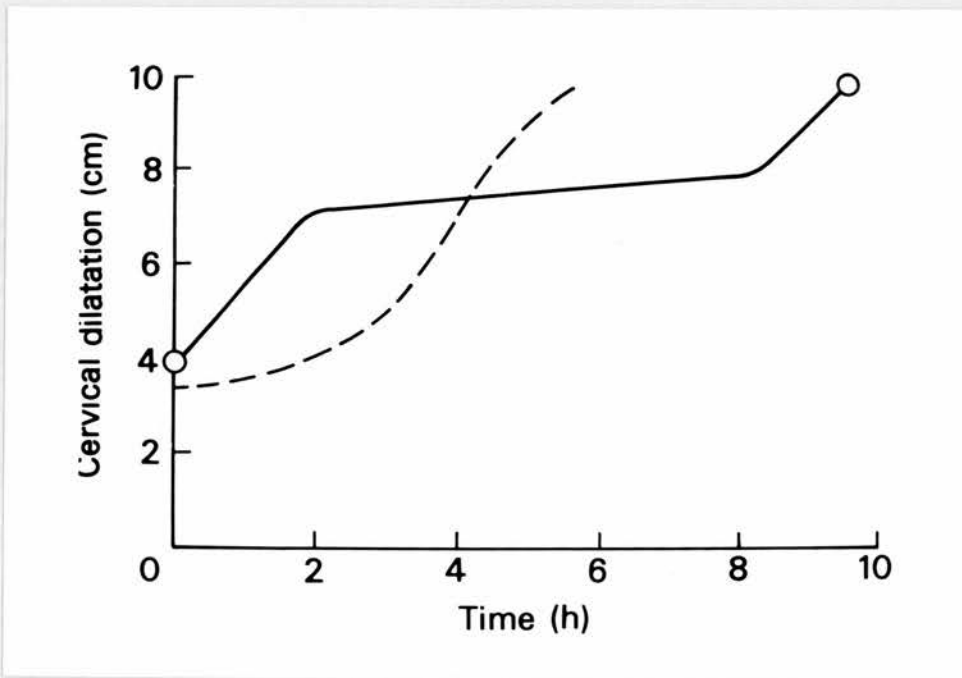
Group B (Fig 14) Prolonged latent phase. This was used to describe labours in which the latent phase exceeded six hours.



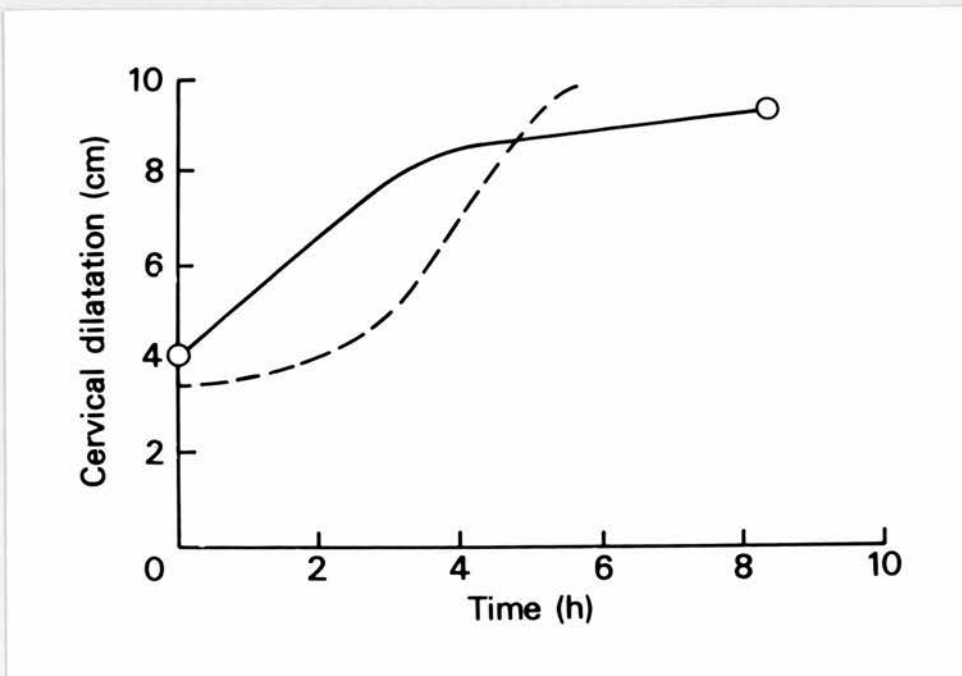
Group C (Fig 15) Primary dysfunctional improved with oxytocin. Primary dysfunctional labour occurred when the active phase of labour progressed at less than 1 centimetre/hour when a normal active phase had not been established.



Group D (Fig 16) Primary dysfunctional labour not improved with oxytocin. In these cases oxytocin failed to correct the abnormality.



Group E (Fig 17) Secondary arrest improved with oxytocin. If the active phase began normally but cervimetric progress stopped for more than 2 hours or showed significantly before full dilatation was reached it was termed secondary arrest.



Group F (Fig 18) Secondary arrest not improved with oxytocin. These were patients in whom oxytocin failed to correct the abnormality.

Results

The mean gestation period for the 684 nulliparae admitted in spontaneous labour was 39.9 weeks and the average birth weight was 3.27 Kg.

As shown in Table 1 63.9% of patients had a normal labour pattern. 26.3% has primary dysfunctional labour the commonest abnormality and 6.3% had secondary arrest of labour.

Type of Cervimetry	No	% cases
Normal	437	63.9
Primary dysfunctional labour	180	26.3
		21.2 (I)
		5.1 (NI)
Secondary arrest of labour	43	6.3
		3.8 (I)
		2.5 (NI)
Prolonged latent phase	24	3.5

(I) - Improved after oxytocin

(NI) - Not improved after oxytocin

Table 1: Spontaneous labour: nulliparae cervimetric progress

80% of those with primary dysfunctional labour had a satisfactory response to oxytocin manifested by improved

labour progress. 93% of those responding subsequently delivered vaginally. 60% of those with secondary arrest of labour showed a satisfactory response to augmentation with 88.4% of those responding delivering vaginally.

In the group that did not show improvement of primary dysfunctional labour after oxytocin treatment the mean maternal height was 4 centimetres less than in all nulliparae and 17.6% of them were under 150 centimetres.

The mean birth weight was 290 grams greater than the mean for all groups and 20.6% of babies in this group weighed over 4 Kg. All these values were statistically highly significant.

2:2. Multiparae: cervimetric progress.

Method.

847 multiparae were studied using the same method of division into cervimetric groups. Great care was exercised and oxytocin withheld from women with abnormal progress until the senior resident on duty had examined the patient to exclude malpresentation or cephalo pelvic disproportion.

Results

The mean gestation period of women in this study was 39.3

weeks and the mean birth weight 3.36 Kg. Types of cervimetric progress are shown in Table 2

Type of labour progress	No	%
Normal	749	(88.7)
Primary Dysfunctional labour	69	(8.1)
		7.39 (I)
		0.8 (NI)
Secondary Arrest of Labour	17	(2.0)
		1.4 (I)
		0.6%(NI)
Prolonged Latent Phase	12	(1.2%)

(I) Improved with oxytocin

(NI) Not improved with oxytocin

Table 2: Spontaneous labour: multiparae cervimetric progress

Normal progress in labour was very much the dominant feature of multigravid labour. When labour progress was abnormal an improvement in progress was seen in the majority of cases and vaginal delivery resulted.

Discussion

What is abnormal labour progress or failure to progress in labour? It is not a diagnosis but a clinical situation

and as such is not a satisfactory justification for operative delivery. It should direct the clinician to a search for its underlying pathological cause.

Failure to progress in labour may be due to:

1. Poor uterine contractions
2. Malpresentation (Brow, etc)
3. Malposition (Occipito posterior)
4. Cephalopelvic disproportion
5. A poor start to labour usually by induction or stimulation after premature membrane rupture.
6. Very rarely true cervical dystocia

Several of the above may coexist; malposition and cephalopelvic disproportion cannot be judged the sole factors responsible for delay in labour until the contractions have been optimized. Prior to the infusion of oxytocin to achieve this a review should be made of the nature of the contractions and the fetopelvic relationship. The stature of the woman should be noted and 150 centimetres considered short.

Pelvic assessment should be performed during vaginal assessment when malposition (occipitoposterior) may be found. Abdominal palpation usually permits some impression of the nature of the contractions to be obtained. In the absence of gross misfit of the

fetopelvic relationship and with a normal fetal heart recording obtained oxytocin augmentation is then given. Augmentation is a better word than acceleration which has been misunderstood by the lay public. It is not a question of "speeding up" contractions to make labour go faster but an attempt to restore progress to normal.

3. OXYTOCIN: RISKS AND BENEFITS

The use of oxytocin is not without hazard. Liston & Campbell (1974) drew attention to this in a poorly designed retrospective study showing that fetal distress, low Apgar scores and admission to the special care baby unit were all commoner in patients treated with oxytocin. These patients also had very frequent contractions compared to others. In that study the clinical criteria were crude and there was no control group. Patients having oxytocin treatment are at risk because of the indication and it may not have been the oxytocin that made the difference. Nonetheless the authors sounded a cautionary note at a time when oxytocin was being very freely used consequent to the enthusiasm for O'Driscoll's Active Management of Labour and in particular the liberal use of high dose oxytocin.

Caldeyro-Barcia and Alvarez (1952) stated that reduction of intervillous blood flow sufficient to cause fetal anoxia will occur if contractions are strong and more frequent than five in ten minutes or if there is persistent hypertonus with the intramyometrial pressure elevated to 30 mm mercury active pressure. Hendricks (1958) in a comprehensive study of the haemodynamics of uterine contractions showed a rise in blood pressure, a

slight rise in heart rate followed by a fall, a reciprocal change in stroke volume, a rise in central venous pressure and an extrusion of approximately 250 mls of blood from the uterus into the maternal venous reservoir during a contraction. Ramsey and Associates (1963) studied the maternal circulation of the haemochorial placenta common to man and the higher primates. They used the rhesus monkey subjecting them to invasive investigation by serial and cineradioangiography. This technique confirmed the validity of the circulating hypothesis derived from previous anatomical and physiological studies. They found that maternal blood enters the intervillous space from the endometrial spiral arterioles in discrete, relatively high-pressure funnel-shaped streams which is curtailed or abolished during uterine contractions. The endometrial spiral arterioles act independently of one another not all of them being patent and discharging blood into the intervillous space simultaneously. Several factors appeared to be responsible for regulation of blood flow into the intervillous space; intrauterine pressure, pattern of uterine contractility and factors which act specifically upon the arteriolar wall. Such a study would not have been possible using normal human pregnancies. However, Borell et al (1965) studied the fetuses of three women which all had severe malformations incompatible with extrauterine life. Arteriographic techniques showed a

marked retardation of blood flow during contractions. However, the degree of retardation varied within different areas of the uterine wall. In those segments in which the retardation was most marked the blood flow was completely inhibited whereas in those in which the retardation was slight, incomplete filling of the intervillous space was the only sign of reduction of flow. The cause of the retardation was interpreted as being due, in part, to local compression of the arterial wall by the myometrium. Some arteries exhibited local or generalized reduction in diameter, probably as a result of constriction of the musculature within the arterial wall. No definite alteration in diameter of the spiral arteries was found.

Brotanek et al (1969) studied relative uterine blood flow by thermistor method, intra uterine pressure, femoral venous and arterial pressures and maternal heart rate. In prelabour uterine blood flow exhibited frequent irregular waves independent of uterine activity. During labour an initial decline in uterine blood flow preceded the contraction by about half a minute, followed by partial or complete recovery in the early contractile phase. A second drop began as the intra uterine pressure reached about 30 millimetres of mercury and the decline continued to the peak of contraction or beyond. After the contraction was completed the uterine blood flow recovered

to its original level.

The fetus is dependent on reserves to tolerate the temporary lack of blood flow during the contractions. Well grown healthy fetuses tolerate a natural sequence of contractions. Growth retarded fetuses have less reserve and may become asphyxiated with few contractions. However, even well grown fetuses may suffer asphyxia because of iatrogenic contractions which are too frequent or hypertonic (hyperstimulation). Too frequent contractions (tachysystolic) occur more than 5 in 10 minutes, hypertonus occurs when the pressure does not return to basal levels between contractions. (figs 19, 20) Kubli & Rutgers (1961) have described this iatrogenic fetal hypoxia in greater detail.

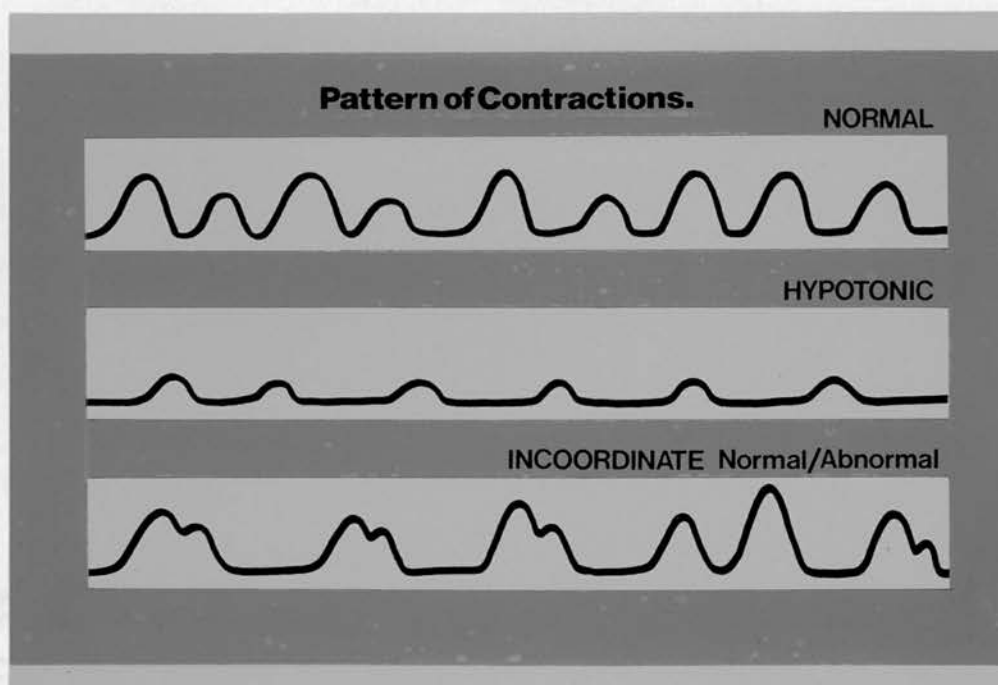


Figure 19: Normal contraction patterns

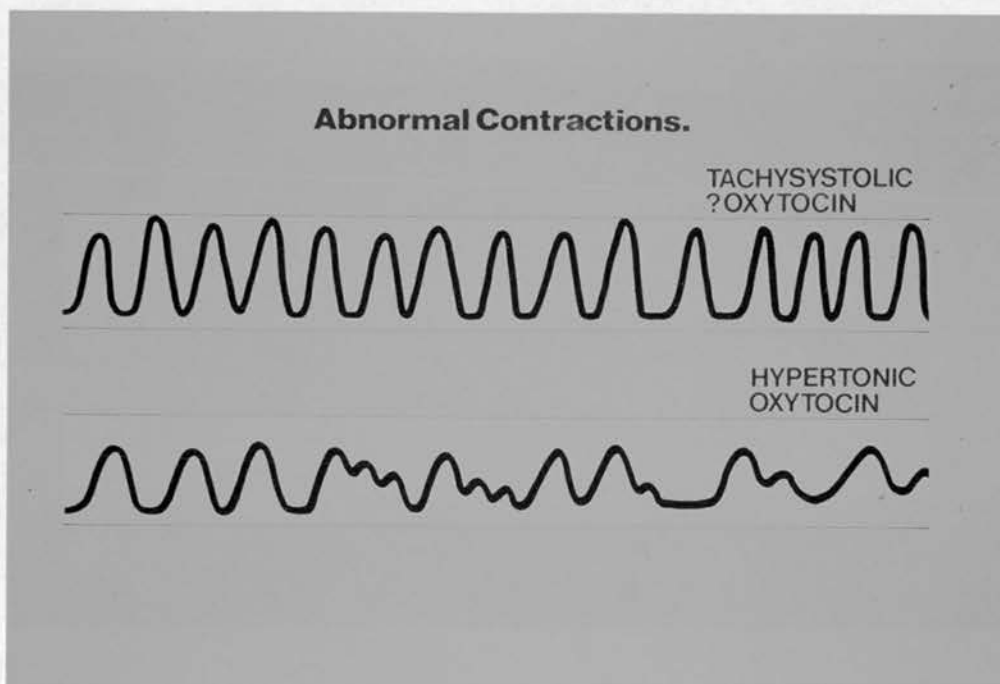


Figure 20: Abnormal contraction patterns

Bleker et al (1975) described a compensatory mechanism suggesting that the intervillous space observed by ultrasound examination becomes distended during a contraction. This may be because the venous channels are obstructed prior to the arterial channels during the contraction. A pool of oxygen is therefore held in this space assuming it is of normal configuration. Bearing in mind the placental appearances of growth retarded pregnancies they may be deprived of the benefits of this mechanism.

Neonatal jaundice has been attributed to the use of oxytocin in labour (Ghosh & Hudson, 1972, Chalmers et al, 1975, Beazley and Alderman, 1975) although other workers have questioned this. Buchan (1979) demonstrated in vitro and in vivo that the vasopression-like action of oxytocin causes osmotic swelling of erythrocytes leading to decreased deformability and hence more rapid destruction with resultant hyperbilirubinaemia in the neonate. The effect is probably less common now as oxytocin is used in lower dosage and for shorter periods of time since the advent of prostaglandins.

Electrolyte imbalance is also attributed to oxytocin therapy (McKenna & Shaw, 1979, Feeney, 1982). There is no doubt that high doses of oxytocin in large volumes of

electrolyte free fluid lead to dilutional hyponatraemia with potentially serious consequences. More subtle effects may occur in the neonate (Schwartz & Jones, 1978) with severe neonatal illness resulting from transplacental hyponatraemia. These adverse results may be limited by avoided high doses of oxytocin in large volumes of administered 5% Dextrose and more easily avoided by using saline instead as the vehicle.

Recognition of the effects of oxytocin is important and it should be respected as any other pharmacological agent. Effects should be viewed in the context of dose as any clinical pharmacologist would expect. The conversion of concentration of oxytocin dissolved in fluid converted to milliunits per minute according to dose rate is shown in Table 3.

Drops per min	4 units per litre	8 units per litre	16 units per litre	32 units per litre
10	2	4	8	16
20	4	8	16	32
30	6	12	24	48
40	8	16	32	64
50	10	20	40	80
60	12	24	48	96

Table 3: Oxytocin dose rate conversion

Too few contractions may lead to morbidity because of prolonged labour and Caesarean section whilst too many contractions may lead to Caesarean section for fetal distress and to other adverse effects of oxytocin. Further study of uterine contractions is therefore necessary.

4. UTERINE ACTIVITY: SPONTANEOUS LABOUR

There are several variables which could be expected to influence uterine activity. Parity, induction of labour, maternal height, birthweight, multiple pregnancy, presentation and position of the presenting part might all be expected to play a role. Uterine activity was therefore studied in clearly defined groups of patients keeping variables constant.

4:1. Nulliparous labour

Patients and methods

Patients

40 subjects were all recruited from the University Unit labour ward at Kandang Kerbau Hospital for Women, Singapore. All were Chinese, nulliparous, aged between 20 and 32 (mean 24.9), >152 cm in height (mean 157.4 range 152-167), at term (mean 39.7, range 37-42 weeks) and in spontaneous normal labour. Spontaneous labour was recognized as occurring when regular painful uterine contractions resulted in the uterine cervix being at least 3 cm dilated and completed effaced.

Methods

Subjects suitable for the study were identified and the patient was informed of the procedure.



Before the Sonicaid-Gaeltec catheter (Sonicaid Limited, Chichester) was inserted into the amniotic cavity its function was checked as recommended (Sonicaid operating handbook) to ensure correct calibration with the built-in circuit.

The patient was placed in the dorsal position and the catheter was introduced through the cervix into the amniotic cavity so that its tip lay 30 cm from the cervix. It was usually passed posterior to the head but if that was unsuccessful an anterior approach was adopted. There was no failed insertion. A fetal scalp electrode was applied. The patient lay on her side until the second stage of labour. Vaginal examinations were performed at hourly intervals to confirm normal progress of labour, defined as that progressing within 2h to the right of a line drawn 1 cm/h from admission dilatation on the partogram. Most patients progress at >1 cm/h. Patients who developed abnormal labour were excluded: no patient had oxytocin.

Continuous monitoring of intrauterine pressure and fetal heart rate was undertaken using a Sonicaid FM3R fetal monitor (Sonicaid Limited, Chichester). The monitor was switched off and then switched on again after insertion of the catheter and before continuous recording as recommended in the Sonicaid instruction manual. Any

patient with an abnormal fetal heart rate tracing was excluded. Uterine activity was quantified on-line with the Sonicaid Uterine Activity Integrator.

Analgesia was administered as required in the form of pethidine (50-100 mg, given intramuscularly every 4 h); epidural analgesia was not used.

When the uterine cervix was fully dilated the intrauterine catheter was removed. The patient adopted the dorsal position and was encouraged to commence expulsive efforts. If the baby was not delivered after 1 h in the second stage of labour the patient was excluded. Any patient requiring assisted delivery during the second stage was excluded.

Apgar scores at 1 and 5 min were recorded and the umbilical vein blood pH measured; none of the newborn was depressed.

Analysis of uterine activity

The profiles of uterine activity were analysed individually and collectively. All activity values were analysed on a TRS-80 model II micro-computer using a program that could selectively analyse all or some of the values to derive centiles for each cervical dilatation. In the study, it was decided that the increase in

dilatation recorded within a 1-h interval should assume a proportionate progression for the four consecutive 15-min intervals. Hence if a patient progressed from 4 cm to 8 cm in 1 h then the activity values were allocated correspondingly to 4 cm, 5 cm, 6 cm and 7 cm respectively.

Individual median levels were obtained for each labour unrelated to cervical dilatation.

Collective analysis with respect to cervical dilatation was performed using both the 'area under the curve method' (kPas/15 min) and the manual method of calculating Montevideo units. These were correlated.

Results

The mean birthweight of the newborn infants was 3169 g and none of them was depressed as measured by Apgar scores, the mean umbilical vein pH was 7.37 (Table 4).

	Mean	Range
Birthweight (g)	3169.0	2560.0–4000.0
Apgar score at 1 min	8.9	8.0–9.0
Apgar score at 5 min	10.0	10.0–10.0
Umbilical vein pH	7.37	7.28–7.49

Table 4: Patient characteristics

Table 5 shows the initial cervical dilatation in all patients; the majority (75%) were admitted to the study at <5 cm dilatation.

Dilatation (cm)	Patients (n)	Cumulative (%)
3	13	33
4	9	55
5	8	75
6	3	83
7	4	93
8	3	100

Table 5: Admission cervical dilatation

Individual analysis of uterine activity

Scrutiny of the individual profiles in kPas/15 min showed a consistently high reading for the second 15 min period in 27 out of 40 patients. In nearly all of them this was more than double the reading for the first and third readings. It was decided to exclude the second readings from analysis in these cases. This peak did not occur when Montevideo units were used and these readings were retained.

Median levels in kPas/15 min are shown in Fig 21. No patient progressed in labour with a median value of <900 kPas/15 min. There was a wide distribution of median levels up to 2500 kPas/15 min.

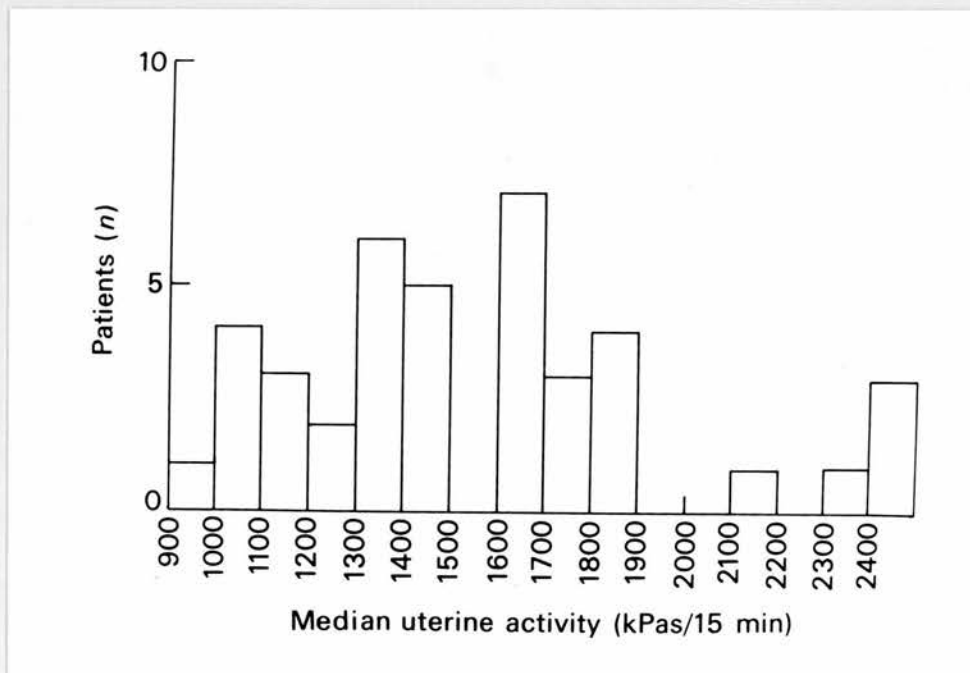


Figure 21: Median uterine activity levels

Overall analysis of uterine activity

There were 427 15-min periods in which uterine activity was quantified; 40 of them were eliminated as second 15-min period readings from the analysis when kPas were used. Table 6 and Fig 22 show the uterine activity centiles related to cervical dilatation for 387 readings. Exploratory analyses of the data showed that some of the distributions of uterine pressure values were asymmetrical when examined for various dilatation sizes. Distributions for dilatations of 5, 7 and 8 cm were found to be significantly skewed to the right while that for a dilatation of 9 cm was shown to be significantly platykurtic. It would therefore appear inappropriate to use the arithmetic mean to summarize these values. Hence, the median (50th centile) and other selected centile values were derived for each set. The median value increased only slowly from 1196 kPas/15 min at 3 cm dilated but subsequently rose sharply to 1785 kPas/15 at 9 cm dilated.

Cervical dilatation (cm)	Uterine activity centiles (kPas/15 min)					No. of readings
	10th	25th	50th	75th	90th	
3	650	767	1196	1419	1516	22
4	726	952	1270	1557	1813	37
5	764	995	1269	1700	2135	47
6	714	883	1375	1606	2125	50
7	853	940	1320	1775	2469	59
8	963	1127	1367	1658	2247	72
9	1202	1477	1785	2359	2500	100
3-10	855	1093	1440	1780	2375	387

Table 6: Uterine activity related to cervical dilatation (k/Pas/15 mins)

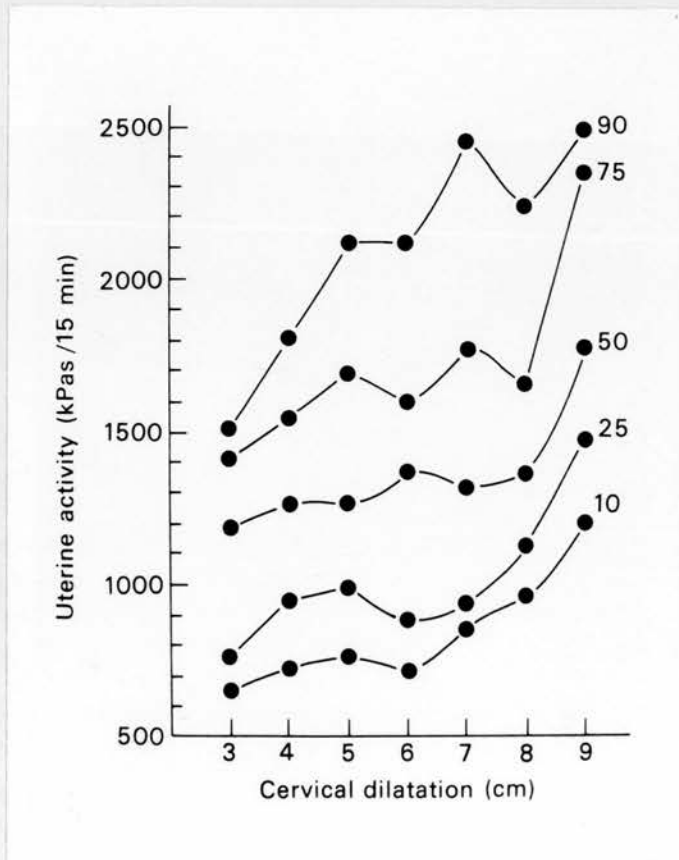


Figure 22: Graphic representation of dilatation specific uterine activity (k/Pas/15mins) in nulliparae

Cervical dilatation (cm)	Uterine activity centiles (Montevideo units)					No. of readings
	10th	25th	50th	75th	90th	
3	110.6	152.9	242.0	279.0	341.0	25
4	152.1	188.0	234.0	279.4	331.0	43
5	155.9	184.3	225.2	274.7	324.3	52
6	142.4	170.1	242.9	284.5	368.1	51
7	149.5	181.3	231.0	301.5	369.8	61
8	170.4	212.6	246.5	290.1	425.5	73
9	230.2	279.0	325.5	436.4	545.6	94
3-10	155.8	198.0	254.0	314.0	422.0	399

Table 7: Uterine activity related to cervical dilatation (Montevideo units/10 minutes)

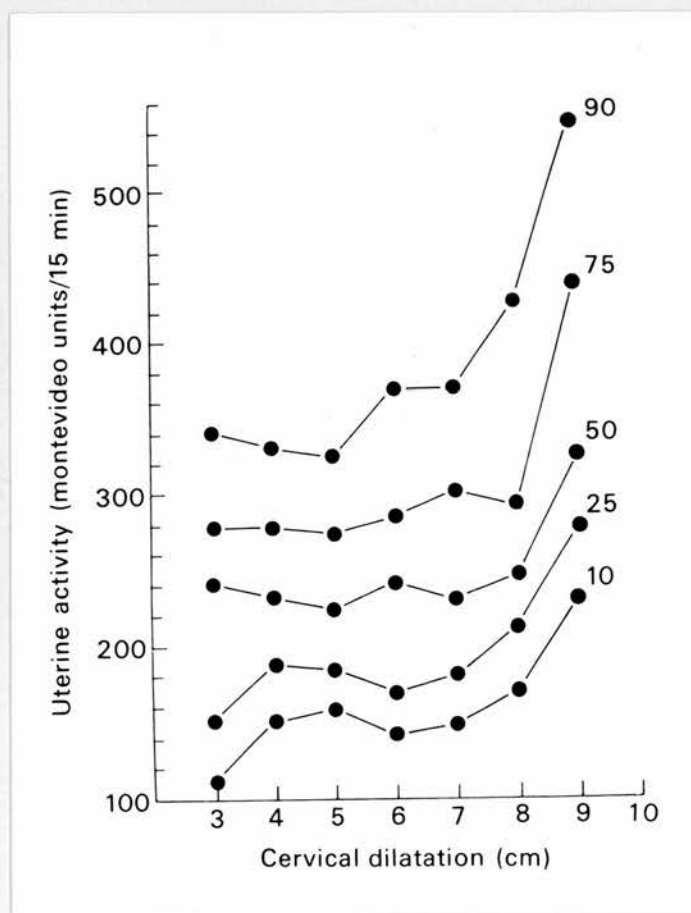


Figure 23: Graphic representation of dilatation specific uterine activity (montevideo units/10 mins)

Analysis using Montevideo units is shown in Table 7 and Fig 23. A similar profile is seen with little rise from 242 Montevideo units/15 min at 3 cm to 246.5 Montevideo units at 8 cm and then 325.5 Montevideo units at 9 cm dilatation.

Fig 24 shows the scatter diagram obtained by plotting each measurement in Montevideo units with its corresponding kPas unit, when available.

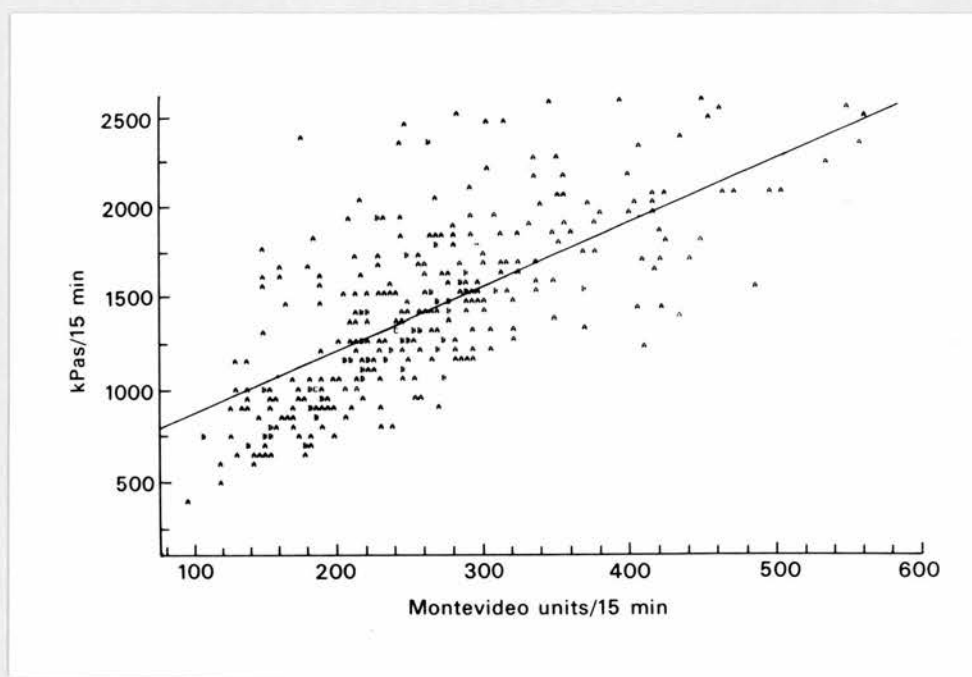


Figure 24: Correlation: k/Pas per 15 mins/Montevideo units per 10 mins

The relation between the two systems of measurement for uterine activity was indicated by a correlation coefficient (r) of 0.71 ($n = 337$, $P < 0.001$). When the measurements in Montevideo units were treated as the

independent variable in the regression analysis, the best-fitting straight line, as given by the method of least squares, was found to be $y = 3.56x + 458.26$. Therefore, we have found that, on the average, for every increase of 1 unit on the Montevideo scale, there is an increase of nearly 4 units on the kPas scale, within the range of measurements obtained in our sample.

Analysis of contraction pattern and baseline tone

Whilst the majority of individual contractions were symmetrical and co-ordinated, a degree of inco-ordination was found. As seen in Fig 25 there was some coupling of contractions and 'a hammock effect' on the baseline between many contractions. Less commonly greater degrees of inco-ordination were seen. Baseline tone tended to vary even allowing for positional changes but we found no consistent change in the baseline as labour progressed: 18 showed no change in the baseline. 12 a decrease of <10 mmHg and 10 an increase of <10 mmHg.

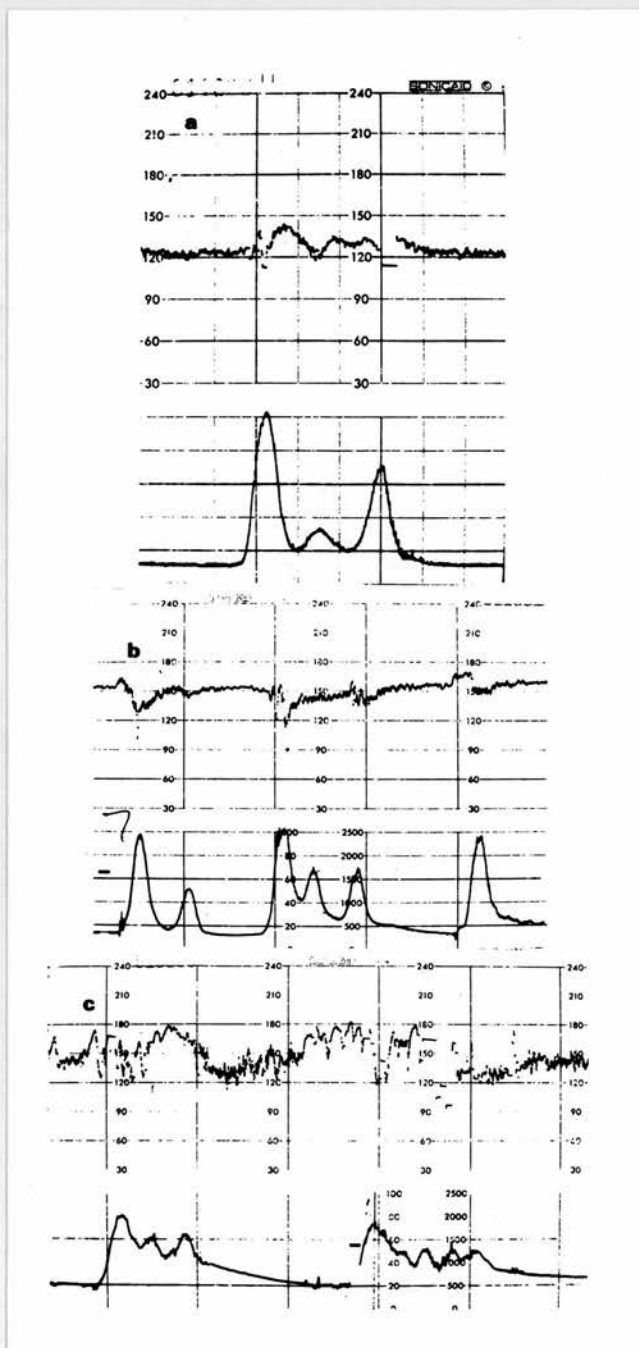


Figure 25: Incoordinate activity in spontaneous nulliparous labour

4:2. Spontaneous multiparous labour

Patients and methods

These were identical to the nulliparous study except all patients had delivered vaginally on one or more preceding occasion.

Results

Table 8 gives the maternal and neonatal characteristics of the 40 patients who fulfilled the study criteria for inclusion, 30 of them had one previous vaginal delivery, eight had two and two had three or more.

	Mean	SD	Range
Age (years)	27.9	3.88	(20–36)
Height (cm)	157.3	6.38	(152–170)
Gestation (weeks)	39.6	1.07	(37–42)
Birthweight (g)	3222.0	407.66	(2500–4200)
Apgar score (1 min)	8.9	0.35	(8.0–10.0)
Apgar score (5 min)	10.0	—	—
Cord pH	7.37	0.049	(7.28–7.46)

Table 8: Patient Characteristics

The patients were representative of the multiparous population delivery in Singapore excluding short patients; with a mean age of 27.9 years, mean height 157.3 cm and mean gestation 39 weeks and 5 days. Table 9 shows the cervical dilatation on admission to the study: 78% of subjects were admitted at <5 cm dilatation. There was no fetal distress, no infant was depressed as measured by Apgar score and umbilical vein pH and all birthweights were in the normal range.

Dilatation size at admission (cm)	No. of patients (<i>n</i> =40)	Cumulative (%)
3	13	33
4	8	53
5	10	78
6	6	93
7	3	100

Table 9: Admission cervical dilatation

Analysis of uterine activity

There were 334 15-min values of uterine activity of which 40 were excluded from profile construction because of

excessively high values for the second 15-min period. Exploratory analysis of the data showed that some of the distribution of uterine activity values was asymmetrical when examined for various dilatation sizes. Hence the median (50th centile) and other selected centiles were derived for each set. Table 10 shows the uterine activity values tabulated in a dilatation-specific manner. These values are illustrated graphically in Fig 26.

Cervical dilatation (cm)	Uterine activity centiles (kPas/15 min)					No. of Readings
	10th	25th	50th	75th	90th	
3-9	623	800	1130	1560	2146	294
3	430	538	815	1081	1727	24
4	526	650	782	1500	1876	33
5	553	745	980	1384	1492	44
6	640	803	1050	1307	1859	41
7	736	900	1120	1433	2170	49
8	628	900	1259	1668	2020	49
9	923	1302	1731	2308	2500	54

Table 10: Uterine activity related to cervical dilatation (k/Pas/15 minutes)

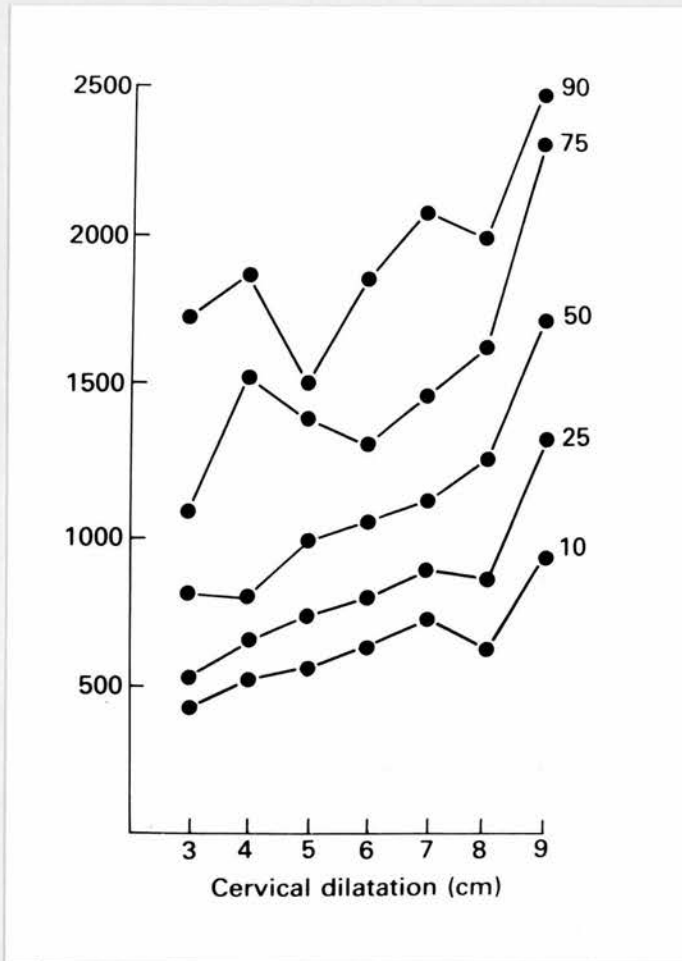


Figure 26: Graphic representation of dilatation specific uterine activity. k/Pas/15 minutes

The median value increased slowly from 815 kPas/15 min at 3 cm dilatation to 1259 kPas/15 min at 8 cm dilatation but then rose sharply to 1731 kPas/15 min at 9 cm dilatation . Values of 2500 kPas/15 min occurred on 23 occasions.

Comparison with study of nulliparous labour

These results were compared with the parallel study of nulliparous labour. The only differences in the two study populations were parity, the mean maternal age was 3 years older in the multiparous subjects and the mean birthweight was 50 g heavier. Maternal height, gestation, Apgar

scores and umbilical vein pH values showed no important differences.

Table 11 and Figure 27 compare the median values of the activity profiles for the two study samples. The median values at 3, 4, 5 and 6 cm dilatation were shown to be significantly lower in the multiparous group compared with those in the nulliparous group using the non-parametric median test. The differences in uterine activity levels by various dilatation sizes are recorded in Table 11. Although the largest difference of 488 kPas/15min was recorded for a cervical dilatation of 4 cm this was not statistically significant at the 5% level ($P=0.0688$) probably because of the small number of readings ($n=69$) available at this dilatation. From 7 cm dilatation onwards, the values in multiparae were also slightly lower than those in nulliparae but the differences were not statistically significant. The overall median value in multiparous labour was 1130 kPas/15 min compared with 1440 kPas/15 min in nulliparous labour.

Cervical dilatation (cm)	Uterine activity (kPas/15 min)			
	Nulliparae	Multiparae	Difference	<i>P</i>
3	1196	815	381	0.0366
4	1270	782	488	0.0688
5	1269	980	289	0.0402
6	1375	1050	325	0.0143
7	1320	1120	200	0.1629
8	1367	1259	108	0.5090
9	1785	1731	54	0.8603

Table 11: Comparison of uterine activity: nulliparae and multiparae

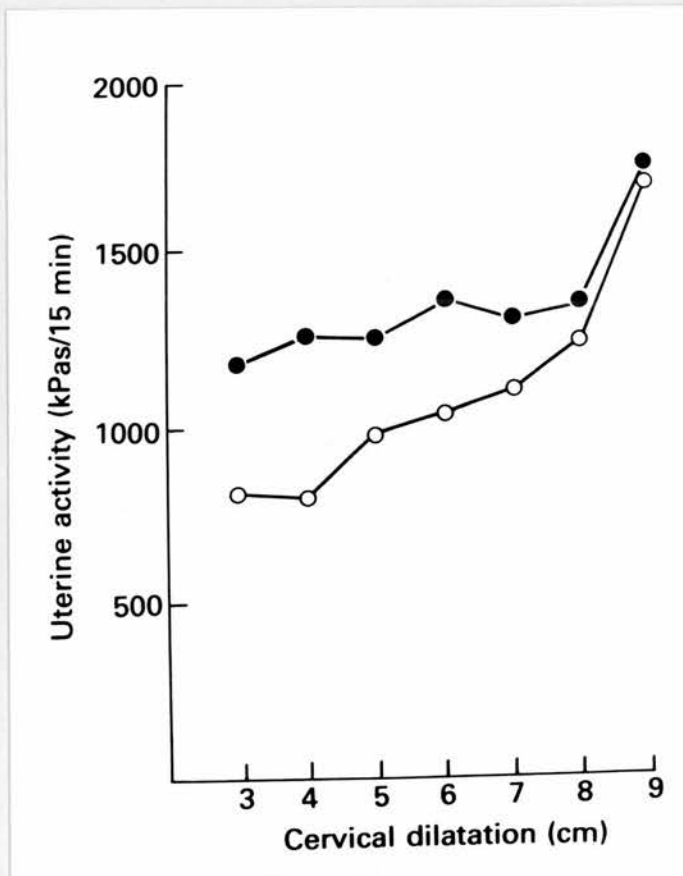


Figure 27: Graphic representation of parity comparison

The 10th centile of activity which may represent the lowest value at which normal progress is probable, ranged from 430 kPas/15 min at 3 cm dilatation to 923 kPas/15 min at 9 cm dilatation in the multiparae compared with the equivalent values of 855 kPas/15 min and 1202 kPas/15 min in the nulliparae.

Discussion

Beazley & Kurjak (1972), Philpott & Castle (1972) and O'Driscoll et al (1973) use a cervical dilatation rate of 1cm/h to distinguish normal from abnormal labour; 1 cm/h is the dilatation rate of the slowest 10% of African patients (Philpott & Castle 1972) and the slowest 5% in Friedman's (1955) study. The point at which action is taken to augment labour varies as, therefore, does the rate of augmentation of labour. A line drawn at 2 cm to the right of a line drawn at 1cm/h in the active phase was used thereby including the slower as well as the faster normal labours. The uterine activity levels associated with progress in labours which adhere to strict criteria of normality are presented.

Caldeyro-Barcia & Poseiro (1960) suggested that uterine activity increased markedly as labour progressed. Cowan et al (1982) did not find such an increase and the results support their finding. Miller et al (1976) and Huey et al (1976) made similar observations but their results are not

comparable in view of a different study population, the use of a fluid-filled catheter system and a different method of computation of uterine work. Fluid-filled catheter systems have been shown to be inferior to the transducer-tipped catheter (Steer et al 1978).

Quantification in Montevideo units (MU) was done to permit comparison with results of Caldeyro-Barcia & Poseiro (1960) and to compare profiles of MU with those of kPas/15 min. The median activity level at 9 cm dilated was 217 MU/10 min similar to the level reported by Caldeyro-Barcia & Poseiro (1960); about 180 MU/10 min in late labour. However, they reported a steady rise of activity during the first stage of labour from 120 MU/10 min to 180 MU/10 min. This was confirmed.. Cowan et al (1982) only reported the mean overall level of 197 MU/10 min. The profiles with Mu and kPas units are similar with a correlation coefficient of 0.71($P < 0.001$) for relevant values.

The results may be compared most closely with those of Cowan et al (1982). The values are lower with an overall median value of 1440 kPas/15 min compared with 1842 kPas/15 min. There may be several reasons for the differences.

The populations differ; the patients were taller with a

mean height of 157 cm compared with 154 cm. Cowan et al (1982) reported a high incidence of forceps deliveries (38%). Short stature and the necessity for forceps delivery may be associated with increased uterine activity to effect delivery. Patients of short stature and those having forceps deliveries were excluded.

Cowan et al (1982) did not report a peak value with all second 15-min readings. Mitchell et al (1977) reported a rapid increase in peripheral plasma concentrations of 13,14-dihydro-15-keto prostaglandin F soon after vaginal examination with or without amniotomy. The results are consistent with the functional result of this in that a transient peak of uterine activity was noted soon after insertion of the intrauterine catheter irrespective of whether amniotomy was performed, the membranes possibly having ruptured spontaneously earlier. It may be related to the manipulation of the lower uterus due to the procedure and therefore excluded these values from profile construction. The fact that the peaks did not occur in MU profiles may be because changes occurred in the elements that kPas units measure which MU do not measure. Cowan et al (1982) allocated all work values to the previously observed cervical dilatation rather than assuming a constant progression of labour described by Friedman (1955). Both these elements associated with their method may result in artificially higher values at early

dilatation of the cervix.

Cowan et al (1982) found their results most at variance with Steer (1977). The observations are more similar to Cowan et al (1982) than to Steer (1977).

Comparison is difficult as Steer (1977) considered induced labour in an unspecified population, but he formulated a normal range of activity value of 700-1500 kPas/15 min. This is much lower than the values in normal spontaneous labour in this study and the Sonicaid FM3R monitor has only been calibrated to record values up to 2500 kPas/15 min. Maximal values of at least 2500 kPas/15 min on 35 occasions in 417 15-min intervals were recorded and the machine could not record the exact value. It is notable that Cowan et al (1982) recorded a maximal value of 3270 kPas/15 min.

Steer (1977) specified that fetal distress was likely to occur at levels above 1500 kPas/15 min but no evidence was found of this in the spontaneous labours and none were excluded for fetal distress. In induced labours there could be some degree of placental compromise which may have been the indication for induction. Uterine activity may unmask this, but it seems unlikely that activity in excess of 1500 kPas/15 min per se precipitates fetal distress.

Whilst specific observation can be made about the wide range of uterine activity seen in normal labour it is more difficult to quantify co-ordination. We have observed marked variation in amplitude , duration and frequency of contractions in individual patients with normal labour progress. This has been confirmed by Schulman & Romney (1970) and Effer et al (1969) and their findings of substantial degrees of inco-ordination associated with normal progress of labour are confirmed. This is not to deny that there is a significant relation between co-ordination and efficiency as originally proposed by Caldeyro-Barcia & Alvarez (1952). The recurrence of an incoordinate pattern throughout labour in an individual patient is striking. Although no anatomical pacemaker has ever been demonstrated, the pathway of uterine excitation appears constant. Just as a finger print of an individual is characteristic, so may be the uterine activity although this has never been studied in sequential pregnancies. However, it is important to distinguish inco-ordinate uterine action from inefficient uterine action either of which may occur without the other. The efficiency of contractions must be assessed by vaginal examination to determine the presence or absence of cervical dilatation. A uterine catheter does not provide useful additional information if partographic labour progress is normal. If an abnormal labour pattern develops this information

assumes greater importance.

The relative place of one or other method of quantification of uterine work may be assessed. An on-line system is preferable and that is why we opted for curve areas as measured by kPas/15 min. But similar pressure profiles are obtained with both methods and whilst MU do not allow for contraction duration, both methods depend on recognition of a baseline. This is not as straight forward as it seems as we have found the baseline to vary. The 'hammock' effect as well as prolonged descent of pressure during relaxation of a contraction will increase the area under the curve. Perhaps a system to quantify the area under the upswing and part of the downswing of the curve would be superior. Tromans et al (1982) have also considered this problem and have suggested that quantification should cease when a threshold value 5 mmHg above the baseline tone is regained. Caldeyro-Barcia & Alvarez (1952) found that pressures <25 mmHg did not lead to labour progress and this pressure was noted to persist after some contractions. This prolonged pressure will be registered as work done although whether it is useful work is unlikely. How the machine recognizes a new baseline is critical.

In Chinese nulliparae normal labour progress occurs when

uterine activity level is at least 650 kPas/15 min with an overall median level of 1440 kPas/15 min. There is a good correlation between MU/15 min and kPas/15 min.

The study of multiparous labour confirms two observations made in the parallel study of nulliparous labour. Firstly, the uterine activity values for the second 15-min period were consistently high; we have suggested that this is due to release of prostaglandins from the lower uterus during the insertion of the catheter. This also supports clinical observations that uterine contractions seem to increase although only temporarily after artificial rupture of the membranes or vaginal examination. Secondly we observed many high activity values as far as the upper limit of the scale on the machine even in early labour in the absence of hypertonus and maternal voluntary expulsive effort. Such values were not associated with fetal distress in these low-risk labours.

In a study of uterine contractions in normal and abnormal labours, Turnbull (1957) found that lower pressures were associated with faster progress in multiparae compared with nulliparae. At that time the concept of the cervimetric progress of labour had not been delineated

although work reported by Friedman (1954) was about to gain acceptance. Reliable methods of quantification of activity had not been developed and the catheter used was the fluid-filled type.

Caldeyro-Barcia & Poseiro (1960) referred only indirectly to the effect of parity on uterine activity. Huey et al (1976) found that multiparous patients expended 36% less uterine activity than the nulliparous group from 3 cm cervical dilatation until delivery. This study has shown that until 6 cm cervical dilatation uterine activity values in the normal multiparae are significantly lower than in the nulliparous counterpart. The uterine activity profile after 6 cm of cervical dilatation rises to peak values at 9 cm dilatation. These values do not rise as high as in the nulliparous patient and the difference between the two groups is no longer statistically significant. The difference seen between these uterine activity profiles and those obtained by Huey et al (1976) may be due to the strict criteria of selection based on height, rate of progress of labour, normal vaginal delivery and the use of the median rather than mean uterine activity value to construct the profile as there was a wide scatter of uterine activity values for each cm cervical dilatation.

Two features appear in the late first stage of labour.

Descent of the head is characteristic of this phase (Friedman 1955) and in the later stages the patient may commence expulsive efforts. It has become clear from the tocographic traces that maternal expulsive effort is a feature of the late first stage of normal multiparous labour. It is more likely to be secondary to the descent of the head than to the cervix being 10 cm dilated.

Examination of the tocographic recordings of patients who are 'pushing' shows that the area under the pressure curve contributed by episodes of 'pushing' is negligible. The previous study showed that even when uterine activity is quantified in Montevideo units, ignoring pressure due to 'pushing', a steep rise of activity occurs at 9 cm dilatation. Whilst pressure registered as a result of 'pushing' cannot strictly be described as uterine activity, it is inseparable from it. Uterine activity in early labour has the functional result of dilatation of the cervix whilst later in the first stage descent of the head must be effected as well as cervical dilatation. This may explain why activity rises to a peak at 9 cm dilatation.

The Ferguson reflex was observed many years ago and it was suggested that stretching and dilatation of the upper vagina caused an increase in uterine activity. Vasicka et al (1978) have shown that this is mediated by oxytocin

release more of which is detected in the late first stage of labour. These observations could be the functional result of such release.

In Singapore patients of Chinese origin less uterine activity is required to effect normal vaginal delivery in multiparous patients than in nulliparous patients. The lowest value likely to be associated with acceptable progress in labour is 430 kPas/15 min at 3 cm dilatation. The overall median level of activity in the active phase was 1130 kPas/15 min. Uterine activity profiles show a gradual rise in activity until 8 cm cervical dilatation with a steeper rise to peak values before the second stage is reached.

5. UTERINE ACTIVITY IN OXYTOCIN INDUCED LABOUR

Successful induction of labour with amniotomy and oxytocin titration has been well documented (Turnbull & Anderson, 1968b). Little is known about the uterine activity in such labours based on parity and cervical score.

The practice of oxytocin titration varies, but is based on achieving adequate uterine contractions. Traditionally the oxytocin dose was titrated in an arithmetic, semiarithmetic or geometric fashion until the uterine contractions were one in 2 to 2 1/2 mins lasting 40 to 50 seconds. (Turnbull & Anderson, 1968, Francis, et al, 1970) In this study the oxytocin dose was increased until the 75th centile of overall uterine activity from 3 to 9 cm observed in spontaneous normal labour was reached unless limited by too frequent contractions i.e. more than 6 in 15 min. Evidence of fetal compromise or of hyperstimulation was sought and the infusion regulated when such events occurred during or after achieving the optimal oxytocin dose.

The uterine activity of 25 nulliparae and 30 multiparae who delivered vaginally was studied to establish the range and pattern of uterine activity in oxytocin induced labour according to parity and cervical score.

Patients and Methods

Patients were selected from those admitted for induction of labour to the University Unit, Kandang Kerbau Hospital, Singapore. Only singleton pregnancies with cephalic presentation without previous uterine scar or operative delivery were included. The leading indications for induction of labour were hypertensive disease of pregnancy, static weight or weight loss at term, prolonged pregnancy and diabetes complicating pregnancy. The induction rate was 9.8%.

The study population was divided into nulliparae and multiparae and further sub-divided into two groups according to the Modified Bishop Score (Bishop 1964). This was performed at the time of induction by allocating scores of 0-2 for each of the following qualities of the cervix, dilatation, effacement, consistency, position and station of the presenting part. All the cases were induced by forewater amniotomy and oxytocin infusion after 30 minutes using an IVAC 503 peristaltic infusion pump which was operated manually to increase the dose from 2 milli units per minute in semi arithmetic fashion every 15 min (2, 4, 6, 7, 10; 12, 16, 20; 24, 32, 40, 48 mu per min) until the uterine activity values reached 1500 k Pascal seconds/15 mins (kPas/15 mins) in multiparae or 1750 kPas/15 min in nulliparae. The number of occasions this was not possible, limiting further increase of oxytocin due to

hyperstimulation (more than 7 contractions in 15 min), was noted. Once the optimal uterine activity was achieved the dosage of oxytocin was maintained until time of delivery. Uterine activity was measured using a Sonicaid FM3R fetal monitor with a uterine activity integrator module coupled to a transducer tipped intrauterine catheter (Gaeltec) which was inserted into the uterine cavity at the time of amniotomy. Any change in baseline was recognised within minutes. Towards the late first stage of labour a small proportion of patients had the sensation to bear down resulting in pushing efforts by the mother. This led to pushing spikes on the tocographic tracing but the contribution of this to the calculation of active contraction area was insignificant. Fetal heart rate was monitored continuously via a fetal scalp electrode. When fetal distress or hypertonic uterine activity was encountered, it was managed clinically by temporary reduction of the oxytocin infusion rate, fetal scalp blood sampling or delivery if necessary. Epidural anaesthesia was not used and Pethidine 50-75 mg intramuscularly was prescribed for pain relief.

A computer coding sheet was commenced in the labour ward recording information on patient's name, age, parity, height and period of gestation. The cervical score, colour of amniotic fluid, fetal heart rate pattern, length of first stage of labour, mode of delivery, umbilical cord

venous pH, Apgar score at 1 and 5 minutes and admission to special care baby unit were documented before the patient was discharged from hospital. Data analysis were carried out using the SPSS package on the IBM 3033N computer of the National University of Singapore. Paired Student t-test was used for statistical analysis.

Results

Fifty-seven patients were studied, of whom two nulliparae were delivered by caesarean section, 1 for cephalopelvic disproportion and the other for failed induction. The uterine activity of 25 nulliparae (13 with poor cervical score) and 30 multiparae (10 with poor cervical score) who delivered vaginally were studied.

Characteristics of the patients studied are shown in Table 12 a.

Parity and cervical score	Mean age in years $\pm 2SD$	Mean height in cms $\pm 2SD$	Mean cervical score $\pm 2SD$	Mean period of gestation in weeks $\pm 2SD$	Mean maximum dose of oxytocin mu/min $\pm 2SD$
Nulliparae, ≤ 5 $n=13$	25.5 \pm 5.26	154.2 \pm 8.81	4.5 \pm 10.3	40.0 \pm 2.68	14.3 \pm 12.46
Nulliparae, ≥ 6 $n=12$	26.1 \pm 8.50	153.7 \pm 7.74	7.6 \pm 1.80	40.1 \pm 2.44	9.0 \pm 7.90
Multiparae, ≤ 5 $n=10$	30.5 \pm 8.71	156.4 \pm 10.03	4.5 \pm 1.41	40.0 \pm 3.63	7.8 \pm 5.48
Multiparae, ≥ 6 $n=20$	29.7 \pm 8.93	157.1 \pm 11.80	7.30 \pm 1.96	40.0 \pm 3.55	8.1 \pm 7.50

Table 12a: Induced labour: patient characteristics

The study groups were similar except for multiparous patients being older. The mean maximum dose of oxytocin to effect successful induction was significantly higher in nulliparae with poor cervical scores than in nulliparae with good scores and in multiparae in whom the dose was not influenced by the cervical score. In cases where the targeted uterine activity level was not reached, further increase in oxytocin did not produce significant increase in uterine activity but led to hypertonic uterine contractions. In five nulliparae, the dose of oxytocin was limited prior to achieving the prescribed uterine activity level due to more than 7 contractions in 15 min and 4 reached the prescribed values with 7 to 8 contractions in 15 min. Two multiparae reached 1500 kPas/15 min with 7 to 8 contractions in 15 min and two had the escalation of oxytocin limited before achieving 1500 kPas/15 min because of more than seven contractions per 15 min. Two cases required temporary reduction of oxytocin because of fetal heart rate abnormalities which returned to normal subsequently. In multiparae with poor score, even though the oxytocin titration was limited to reach 1500 kPas/15 min, it reached its own stable phase of 1800 kPas/15 min.

The obstetric outcome in the four groups of patients is shown (Table 12b.)

Characteristics	Nulliparae		Multiparae	
	Poor cervical score (≤ 5)	Good cervical score (≥ 6)	Poor cervical score (≤ 5)	Good cervical score (≥ 6)
Number of patients	13	12	10	20
Length of first stage of labour (in hours) Mean \pm 2SD	8.4 \pm 7.21	4.6 \pm 2.70	4.9 \pm 4.0	3.4 \pm 3.62
No. of assisted vaginal deliveries	5	3	0	1
Mean Apgar score at 1 min	9.0	8.8	8.9	9
Mean Apgar score at 5 mins	9.8	10.0	9.9	10
Cord venous PH Mean \pm 2SD	7.34 \pm 0.09	7.33 \pm 0.09	7.35 \pm 0.08	7.39 \pm 0.12
Birth weight (in gms) Mean \pm 2SD	3320 \pm 801	2965 \pm 645	3116 \pm 1038	3297 \pm 933

Table 12b: Obstetric outcome, parity of cervical score

The length of first stage of labour was shortest in multiparae with good cervical scores and longest in nulliparae with poor cervical scores. Assisted delivery was more frequent in nulliparae with poor cervical scores. The neonatal condition assessed by mean Apgar score at 1 min, 5 min and umbilical cord venous pH were satisfactory and similar in all groups. The mean birth weights in the four groups were within the normal range for the population.

Since the length of labour varied a representation of the uterine activity in various phases of the first stage of labour was obtained by dividing the uterine activity into

five portions. The initial phase of induced labour when oxytocin infusion was titrated to achieve adequate uterine contractions beyond which the oxytocin dose was not increased was called the incremental phase. From the end of the incremental phase until the onset of the second stage of labour, the uterine activity values were divided into four equal portions. This enabled observation of sequential values of uterine activity with progress of labour. As the distribution of uterine activity levels in different groups was skewed, it was decided to use the median value in each of those five portions according to parity and cervical score is shown in Table 13 and is graphically represented in Fig 28.

Characteristics		Nulliparae		Multiparae	
		Poor cervical score (≤ 5)	Good cervical score (≥ 6)	Poor cervical score (≤ 5)	Good cervical score (≥ 6)
Number of patients		13	12	10	20
Uterine activity in	Median	1290	1364	1193.5	1012.5
Incremental phase	No. of observations	111	61	66	82
k Pas/15 min					
Uterine activity	Median	1745	1882.5	1800	1500
Stable phase (1st 25%)	No. of observations	82	42	39	36
k Pas/15 min					
Uterine activity	Median	1815	1950	1970	1625
Stable phase (2nd 25%)	No. of observations	76	39	36	36
k Pas/15 min					
Uterine activity	Median	1852	1990	1980	1750
Stable phase (3rd 25%)	No. of observations	74	36	31	33
k Pas/15 min					
Uterine activity	Median	1930	2468	2103	2333
Terminal phase (4th 25%)	No. of observations	71	33	26	31
k Pas/15 min					

Table 13: Uterine activity by parity and cervical score

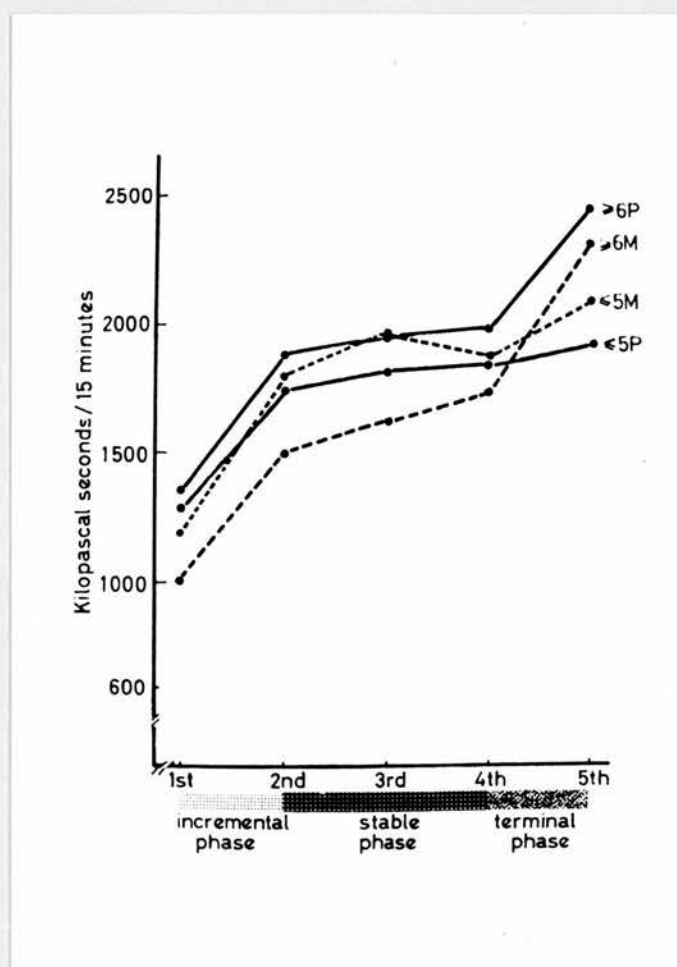


Figure 28: Active contraction are profile according to parity and cervical score. P-nulliparae, M-multiparae. < 5 poor score, > 6 good score.

The uterine activity showed a significant steep rise (incremental phase, $p < 0.001$) with increments of oxytocin infusion and reached a plateau when the uterine activity levels reached around 1750 kPas/15 min in nulliparae and multiparae with poor score and 1500 kPas/15 min in multiparae with good score. Oxytocin dosage was maintained once this stable phase was achieved. Towards

the late first stage of labour, there was a significant increase in uterine activity (terminal phase) despite no further increase in oxytocin in patients with a cervical score of 6 or more (nulliparae $p < .002$, multiparae $p < .006$). This rise was not significant in those patients who had a poor cervical score at induction.

Discussion

Steer et al (1975) and Woolfson et al (1976) studied uterine activity in induced labour but the results were not reported in the SI units of the Uterine Activity Integral (UAI). The subsequent studies by Steer et al (1979) did not analyse data according to parity or cervical score in calculating the uterine activity values. The final outcome anticipated in induced labour is progressive effacement and dilatation of the cervix and descent of the head resulting in unassisted vaginal delivery of a neonate in good condition. On this basis the partographic progress remains the final arbiter, though the assessment of uterine function which is reflected by rate of cervical dilatation is based on clinical palpation or external tocography both of which are unreliable. (La Croix, 1968) The active contraction area has been shown to be a more reliable indicator of the rate of cervical dilatation than the frequency of amplitude of uterine contractions in spontaneous and induced labour. (Steer, 1977, Steer et al, 1984) With

modern electronic techniques it is easy to measure the active contraction area on line as a guide to control oxytocin infusion. In order to rationally use this information, uterine activity values in successfully induced labours with good outcome has to be defined. Uterine activity in oxytocin induced labours has been shown to increase until a stable phase is achieved, (Steer et al, 1975, Caldeyro & Heller, 1959) following which there is little alteration until the late first stage of labour. However, in the same patient uterine sensitivity to oxytocin may increase as labour advances (Beazley et al, 1975) and a reduction of the dose may be necessary. Since uterine sensitivity to oxytocin is influenced by cervical score, and uterine activity in spontaneous labour is influenced by parity, uterine activity in induced labour was studied according to parity and cervical score. In contrast to spontaneous labour where there was a small increase in uterine activity with progressive cervical dilatation, the progressive cervical effacement and dilatation in induced labour occurred with a stable phase of uterine activity. This stable phase of uterine activity was achieved with 6 to 7 contractions every 15 min and eventually resulted in good labour outcome in terms of fetal condition and duration of labour. It is difficult to relate uterine activity levels to progressive cervical dilatation in induced labour or to compare them with dilatation specific uterine activity values of

spontaneous labour. But the overall median uterine activity levels could be compared.

The lowest median uterine activity in the stable phase for nulliparae with good cervical score was 1882 kPas/15 min and was 1745 kPas/15 min in nulliparae with poor cervical score compared to an overall median activity of 1440 kPas/15 min in spontaneous nulliparous labour. The lowest median stable phase uterine activity in multiparae with good cervical score was 1500 kPas/15 mins and was 1880 kPas/15 mins in multiparae with a poor cervical score compared to the overall median activity of 1130 kPas/15 min in spontaneous multiparous labour. These values show that higher levels of uterine activity are reached in induced labour and are maintained for longer periods than spontaneous labour. These findings are at variance with those of Steer (1979) who reported similar uterine activity profiles in spontaneous and induced labour in nulliparae and multiparae and did not differentiate the activity profiles according to cervical score. The only difference in uterine activity in induced labour was in multiparae with good cervical score whose first 50% of the stable phase activity was significantly less than multiparae with good cervical score. Similarly multiparae with good score had less uterine activity in incremental and stable phase compared to nulliparae with poor or good score. The idea of selecting the lowest dose of oxytocin

to produce optimal uterine activity was suggested by Woolfson in 1976. The stable phase uterine activity patterns according to parity and cervical score have been established in SI units as a more reliable guide for oxytocin administration for induction of labour.

The terminal rise of uterine activity in the late first stage of induced labour in patients with good cervical score was similar to that observed in spontaneous labour. (Cowan et al 1982) This rise is compatible with the Ferguson reflex (Ferguson, 1941) seen in the late first stage of labour which is a functional effect of the release of oxytocin due to stretching of the cervix and upper vagina. (Vasicka et al, 1978) The terminal spurt of activity was not significantly higher than the stable phase in those with poor cervical scores, probably because the cervix and uterus were not ready to labour in the absence of the Ferguson reflex. This may be one of the factors for the 38.5% forceps rate in nulliparae with poor cervical scores in contrast to 25% in nulliparae with good cervical scores. The terminal increase of uterine activity may be due to release of endogenous oxytocin by Ferguson reflex or due to increased sensitivity of the uterus with progress of labour (Sica Blanco & Sala, 1961, Krapohl et al, 1965) since the increase was observed despite no increase of oxytocin infusion.

The fetal outcome in induced labour assessed by Apgar scores at one and 5 mins and umbilical cord venous pH compared favourably to that observed in spontaneous labour except in nulliparae with good cervical score who had significantly lower but normal umbilical venous pH values. (Table 14)

Labour characteristics	Nulliparae		Multiparae	
	No.	Mean umbilical venous pH \pm 2SD	No	Mean umbilical venous pH \pm 2SD
Spontaneous labour	40	7.37 \pm 0.10	40	7.37 \pm 0.09
Induced labour \leq 5	12	7.34 \pm 0.08	9	7.35 \pm 0.07
Induced labour \geq 6	12	7.32 \pm 0.08**	18	7.39 \pm 0.12

** Only statistical significance was in nulliparae with good cervical score who had a lower pH to that of spontaneous labour

Table 14: Umbilical cord venous pH in spontaneous and induced labour

Titration of the oxytocin to reach the stable phase uterine activity and maintaining that level may obviate the errors made by clinical palpation or external tocography. If labour does not progress satisfactorily even with optimal uterine activity levels according to parity and cervical

score, a mechanical problem of disproportion of malposition has to be considered.

Uterine activity in induced labour was higher than spontaneous normal labour but was not significantly different according to parity and cervical score except multiparae with good cervical score. Oxytocin titrated manually or automatically to maintain 75th centile of overall uterine activity from 3 to 9 cm observed in spontaneous labour (in a multiparae - 1500 kPas/15 min and in nulliparae - 1750 kPas/15 min) unless limited by hyperstimulation should result in successful induced labour with good neonatal outcome.

6. UTERINE ACTIVITY IN INDUCED LABOUR: COMPARATIVE METHODS OF OXYTOCIN ADMINISTRATION

Subsequent to the acceptance of induction of labour by artificial rupture of the membranes and oxytocin titration more automated methods of undertaking this procedure have been suggested. A semi-automatic open loop infusion system (Cardiff pump) was devised increasing the dosage automatically until acceptable contractions were observed with subsequent conversion to manual mode to maintain this dosage (Francis et al 1970). A closed loop automatic infusion system for titrating the dosage of oxytocin according to a present programme using data derived from an intrauterine catheter has been developed recently (Carter & Steer 1980) Figures 29 and 30 shows this machine with its disposable driven cassette system. Figure 31 illustrates the closed loop. The afferent side of the loop carries information concerning uterine pressure and activity to the machine. It compares the recognised pressure with expected pressure then linking to the driving system which ensures delivery of a dose of oxytocin considered necessary.

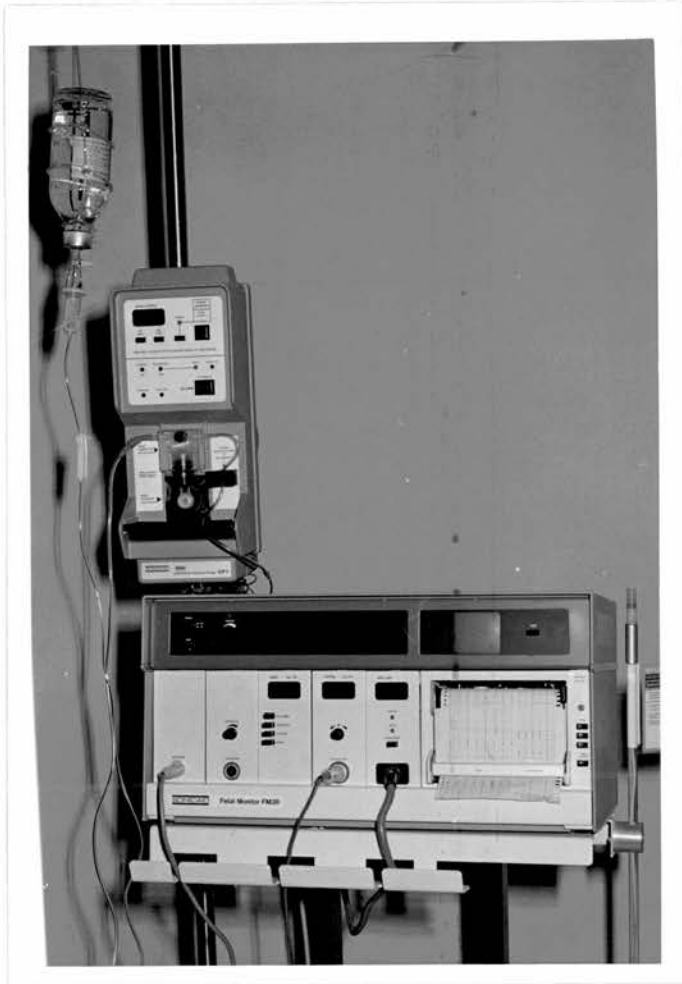


Figure 29: AIS attached to monitor



Figure 30: AIS cassette system

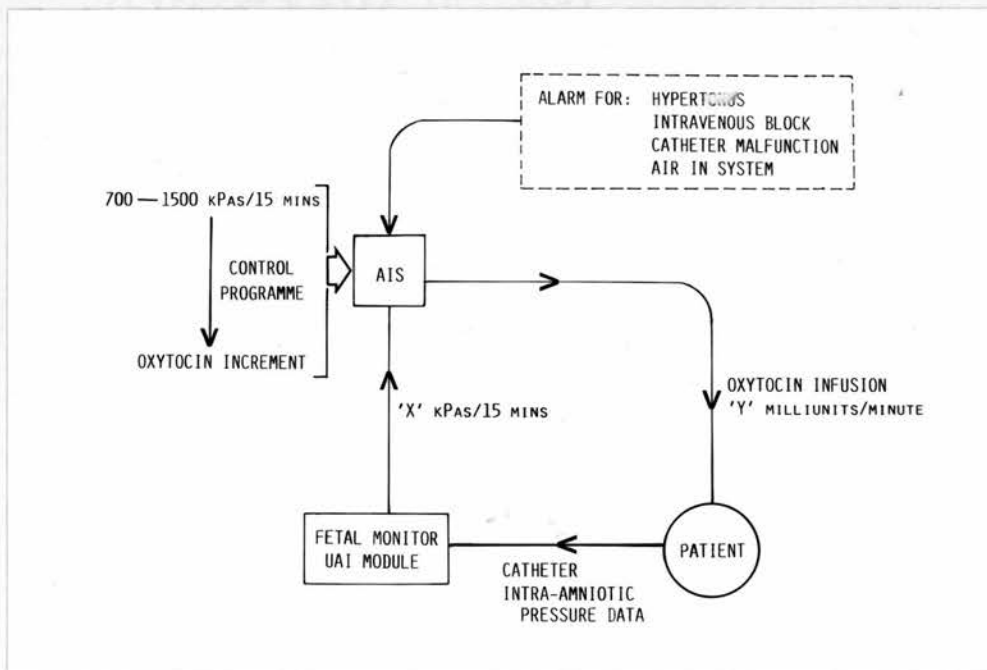


Figure 31: Closed loop feedback

It is important to assess fully new equipment and methods before their introduction into routine clinical practice. A study was designed to assess the automatic infusion system (AIS) compared with the more traditional method.

Patients and methods

Patients were selected from those having labour induced in the University Unit, Kangas Kerbau Hospital, Singapore. The induction rate was 9.8% and the leading indications were hypertensive disease of pregnancy, prolonged pregnancy and abnormal weight gain at term. The study was restricted to singleton pregnancies presenting by the vertex with no history of previous operative delivery and having a good prospect of vaginal delivery.

All patients were examined before induction and the cervical condition was assessed by a modified Bishop score. A score of 0-2 was allocated for each of the following five characteristics: dilatation, effacement, consistency, position and station. Induction was by artificial rupture of the membranes and oxytocin infusion. A transducer-tipped intrauterine catheter (Gaeltec Sonicaid) was inserted and a fetal scalp electrode applied. A Sonicaid FM3R fetal monitor was used for continuous monitoring of uterine activity and fetal heart rate. Patients were allocated to the automatic infusion system (AIS, Sonicaid) or peristaltic infusion pump

depending on availability of the equipment. The AIS was used as recommended by the manufacturer (Sonicaid Ltd. Chichester) with the pump infusing oxytocin to achieve uterine activity levels of 700-1500 kPas/15 min with the dose being escalated arithmetically in increments of 2 m-units/min every 15 min from a starting dose of 2 m-units/min. Whenever a 'stable phase' of activity (700-1500 kPas/15 mins) was achieved the dose rate was maintained and if a level above 1500 kPas/15 min occurred the dosage was reduced. If labour progress was unsatisfactory after 9h the facility for manual override was used to achieve higher activity levels or satisfactory contractions as determined by clinical assessment with contractions occurring every 2-2.5 min lasting 40-50 secs. The peristaltic infusion pump (IVAC 503 California) was operated manually to increase the dosage of oxytocin from 2 m-units/min in a semi-arithmetic fashion until uterine activity was clinically satisfactory or attained 2000 kPas/15 min in a nullipara or 1500 kPas/15 min in a multipara. If fetal distress was encountered it was managed clinically including temporary reduction of the oxytocin infusion rate, fetal scalp blood sampling or delivery, if necessary. Epidural analgesia was not used; pethidine in a dosage 50-75 mg was prescribed for pain relief. Maternal age, height, gestation, cervical score, length of first stage of labour, dose of oxytocin, mode of delivery, birthweight. Apgar score at 1 and 5 min and

umbilical cord vein blood pH were recorded and analysed. Student's t-test was used for statistical analysis.

Results

The 121 patients in the study comprised 63 nulliparae and 58 multiparae; 30 of the nulliparae and 36 of the multiparae had a good cervical score (6-10), the others (33 nulliparae and 22 multiparae) had a poor cervical score (<5).

Eleven patients were delivered by caesarean section, all but two were nulliparae. Nine of these patients had been managed by automatic infusion and subsequent manual override. The indications for caesarean section were cephalopelvic disproportion in eight patients, failed labour in two and fetal distress in one. There was no statistically significant difference in the caesarean section rate between the two modes of management, probably due to the small numbers.

Table 15 shows the distribution of the 110 patients who were delivered vaginally by parity, cervical score and mode of oxytocin infusion.

Mode of infusion	Cervical score ≤ 5		Cervical score ≥ 6	
	Nulliparae	Multiparae	Nulliparae	Multiparae
Automatic infusion (AIS)	15	11	14	15
Peristaltic infusion pump (IVAC)	13	10	12	20

Table 15: Distribution by mode of infusion, parity and cervical score

Of the 28 nulliparae with poor cervical scores, 15 were allocated to the AIS group and 13 to the IVAC group. Table 16 shows the patient characteristics and outcome in these two groups. There were no significant differences between the two groups in maternal age, height, gestational age, cervical score, mode of delivery, birthweight. Apgar scores and umbilical cord vein blood pH. The length of the first stage of labour was longer in the AIS group although the difference was not significant. Manual override had been necessary in 53.3% of the patients because the system proved inadequate.

	Cervical score \leq 5				Cervical score \geq 6			
	Nulliparae		Multiparae		Nulliparae		Multiparae	
	AIS (n = 15)	IVAC (n = 13)	AIS (n = 14)	IVAC (n = 10)	AIS (n = 14)	IVAC (n = 12)	AIS (n = 15)	IVAC (n = 20)
Age (years)	26.1 (5.8)	25.5 (5.3)	28.5 (8.9)	30.5 (8.7)	26.3 (7.5)	26.1 (8.5)	27.9 (7.9)	28.8 (8.9)
Maternal height (cm)	156.9 (11.0)	154.2 (8.8)	154.5 (11.1)	156.4 (10.0)	156.7 (13.2)	153.7 (7.7)	159.0 (7.0)	157.0 (11.8)
Gestation (weeks)	40.0 (2.8)	40.0 (2.7)	40.3 (3.2)	40.0 (3.6)	40.2 (2.6)	40.1 (2.4)	39.8 (2.7)	40.1 (3.6)
Cervical score	4.3 (1.4)	4.5 (1.0)	4.5 (1.6)	4.5 (1.4)	7.5 (2.5)	7.6 (1.8)	7.3 (1.9)	7.3 (2.0)
Length of first stage of labour (h)	11.2 (7.5)	8.4 (7.2)	10.2 (4.6)*	4.9 (4.0)*	9.1 (3.3)**	4.6 (2.7)**	5.0 (7.0)	3.4 (3.6)
Manual override (n)	8	—	3	—	3	—	2	—
Assisted delivery (n)	7	5	1	0	5	3	1	1
Mean Apgar score								
At 1 min	8.6	9.0	8.9	8.9	8.9	8.8	9.0	9.0
At 5 min	9.9	9.8	10.0	9.9	10.0	10.0	10.0	10.0
Umbilical vein blood pH	7.35 (0.06)	7.34 (0.09)	7.36 (0.07)	7.35 (0.08)	7.32 (0.07)	7.33 (0.09)	7.36 (0.1)	7.39 (0.12)
Birthweight (g)	3392 (891)	3320 (801)	3072 (1198)	3116 (1038)	3130 (747)	2965 (645)	3395 (975)	3297 (933)

Results are mean (SD) where appropriate.

Significance of difference between the two modes of infusion: *P<0.01; **P<0.001.

Table 16: Patient characteristics and outcome

Maternal characteristics and fetal outcome in the 26 nulliparae with good cervical scores were not significantly different between the two management groups except for the first stage of labour which was significantly longer ($P<0.001$) in the AIS group, manual override was necessary in three patients.

In the 21 multiparae with poor cervical scores the maternal characteristics and fetal outcome were not significantly different between the two management groups except for the first stage of labour which was

significantly longer ($P < 0.01$) in the AIS group, manual override was necessary in three patients.

Maternal characteristics and fetal outcome in the 35 multiparae with good cervical scores were not significantly different between the two management groups and although manual override had been necessary in two patients in the AIS group the length of the first stage was similar in both groups.

Fetal distress necessitated alteration in the rate of oxytocin infusion in two patients in the peristaltic infusion group. Subsequently increments of oxytocin were reinstated when the fetal heart rate became normal. In one patient in the AIS group fetal distress occurred within 45 min of induction when uterine activity levels were < 1000 kPas/15 min and the patient had received no oxytocin. She was delivered by caesarean section.

Discussion

Placental blood flow is temporarily restricted during uterine contractions (Borell et al 1965) although the placental pool of maternal blood increases in volume (Bleker et al 1975). Kubli & Ruttgers (1961) demonstrated the adverse effect of a poorly controlled oxytocin infusion on the fetus. A balance has to be achieved between protection of the fetus and maintaining adequate

progress in labour during oxytocin infusion.

An early study of induction of labour proposed a regimen of artificial rupture of the membranes followed immediately by escalation of oxytocin in a geometric fashion doubling the dose every 10 min until satisfactory uterine contractions were observed clinically (Turnbull & Anderson 1968a) (lasting 45-50 secs at 2-3 min intervals). This geometric escalation was justified on the grounds that uterine contractility and oxytocin sensitivity are very variable before the onset of labour (Turnbull & Anderson 1968b). The open loop automatic infusion system (Cardiff pump) doubled the dose rate every 12.5 min until acceptable contractions were attained. Maintenance dosage was controlled manually. A low incidence of fetal distress, babies with good Apgar scores and a shortened induction-delivery interval were reported.

Labour should be induced so as to mimic the physiological process of spontaneous labour as far as possible and protect the fetus from hypoxia. The danger of hypoxia is greater when there is diminished fetoplacental reserve and this varies between patients. The occurrence of fetal distress does not depend on the stress of uterine contraction per se but on the underlying fetoplacental function. No fetal distress was encountered in low-risk spontaneous labours with uterine activity

levels >2500 kPas/15 min.

A programme in an automatic infusion system should be based on activity levels observed in spontaneous labour. Considerably higher activity levels have been observed in spontaneous labour by us and by Cowan et al, 1982, than those incorporated in the AIS system. Uterine activity levels in multiparae have been shown to be considerably lower than in nulliparae, Turnbull et al. (1968a) found labour more difficult to induce in patients with poor cervical scores and more uterine activity may be necessary in such patients. An AIS with a single programme does not allow for the extensive individual variability of induced labour. The outcome of labours induced with AIS was compared with those induced with a more conventional peristaltic infusion pump regulating the dosage based on the data derived from spontaneous normal labour.

The patients delivered by caesarean section were excluded from the analysis because of the confounding effect of this procedure on the length of the first stage, apgar scores and umbilical vein blood pH. Although numbers were small there were more caesarean sections in the AIS group which cannot solely be accounted for by fetopelvic relations as the patient characteristics were very similar. A diagnosis of cephalopelvic disproportion also depends on a well-conducted trial of labour which may not

have been achieved in spite of manual override of the AIS.

Significantly longer labours occurred in the patients induced by AIS which is not surprising on account of the low levels of uterine activity in the programme compared with levels in normal spontaneous labour. The neonatal outcome was very similar in both groups no added protection being provided by the AIS. If manual override had not been used more patients might have been delivered by caesarean section. The use of an AIS involves the additional cost of the machine and disposable cassettes for administration of the infusion.

On account of the wide range of expected uterine activity values, it is difficult to set the programme of a closed loop system. Even if the values recognised by the machine had been set higher it is doubtful if it would have functioned efficiently. Another problem was the sensitivity of the alarm system for air in the system, infusion block and hypertonus. They appeared to be oversensitive cutting the dose rate of the infusion and prolonging the labour when this was not necessary. Alarm systems are very important. However, their presence is dictated by the automatic nature of the system. The current climate of opinion in childbirth is suspicious of technology. Although dose rates of oxytocin are lower with such systems this could also be achieved by an

experienced midwife. This machine appears to be of little value.

Although this conclusion was reached by the study, the results stimulated thoughts about the uterine activity required to deliver vaginally and to what factors this might be related. This was studied further.

7. TOTAL UTERINE ACTIVITY

Turnbull (1957) suggested that the resistance of the cervix and pelvic floor is much less in multiparae because these structures have been stretched in the previous labour. Crawford (1975) and Rossavik (1978) studied the cervical and pelvic tissue resistance indirectly by studying the work done by the uterus to overcome this resistance. Rossavik (1978) calculated the uterine work as the product of active pressure (in kilo Pascals) and the duration of contractions (in seconds) and termed it the uterine impulse based on $\text{force} \times \text{time} = \text{impulse}$ (Alfonso & Finn 1967). He confirmed the suggestion by Turnbull (1957) that the total uterine work needed to effect vaginal delivery was less in multiparae. Clinical experience and scientific evidence suggests that labour is more difficult when induced with a poor cervical score (Turnbull & Anderson, 1967, 1968). In these circumstances the total uterine work needed may be greater in patients with low parity. Caldeyro-Barcia & Poseiro (1960) recognised that if the intensity of contractions was low, more contractions were needed to effect vaginal delivery.

Total uterine activity needed to effect vaginal delivery according to parity, cervical score, and mode of oxytocin infusion was studied.

Patients and methods

Data derived from the preceding study of comparative methods of induction of labour were used.

The total uterine activity (TUA) was calculated by cumulating all sequential 15-min uterine activity values for each individual labour until the catheter was removed at full dilatation of the cervix. These TUA values were grouped according to parity, cervical score and mode of oxytocin infusion for analysis.

Non-parametric statistical methods were used for the data analysis as the distribution of oxytocin readings as well as the uterine activity levels by parity and cervical score displayed large heterogeneity of variance and were shown to be skewed. Hence, median values are presented for these variables and the Mann-Whitney U test was used for the comparison of maximum dose of oxytocin and of uterine activity levels by the different methods. The median test was applied to TUA values.

Results

Of the 121 patients 63 were nulliparae and 58 multiparae; 30 of the nulliparae and 36 of the multiparae had a good cervical score (6-10), whilst 33 of the nulliparae and 22 of the multiparae had a poor cervical score (<5).

Eleven patients (9%) were delivered by caesarean section; all but two were nulliparae. Nine of these patients had been managed by automatic infusion and subsequent manual override. The indications for caesarean section were cephalopelvic disproportion in eight, failed labour in two and fetal distress in one patient. These patients were excluded from the analysis.

The obstetric characteristics and the labour outcome in the 110 patients who were delivered vaginally have been detailed in the previous section. The maternal age, height, gestational age, cervical score, mode of delivery, birthweight, Apgar scores and umbilical vein blood pH were not significantly different between the two infusion groups, when controlled for parity and cervical score. The duration of labour was significantly shorter in the peristaltic infusion group except in the nulliparae with a poor cervical score, due to frequent manual override in (53.3%) in the AIS group, and in the multiparae with a good cervical score because labour was short in both infusion groups. Table 17 shows the median maximum dose of oxytocin according to parity and cervical score with different modes of infusion. The only significant difference was in nulliparae with a poor cervical score where the dose was significantly higher in the peristaltic infusion group.

Parity	Cervical score	Infusion system	No. of patients	Median maximum dose of oxytocin	Mann-Whitney <i>U</i> test
Nulliparae	≤5	AIS	15	4.9	<i>U</i> = 21.5
		IVAC	13	10.8	<i>P</i> < 0.001
	≥6	AIS	14	6.2	<i>U</i> = 59.5
		IVAC	12	8.5	NS
Multiparae	≤5	AIS	11	4.0	<i>U</i> = 39.5
		IVAC	10	8.0	NS
	≥6	AIS	15	4.3	<i>U</i> = 111.0
		IVAC	20	7.8	NS

Table 17: Median maximum doses of oxytocin delivered by AIS and peristaltic infusion systems

The uterine activity showed an initial significant steep increase (incremental phase) followed by a long period of little increase (stable phase) terminating in a steep rise (terminal phase). The incremental phase corresponded to the increase of oxytocin until the maximum dose was achieved. Most of the cervical dilatation occurred in the stable and terminal phases, the latter phase corresponding to the late first stage of labour. The uterine activity throughout labour was divided into five portions, the first representing the incremental phase and the rest divided into four equal portions. Table 18 compares the uterine activity in these different phases in patients grouped according to parity, cervical score and infusion system.

Parity	Cervical score	Infusion system	No. of patients	Median uterine activity (kPas)				
				Incremental phase	Stable phase 1st 25%	Stable phase 2nd 25%	Stable phase 3rd 25%	Terminal phase 4th 25%
Nulliparae	≤5	AIS	15	886.5	1170.5	1225	1500	1810
		IVAC	13	1290	1745	1815	1825	1930
	≥6	AIS	14	730	1062.5	1100	1136	1769
		IVAC	12	1364	1882.5	1950	1990	2468
Multiparae	≤5	AIS	11	719	1078	1140	1350	1653
		IVAC	10	1193.5	1800	1970	1890	2103
	≥6	AIS	15	679	1077.5	1060	1165	1515
		IVAC	20	1012.6	1500	1625	1750	2333
				<i>P</i> <0.001	<i>P</i> <0.001	<i>P</i> <0.001	<i>P</i> <0.001	<i>P</i> <0.001
				<i>P</i> <0.001	<i>P</i> <0.001	<i>P</i> <0.001	<i>P</i> <0.001	<i>P</i> <0.001

Table 18: Comparison of median uterine activity values in different phases of labour unmatched for parity and cervical score by AIS and peristaltic system.

The uterine activity was significantly higher in the incremental, stable and terminal phases of labour in the peristaltic infusion group than in the AIS group. These differences in uterine activity according to parity and cervical score are illustrated in Figs 32 and 33.

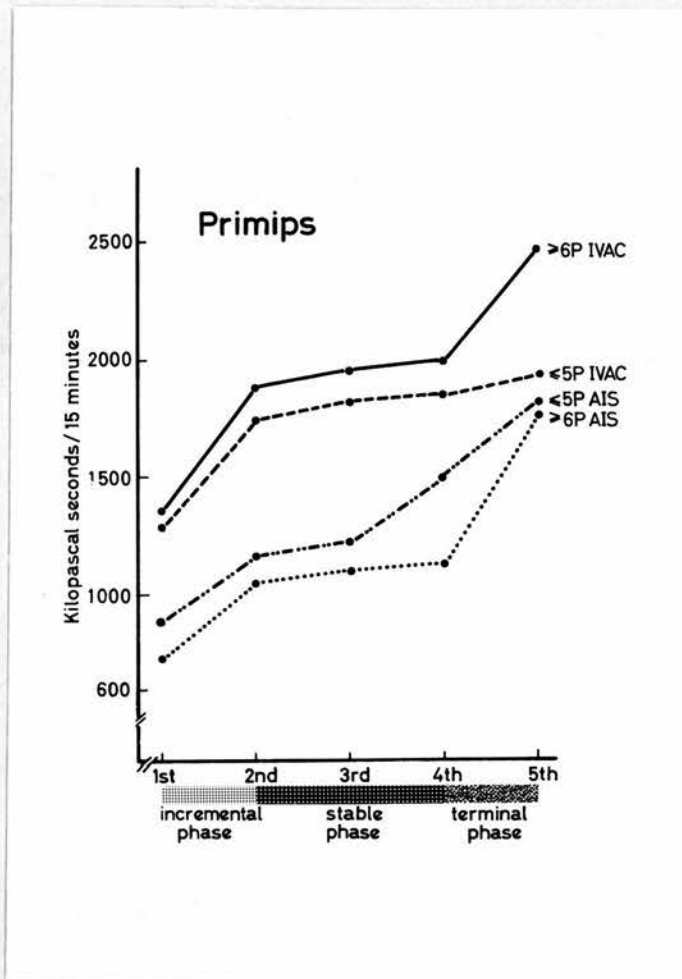


Figure 32: Uterine activity in different phases of nulliparous induced labour according to cervical score and infusion system

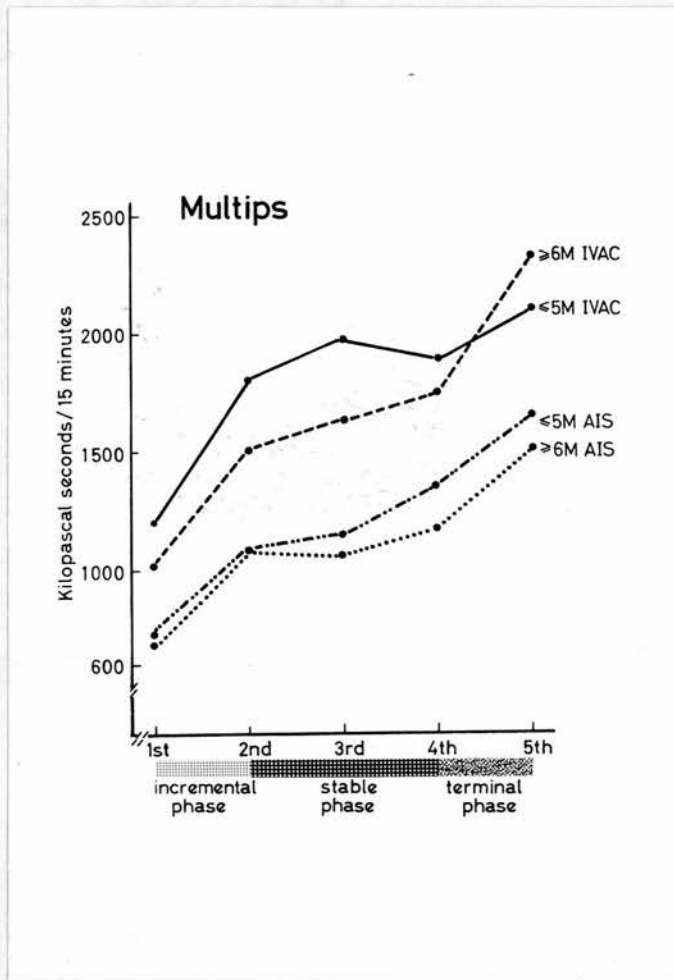


Figure 33: Uterine activity in different phases of multiparous induced labour according to cervical score and infusion system

The total uterine activity performed by each individual patient according to parity, cervical score and modes of oxytocin infusion is given in Figure 34.

The median total activity values in each of these groups is given in Table 19

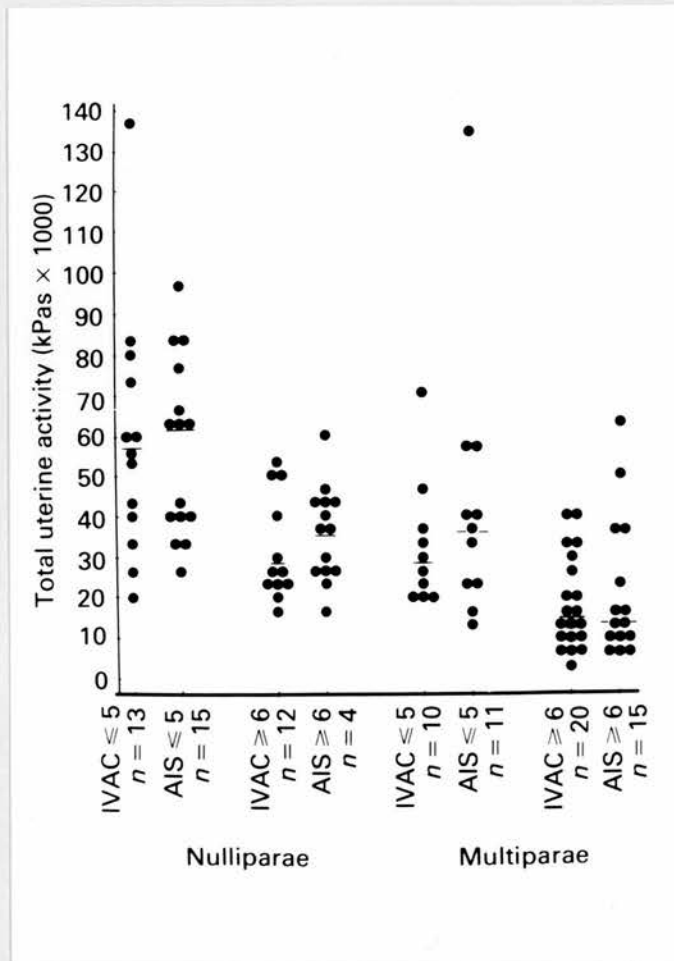


Figure 34: Total uterine activity according to parity cervical score and mode of infusion: individual values

PARITY	CERVICAL SCORE	TOTAL UTERINE ACTIVITY (k Pas)	
		IVAC	AIS
NULLIPARAE	≤ 5	56.878	61.685
	≥ 6	27.065	35.619
MULTIPARAE	≤ 5	27.633	35.155
	≥ 6	15.632	14.488

Table 19: Median total uterine activity by parity and cervical score according to different system

There was no significant difference in the total uterine activity between the AIS and IVAC groups of comparable parity and cervical score. There were significant differences in TUA independent of mode of infusion but dependent on cervical score and parity except between that in nulliparae with a good score and multiparae with a poor score. TUA progressively declined from the highest level required in nulliparae with a poor cervical score to the lowest level in multiparae with a good score.

Discussion

The pregnant uterus adapts its role from that of a receptacle of the fertilized ovum to a powerful muscular organ capable of expelling the fetus. It performs work in the form of uterine contractions to bring about cervical effacement and dilatation along with descent of the head through the maternal pelvis overcoming the pelvic tissue resistance. Cervical and pelvic tissue resistance may differ in induced and spontaneous labour and according to parity, cervical score, presentation, position, maternal height and birthweight of the baby. The total uterine activity required in each case may be considered to be proportional to the cervical and pelvic tissue resistance in the absence of unfavourable fetopelvic relations.

The total uterine activity required to achieve vaginal delivery was similar in nulliparae with a good score and

multiparae with a poor score. The multiparae with a good score had to perform significantly less and nulliparae with poor score significantly more work compared to the other two groups. This supports the clinical observation that a multipara with a good score when induced has a shorter and easier labour compared to a nullipara with a poor score who has a longer and more difficult labour.

It appears that the cervical and pelvic tissue resistance as measured by total uterine activity differs according to the cervical score and parity. This supports the suggestion that parity influences the cervical and pelvic tissue resistance (Turnbull 1957). Cervical and pelvic tissue resistance is not significantly different in a given parity and cervical score even when two ranges of 15-min uterine activity levels were maintained by different modes of infusion. The lower level was compensated for by the longer duration of labour consistent with the observations made by Caldeyro Barcia (1960) in spontaneous labour. Neonatal condition was not significantly different irrespective of different uterine activity levels in both groups. It appears that if fetal compromise is encountered in induced labour, vaginal delivery may still be possible by maintaining a significantly lower level of uterine activity in the stable phase (700-1500 kPas/15 min). In such situations

an intrauterine catheter and maintenance of satisfactory uterine activity levels should be useful. From studies of spontaneous labour both in nulliparae and multiparae it appears that labour progress may be satisfactory if the uterine activity levels are maintained above 700 kPas/15 min.

In induced labour if the progress is not satisfactory even after the uterus has performed more than the 90th centile of the total uterine work according to parity and cervical score, it may indicate cephalopelvic disproportion or malposition and in the absence of these factors failed induction of labour. The median total uterine work of these groups indicates that a nullipara with a poor cervical score has to do nearly four times, and nullipara with good score and multipara with poor score nearly twice the total uterine work of a multipara with good score. It is concluded that measurement of total uterine activity in induced labour may prove useful in conditions of fetal compromise to decide whether to continue labour at lower but acceptable activity levels or to deliver abdominally if the compromise is evident at lower activity levels. Furthermore if the total uterine work already performed is high in a labour with abnormal progress it will alert the obstetrician to the possibility of cephalopelvic disproportion, malposition or failed induction of labour. Fetal monitor manufacturers might consider including a

piece of software in new machines that would compute and display progressive total uterine activity.

8. CLINICAL IMPLICATION AND CURRENT STATUS

An understanding of the physiology and pathophysiology of uterine contractility should lead to improved clinical management. Associated events must be recognised; the transient rise in activity following vaginal examination and artificial rupture of the membranes, the reactively irritable uterus associated with bleeding from the placental site, the tense, poorly contracting uterus associated with polyhydramnios (Caldeyro-Barcia et al, 1957).

Topozada et al (1967) studied the effects of the full urinary bladder and of the distended rectum on uterine activity. They demonstrated that whilst the distended rectum had no effect on uterine activity the long held belief of the inhibitory effect of the full bladder was confirmed. This could well be due to failure of the presenting part to impinge on the cervix thereby stimulating the release of oxytocic agents.

Gaafar et al (1967) showed the effect of amniotomy on uterine activity with a significant increase. Posture also has some effect on uterine contractility. Caldeyro-Barcia et al (1960) found that when the patient lies on her left or right side, uterine contractions have a stronger intensity and a lower frequency than when the patient lies on her back. The effects of the change of

position on uterine contractility appears immediately and last for as long as the new position is maintained. Roberts et al (1984) showed that lateral recumbency was accompanied by more intense, less frequent and more efficient contractions than sitting. Studies not using uterine pressure measurement have produced conflicting results concerning the effect of the upright posture and ambulation on labour performance (McManus & Calder 1978, Flynn et al, 1978).

Unresolved problems in implementing uterine pressure measurement in a busy labour ward include the fragility of the catheter, lack of care and expertise on the part of the user and expense of replacement equipment.

The complexity of the measurement system is an obstacle to understanding. This might be resolved by the new system suggested by Phillips & Calder (1987). Introduction of a new system is likely to take time and involve a long educational process. There are implications in the design of the equipment. However, these are not insurmountable obstacles if clinicians feel motivated by a need.

The need is apparent in the rising Caesarean section rates due to dystocia and repeat Caesarean section (NIH Consensus Report 1981). When induction or augmentation

becomes difficult requiring high doses of oxytocin above 12 milliunits per minute pressure measurement has a role to play. Arulkumaran et al (1987) have shown that oxytocin titration to achieve preset active concentration ^{contraction} area values does not improve the outcome of induced labour compared with the traditional practice of titrating the oxytocin infusion to achieve a preset frequency of uterine contractions. No randomized prospective controlled study has yet shown the advantages of such a technique.

Randomized controlled trials are not necessary to appreciate the benefit gained if these devices are used when oxytocin is administered to women with a previous Caesarean section scar or breech presentation.

9. CONCLUSION

Valuable information and insight into the mechanism of labour has been gained from these studies. The documentation of detailed normal values is often overlooked by investigators anxious to study the abnormal. Much remains to be done in elucidating the uterine response during oxytocic treatment and therefore determining the dose and the length of time treatment should continue. Randomized controlled trials would be complex and logistically difficult. Nonetheless they would be of great value.

Detailed studies of the physiological, endocrinological and anatomical correlates of the labour progress would be fascinating. Much remains to be done.

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A comparative study of methods of oxytocin administration for induction of labour

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Summary. Equipment has become available for the automatic infusion of oxytocin in a closed loop system for the induction of labour. This system was compared with manual administration of oxytocin by peristaltic infusion pump, the dosage being based on data derived from an intrauterine catheter or by clinical assessment of uterine activity. A total of 121 patients classified according to parity and cervical score were allocated to an automatic infusion system (AIS) or a peristaltic infusion pump system. Patient characteristics were similar in both groups. Labour was significantly longer in those induced by automatic infusion system particularly in nulliparae and patients with poor cervical scores. In 53.3% of the nulliparae with poor cervical scores the automatic infusion system proved inadequate to effect vaginal delivery. Neonatal outcome was similar in both groups. Automatic infusion of oxytocin by the present system increased the length of induced labour and had no statistically significant effect on neonatal outcome, conferring no advantage over a more traditional method of oxytocin administration.

Induction of labour has been practised for many years by medical, surgical or combined methods. The discovery of the oxytocic activity of posterior pituitary extract (Dale 1906) and its subsequent introduction into clinical use (Blair Bell 1925) was a historic advance in obstetric practice. Oxytocin was given by the buccal route (Maxwell 1964) and the nasal route (Hofbauer & Hoerner 1927) but it was Theobald *et al.* (1948) who introduced the intravenous pitocin drip. Although Theobald described his dosage regimen as physiological, its pharmacological nature was later demonstrated by the finding of extremely low levels of endogenous oxytocin in spontaneous labour (Chard *et al.* 1970).

Dangers to the fetus during oxytocin infusion (Liston & Campbell 1974) and the possibility of uterine rupture even in primigravidae (Daw

1973) were reported. Intrapartum fetal hypoxia was associated with poorly controlled oxytocin infusion (Kubli & Ruttgers 1961); an increased incidence of neonatal jaundice after oxytocin-induced labours (Ghosh & Hudson 1972) and the possibility of electrolyte disturbance in the mother (Burt *et al.* 1969) were reported.

Efficient uterine contractions are necessary for adequate progress of labour but the fetus may be temporarily deprived of oxygen during a contraction. An ideal system combines acceptable labour progress with maximum protection of the fetus. A system of artificial rupture of membranes (ARM) and immediate oxytocin titration was first proposed by Turnbull & Anderson (1968a). Later a semi-automatic open loop infusion system (Cardiff pump) was devised increasing the dosage automatically until acceptable contractions were observed with subsequent conversion to manual mode to maintain this dosage (Francis *et al.* 1970). A closed loop automatic infusion system for titrating the

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dosage of oxytocin according to a preset programme using data derived from an intrauterine catheter has been developed recently (Carter & Steer 1980).

It is important to assess fully new equipment and methods before their introduction into routine clinical practice. The purpose of our study was to assess the automatic infusion system compared with a more traditional method.

Patients and methods

Patients were selected from those having labour induced in the University Unit, Kangar Hospital, Singapore. The induction rate was 9.8% and the leading indications were hypertensive disease of pregnancy, prolonged pregnancy and abnormal weight gain at term. The study was restricted to singleton pregnancies presenting by the vertex with no history of previous operative delivery and having a good prospect of vaginal delivery.

All patients were examined before induction and the cervical condition was assessed by a modified Bishop score. A score of 0–2 was allocated for each of the following five characteristics: dilatation, effacement, consistency, position and station. Induction was by artificial rupture of the membranes and oxytocin infusion. A transducer-tipped intrauterine catheter (Gaeltec Sonicaid) was inserted and a fetal scalp electrode applied. A Sonicaid FM3R fetal monitor was used for continuous monitoring of uterine activity and fetal heart rate. Patients were allocated to the automatic infusion system (AIS, Sonicaid) or peristaltic infusion pump depending on availability of the equipment. The AIS was used as recommended by the manufacturer (Sonicaid Ltd, Chichester) with the pump infusing oxytocin to achieve uterine activity levels of 700–1500 kPas/15 min with the dose being escalated arithmetically in increments of 2 m-units/min every 15 min from a starting dose of 2 m-units/min. Whenever a 'stable phase' of activity (700–1500 kPas/15 mins) was achieved the dose rate was maintained and if a level above 1500 kPas/15 min occurred the dosage was reduced. If labour progress was unsatisfactory after 9 h the facility for manual override was used to achieve higher activity levels or satisfactory contractions as determined by clinical assessment with contractions occurring every 2–2.5 min lasting 40–50 s. The peristaltic infusion pump (IVAC 503 California) was operated manually

to increase the dosage of oxytocin from 2 m-units/min in a semi-arithmetic fashion until uterine activity was clinically satisfactory or attained 2000 kPas/15 min in a nullipara or 1500 kPas/15 min in a multipara. If fetal distress was encountered it was managed clinically including temporary reduction of the oxytocin infusion rate, fetal scalp blood sampling or delivery, if necessary. Epidural analgesia was not used; pethidine in a dosage 50–75 mg was prescribed for pain relief. Maternal age, height, gestation, cervical score, length of first stage of labour, dose of oxytocin, mode of delivery, birthweight, Apgar score at 1 and 5 min and umbilical cord vein blood pH were recorded and analysed. Student's t-test was used for statistical analysis.

Results

The 121 patients in the study comprised 63 nulliparae and 58 multiparae; 30 of the nulliparae and 36 of the multiparae had a good cervical score (6–10), the others (33 nulliparae and 22 multiparae) had a poor cervical score (≤ 5).

Eleven patients were delivered by caesarean section, all but two were nulliparae. Nine of these patients had been managed by automatic infusion and subsequent manual override. The indications for caesarean section were cephalopelvic disproportion in eight patients, failed labour in two and fetal distress in one. There was no statistically significant difference in the caesarean section rate between the two modes of management, probably due to the small numbers.

Table 1 shows the distribution of the 110 patients who were delivered vaginally by parity, cervical score and mode of oxytocin infusion.

Of the 28 nulliparae with poor cervical scores, 15 were allocated to the AIS group and 13 to the IVAC group. Table 2 shows the patient characteristics and outcome in these two groups. There were no significant differences between the two groups in maternal age, height, gestational age, cervical score, mode of delivery, birthweight, Apgar scores and umbilical cord vein blood pH. The length of the first stage of labour was longer in the AIS group although the difference was not significant. Manual override had been necessary in 53.3% of the patients because the system proved inadequate.

Maternal characteristics and fetal outcome in the 26 nulliparae with good cervical scores were not significantly different between the two management groups except for the first stage of

Table 1. Distribution of 110 patients delivered vaginally, by parity, mode of infusion and cervical score

Mode of infusion	Cervical score ≤ 5		Cervical score ≥ 6	
	Nulliparae	Multiparae	Nulliparae	Multiparae
Automatic infusion (AIS)	15	11	14	15
Peristaltic infusion pump (IVAC)	13	10	12	20

labour which was significantly longer ($P < 0.001$) in the AIS group, manual override was necessary in three patients.

In the 21 multiparae with poor cervical scores the maternal characteristics and fetal outcome were not significantly different between the two management groups except for the first stage of labour which was significantly longer ($P < 0.01$) in the AIS group, manual override was necessary in three patients.

Maternal characteristics and fetal outcome in the 35 multiparae with good cervical scores were not significantly different between the two management groups and although manual override had been necessary in two patients in the AIS group the length of the first stage was similar in both groups.

Fetal distress necessitated alteration in the rate of oxytocin infusion in two patients in the peristaltic infusion group. Subsequently increments of oxytocin were reinstated when the fetal heart rate became normal. In one patient in the AIS group fetal distress occurred within 45 min of induction when uterine activity levels were < 1000 kPas/15 min and the patient had received no oxytocin. She was delivered by caesarean section.

Discussion

Placental blood flow is temporarily restricted during uterine contractions (Borell *et al.* 1965) although the placental pool of maternal blood increases in volume (Bleker *et al.* 1975). Kubli & Ruttgers (1961) demonstrated the adverse effect of a poorly controlled oxytocin infusion on the fetus. A balance has to be achieved between protection of the fetus and maintaining adequate progress in labour during oxytocin infusion.

An early study of induction of labour proposed a regimen of artificial rupture of the membranes followed immediately by escalation of oxytocin in a geometric fashion doubling the dose every 10 min until satisfactory uterine contractions were observed clinically (Turnbull & Anderson 1968a) (lasting 45–50 s at 2–3 min

intervals). This geometric escalation was justified on the grounds that uterine contractility and oxytocin sensitivity are very variable before the onset of labour (Turnbull & Anderson 1968b). The open loop automatic infusion system (Cardif pump) doubled the dose rate every 12.5 min until acceptable contractions were attained. Maintenance dosage was controlled manually. A low incidence of fetal distress, babies with good Apgar scores and a shortened induction–delivery interval were reported.

Labour should be induced so as to mimic the physiological process of spontaneous labour as far as possible and protect the fetus from hypoxia. The danger of hypoxia is greater when there is diminished fetoplacental reserve and this varies between patients. The occurrence of fetal distress does not depend on the stress of uterine contraction *per se* but on the underlying fetoplacental function. No fetal distress was encountered in low-risk spontaneous labours with uterine activity levels > 2500 kPas/15 min (Gibb *et al.* 1984).

A programme in an automatic infusion system should be based on activity levels observed in spontaneous labour. Considerably higher activity levels have been observed in spontaneous labour (Cowan *et al.* 1982; Gibb *et al.* 1984) than those incorporated in the AIS system. Uterine activity levels in multiparae have been shown to be considerably lower than in nulliparae (Arulkumaran *et al.* 1984). Turnbull *et al.* (1968a) found labour more difficult to induce in patients with poor cervical scores and more uterine activity may be necessary in such patients. An AIS with a single programme does not allow for the extensive individual variability of induced labour. We therefore compared the outcome of labours induced with AIS with those induced with a more conventional peristaltic infusion pump regulating the dosage based on our data derived from spontaneous normal labour (Gibb *et al.* 1984; Arulkumaran *et al.* 1984).

We excluded the patients delivered by cae-

Table 2. Patient characteristics and outcome

	Cervical score ≤ 5				Cervical score ≥ 6			
	Nulliparae		Multiparae		Nulliparae		Multiparae	
	AIS (n = 15)	IVAC (n = 13)	AIS (n = 14)	IVAC (n = 10)	AIS (n = 14)	IVAC (n = 12)	AIS (n = 15)	IVAC (n = 20)
Age (years)	26.1 (5.8)	25.5 (5.3)	28.5 (8.9)	30.5 (8.7)	26.3 (7.5)	26.1 (8.5)	27.9 (7.9)	28.8 (8.9)
Maternal height (cm)	156.9 (11.0)	154.2 (8.8)	154.5 (11.1)	156.4 (10.0)	156.7 (13.2)	153.7 (7.7)	159.0 (7.0)	157.0 (11.8)
Gestation (weeks)	40.0 (2.8)	40.0 (2.7)	40.3 (3.2)	40.0 (3.6)	40.2 (2.6)	40.1 (2.4)	39.8 (2.7)	40.1 (3.6)
Cervical score	4.3 (1.4)	4.5 (1.0)	4.5 (1.6)	4.5 (1.4)	7.5 (2.5)	7.6 (1.8)	7.3 (1.9)	7.3 (2.0)
Length of first stage of labour (h)	11.2 (7.5)	8.4 (7.2)	10.2 (4.6)*	4.9 (4.0)*	9.1 (3.3)**	4.6 (2.7)**	5.0 (7.0)	3.4 (3.6)
Manual override (n)	8	—	3	—	3	—	2	—
Assisted delivery (n)	7	5	1	0	5	3	1	1
Mean Apgar score								
At 1 min	8.6	9.0	8.9	8.9	8.9	8.8	9.0	9.0
At 5 min	9.9	9.8	10.0	9.9	10.0	10.0	10.0	10.0
Umbilical vein blood pH	7.35 (0.06)	7.34 (0.09)	7.36 (0.07)	7.35 (0.08)	7.32 (0.07)	7.33 (0.09)	7.36 (0.1)	7.39 (0.12)
Birthweight (g)	3392 (891)	3320 (801)	3072 (1198)	3116 (1038)	3130 (747)	2965 (645)	3395 (975)	3297 (933)

Results are mean (SD) where appropriate.

Significance of difference between the two modes of infusion: * $P < 0.01$; ** $P < 0.001$.

sarean section from the analysis because of the confounding effect of this procedure on the length of the first stage, Apgar scores and umbilical vein blood pH. Although numbers were small there were more caesarean sections in the AIS group which cannot solely be accounted for by fetopelvic relations as the patient characteristics were very similar. A diagnosis of cephalopelvic disproportion also depends on a well-conducted trial of labour which may not have been achieved in spite of manual override of the AIS.

We found significantly longer labours in the patients induced by AIS which is not surprising on account of the low levels of uterine activity in the programme compared with levels in normal spontaneous labour. The neonatal outcome was very similar in both groups no added protection being provided by the AIS. If manual override had not been used more patients might have been delivered by caesarean section. We were unable to justify continuation of the study on account of unacceptable prolongation of labour in the AIS group.

The use of an AIS involves the additional cost of the machine and disposable cassettes for administration of the infusion.

We conclude that the more expensive automatic infusion system leads to longer labours and confers no advantage to the fetus. As presently designed its introduction into routine clinical use is not justified.

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7

Assessment and management of uterine contractions

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The last decade has seen a marked rise in Caesarean section (CS) rates and a steady decline in perinatal mortality rates (PNMR), with limited evidence to suggest a causal relationship (O'Driscoll and Folley, 1983; Shearer, 1983). More recently, there has been a smaller decline in perinatal mortality rates, despite the continuing trend of rising CS rates both in the developed (Maternity Alliance, 1983; National Institute of Health (NIH) consensus statement, 1981) and developing countries (Arulkumaran et al, 1985a). Such a trend has been attributed to the obstetrician's concern to reduce perinatal morbidity, but parents' attitudes to a small family size, privatization of health care, and concern over litigation, have also contributed to increasing numbers of Caesarean births. The NIH consensus report from the USA and recent reports from the UK (Yudkin and Redman, 1986), have highlighted dystocia and previous CS as major contributory factors, fetal distress and breech presentation playing a more minor role in this increasing trend.

The uterus, whilst contracting to effect delivery of the fetus, reduces the utero-placental blood supply intermittently resulting, at times, in fetal hypoxia necessitating an abdominal delivery. This complication is more likely when oxytocin is used injudiciously to augment weak uterine contractions. Hyperstimulation of the uterus, and its consequences, has become the commonest cause of litigation in obstetric practice in the USA (Fuchs, 1985). Owing to concern over this, or due to lack of understanding of augmentation of labour, oxytocin is not used, or is misused, in the management of abnormal labour, resulting in prolonged labour and probable CS for dystocia. These patients are subjected to repeat CS in their next pregnancy, thus increasing the CS rate further. Despite adequate evidence of uncomplicated vaginal deliveries in cases with previous CS, many centres practise routine repeat CS. Some permit labour in cases with previous lower segment CS if in spontaneous labour with normal progress, but are reluctant to augment abnormal labour. These attitudes are related to the difficulty in predicting and diagnosing scar dehiscence. In such situations, assessing levels of uterine activity and limiting excessive activity may be of value. The management of problems of dystocia, fetal distress and previous CS are related to uterine contractions. A

sound understanding of uterine contractions, and their management under these circumstances, should contain the rising CS rate without compromising the health of the mother or her fetus. Apart from the desirability of good practice, it will not be long before litigation is pursued because of unnecessary Caesarean section.

ASSESSMENT OF UTERINE CONTRACTIONS

Uterine contractions are most often assessed by a hand placed midway between the umbilicus and the uterine fundus. The frequency and the approximate duration of contractions can be determined as the uterus becomes firmer during contractions. Using this clinical method it is impossible to measure the strength, or amplitude, of the contractions and the basal pressure between contractions. In current clinical practice external tocographic recorders in conventional fetal monitors are commonly used to assess uterine contractions. A transducer placed near the uterine fundus detects the changes in the anteroposterior diameter of the abdomen during uterine contractions. The transducer is a plastic plunger or a membrane, which at times may be uncomfortable to the mother, but is noninvasive and unlikely to harm the mother or her fetus. External tocography provides a good measure of contraction frequency, an approximation of contraction duration, but a poor estimate of contraction intensity, especially in an obese or restless patient with difficult labour, when this information is most required. An intrauterine catheter measures actual pressures and gives more accurate information.

The introduction of the transducer-tipped catheter (Steer et al, 1978) has obviated the technical problems of a fluid-filled catheter, such as blockage by vernix blood clot and meconium, or attenuation of the pressure wave by air in the system (Odendall et al 1976). The transducer-tipped catheter (Figure 1) (Sonicaid Gaeltec: Sonicaid Ltd, Chichester, UK) is simple to use, unlikely to cause trauma, and ideal for use in the ambulant patient. The transducer is mounted on the end of a 90 cm catheter (Figure 2) with a sensing area which is recessed, thus minimizing accidental damage to the device and enabling realistic fluid pressure measurements, and not the impact of the head or end-on pressure. The transducer tip lies in the amniotic cavity and all transmission is then electronic through the catheter via a 2 m flexible extension cable connected to the contraction module of a standard fetal monitor. The easy use of the catheter and its reliable recording have been well documented (Steer, 1977; Steer et al, 1984, 1985a; Gibb et al, 1984, 1985).

The uterine activity needed, in labour, to expel the fetus by dilating the cervix and promoting the descent of the presenting part is best represented by the pressure exerted by the contraction and its duration. This concept was first suggested by Bourne and Burn (1927). Though extensive work on uterine activity measurements was done by Caldeyro Barcia et al (1950, 1957, 1961), technology was not available for online computation of the area under each contraction tracing. They quantified uterine activity in Montevideo units: a product of average amplitude and frequency over a 10 minute period, not considering the duration of contractions. El Sahwi et al (1967) included the

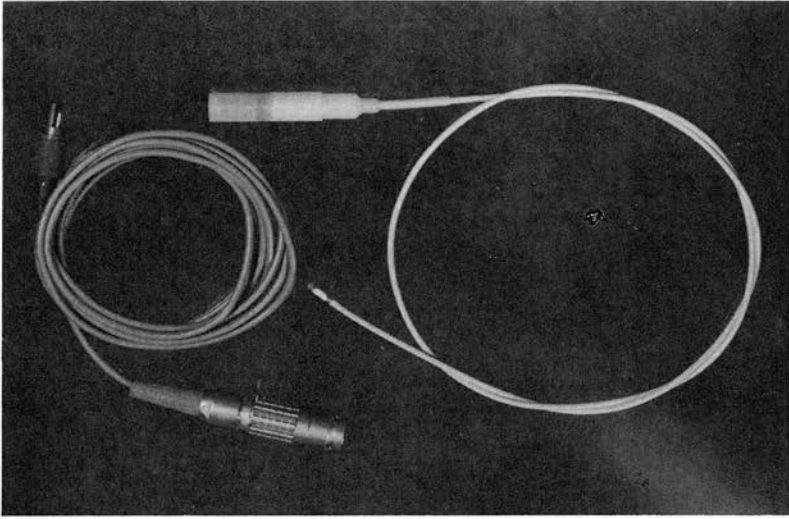


Figure 1. The transducer-tipped (Gaeltec) catheter with the connecting cable.

average duration of contraction with the elements of average amplitude and frequency to formulate the Alexandria units.

It has been debated whether total contraction area (area under the curve including the area under the baseline) or active contraction area (area of the curve above the baseline) represents useful uterine work. The useful work of

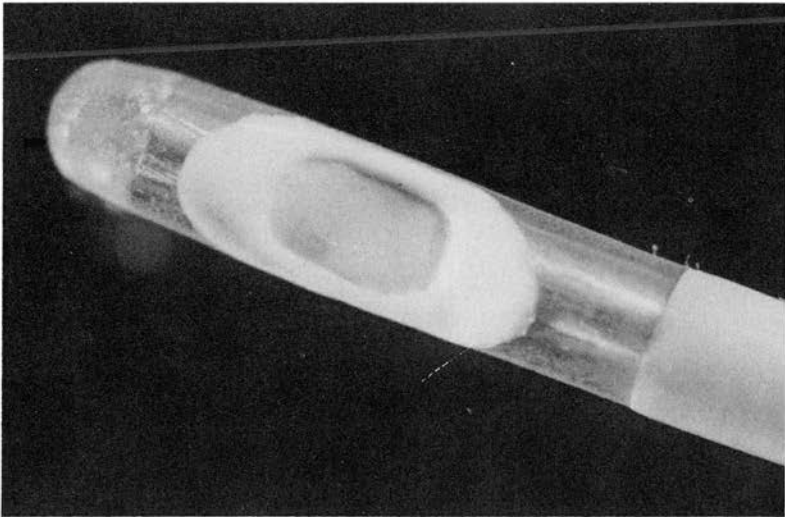


Figure 2. An enlarged view of the catheter tip with the pressure sensitive membrane.

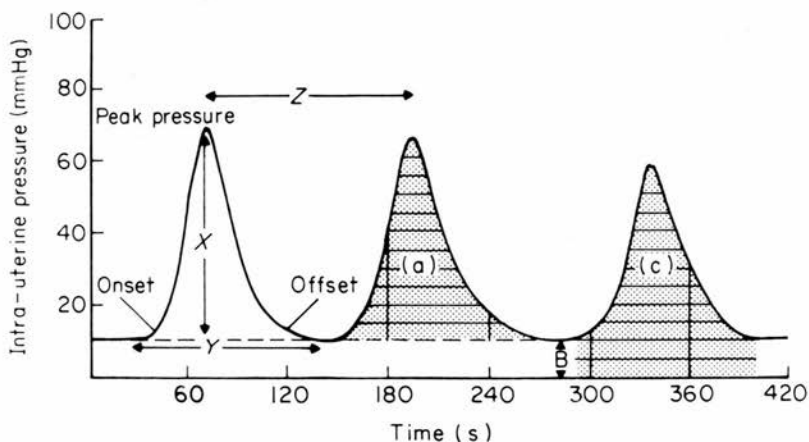


Figure 3. Elements and terminology of uterine contractions: (x) active pressure (amplitude); (y) duration; (z) contraction interval (related to frequency); (a) active contraction area; (b) basal tone; (c) total contraction area.

the uterus depends on the absolute intensity of the contractions (Caldeyro-Barcia et al, 1950) rather than the total area, which, because it includes the area under the baseline, is a less sensitive index. The quantification of uterine activity by integration (Jilek et al, 1972) affords a quick and convenient method of measuring the area under a curve. It is more accurate and less time consuming than planimetric measurement, being especially useful with asymmetric curves, or when curves with different profiles occur successively or at irregular intervals (Miller et al, 1976). Hon and Paul (1973) developed this concept (calculating total contraction area) in order to standardize activity measurement and to facilitate 'on-line' analysis so that it could be used during labour management rather than retrospectively. They proposed that one uterine activity unit (UAU) be equivalent to a rectangle 1 mm high which lasts for 1 min, and called it 1 Torr-minute. In the trend towards Système International (SI) units, Steer (1977) used the SI unit of pressure, the pascal (Pa) instead of millimetres of mercury (mmHg) (1 kPa = 7.52 mmHg). One kilopascal of pressure existing over a duration of one second is one kilopascal-second (1 kPa s). The active contraction area is quantified over a period of time, and this is usually 15 minutes, so the uterine activity is expressed as kPa s/15 min. Fifteen minutes was selected because of the time taken by the uterus to respond to changes in the rate of oxytocin infusion, and because of short-term variations in the frequency of contractions. This quantity is termed the uterine activity integral (UAI). The elements of uterine contractions which have some bearing on their efficiency are frequency, active pressure, duration, and coordination. These elements, and the measurement of uterine activity based on them, are shown in Figure 3. The UAI bears a closer correlation to the rate of cervical dilatation than either the frequency or amplitude of uterine contractions (Steer et al, 1984). Equipment to measure UAI on line (UAI module) has been incorporated into fetal monitors (Sonicaid FM3R). This

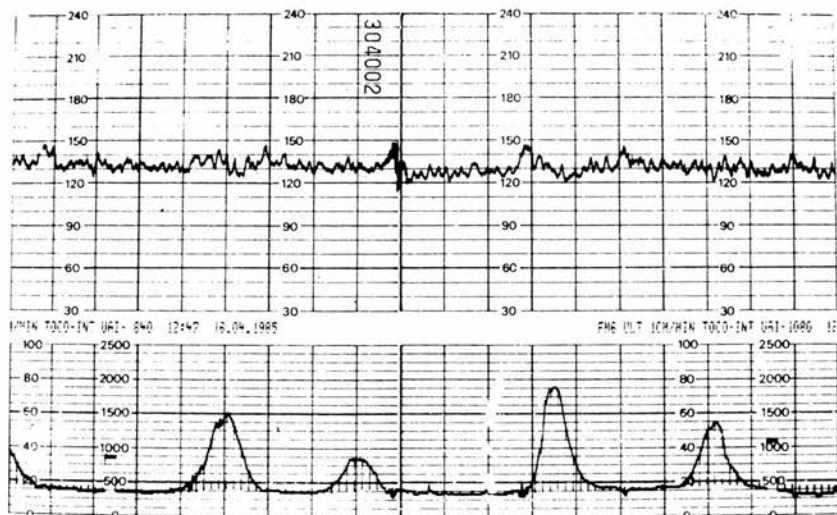


Figure 4. Recording of UAI as a short dark line against a vertical axis from 0 to 2500 kPa s and the numerical print out of the UAI in addition to mode of recording, date, and time.

module exhibits the computed UAI as a digital display every 15 minutes. In addition to this display, the value is marked by a short dark line on the two-channel chart recording paper against a vertical scale marked from 0 to 2500 kPa s/15 min. Later equipment (Sonicaid FM6) prints these values numerically on the two-channel recording paper, along with mode of recording, date, and time (Figure 4). The appropriate application of this advanced technology is discussed in this chapter.

UTERINE ACTIVITY IN SPONTANEOUS NORMAL LABOUR

The work done by the uterus to effect normal labour and unassisted vaginal delivery tends to differ greatly from patient to patient. The uterine activity values vary according to the cervical dilatation and stages of labour. A wide range of activity is seen in a specified group of patients (e.g. nulliparae over 152 cm tall in a specified population (Figure 5)—Gibb et al, 1984), but the median uterine activity tends to differ in subgroups, e.g. according to parity (Arulkumaran et al, 1984) (Figure 6). Similar differences according to parity were observed by Willcourt (1983), Huey et al (1976), and Miller et al (1976). Differences may be expected in relation to height, birthweight, gestational age, presentation, and multiple pregnancy. The profiles of uterine activity values observed in specified groups may be of value in managing patients who develop problems with labour progress or fetal distress. If spontaneous labour progress is normal there is little to be gained by this advanced technology.

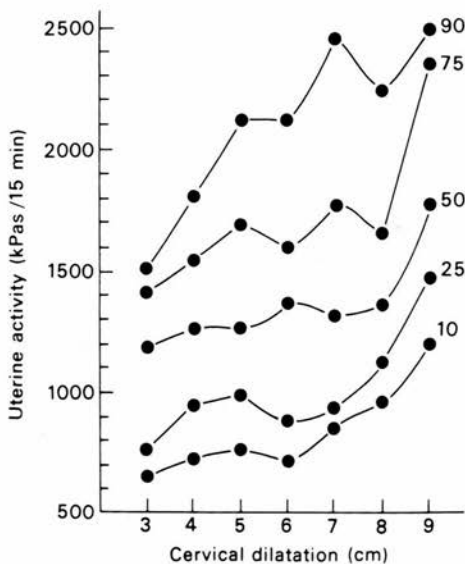


Figure 5. Uterine activity in nulliparae showing a wide range of UAI associated with normal labour progress. From Gibb et al (1984), with permission.

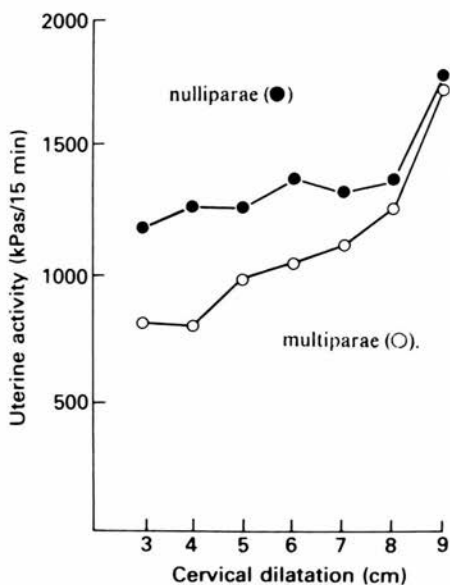


Figure 6. Comparison of median uterine activity in nulliparous and multiparous labour. x---x nulliparae. ○---○ multiparae. From Arulkumaran et al (1954), with permission.

REGULATION OF UTERINE ACTIVITY

A certain total work has to be performed by a uterus to overcome the cervical and pelvic tissue resistance to effect the delivery of a fetus. Rossavik (1978) called this total uterine impulse and calculated the value to be between 5 and 10 cm and found this to correlate positively with the frequency of operative vaginal deliveries, especially in nulliparae. The same concept was applied to induced labour by Arulkumaran et al (1985c). They calculated the cumulative UAI values, termed total uterine activity or TUA, according to parity, cervical score (Table 1), and mode of oxytocin infusion in those patients reported by Gibb et al (1985). Though the automatic infusion system (AIS)* generated less UAI per 15 min period, compared with the peristaltic infusion system (IVAC)†, the TUA was found to be not significantly different in patients within the same parity and cervical score.

Nulliparae with a poor cervical score required the greatest amount of uterine activity (60000 kPa s), whilst nulliparae with good score and multiparae with a poor score required 30000 kPa s, and multiparae with a good score required the least, about 15000 kPa s. These differences were all statistically significant. In induced labour, if the TUA exceeds the value expected for the relevant parity and cervical score with failure of labour progress, the possibility of cephalopelvic disproportion, malposition or failed induction of labour should be considered. The ability to withstand the hypoxic stress of labour varies from fetus to fetus, depending on the integrity of the fetoplacental unit and to the degree of interruption of the placental perfusion caused by uterine contractions. The studies of Gibb et al (1985b) showed that mode of delivery or neonatal outcome was not affected in the groups studied, whether oxytocin was titrated to achieve 50th or 75th centile uterine activity values observed in spontaneous normal labour according to parity. The length of labour and the dose of oxytocin were the two parameters affected, but to a significant degree only in nulliparae with poor cervical score. Based on this, it is possible to effect delivery with lower uterine activity values over a longer period of time in situations of borderline fetoplacental function. Uterine activity measurements may help to reduce the oxytocin dose, when fetal heart rate changes are observed to achieve optimal uterine activity levels adequate for satisfactory progress of labour without compromising the fetus. If signs of fetal compromise are observed with minimal uterine activity unlikely to be associated with progress of labour (Steer et al, 1984), it may be wise to deliver the fetus abdominally in a good condition.

DYSTOCIA

Dystocia refers to difficult labour, implying the labour progress to be abnormal and the labour potentially prolonged. The NIH consensus report (1981) has documented 30% of the rise in the CS rate to be due to dystocia

*AIS: Sonicaid Ltd, Chichester, UK.

†IVAC: IVAC Co., San Diego, USA.

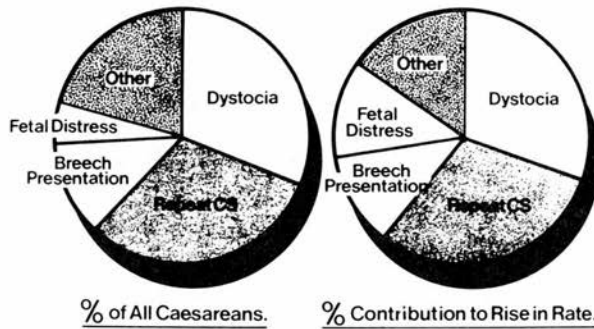


Figure 7. Principal indications for CS (National Institute of Health, 1981).

(Figure 7). Yudkin and Redman (1986) also highlighted the significant contribution of dystocia to the CS rate. Dystocia is due predominantly to inadequate uterine contractions and, to a lesser extent, to cephalopelvic disproportion (CPD) or malposition, or to a combination of these. Steer et al (1985a) reported that 75% of patients who had slow progress of labour (< 3 cm in 4 h) in the active phase of labour showed levels of uterine activity below the 10th centile for normal spontaneous labour. About three-quarters of these patients delivered vaginally on achieving satisfactory uterine activity levels in response to oxytocin augmentation. Dystocia, attributed to a cervical factor, is often a result of induction of labour with a poor cervical score, especially in nulliparae, and is rarely due to secondary cervical scarring arising, for example, as a result of previous surgery. Mechanical difficulty due to pelvic tumours or large presenting part, as in brow presentation or hydrocephalus, is rare but should be excluded in the presence of abnormal labour. A conclusion that dystocia is due to CPD, malposition, or an unfavourable cervix should be made only retrospectively after labour fails to progress, despite good uterine contractions for an adequate length of time. With improved nutrition and health in the present generation of mothers, it is less probable that a small maternal pelvis is the reason for dystocia. Premature intervention in spontaneous labour, inadequate or non-existent active management policies, or the inefficient implementation of those that are in use, seem to be major factors leading to inappropriate CS.

DYSTOCIA IN SPONTANEOUS LABOUR

The diagnosis of the onset of labour is important as it may affect subsequent management. Unless the labour is well advanced with the cervix effaced and more than 3 cm dilated with a frequency of uterine contractions greater than one in 5 minutes, confirmation of the diagnosis of labour may need two assessments a few hours apart. Observation of such patients in the labour ward longer than necessary increases the chances of inappropriate intervention by artificial rupture of the membranes. This action, before the patient is well established in labour, may lead to longer labour requiring augmentation.

Labour may appear prolonged, even after subsequent augmentation prompting operative intervention without giving adequate time for good uterine contractions to effect vaginal delivery. Such problems can be overcome by a clear management policy regarding the diagnosis of labour and artificial rupture of the membranes.

Use of partograms and nomograms (Philpott and Castle, 1972a,b; O'Driscoll et al, 1969; Studd, 1973) helps to identify abnormal labour progress, prompting careful scrutiny and proper management to avoid prolonged and difficult labour. Corrective action by oxytocin augmentation may be taken either when the progress of cervical dilatation is just to the right of an expected progress line of 1 cm/h (O'Driscoll et al, 1973) or when the deviation is greater than a 2-hour grace period to the right of a nomogram (Studd, 1973). The former course of action results in more cases being augmented, whilst the latter results in fewer treated cases. There are hospitals where augmentation is not undertaken for poor progress of labour, especially in multiparae, thus increasing the CS rate for dystocia. All labour units should adhere to an active management policy to avoid unnecessary CS for dystocia. In the majority of augmented cases, the rate of labour progress improves, resulting in a vaginal delivery (Gibb et al, 1982; Cardozo et al, 1982). Inadequate augmentation with suboptimal uterine contractions, and impatience on the part of the clinician who allows insufficient time after achieving optimal contractions, contribute to the increased diagnosis of dystocia. When the labour progress is unsatisfactory after augmentation proper assessment and control of uterine contractions will optimize the results.

In normal clinical practice, oxytocin is titrated to achieve clinically satisfactory uterine contractions with a frequency of one in a 2–2.5 min period, assessed by palpation or external tocography. On achieving this, the rate of oxytocin infusion is maintained. If the cervix does not dilate despite clinically adequate uterine contractions for 3 hours, another 3 hours should be allowed before deciding to perform a CS for dystocia, provided fetal condition is uncompromised and there is no obvious disproportion. These cases will benefit from the use of an intrauterine catheter and uterine activity measurement. Optimal uterine activity between the 50th and 75th centiles, observed in spontaneous normal labour according to parity (Gibb et al, 1984; Arulkumaran et al, 1984), can be achieved by escalation of oxytocin dose, unless limited by fetal heart rate changes or hyperstimulation. Maintenance of such activity levels for 3–4 hours should produce the satisfactory progress of labour. In the absence of such progress, a decision to perform CS can be made rationally. Dystocia is not a diagnosis but describes the event of prolonged or difficult labour. Having positively established that uterine activity was adequate for a sufficient length of time a diagnosis of CPD, malposition, or cervical factor can be made.

Each pregnant uterus contracts optimally at a specific dose of oxytocin. This varies from patient to patient and depends on parity, period of gestation, state of the cervix, presence or absence of membranes, and whether or not labour is established. Even a small dose of 2 mU/min is adequate in some patients. A semi-arithmetic regimen of dose escalation, initially by 2 mU increments from 2 to 12 mU/min, followed by 4 mU increments from 16 to 24

mU/min, and then by 8 mU increments from 32 to 48 mU/min and, exceptionally, to higher doses, until optimal uterine activity is achieved, is a safe and effective method of using this drug. When the higher concentrations are being used, uterine contractions should be monitored internally and special consideration given to ensure the use of isotonic fluids to maintain electrolyte balance. Such cautious increments safeguard against the possibility of hyperstimulation and its consequences. A regimen of doubling the dose of oxytocin described by Baxi et al (1980) may bring about the desired clinical effect of optimal uterine contractions sooner than a semi-arithmetic regimen, but may also produce more hyperstimulation. Fuchs (1985) states that it may be acceptable to double a dose of 2 mU/min: he would not double a dose of 4 mU/min, and he shuddered at the thought of doubling 8 mU/min! Two additional factors to be considered when oxytocin is used are the time interval between increments and the inherent increase in sensitivity of the uterus to oxytocin with progress of labour. A period of $12\frac{1}{2}$ minutes is adequate to observe the response of the uterus to a given dose of oxytocin (Caldeyro-Barcia et al, 1957). An interval of 10–15 minutes for increasing the dose, as has become customary, is not adequate to observe the full response of a given dosage and intervals of 30 minutes more appropriate. The sensitivity of the uterus to a constant dose of oxytocin increases with the progress of labour (Sica Blanco and Sola, 1961) due to a process of biochemical maturation of the myometrium (Fuchs, 1985). This can lead to hyperstimulation of the uterus even when small constant doses of oxytocin are being maintained having already achieved optimal contractions. Accurate monitoring of uterine contractions will enable the correct titration of oxytocin to achieve the optimal uterine activity. Further, it will allow the early identification of hyperstimulation so that the dose of oxytocin can be reduced before the fetus becomes seriously hypoxic. The use of reliable infusion pumps, to allow precise control of the dose of the drug, should avoid unnecessary CSs for prolonged labour due to understimulation and fetal distress due to overstimulation. A simple peristaltic infusion pump with drop counter is adequate.

DYSTOCIA IN INDUCED LABOUR

There is little doubt that CSs after induction of labour are more frequent than during spontaneous labour (Yudkin and Redman, 1986; Arulkumaran et al, 1985a). Dystocia in induced labour is mostly due to cervical resistance, especially in nulliparae due to the procedure being performed when the cervix is unfavourable. To facilitate comparison of results, and to predict the progress of labour, cervical scoring should be performed. A suitable system is outlined in Table 1.

A study of 1057 consecutive inductions reported a 16.5% incidence of CS, nearly twice that found in spontaneous labour (Arulkumaran et al, 1985b). Detailed analysis showed that 9.4% were for dystocia, of which 1.8% was contributed by CPD and 0.6% by malposition. The remaining 7.0% were attributed to failed induction, defined as cases delivered by CS for reasons other than for fetal distress, CPD, or malposition. The initial mean cervical

Table 1. Cervical score (modified Bishop score 0–10).

Characteristics	Score		
	0	1	2
Position	Posterior	Axial	Anterior
Length	2 cm	1 cm	< 1 cm
Dilatation	< 1 cm	1 cm	2 cm
Consistency	Firm	Soft	Soft and stretchable
Station of the presenting part	-2	-1	0

score of the failed induction group was 4.0, using the scoring system described, and the mean cervical dilatation at the time of CS was 3.5 cm. There was a 45% incidence of CS for failed induction in nulliparae if the score was 3 or less, 10% if it was 4–6, and 1.4% of those with a score of 7–10. Similar figures for multiparae were 7.7%, 3.9%, and 0.9%, respectively. These cases resulted in CS, despite the use of high doses of oxytocin (with a mean of 24.7 mU/min) and clinically adequate uterine contractions for durations of 12 hours. A higher dose of oxytocin, and a longer duration, might have led to a few more cases delivering vaginally, but a rational approach would entail a critical selection of cases for induction. In cases with a poor cervical score, especially nulliparae, it is wiser to review the indication for induction than to adhere to rigid induction policies. Even with good uterine contractions over a long duration of time, it may not be possible to overcome the cervical tissue resistance in cases with a poor cervical score.

Uterine activity measurement may not be of value in all induced labours. Ideally, it should help to titrate oxytocin to achieve uterine activity values which will optimize the length of induced labour without compromising the fetus. Gibb et al (1985b) compared a manually operated system (IVAC) with an automatic infusion system (AIS) to titrate oxytocin for induction of labour. The manual titration was used to escalate the dose of oxytocin every 15 minutes until the activity reached 75th centile values observed in spontaneous normal labour according to parity. The escalation of the dose according to the protocol was not undertaken if the patient achieved clinically adequate uterine contractions (painful contractions of one in 2–2.5 min), or if the fetal heart rate tracing became suspicious or abnormal. The escalation of the oxytocin infusion was automatically controlled in the AIS group until the uterine activity levels were near the 50th centile values observed in spontaneous normal labour according to parity (Gibb et al, 1984; Arulkumaran et al, 1984). The cases who had the oxytocin titrated to achieve 75th centile values, or clinically adequate uterine contractions, had a shorter duration of labour in

nulliparae. However, there was no significant difference with increase of parity and cervical score. The dose of oxytocin, mode of delivery, and the neonatal outcome, judged by cord venous blood pH values, Apgar scores at 1 and 5 min, birthweights, and admissions to the neonatal ward, were similar in the groups studied.

Steer et al (1985b) compared the AIS system with manual oxytocin titration, the AIS titrating oxytocin to achieve preset uterine activity values and the manual method to achieve clinically adequate contractions. Higher doses of oxytocin were used in the manual method, though there was no difference in the other parameters, including the neonatal outcome. The observations made by Gibb et al (1985b) which differed from those of Steer et al (1985b) may be due to the categorization according to parity and cervical score.

Titration of oxytocin to achieve 75th centile uterine activity values observed in spontaneous normal labour (according to parity), compared to the traditional method of oxytocin titration to achieve clinically adequate uterine contractions recorded by external tocography, failed to show any benefits (Arulkumaran et al, 1986a). In nulliparae with a poor cervical score, the dose of oxytocin needed to achieve the 75th centile uterine activity values was higher compared with the group in which oxytocin was titrated to achieve clinically adequate uterine contractions. The incidence of hyperstimulation in the former group was also higher. The duration of labour, mode of delivery, and neonatal outcome, were similar in both groups. This study, and that of Gibb et al (1985b), show that oxytocin titration to achieve preset uterine activity values does not improve the outcome of induced labour.

Caldeyro-Barcia et al (1957) showed proportionately increasing uterine activity with increase of oxytocin dose, finally reaching a plateau characteristic for each patient, which he called the maximal uterine activity phase, beyond which further oxytocic stimulation produced hypertonus rather than an increase of uterine activity. Steer et al (1975) confirmed this and called it the 'stable phase activity'. Willcourt (1983) titrated oxytocin by an automatic infusion pump to achieve this efficient stable phase activity and showed a marked reduction in the mean total dose and hourly rate of oxytocin compared with patients managed conventionally. In busy clinical practice, it is easier to assess clinically-adequate uterine contractions by frequency rather than the maximal uterine activity phase or stable phase uterine activity which varies widely from patient to patient. Despite clinically-adequate uterine contractions, if no cervical change is observed an intrauterine catheter and the recording of uterine activity measurements may be of some value. If uterine activity is not adequate, despite clinically satisfactory uterine contractions, oxytocin may be increased to achieve optimal uterine activity levels. However, without uterine activity measurements it is possible to infuse large doses of oxytocin (422.4 mU/min) with little improvement in uterine activity (Toaff et al, 1978) and fetal distress (Kubli and Ruttgrens, 1971), hyponatraemia (Burt et al, 1969), and neonatal hyperbilirubinaemia, (Ghosh and Hudson, 1972) become real possibilities.

UTERINE ACTIVITY MEASUREMENTS IN CASES WITH PREVIOUS CS

Craigin (1916) introduced the concept 'once a Caesarean, always a Caesarean' when the low transverse uterine incision was not widely practiced and modern anaesthesia, blood storage techniques, and antibiotics, were not available. Subsequently, many authors have published 63–78% success rates of vaginal delivery after previous CS with little danger to the mother or fetus, even when oxytocin was used (Gibbs, 1980; Eglinton et al, 1984). Despite such good outcome, there is reluctance to allow a trial of labour in cases with a previous Caesarean scar, and the reluctance is greater if oxytocics become necessary. This is due to the difficulty in evaluating whether the cause of the slow labour is inadequate power or possible CPD. If oxytocics are used in the presence of the latter, fear of scar dehiscence is real. The difficulties of assessing the integrity of the scar and the possibility of diagnosing scar dehiscence or rupture only after the event has occurred add further dimensions to the problem.

Cervical dilatation-specific uterine activity in spontaneous normal labour in patients with a previous Caesarean scar was studied by Arulkumaran et al (1986b). Patients who had not delivered vaginally and had a CS, electively or during labour, in their previous pregnancy, formed one group (A) and those

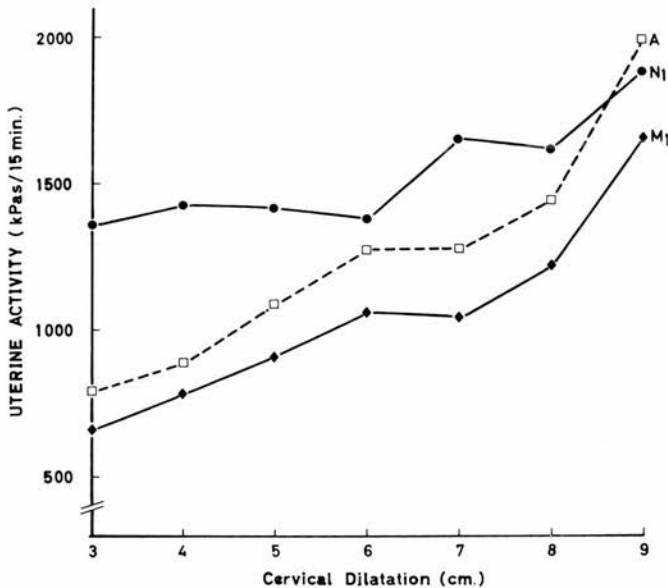


Figure 8. Median uterine activity profile in normal labour in patients with a previous CS scar and no previous vaginal delivery (A) compared with that of control nulliparae (N1) and control multiparae (M1). From Arulkumaran et al (1986b), with permission.

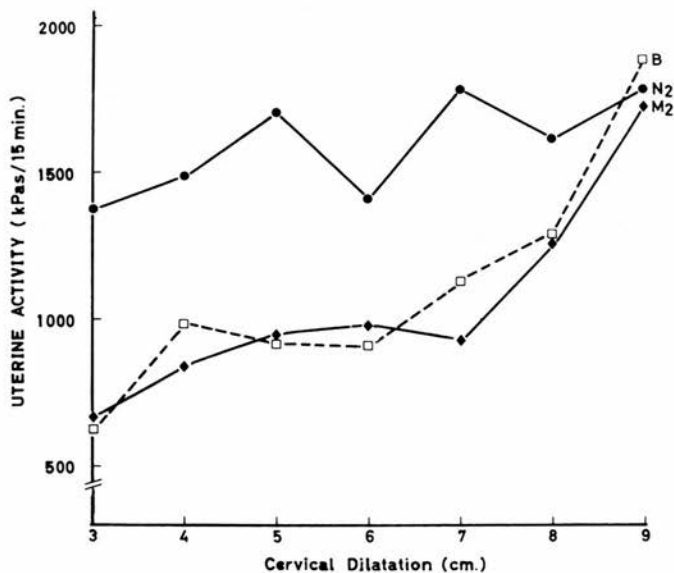


Figure 9. Median uterine activity profile in normal labour in patients with a previous CS scar and a previous vaginal delivery (B) compared with that of control nulliparae (N2) and control multiparae (M2). From Arulkumaran et al (1986b), with permission.

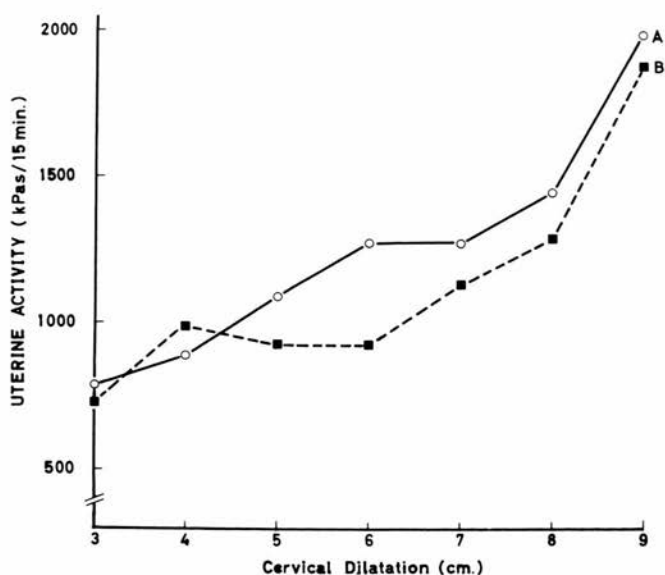


Figure 10. Median uterine activity of patients with previous Caesarean scar with no previous vaginal delivery (A) compared with those who had a previous vaginal delivery (B). From Arulkumaran et al (1986b), with permission.

who had a CS, but also had a vaginal delivery either before or after the operation, formed the second group (B). The cervical dilatation-specific median uterine activity profiles in those groups were compared with control nulliparae (N1 for group A and N2 for group B) and multiparae (M1 for group A and M2 for group B) in Figures 8 and 9. Group A behaved like multiparae at all except 8 and 9 cm, at which stage there was a spontaneous steep rise in uterine activity. The activity levels were significantly lower than control nulliparae, except at 8 and 9 cm, demonstrating the similarity to multiparae rather than nulliparae. Group B behaved like multiparae, with uterine activity levels similar to the control multiparae (M2) and being significantly different from the control nulliparae (N2), except at 8 and 9 cm (Figure 9). The median uterine activity profiles of groups A and B are shown in Figure 10. The group A activity was found to be slightly higher at 5 and 6 cm and was found to be similar at other cervical dilatations when compared with group B.

These findings show that though group A had not previously achieved vaginal delivery, they required uterine activity values more comparable to multiparae than nulliparae to effect vaginal delivery. This group constituted those who had elective surgery prior to labour and those who had a CS in established labour, and the uterine activity in these two subgroups did not differ significantly. This suggests that the previous pregnancy to term exerts an influence on the uterus and cervix so reducing the uterine work required during a subsequent labour. Consequently, if oxytocin augmentation is undertaken in cases with a lower segment scar for poor progress of labour with suboptimal uterine activity values and no contraindication to a trial of labour, escalation of the oxytocin dose and its maintenance should be guided to achieve median uterine activity values observed in groups A and B (1000–1250 kPa-s/15 min) in the absence of uterine hyperstimulation or fetal heart rate changes.

All groups showed a steep rise of uterine activity in the late first stage of labour which persisted in the second stage. Such high activities for long periods may not be advisable in the presence of a uterine scar. This supports the clinical practice of well judged prophylactic forceps delivery in cases where there is likely delay in the second stage.

For a given scar, the total force exerted on the scar is better quantified by the active contraction area than the frequency of contractions: it represents the actual work done or force exerted within the uterus and thus on the scar. Thus, in cases with previous CS we would advocate the use of an intrauterine catheter, especially when oxytocic drugs are used.

UTERINE CONTRACTIONS AND FETAL DISTRESS

Inhibition of uterine activity

Decelerative fetal heart rate (FHR) changes observed in labour may signify fetal hypoxia, but at times can be due to other causes. Prolonged bradycardia of about 100 beats/min in the first stage of labour may be an innocuous

finding, as the FHR will usually recover spontaneously, or after a shift in position of the patient. In a few cases, prolonged bradycardia may be an indication of a serious complication, such as cord prolapse, abruptio placentae, or severe fetal asphyxia, especially if preceded by an ominous FHR pattern. Hypoxia of unknown origin, or due to abnormal uterine activity, often induced by injudicious administration of oxytocin, can be related to such FHR patterns. In the modern management of labour, procedures such as vaginal examination, artificial rupture of the membranes, application of a scalp electrode, insertion of an intrauterine catheter, and paracervical or epidural anaesthesia for pain relief, may be associated with prolonged bradycardia. In most instances the cause is unknown, or is associated with abnormal uterine contractions, but these patterns give rise to much anxiety, particularly if sustained after the usual corrective action, and lead to emergency instrumental vaginal delivery or CS, which may be unnecessary and potentially traumatic. The treatment of these FHR changes by the use of uterine relaxants has been attempted, and β -adrenergic receptor agonists, such as terbutaline (Anderson et al, 1975; Arias, 1978; Ingemarsson, 1982), hexoprenaline (Lipshitz, 1977), adrenaline (Wong and Paul, 1979), or uterine muscle relaxants, such as magnesium sulphate (Reece et al, 1984) have been used. A recent study (Ingemarsson et al, 1985) reported the response and outcome of 33 cases of prolonged bradycardia not responding to conventional management and treated with a 250 μ g bolus intravenous injection of terbutaline with apparently good results in 22. It appears that tocolysis in selected cases can be of benefit, but the presence of an ominous FHR pattern preceding the prolonged bradycardia, abruption, cord prolapse, an episode of bradycardia greater than 10 min, and a flat baseline for 4 min during the bradycardia, is a poor sign. In the absence of these features, though preparation for emergency delivery should be made, a recovery could be awaited as, in those who are likely to respond, most (99%) will do so within 6 min and 100% within 9 min of the injection.

The uterus may not contract to oxytocics if the patient is delivered abdominally soon after the use of the β -adrenergic receptor agonist, in which case a bolus dose of β -blocker, such as propranolol 1–2 mg IV is indicated. If a patient delivers vaginally the uterus contracts well and there may be little need for reversal of the beta agonist activity.

Intrauterine resuscitation by abolishing uterine contractions for an average period of 15 min (range 6–28 min) will be of value in case of delay in delivery due to problems in getting an anaesthetist, theatre facilities, or an obstetrician. Even when they are readily available, it gives the opportunity for the fetus to correct its hypoxic and metabolic deficits through an intact placental circulation.

CONCLUSION

Continuous intrauterine pressure measurement does not provide useful additional information in spontaneous labour if progress is normal. The

decision to augment labour should be based on the observed progress of labour, as normal progress is associated with a wide range of uterine activity. Information about uterine activity is of value in spontaneous labour, if the progress is abnormal, to decide about augmentation especially in multiparae and in cases with a previous CS scar.

In induced labour, it is of value in difficult cases, such as nulliparae with a poor cervical score and when labour is prolonged, or fetal heart rate changes are suspicious of fetal compromise. During augmentation or induction, if the progress of labour is satisfactory, oxytocin titration based on external tocography may be adequate. However, if the progress of labour is not optimal, uterine activity measurements may be useful and constitute an aid to differentiate dystocia due to inadequate uterine activity from that due to cephalopelvic disproportion or malposition. The decision to escalate the dose of oxytocin, or to terminate labour by CS, will then be on a more rational basis without further prolongation of labour to avoid risk of fetal asphyxia or uterine rupture and the mental and physical distress to the patient.

Patients with previous CS scar can deliver safely with good monitoring of labour, though ready access to CS should be available. Decisions to perform a repeat CS should not be made early in pregnancy based on static pelvic measurements, but on the clinical indices in late pregnancy, like size of the fetus and engagement of the head. Uterine activity measurements may help to avoid harmful uterine activity when oxytocics are used.

In a healthy fetus with a reactive trace at the onset of labour fetal distress is often iatrogenic or transient unless the labour is longer than 3–4 h (MacDonald et al, 1986; Morris, 1986; Ingemarsson et al, 1986). A healthy fetus should be able to resuscitate itself in utero, if the acute distress was due to excessive uterine activity, by abolishing the contractions for a short period.

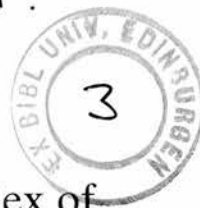
Proper assessment and management of uterine contractions should lead to less surgical interference with reduction in short- and long-term morbidity to the mother without compromising the fetus.

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Total uterine activity in induced labour—an index of cervical and pelvic tissue resistance

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Summary. Uterine activity was studied during labour induced using an automatic infusion system (AIS) or a peristaltic infusion pump (IVAC) to administer oxytocin. In the 110 patients who achieved vaginal delivery the total uterine activity required to effect full dilatation of the uterine cervix was found to vary according to parity and cervical score but not according to mode of oxytocin infusion. Irrespective of whether the uterine activity level per 15 min was maintained at between 700 and 1500 kPas or at between 1500 and 2000 kPas, the total uterine activity was similar the lower levels being compensated for by a longer duration. Fetal outcome, in terms of 1- and 5-min Apgar scores and umbilical vein blood pH, was unaffected by the level of uterine activity. The cervical and pelvic tissue resistance varies according to parity and cervical score and the uterus has to achieve a certain total uterine activity in induced labour which is best achieved by maintaining optimal uterine activity levels of 1500–2000 kPas/15 min to effect vaginal delivery of the baby in good condition in optimal time.

Turnbull (1957) suggested that the resistance of the cervix and pelvic floor is much less in multiparae because these structures have been stretched in the previous labour. Crawford (1975) and Rossavik (1978) studied the cervical and pelvic tissue resistance indirectly by studying the work done by the uterus to overcome this resistance. Rossavik (1978) calculated the uterine work as the product of active pressure (in kilo Pascals) and the duration of contractions (in seconds) and termed it the uterine impulse based on $\text{force} \times \text{time} = \text{impulse}$ (Alfonso & Finn 1967). He confirmed the suggestion by Turnbull (1957) that the total uterine work needed to effect vaginal delivery was less in multiparae. Clinical experience and scientific evidence sug-

gests that labour is more difficult when induced with a poor cervical score (Turnbull & Anderson, 1967, 1968). In these circumstances the total uterine work needed may be greater in patients with low parity. Caldeyro-Barcia & Poseiro (1960) recognized that if the intensity of contractions was low, more contractions were needed to effect vaginal delivery.

We have indirectly studied the cervical and pelvic tissue resistance in induced labour by calculating the total uterine activity needed to effect vaginal delivery according to parity, cervical score, and mode of oxytocin infusion.

Patients and methods

Selection of patients and management methods were as reported by Gibb *et al.* (1985).

Uterine activity was quantified during induced

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labour using a transducer-tipped intrauterine catheter attached to a Sonicaid FM3R fetal monitor which was also used for continuous monitoring of fetal heart rate. Patients were allocated to either method of infusion depending on the availability of the equipment. The automatic infusion system (AIS) infused oxytocin according to its closed-loop programme to achieve uterine activity levels of 700–1500 kPas/15 min. Manual override was used after 9 h if labour progress was inadequate. The peristaltic infusion pump (IVAC 503) was operated manually to increase the dosage of oxytocin in a semi-arithmetic fashion until uterine activity was clinically satisfactory or attained 2000 kPas/15 min in a nullipara or 1500 kPas/15 min in a multipara.

The total uterine activity (TUA) was calculated by cumulating all sequential 15-min uterine activity values for each individual labour until the catheter was removed at full dilatation of the cervix. These TUA values were grouped according to parity, cervical score and mode of oxytocin infusion for analysis.

Non-parametric statistical methods were used for the data analysis as the distributions of oxytocin readings as well as the uterine activity levels by parity and cervical score displayed large heterogeneity of variance and were shown to be skew. Hence, median values are presented for these variables and the Mann–Whitney *U* test was used for the comparison of maximum dose of oxytocin and of uterine activity levels by the different methods. The median test was applied to TUA values.

Results

Of the 121 patients 63 were nulliparae and 58 multiparae; 30 of the nulliparae and 36 of the

multiparae had a good cervical score (6–10), whilst 33 of the nulliparae and 22 of the multiparae had a poor cervical score (≤ 5).

Eleven patients (9%) were delivered by caesarean section; all but two were nulliparae. Nine of these patients had been managed by automatic infusion and subsequent manual override. The indications for caesarean section were cephalopelvic disproportion in eight, failed labour in two and fetal distress in one patient. These patients were excluded from the analysis.

The obstetric characteristics and the labour outcome in the 110 patients who were delivered vaginally have been detailed in the previous paper (Gibb *et al.* 1985). The maternal age, height, gestational age, cervical score, mode of delivery, birthweight, Apgar scores and umbilical vein blood pH were not significantly different between the two infusion groups, when controlled for parity and cervical score. The duration of labour was significantly shorter in the peristaltic infusion group except in the nulliparae with a poor cervical score, due to frequent manual override in (53.3%) in the AIS group, and in the multiparae with a good cervical score because labour was short in both infusion groups. Table 1 shows the median maximum dose of oxytocin according to parity and cervical score with different modes of infusion. The only significant difference was in nulliparae with a poor cervical score where the dose was significantly higher in the peristaltic infusion group.

The uterine activity showed an initial significant steep increase (incremental phase) followed by a long period of little increase (stable phase) terminating in a steep rise (terminal phase). The incremental phase corresponded to the increase of oxytocin till the maximum dose was achieved. Most of the cervical dilatation occurred in the stable and terminal phases, the

Table 1. Comparison of median maximum doses of oxytocin given by automatic infusion (AIS) and peristaltic infusion (IVAC) systems

Parity	Cervical score	Infusion system	No. of patients	Median maximum dose of oxytocin	Mann–Whitney <i>U</i> test
Nulliparae	≤ 5	AIS	15	4.9	$U = 21.5$
		IVAC	13	10.8	$P < 0.001$
	≥ 6	AIS	14	6.2	$U = 59.5$
		IVAC	12	8.5	NS
Multiparae	≤ 5	AIS	11	4.0	$U = 39.5$
		IVAC	10	8.0	NS
	≥ 6	AIS	15	4.3	$U = 111.0$
		IVAC	20	7.8	NS

latter phase corresponding to the late first stage of labour. The uterine activity throughout labour was divided into five portions, the first representing the incremental phase and the rest divided into four equal portions. Table 2 compares the uterine activity in these different phases in patients grouped according to parity, cervical score and infusion system. The uterine activity was significantly higher in the incremental, stable and terminal phases of labour in the peristaltic infusion group than in the AIS group. These differences in uterine activity according to parity and cervical score are illustrated in Figs 1 and 2. The total uterine activity performed by each individual patient according to parity, cervical score and modes of oxytocin infusion is given in Fig. 3. The median total activity values in each of these groups is given in Table 3.

There was no significant difference in the total uterine activity between the AIS and IVAC groups of comparable parity and cervical score. There were significant differences in TUA independent of mode of infusion but dependent on cervical score and parity except between that in nulliparae with a good score and multiparae with a poor score. TUA progressively declined from the highest level required in nulliparae with a poor cervical score to the lowest level in multiparae with a good score.

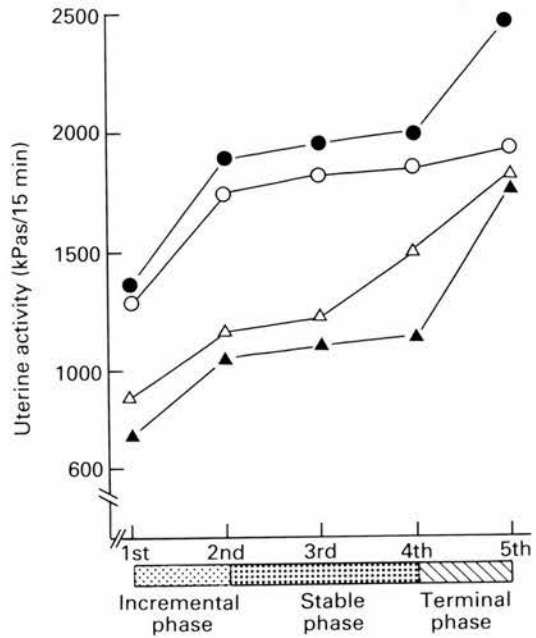


Fig. 1. Uterine activity in different phases in nulliparous induced labour according to cervical score and infusion system. ● Cervical score ≥ 6 , peristaltic infusion; ○ cervical score ≤ 5 , peristaltic infusion; ▲ cervical score ≥ 6 , automatic infusion; △ cervical score ≤ 5 , automatic infusion.

performs work in the form of uterine contractions to bring about cervical effacement and dilatation along with descent of the head through the maternal pelvis overcoming the pelvic tissue resistance. Cervical and pelvic tissue

Discussion

The pregnant uterus adapts its role from that of a receptacle of the fertilized ovum to a powerful muscular organ capable of expelling the fetus. It

Table 2. Comparison of uterine activity (median values) in different phases of labour matched for parity and cervical score by automatic infusion (AIS) and peristaltic infusion (IVAC) systems

Parity	Cervical score	Infusion system	No. of patients	Median uterine activity (kPas)					
				Incremental phase	Stable phase 1st 25%	Stable phase 2nd 25%	Stable phase 3rd 25%	Terminal phase 4th 25%	
Nulliparae	≤ 5	AIS	15	886.5	1170.5	1225	1500	1810	
		IVAC	13	1290	1745	1815	1825	1930	
	≥ 6	AIS	14	730	1062.5	1100	1136	1769	
		IVAC	12	1364	1882.5	1950	1990	2468	
Multiparae	≤ 5	AIS	11	719	1078	1140	1350	1653	
		IVAC	10	1193.5	1800	1970	1890	2103	
	≥ 6	AIS	15	679	1077.5	1060	1165	1515	
		IVAC	20	1012.6	1500	1625	1750	2333	
					$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$
					$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$

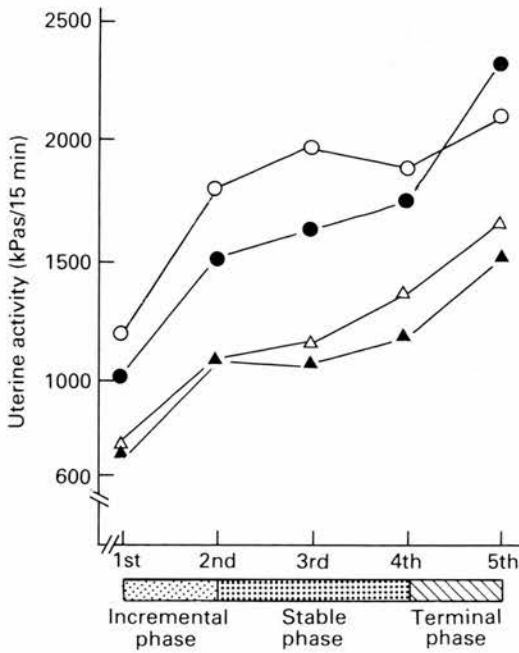


Fig. 2. Uterine activity in different phases in multiparous induced labour according to cervical score and infusion system. Symbols as Fig. 1.

Table 3. Median total uterine activity by parity and cervical score in automatic infusion (AIS) and peristaltic infusion (IVAC) systems

Parity	Cervical score	Total uterine activity (kPas)	
		IVAC	AIS
Nulliparae	≤5	56 878	61 685
	≥6	27 065	35 619
Multiparae	≤5	27 633	35 155
	≥6	15 632	14 488

resistance may differ in induced and spontaneous labour and according to parity, cervical score, presentation, position, maternal height and birthweight of the baby. The total uterine activity required in each case may be considered to be proportional to the cervical and pelvic tissue resistance in the absence of unfavourable fetopelvic relations.

We have reported the total uterine activity in induced labour according to parity and cervical score in patients with vertex presentation delivered vaginally. The total uterine activity required to achieve vaginal delivery was similar in nulliparae with a good score and multiparae with a poor score. The multiparae with a good

score had to perform significantly less and nulliparae with poor score significantly more work compared to the other two groups. This supports the clinical observation that a multipara with a good score when induced has a shorter and easier labour compared to a nullipara with a poor score who has a longer and more difficult labour (Gibb *et al.* 1985).

It appears that the cervical and pelvic tissue resistance as measured by total uterine activity differs according to the cervical score and parity. This supports the suggestion that parity influences the cervical and pelvic tissue resistance (Turnbull 1957). Cervical and pelvic tissue resistance is not significantly different in a given parity and cervical score even when two ranges of 15-min uterine activity levels were maintained by different modes of infusion. The lower level was compensated for by the longer duration of labour consistent with the observations made by Caldeyro Barcia (1960) in spontaneous labour. Neonatal condition was not significantly different irrespective of different uterine activity levels in both groups. It appears that if fetal compromise is encountered in induced labour, vaginal delivery may still be possible by maintaining a significantly lower level of uterine

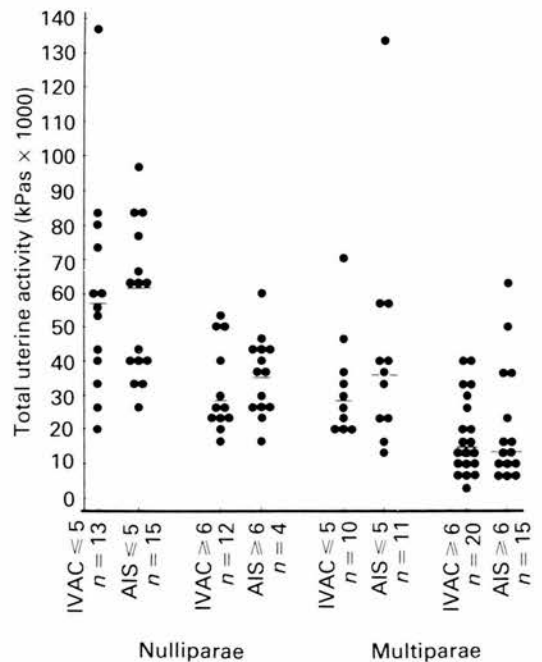


Fig. 3. Total uterine activity according to parity, cervical score (≤5 or ≥6) and mode of infusion. AIS, Automatic infusion system; IVAC, peristaltic infusion system.

activity in the stable phase (700–1500 kPas/15 min). In such situations an intrauterine catheter and maintainance of satisfactory uterine activity levels should be useful. From studies of spontaneous labour both in nulliparae and multiparae (Steer *et al.* 1984; Gibb *et al.* 1984; Arulkumaran *et al.* 1984) it appears that labour progress may be satisfactory if the uterine activity levels are maintained above 700 kPas/15 min.

In induced labour if the progress is not satisfactory even after the uterus has performed more than the 90th centile of the total uterine work according to parity and cervical score, it may indicate possible cephalopelvic disproportion or malposition and in the absence of these factors failed induction of labour. The median total uterine work of these groups indicates that a nullipara with a poor cervical score has to do nearly four times, and nullipara with good score and multipara with poor score nearly twice the total uterine work of a multipara with good score. We conclude that measurement of uterine activity in induced labour may prove useful in conditions of fetal compromise to decide whether to continue labour at lower but acceptable activity levels or to deliver abdominally if the compromise is evident at lower activity levels. Furthermore if the total uterine work already performed is high in a labour with abnormal progress it will alert the obstetrician to the possibility of cephalopelvic disproportion, malposition or failed induction of labour.

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The effect of parity on uterine activity in labour

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Summary. Uterine activity was studied in 40 multiparous Singapore women of Chinese origin who were in normal labour and had a normal delivery. A catheter tip pressure transducer coupled with a uterine activity integrator was used to quantify uterine activity. Normal labour progress was defined as labour progressing within 2 h to the right of a line drawn on the partogram at 1 cm/h in the active phase of labour. A wide range of activity was observed. The median level of uterine activity rose from 815 kPas/15 min at 3 cm dilatation to 1731 kPas/15 min at 9 cm dilatation with an overall median level of 1130 kPas/15 min. The 10th centile value rose from 430 kPas/15 min at 3 cm dilatation to 923 kPas/15 min at 9 cm dilatation. Profiles of dilatation-specific activity values were constructed. These values were significantly lower than in a comparative group of nulliparous patients. The parous uterus requires to expend significantly less effort to effect normal vaginal delivery than its nulliparous counterpart.

The functional difference between nulliparous and multiparous labour has been debated for many years. Clinicians acknowledge that the multiparous woman with a previous vaginal delivery seems more likely to have an easy labour than her nulliparous counterpart. Whether this is due to a later admission cervical dilatation, more efficient uterine action, reduced cervical and pelvic tissue resistance or a combination of these factors is not clear.

Internal tocography with insertion of an intra-uterine catheter by the vaginal route (Williams & Stallworthy 1952) or by the abdominal route (Alvarez & Caldeyro 1950) provides the most reliable recordings of intrauterine pressure. The method of Williams & Stallworthy (1952) was used by Turnbull (1957) in an extensive study of uterine contractions in normal and abnormal labour. Various investigators recognized the

problem of the fluid-filled catheter becoming blocked by vernix, mucus, meconium or blood clot. Steer *et al.* (1978) introduced the catheter tip pressure transducer which obviated these problems.

Quantification of the uterine activity has presented difficulties. Caldeyro-Barcia *et al.* (1957) introduced the Montevideo unit, Hon & Paul (1973) the on-line quantification of the uterine activity unit (UAU) and Steer (1977) the method of quantification of the area under the pressure curve excluding basal tone as kPas/15 min. We have used the pressure data derived from a transducer-tipped catheter and uterine activity integrator quantifying kPas/15 min.

Turnbull (1957) observed lower pressures associated with faster progress in the multiparous patient compared with the nulliparous. He proposed that this was due to reduced resistance of the cervix and pelvic floor requiring less pressure to overcome it. Hendricks *et al.* (1970) and Duignan *et al.* (1975) subsequently showed in cervimetric studies not observing intrauterine pressure that multiparous labour was shorter

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because the cervical dilatation on admission to hospital (admission dilatation) was greater and because constant acceleration of the rate of progress led to apparently faster rates in those admitted in labour at more advanced cervical dilatation. They found great similarity between the progress curves of nulliparae and multiparae corrected for admission dilatation.

Patients in different types of labour would be expected to exhibit different uterine activity profiles. Parity, race, age, height, induction of labour, acceleration of labour, birthweight, multiple pregnancy, presentation and position of the presenting part might be expected to play a role. We have previously reported (Gibb *et al.* 1984) uterine activity profiles in normal nulliparous labour and now report the profiles in multiparous labour and a comparison.

Materials and methods

Patients

The subjects in the study were recruited from admissions to the University Unit Labour Ward, Kandang Kerbau Hospital for Women, Singapore. All were Singapore-Chinese, multiparous, at least 152 cm tall, at term and in spontaneous normal labour. They had regular, painful uterine contractions and the uterine cervix was effaced and at least 3 cm dilated.

Subjects and methods

The subjects were identified as being suitable for the study and informed of the procedure.

The function of the Sonicaid-Gaeltec (Sonicaid Ltd, Chichester, West Sussex) catheter and its calibration were checked as recommended (Sonicaid operating handbook). The sterile catheter was inserted to a length of 30 cm with the patient in the dorsal position. Most often the catheter was passed posterior to the head but if difficulty was encountered an anterior approach was used. A fetal scalp electrode was applied to monitor the fetal heart rate and the patient was placed in a lateral position. Intrauterine pressure and fetal heart rate were continuously monitored with a Sonicaid FM3R fetal monitor. The monitor was switched off and then switched on again after insertion of the catheter and before continuous recording, as recommended in the Sonicaid instruction manual. Uterine activity was quantified on-line with the Sonicaid Uterine Activity Integrator.

Vaginal examinations were made every hour to allocate the uterine activity values to the appropriate cervical dilatation. Labour was considered normal if the cervical dilatation progressed within 2 h to the right of a line drawn on the partogram at 1 cm/h from the admission dilatation. Patients who developed abnormal labour and required oxytocin were excluded from the analysis. Analgesia was offered in the form of pethidine, 50–100 mg every 4 h; epidural analgesia was not used. The intrauterine catheter was removed when the uterine cervix was 10 cm dilated and the patient was placed in the dorsal position to commence expulsive efforts. If delivery had not occurred after 30 min in the second stage or if instrumental delivery was necessary for any reason, the patient was excluded from the analysis.

Neonatal Apgar scores were recorded, the umbilical vein blood pH was measured and the infant was weighed.

Relevant information was recorded in a data coding sheet immediately after delivery.

Analysis of uterine activity

Uterine activity values were analysed individually and collectively using a TRS-80 model II micro-computer with a program, developed by one of us (K.C.L.), that could selectively analyse all or some of the values to derive centiles for each cervical dilatation. The four uterine activity values during 1 h were allocated to the cervical dilatation appropriate to the progress of labour in that hour. Thus, if a patient progressed from 4 to 8 cm dilatation in 1 h the 15-min uterine activity values were allocated to 4, 5, 6 and 7 cm respectively. The second 15-min readings were consistently very high and were rejected for use in profile construction. This high peak occurred whether or not the membranes were artificially ruptured at the time of catheter insertion. 'Dilatation-specific' uterine activity values were analysed collectively.

Results

Table 1 gives the maternal and neonatal characteristics of the 40 patients who fulfilled the study criteria for inclusion, 30 of them had one previous vaginal delivery, eight had two and two had three or more.

The patients were representative of the multiparous population delivered in Singapore.

excluding short patients; with a mean age of 27.9 years, mean height 157.3 cm and mean gestation 39 weeks and 5 days. Table 2 shows the cervical dilatation on admission to the study; 78% of subjects were admitted at ≤ 5 cm dilatation. There was no fetal distress, no infant was depressed as measured by Apgar score and umbilical vein pH and all birthweights were in the normal range.

Analysis of uterine activity

There were 334 15-min values of uterine activity of which 40 were excluded from profile construction because of excessively high values for the second 15-min period. Exploratory analysis of the data showed that some of the distribution of

Table 1. Maternal and neonatal characteristics of the 40 study patients

	Mean	SD	Range
Age (years)	27.9	3.88	(20-36)
Height (cm)	157.3	6.38	(152-170)
Gestation (weeks)	39.6	1.07	(37-42)
Birthweight (g)	3222.0	407.66	(2500-4200)
Apgar score (1 min)	8.9	0.35	(8.0-10.0)
Apgar score (5 min)	10.0	—	—
Cord pH	7.37	0.049	(7.28-7.46)

Table 2. Distribution of the 40 patients by cervical dilatation size at admission

Dilatation size at admission (cm)	No. of patients (n=40)	Cumulative (%)
3	13	33
4	8	53
5	10	78
6	6	93
7	3	100

Table 3. Levels of uterine activity by centiles (excluding second reading)

Cervical dilatation (cm)	Uterine activity centiles (kPas/15 min)					No. of Readings
	10th	25th	50th	75th	90th	
3-9	623	800	1130	1560	2146	294
3	430	538	815	1081	1727	24
4	526	650	782	1500	1876	33
5	553	745	980	1384	1492	44
6	640	803	1050	1307	1859	41
7	736	900	1120	1433	2170	49
8	628	900	1259	1668	2020	49
9	923	1302	1731	2308	2500	54

uterine activity values was asymmetrical when examined for various dilatation sizes. Hence, the median (50th centile) and other selected centiles were derived for each set. Table 3 shows the uterine activity values tabulated in a dilatation-specific manner. These values are illustrated graphically in Fig. 1.

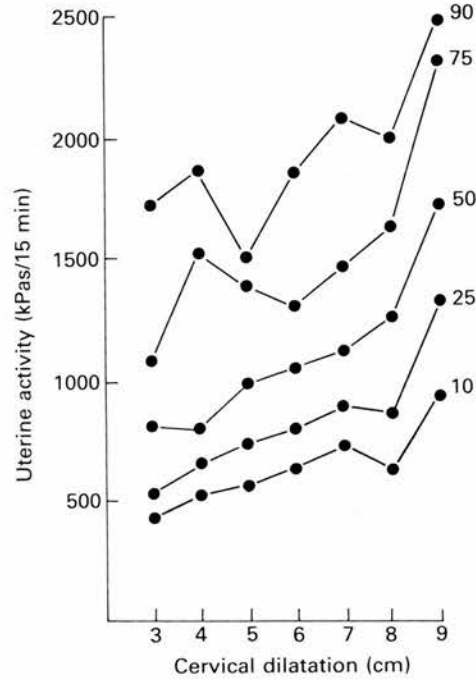


Fig. 1. Uterine activity centile values related to cervical dilatation.

The median value increased slowly from 815 kPas/15 min at 3 cm dilatation to 1259 kPas/15 min at 8 cm dilatation but then rose sharply to 1731 kPas/15 min at 9 cm dilatation. Values of 2500 kPas/15 min occurred on 23 occasions.

Comparison with study of nulliparous labour

These results were compared with those of a parallel study of nulliparous labour.

The only differences in the two study populations were parity, the mean maternal age was 3 years older in the multiparous subjects and the mean birthweight was 50 g higher. Maternal height, gestation, Apgar scores and umbilical vein pH values showed no important differences.

Fig. 2 compares the median values of the activity profiles for the two study samples. The median values at 3, 4, 5 and 6 cm dilatation were shown to be significantly lower in the multiparous group compared with those in the nulliparous group using the non-parametric median test. The differences in uterine activity levels by various dilatation sizes are recorded in Table 4. Although the largest difference of 488 kPas/15 min was recorded for a cervical dilatation of 4 cm this was just not statistically significant at the 5% level ($P=0.0688$) probably because of the small number of readings ($n=69$) available at this dilatation. From 7 cm dilatation onwards, the values in multiparae were also slightly lower than those in nulliparae but the differences were not statistically significant. The overall median value in multiparous labour was 1130 kPas/15 min compared with 1440 kPas/15 min in nulliparous labour.

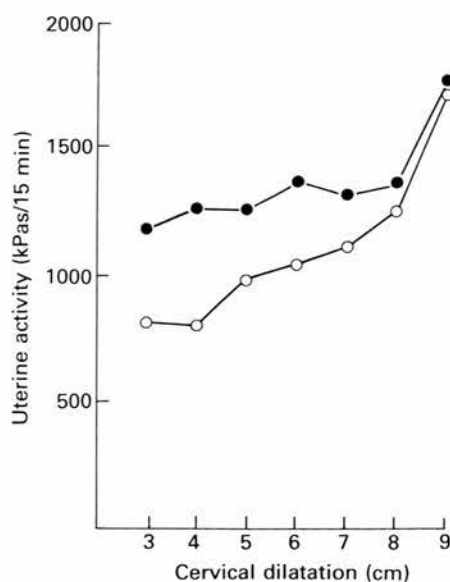


Fig. 2. Comparison of median uterine activity values in nulliparae (●) and multiparae (○).

Table 4. Differences in uterine activity levels at various cervical dilatation

Cervical dilatation (cm)	Uterine activity (kPas/15 min)			
	Nulliparae	Multiparae	Difference	P
3	1196	815	381	0.0366
4	1270	782	488	0.0688
5	1269	980	289	0.0402
6	1375	1050	325	0.0143
7	1320	1120	200	0.1629
8	1367	1259	108	0.5090
9	1785	1731	54	0.8603

The 10th centile of activity, which may represent the lowest value at which normal progress is probable, ranged from 430 kPas/15 min at 3 cm dilatation to 923 kPas/15 min at 9 cm dilatation in the multiparae compared with the equivalent values of 855 kPas/15 min and 1202 kPas/15 min in the nulliparae.

Discussion

In clinical management a line drawn at 1 cm/h in the active phase of labour has been used to distinguish normal from abnormal labour (Philpott & Castle 1972; O'Driscoll *et al.* 1973). The use of such a line to identify patients requiring augmentation of labour results in a high augmentation rate (O'Driscoll *et al.* 1973). Studd (1973) suggested drawing a line 2 h to the right of a nomogram of expected progress and augmenting labour when the cervimetric progress curve crossed this line. We decided to draw a line 2 h to the right of the line drawn at 1 cm/h so that we would include patients with slow but acceptable labour progress.

This study confirms two observations made in a previous study (Gibb *et al.* 1984). Firstly, the uterine activity values for the second 15-min period were consistently high; we have suggested that this is due to release of prostaglandins from the lower uterus during the insertion of the catheter. This also supports clinical observations that uterine contractions seem to increase although only temporarily after artificial rupture of the membranes or vaginal examination. Secondly we observed many high activity values as far as the upper limit of the scale on the machine even in early labour in the absence of hypertonus and maternal voluntary expulsive effort. Such values were not associated with fetal distress in these low-risk labours.

In a study of uterine contractions in normal and abnormal labours Turnbull (1957) found that lower pressures were associated with faster progress in multiparae compared with nulliparae. At that time the concept of the cervimetric progress of labour had not been delineated although work reported by Friedman (1954) was about to gain acceptance. Reliable methods of quantification of activity had not been developed and the catheter used was the fluid-filled type.

Caldeyro-Barcia & Poseiro (1960) referred only indirectly to the effect of parity on uterine activity. Huey *et al.* (1976) found that multiparous patients expended 36% less uterine activity than the nulliparous group from 3 cm cervical dilatation until delivery. We have shown that until 6 cm cervical dilatation uterine activity values in the normal multiparae are significantly lower than in the nulliparous counterpart. The uterine activity profile after 6 cm of cervical dilatation rises to peak values at 9 cm dilatation. These values do not rise as high as in the nulliparous patient and the difference between the two groups is no longer statistically significant. The difference seen between our uterine activity profiles and those obtained by Huey *et al.* (1976) may be due to our strict criteria of selection based on height, rate of progress of labour, normal vaginal delivery and the use of the median rather than mean uterine activity value to construct the profile as there was a wide scatter of uterine activity values for each cm cervical dilatation.

Two features appear in the late first stage of labour. Descent of the head is characteristic of this phase (Friedman 1955) and in the later stages the patient may commence expulsive efforts. It has become clear to us from the tocographic traces that maternal expulsive effort is a feature of the late first stage of normal multiparous labour. It is more likely to be secondary to the descent of the head than to the cervix being 10 cm dilated.

Examination of the tocographic recordings of patients who are 'pushing' shows that the area under the pressure curve contributed by episodes of 'pushing' is negligible. We have shown in our previous study (Gibb *et al.* 1984) that even when uterine activity is quantified in Montevideo units, ignoring pressure due to 'pushing', a steep rise of activity occurs at 9 cm dilatation. Whilst pressure registered as a result of 'pushing' cannot strictly be described as uterine activity it is inseparable from it.

Uterine activity in early labour has the functional result of dilatation of the cervix whilst later

in the first stage descent of the head must be effected as well as cervical dilatation. This may explain why activity rises to a peak at 9 cm dilatation.

The Ferguson reflex was observed many years ago and it was suggested that stretching and dilatation of the upper vagina caused an increase in uterine activity. Vasicka *et al.* (1978) have shown that this is mediated by oxytocin release more of which is detected in the late first stage of labour. Our observation should be the functional result of such release.

Conclusion

We conclude that in Singapore patients of Chinese origin less uterine activity is required to effect normal vaginal delivery in multiparous patients than in nulliparous patients. The lowest value likely to be associated with acceptable progress in labour is 430 kPas/15 min at 3 cm dilatation. The overall median level of activity in the active phase was 1130 kPas/15 min. Uterine activity profiles show a gradual rise in activity until 8 cm cervical dilatation with a steeper rise to peak values before the second stage is reached.

Acknowledgment

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