Chapter 1

Pelvic and fetal cranial anatomy and mechanism of labour

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Introduction

Labour is the series of events whereby the contents of the gravid uterus, the fetus, amniotic fluid, placenta and membranes, are expelled from the pregnant woman. This process usually occurs approximately 280 days from conception.

In order for labour to be successful there needs to be a combination of efficient uterine contractions (power), an adequate roomy pelvis (passage) and an appropriate fetal size (passenger).

The female pelvis

The human being has an unusual pelvis; the distinctive shape of the hominid pelvis is probably as a result of an adaptation to bipedal gait [1].

The pelvis is comprised of two hip (innominate) bones that are joined anteriorly via the symphysis pubis (3.5 cm long), and posteriorly they articulate with the sacrum (12 cm long) at the sacro-iliac joint. Each hip bone is composed of three bones that are joined together at the acetabulum; these bones are the pubis, ischium and ilium (Figure 1.1).

The female pelvis is tilted forwards relative to the spine. The angle of inclination is variable between different individuals and between different races; in adult Caucasian females, the pelvis is usually about 55° to the horizontal plane. Pelvic 'tilt', or inclination, is position-dependent and increases with growth into adulthood [2].

The 'true' pelvis is bounded anteriorly by the symphysis pubis, the iliopectineal line laterally, and the sacrum posteriorly. It is composed of an inlet, a cavity and an outlet (Figure 1.2).

The female pelvis can be classified into four basic shapes [3]; gynaecoid (which is the classical female pelvis and the most common), android (heart-shaped inlet, a funnel-shaped cavity and a narrow outlet), anthropoid (the inlet is oval with the widest diameter being antero-posterior, the cavity is long and narrow) and platypoid (flattened inlet with the antero-posterior diameter at the inlet shorter than a gynaecoid pelvis and the transverse diameter wider) (Figure 1.3). The final shape of the female pelvis seems to be determined by culture and environment, as well as by genetics, with a suggestion that the age of acquisition of erect posture might play a vital role [4].

The pelvic inlet of an adequately sized gynaecoid pelvis is usually more than 12 cm antero-posteriorly, and 13.5 cm in the transverse diameter. The inlet is bounded anteriorly by the pubic crest, posteriorly by the promontory of the sacrum, and laterally by the ilio-pectineal line. The antero-posterior diameter of the pelvic inlet is also known as the true conjugate. However, clinically the most important diameter is the obstetric conjugate, which is the line between the promontory of the sacrum and the innermost part of the symphysis pubis – it is usually more than 10 cm (Figure 1.2). The line between the sacral promontory and the lowermost point of the symphysis is termed the diagonal conjugate. The mid cavity is spacious yet shallow, with both antero-posterior and transverse diameters usually approximately 12.5 cm. The birth canal narrows down inferiorly in the transverse section at the level of the ischial spines, but still measures more than 10 cm. In an ideal pelvis the ischial spines do not indent prominently into the pelvic cavity. The pelvic outlet is bounded by the inferior aspect of the pubic arch anteriorly, the tip of the coccyx posteriorly, and the ischial tuberosities and the surrounding ligaments laterally, with diameters of 12.5 cm antero-posteriorly and 11 cm transversely.

Best Practice in Labour and Delivery, ed. R. Warren and S. Arulkumaran. Published by Cambridge University Press.

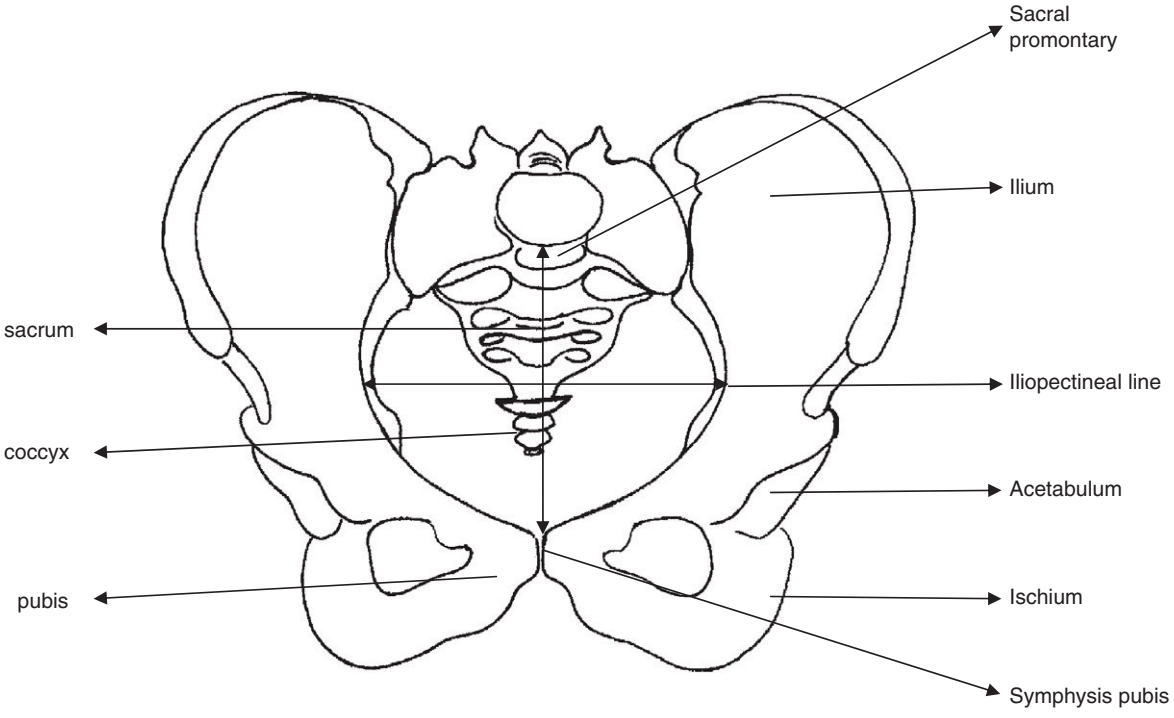
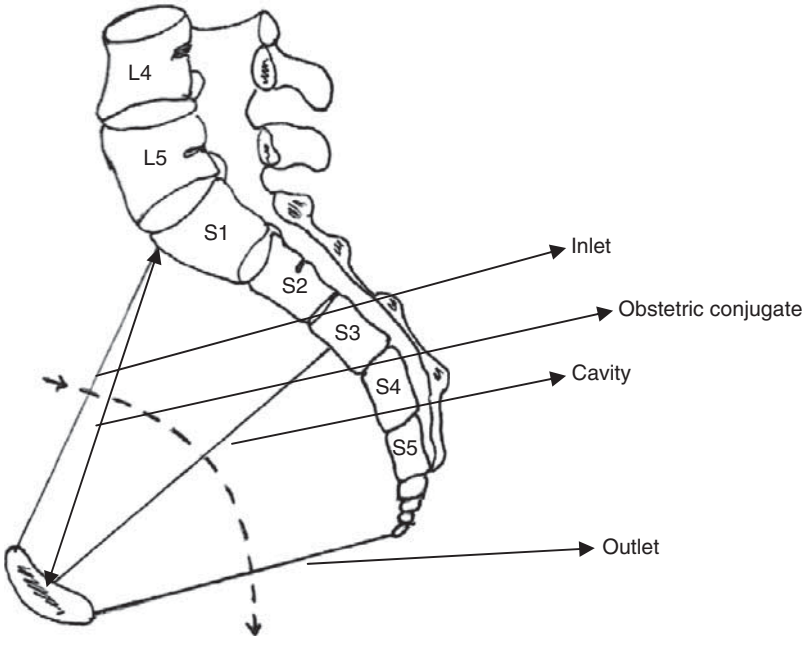


Figure 1.1 The female pelvis. The anterior–posterior diameter of the pelvic inlet is 12 cm and the transverse diameter is 13.5 cm

Figure 1.2 Vertical section of the pelvis



Median view of the pelvis.
Note the curvature of the birth canal_ _ _ _
Also note the AP diameters,
Inlet 12 cm
cavity 12.5 cm
outlet 12.5 cm

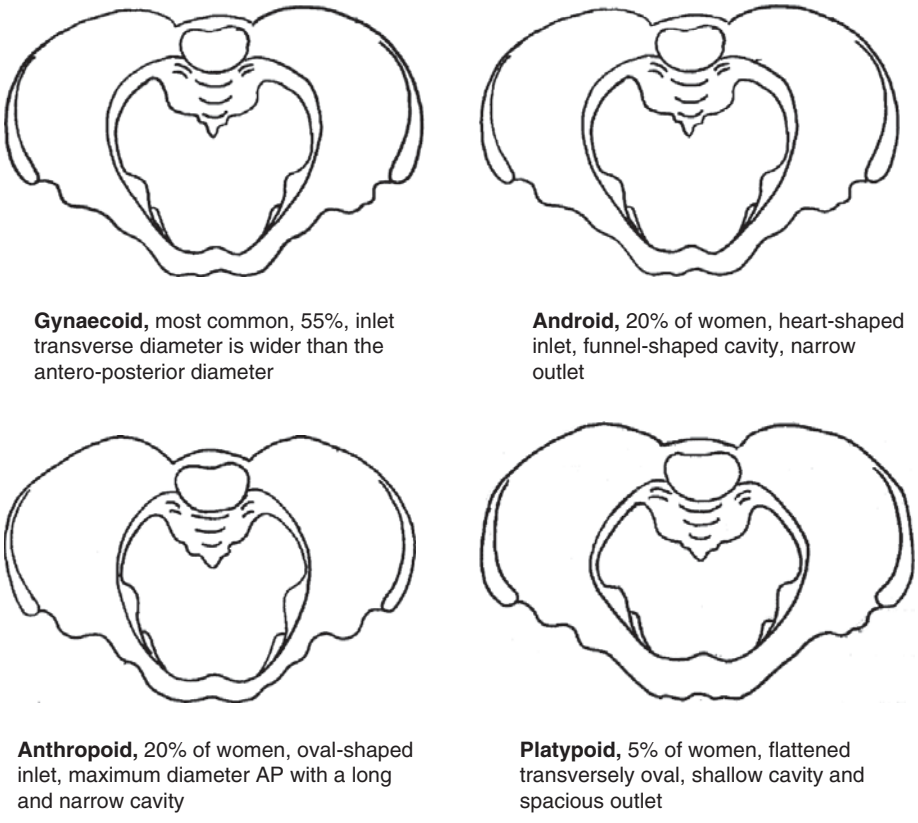


Figure 1.3 Basic shapes of the female pelvis

It is through these various curves and bony canal that the fetus has to pass in order to achieve a successful vaginal delivery.

The fetal skull

Compared to the adult skull, the fetal skull is made of the large cranium and a relatively small face. The fetal cranium is composed of nine bones (occipital, two parietal, two frontal, two temporal, sphenoid and ethmoid). The first five are of clinical importance during birth. These bones are held together by membranes, also called sutures, which permit their movement and overlap during labour. The junction between the two parietal bones is called the sagittal suture, between the two frontal bones it is called the frontal suture, between the two frontal and two parietal bones the suture is called the coronal suture, and the suture between the two parietal bones and the occipital bone is called the lambdoid suture. The diamond-shaped junction where the two coronal sutures meet with the frontal and sagittal sutures is called the anterior fontanelle, whilst the triangular junction between the sagittal suture and the two lambdoid sutures is called the posterior fontanelle (Figure 1.4).

Moulding is the process whereby the anatomical relationship between the cranial bones is changed as a response to external pressures/forces. Moulding occurs in labour to a varying degree as the fetal head descends in the birth canal, allowing the fetal head to accommodate to the geometry of the birth canal. Moulding is often more marked when there is a partially contracted pelvis, as moulding reduces the diameter of the presenting part of the fetal head and helps descent and progress towards a vaginal delivery. Classically, it was thought that moulding is due to overlapping of the parietal bones over other cranial bones. Some authors, however, argue that the actual mechanism is due partially to unbending and straightening of the parietal bones that allow moulding, with a locking mechanism occurring in protracted labours when the free edges of the cranial bones are forced into one another [5,6].

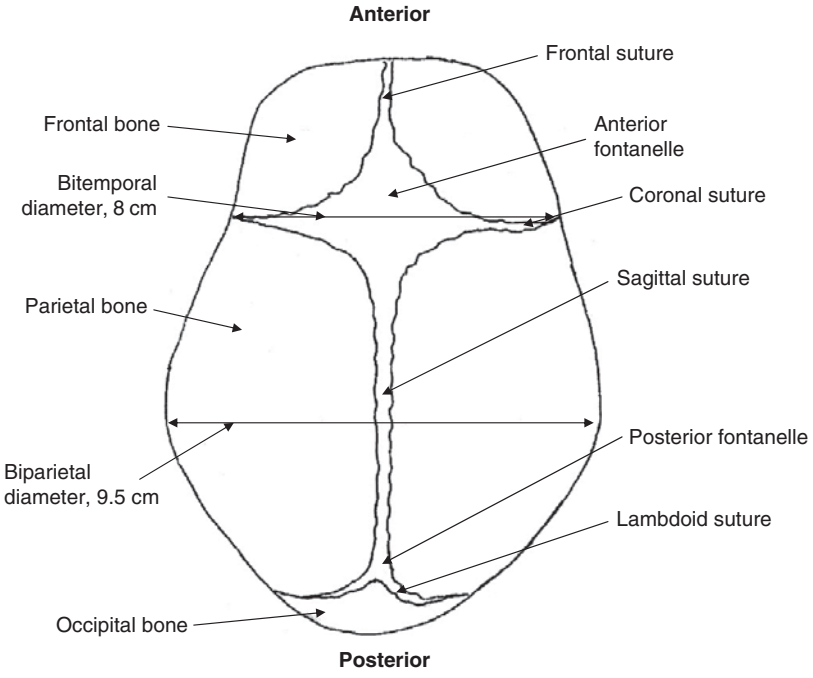


Figure 1.4 The sutures and fontanelles of the fetal skull

For descriptive purposes, the fetal head has been divided into regions that aid in defining the lowermost presenting part on vaginal examination during labour. The vertex is the area between the anterior and posterior fontanelle and extends to the parietal eminences on each side. The occiput is the area behind the posterior fontanelle. The area of the anterior fontanelle is called the bregma and the area in front of the anterior fontanelle to the root of the nose is known as the brow. The area between the root of the nose and the chin is the face (Figure 1.5).

The degree of flexion of the fetal head during labour determines which region of the fetal skull is presenting, and hence it is customary to describe lines that correspond to the diameter of the presenting region of the head (Figure 1.6). The suboccipito-bregmatic (fully flexed vertex) and the submento-bregmatic (face) are the narrowest diameters at 9.5 cm each. The widest diameter is 13.5 cm which is the mento-vertical of a brow presentation and the other diameters are suboccipito-frontal (10.5 cm) and occipito-frontal (11.5 cm); both the latter are seen with deflexed vertex presentations.

Caput succedaneum is the term that refers to the subcutaneous sero-haematic extravasation that usually, but not always, occurs in a labour that is especially protracted and when the vertex is the presenting part. It is a boggy and soft swelling that may extend over the suture line. It usually resolves within a few days after birth, although extremely rarely it may result in alopecia [7]. Preterm prelabour rupture of the membranes seems to be a predisposing factor for in-utero formation of caput succedaneum [8]. The presence of severe caput succedaneum can make defining the position of the fetus in the second stage of labour difficult [9]; however, it seems to have only minimal influence on the pH of blood obtained from the scalp during fetal blood sampling [10].

Parturition, initiation of labour and myometrial contractility

Uterine activity in pregnancy, or 'phenotype', can be described in four different stages during the parturition process. Uterine myometrial activity is quiescent during 95% of pregnancy (phase 0); it is believed that this is mainly due to the action of progesterone. Activation corresponds to phase 1 and is affected predominantly by mechanical influence, but also by uterotrophins such as oestrogen and through increased expression of contraction-associated proteins. Stimulation corresponds to phase 2, when endogenous uterotronins,

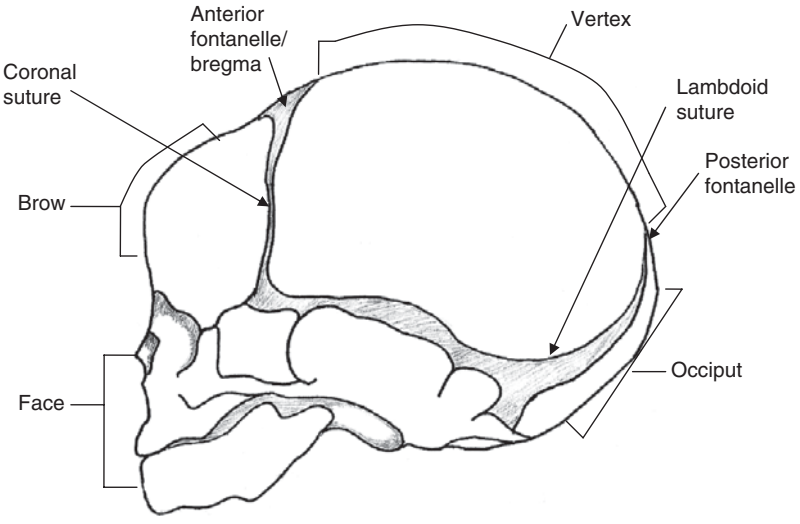
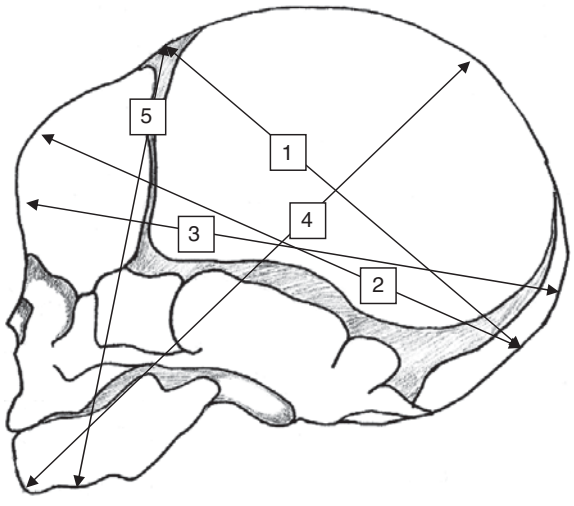


Figure 1.5 The regions of the fetal skull



1. Suboccipito-bregmatic, 9.5 cm
2. Suboccipito-frontal, 10.5 cm
3. Occipito-frontal, 11.5 cm
4. Mento-vertical, 13.5 cm
5. Submento-bregmatic, 9.5 cm

Figure 1.6 The diameters of the fetal skull

including prostaglandins and oxytocin, act on the activated myometrium. Postpartum involution corresponds to phase 3. In this sequence of events, the initiation of parturition corresponds to the transition from phase 0 to phase 1 [11].

The mechanisms that instigate parturition in humans have been elusive to discovery [12]. Unlike animals, the fetal hypothalamic–pituitary–adrenal (HPA) axis has a supportive, rather than an essential, role [13]. During pregnancy the uterus grows under the action of oestrogen; growth ceases towards the end of pregnancy, and at the same time an increasing tension of the uterus may herald the signal of the onset of labour. Relaxation of the uterine myometrium appears to be regulated by progesterone [12]. Progesterone levels do not fall with the onset of labour per se, but it is believed that there is a change in the expression of progesterone receptors from type B to types A and C, constituting a 'functional' progesterone withdrawal [12,14,15].

As pregnancy advances, there is an increased production of placental corticotrophin-releasing hormone (CRH). Maternal levels of CRH increase, peaking at the time of delivery. As a result, the adrenals release cortisol and dehydroepiandrosterone sulphate (DHEAS). The latter is rapidly metabolized by the placenta into oestrogen. Increased cortisol stimulates further production of CRH, generating a positive feed-forward reaction. CRH acts on multiple sites in the mother and the fetus to initiate the changes associated with parturition. Cortisol production by the fetus induces maturation of the lungs via surfactants and phospholipids. The latter enter the amniotic fluid and result in increased levels of cyclooxygenase-2 (COX-2) and prostaglandin E_2. Prostaglandins mediate the release of the metalloproteases that weaken the placental membranes, leading to rupture of membranes [12,16]. Prostaglandins mediate cervical ripening, directly stimulate uterine contractions, and indirectly increase fundally dominant myometrial contractility

by up-regulation of oxytocin receptors and, thereby, allow synchronization of contractions [17].

The microanatomy of the term-pregnant human uterus is that of clearly defined structural elements [18]. In labour, a group of proteins called contraction-associated proteins (CAPs) act on the relaxed uterus to initiate powerful rhythmic contractions that push the fetus down the birth canal. There are three types of CAPs: those that cause myocyte contraction, those that increase myocyte excitability, and those that promote intercellular connectivity [12]. This has led to the suggestion of a functional partitioning of the myometrium during pregnancy, whereby the lower segment displays a contractile phenotype throughout gestation but changing to a relaxatory phenotype at labour, whereas the upper uterine segment maintains a relaxatory phenotype throughout most of gestation to accommodate the growing fetus and adopts a contractile phenotype during labour [19]. Myometrial contraction itself is a function of actin and myocin; this is aided by myocin light-chain kinase, calmodulin, calcium and connexin-43. The electrochemical potential of the myocytes' plasma membrane is intracellularly negative, due to the action of the sodium–potassium pump. This changes at the time of labour, with a low-intensity stimulus only required for depolarization and thereby contraction. Connections between myocytes in labour are formed by paracrine release of prostaglandins $F_{2\alpha}$. The end result is extensive depolarization waves over large areas of the uterus. This activity is fundally dominant, synchronized, (with periods of relaxation in between contractions to allow increased blood flow to the fetus), and leads to expulsion of the fetus [12].

Labour and its mechanism

In order to achieve a safe and successful vaginal delivery and to minimize the risks of complications to the mother and baby, the fetal lie, presentation and position should be determined at the beginning of the first stage of labour.

Lie

This describes the relationship of the fetal longitudinal axis to that of the uterus. It is either longitudinal (which is the case in over 99% of singleton term babies), transverse (0.3%) or oblique. Oblique lies usually change during the course of labour into either longitudinal or transverse.

The main causes for persistent transverse lie in pregnancy include prematurity, multiparity, multiple pregnancy, placenta praevia, a fundal placenta, polyhydramnios, uterine fibromatas, congenital uterine anomalies, intrauterine fetal death and extrauterine masses obstructing the birth canal, e.g. a large ovarian cyst.

Compared to those babies presenting with a longitudinal lie at the onset of labour, babies who are in transverse lie have been found to have a lower absolute pH, more frequent chance of developing severe acidosis, lower birth weight, and are more likely to sustain birth trauma and long-term residual effects [20].

Presentation

The presenting part of the fetus is the lowermost part of the fetal body within the birth canal that can be felt during a vaginal examination. At term most babies present by the vertex. The degree of flexion of the fetal head will determine the presentation, and whereby, for example, a deflexed head may result in a brow or face presentation.

In transverse or oblique lies, the presenting part is usually the shoulder or, rarely, the umbilical cord.

In breech presentation, the description of the presenting part depends on the relationship of the lower extremities to the fetal hips. With extended (frank) breech, both thighs are flexed and both knees are extended, this being the most common (65%). Flexed (complete) breech is when both the thighs and the knees are flexed (25%). Least common is the footling (incomplete) breech, when one hip is flexed whilst the other is extended (10%).

Finally, compound presentations refer to more than one part of the fetal body presenting together, e.g. a hand and vertex.

Position

The fetal position refers to the relation of a reference point that is an easily definable point on the periphery of the presentation, usually a bony prominence, to fixed points of the maternal pelvis. The 'denominator' for the vertex is the occiput (O). For the face, the denominator is the chin (mentum) (M); for the shoulder, the acromion (A), although for practical reasons the back is taken as reference; and for the breech it is the sacrum (S).

Since, at term, the presentation of most fetuses is cephalic, the occiput is used in this text for descriptive purposes. A left-sided (L) occiput is more common than a right (R) occiput. Either side, the occiput can be placed anteriorly (A), transversely (T) or posteriorly (P), resulting in eight possible different positions. The same principles apply to each of the other three presentations when describing their denominator's relationship to the maternal pelvis.

Asynclitism

Asynclitism describes the relationship of the sagittal plane of the fetal head to that of the coronal planes of the symphysis pubis and the sacral promontory. Usually the planes are not parallel and a slight degree of asynclitism is the norm. Significant asynclitism occurs with relative cephalo-disproportion, as the fetal head rocks on entering the pelvis in an attempt to make progress, the infra-supra parietal diameter (8.5 cm) usually being nearly 1 cm shorter than the biparietal. If the tilt of the sagittal plane is directed towards the symphysis pubis, then more of the posterior aspect of the fetus's head is felt vaginally during examination; this is called posterior asynclitism. Anterior asynclitism occurs if more of the anterior part of the fetal head is felt on examination.

Attitude

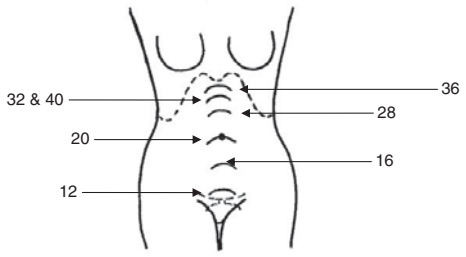
This refers to the characteristic posture that the fetus adopts during the last weeks of pregnancy. Attitude describes the relation of the various fetal parts to other parts of the body, e.g. arms folded over the chest or parallel by the sides. During the latter months of pregnancy, with the fetal head, trunk and limbs all flexed, the universal attitude is that of flexion.

Abdominal and pelvic examination during pregnancy and labour

Abdominal examination

The uterus may be palpated through the maternal abdomen from 12 weeks gestation and the uterine fundus reaches the level of the xiphisternum by 36 weeks.

In addition to the usual standard methods of clinical assessment of inspection, palpation, percussion and auscultation, there are specific palpation methods used in pregnancy; these include the assessment of the symphyseal–fundal height (SFH) and the Leopold manoeuvres.



The abdominal markings of uterine growth related to the number of weeks of pregnancy. At 12 weeks the uterus is just palpable abdominally, by 20 weeks the uterine fundus is at the level of the umbilicus. Maximum fundal height is achieved at 36 weeks gestation.

Figure 1.7 The SFH at different stages in pregnancy

SFH may be used as a screening tool to assess fetal growth; it can be achieved either by hand or by using a tape measure. When a tape measure is used, the measurement is made by identifying the variable point, the fundus, and then measuring to the fixed point of the top of the symphysis pubis, with the option of centimetre values being hidden from the examiner [21].

Alternatively, without a measure, approximately every two finger breadths between the symphysis pubis and the umbilicus equals 2 weeks gestation added to the 12 weeks mark suprapubically; therefore, the uterus is about 20 weeks size when it is at the level of the umbilicus. Above the umbilicus every single finger breadth equals approximately 2 weeks gestation (see Figure 1.7).

In the nineteenth century, Christian G. Leopold described the manoeuvres which came to bear his name. The aim of these manoeuvres is to check fetal lie, presentation, position, station and attitude (see Figure 1.8). Leopold's manoeuvres are undertaken with the patient, having emptied her bladder, in a reclining position, preferably with a left-sided tilt.

First manoeuvre

The uterine fundal area is palpated in order to determine what part of the fetus is occupying the fundus (Figure 1.8a), usually the breech or head; the head is round and ballottable, while the breech is softer.

Second manoeuvre

The lateral walls of the uterus are felt to determine on which side is the fetal back, which is large and firm. The fetal abdomen is soft and extremities are soft and mobile (Figure 1.8b).

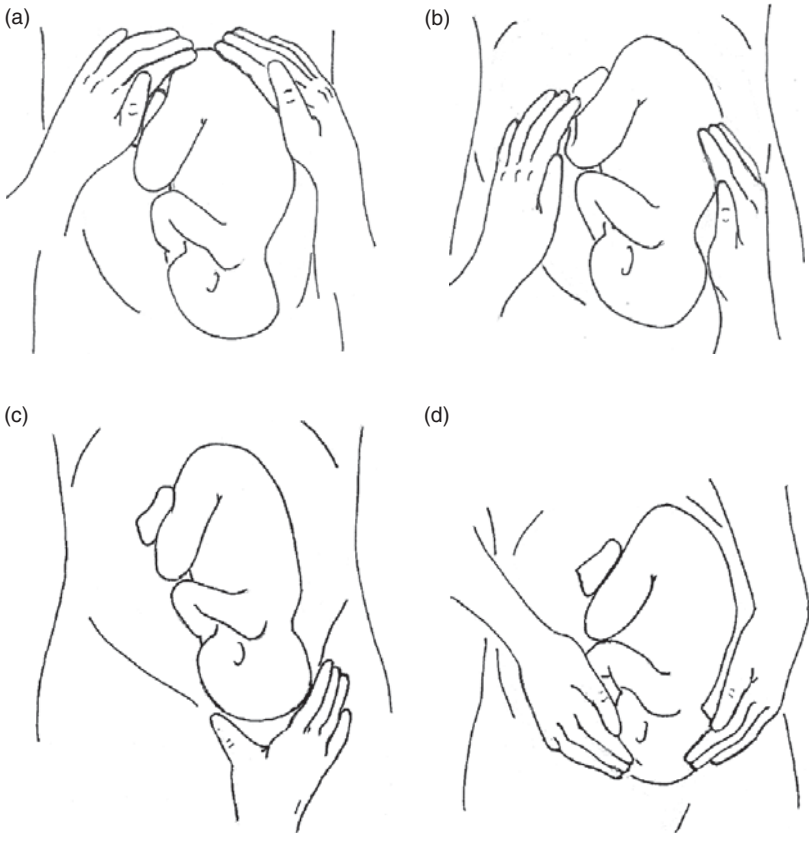


Figure 1.8 The Leopold Manoeuvres

Third manoeuvre

Also called the Pawlik's manoeuvre. A gentle grip with thumb and fingers placed on the area over the symphysis pubis to determine what part of the fetal head is lying over the pelvic inlet and the amount of that presenting part that is palpable abdominally (Figure 1.8c). The same principles apply in differentiating a cephalic from a breech presentation. Pawlik's manoeuvre may be uncomfortable for the pregnant woman and, if examination is performed in this way, it must be undertaken gently. Alternatively, and in preference, the necessary clinical information may be obtained through the fourth manoeuvre.

Fourth manoeuvre

The examiner turns towards the patient's feet and places his/her hands on the lower part of the uterus to confirm the presentation and on which side is the prominence of the presenting part (Figure 1.8d).

When used by experienced clinicians, the above manoeuvres can be used as a screening tool for fetal malpresentation with a high sensitivity (88%) and specificity (94%) [22].

Whichever technique is used, it is customary to describe the amount of the fetal head that is palpable outside of the pelvis in fifths (Figure 1.9). Traditionally, the fifths are described based on the number of fingers needed to cover the fetal head above the pelvic brim. When all of the fetal head is palpable above the pelvis it is described as 5/5 (five-fifths palpable). When the fetal head is engaged, it is usually 2/5th palpable, and when it is deeply engaged it is 0/5th palpable.

On completion of a clinical examination it is usual to describe, in order, the sympyseal–fundal height, fetal lie, presentation and engagement. The fetal heart should be auscultated.

Pelvic examination

This is divided into two types: speculum examination and digital vaginal examination.

A sterile **speculum examination**, allowing visual inspection, is indicated in cases of preterm labour,

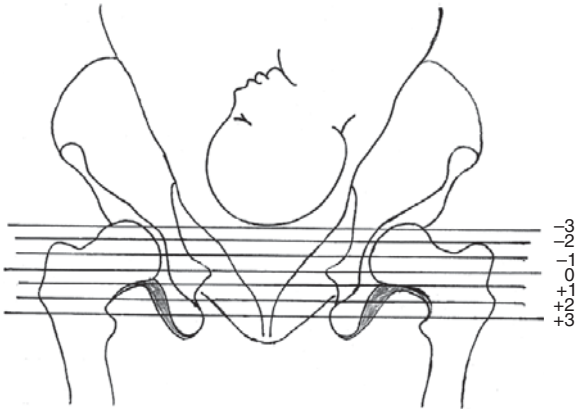


Figure 1.9 Fetal head engagement in the maternal pelvis

Table 1.1 Bishop score for status of the cervix.

Score	0	1	2	3
Dilatation (cm)	0	1–2	3–4	5+
Length of cervix (cm)	3	2	1	0
Station	−3	−2	−1, 0	+1, +2
Consistency	Firm	Medium	Soft	
Position	Posterior	Mid	Anterior	

Note: Score each component and add scores.

vaginal bleeding and suspected rupture of membranes. It must be avoided when there is any suspicion of placenta praevia.

During examination the following should be described and noted: inspection of vulva and vagina to ascertain/establish the presence or absence of any liquor, blood or discharge, and inspection of the cervix to establish its length, thickness and position (anterior, mid-position or posterior).

The features assessed during sterile **digital vaginal examination** change during the course of labour. Throughout prelabour, during assessment for induction of labour, and during the initial stages of labour, it is customary to start with an assessment of the cervical length (effacement), dilatation, consistency, position, and the presentation and station of the presenting part relative to the ischial spines. These features make up the Bishop score (see Table 1.1). Cervical dilatation is a better predictor of the likelihood of successful induction of labour and vaginal delivery than the Bishop score or any other Bishop score component characteristic [23]. In the active stage of labour, the clinician assesses the progress of cervical dilatation, the shortening of the length of the cervix (effacement), the station and position of the presenting part, and whether there is any caput succedaneum, asynclitism and/or moulding.

Cervical effacement

The normal prelabour cervical length is 3–4 cm. The cervix is said to be 50% effaced when it shortens to approximately 2 cm, and fully effaced when there is no length and it is as thin as the adjacent lower segment of the uterus. Effacement is determined by assessing the length of the cervix from the external to the internal os. Complete cervical effacement is associated with a characteristic and profound alteration in the gene expression profile of cervical cells. The majority of these genes encode cytokines, transcription factors and cell-matrix-associated proteins [24].

The process of cervical effacement and dilatation differs between primigravida and multiparous patients. In the latter, effacement and dilatation are occurring simultaneously, whilst in the case of primigravidae, effacement precedes dilatation.

Cervical position describes the location of the cervix in relation to the maternal pelvis. During labour, the position progresses from posterior to mid-position and then to anterior.

Cervical consistency ranges from firm to soft. Cervical softening during pregnancy is a unique phase of the tissue remodelling process characterized by increased collagen solubility, maintenance of tissue strength, and up-regulation of genes involved in mucosal protection [25]. During this process, the junction between the fetal membranes and the decidua breaks down, and an adhesive protein – fetal fibronectin – enters vaginal fluids. This is a clinically useful predictor of imminent delivery [12].

Identifying the **position of the presenting part** is accomplished by identifying the bony sutures of the fetal head, following the suture until it leads to a fontanelle and then identifying the sutures radiating from it. Provided the head is low and the patient has good pain relief, it may also be possible to locate the ear of the fetus and to assess to which side it faces. The nose and mouth can usually be identified in a face presentation, whilst the sacrum, genitalia and anus should be identifiable with a breech presentation.

The **station** of the presenting part describes the distance of the leading bony part of the fetal head relative to the ischial spines. The usual method is to measure the distance above and below the spines in centimetres, with the areas above being given a minus sign and those below the spines being given a positive sign. For example, –2 indicates that the lowest part of the fetal head is 2 cm above the level of the ischial spines, whilst +1 indicates that the head is 1 cm below the level of the spines (Figure 1.9).

Stages of labour, its mechanism and cardinal movements

Labour is divided into three stages, with the first stage of labour beginning with the onset of painful regular contractions resulting in cervical changes. The first stage ends when the cervix is fully dilated at 10 cm. The second stage of labour then starts, ending with the delivery of the fetus. The third stage begins from the birth of the baby and lasts until the uterus is emptied with the expulsion of placenta and membranes.

The **first stage of labour** is divided into a latent phase and an active phase. The **latent phase** is defined as the period of time, not necessarily continuous, when there may be painful contractions as well as cervical change, including cervical effacement and with cervical dilatation up to 4 cm. The established, **active phase of labour** begins when there are regular painful contractions and there is progressive cervical dilatation from full effacement and 4 cm dilatation onwards. The length of the active first stage of labour varies between women; first labours last on average 8 h and are unlikely to last over 18 h. Second and subsequent labours last on average 5 h and are unlikely to last over 12 h [26] [27].

Mechanism of labour

The mechanism of labour, or its cardinal movements, describes the series of changes in the position of the fetal head with its passage through the birth canal (Figures 1.10 and 1.11). These are as follows.

Engagement

This is the mechanism whereby the biparietal diameter of the fetal head enters the 'true' pelvis. The fetal head is engaged when its maximum diameters (suboccipito-bregmatic and biparietal, when the head is well flexed) have passed the pelvic inlet. On engagement, the biparietal diameter lies at the level of the true conjugate and the vertex is 1 cm above the ischial spines. In nulliparous women, engagement usually takes place from the middle of the third trimester onwards, but in some of these women, and in most multiparous women, engagement may not take place until the onset of labour. Studies that have looked at post-term nulliparous patients (defined after 41 weeks gestation) with an unengaged vertex concluded that they are 12.4-times more likely to be delivered by caesarean section than those with an engaged fetal head.

Descent

This is the downward movement of the fetal head in the pelvis. Descent is usually described by the number of fifths of the presenting part still palpable above the pelvis, and by the station (the relative position of the presenting part to the ischial spines). In nulliparous women, descent may not take place until the second stage of labour. Descent is usually brought about by uterine contractions and is aided in the second stage of labour by maternal effort.

Flexion

Uterine contractions will usually cause flexion of the fetal head forwards as it is pressed against the lower segment of the uterus, the pelvic side walls and pelvic floor. This results in the fetal chin coming into contact with the fetal chest and the smallest diameter (suboccipito-bregmatic diameter, in the case of a fully flexed head) continues to pass through the birth canal.

Internal rotation

This is the gradual turning of the fetal head (which usually enters the pelvis with the sagittal suture in the transverse) so that the occiput turns to be behind the symphysis pubis (occipito-anterior). In preterm labour and with small babies, labour may progress without internal rotation of the fetal vertex.

Extension

As the fetal head descends to the level of the pelvic outlet, the base of the occiput will come into contact with the inferior margin of the symphysis pubis where the birth canal curves upward and forward. The head is delivered through the maternal vaginal introitus by extension from the flexed position. First to deliver is the occiput, then with further extension the vertex, bregma, forehead, nose, mouth and finally the chin.