CHAPTER 1

CEPHALOPELVIC DISPROPORTION – AN OVERVIEW

This chapter defines cephalopelvic disproportion (CPD) and briefly describes how it is diagnosed during a trial of labour. The clinical effects and public health significance of CPD are discussed, especially in the context of health services in sub-Saharan Africa. The chapter presents and discusses evidence for the commonly held belief that CPD is a relatively frequent complication of pregnancy in African women.

1.1 DEFINITION AND CLASSIFICATION

Cephalopelvic disproportion (CPD) occurs in a pregnancy where there is mismatch in size between the fetal head and the maternal pelvis, resulting in 'failure of the fetus to pass safely through the birth canal for mechanical reasons'.[1] This may be caused by the fetal head outgrowing the capacity of the maternal birth canal, or by presentation in a position or attitude that will not allow descent through the pelvis. Untreated, the consequence is obstructed labour, which endangers the lives of both mother and fetus. A clinical classification of CPD was proposed by Craig[2] from Cape Town in 1961. He divided CPD into absolute and relative entities as shown below.

Absolute CPD – true mechanical obstruction

Permanent (maternal):

- Contracted pelvis
- Pelvic exostoses
- Spondylolisthesis
- Anterior sacrococcygeal tumors

Temporary (fetal):

- Hydrocephalus
- Large infant

Relative CPD

- Brow presentation
- Face presentation – mentoposterior
- Occipitoposterior positions
- Deflexed head

This definition is still clinically useful. The most frequent cause of CPD is contracted pelvis with an average sized infant.[1]

1.2. DIAGNOSIS OF CPD: TRIAL OF LABOUR

While Craig's suggested definition of CPD is conceptually clear, the diagnosis of CPD is somewhat more difficult. Explaining the mechanical reasons for failure of descent of the fetal head through the pelvis, Philpott[1] cautioned: 'The difficulty is that these two components each vary from one labour to another in their three-dimensional size and shape and also in the degree to which the fetal head may be permitted to undergo compression without immediate or later damage to the fetal brain. Each of these factors are difficult to quantify and even more difficult to put together as one measurement'.

Measurement of mother and fetus has been attempted as a means of detecting CPD before the onset of labour. Later discussion will evaluate external maternal measurements, internal clinical pelvic assessment, X-ray pelvimetry, and ultrasound and magnetic resonance imaging. It will be shown that none of these methods can reliably diagnose CPD. They may improve the predictive value, but many if not most women will give birth normally even when such measurements suggest an unfavourable cephalic-pelvic relationship.

CPD is best diagnosed by trial of labour in a nullipara. The assumption is that adequate uterine contractions, augmented if necessary by oxytocin infusion, will effect descent and delivery of the fetal head through the birth canal. Failure to do so constitutes CPD. Authors differ on diagnostic criteria. Table 1.1 summarises clinical definitions of the diagnosis of CPD. All studies shown included trial of labour as a prerequisite. With the exception of Tsu,[3] all authors restricted their definitions to nulliparous women. The final arbiter is usually the need for caesarean section or symphysiotomy. Stewart, Cowan and Philpott[4] attempted to confirm the clinical diagnosis of major CPD by performing X-ray pelvimetry after delivery. Some of their findings will be dealt with in the discussion on pelvic contraction in sub-Saharan Africa. The criteria for diagnosis of CPD range from very loose[5,6] to extremely tight.[7] The inclusion by Liselele, Boulvain, Tshibangu, *et al.*[5] of assisted vaginal deliveries and vaginally delivered intrapartum stillbirths is difficult to understand, as CPD frequently is not the reason for such occurrences. Impey and O'Herlihy's exclusion[7] of occipitoposterior positions and deflexed heads strives for purity of definition in terms of 'absolute' CPD as suggested by Craig.[2] However, labour arrest unresponsive to oxytocin does occur in association with malposition and deflexion, and in such circumstances should be categorized as being caused by CPD. A remarkable finding in Impey and O'Herlihy's series[7] was a 68% successful vaginal delivery rate in women who had previous caesarean sections for CPD according to their own strict criteria. Diagnosing CPD is an imperfect activity and it should be accepted that many women whose labour is terminated for 'CPD' may only have relative disproportion or simply inadequate uterine contractions.

CPD is less frequent in multiparous women who have had a previous normal delivery.[10] It may occur if the woman carries a much larger baby than in previous pregnancies, or if there is relative CPD with a fetal malposition. Occasionally, lumbosacral spondylolisthesis may develop between pregnancies and reduce the effective anteroposterior diameter of the pelvic brim, rendering a previously adequate pelvis inadequate.[2] Trial of labour in a multipara is problematic as the uterus may rupture in the presence of CPD if labour is augmented with oxytocin.[1,8,11] Where labour progress is poor in a multipara, Philpott[1] has advised that careful attention be paid to head descent and moulding, as CPD is diagnosed when there is increasing moulding of the fetal head without descent into the pelvis. Clinical experience and skill are thus prerequisites in the assessment of poor labour progress in a multipara.

Table 1.1. Assignment of diagnostic criteria for cephalopelvic disproportion (CPD) in nulliparous women.

First author	Criteria for CPD
O'Driscoll (1970) Ireland[8]	Caesarean section for delivery not occurring within 24 hours of admission in labour, following active management (early amniotomy and oxytocin augmentation)
Stewart (1979) South Africa and Zimbabwe[4]	Minor = assisted vaginal delivery following 6 hours of oxytocin augmentation for poor labour progress (cervix <1 cm/hour) Major = caesarean section for poor progress (cervix <1 cm/hour or head >2/5 above brim with moulding) following 6 hours of oxytocin augmentation for poor labour progress
Mahmood (1988) United Kingdom[9]	Caesarean section associated with 1) first stage >12 hours in spite of effective uterine activity or 2) failure of the head to descend or evidence of severe moulding or fetal distress in later first stage with secondary arrest or prolonged second stage
Tsu (1992) Zimbabwe[3]	Caesarean section or assisted vaginal delivery with arrest or delay of labour, and moulding (+) or caput (+++), with later review of clinical notes by a panel of experienced obstetricians. Includes multiparous women.
Impey (1998) Ireland[7]	Caesarean section at term for a normally formed fetus with a flexed non-occipitoposterior vertex presentation, with secondary arrest of cervical dilatation with the cervix at least 6 cm dilated, unresponsive to oxytocin infusion, in accordance with a standardized protocol for active management of labour.
Liselele (2000) Democratic Republic of Congo[5]	1) Caesarean section for failure to progress in labour, or 2) vacuum or forceps delivery, or 3) vaginal delivery with intrapartum stillbirth
Young (2002) USA[6]	Caesarean section for little or no progress over 2-4 hours with adequate uterine contractions and the cervix at least 3 cm dilated.

In summary, major CPD can be confidently excluded (retrospectively) if labour progresses to vaginal delivery, whether assisted or not. A population of women who have caesarean sections for poor progress in labour will include all those who had true CPD, and a variable number with relative CPD and no CPD. This latter proportion of 'false positives' will likely depend on the prevalence of CPD in that community, and the threshold for caesarean section in the institution studied.

1.3. CPD AS A PUBLIC HEALTH PROBLEM

Obstructed labour, the direct clinical consequence of CPD, is responsible for 8% of maternal deaths worldwide, according to figures quoted in the 2005 World Health Report of the World Health Organisation (WHO).[13] The report estimates that, in 2000, obstructed labour complicated 4.6% of live births (six million births), resulting in 42 thousand maternal deaths, most in sub-Saharan Africa. In addition, it is likely that obstructed labour played a role in a high proportion of deaths that were caused by postpartum haemorrhage and infections, which are classified separately in the report (Figure 1.1). The South African Confidential Enquiries into Maternal Deaths[14] found that obstructed labour contributed directly to 4.1% of maternal deaths in 1999-2001, as a predisposing factor for postpartum haemorrhage or puerperal sepsis.

The only treatment for absolute CPD is caesarean section, symphysiotomy or fetal craniotomy.[2] Without such relief, the consequences are serious. In a classic review, Philpott[15] described the natural history of obstructed labour in primigravid and multigravid women. In the primigravida, sustained contractions result in fetal anoxia and death, with eventual delivery of a macerated, collapsed and infected baby, frequently followed by atonic postpartum haemorrhage with or without puerperal infection. The survivor may be left with vesicovaginal or rectovaginal fistula, infertility and chronic pelvic pain.[11] In the multigravida, uterine rupture is the rule, usually associated with extrusion of the fetus into the abdominal cavity, and maternal death from massive internal haemorrhage.

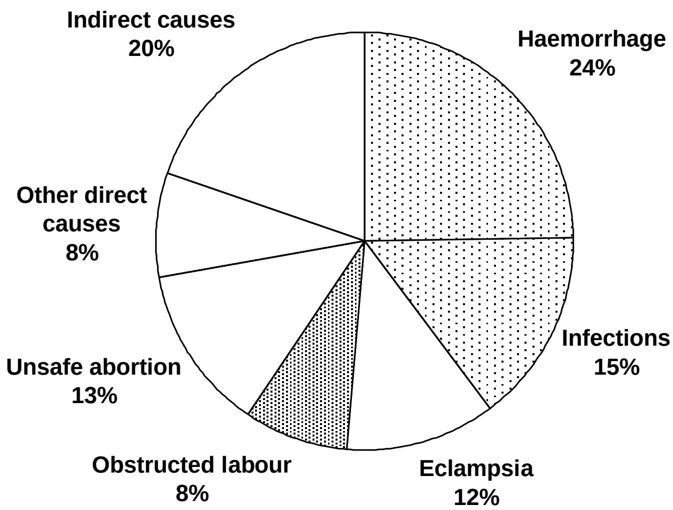


Figure 1.1. The contribution of obstructed labour (dark shading) to the causes of maternal mortality worldwide. In addition, a significant but unknown proportion of deaths resulting from haemorrhage and infection (light shading) may be associated with obstructed labour. (Adapted from the WHO's World Health Report 2005.[13])

1.4. PREVALENCE OF CPD

Estimates on the prevalence of CPD vary widely, depending on the criteria for diagnosis. Where CPD is diagnosed by the need to undertake caesarean section for poor progress in labour, this further depends on the clinicians' threshold for caesarean section. Uncritical reading of the literature might suggest that CPD is common in Europe and the USA, and less so in Africa. Mahmood, Campbell and Wilson,[9] reporting on white primigravidae in the United Kingdom, and Young and Woodmansee,[6] describing a private practice population of mostly white primigravidae in the USA, showed prevalences of 13% and 12% respectively. However, United States National Center for Health Statistics figures,[16] based on over eight million births from 1995 to 1997, suggest that the caesarean section rate for CPD is 2.3% in the USA for infants weighing 3000 to 3999 g at birth, and 5.8% for those weighing 4000 g or more. African estimates of CPD prevalence, based on the need for caesarean section, vary from 2.8% and 4.5% in Nigeria[17,18] to 4.3% in the Democratic Republic of Congo[5] and 4.7% in Johannesburg, South Africa.[19] A systematic review of caesarean section in Africa, published by the MOMA study group,[20] reported rates of CPD ranging from 1.4% to 8.5%. CPD was found to be the commonest indication for caesarean section in sub-Saharan Africa.

O'Driscoll, Jackson and Gallagher[8] studied 1000 consecutive Irish primigravidae and found that disproportion could be confirmed in only 0.9% of these women. They felt that reported high rates of CPD from other centres were the result of 'confusion between inefficient uterine action and cephalopelvic disproportion'. Their series showed how a closely monitored trial of labour, with early recourse to oxytocin stimulation ('active management of labour'), could produce safe and successful vaginal delivery in almost all primigravidae. In a later review, O'Driscoll and Meagher[12] wrote that obstetricians' preoccupation with CPD could be traced to the early 20th century when rickets was an important cause of pelvic contraction in European women. 'Ironically', they stated, the art and science of pelvimetry ‘was perfected at the same time that the conditions that gave rise to rickets were eradicated’.

In similar work in Zimbabwe in 1972, Philpott and Castle[21,22] followed the progress of 624 primigravidae in labour. By using a policy of epidural analgesia, amniotomy and oxytocin stimulation in women who crossed alert and action lines on a labour graph, only 16 (2.6%) required caesarean section. The presence of CPD was confirmed by performing X-ray pelvimetry after delivery.

It is likely that women of African descent are at greater risk for developing CPD. A direct comparison of labour outcome in primigravidae of different racial groups treated in the same hospital was made in London by Thom, Chan and Studd[23] in 1979. Of 558 white primigravidae, 3.2% required caesarean section for poor progress, compared to 7.8% of 127 black (Afro-Caribbean) women.

1.5. PELVIC CONTRACTION IN SUB-SAHARAN AFRICA

Pelvic contraction, the predominant cause of CPD, is more frequent in Africans than in Europeans. In 1978, Kolawole, Adamu and Evans[24] reported on a comparison of pelvic dimensions between 51 Nigerian and 50 Welsh women using single lateral radiographs. Although the Nigerian women were on average 5 cm taller than their Welsh counteparts, they had more shallow pelves, with reductions in all pelvic dimensions. The mean anteroposterior diameter of the brim was 11.1 cm in the Nigerian women, and 12.2 cm in the Welsh women, a statistically significant difference. The authors pointed out, from their own and cited work, that the heads of African neonates were not smaller than those of Europeans.[25] Thus, pelvic contraction (the passage) rather than fetal size (the passenger) should be the cause of CPD in African women. Stewart, *et al.*,[4] in Zimbabwe and South Africa, studied X-ray pelvimetric measurements in 156 African primigravidae who had undergone trial of labour. Women with uneventful labour had mean pelvic brim areas of 97.2 cm^2 (Zulus from South Africa) and 102.2 cm^2 (Shonas from Zimbabwe). The authors cited several studies from the United Kingdom and the USA which found significantly larger mean brim areas, ranging from 115.0 to 137.6 cm^2 in 'normal' subjects. Zulu and Shona women who required caesarean section for CPD had mean brim areas of only 90.1 and 83.4 cm^2 respectively.

Why do African women have smaller pelves? It is tempting to presume a genetic aetiology. A scholarly but entertaining review by Stewart[26] discussed 'nature or nurture?' in pelvic size and shape. Genetically, Stewart pointed out, it was self-evident that shorter women would have smaller pelves, and probably, smaller babies. We know, however, from Heyns' work[25] in Johannesburg in the 1940s, that African newborns have head circumferences no different from Europeans. Regarding an environmental aetiology, Stewart described convincing evidence, mostly from Scotland, that poorer women are shorter and have smaller and more deformed pelves, and consequently more difficult labours. His explanation is that infant malnutrition, before the child walks, causes flattening of the pelvis due to repeated falling on the buttocks. This results in a platypelloid pelvic shape. Interestingly, this pelvic type was commonly associated with CPD in the Zimbabwean and South African study described earlier.[4] Stewart did not dismiss the possibility of racial differences in pelvic sizes and shapes, but emphasized that there was no evidence to support the contention that some races, for example Africans, have genetically distinct pelves. None of the studies comparing African and European pelves have controlled for environmental factors, especially during pelvic development in childhood. Philpott[1] agrees that CPD is an issue of infant and childhood malnutrition. It is conceivable that well nourished African girls will grow up to have pelves that are obstetrically the equal of any in the world. Whatever the cause of pelvic contraction, Africa remains poor and many of its women will have small pelves, and will suffer the consequences of CPD for many decades to come.

Chapter 1: Summary points

- Cephalopelvic disproportion (CPD) is ‘failure of the fetus to pass safely through the birth canal for mechanical reasons’
- There are numerous causes for CPD, but the most frequent is contracted pelvis with an average sized infant
- CPD is best diagnosed by a trial of labour in a primigravida with oxytocin augmentation, if needed, to ensure adequate uterine contractions
- CPD can be assumed when there is a need for caesarean section or symphysio-tomy for poor labour progress, in the presence of adequate uterine contractions
- Untreated CPD results in obstructed labour, which is responsible for 8% of maternal deaths worldwide. Most of these deaths occur in subSaharan Africa
- CPD is more frequent in African than in European women, and complicates between 1.4 and 8.5% of pregnancies
- There is good evidence from radiological studies that African women have, on average, smaller pelves than European women

CHAPTER 2

ANTEPARTUM CLINICAL PREDICTORS OF CPD

This chapter describes the role of antepartum clinical examination and measurement in the possible prediction of CPD. This includes maternal height, shoe size, external measurements, clinical pelvic assessment and head-fitting tests. The significance of non-engagement of the head before labour is discussed. The chapter concludes with a brief review of the history and status of imaging pelvimetry.

2.1. MATERNAL ANTHROPOMETRIC MEASUREMENTS

2.1.1. Maternal height

Short stature in women is known to be associated with difficulties in labour. In 1952, Bernard, cited by Stewart,[26] reported on social status, height, and X-ray pelvimetry findings in a Scottish community. Smaller pelves, prevalence of flat pelvis, and short stature were more frequent in working class subjects. As expected, pelvic size and shape correlated with height. Thirty-four per cent of women shorter than 5 feet (152.5 cm) had flat (platypelloid) pelves compared with 7% of women taller than 176 cm. Jordaan[27] showed a similar association in X-ray studies done in the 1970s on African women in Cape Town. Another Scottish study, published by Mahmood, *et al*.[9] in 1988, reported significantly higher rates of caesarean section (20%) for women shorter than 160 cm than for women taller than 159 cm (9%). However, the 160 cm cut-off had little clinical significance as 80% of the shorter women achieved vaginal delivery. Molloy,[28] from

Australia, made a similar point, finding that women shorter than 5 feet had an almost doubled likelihood of caesarean section (14.8%) compared with taller women (7.6%). Again, this still meant that 85.2% of short women delivered vaginally.

In their original description of the labour graph, Philpott and Castle[21,22] identified a group of nulliparous women who crossed the action line and did not respond to oxytocin augmentation. CPD was the probable cause of poor progress. These 14 women had an average height of 156 cm, only 2 cm shorter than 488 who had entirely normal labours. This difference was not statistically significant. Later work, also in Zimbabwe, by Stewart, *et al.*,[4] showed a larger difference (151 vs. 157 cm) in women with and without CPD respectively. In neighbouring Mozambique, Liljestrand, Bergström and Westman[29] showed that the risk of caesarean section increased markedly below a height of 150 cm, and was 100% (5/5) in women shorter than 145 cm. In addition, short maternal stature was related to increased risk of perinatal loss. At that time Mozambique had a policy that dictated referral of women shorter than 150 cm to provincial hospitals for delivery. The intention was presumably to prevent attempted or inadvertent home delivery and obstructed labour. South Africa has no such policy, perhaps because of low home delivery rates.[30,31] One South African study,[32] done on 50 women in Cape Town, found poor correlation between maternal height and pelvic dimensions on X-ray pelvimetry.

Several other African studies, from the Democratic Republic of Congo,[5] Sierra Leone,[33] Nigeria,[18] and further studies from South Africa[34] and Zimbabwe[3] found significantly increased risks of caesarean section associated with short stature. In each instance, there was still a high likelihood of normal delivery for short women. There may be a place for referral of short women to hospital for trial of labour, although the effectiveness of such policies has not been evaluated.[35,36] It is also possible that clinicians might display a lower threshold for caesarean section in short women, thus perpetuating the notion that short women cannot deliver normally. This contention has also not been tested.

2.1.2. Shoe size

Maternal shoe size (British size less than 4) has been reported to be a predictor of CPD.[36] Conversely, a shoe size of greater than 5 is said to make disproportion ‘rather unlikely’.[37] The first scientific study on this topic was done by Kennedy and Greenwald[38] in the USA in 1980. These researchers found a 60% caesarean section rate for CPD in short women (less than 5 feet tall) who wore shoes of less than American size 6, compared to a 10% rate for women who were taller and wore larger shoes. The study may well have been biased by clinicians having a lower threshold for caesarean section in short, small-footed women. A study done in London by Frame, Moore, Peters, *et al*.[39] found that women with shoe size of 4 or less had a 21% caesarean section rate, as opposed to 3% in women with shoe size of greater than 6. However, Mahmood, *et al*.[9] found no significant difference in mean shoe size between women who delivered vaginally and those who had caesarean section. In their study, shoe size showed weak correlation with the transverse diameter of the pelvic brim, but none with the more critical anteroposterior diameter. Burgess,[35] in a study of Hispanic women in the USA, compared 60 women who had CPD with an equal number who delivered normally, and found that the former were shorter and had significantly smaller feet. However, foot measurement did not add to the predictive value of height in screening for CPD.

There are two South African reports[34,40] on shoe size and mode of delivery. Both showed weak associations between smaller shoe size and caesarean section. Philpott's opinion,[1] based on data not cited nor presented in his review, was that 'foot and external measurements, though smaller than average (in women with CPD), had a wide range and could not be used for prediction or even screening purposes'. There is probably no place for shoe size screening of pregnant women to receive special care in labour.

2.1.3. Maternal and paternal head to height ratio

Connolly, Naidoo, Conroy, *et al*.[41] recently published intriguing results of an Irish case-control study, which compared 60 women who had CPD with an equal number who delivered vaginally. Significant predictors for CPD were nulliparity, maternal short stature, paternal tall stature, increased maternal head to height ratio and increased paternal head to height ratio. Using veterinary data, the authors explained that cow head to height ratio is known to be a risk factor for operative delivery in cattle. They speculated that women with an increased head circumference to height ratio may have suffered a 'less than optimal intrauterine environment with consequent head sparing in relation to height and by extension pelvic size'. The author is not aware of any other studies that have investigated this relationship.

2.2. CLINICAL ASSESSMENT OF THE FETOPELVIC RELATIONSHIP

2.2.1. Clinical pelvic assessment

The practice of clinical pelvic assessment, also known as clinical pelvimetry, has seen a steady decline in the second half of the last century. By the 1950s, external pelvic measurements such as the interspinous, intercristal and external conjugate had been largely abandoned by obstetricians, given that they were 'unreliable in indicating the presence or absence of pelvic deformity and may prove misleading'.[42] However, even recently, internal pelvimetry still had its adherents, for example Donald,[37] who stated in the 1979 edition of his classic textbook that 'the primigravida is a dark and untried horse' and that vaginal pelvic assessment should be 'routine practice' at the 36th week of pregnancy. In 1982, Philpott[1] cautioned that 'digital pelvic measurement in late pregnancy is less accurate than most realize or will admit'. He did however support selective use of the diagonal conjugate of the brim as a guide to pelvic adequacy, but not as a replacement for a trial of labour. The 2005 edition of the respected Williams Obstetrics textbook[43] still includes a detailed description of clinical diagonal conjugate measurement.

Very few studies have evaluated clinical pelvic assessment in the prediction of CPD. Megafu[18] performed pelvic assessments on 217 nulliparous Nigerian women at term and classified six as contracted, 31 as borderline and 179 as adequate. Three (50%) of the six with contracted pelves, four (13%) of the borderline and 14 (8%) of the adequate group required caesarean section. This meant that assessment of pelves as borderline or contracted missed 14 of the 21 women who had CPD. Clinical pelvic assessment therefore gave misleading information. Rather better results were reported by Bauer, Kingu, Lausen, *et al.*[44] from Tanzania, who assessed the diagonal conjugate as a screening tool in 133 primigravidae in the third trimester. Failure to reach the sacral promontory with the examining fingers (n=104) was associated with a 100% vaginal delivery rate, while easy palpation of the promontory (n=9) was associated with a 56% caesarean section rate. The authors claimed, with no evidence from their results, that simplified pelvic assessment along these lines would 'reduce fetal and maternal mortality as well as reduce costs in health care facilities.'

In 1993, Hanzal, Kainz, Hoffman, *et al.*[45] from Austria revisited external pelvimetry in a case-control comparison of 107 women with CPD. Using multiple linear regression, they found the external conjugate diameter to be an independent predictor for CPD. Differences in measurements were however small, and the authors concluded that determination of external pelvic measurements does 'not allow one to identify clearly women in whom a trial of labor is not justified'. In a more recent study, Liselele, *et al.*[5] investigated external pelvimetry in a large group of nulliparous women in the Democratic Republic of Congo. They found transverse diagonal measurement of the Michaelis sacral rhomboid area (taken with a tape measure on the skin of the lower back) to be an independent predictor of subsequent CPD. The authors suggested that this measurement could be combined with maternal height as a means of identifying women at risk for disproportion, so that they could be referred for hospital delivery. These findings have not been validated.

In the author's experience, internal clinical pelvic assessment is invasive, painful and difficult, and may give misleading information. A recent review[46] of the performance and utility of routine clinical pelvic assessment in 660 women in two American military hospitals showed that the results of this examination were uniformly ignored by obstetric staff and provided no useful clinical information. The authors recommended that the practice should be abandoned. No randomized trials have evaluated a policy of routine or selective antepartum or intrapartum clinical pelvic assessment. There is probably no place for antepartum clinical pelvic assessment in obstetric practice anywhere.

It has been suggested that there is value in selective intrapartum clinical pelvic assessment, or, more precisely, measurement of the diagonal conjugate.[47] The widely distributed South African midwives' textbook, the Perinatal Education Programme Maternal Care Manual,[48] describes intrapartum clinical pelvic assessment as an adjunct in the evaluation of a woman who has poor progress in labour ('powers, passage, passenger'). The manual includes a separate 'skills workshop' which describes the technique. There appear to be no studies that have investigated the value of intrapartum clinical pelvic assessment in cases of poor labour progress.

2.2.2. Non-engagement of the fetal head before labour

Older obstetric texts made much of the phenomenon of lightening. This is the feeling of the baby 'dropping' as its head engages in the pelvis in the last weeks of pregnancy, before the onset of labour. Hunter[42] remarked, in 1951, that 'if the head has not completely engaged in the pelvic cavity by the 36th week of pregnancy at latest, in either a primigravida or a multigravida, a vaginal examination is essential'. The concern was that non-engagement of the head provided an early warning of CPD. Formal study of antepartum head descent was not done until 1975, when Weekes and Flynn[49] reported on their findings in 462 consecutive English primigravidae. They revealed that only 23% showed head engagement by the end of the 37th week. Engagement occurred in the majority of pregnancies at 38 to 42 weeks. The median interval between engagement and delivery was 10 days. The study provided good evidence that lightening does occur, but that it occurs much later than was traditionally thought. Citing Weekes and Flynn, Donald[37]still insisted that 'a high head at term in a primigravida is not a welcome finding'.

It has been said that many African women may not experience lightening at all, and that head engagement is often delayed until late in the first stage of labour.[1] In 111 Zimbabwean nulliparae, Stewart and Philpott[50] found the mean level of the head on admission in labour to be 3.3 fifths, well above the two-fifths level that corresponds to engagement. Megafu[18] observed engagement before the onset of labour in only 19% of 284 Nigerian nulliparae, and suggested that non-engagement in these women should not be taken as evidence of CPD, as the majority delivered normally. The reason for late engagement in African women is unknown. Stewart, *et al.*[4] and Megafu[18] have ascribed this to a greater angle of pelvic inclination, but Briggs,[51] with the aid of lateral X-ray pelvimetry in Nigerian women, could find no association between delayed engagement and the angle of pelvic inclination. Another possibility is one frequently stated by clinicians, that African women have strong pelvic support structures that may resist passive descent of the fetal head. This is partially borne out by recent work comparing African American with white women. In two studies, genuine stress incontinence, a condition related to weakness of pelvic supports, was found to be significantly less frequent in African American women.[52,53] Also, magnetic resonance imaging has demonstrated greater levator ani muscle bulk in a small sample of such women compared with white Americans.[54]

2.2.3. Head-fitting tests

With non-engagement of the head at term, a suggested method of testing the cephalic-pelvic relationship has been a head-fitting test. If the head can be forcibly pushed into the pelvis by the obstetrician, CPD can be excluded. The head is not expected to stay engaged in the pelvis as a result of this maneuver, which is merely a test of fit. Munro-Kerr's head-fitting test is probably the most well known.[55] The obstetrician, standing on the woman's right side, attempts to push the head into the pelvis with the left hand while feeling for descent with fingers of the right hand in the vagina. Descent and engagement of the head provides reassurance, while failure of descent, and especially overlap of the head above the symphysis, suggests the possibility of CPD. Donald[37] described a method without a vaginal examination, using both hands to push the head down.

None of the head-fitting tests have undergone scientific scrutiny, and their predictive values are unknown. Philpott's opinion[1] was that if descent occurred (positive test), the test was valuable. A negative test, however, could be attributed to many factors other than CPD. As recently as 1997, in an editorial in Tropical Doctor, Payne[56] advocated head-fitting tests for women with a high head at term. The editorial was heavily criticized in subsequent correspondence in the journal. The writers came out in support of trial of labour rather than antenatal measurements and maneuvers for diagnosis of CPD.[47,57-59]

Since head descent is unusual before the onset of labour in African women, head-fitting tests would have to be done in a majority of African pregnancies. This practice should be discouraged unless research shows substantive benefit rather than provision of misleading information.

2.2.4. Estimation of fetal weight

CPD describes a mismatch between fetus and pelvis – a large baby, a small pelvis, or both. Much of the discussion so far has focused on maternal height and pelvic size. In addition, clinical estimation of fetal size may have the potential for identifying pregnancies at risk for CPD. This is mostly an intrapartum clinical activity and will be discussed in detail in Chapter 4.

2.3. PELVIMETRY USING IMAGING TECHNOLOGY

This literature review is concerned primarily with the application of clinical methods in the prediction of CPD. However, a brief discussion on the history and current status of imaging pelvimetry and cephalopelvimetry would be appropriate. Imaging methods have been essential to the development of an understanding of CPD.

2.3.1. X-ray pelvimetry

The 1920s and 1930s brought refinements in X-ray diagnostic technology, medicalisation of obstetrics, and improved safety and utility of caesarean section for disproportion. Radiological pelvimetry provided an opportunity to study the pelves of live pregnant women and possibly to predict the course of labour. Chassar Moir[60,61] wrote an excellent introduction to this science in two reviews published in 1946 and 1947, concluding: 'let no-one suppose that radiology provides an easy short cut to good obstetrics. Only by sound clinical judgment can that end be reached. But sound judgment depends on the observation and appreciation of many diverse clinical features, and it is regarding one of the more important of these that radiology gives a keenness of perception unimagined…'

In 1961, the prominent South African obstetrician Crichton,[62] who devoted much of his research time to X-ray pelvimetry, described his experience of intrapartum cephalopelvimetry in Durban. He added fetal cephalometry to pelvimetric measurements in radiographs of the pelvis to predict the progress of labour. In a randomized trial of 305 high-risk women he compared the performance of cephalopelvimetry with doing no radiological investigation. Cephalopelvimetry was associated with a 43% rate of caesarean section and a 13% rate of neonatal asphyxia. Women who did not undergo the investigation had a 32% caesarean section rate, and 20% of their newborns had neonatal asphyxia. The intrapartum-related perinatal mortality rate was less (3% vs. 5%) in the cephalopelvimetry group. In retrospect, these findings are not that impressive, given the inconvenience of intrapartum radiography and the statistically non-significant reduction in perinatal mortality. It has to be said that Crichton was a man well ahead of his time, as few people in clinical medicine had even heard of randomized trials 46 years ago!

X-ray pelvimetry become popular in some units in developed countries from the 1950s to the 1970s, mainly for predicting outcome of labour in cases of suspected CPD (e.g. high head before labour at term), breech presentation, and previous caesarean section.[37] Usage declined with evidence of a slightly increased risk of malignancies in the offspring of imaged mothers[63] and the realization of limited clinical value.[64] In 1975, Joyce, Giwa-Osagie and Stevenson[65] critically evaluated 55 consecutive antepartum lateral pelvimetries ordered for high fetal head in one British hospital, and could not find a single case in which the taking of the X-ray film made a difference to the clinical management and outcome. Fine, Bracken and Berkowitz[66] compared traditional X-ray pelvimetry views with clinical pelvic assessment in 100 American women and found poor prediction of CPD with both methods. One quarter of women with ‘absolute disproportion’ delivered normally. They concluded that ‘no clear-cut role exists for X-ray pelvimetry in the diagnosis and management of cephalopelvic disproportion.’ Promising findings on X-ray pelvimetry combined with ultrasound assessment of fetal head size were published by Morgan and Thurnau[67,68] in a series of articles describing the ‘fetal-pelvic index’. Subsequently, however, a study with similar methodology gave disappointing results in prediction of CPD and could not validate the findings.[69]

In a recent meta-analysis of four randomized trials of antepartum X-ray pelvimetry, Pattinson and Farrell[70] showed that use of this investigation was associated with increased caesarean section rates and no significant reduction in perinatal mortality rate. One of these trials was performed in South Africa by Thubisi, Ebrahim, Moodley, *et al.*[71] who showed, in 288 women with previous caesarean section, that antepartum pelvimetry was associated with an 84% rate of repeat operation, compared with 58% in women who did not undergo pelvimetry. X-ray pelvimetry probably has no place in the prediction and diagnosis of CPD, in Africa or elsewhere.

2.3.2. Other imaging methods

In the 1990s, conventional X-ray pelvimetry was largely replaced in developed countries by computed tomography (CT) pelvimetry.[72] This had the advantage of a significant reduction in the radiation dose to the fetus. However, no substantial advantage has been shown with CT pelvimetry over convential X-ray pelvimetry in terms of predicting CPD. Ferguson and Sistrom[73] reviewed this subject in some detail in 2000.

In 1987, Deutinger and Bernaschek,[74] from Austria, reported impressive results in measuring true conjugate diameters in 74 women using transvaginal ultrasound scanning. X-ray pelvimetry was also done, and agreement between the methods was considered satisfactory. Similar work was not repeated until 1999, when Katanozaka, Yoshinaga, Fuchiwaki, *et al.*[75] described measurement of the obstetric conjugate by transabdominal ultrasound in 209 Japanese pregnant women. They verified these measurements by X-ray pelvimetry and found very good correlation between the methods (r=0.91), with a trend to more caesarean sections with lower conjugate measurements. Further studies need to be done to evaluate this radiation-free and apparently convenient method of measuring the anteroposterior diameter of the pelvic brim. Information provided by such a method should however provide significantly greater clinical benefit than what X-ray pelvimetry has offered.

Magnetic resonance imaging (MRI) has enjoyed some interest in recent years. This provides high-quality imaging without radiation exposure, giving volumetric calculations for the pelvis and fetal head. A very recent study by Zaretsky, Alexander, McIntire, *et al*.[76] from the USA, reported on 101 women undergoing MRI pelvimetry, and found significant associations between imaged pelvic size and the risk of dystocia requiring caesarean section. The authors reviewed the literature on MRI and traditional pelvimetry modalities and noted that their results unfortunately offered no improvement on previously described methods. They commented that MRI was 'similar to those that have come before; pelvimetry identifies those women at risk for dysfunctional labour but cannot with accuracy predict those who will require caesarean delivery'.

Chapter 2: Summary points

- Short maternal stature is predictive for CPD and may be of value in screening pregnancies for hospital delivery in poorly resourced rural areas**.** However, the majority of short women give birth vaginally
- Shoe size is weakly predictive for CPD and adds little to measurement of maternal height, and should therefore not be used as a screening tool for CPD
- External maternal measurements, despite favourable reports from isolated studies, are of little value in the prediction of CPD
- Antepartum clinical pelvic assessment is invasive and difficult, and may give misleading information. It has little or no value as an antepartum screening tool for CPD
- Non-engagement of the fetal head before the onset of labour is normal, especially in African women. It is not a significant risk factor for CPD
- Head-fitting tests have not been evaluated in antepartum assessment for prediction of CPD. Failure of the head to engage in a head-fitting test should not be used as evidence of CPD
- X-ray pelvimetry has been consistently disappointing as a predictor for CPD, and is now rarely used. Newer imaging methods deliver less radiation to the fetus, but have been similarly disappointing
- Antepartum examination, measurement and imaging rarely, if ever, predicts CPD with sufficient accuracy to preclude a trial of labour

CHAPTER 3

INTRAPARTUM PREDICTION AND RECOGNITION OF CEPHALOPELVIC DISPROPORTION

This chapter reviews the value of intrapartum clinical assessment in the prediction and recognition of CPD. Cervical dilatation and fetal head position are discussed in detail, but the greatest emphasis is placed on estimation of fetal head descent and assessment of fetal skull moulding. The accuracy and reproducibility of these clinical methods is also reviewed.

3.1. CERVICAL DILATATION AND CPD

3.1.1. Friedman's studies

The predominant clinical observation in the assessment of labour progress is cervical dilatation. In 1955 Friedman[77] published his classic paper 'Primigravid labor – a graphicostatistical analysis', in which he described the graphic depiction of increasing cervical dilatation during labour, plotted against time. Using data from 500 labouring primigravidae, Friedman was able to describe labour progress in terms of cervical dilatation, and define the limits of normal. Thirty-nine women (7.8%) in this series were considered, by clinical and X-ray pelvimetry (not by need for caesarean section), to have some degree of CPD. Of 22 with prolonged latent phase, six (22%) had CPD, and of 46 with 'clinical inertia', 13 (28%) had CPD. Friedman did a similar analysis on 500 multiparae, including 29 women (5.8%) with evidence of CPD. In general, multiparous labour was found to be more rapid and efficient than that of primigravidae. In 28 multiparae with prolonged latent phase and 33 with clinical inertia, CPD was infrequent. According to Friedman[10] 'the causal relationship noted for cephalopelvic disproportion in inert primigravid labors was not so found in multiparae. This verifies the frequently stated clinical impression that multiparae behave differently in labor from primigravidae concerning bony dystocia, the former overreacting with strong uterine contractions, the latter underresponding with hypotonic labor'. This implies that a multipara with CPD will contract strongly to overcome the obstruction, with the obvious risk of uterine rupture in the presence of unrecognized absolute CPD.

Friedman and Sachtleben[78,79] followed up with detailed studies of dysfunctional labour, based on data from 28 750 labours in Sloane Hospital, New York. In separate articles, they described protracted active phase dilatation, and secondary arrest of dilatation in nulliparae in 107 and 371 women respectively. The most significant finding was that CPD was the most common cause of secondary arrest (static cervical dilatation for at least two hours) in the active phase of labour. Forty-five per cent of these women had CPD on clinical and X-ray pelvimetry, with 29% of them requiring caesarean section (absolute CPD) and 30% mid-forceps delivery. Typically, CPD was associated with arrest early in the active phase of labour, with occipitoposterior position more frequently associated with later arrest. Oxytocin was found to be effective in restoring labour progress in the absence of CPD. In contrast, protracted active phase dilatation was less frequently associated with CPD, relatively unresponsive to oxytocin augmentation, and best left alone to progress slowly at its own rate.

A subsequent study by Cardozo, Gibb, Studd, *et al.*[80] from the United Kingdom investigated cervimetric labour patterns in 684 primigravidae admitted in spontaneous labour. Interestingly, they found that CPD was associated with primary dysfunctional labour (protraction disorder) that did not respond to oxytocin augmentation, and that secondary arrest in the active phase had a better prognosis, possibly due to its association with occipitoposterior position. These findings are opposite to what would have been expected based on Friedman's work.[78,79] What is beyond doubt is that a trial of labour in a primigravida, with use of oxytocin for poor progress, is the best way to recognize CPD, irrespective of whether there is a protraction or arrest disorder.

3.1.2. Active management of labour

'Active management of labour' as described by O'Driscoll, *et al*.,[8] provided an attractive way of excluding CPD in primigravidae using a labour graph. This included early recourse to oxytocin stimulation if the cervix dilated at a rate of less than 1 cm per hour from the time of diagnosis of labour (Figure 3.1). CPD was diagnosed and caesarean section was done if the fetal head failed to descend once adequate uterine contractions had been achieved. This occurred in nine (0.9%) out of 1000 labours. It was emphasized that true CPD was rare and that the vast majority of women whose cervix dilated at a slow rate simply had inefficient uterine activity, easily corrected with oxytocin infusion.

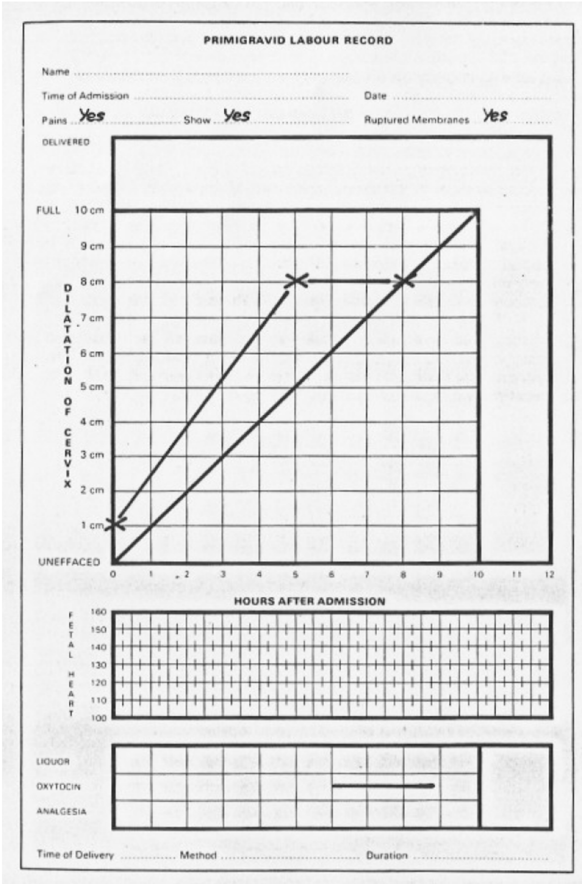


Figure 3.1. Labour graph showing arrest disorder of cervical dilatation at 8 cm with failure to respond to oxytocin infusion, suggestive of CPD. (Reproduced from O'Driscoll, Jackson and Gallagher.[8])

3.1.3. Philpott: alert and action lines

In 1972 Philpott and Castle[21,22] published their classic original description of the composite labour graph, or partogram, in Rhodesia (now Zimbabwe). They showed how the plotting of cervical dilatation against time, using alert and action lines, successfully identified primigravidae with CPD. The alert line, corresponding to progress in cervical dilatation of 1 cm per hour, was drawn from the time the woman was found to be in labour with the cervix 3 cm dilated or more. This line corresponded to the mean of the slowest 10% of labours in their institution. If labour progress crossed to the right of the alert line, this was considered to be abnormal. If the woman was at a clinic, she was transferred to hospital. No specific management was instituted at that stage. Another line, the action line, was drawn parallel and four hours to the right of the alert line. If labour progress crossed the action line, the woman was moved to the obstetric intensive care unit, an epidural block was given, and oxytocin infusion was started. Failure to progress on this regimen constituted CPD and required caesarean section or vacuum extraction. In their sample of 624 primigravidae, 488 gave birth before crossing the alert line, including two who had caesarean section. One hundred and thirty-six labours crossed the alert line, of which 68 (50%) delivered vaginally, 14 by vacuum extraction, before reaching the action line. Of the remaining 68 that crossed the action line, 14 (2.2% of the total) required caesarean delivery and 35 vacuum extraction. The women whose labour progress crossed the action line had significantly smaller pelvic brim areas on X-ray pelvimetry than those with normal labour progress. This demonstrated that CPD was successfully identified using alert and action lines on the labour graph.

Many years after its inception in Zimbabwe, the Philpott labour graph was evaluated by the World Health Organisation (WHO)[81] in a multicentre cluster randomized trial in South-East Asia, in comparison to non-graphic ‘active management of labour’. Use of the ‘WHO partograph’ was associated with a significant reduction in caesarean section rate for CPD.

Further work in South Africa and Zimbabwe by Stewart, *et al.*,[4] confirmed how a trial of labour, with recourse to oxytocin stimulation, successfully identified CPD in primigravid women. While they did not include multiparae in their study, the authors discussed the difficulties in recognizing CPD in such women. In their experience, multiparous women showed unpredictable cervical dilatation rates in the presence of CPD. Some showed normal cervical dilatation rates without head descent. In such cases, the clue to CPD was a high degree of moulding. Undetected CPD in multiparae is potentially dangerous as oxytocin augmentation for poor progress in these circumstances may lead to uterine rupture.[12]

3.1.4. Accuracy and reproducibility – cervical dilatation

Few articles mention the reproducibility of cervical assessment. It is frequently assumed that cervical dilatation is always reported correctly. For labour graphs to be used effectively, there should be some assurance that the examinations done reflect the true cervical dilatation. Neilson, Lavender, Quenby, *et al*.[11] pointed out in their recent review on obstructed labour that 'this measure, although generally accepted, may not be precise and there are no reported trials of either interobserver or intra-observer reproducibility'. In a search for a verifiable means of cervical assessment, Friedman[82] invented a cervimeter in 1956. This was attached to the dilating edges of the cervix, acting as a caliper and giving readings on a scale attached to forceps-like handles. This apparently objective method of obtaining continuous cervical dilatation readings appeared to have some promise, and an electronic version was produced some years later.[83] Unfortunately, technical difficulties did not allow the instrument to go into general use. Very recently, a cervimeter has been described in a report by Letic[84] from Serbia and Montenegro, but this still requires further testing. Estimation of cervical dilatation remains an entirely clinical yet extremely important activity.

The author could find no studies that evaluated interobserver or intraobserver variability in assessment of cervical dilatation in women. Simulated cervical assessment has been investigated using hard circular models very unlike the human cervix.[85,86] Such models are sometimes mounted in labour wards to help clinicians calibrate their measurements. Only one study, by Huhn and Brost,[87] attempted a realistic simulation using soft models made of glove-covered foam, along with traditional hard models. Thirty clinicians were each provided with 12 sets of soft and 12 sets of hard models with different dilatations. Of 360 blinded dilatation measurements, only 19% were exactly correct in cm with the soft models, with 54% correct on the hard models. There was a trend to lesser accuracy among registrars (trainees). It is evident that hard models may be less satisfactory as a simulation compared with soft models. It is also likely that measurement of cervical dilatation is relatively inexact and requires considerable experience.

3.2. OCCIPITOPOSTERIOR POSITION

Occipitoposterior (OP) position has been associated with obstructed labour.[36] Craig's definition[2] of CPD classifies OP position as a cause of relative CPD. This makes sense, as deflexion of the head in OP position results in greater cephalic diameters presenting at the pelvic brim. Yet the association is not strong, and has not been confirmed with any consistency or certainty. Caldwell, Moloy and d'Esopo's landmark work[88] on fetal head engagement in 200 white American primiparae showed that OP position was frequent

(18.5-25.5%) in normal labour, especially in the presence of anthropoid and android pelvis. Their findings, published in 1934, were based on intrapartum stereoradiographs taken of the pelvis and fetal head.

3.2.1. Calkins' study

In a classic description of 2130 labours, Calkins[89] in 1939 should have put to rest much of the dread associated at that time with management of the OP position. His findings, from an 80% white and 20% black community in the USA, are worth describing in some detail. No fewer than 48.3% of women laboured with an OP position, with no significant difference between nulliparae and multiparae. Calkins expressed his doubts about OP position being an abnormality ('malposition') at all. Both first and second stages of labour were somewhat prolonged with OP positions in comparison with occipitoanterior (OA) and occipitotransverse (OT) positions (Table 3.1). In all other respects, OP labours fared no worse, with similar associated perinatal mortality. There were marginally raised rates of operative delivery (20.7% vs. 17.1%), mostly by outlet forceps. For nulliparae the caesarean section and mid-forceps delivery rates were very low (1.1% and 1.6% respectively). These were not broken down into separate OP and OA/OT categories. Calkins felt that labour with the OP position should be managed as any other, with some patience being required 'to the extent of one hour more waiting'. Nowhere in his article is there any mention of dystocia, cephalopelvic disproportion, or obstructed labour. It is difficult to criticize or question these findings, except that OT should perhaps not have been 'lumped' into the OA category. Even so, the morbidity rates associated with OP position were extremely low. Regarding accuracy of clinical assessment as OA, OP or

OT position, Calkins emphasized that every examination was checked by an experienced member of staff and that he expected an error rate of no more than 5%.

Table 3.1. Length of first and second stages of labour in Calkins' series,[89] classified by occipitoposterior (OP) and occipitoanterior or occipitotransvers (OA/OT) positions.

		OA/OT	OP
First stage of labour (hours)	Nulliparae	10.8	12.5
	Multiparae	6.8	7.7
Second stage of labour (minutes)	Nulliparae	52	65
	Multiparae	20	25

3.2.2. Controversy about the occipitoposterior position

In contrast, Friedman,[77] in his analysis of primigravid labour, found OP position to have an incidence of only 17.2%, and to be weakly associated with CPD (12%, vs. 7.8% in his whole study). The caesarean section rate was also higher (5% vs. 1.8%). He suggested that the pelvic abnormality that caused the OP position, i.e. android pelvis, was the cause of dystocia, rather than the OP position itself. In Friedman's analysis[10] of multiparous labour, OP position had an incidence of 15% and was not associated with any aberrations, except for a prolonged deceleration phase. Later work by Friedman and Sachtleben[78,79] on arrest and protraction disorders confirmed that OP position was twice as common in both of these disorders as in normal labour, and was associated especially with secondary arrest late in the first stage. However, the vast majority of women with OP positions delivered vaginally. Cibils and Hendricks,[90] in studies using intrauterine pressure transducers, showed clearly that labour with OP position requires significantly more uterine work and takes longer than with occipitoanterior (OA) position. It is conceivable that the effort for flexion and rotation to achieve full descent requires relatively more frequent and more efficient contractions.

Not all studies are as sanguine about the OP position. In 1975, Sokol, Roux and McCarthy[91] compared 36 American women who presented in labour with OP position to an equal number of parity-matched OA controls, and found increased numbers with protracted cervical dilatation (29 vs. 21), secondary arrest of dilatation (10 vs. 2) and delay in descent (14 vs. 8). Use of epidural analgesia (26 vs. 19), caesarean section (5 vs. 0) and midforceps delivery (22 vs. 1) were more frequent with OP position. It is hard to accept that such a large number of midforceps deliveries were truly necessary. The study was done in a high risk referral unit, and this may in some way have influenced these rates of interference. Briggs,[92] from Nigeria, provided the only African study on the topic, and made a strong case for an association between OP position and CPD. He compared 100 consecutive labouring women with OP positions with 100 OA/OT controls. Duration of labour was significantly longer with OP position, and caesarean sections were more frequent (32% vs. 9%), as were midcavity forceps deliveries (11% vs. 3%). Briggs ascribed these high morbidity rates to associated pelvic contraction common in Africans. These findings may be challenged, again because they represent results from a referral hospital in a country where institutional delivery was not the norm at the time.

Ultrasound, as will be discussed later, has allowed more accurate determination of fetal position in labour. In a recent study, Akmal, Kametas, Tsoi, *et al.*[93] in London ascertained fetal position by transabdominal ultrasound in 601 singleton pregnancies at term in early labour, and 35% of these were found to have OP positions. The caesarean section rate with OP positions was 19%, and that with non-OP positions 11%. Multiple logistic regression revealed OP position to be an independent predictor for caesarean section. The idea that slight to moderate delay in labour progress with OP positions is a normal phenomenon finds support from three studies done on women with delay in the first stage of labour. Cowan, van Middelkoop and Philpott,[94] studying African women in Durban, found OP position to be relatively frequent in association with first-stage delay, but this was mostly benign, with augmentation or expectant management usually followed by vaginal delivery. Women requiring caesarean section for CPD were far more likely to have OA or OT positions. Similar findings have been reported by Handa and Laros,[95] and Rayburn, Siemers, Legino, *et al*.,[96] from the USA.

The finding of an OP position in labour is, if anything, only a weak predictor for CPD. It is of course possible that a fetus with this ‘malposition’ may have difficulty in negotiating a borderline pelvis, but this does not preclude the use of a partogram with a standard trial of labour in the hope of a normal delivery. Vigilance is still necessary, both in the first and second stages of labour. It is however appropriate here to call on the wisdom of Calkins[89] who felt that the ‘inability of the patient to delivery herself spontaneously of an occiput posterior is due to causes other than the occipitoposterior presentation’.

3.2.3. Accuracy and reproducibility – fetal position

Most of the authors on OP position cited above made the assumption that clinical assessments of fetal position were correct. However, a number of recent studies have found clinical examination to be wanting. Rayburn *et al.*[96] in 1989 were the first to point out the value of ultrasonographic determination of fetal position, and since 2002, a number of studies have exposed the limitations of clinical assessments. Scherer, Miodovnik, Bradley, *et al.*,[97] from the USA, performed ultrasound scans in 102 women in the active phase of labour and compared the fetal position obtained with that of the clinicians' digital vaginal examinations. Only 47% of digital examinations were found to be within 45 degrees of the ultrasound position. Forty-five degrees or less is considered an acceptable error in assessment of position. For example, if the ultrasound finds right OT, and the clinician right OP, this as a 45 degree error would be considered acceptable. Akmal, Tsoi, Kametas, *et al*.[98] from London did a similar study on 496 subjects. In 34% of examinations, the clinicians (midwives and doctors) were unable to define any fetal position. Where they did decide on a position, the clinicians were correct (within 45 degrees) in only 49% of examinations. Errors in both of these studies were more frequent with lesser degrees of dilatation, greater degrees of fetal caput succedaneum, and lower levels of clinician experience.

With prolongation of the second stage of labour, assessment of fetal position is important, as knowledge of position is a prerequisite for assisted vaginal delivery. Scherer, Miodovnik, Bradley, *et al.*,[99] in a study on 112 women in the second stage, found clinical digital examination to be incorrect by more than 45 degrees in 39% of women examined by senior registrars and consultants. Studies by Akmal, Kametas, Tsoi, *et al*.,[100] Dupuis, Ruimark, Corrine, *et al*.[101] from France, and Chou, Kreiser, Taslimi, *et al*.[102] from the USA, had similar results, although the error rates were not as great (19% to 29%).

Evaluation of transabdominal ultrasound by Akmal, Tsoi and Nicolaides[103] in the identification of fetal position found very good interobserver variation. However, a further and very recent refinement in diagnosis of fetal position is transvaginal scanning. Zahalka, Sadan, Malinger, *et al*.,[104] from Israel, reported on a study of 60 women in the second stage of labour and found that transvaginal diagnosis of position was more rapid and more accurate than the transabdominal method, previously considered to be the 'gold standard'. The reason for problems with transabdominal scanning, generally overlooked before this, was that the position could not be determined easily if the head was deeply engaged or on the pelvic floor.

OP position can be diagnosed clinically, but this is subject to considerable error. This may bring into question much of the clinically based research on the topic, even that of Calkins and Friedman. The author trusts that their clinical skills were, if only by necessity, more sophisticated than are those of obstetricians in the technology-dependent new millennium.

3.3. FETAL HEAD DESCENT

It is obvious that CPD will not allow easy descent of the fetal head through the pelvis. Almost always, obstruction will be at the level of the pelvic brim.[50,105] Once the widest diameter of the head has negotiated the brim, uneventful descent should be expected, depending on the compliance of the maternal soft tissues, the strength of contractions, and the ability of the mother to push in the second stage.[1,37] Assessing head descent should therefore centre on whether engagement has occurred or not.

3.3.1. Methods of estimating head descent

At this point it is worth defining the concept of engagement and how it is detected clinically. The obstetric definition of engagement is passage of the widest portion of the presenting part through the pelvic brim.[59,106] For a vertex presentation, this is the biparietal diameter (BPD). One cannot talk of degrees of engagement: the head is either not engaged (BPD above the level of the brim of the true pelvis) or engaged (BPD below the level of the brim). Detection of engagement is problematic because this is an internal process and the bony landmarks (brim, BPD) cannot be identified by clinical examination. Therefore, engagement has to be inferred by indirect measurement.

Two indirect measures are available. Station, described by Müller in 1868 (cited by Friedman[107]), assumes that when the leading edge of the vertex is felt at the level of the ischial spines, the biparietal diameter will have just passed through the pelvic brim. The leading edge of the vertex at the level of the ischial spines is designated as being at station 0. If the leading edge is 1 cm below the level of the spines, this is referred to as station +1. Usually, a head on the pelvic floor is at station +4 or +5. A head not yet engaged and still 2 cm above the level of the spines is at station -2, and so on (Figure 3.2). The other method of defining engagement is by abdominal palpation, described by

Crichton[108] in 1962 and published in 1974.[106] This classifies head descent according to the proportion of fifths of the head palpable above the symphysis pubis. A head that is two fifths palpable or lower is assumed to be engaged in the pelvis. This is shown in Figures 3.3 and 3.4. Critique and discussion of the two methods will follow later.

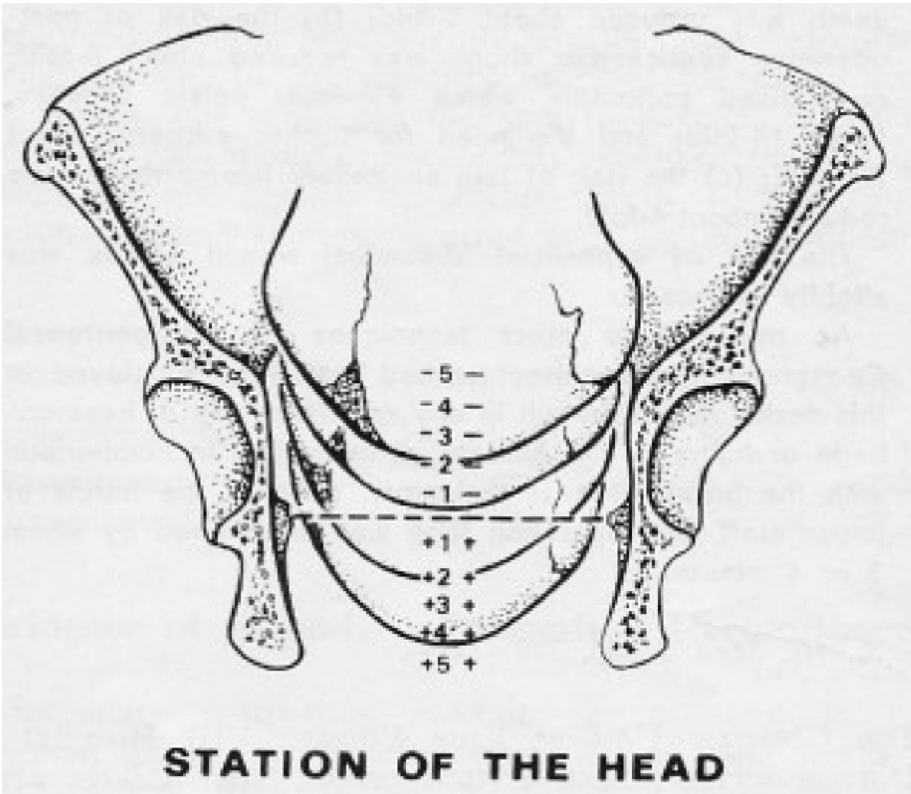


Figure 3.2. Transvaginal estimation of head descent using station. The dashed line represents the bispinous diameter, at station 0. At station -5 to -1, the head has not engaged in the pelvis. At station 0 to +5, the head is engaged. (Reproduced from Crichton[106])

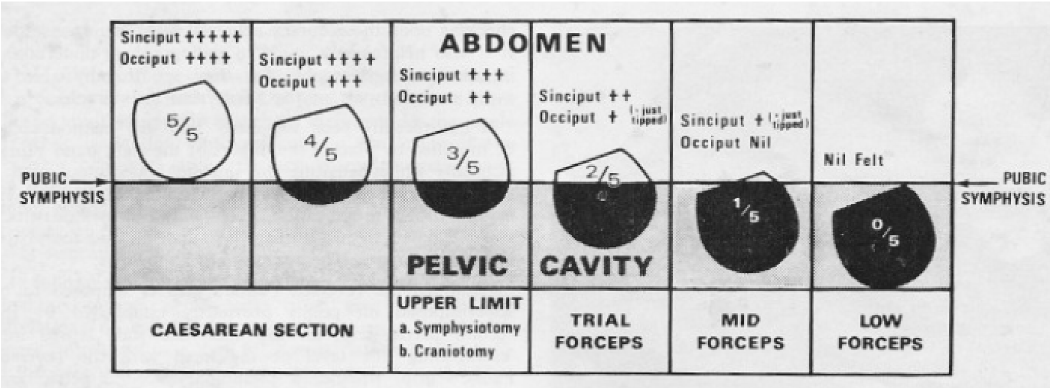


Figure 3.3. Transabdominal estimation of head descent using fifths of head palpable above the pelvic brim, based on palpation of sinciput and occiput. With the head 5/5 to 3/5 above the brim, the head has not engaged in the pelvis. At 2/5, 1/5 and 0/5 palpable, the head is engaged. (Reproduced from Crichton[106])

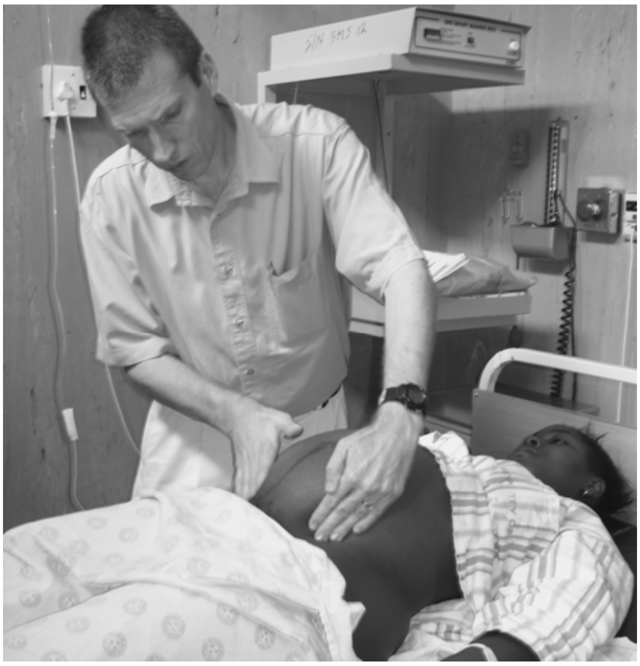


Figure 3.4. Abdominal palpation for fifths of head above the pelvic brim (the author in Chris Hani Baragwanath labour ward).

3.3.2. High head in labour

Friedman and Sachtleben,[109] in their landmark studies of labour progress, measured descent of the fetal head in 421 nulliparae and 389 multiparae. At onset of the active phase of labour the mean station observed in nulliparae was +0.4, and that in multiparae was -0.3. This is in keeping with the well known phenomenon of relatively late descent of the head in normal multiparae.[110]

Friedman and Sachtleben[111] demonstrated that there is sustained but slow descent throughout the first stage of labour, this being accelerated late in the first stage and even more so in the second stage. CPD, according to their definition, was more frequent with higher stations, and absent when the station was +1 or greater at the onset of labour. They showed a close association between high station and dysfunctional labour patterns associated with CPD in nulliparae, but not in multiparae.

A number of studies have subsequently shown a significant association between high head in the active phase of labour and subsequent caesarean section. Stipp,[112] in 1969, reported from the USA on 430 primigravidae with singleton pregnancies at term. In 193 (45%) the fetal head was found to be engaged on admission to the labour ward, and in 237 (55%) it was not. The unengaged group had a nine times higher caesarean section rate (4.6% vs. 0.5%). However, this still meant that over 95% of women with unengaged fetal heads at onset of labour went on to deliver vaginally. Stipp correctly pointed out that an unengaged head in early labour was generally not a reason for concern.

More recent studies with a similar design follow the same trend (Table 3.2). The one exception is that of Falzone, Chauhan, Mobley, *et al*.,[113] who in a prospective cohort study showed remarkably high caesarean section rates (20/33; 61%) in women with unengaged fetal heads. This could have been explained by a high rate of chorioamnionitis and induction of labour in the unengaged group, although multivariate analysis found high station to be the only independent predictor. The specialist team at the institution did not consider any of the caesarean sections to have been unnecessarily performed. The results of the Nigerian study by Briggs[51] bear out the impression that lack of descent in early labour in African women is not abnormal. Diegmann, Chez and Danclair,[114] in a mostly African-American population, reported similar results with only three caesarean sections for CPD or poor progress out of a hundred nulliparae with unengaged fetal heads at the onset of labour. While a high head in early labour may not be strongly predictive for obstruction, this changes as labour advances. Debby, Rotmensch, Girtler, *et al.*,[115] from Israel, showed that 100% of women with a 'floating' head (station -3 or higher) at 7 cm dilatation required caesarean section.

Table 3.2. Comparison of caesarean section rates in studies reporting findings of unengaged and engaged fetal heads in the active phase of labour

First author	Country	Number of subjects	Caesarean section rate (%)	
			Unengaged head	Engaged head
Stipp (1969)[109]	USA	430	4.6	0.5
Briggs (1981)[51]	Nigeria	62	0	0
Falzone (1998)[110]	USA	77	60.6	4.5
Roshanfekr (1999)[116]	USA	803	14	5
Debby* (2003)[115]	Israel	349	17.1	4.2

*'Unengaged' in this study refers to station -3 or higher.

Handa and Laros[95] showed that high station associated with arrest in the active phase of labour was an independent predictor for caesarean section. A problem with most of these reports is that caesarean section as an outcome is entirely influenced by the obstetric befiefs and decision-making in the institution concerned. If the clinicians believe that a high head in labour indicates CPD, they will interrupt that labour and do a caesarean section, which 'proves' that a high head in labour is a predictor for CPD. This is a problem in studies where the observer is also the clinician and surgeon. The possibility of such bias could be reduced by using an observer not involved in obstetric treatment decisions. However, even with a non-participant observer, the clinicians could still perform interventions such as caesarean section based on their observations which may be the same as the observer's. Alternatively, a form of objective verification for CPD would be required, for example X-ray pelvimetry, despite its limitations.

Pelvimetric verification of CPD in cases of poor head descent was provided in Friedman's work.[109,111] Such verification was also forthcoming in two valuable studies from Philpott's obstetric unit in Zimbabwe. These two studies used fifths of head above the brim, and not station, as the marker of descent. In a prospective study that described the original labour graph, Philpott and Castle[21,22] showed that crossing the alert line (136 women) was associated with higher mean level of head (4.1 fifths) at the onset of labour than if labour progressed normally (3.3 fifths; P<0.001). Sixty-eight labours subsequently crossed the action line. At the time of crossing the action line, those with major CPD, (eventually requiring caesarean section), had higher mean level of head (4.0 fifths) than those who delivered normally after oxytocin augmentation (3.3 fifths; P<0.01), or by vacuum extraction (3.5 fifths; $P<0.05$). The finding of major CPD was verified by X-ray pelvimetry. A very similar study[50] was done in the same unit some years later and confirmed these findings (Table 3.3). X-ray pelvimetry verification was again available. It seems clear that failure of descent in the presence of poor progress in the first stage of labour is an important sign of CPD, and may assist in making decisions on obstetric management, such as caesarean section.

Table 3.3. Association between fetal head descent in fifths and delivery outcome in women with poor labour progress from two Zimbabwean studies.

First author		Primary uterine dysfunction: normal delivery	Minor CPD: vacuum extraction	Major CPD: caesarean section or symphysiotomy
Philpott (1972)[21,22]	Number	19	35	14
	Mean level of head in fifths	3.3	3.5	4.0
Stewart (1980)[50]	Number	11	19	46
	Mean level of head in fifths	2.7	3.6	3.8

3.3.3. Station versus fifths in assessing head descent

The importance of assessing head descent for the recognition of CPD is clear. However, there is no consensus about the best clinical method to do this. As stated above, the options are abdominal assessment in fifths, or vaginal assessment by station. The choice seems to be dictated by the obstetric culture of the institution or country concerned. All of the studies described in the above paragraphs, with the exception of the two from Zimbabwe, used station. Philpott,[117] in a description of the labour graph, recommended only the fifths method, this being plotted on the same graph as cervical dilatation. The

WHO partograph follows this exactly.[81] Cronje's South African obstetric textbook[118] mentions only fifths, as does the Perinatal Education Programme midwifery manual.[48] Nel's South African textbook[119] suggests using both fifths and station in describing descent, with the same approach being taken by the British textbook 'High Risk',[120] and by Studd[121] in his review of labour management. Calder,[122] writing in Dewhurst's respected British textbook, briefly compared station and fifths and stated that the latter 'may in the final analysis represent a more valid and reliable measure of progress'. The textbook Williams Obstetrics,[123] from the United States, describes assessment of station in some detail, quoting guidelines from the American College of Obstetricians and Gynaecologists. It makes no mention of fifths or abdominal examination as measures of fetal head descent in labour.

Friedman[107] stated that 'it is essential to delineate the degree of engagement and the progressive descent of the fetal presenting part by means of accurate examinations of station'. He cautioned that station designations only refer to the level of the leading edge of the presenting part, and cannot specify exactly where the biparietal diameter is in relation to the pelvic brim. He acknowledged that an elongated head, as occurs with moulding or caput succedaneum, may give an impression of engagement, with the leading edge below the level of the ischial spines before passage of the biparietal diameter through the pelvic brim (Figure 3.5). Despite these potential shortcomings, Friedman felt that station was reproducible and easy to quantify, using a 'familiar centimeter scale'. Station remains a popular and apparently simple way of estimating descent, although Roshanfekr, Blakemore, Lee, *et al*.[116] commented that 'evaluation of station is rather difficult, and the findings may vary from individual to individual'. What is often not mentioned in the literature is that assessment of station is invasive because it requires vaginal examination, and, in the author's experience, it is frequently uncomfortable for the woman being examined.

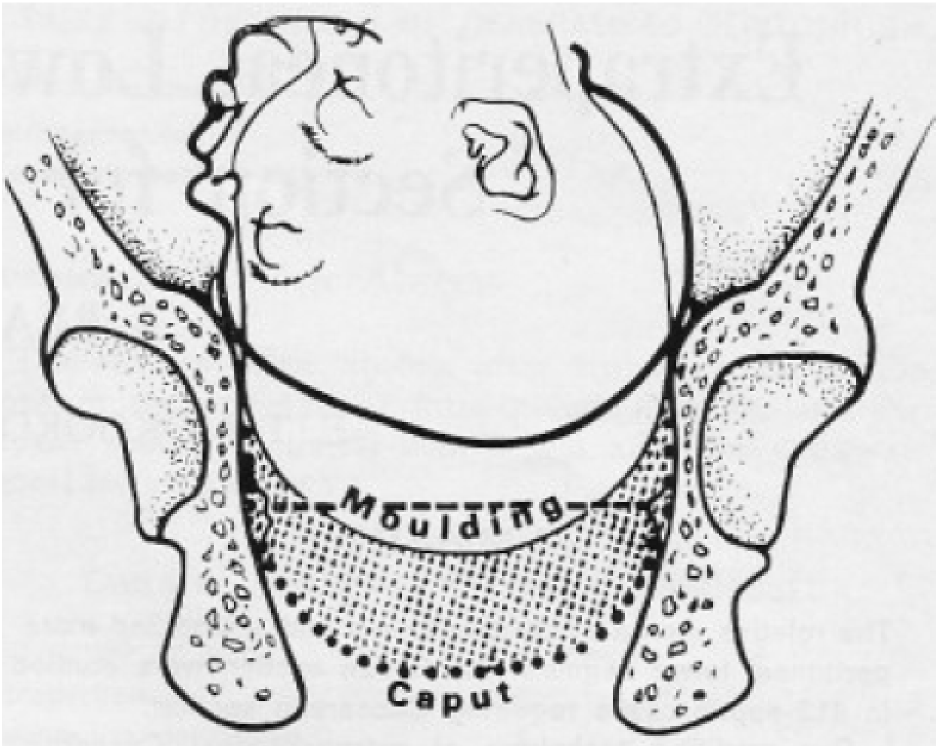


Figure 3.5. Misleading assessment of engagement using station. The fetal head has not engaged in the pelvis, yet moulding and caput succedaneum bring the leading edge below the level of the bispinous diameter. (Reproduced from Crichton[106])

Crichton's description[106] of the fifths method of assessing descent was based on a critique of station. He was not convinced by the assumption of engagement when the leading edge of the head reached the level of the ischial spines. His problem was with the landmarks used: 1) the leading edge of the head was not indicative of the level of the widest diameter of a head elongated by caput or moulding, and 2) the bispinous diameter of the pelvis did not bear a constant relationship to the pelvic brim. Thus, in a woman with CPD (fetal moulding with or without a flat pelvis), station could indicate good descent before the brim had even been negotiated (Figure 3.5). He therefore described the fifths method, using the relative proportions of sinciput and occiput palpable abdominally to determine the level of the head (Figures 3.3 and 3.4). Philpott[1] agreed with the concept of abdominal assessment of descent, and wrote that 'the most meaningful method of recording the level of the head is by number of fifths'. Studd[121] noted in 1973 that 'this new assessment…of head level was easily achieved, being reproducible among both senior and junior staff (and giving) precise appreciation of head level'. Friedman himself[107] admitted that the fifths method was 'a useful adjunct in diagnosing engagement', especially where there was moulding, but remained convinced that it was not as accurate as assessing station, nor as reproducible.

A modification of the fifths method was suggested by Notelowitz[124] in 1973. He recommended that the proportion of fifths could be determined from the number of fingers transversely placed suprapubically over the head. For example, if four fingers could be placed over the head, the head was four-fifths above the brim. This was done with the left hand simultaneously palpating the sinciput and occiput in a reverse Pawlik's grip. Crichton[106] criticized this method as being inexact at lower levels of head such as one-fifth to two-fifths.

The Notelowitz method, using fingerbreadth measurement, raises the possibility of more precise estimation using a tape-measure. The sinciput can be easily palpated and marked on the overlying skin with a pen. The distance from the pubic symphysis to this mark could provide a measure of head descent. This has not been reported in the literature.

It is remarkable that the beliefs of every one of the five authorities above – Friedman, Crichton, Studd, Philpott and Notelowitz – are based entirely on theoretical considerations and clinical experience. No evidence from research is presented to support claims in favour of the fifths or station method over the other in the prediction or recognition of CPD, or as a true measure of engagement. In the years following these debates, only one article has been published on the relative value of abdominal (fifths) vs. vaginal examination (station) for the diagnosis of fetal head engagement. Knight, Newnham, McKenna, *et al*.[125] reported a retrospective study of 104 Australian women in the second stage of labour, who were being evaluated for planned operative vaginal delivery. All underwent both abdominal and vaginal assessments. Abdominal palpation (head one-fifth or less above the brim) as the criterion for expecting successful delivery was a correct predictor in 94% of cases, compared with 80% using vaginal examination (head at station 0 or lower). The station method therefore overestimated descent in a significant number of cases. The authors explained that this discrepancy could have been caused by moulding, based on a suggestive but nonsignicant trend shown on logistic regression analysis. This lent support to Crichton's concerns described earlier. The authors concluded that 'abdominal palpation is important if operative vaginal deliveries are to be avoided when moulding causes the presenting bony part of an unengaged head to be deceptively low in the pelvis'.

This Australian study was only concerned with the second stage of labour, and was limited by its retrospective nature and by the fact that the examinations were done by the same obstetricians who made the decisions on mode of delivery. The authors acknowledged that abdominal palpation had been the preferred predictor in that institution for assisted vaginal delivery before the study was done, and that this could have biased the results. Importantly, the authors stated: 'Ideally, a comparative evaluation of these two methods of examination would require a study in which the clinical examination is performed by one or more experienced persons who are not involved in the clinical care and whose findings are not available for planning the mode of delivery. Such a study would be difficult to perform but the results would be invaluable'. Therefore, a prospective study with a non-involved researcher as suggested, is needed to determine which of the methods is more useful, not only in deciding on assisted vaginal delivery, but in predicting CPD.

3.3.4. Accuracy and reproducibility – fetal head descent

Two recent studies have evaluated transvaginal assessment of station. The first, done in the USA by Scherer and Abulafia,[126] compared clinical assessment of station with 'gold standard' transverse suprapubic transabdominal ultrasound determination of fetal head engagement in 222 women. Assessment of engagement by station showed fair agreement with ultrasound in nulliparae (Kappa = 0.61) and good agreement in multiparae (Kappa = 0.80). Abdominal assessment (fifths) was not compared. A criticism of this study, not acknowledged by the authors, is that their 'gold standard' was not validated, and was based on assumptions gleaned from anatomy textbooks. Dupuis, Silveira, Zentner, *et* *al.*,[127] in France, evaluated 57 doctors' assessments of station in a birth simulator using a mannequin fetus placed at various pre-set stations. More than half of all assessments were incorrect by 1 cm or more, and 12% of unengaged mannequins were assessed as engaged. The authors concluded that 'accuracy of clinical transvaginal examination is poor'. They were concerned that errors based on misdiagnosis of engagement could lead to the performance of ill-advised high forceps deliveries, and suggested appropriate adjustments to registrar training programmes.

The author could find no studies that evaluated measurement of head descent in fifths, either against a gold standard in models, or in terms of interobserver or intraobserver variability.

3.4. MOULDING

Moulding is the change in shape of the fetal skull that occurs in late pregnancy and labour. This is in response to pressure by uterine contractions against the lower uterine segment walls and cervix, and to a certain extent, against the bony pelvis. CPD is thought to cause a high degree of moulding, resulting from the head being squeezed into a contracted pelvic cavity.[3,9,48,120] An important component of moulding is overlap of fetal skull bones along various suture lines (Figure 3.6). This can be easily palpated through a dilated cervix. In his review of CPD, Philpott[1] gave prominence to moulding, stating that failure of descent of the head during labour with an increase in degree of moulding was the 'ultimate index of CPD'. Moulding is now routinely recorded on labour graphs, in South Africa and elsewhere.[30,81,121]

While moulding had long been recognized in newborn infants, it was the development of X-ray diagnostic technology that allowed more meaningful study of the phenomenon. In 1934, Caldwell, Moloy and d'Esopo[88] reported on radiographic studies of head engagement and observed overlap at the coronal and lambdoidal sutures with the head well above the pelvic brim. They concluded that this could only have been caused by pressure of the head against 'the tense soft parts of the lower uterine cervix and uterus'. According to them, radiographic observation of overlapping at these suture lines was 'the most characteristic sign that labor is in progress, other than the straightness noted in the vertebral column'. Moulding, therefore, can be thought of as a marker of efficient labour.

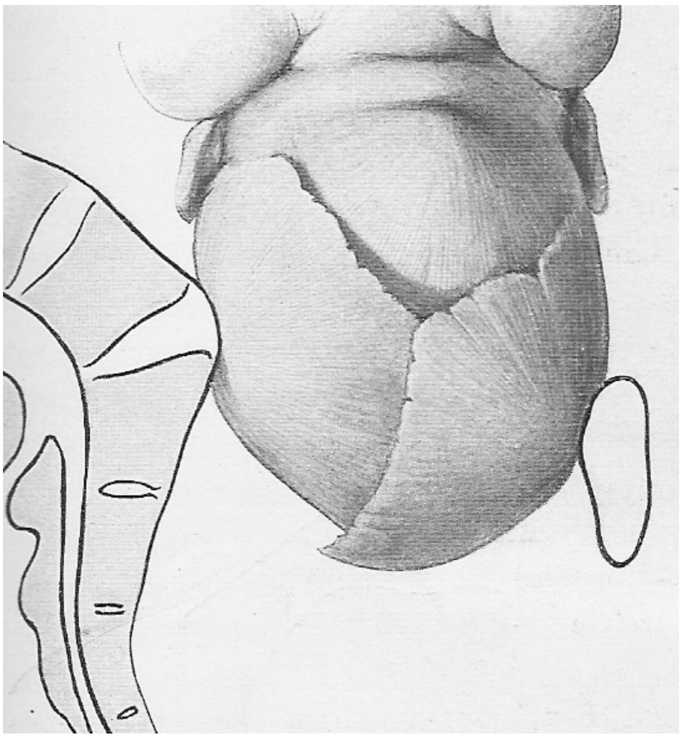


Figure 3.6. Exaggerated depiction of moulding associated with cephalopelvic disproportion. The anterior parietal bone overlaps its posterior couterpart and the occipital bone has slid under the parietal bones at the lambda. (Reproduced from Bumm[128])

3.4.1. Mechanism of moulding

Moloy[129] in 1942 performed X-ray studies of 64 immediately newborn infants and compared observations between babies born after prolonged difficult labour with those delivered by elective caesarean section. To simulate intrauterine pressures, moderate towel compression was applied (apparently without ill effect) to a number of these newborns while exposures were taken. Observations were based mainly on lateral radiographs, precluding meaningful study of the sagittal suture or biparietal diameter. The principal findings of intrapartum moulding were:

1. Increased maxillovertical diameter (i.e. lengthening of the skull) due to unbending and elevation of the parietal bones
2. Decrease in the occipitofrontal diameter (i.e. narrowing of the skull)
3. Some elevation of the occipital bone on its hinge
4. Slight elevation of the base of the skull including the petrous temporal bone
5. Elevation of the parietal bones, creating a ‘step’ down to the frontal bones at the coronal suture, and allowing sliding of the occipital bones under the parietal bones at the apex of the lambdoidal suture
6. ‘Locking’ of the coronal and lambdoidal sutures in their distal (inferior) parts, beyond which they overlap the parietal bones, allowing no further overlap at these sutures.

Some of these changes are shown in Figures 3.7, 3.8 and 3.9, reproduced from Moloy’s article. Despite limitations (convenience sample and technical difficulties with radiography), Moloy's findings were mostly consistent and provided a strong base for further understanding of skull moulding. He did not attempt to establish a quantitative link between moulding and CPD, but did suggest that moulding was probably more pronounced in the presence of disproportion.

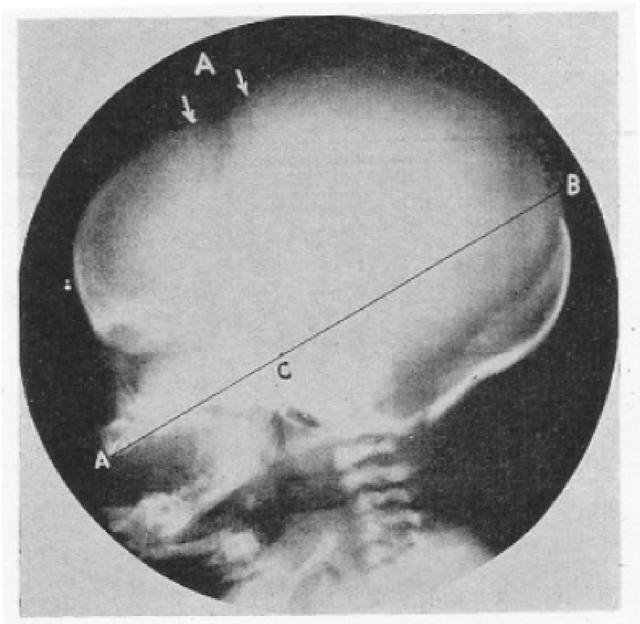


Figure 3.7. Lateral radiograph of a newborn after elective caesarean section, showing an unmoulded head. There is no overlap or elevation of the parietal bones at the anterior fontanelle A and the posterior fontanelle B. (Reproduced from Moloy[129])

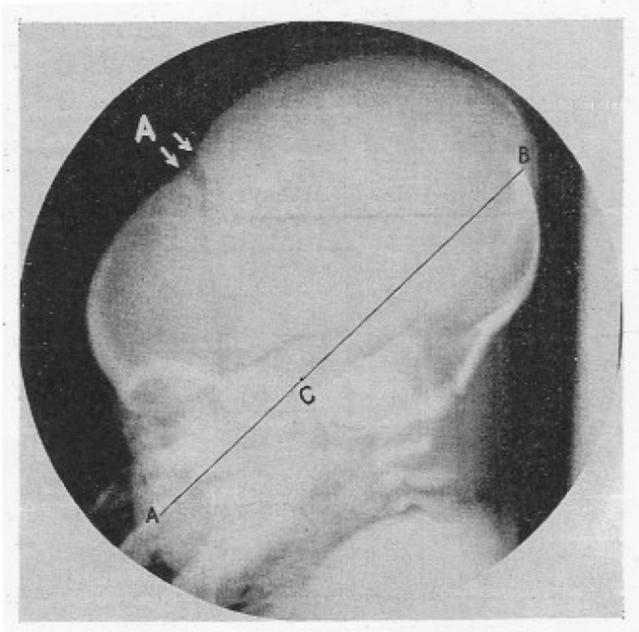


Figure 3.8. Lateral radiograph of a newborn after vaginal delivery. There is elongation of the maxillovertical diameter AB, with overlap and elevation of the parietal bones at the anterior fontanelle (large A) and posterior fontanelle (B). (Reproduced from Moloy[129])

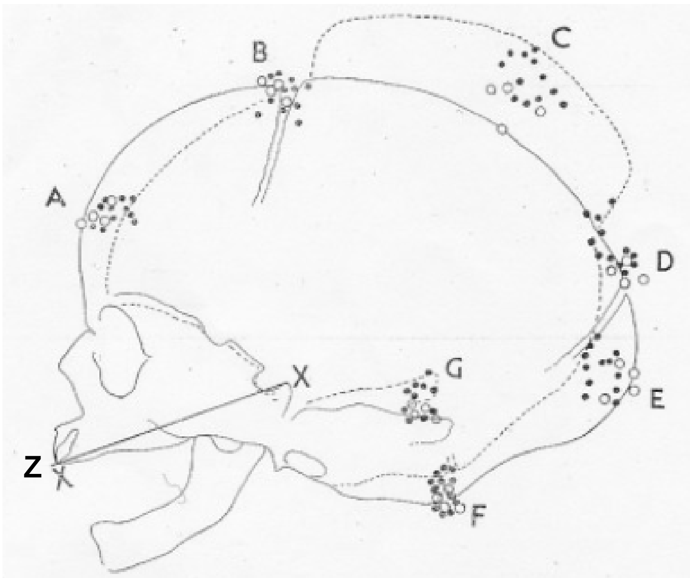


Figure 3.9. Composite diagram of lateral radiographs of moulded and unmoulded newborn heads. The solid outlines with hollow circles at critical landmarks represent 4 unmoulded heads, while the dotted lines with solid circles represent 12 moulded heads. The diagram clearly shows marked elevation of the parietal bone at C and D, and depression of the occipital bone at E. This reduces the occipitofrontal diameter AE and increases the maxillovertical diameter ZC. (Reproduced from Moloy[129])

In 1946, Baxter[130] described a series of experiments in which he dissected the scalps, skulls and cranial vaults of stillborn infants. Unfortunately, he gave few details of his methods, with no mention of the numbers of infants studied and no indication of how forces were applied to these heads. He stated only that his observations referred to ‘the full-time fetus weighing 7 to 8 lb.’ He confirmed most of the findings described by Moloy, with simulated head compression producing inward movement of the upper parts of the frontal bones and the occipital bone, and some overlap of these by the parietal bones. This inward pressure on the cranial contents resulted in compensatory straightening and elevation of the parietal bones. Baxter recognized that overlap of skull bones was limited by the width and compliance of the membranes connecting the bones, and that this was never likely to exceed 3 mm. Overlap was found to be most significant at the superior ends of the coronal and lambdoidal sutures, at the anterior and posterior fontanelles respectively. Sagittal suture overlap required a greater degree of force, with pressure across the biparietal diameter causing overlap close to the anterior fontanelle, with some divergence of the suture at the vertex. The implication is that occipito-parietal (lambdoidal suture) moulding precedes parieto-parietal (sagittal suture) moulding.

Further observations on moulding were made in studies of X-ray cephalopelvimetry. Chassar Moir in 1946 noted that moulding was more marked in preterm fetuses, presumably the result of softer skull bones and more compliant suture lines.[61] Crichton in 1962 observed that moulding caused elongation and narrowing of the head with an increase in the suboccipitovertical diameter and a decrease in the biparietal diameter

(BPD).[62] Exact measurements were not given. Crichton did not explain whether the decreased BPD was caused by unbending of the parietal bones or by overlap at the temporal and sagittal sutures.

Using intrauterine tocography (pressure monitors) in 36 labouring women, Lindgren[131] demonstrated in 1960 that the greatest pressure on the fetal head in the first stage of labour was exerted by the uterine wall at right angles to the direction of delivery at the level of the BPD. This explained the reduction in BPD, with fetal head elongation, noted in previous studies. Interestingly, in the second stage of labour, Lindgren observed that pressure was also exerted by the pelvic floor against the vertex opposite to the direction of delivery, thus providing a counter to the pressure on the BPD. This normalized the shape of the head, paradoxically reducing the degree of moulding.

An important article on moulding and CPD was published in 1958 by Borell and Fernström[132] from Sweden. They reviewed 3000 pelvic radiographs of parturient women and selected 18 where there was contracted flat pelvis, and three with outlet obstruction. In all of these cases, there was excessive overlap (greater than 4 mm) at the sagittal suture, resulting from failure of one of the parietal bones to elevate normally. This is shown in Figure 3.6, where the sacral promontory prevents elevation of the posterior (right) parietal bone, and pushes it underneath its anterior counterpart. The authors distinguished normal moulding, caused by uterine resistance, from pathological moulding, caused by CPD. The hallmark of CPD was excessive parieto-parietal overlap. Interestingly, if the fetal head overcame the obstruction at the pelvic brim, the overlap reduced, followed in most cases by normal delivery. Although limited by a small sample and possible bias in selection of cases, this study is the only one to provide a clear description of changes at the parieto-parietal junction associated with CPD.

In 1977 Lindgren[133] reviewed combined evidence of intrauterine tocography and radiographic images of fetal heads in labour. He described moulding characteristic of normal labour as follows: ‘The high head to cervix pressure at the equator (of the fetal head) causes a moulding of the skull bones. The parietal bones are elevated in relation to the frontal and occipital bones, giving a level difference in the coronal and lambdoid sutures’. He stated that moulding associated with pelvic contraction resulted in elevation of only one of the parietal bones by the bony pelvis where it met the descending head. The consequence was ‘a level difference in the sagittal suture’. Moulding would therefore be expected at the lambdoidal and coronal sutures in normal labour, while sagittal suture moulding was associated with CPD.

More recent work on moulding has attempted to provide a reproducible scientific description of the phenomenon. In 1983 Sorbi and Dahlgren[134] described a moulding index (MI) as follows:

MI = 2 (maxillovertical diameter) / (biparietal diameter × suboccipitobregmatic diameter)

This was applied to photographic studies of 319 heads of newborns immediately after, and again three days after, normal vaginal delivery. The findings confirmed and validated much of the less rigorous research done in previous decades. McPherson and Kriewall[135] gave more emphasis to changes in the shapes of the skull bones using mathematical models based on the bones' bending properties. A review by Carlan, Wyble, Lense, *et al*.[136] in 1991 emphasized the importance of unbending rather than overlap of bones. Lapeer and Prager[137] in 2001 applied an updated mathematical model to moulding, based on intrauterine, and head to cervix pressures, in addition to the properties of the fetal skull bones and sutures. This work validated traditionally accepted beliefs about moulding in labour. All of these studies however investigated or described moulding in normal labour and did not consider the influence of CPD.

3.4.2. Grades of moulding and CPD

The author could find only one publication that investigated moulding as a clinical sign in the recognition of CPD. Stewart and Philpott[50] made detailed observations of nulliparae in labour classified into major CPD (caesarean section), minor CPD (vacuum extraction), primary uterine dysfunction (slow progress, normal delivery) and control (normal progress, normal delivery). Moulding was measured at the occipito-parietal and parieto-parietal suture lines. Moulding was graded as follows:

Grade 0	Bones normally separated
Grade 1	Suture line closed, without overlap
Grade 2	Overlap of bones, reducible by digital pressure from examiner
Grade 3	Irreducible overlap

The findings are summarized in Table 3.4. To quote the authors: 'It is seen that moulding at the occipito-parietal suture line preceded and was more marked than moulding at the parieto-parietal suture line in each of the four groups.' Although significance tests were not done, the comparison of normal and dysfunctional labour with CPD showed that parieto-parietal moulding was more strongly associated with CPD, while occipito-parietal moulding was frequent in all groups and not necessarily a sign of obstruction. This confirms the observations of Borell and Fernstrom,[132] that sagittal suture overlap is a feature of CPD, and that lambdoidal suture overlap is a feature of normal labour.

Stewart and Philpott[50] described a moulding score in which the occipito-parietal was added to the parieto-parietal score, giving a maximum score of 6. However, from their data and from previous studies on moulding, a simple parieto-parietal score might have been more predictive for CPD than the combined score they suggested. In respect of moulding in the recognition of CPD, their study was limited by the fact that the clinicians who performed the moulding scores also diagnosed CPD. It is difficult to exclude the possibility of biased clinical assessment in such circumstances. An examiner blinded to the progress of labour and the decision on mode of delivery would have provided a more reliable assessment.

Moulding is clearly a feature of normal labour, although it appears to be more marked in association with CPD, most prominently at the sagittal suture. It is surprising that so few studies have investigated moulding and its value in recognizing CPD. Even Friedman[107] was almost silent on moulding, mentioning it only as a possible source of error in vaginal assessment of fetal head descent (station). This deficiency in the obstetric literature has not gone unrecognized. Neilson, *et al.*[11] remarked recently that the 'importance of the observation of degrees of moulding of the fetal head also warrants further study'.

Table 3.4. Grades of moulding at delivery (means ± standard errors) associated with normal labour, primary uterine dysfunction, minor CPD and major CPD in primigravidae in Zimbabwe, from Stewart and Philpott.[50]

	Normal labour	Primary uterine dysfunction: normal delivery	Minor CPD: vacuum extraction	Major CPD: caesarean section or symphysiotomy
Number	27	11	19	46
Occipito-parietal moulding	1.90 (±0.05)	2.10 (±0.09)	2.69 (±0.13)	2.95 (±0.03)
Parieto-parietal moulding	1.10 (±0.05)	1.40 (0.15)	1.92 (±0.09)	2.91 (±0.04)

3.4.3. Accuracy and reproducibility - moulding

No studies could be found that investigated the reliability or accuracy of clinicians' assessment of moulding, on models or in humans. Moulding should be a fairly easily appreciated and reproducible clinical sign. However, the presence of marked caput succedaneum (scalp oedema) or intact forewaters could hamper identification and assessment of the suture lines.

3.5. CAPUT SUCCEDANEUM AND OTHER CLINICAL SIGNS

Less frequently reported findings detected on vaginal examination are caput succedaneum, degree of head flexion and asynclitism. It is conceivable that these may contribute to the recognition of CPD, and a review of available scientific evidence is presented here.

3.5.1. Caput succedaneum

This is swelling of the scalp over the presenting vertex.[123] Probably, the dilating cervix acts as a constricting band over that part of the head. This obstructs venous return from the scalp and produces subcutaneous oedema. A severe degree of caput has been associated with prolonged labour and CPD.[120,138] Caput has however been observed on ultrasound examination before the onset of labour, and its formation therefore does not always depend on the presence of prolonged labour or even strong uterine contractions.[139,140]

Caput is best known for its nuisance value in transvaginal assessment of labour progress. A large caput may cause a clinician to overestimate station of the fetal head. The worst case is a non-engaged head with a caput that bulges the perineum.[101,106] This concern is probably more theoretical than real. Knight, *et al*.[125] showed that moulding, rather than caput, influenced discrepancies between abdominal (fifths) and vaginal (station) assessment of head descent in the second stage of labour. Caput may also hinder accurate assessment of fetal position by obscuring the sutures and fontanelles from palpation.[96] Similarly, caput might make it difficult to assess grades of moulding along the suture lines.

Only one study has described caput formation and its relation to CPD. Stewart and Philpott[50] classified caput as follows: 'absent (-), moderate (+) or marked (++), … pelvic when demarcated by the bony pelvis or cervical when demarcated by the cervical os'. In their study, cases with major CPD had a mean caput score of 2.0, those with minor CPD 1.9, those with primary uterine dysfunction 1.7, and the normal controls 0.8 plusses. Caput scores in the major CPD, minor CPD and primary uterine dysfunction groups did not differ significantly. The three groups had in common a long duration of labour (mean 22-26 hours) compared with the normal controls (13 hours). The authors concluded that the degree of caput was probably associated more with the duration of labour than CPD itself. However, a finding of 'pelvic' caput was suggestive of CPD, being observed in 13% of cases in the major CPD group and in none of the other groups.

Caput succedaneum is still charted routinely in partograms in South Africa,[30] but is not included in those used in the United Kingdom[121] nor in the WHO partograph.[81] Clinicians need to be aware of caput as a pitfall in the assessment of station, position and moulding, and as a marker of prolonged labour, possibly caused by CPD.

3.5.2. Flexion

Without flexion of the fetal head, normal passage through the maternal pelvis is almost impossible.[37] Induced by the pressure of uterine contractions, flexion allows the shortest diameters of the presenting part (biparietal, suboccipitobregmatic) to negotiate the birth canal. The finding of deflexion on vaginal examination is suggestive of OP position or inadequate uterine activity rather than CPD.[120] Extreme deflexion, as in brow presentation, is of course a different entity, an example of 'relative CPD'. No studies could be found that specifically investigated the value of clinical determination of fetal head flexion in labour.

3.5.3. Asynclitism

This is lateral flexion, or side-to-side rocking, of the fetal head as it negotiates the birth canal in the OT position. Small degrees of asynclitism are normal and not a cause for alarm.[37,123] Anterior asynclitism (Naegele's obliquity) is the more frequent, where the anterior parietal bone presents predominantly, with the sagittal suture facing the sacrum. The converse is posterior asynclitism (Litzmann's obliquity), which, according to Donald,[37] is frequently associated with CPD. No studies could be found to support the view that asynclitism may be suggestive of CPD.

3.6. CLINICAL PELVIC ASSESSMENT

Clinical pelvic assessment has been discussed in detail in Chapter 2. Surprisingly, there appear to be no studies that have evaluated intrapartum clinical pelvic assessment as a predictor for CPD. The inconsistencies of antepartum assessment may apply similarly to intrapartum assessment.

Chapter 3: Summary points

- Both arrest and protraction disorders of cervical dilatation in labour are associated with CPD. This is well demonstrated in primigravidae but less so in multiparae
- Clinical assessment of cervical dilatation is moderately accurate and reliable, based on studies done on models. Reproducibility and interobserver variation have not been investigated in studies on humans
- There is a weak and inconsistent association between OP position and CPD. OP position may occur in the presence of CPD, but is rarely the cause of CPD
- Studies using ultrasound have shown that clinical assessment of fetal position is generally inaccurate and unreliable
- Failure of head descent in labour is associated with CPD, especially in the presence of arrested or protracted cervical dilatation
- Head descent may be measured abdominally using fifths of head palpable, or transvaginally using station. No studies have investigated which of the two methods has greater value in the prediction of CPD
- Abdomimal estimation of head descent using a tape-measure could be more precise than the fifths method but has not been investigated
- The assessment of station is subject to significant error, based on one study done using a birth simulator. The accuracy and reliability of the fifths method of measuring head descent has not been studied

- Fetal skull moulding is a feature of normal labour, and is most commonly caused by uterine contractions. This results in lengthening and narrowing of the head to facilitate delivery
- Parieto-parietal moulding (overlap) appears to be associated with CPD, while occipitoparietal moulding is a frequent finding in normal labour
- Most studies describing associations between intrapartum clinical findings and CPD are subject to bias because the observers of these findings are also the clinicians making decisions, e.g. doing caesarean section for CPD

CHAPTER 4

INTRAPARTUM ESTIMATION OF FETAL WEIGHT

This chapter reviews methods for estimating fetal weight in labour, by measurement, by palpation, and by ultrasound, and how such estimation assists in predicting CPD. Emphasis is placed on birth weight estimation at term, the aim being identification of large babies with an increased risk for CPD. Clinical and ultrasound methods are compared in terms of their accuracy in predicting birth weight .

4.1. FETAL WEIGHT ESTIMATION AND CPD

It seems self-evident that an accurate estimate of fetal weight during labour would be of value in predicting CPD. A large fetus should have more problems in passing through a contracted pelvis than a small one. However, two prominent South African obstetric researchers, in reviews written 22 years apart, paid little attention to fetal weight estimation. Philpott,[1] in his 1982 review on the recognition of cephalopelvic disproportion, wrote that 'the commonest cause of CPD in the developing world is a contracted pelvis with an average-sized fetus'. This was supported by work from his own unit in Zimbabwe,[4] where it was found that the mean pelvic brim area of women who developed CPD was 83.4 cm^2, and the mean birth weight was 3118 g. Philpott went on to state that 'sometimes the cause of the CPD is a large baby with an average-sized pelvis'. His review discussed pelvic assessment, maternal height and foot size, head descent and moulding, but did not mention fetal weight estimation. Hofmeyr,[36] in his 2004 review on obstructed labour, wrote only that ‘neither clinical nor ultrasound estimation of fetal weight has been shown to be effective for predicting obstructed labour’. The implications are firstly, that fetal weight estimation itself may be inaccurate, and secondly, that CPD occurs in a very wide range of birth weights, with the majority of cases associated with babies of normal weight.

One study was however found that investigated fetal weight estimation and its association with subsequent CPD. This was an American retrospective review by Handa and Laros,[95] who attempted to identify predictors for caesarean delivery associated with active phase arrest of labour in 238 women. Fetal weight estimation was found to be the strongest predictor (P=0.002), followed by fetal station (P=0.015). A fetal weight estimate of over 4000 g was associated with a caesarean section rate of 75%. It was presumed, probably correctly, that caesarean section in these circumstances was done for CPD. The authors conceded that the estimation of birth weight itself, rather than true CPD, may have led to a decision to perform caesarean section. Such bias could not be prevented because of the retrospective nature of their study design. Prospective studies, where fetal weight estimations are done by persons not involved in the decisions to perform caesarean section, would eliminate this deficiency and determine more clearly if fetal weight estimation has a role in predicting CPD.

4.2. UTERINE MEASUREMENTS

4.2.1. Early studies

The first scientific description of fetal weight estimation was made by Poulos and Langstadt[141] in 1953. Using the calipers of an external pelvimeter, they measured longitudinal (symphysis-fundal and anal-fundal distances) and transverse uterine diameters of 45 women in labour. Using the formula for the volume of a sphere, they assumed that these measurements could be translated into a uterine volume estimate, which would be proportional to the birth weight. Their results showed a correlation coefficient (r) of 0.62 to 0.70, superior to simple clinical palpation (r=0.52). The anal-fundal measurement was marginally superior to the symphysis-fundal measurement. They derived the following formula: Birth weight (g) = $1870 + 0.11D^3 \pm 250$, with D being the mean of the transverse and longitudinal uterine diameters.

A year later, Johnson and Toshach[142] reported their findings of fetal weight estimation in labour using tape measure symphysis-fundal measurement alone. They argued that 'since the tape followed the curvature of the abdomen, it is believed that this single measurement partially represents changes in volume as well as length'. Therefore, they did not include transverse diameter or abdominal girth measurements. Based on results from 200 subjects, they reported that a symphysis-fundal height of 34 cm could be expected with an 'average-sized baby' of 7 pounds, 8 ounces (3360 g). They found that fetal weight estimation could be affected by head descent (station), and by maternal obesity, and derived a formula that included corrections for these variables as follows:

Birth weight = 7 pounds, 8 ounces + [(M + S – O – 34) (5.52 ounces)] where:

M = height of fundus in cm

S = station, subtracting 1 cm for minus stations, adding 1 cm for plus stations

O = obesity, subtracting 1 cm for women weighing over 200 pounds (91 kg).

Johnson[143] presented a simplification of this formula in 1957. For a non-engaged fetal head, modified for the metric system of measurement:

Birth weight in g = (SFH measurement in cm – 13) (155)

Adjustments were added for obesity and for fetal head engagement. This simplified formula was however presented without any evidence of its effectiveness in predicting birth weight.

McSweeney[144] in 1958 warned that ‘the estimation of the weight of a fetus in utero is invariably not only difficult and inaccurate, but may be catastrophic because of gross errors in reckoning’. He therefore supported the concept of objective measurement, and described a combined approach with an external pelvimeter and a tape measure, using both longitudinal and transverse diameters of the uterus. The simple addition of the two longitudinal and two transverse diameters, with correction for station and obesity, was intended to give some assurance of fetal maturity. A combined measurement of greater than 95 cm provided assurance that the baby was unlikely to be immature, or small, at birth. McSweeney however made his measurements before the onset of labour and included an adjustment for expected daily fetal weight gain before making his calculations.

At that time, such formulae and calculations might have provided an attractive method to clinicians concerned with the size or maturity of unborn infants. It was only in 1970 that the methods of Johnson and Toshach, and McSweeney, were subjected to an attempt at verification. Niswander, Capraro and Van Coevering[145] applied these formulae in the practices of two obstetricians with a combined total of 1607 pregnant women. Both the Johnson and Toshach and the McSweeney methods gave disappointing results. There was considerable interobserver variation between the two obstetricians, despite their observations being based on apparently objective measurements. There was also a tendency to overestimate the size of small babies, and underestimate that of large infants. These findings discredited the two methods and the authors concluded that 'quantification of fundal measurements, in our hands, has added little to the accuracy of fetal weight estimation by simple abdominal palpation'. Recently, however, Banerjee, Mittal and Kumar[146] reported good correlation between birth weight and SFH (r=0.52) using the Johnson formula[143] applied to 46 Indian women. This is the only study to have correlated fetal weight estimation by SFH with simple clinical palpation (r=0.65) and ultrasound (r=0.67). The authors suggested that SFH measurement with conversion to fetal weight estimation using the Johnson formula can be easily taught to inexperienced and semi-skilled health workers. Interpretation of their results is limited by small sample size and their selection of subjects. None were in labour and adjustments for expected weight gain were made based on the lag time to delivery.

Pschera and Soderberg[147] studied symphysis-fundal height (SFH) and abdominal girth measurements by 18 midwives in 2108 women less than 24 hours before delivery. Presumably, most of these women were in labour. Abdominal girth had a lower correlation (r=0.47) with birth weight than SFH (r=0.57), and the product of girth and SFH measurements gave only a marginally better correlation (r=0.63). The authors offered no practical formula for birth weight estimation and concluded that these measurements were 'unfortunately not a sufficiently accurate predictive method', saying that the method was no better than simple palpation. However, they did not compare measurement with palpation. Woo, Ngan, Au, *et al.*[148] measured abdominal girth in 208 primigravidae and found it to be less effective (r=0.56) than SFH (r=0.71) for prediction of birth weight. Using a combined model based on SFH and girth, variation and error was greatest for birth weights less than 2500 g and greater than 3500 g. The method systematically overestimated the weight of small babies, and underestimated that of larger infants. The authors concluded that these errors were too large for SFH, girth or a combination of the two to be clinically useful.

4.2.2. Correlation between SFH measurements and birth weight

Several African studies have investigated SFH measurements in the prediction of birth weight. Bergström and Liljestrand,[149] from Mozambique, studied 277 women in labour. These were separated into four subgroups according to nulliparity and multiparity, and engagement and non-engagement of the fetal head. Nomograms were presented for each subgroup, with centile lines to assist in screening for small babies. The accuracy of SFH in identifying larger babies was not mentioned. The authors concluded that SFH measurement was useful in under-resourced settings, mainly to identify small babies to allow referral to institutions with neonatal care facilities. Jeffery, Pattinson and Makin,[150] from Pretoria, reported similar findings in an impressive study of 1216 women in labour, with very good correlation between SFH and birth weight (r=0.74). They identified an SFH measurement of 29 cm as a critical lower cut-off for identifying babies weighing less than 2000 g. Again, no mention was made of a critical upper cut-off for identifying large infants. It must be presumed that both studies found this aspect of SFH measurement to be of little value. There were similar findings in a study done by Labrecque and Boulianne[151] on 412 women in labour in the Comores. Correlation of SFH with birth weight was good (r=0.59), with a critical lower cut-off of 31 cm to detect an infant less than 2500 g. Their linear regression model was 'not strong enough to predict birth weight'. A study of 1509 women in early labour from a district hospital in Tanzania, reported by Walraven, Mkanje, van Roosmalen, *et al*.,[152] found good correlation between SFH and birth weight on multivariate analysis (r=0.64). Measurements of maternal height, weight and mid-upper arm circumference were also contributory. An SFH measurement less than 30 cm was considered critical for identification of babies weighing less than 2000 g, and one greater than 38 cm was deemed to be suggestive of twin pregnancy or a large fetus (greater than 4000 g). There was no analysis for prediction of large fetuses alone.

Bothner, Gulmezoglu and Hofmeyr[153] reported on SFH and abdominal girth measurements in 248 women in labour at Coronation Hospital, Johannesburg. Correlation was better with SFH (r=0.56) than with abdominal girth (r=0.47). The product of SFH and girth did not add significantly to the correlation (r=0.57), while the best correlation was obtained for SFH when the level of fetal head in fifths (one-fifth for each cm) was subtracted from the SFH measurement (r=0.64). Status of the membranes had no influence. The formula for birth weight based on this model was however considered by the authors to be 'not sufficiently accurate to be clinically useful'.

A recent article by Mongelli and Gardosi,[154] based on measurements on 325 Caucasian women in England, provides an attractive formula and table for extrapolation of fetal weights based on SFH measurements (r=0.85). However, 51% of the pregnancies studied were preterm at the time of measurement and none of the women were in labour. Furthermore, the gold standard was not birth weight, but a retrospective fetal weight projection based on a 'GAP interpolation method', allowing this weight to be estimated from eventual birth weight and a proportionality fetal growth function. Mongelli and Gardosi's findings are therefore not applicable to intrapartum fetal weight estimation at term.

4.2.3. Limitations of SFH measurement, and standardization

This review has found that SFH measurement alone is preferable to abdominal girth or transverse uterine diameter, or combinations of these, in the prediction of birth weight. SFH measurement has its limitations. There are variable effects of maternal obesity and fetal head descent, and the method tends to overestimate the size of small babies, and underestimate that of large infants, as shown above. It is also subject to significant inter-observer variation.

In a study evaluating SFH measurement, Bailey, Sarmandal and Grant[155] described two clinicians' measurements on the same 39 women and found differences of 2 cm or more in 19. Using limits of agreement analysis, they showed, for example, that at 35 weeks' gestation, there was a 10% probability of the SFH measurement being less than 29 cm or more than 37 cm. They concluded that 'it is not possible for different observers to measure the symphysis-fundal height with sufficient agreement to separate reliably small fundal heights from those that are not small'. Engstrom, McFarlin and Sampson[156] compared clinician estimates of the uterine fundal height marked with a pen, with those verified by transabdominal ultrasound, and found 42% of clinical measurements to be incorrect by more than 1 cm. These errors were not related to thickness of maternal subcutaneous fat.

Investigating the influence of bladder volume, Engstrom, Ostrenga, Plass, *et al*.[157] found that pre-void SFH measurements were significantly higher (mean 0.63 cm) than postvoid measurements by the same examiners in 200 antepartum women. The examiners were blinded to the measurements and to the voiding volumes. One third of measurements differed by more than 1 cm. It is therefore possible that intrapartum measurements of SFH are affected by a full bladder.

Standardisation of SFH measurement is likely to reduce the influence of error and interobserver variation on clinical assessments. Westin[158] provides a clear description: ‘the patient should be supine. Legs should be straight otherwise the pubic symphysis moves upwards. The uterus should be relaxed and the bladder empty… measurements should be performed along the longitudinal axis of the fetus whereby fetal crown-rump length will be reflected’. To this may be added the advice of Bothner, *et al*.[153] that the measurement is taken from the upper border of the symphysis pubis and that the fundus is defined by ‘gentle pressure exerted in a plane at right angles to the abdominal wall’. Theron suggests, in the widely used South African Perinatal Education Programme Maternal Care Manual,[159] that the fundal height be marked with a pen on the abdominal skin.

4.3. UTERINE PALPATION

Palpation of the pregnant uterus gives an impression of size, which can be converted into a fetal weight estimate. In 1967, Insler, Bernstein, Rikover, *et al*.[160] published the first detailed report on fetal weight estimation performed by ‘simple external palpation of the fetal body through the maternal abdominal and uterine walls’. Three experienced clinicians estimated fetal weights of 1250 women admitted to a labour unit in Israel. Sixty-nine percent of estimates fell within 10% of the birth weight. While observing that palpation provided ‘fairly accurate’ fetal weight estimation, the authors cautioned against over-reliance of the method, as about 15% of weight estimations were incorrect by over 500 g.

Later in the same year, Loeffler[161] reported 2868 fetal weight estimations on 585 parturient women by 101 members of staff in a London maternity unit. Eighty per cent of estimates were found to be within one pound (454 g) of the birth weight. Loeffler made the important observation that clinical fetal weight estimation was least accurate at the lower and upper extremes of birth weight. With birth weights of less than 5 pounds (2270 g) and greater than 10 pounds (4540 g), only 43% and 19% of estimates respectively were within one pound of the birth weight. Fetal weight estimation should ideally have the ability to detect unusually small (preterm or growth-restricted) or large (macrosomic) babies, but this is where the method is least accurate. This was also found in studies of fetal weight estimation by SFH, as discussed earlier.

In 1972, Ong and Sen[162] reported on 1000 fetal weight estimations by all levels of clnical staff in 506 Malaysian women. Most of these women were in labour. In total, 83% of estimates were within 1 pound of the birth weight. The trend to better estimation at normal birth weights was confirmed, with 92% of birth weights being accurate to within a pound in the 6 to 7 pound birth weight interval. As birth weight moved away from the average, the accuracy of estimations deteriorated. The authors cautioned that ‘the present methods of assessment cannot be complacently accepted as being adequate’.

4.3.1. Demographic, constitutional and pregnancy factors

It should be understood that estimation of fetal weight by abdominal palpation is rarely done in isolation from other variables. The clinician’s knowledge of the mother’s race, size, past obstetric history, gestational age and colleagues’ estimates is likely to play a role.[163] For example, a tall overweight north European woman in labour at 41 weeks' gestation will probably give birth to a larger infant than a petite Indian woman in labour at 37 weeks. The studies by Insler, *et al*.[160] and Ong and Sen[162] did not mention blinding of the obstetricians and midwives to maternal characteristics and gestational age. However, Loeffler[161] acknowledged that the 'staff had full access to relevant antenatal records but were asked to refrain from looking at their colleague's predictions'. Therefore, abdominal palpation in most cases gives a subjective estimate that may take into account demographic, constitutional and clinical factors that the clinician feels are associated with birth weight. This is not necessarily a weakness, and provides a potential advantage over measurement-based methods, such as SFH and ultrasound.

Some researchers have attempted to include maternal characteristics in models for fetal weight estimation. In 1999, Nahum, Stanislaw and Huffacker[164] produced a birth weight equation that included gestational age, fetal sex, maternal height, maternal weight at 26 weeks, and maternal weight gain in the third trimester, all of which were positively correlated with birth weight. Walraven, *et al*.,[152] in Tanzania, found a negative correlation between maternal mid-upper arm circumference (a marker of nutritional status), and birth weight. Gestational glucose intolerance and diabetes mellitus are well known causes of fetal macrosomia.[165] Maternal smoking, pre-eclampsia, and residence at high altitude are negatively correlated with birth weight, and birth weight predictions can be adjusted according to the presence and magnitude of such influences.[166-169] Wikstrom, Bergstrom, Bakketeig, *et al*.,[169] from Norway, reported good birth weight prediction using a multivariate model that included maternal characteristics such as pregnancy weight gain, previous large infant, and smoking, combined with symphysis-fundal height measurement. While the recognition of maternal characteristics as modifiers of birth weight is well recognized, the formal inclusion of such characteristics in birth weight prediction formulae has not found widespread favour in clinical settings.

4.3.2. Uterine palpation versus ultrasound

Willocks, Donald, Guggan, *et al*.[170] were the first to describe ultrasound estimation of fetal weight in 1964. They found very good correlation (r=0.77) between biparietal diameter and birth weight in a sample of 152 women, with 67% of birth weights predicted within one pound using their derived formula. Advertising the new technology, they contended that 'clinician estimate of fetal weight is little more than guesswork'. As obstetric ultrasound became popular in the 1970s, numerous fetal weight equations were produced, associated with Hadlock,[171] Shepherd,[172] Campbell[173] and Warsof,[174] based on biometry such as biparietal diameter, femur length and abdominal circumference. Enthusiastic about the potential of ultrasound, Warsof, Gohari, Berkowitz, *et al*.[174] commented in 1977 that 'the time honoured ritual of palpating the uterine fundus is notoriously inaccurate'. However, Hanretty and Faber[175] reported disappointing results in a South African evaluation of the Campbell and Warsof formulae. In 51 labouring women they found only 49% of Campbell and 41% of Warsof estimates to fall within 10% of the birth weight. Benacerraf, Gelman and Frigoletto,[176] in a study of 1301 estimations, acknowledged the limitations of ultrasound based fetal weight estimations. More recently, greater accuracy in fetal weight estimation has been shown using magnetic resonance imaging,[177] and three-dimensional ultrasound.[178,179] However, these techniques are likely to be impractical in the evaluation of women during labour.

Patterson[180] in 1985 reported the first comparison of ultrasound and clinical fetal weight estimation, done on 62 women in the first stage of labour at term. After exclusions for mostly technical reasons, only 43 subjects were available for analysis. Patterson suggested, from this small sample, that ultrasound was more accurate than abdominal palpation. In contrast, Watson, Soisson and Harlass[181] found similar accuracy between the two methods in 100 women examined before the onset of labour, as did Hanretty, Neilson and Fleming.[182] Most subsequent comparisons have shown that intrapartum fetal weight estimation by ultrasound is less accurate, or equivalent to, abdominal palpation. Table 4.1 summarises the findings of nine studies that reported comparisons of fetal weight estimation by abdominal palpation with ultrasound. All of these studies, except that of Hendrix, Grady and Chauhan[183] compared palpation with ultrasound measurements in the same women. The Hendrix study randomized women in labour to either palpation estimate or ultrasound estimate, with the finding of only 39% of estimates by ultrasound being correct within 10% of the birth weight. Estimates were made by second to fourth year residents. The study by Chauhan, Hendrix, Magann, *et al.*[184] from 1998 included a large number of preterm infants, and found that intrapartum ultrasound before, but not at term, was superior to clinical palpation in fetal weight prediction. Only the Shamley study found ultrasound to be superior to clinical estimation at term.[185]

Table 4.1 Studies that reported percentage of intrapartum fetal weight estimations within 10% of birth weight, in comparisons of abdominal palpation and ultrasound methods.

First author	Country	Number of subjects	Percentage of estimations within 10% of birth weight	
			Abdominal palpation	Ultrasound
Chauhan (1992)[186]	USA	101	70	42
Chauhan (1993)[187]	USA	200	65	56
Shamley (1994)[185]	USA	223	66	79
Barnhard (1996)[188]	Israel	124	70	68
Chauhan (1998)[184]	USA	1034	55	58
Sherman (1998)[189]	Israel	1717	72	69
Hendrix (2000)[183]	USA	758	58	39
Baum (2002)[190]	USA	200	64	63
Noumi (2005)[191]	USA	192	72	74

There were varied comments by the authors of the articles shown in the table. Ultrasound estimates that included measurement of biparietal diameter (e.g. Shepard) were of little value because of moulding and descent of the head into the pelvis.[188] The Hadlock formula, relying only on abdominal circumference and femur length, was generally more useful.[185,188] Chauhan, Lutton, Bailey, *et al*.[186] observed that intrapartum ultrasound is limited by movement and restlessness of the parturient woman, and possibly by a lack of round-the-clock expertise in a labour ward. Sherman, Arieli, Tovbin, *et al*.[189] acknowledged the better performance of clinical fetal weight estimation, but added that palpation estimation, unlike ultrasound measurement, was influenced by prior knowledge by the clinician about the pregnancy and the mother. Using a simple arithmetic model, they suggested that fetal weight can be predicted in 50% of estimations to within 10% of the birth weight by simply guessing the average expected term birth weight for that population. They also demonstrated poor performance of both ultrasound and clinical methods for predicting macrosomia.[190] The study by Noumi, Collado-Khoury, Bombard, *et al.*[191] included fundal measurement as part of clinical birth weight prediction, but no information was given about how this measurement was used.

In an editorial published in the British Journal of Obstetrics and Gynaecology, Hall[192] reviewed attempts to improve fetal weight estimation by ultrasound technology, and concluded that 'clinical assessment was just as good as scanning' and that 'a simple tape measure and clinical expertise will serve as well as an ultrasound estimated fetal weight in detecting the big baby'.

4.4. FACTORS AFFECTING ACCURACY

A number of factors may affect the accuracy of fetal weight estimation. Early work by Johnson and Toshach,[142] and by McSweeney,[144] included head descent and measures of maternal obesity in formulae for fetal weight estimation. Subsequent studies have however shown that maternal obesity has minimal influence on both clinical and ultrasound estimates. Field, Piper and Langer[193] studied 998 American subjects, of which 32% were classified as obese (body mass index greater than 29.0 kg/m^2). Estimation was within 10% of birth weight in two-thirds of women for both clinical and ultrasound methods. The authors of the study did not say whether their subjects were in labour or not, only that they were examined 'within five days of delivery'. Noumi *et al.*,[191] in their study of 192 women in the active phase of labour, found no influence of body mass index on both clinical and ultrasound estimates. However, Bothner, *et al*.[153] stated that symphysis-fundal measurements during labour in obese women ‘exceeded those in thin women by about 4 to 5 cm, relative to fetal weight’. No further data were provided.

Descent of the fetal head may theoretically reduce the fundal height. Bothner, *et al*.[153] observed that ‘engagement of the fetal head was associated with a reduction in symphysis fundal measurements on average of about 1 cm per fifth of head’ above the brim. No other studies have investigated the influence of head descent during labour on fundal height measurement or clinical fetal weight estimation.

Rupture of the membranes may reduce uterine volume and influence estimation of fetal size. In one study, oligohydramnios was found to reduce the accuracy of both clinical and ultrasound estimations. Using ultrasound, Barnhard, Bar-Hava and Divon[188] identified 32 women in labour with oligohydramnios, and showed that clinical fetal weight estimation was significantly less accurate in these women than in those with normal liquor volume (50% v. 74% of estimates within 10% of birth weight). However, three studies, including two from South Africa,[150,153,185] found that membrane status had no significant influence on the accuracy of fetal weight estimation.

There are conflicting findings on the effect of the level of experience of the examiner in the accuracy of clinical fetal weight estimation. In one of the earliest studies on this subject, Loeffler[161] noted that estimates improved with experience in 11 out of 12 participating clinicians. Nahum,[194] in the USA, found that house officers made significantly better fetal weight estimates than medical students. In contrast, Ong and Sen[162] in Malaysia reported that medical students' estimates were more accurate than any other category of clinician (nurses, house officers, medical officers and lecturers). Baum, Gussman and Wirth[190] found that senior registrars made better estimations than their junior colleagues, while Herrero and Fitzsimmons,[195] Chauhan, Cowan, Magann, *et al*.[196] and Noumi, *et al*.,[191] could show no differences in accuracy between levels of staff.

4.5. MATERNAL ESTIMATION OF FETAL WEIGHT

In 1992 Chauhan, *et al*.[186] made the intriguing observation that pregnant women were able to give relatively accurate estimates of their own infants' weights. One hundred and six parous women in labour at term were asked to guess the weights of their babies, based on their previous childbirth experiences. Sixty-nine per cent of their estimates were within 10% of the birth weight, compared to 66% of their doctors' clinical estimates, and 42% of ultrasound estimates. In the editorial cited earlier, Hall[192] commented that 'when a woman has had a baby before, her own estimate is likely to be as good as an ultrasound measurement'. Herrero and Fitzsimmons[195] confirmed Chauhan, *et al*.'s observations[186] in a study of 471 multiparous women in labour. They found, as with clinical and ultrasound estimations, that maternal predictions were most accurate for birth weights between 2500 and 4000 g. Recently, Baum, Gussman and Wirth[190] included nulliparae in a similar study on a mostly Chinese population, and found their estimates to be not significantly less accurate than multiparae in estimating their own infants' weights (48% vs. 57% within 10% of birth weight). Senior registrars in that study appeared to provide better clinical estimations than the mothers (75% within 10% of birth weight). Surprisingly, the authors suggested in their conclusion that maternal estimation has equal value to that of clinical and ultrasound estimation. No studies have been done on maternal estimation of fetal weight in developing countries.

4.6. PREDICTING MACROSOMIA

When cephalopelvic disproportion is a concern, fetal weight estimation should be able to identify the large infants. This applies equally or even more in the prediction of shoulder dystocia, typically associated with delivery of large infants.[197] It has been shown that fetal weight estimation, by whatever method, diminishes in accuracy as birth weight increases. Herrero and Fitzsimmons[195] showed that only 46% of clinical estimates were within 10% of the birth weight for infants heavier than 4000 g at birth, compared to 64% of estimates in the range of 2500 to 4000 g. Sherman, *et al*.[189] found a similar reduction in accuracy, from 75% to 61%.

A number of studies have investigated the predictive value of fetal weight estimation for macrosomia, defined as a birth weight of 4000 g or more. Hanretty, *et al.*[182] compared clinical and ultrasound fetal weight estimates for macrosomic infants, and found better prediction with clinical estimation (mean absolute error 394 g vs. 500 g), although this was not statistically significant (P=0.08). Observed sensitivities and specificities in three studies for predicting macrosomia are shown in Table 4.2. Ultrasound appears no better than clinical estimation in identifying macrosomic infants, although both methods perform poorly in terms of sensitivity. In an evaluation of eight ultrasound formulae for fetal weight in 602 subjects, Chauhan, *et al*.[196] found clinical estimation to be superior to four of these formulae and equivalent to the other four. Sixty-seven (11.1%) of the infants weighed 4000 g or more at birth. Clinical estimation of fetal weight fell within 10% of the birth weight in 54% of these, while the ultrasound formulae were within 10% of the birth weight in 36 to 51% of cases. O'Reilly-Green and Divon[197] reviewed methods for detecting fetal macrosomia and concluded that 'clinical estimates performed as well as or better than commonly used sonographic methods'. SFH measurement has not been studied specifically, and no suggested cut-off values have been offered for predicting a birth weight of 4000 g or more. There are no reports of prediction of macrosomia in Southern African populations, where the percentage of newborns weighing 4000 g or more ranges from 2.3% to 3.4%.[198,199]

Table 4.2. Studies reporting sensitivities and specificities for intrapartum detection of infants with birth weight ≥4 000 g, using clinical and ultrasound methods.

First author	Number of subjects	Newborns ≥4000 g (%)	Clinical estimation		Ultrasound estimation	
			Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Chauhan (1998)[184]	1034	7.5%	54	95	71	92
Hendrix (2000)[183]	758	10.6%	34	97	12	99
Noumi (2005)[185]	192	6.3%	50	95	50	97

Chapter 4: Summary points

- SFH measurement is an objective method which is potentially easy to learn but suffers from inaccuracies related to high interobserver variation
- No simple formula exists to translate an intrapartum SFH measurement into a birth weight, and no upper cut-off measurement has been suggested as a useful screening tool to detect a large baby
- Uterine palpation is a moderately accurate method of predicting birth weight, but requires some training and experience for it to be most useful
- Birth weight predictions based on uterine palpation may be influenced by maternal and obstetric characteristics
- At term, uterine palpation is as accurate, or slightly more so, than ultrasound calculations. Ultrasound-based estimates before 37 weeks' gestation are more accurate than uterine palpation in the estimation of fetal weight
- No studies have compared intrapartum SFH measurement with uterine palpation in the prediction of birth weight at term
- Maternal estimation of fetal weight compares well with ultrasound and uterine palpation, although palpation by experienced clinicians has been shown to be more accurate in one study
- The greatest weakness of intrapartum fetal weight estimation at term is its diminishing accuracy with increasing birth weight. Average sized birth weights can be predicted with impressive accuracy, but large fetuses are frequently missed. The

sensitivities of palpation and ultrasound for detecting infants with birth weights greater than 4000 g are poor.

- Intrapartum fetal weight estimation has not been shown in prospective studies to predict cephalopelvic disproportion

CHAPTER 5

PROBLEM STATEMENT AND OBJECTIVES

This chapter develops a problem statement based on gaps in knowledge identified from the literature review. Research opportunities are described, with the hope that a prospective study design may clarify the role of intrapartum clinical findings in the prediction of CPD. The primary objectives of such a study are listed.

5.1. INTRODUCTION

In reviewing the literature on cephalopelvic disproportion, the author set about exploring the current state of knowledge of the condition, with emphasis on prediction and recognition using clinical methods. The purpose was to identify gaps in knowledge and to generate research questions.

5.1.1. Antepartum prediction of CPD

Overwhelmingly, antepartum diagnosis of CPD has given way to prediction, or designation as ‘high risk’. Pregnant woman with short stature, suspected small pelves, or who are carrying large babies, are normally subjected to a trial of labour. In some parts of the world, where health services are distant from homes or road transport is a problem, such women may be advised to give birth in a hospital, because of their increased risk for CPD and caesarean section. There is general consensus that CPD, with very few exceptions, should only be diagnosed after a properly conducted trial of labour. In terms of research, there is little place for refinement of what is already known about height, shoe size, and pelvimetry. New formulae, for example maternal head circumference to height ratio, may still be investigated, but it is unlikely that these will deliver anything new other than another risk factor to prompt referral for a properly supervised trial of labour.

5.1.2. Cervical dilatation - trial of labour

What of the trial itself? Cervical dilatation remains the principal indicator of labour progress. CPD is an important cause of a subnormal cervical dilatation rate, irrespective of the nature of the disorder – arrest, protraction, or crossing an alert or action line on a partogram. It is accepted that if progress in labour is poor, the problem is caused either by ineffective uterine contractions or mechanical obstruction, or, very rarely, true cervical dystocia. Generally, the simple correction of poor uterine activity will result in normal progress and delivery if there is no CPD. This may be done by amniotomy or oxytocin infusion or both. Failure to progress in such circumstances indicates CPD. This is well known and is not likely to be challenged.

5.1.3. Clinical observations that may predict CPD

Correction of ineffective uterine activity is not necessarily safe. In multiparae, ruptured uterus is a significant risk when oxytocin is used to augment labour in the presence of CPD. Is it fair to augment labour in a primigravida when there is evidence of CPD and when contractions appear to be clinically adequate? What constitutes evidence of CPD? Is it a high head in labour, the suspicion of a large baby, occipitoposterior position, moulding, caput succedaneum, deflexion, asynclitism, or some or all of these? In this respect, the literature was found to be deficient. There are very few or no prospective studies on size of baby, and on moulding and caput. There is conflicting evidence on occipitoposterior position, and no studies at all on flexion and asynclitism. Furthermore, all studies that described intrapartum findings with respect to subsequent CPD were potentially biased in that the clinical findings were reported by the same clinicians who made the eventual diagnosis of CPD. No studies were found where an experienced obstetrician researcher, blinded to other clinicians' findings, made intrapartum clinical observations but played no part in the management of the parturient women. The validity of intrapartum observations can only be properly tested in this blinded non-participant way.

5.2. RESEARCH OPPORTUNITIES

A prospective study, with a non-participant researcher making clinical observations as described above, would provide greater clarity on the predictive value for CPD of a number of intrapartum clinical findings. A non-participant would also be able to assess interobserver agreement of these findings if the observations were made simultaneously with those of the staff examining the women.

5.2.1. Cervical dilatation

The role of cervical dilatation in prediction of CPD has been well demonstrated. However, interobserver variation in estimation of cervical dilatation has not been investigated in human subjects.

5.2.2. Head descent

In the presence of CPD, the fetal head cannot negotiate the pelvic brim. This seems obvious, but it is well known that the head may descend only late in the first stage or even in the second stage of labour, especially in African women. Failure of head descent in the first stage of labour is not necessarily a cause for alarm, but may be suggestive of CPD. This needs further clarification.

Another problem is the uncertainty about the best method to measure head descent, whether abdominally (fifths) or transvaginally (station). No studies, prospective or retrospective, have been done to compare the two methods in the first stage of labour. The Crichton and Notelowitz methods have not been compared, and the notion of tape-measure assessment of head descent has not been investigated. In addition, interobserver agreement in estimating fifths and station has not been studied in human subjects.

5.2.3. Moulding

Early studies dating back to the ‘golden age’ of pelvimetry showed fetal skull moulding to be an entirely normal process in labour. The available scientific literature supports the concept that parieto-parietal overlap is more predictive of CPD than occipito-parietal overlap. An increasing degree of moulding, in the absence of descent of the head, has been described as the ‘ultimate index’ of CPD. Many modern textbooks and manuals now consider moulding at any suture to be a sign of CPD. The predictive value of moulding at the different suture lines has not been tested in studies using a blinded non-participant observer. Interobserver agreement in estimating different grades of moulding has also not been investigated.

5.2.4. Occipitoposterior position

The role of this malposition in CPD remains controversial. Studies have shown a range of results, from no association whatsoever to high rates of caesarean section. Recently, ultrasound studies have consistently shown that clinical assessment of fetal position is unreliable. This may devalue studies that depended on clinical identification of occipitoposterior position. Future research should be prospective with non-participant ultrasound assessment of position.

5.2.5. Fetal weight estimation

Many studies have investigated intrapartum fetal weight estimation at term. These have concentrated mainly on accuracy of clinical estimates and ultrasound measurements. It is however not clear if clinical estimation of fetal weight is a predictor of CPD. Predicting a large baby is more difficult than predicting an average-sized infant. SFH fetal weight prediction in labour has received less attention than simple palpation, and no studies have directly compared clinical estimation with SFH measurement. There is no simple formula that translates an SFH measurement into a fetal weight. One study suggested 38 cm as a useful upper cut-off for a large fetus. In the author's experience, many clinicians consider 40 cm or more to indicate a large baby, seemingly without scientific evidence.

5.2.6. Clinical pelvic assessment

No studies have evaluated the role of intrapartum clinical pelvic assessment in the prediction of CPD. This examination has for the most part been disappointing as a clinical exercise. It is painful for the mother, difficult to do, and gives inconsistent results. Non-participant estimation of the diagonal conjugate distance in a prospective study may define a role for intrapartum clinical pelvic assessment.

5.2.7. Other observations

No studies have mentioned the predictive value, if any, of fetal head deflexion or asynclitism for CPD. Only one study has investigated caput succedaneum. All of these phenomena may be part of the normal process of head descent in labour. It is however possible that persistent deflexion, severe asynclitism, or a high degree of caput, may be associated with or predict CPD.

5.3. OBJECTIVES

Based on the above problem statement, and the research opportunities listed, the author considered that a prospective study could add substantially to current knowledge regarding clinical prediction of CPD. Such a study would have three primary objectives, as listed below.

5.3.1. Objective 1 - descent, moulding and other clinical findings

The first objective was to investigate the predictive value of commonly assessed intrapartum clinical findings for CPD, especially descent and moulding. For descent, this included comparison of abdominal (fifths) and vaginal (station) assessment, and comparison of the Crichton, Notelowitz, and a new tape-measure method for estimating level of the head. For moulding, the objective was the comparison of parieto-parietal and occipitoparietal moulding. The contribution of fetal weight estimation, cervical dilatation, occipitoposterior position, caput succedaneum, deflexion and asynclitism would also be investigated.

The achievement of this objective would allow the production of evidence-based recommendations for intrapartum recognition of CPD. The importance of moulding as a sign of CPD would be clarified. The debate on fifths vs. station for fetal head descent could be re-opened and even resolved.

5.3.2. Objective 2 – interobserver agreement of clinical findings

The second objective was to determine interobserver agreement of the commonly assessed intrapartum clinical findings, such as cervical dilatation, head descent using abdominal and vaginal methods, fetal position, moulding and caput.

A predictive clinical observation is of little value if clinicians cannot agree on its findings. The achievement of this objective would identify which of the clinical findings predictive for CPD were easily reproducible. Those that were both predictive and reproducible would have the greatest clinical value, and these could be recommended and used with confidence in the care of parturient women.

5.3.3. Objective 3 – estimation of fetal weight

The third objective was to compare clinical estimation with SFH measurement in the intrapartum prediction of birth weight at term, both in overall accuracy and also in their ability to detect large fetuses.

If SFH estimation could be shown to be an equivalent or better predictor of birth weight than clinical estimation, it would be possible to produce a simple equation for birth weight based on SFH. Validation of such an equation in a subsequent study would justify its use in clinical practice. The same can be said of a high cut-off value of SFH for a large baby.

Chapter 5: Summary points

- There is general consensus that CPD is best diagnosed by means of a properly conducted trial of labour
- The role of fetal head descent and moulding in the prediction of CPD is not disputed. However, there is uncertainty about the best way to assess head descent, and about the significance of moulding observed along different suture lines
- Interobserver variation of clinical observations in labour has not been investigated in humans
- Intrapartum clinical fetal weight estimation and SFH measurement have not been compared directly in their ability to predict birth weight
- The author undertook a prospective study using blinded non-participant clinical assessesment in labour, to clarify the value of commonly used clinical observations in the prediction of CPD
- The first objective of such a study was to investigate the predictive value of head descent, moulding and other intrapartum clinical observations for CPD
- The second objective was to determine interobserver agreement of commonly used intrapartum clinical observations
- The third objective was to compare clinical fetal weight estimation with SFH measurement as predictors of birth weight

CHAPTER 6

SETTING AND METHODS

This chapter describes the study setting at Chris Hani Baragwanath Hospital. It proposes a prospective cross-sectional study design to investigate the predictive value of intrapartum clinical findings for CPD, and the accuracy of fetal weight estimation. The study population is defined, and a sample size estimate is given. The data collection procedure and data analysis methods are explained in detail.

6.1. STUDY DESIGN

This was a prospective cross-sectional study, in which the author performed intrapartum clinical examinations without knowledge of the mothers' parities or previous clinical findings in labour, and with no responsibility for obstetric care of these women. This 'non-participant' examination was done at the time of the labour ward clinicians' routine rounds. This included measurements, abdominal examination and vaginal examination. It was important that the attending clinician and the author were blinded to each other's clinical findings, so that the author's examination could be truly non-participant. Subsequent mode of delivery and birth weight were determined, to establish associations with the author's clinical findings. The main outcome measure was caesarean section for CPD. All data collection was done by the author. The study was approved by the Human Research and Ethics Committee of the University of the Witwatersrand, protocol number M02-02-06 (Appendix A).

6.2. SETTING

6.2.1. The ideal setting

For a study that proposed to investigate the clinical findings that predict CPD, as stated in the objectives in the previous chapter, the ideal setting would be one where: 1) there is a high incidence of CPD in the community served, 2) women with prolonged labour are received as referrals from midwife-run peripheral clinics, 3) trial of labour is practised, using a labour graph and oxytocin augmentation when progress is poor, 4) clinicians are experienced with trial of labour, and do not have a low threshold for caesarean section, 5) patients are not averse to being subjects in research projects and 6) clinicians do not obstruct and do not feel threatened by clinical research that involves their co-operation.

6.2.2. Chris Hani Baragwanath Maternity Hospital

This is the author’s place of work, a university teaching and referral centre situated in Soweto, south-west of Johannesburg. Chris Hani Baragwanath Maternity Hospital serves a population of about two million. The hospital receives referrals from five midwife obstetric units in Soweto, one in the southern suburbs of Johannesburg, and one in Lenasia South (Figure 6.1). The midwife obstetric units together deliver some 8000 women each year, and the hospital about 20 000. The hospital caesarean section rate is about 27%, with CPD being the most frequent indication in primary caesarean sections.

In terms of the ‘ideal setting’ described above, Chris Hani Baragwanath Maternity was well suited to the performance of a prospective study to investigate clinical findings predictive for CPD. It receives large numbers of referred women with prolonged labour.

Trial of labour is the norm for intrapartum care, with decisions on labour management made by specialist clinicians, either obstetric registrars or consultants. Caesarean section thresholds are high, driven by an academic environment and a shortage of operating theatre time. In addition, research projects are commonplace at Chris Hani Baragwanath, and generally acceptable to staff and patients.

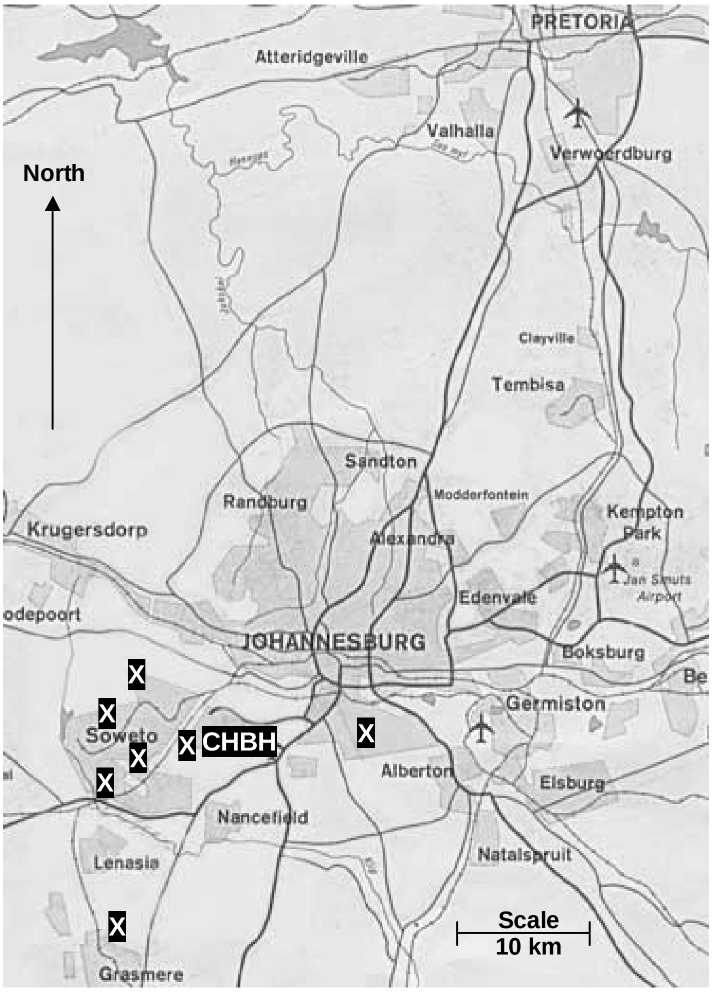


Figure 6.1. Map showing the location of Chris Hani Baragwanath Hospital (CHBH) and the primary care centres (X) that refer problem pregnancies and labours. The hospital serves south-western Johannesburg, and referrals are received from five clinics in Soweto (from above: Itireleng, Zola, Lillian Ngoyi, Mofolo and Chiawelo), from Lenasia South (extreme south-west), and South Rand (to the east of CHBH).
Map: http://www.johannesburgcitytourist.com/johannesburg-map.html (last accessed 19 December 2006)

6.3. STUDY POPULATION

For a study of predictors of CPD, the study population needed to be women at risk for CPD, not likely to require caesarean section for any other reason.

Inclusion criteria were:

- Women in the active phase of labour, defined as painful contractions with the cervix greater than or equal to 3 cm dilated and fully effaced
- Pregnancy at term, defined as 37 or more completed weeks of gestation
- Live fetus
- Vertex presentation

Exclusion criteria were:

- Severe maternal medical conditions, e.g. heart disease, diabetes mellitus
- Severe pre-eclampsia
- Known life-threatening fetal abnormality, including hydrocephalus
- Previous caesarean section
- Evidence of fetal distress, defined as late or severe variable decelerations of the fetal heart rate, or thick meconium staining of the liquor
- Unable to give consent as a result of: bearing down in the second stage of labour, severe labour pains, or sedation by opiate drugs
- Author aware of parity and previous intrapartum clinical findings

All ages and parities were acceptable for inclusion, as was twin pregnancy, provided all inclusion criteria and no exclusion criteria were present.

6.4. SAMPLING AND SAMPLE SIZE

A convenience sampling method was used, based on the availability of the author. Sabbatical leave was used for the study data collection, so that the author had at his disposal large blocks of time from morning until evening, most days of the week. This enabled him to attend the clinicians' labour ward rounds and recruit eligible women to participate in the study.

Sample size calculations usually make use of published data on similar work, or pilot studies, for estimation of expected frequencies of outcomes in groups to be compared. Such studies had not been done previously, so no comparable data were available. There were certainly no data for comparison of fifths and station as measures of descent. Stewart and Philpott[50] provided some figures on parieto-parietal and occipito-parietal moulding from their work in Zimbabwe.

The author therefore used his own experience combined with interpretation of the findings from the study by Stewart and Philpott[50] to suggest a sample size for investigation of moulding. The expected comparison was the predictive value of grade 2 or more parieto-parietal moulding with grade 2 or more occipito-parietal moulding, as opposed to lesser degrees of moulding at these sutures. A difference in positive predictive value (caesarean section rate for CPD) of 45% vs. 30% respectively would require a sample size of 352, assuming a significance level (alpha) of 0.05 and a power (1 – beta) of 80%. This was the minimum number of subjects required for the study. To facilitate investigation of other variables, for which no sample size had been calculated, the author decided to exceed this number if he had sufficient time for further recruitment and data collection.

6.5. RECRUITMENT AND INFORMED CONSENT

About thirty minutes to one hour before the scheduled clinician's ward round, the author approached each labouring mother to determine if she was eligible for participation in the study. The study design did not allow the author to read the clinical notes as this would eliminate blinding and introduce bias into his clinical examination. To determine eligibility for the study, women were asked if they: 1) were 9 months pregnant, 2) had labour pains, 3) had been feeling the baby moving, and 4) had any previous abdominal operation, and if so, was it caesarean section? The attending midwifery staff and doctors frequently facilitated this procedure, either because they knew the mothers or by reading the notes. Women who were suffering excessively from labour pains, or who were clearly about to give birth, were not approached. This also applied if it was clear that a mother was sedated by opiate drugs. Language problems, where they arose, were overcome by using ward staff as interpreters.

If a woman was possibly eligible for the study, based on the answers to the four questions above, she was informed about the nature and objectives of the research. This included specific mention of an additional vaginal examination that would be done immediately after that of the attending clinician. The content of the informed consent form was either read by the mother, or explained by the author. Both the mother and the author signed the consent form (Appendix B). This procedure was followed for all possibly eligible women and the author then waited for the clinician to start the ward round.

6.6. OUTCOME MEASURES

The main outcome measure was the presence or absence of CPD. This was defined as caesarean section for CPD or for poor progress, or ruptured uterus. Where caesarean section was done for CPD and fetal distress, or for poor progress and fetal distress, this was accepted as CPD. Normal vaginal delivery and assisted vaginal delivery were taken as evidence of no CPD. CPD could not be assumed when caesarean section was done for fetal distress alone, and these women had to be excluded from analysis where CPD was an outcome measure.

The second outcome measure was birth weight. All newborns were weighed within an hour of birth by nursing staff on one of two scales. These were a Tanita analogue scale giving readings to the nearest 50 g, and a Seca digital scale giving readings to the nearest 10 g. Both scales were calibrated once by the author using standardized weights. At irregular intervals the author weighed the same babies on both scales to confirm agreement between the two instruments. Spot checks of weights charted by nurses were also done by reweighing a number of infants. The accuracy of both scales was excellent throughout, as was the reliability of the nurses’ records of birth weight.

6.7. INDEPENDENT VARIABLES

Variables that could possibly influence the outcome measures are shown in the specimen data sheet (Appendix C). The variables are divided into basic demographic and obstetric data, external measurements, rank of examining clinician, findings on internal (vaginal) examination, and details of labour progress and outcome. The variables, their definitions, and how they were recorded, are described below.

6.8. DATA COLLECTION

The author informed the attending clinician (registrar or consultant) about the study and accompanied him or her to all the possibly eligible women described above. The clinician was told that no clinical information should be shared with the author, and that the author would not reveal his findings to the clinician.

6.8.1. Shoe size, foot size and height

Mothers were asked their South African shoe size (equivalent to British). Half-sizes, e.g. 4½, were accepted, and were used if the shoe size was stated as a range, e.g. 4 to 5. The author measured the length of the right foot using a soft tape-measure. The length was taken as the linear distance from the back of the heel at the level of the sole of the foot, to the tip of the big toe. The height was measured a metal tape-measure, with the woman lying supine as straight as possible. The author lined up her head with the edge of the mattress at the head of the bed, and measured the distance from the mattress edge to the base of her heel. Supine measurement was chosen because of the obvious inconvenience for these women in getting off a high bed and standing up straight. This measurement is termed ‘supine height’ but could be stated as ‘maternal length’. For the most part, the author obtained data on shoe size, foot size and height before arrival of the clinician. This saved time and allowed the author to gain the confidence of the mother. It also prevented the clinician from using the author’s data on shoe size and height to make obstetric decisions.

Supine measurement of height in adults is not conventional. It was possible that supine height measurement would be inaccurate or differ systematically from standing measurement. A convenience sample of 54 women in the study was used to quantify such differences. These women were measured standing in the postnatal wards using a vertical scale with a right-angled block to mark the top of the head. The standing heights were then compared with the intrapartum supine heights.

6.8.2. Abdominal palpation and symphysis-fundal height

While the clinician read the mother’s clinical notes, the author prepared her for examination. Abdominal examination was done between contractions with the mother supine. Women with palpably full bladders were asked to pass urine before examination could proceed. The author first palpated the pregnant uterus and estimated the fetal weight. SFH was then measured using a soft non-flexible tape, following the method described by Theron.[48] Using only the left index finger, the highest point on the uterus was identified, not necessarily in the midline, and marked with a ball-point pen. The SFH was taken from the upper edge of the symphysis pubis in the midline to the mark. (Figure

6.2). Importantly, the fetal weight estimate obtained from palpation was not changed after SFH measurement.

Figure 6.2. Measurement of symphysis-fundal height with a tape-measure.

6.8.3. Estimation of head descent

The author then identified the fetal sinciput and occiput as described by Crichton[106] (Figure 3.4), and estimated fifths of head palpable above the pelvic brim. This was followed by estimation of descent using the fingerbreadth method described by Notelowitz[124] (Figure 6.3). Using a ball-point pen, the author then marked the site of the sinciput on the skin exactly vertically above where the point of the sinciput was felt, and measured the distance from the upper edge of the symphysis pubis in the midline to this mark, to the nearest cm (Figure 6.4). Most of the attending clinicians were not aware of the significance of the mark. Where the clinician knew that the mark represented the sinciput, the author placed one or two dummy marks on the lower abdomen to prevent unblinding of the clinician to the author's findings.

Figure 6.3. The Notelowitz method of estimating level of head in fifths. In this example, three fingers cover the head, indicating that the head is at three-fifths above the brim.

Figure 6.4. Measurement of symphysis to sinciput using a tape measure.

6.8.4. The clinician's examination

The attendant clinician then performed abdominal and vaginal examination as part of the routine intrapartum assessment. The clinician's findings to be recorded in this study were fetal weight estimation, level of head in fifths, cervical dilatation, moulding, caput, fetal position, and station. The clinician's level of experience was also noted (registrar according to completed years of training, or consultant). To prevent unblinding to the clinician's findings, the author left the cubicle if the clinician was in the habit of dictating or speaking out the findings on vaginal examination, or if the clinician was teaching a medical student or midwife. If the clinician needed to rupture membranes, the author asked that the findings after membrane rupture were recorded.

6.8.5. Vaginal examination

The author then performed vaginal examination, immediately after the clinician, before the mother turned back onto her side. This was done to prevent recontamination of the vulva and minimize the risk of infection associated with repeated vaginal examinations. The author estimated cervical dilatation to the nearest cm, station of the head, moulding at the parieto-parietal and occipito-parietal sutures, caput succedaneum, position, degree of flexion, and asynclitism. If the degree of moulding differed between the right and left occipitoparietal sutures, the greater of the two was recorded. The state of the membranes was also noted (intact, ruptured at the time of clinician's examination, ruptured before the clinical assessment). In each case, the author made a subjective judgment on whether the mother displayed significant discomfort during examination.

During the course of the study, it became apparent that the author and the clinicians frequently disagreed about fetal position. The unreliability of clinician assessment of position was also shown in several articles that were published after the study protocol was written. Ultrasound verification of position immediately after clinical assessment was therefore done by the author in a convenience sample of women late in the study, to determine accuracy of the author's and clinicians' assessments of position. A 5 MHz curvilinear Siemens ultrasound probe was placed suprapubically and the orientation of the head was noted, with particular reference to the eyes, the falx cerebri, the thalami and the cavum septum pellucidum. This gave an accurate indication of the position.

6.8.6. Data capture

Immediately after clinical examination, the author recorded the findings on the study data sheet. These were not communicated to the clinician. The clinician's findings were obtained verbally immediately, or later from the case notes, whichever was more convenient. Following delivery of the baby, the author obtained the mother's file, and recorded her age, parity, weight at first antenatal clinic visit, HIV status, and gestational age by best assessment. 'Best assessment' means greatest reliance on early pregnancy ultrasound for gestation, followed by sure menstrual dates, followed by midwife or doctor's best clinical estimate. Most women who give birth at Chris Hani Baragwanath Hospital do not have early pregnancy ultrasound examinations. Details on labour and delivery were recorded. These included length of the active phase of labour in completed hours, whether the partogram alert line (1 cm per hour) or action line (1 cm per hour plus 4 hours) had been crossed, time from examination to delivery, use of oxytocin augmentation, mode of delivery, birth weight, and live or still birth. Where there was early maternal or neonatal death or severe morbidity, this was also recorded.

6.8.7. Issues around blinding of clinical findings

The clinicians were aware that blinding to each other's findings was central to the study design. However, some would ask if their clinical findings were in agreement with those of the author. This was understandable for the registrars, all of whom were the author's students. The author tried his best to handle such requests tactfully, giving somewhat evasive answers, such as 'we generally agreed on most of the findings' or 'that position was difficult, it was probably occipitoposterior'. Such interactions always occurred after the clinicians had made their obstetric management decisions, and did not influence the obstetric management plans. Full disclosure of the author's findings was however permitted after delivery of the baby.

There was a possibility that the author, as a senior obstetrician, could consider the clinician's management to be potentially harmful. In such circumstances, it would have been unethical for him not to raise his concerns. It was decided that the author would divulge his clinical findings in such circumstances, and discuss the management with the clinician. This happened only once in the study, when a registrar prescribed oxytocin to a poorly progressing multipara with some evidence of CPD. A caesarean section was arranged, but, parodoxically, the mother delivered normally before the operation could be done.

At times, registrars asked the author for his opinion on management of women in the study. The study protocol did not allow him to be involved and he referred them to their duty consultants for advice, or to the labour ward guidelines booklet.

6.9. DATA ANALYSIS

Database management and statistical analysis were performed on Microsoft Excel 2003, Epi-Info 6 for DOS statistical software, and SAS software version 9.1 (SAS Institute Inc, Cary, NC). In all sections of data analysis, descriptive statistics were employed with statements of frequencies with percentages, and 95% confidence intervals. Continuous and ordinal data were presented using means and standard deviations (SDs), medians and ranges. Analytic statistical methods are described below. For all tests, statistical significance was accepted at a P value of less than 0.05.

6.9.1. Predictors for CPD

To determine crude associations between independent variables and CPD, separate analyses were done for nulliparous and multiparous women. The tests used were the Chi-squared test and Fisher's exact test for discrete variables, and Student's t test and the Mann-Whitney test for continuous and ordinal variables. Univariate and multivariate maximum likelihood logistic regression analyses were done to determine independent predictors for CPD, using odds ratios and 95% confidence intervals. Stepwise logistic regression models were produced to quantify the degree of prediction for each variable. Sensitivity, specificity, positive and negative predictive values, and likelihood ratios for CPD were calculated at different level of head cut-offs, for Crichton, Notelowitz, symphysis-to-sinciput measurement and station. These were calculated for combinations of predictors where such combinations could be clinically useful. Receiver-operated characteristic (ROC) curves were constructed where applicable.

6.9.2. Interobserver agreement

Absolute agreement rates and Kappa statistics were calculated for interobserver agreement between the author and the attending clinicians for cervical dilatation, level of the head, position, and caput succedaneum. Multivariate ordinal regression analysis was performed to identify independent predictors of disagreement in estimation of cervical dilatation. Logistic regression analysis was done for identification of independent predictors of disagreement for assessment of engagement of the head.

6.9.3. Estimation of fetal weight

Mean percentage error in fetal weight estimation was calculated for the author's and clinicians' estimates, using birth weight as the denominator. The percentage of fetal weight estimates falling within 10% of the birth weight was also calculated, for the author and the clinicians. Simple linear regression of fetal weight estimation and SFH was done, with calculation of Pearson's correlation coefficient r. Univariate and multivariate linear regression was performed to identify independent predictors of birth weight. SFH and the author's estimated fetal weight were considered separately. Stepwise linear regression was done to determine the percentage contribution, using Spearman's partial correlation co-efficient r^2, for each predictor of birth weight. Again, estimated fetal weight and SFH were considered in separate regression models.

Sensitivity, specificity, positive and negative predictive values, and likelihood ratios for large infants were calculated at different SFH and estimated fetal weight cut-offs. ROC curves were constructed where applicable.

Chapter 6: Summary points

- A prospective cross-sectional study was planned, with the author performing non-participant intrapartum examinations at the same time as the clinician doing the routine labour ward round
- The author and clinician were blinded to each other's findings at each examination
- The study population was pregnant women at Chris Hani Baragwanath Hospital, at term in the active phase of labour with live infants and cephalic presentations, without previous caesarean section, and with no evidence of fetal distress
- A convenience sample was used, depending on the availability of the author, who did all the examinations himself. Participant women were recruited before the routine labour ward rounds. Written informed consent was obtained for measurements, abdominal examination and vaginal examination by the author
- The main outcome measures were CPD, defined as caesarean section for poor progress, and birth weight
- Independent variables collected included maternal age, parity, weight, height, shoe size, HIV status, gestation, estimated fetal weight, SFH, level of head on abdominal and vaginal examination, cervical dilatation, moulding, caput, and duration of labour
- Data analysis was done on Microsoft Excel, Epi-Info 6 and SAS 9.1 software, using descriptive statistics, and univariate and multivariate analyses. Sensitivity, specificity, predictive values and likelihood ratios were used to investigate the predictive values of individual observations. Kappa statistics were calculated to determine inter-observer agreement of clinical estimations.

CHAPTER 7

CEPHALOPELVIC DISPROPORTION: RESULTS AND DISCUSSION

This chapter begins by describing the study sample in demographic and clinical terms. A comparison of women with and without CPD is presented, separately for nulliparae and multiparae, with univariate analysis for association of each clinical variable with CPD. The findings of multivariate analysis are presented to identify independent predictors for CPD. There is also comparison of the predictive value of different methods of estimating head descent.

7.1. THE STUDY SAMPLE

The author examined 508 women in the active phase of labour. Their mean age was 25.0 ± 5.8 years, with a range of 14 to 43 years. There were 493 African (97.0%) and 15 Coloured women. HIV results were available for 411 (80.9%) and among these, 115 women (28.0%) were seropositive. There were four twin pregnancies. Basic clinical data and labour outcomes are described below and displayed in Table 7.2.

7.1.1. Parity and gestation

Three hundred and twenty-one women (63.2%) were nulliparous. Among multiparae, 107 women (57.2%) were para 1, 49 (26.2%) were para 2, 14 (7.5%) were para 3, 11 (5.9%) were para 4, 4 (2.1%) were para 5 and 2 (1.1%) were para 6. The mean gestational age was 39.3 ± 1.6 weeks, with a range of 37 to 43 weeks. There were 50 pregnancies (9.8%) with a gestation of 42 weeks or more.

7.1.2. Weight and height

Weights were available for 492 women (96.9%). The mean weight of the women at first antenatal visit was 69.2 ± 13.9 kg, with a range of 43 to 134 kg. Multiparae were, on average, heavier (74.1 kg) than nulliparae (66.3 kg; P<0.0001). The gestational ages at first antenatal visits were not recorded.

The mean intrapartum supine height was 162.4 ± 6.4 cm, with a range of 144 to 183 cm. On average, supine heights were 4.9 cm greater than standing heights in a sample of 54 women in the study (Table 7.1). The mean body mass index (BMI) was 26.2 kg/m^2, with a range of 16.5 to 46.8 kg/m^2. The BMI exceeded 30 kg/m^2 in 96 women (19.5%). The BMI values were calculated using supine height, and are therefore underestimates.

7.1.3. Labour

Labour was induced in 54 women (10.6%). The most frequent reason for induction was prolonged pregnancy (n=26), followed by hypertension (n=14), prelabour rupture of membranes (n=9), and other or unknown reasons (n=5).

Table 7.1. Comparison of supine height with standing height measured in a sample of women in the study (n=54). For each standing height measurement shown on the left, the mean supine height difference is shown, with the range. For example, there were 2 women with standing measurements of 155 cm, and their supine heights were on average 4.5 cm greater than the standing measurements. Composite data are shown in the lowest cell.

Standing height after delivery (cm)	Intrapartum height difference (cm)			
	Number of women	Mean	Lowest	Highest
<153	5	+3.20	+1	+5
153	4	+3.50	+3	+4
155	2	+4.50	+3	+6
157	2	+3.00	+2	+4
159	4	+4.00	+2	+7
160	1	+3.00	+3	+3
161	4	+5.50	-1	+9
162	7	+5.00	0	+8
163	3	+5.00	+4	+6
164	2	+4.50	+3	+6
165	4	+5.75	+5	+8
166	4	+5.75	+5	+7
167	2	+7.00	+7	+7
168	1	+5.00	+5	+5
169	3	+6.00	+4	+8
170	1	+5.00	+5	+5
171	1	+8.00	+8	+8
>171	4	+6.25	+3	+9
Mean difference = +4.93 (95% CI +4.34 to +5.52). Standard deviation = 2.21				

The mean cervical dilatation at examination was 6.0 ± 1.9 cm, with a median and mode of 5 cm. The cervix was fully dilated (10 cm) in 37 (7.3%). Significant discomfort at vaginal examination was felt by more nulliparae than multiparae (14.6% vs. 7.0%; P=0.011). The mean duration of the active phase of labour was 8.7 ± 5.1 hours, with a median of 8 hours. The longest labour lasted 26 hours. Oxytocin augmentation was used in 255 women (50.2%). Nulliparae had longer mean durations of labour (9.4 hours) than multiparae (7.4 hours; P<0.0001). The alert line was crossed in 401 labours (78.9%). Of these, 229 (45.1% of the total) went on to cross the four-hour action line. Therefore, normal labour progress, where no partogram lines were crossed, occurred in only 107 women (21.1%). This is indicative of the high risk population selected for this study.

Fetal position was identified in 500 cases (98.4%). The most frequent fetal position was right occipitoposterior (27.2%), followed by left occipitoanterior (26.0%), left occipitotransverse (23.6%), right occipitotransverse (10.4%), left occipitoposterior (6.8%) and right occipitoanterior (5.2%). Ultrasound verification of position was done on a sample of women and the results are presented in Chapter 8. Assessment of asynclitism was abandoned midway through the study. The author found this to be subjective, lacking in anatomical landmarks, and susceptible to detection bias. Asynclitism seemed to become noticeable whenever there was a high head with parieto-parietal moulding.

7.1.4. Mode of delivery and definition of CPD

There were 350 normal vaginal deliveries (68.9%) and 21 assisted vaginal deliveries (4.1%). According to the study definition, all of these women were classified as not having CPD. One hundred and thirteen caesarean sections were done for poor progress or CPD (22.2%) and 24 were done for fetal distress (4.7%). There were no ruptured uteri. The 24 women who had caesarean sections for fetal distress could not be defined as having or not having CPD. This left a total of 484 women in whom prediction for CPD could be studied.

7.1.5 Birth weight and fetal outcome

The mean birth weight was 3184 ± 439 g, with a range of 1880 to 4890 g. The median birth weight was 3195 g, with 25th and 75th centiles of 2900 and 3450 g respectively. There were three fresh stillbirths, all related to intrapartum hypoxia, and two early neonatal deaths, one related to intrapartum hypoxia and one to multiple congenital abnormalities, which had not been diagnosed antenatally. Both infants that died in the neonatal period had vaginal births. Thirteen infants were admitted to the neonatal unit, 10 for ‘asphyxia’ and three for other reasons. Four of the babies admitted for ‘asphyxia’ went on to develop moderate to severe (grade 2 to 3) hypoxic ischaemic encephalopathy. Of these four, two were born by caesarean section, and two had vaginal births.

7.2. PREDICTORS FOR CPD

The association between CPD and demographic factors, maternal measurements and intrapartum findings was investigated. Nulliparae and multiparae were considered separately in crude comparisons between women with and without CPD. This was followed by unseparated univariate and multivariate analysis, with parity considered as one of the possible predictors. A maximum likelihood stepwise logistic regression model was applied to determine independent clinical predictors for CPD.

Table 7.2. Basic clinical data and labour outcomes for the whole study sample, presented separately for nulliparae and multiparae. Means are shown ± standard deviation (n=508). P values are given for differences between nulliparae and multiparae

		All (n=508)	Nulliparae (n=321)	Multiparae (n=187)	P value
Mean age (years)		25.0 ±5.8	22.3 ±3.9	29.7 ±5.6	<0.0001
HIV status	Positive	115 (22.6%)	71 (22.1%)	44 (23.5%)	0.62
	Negative	296 (58.3%)	192 (59.8%)	104 (55.6%)	
	Unknown	97 (19.1%)	58 (18.1%)	39 (20.9%)	
Mean gestational age (weeks)		39.3 ±1.6	39.4 ±1.6	39.2 ±1.6	0.35
Mean weight (kg) (n=492)		69.2 ±13.9	66.3 ±13.3	74.1 ±13.4	<0.0001
Mean supine height (cm)		162.4 ±6.4	162.1 ±6.3	162.9 ±6.5	0.16
Mean body mass index (kg/m^2) (n=492)		26.2 ±4.9	25.2 ±4.5	27.9 ±5.2	<0.0001
Mean cervical dilatation at examination (cm)		6.0 ±1.9	6.0 ±2.0	6.0 ±1.7	0.95
Membranes not intact at time of examination		439 (86.4%)	285 (88.8%)	154 (82.4%)	0.041
Discomfort at examination		60 (11.8%)	47 (14.6%)	13 (7.0%)	0.011
Mean duration of labour (hours)		8.7 ±5.1	9.4 ±5.3	7.4 ±4.6	<0.0001
Oxytocin augmentation		255 (50.2%)	189 (58.9%)	66 (35.3%)	<0.0001
Partogram lines crossed:	None	107 (21.1%)	57 (17.8%)	50 (26.7%)	0.0012
	Alert line only	172 (33.9%)	100 (31.2%)	72 (38.5%)	
	Four hour action line	229 (45.1%)	164 (51.1%)	65 (34.8%)	
Delivery:	Normal vaginal	350 (68.9%)	205 (63.9%)	145 (77.5%)	0.0013
	Assisted vaginal	21 (4.1%)	21 (6.5%)	0 (0.0%)	<0.0001
	Caesarean for CPD	113 (22.2%)	80 (24.9%)	33 (17.6%)	0.057
	Caesarean for fetal distress	24 (4.7%)	15 (4.7%)	9 (4.8%)	0.94
Mean birth weight (g)		3184 ±439	3138 ±414	3263 ±470	0.0020
Perinatal death		5 (1.0%)	5 (1.6%)	0 (0.0%)	0.16

7.2.1. Nulliparae

In terms of maternal demographics and measurements, there were no significant associations between CPD and maternal age, HIV status, maternal weight, body mass index and shoe size. CPD was however associated with smaller feet, greater gestational age and shorter stature (Table 7.3).

Table 7.3. Association of maternal demographics and measurements with CPD in nulliparae (n=306)

	Number	No CPD (n=226)	CPD (n=80)	P value
Mean age in years	306	22.1 ±3.8	22.7 ±3.7	0.18
HIV positive	250	49/184 (26.6%)	18/66 (27.3%)	0.92
Mean weight in kg	295	66.1 ±11.7	66.6 ±17.3	0.41
Mean supine height in cm	306	163.6 ±6.2	160.6 ±6.5	0.014
Mean body mass index in kg/m^2	295	25.0 ±4.1	25.7 ±5.5	0.71
Mean shoe size (British)	306	5.3 ±1.2	5.2 ±1.2	0.43
Mean foot length in cm	306	23.6 ±1.2	23.3 ±1.2	0.04
Mean gestational age in weeks	306	39.2 ±1.6	39.8 ±1.6	0.003

On intrapartum assessment, no significant associations were found between CPD and occipito-parietal moulding, fetal position, head flexion and discomfort at examination. CPD was significantly associated with increased estimated fetal weight, greater SFH, higher level of the head above the pelvic brim (by all three methods: Crichton, Notelowitz and symphysis-to-sinciput), reduced cervical dilatation, higher station of head, parieto-parietal moulding, caput succedaneum, crossing of the partogram alert and action lines, increased duration of labour, and use of oxytocin for labour augmentation

(Table 7.4). One nullipara had twin pregnancy. Fetal weight estimation and SFH were not applicable to her. Station of head could only be estimated in 268 nulliparae (87.6%) because of occasional difficulty in identifying the ischial spines. Occipito-parietal moulding could only be assessed in 202 cases (66.0%), mostly because of head deflexion, with the lambdoidal sutures not accessible.

7.2.2. Multiparae

Regarding maternal demographics and measurements, the findings were similar to those for nulliparae. However, foot size was not significantly associated with CPD, and the only variables found to be significantly associated were maternal height and gestational age (Table 7.5). At intrapartum assessment, there were no statistically significant associations between CPD and level of the head by Crichton and Notelowitz methods and station, cervical dilatation, occipito-parietal moulding, fetal position, flexion of the head, use of oxytocin for augmentation of labour, and discomfort at examination. Significant associations were found between CPD and increased estimated fetal weight, increased SFH, increased symphysis-to-sinciput measurement, parieto-parietal moulding, caput succedaneum, crossing of partogram alert and action lines, and increased duration of labour (Table 7.6). Comparison with nulliparae showed that the mean level of fetal head, by fifths, by symphysis-to-sinciput, and by station, was higher in multiparae (all $P<0.0001$). Fetal weight estimation and SFH were not considered in three multiparae with twin pregnancies. Station of the head could only be assessed in 166 women (93.3%), and occipito-parietal moulding could only be estimated in 136 (76.4%).

Table 7.4. Association of intrapartum clinical observations with CPD in nulliparae (n=306)

		Number	No CPD (n=226)	CPD (n=80)	P value
Mean estimated fetal weight by author in kg		305	3145 ±300	3376 ±358	<0.0001
Mean symphysis-fundal height in cm		305	36.0 ±3.1	38.6 ±4.0	<0.0001
Mean level of head above brim in fifths (Crichton)		305	2.5 ±1.2	3.2 ±1.0	<0.0001
Mean level of head above brim in fifths (Notelowitz)		305	2.7 ±1.2	3.4 ±0.9	<0.0001
Mean symphysis to sinciput distance in cm		305	8.7 ±3.5	10.4 ±2.1	<0.0001
Mean cervical dilatation in cm		306	6.3 ±2.1	5.2 ±1.4	<0.0001
Discomfort at examination		306	33 (14.6%)	10 (12.5%)	0.22
Mean station of head		268	+0.1 ±1.2	–0.8 ±1.2	<0.0001
Moulding score (parieto-parietal)	Grade 0	303	141 (62.9%)	23 (29.1%)	<0.0001*
	Grade 1		57 (25.4%)	27 (34.2%)	
	Grade 2		25 (11.2%)	26 (32.9%)	
	Grade 3		1 (0.0%)	3 (3.8%)	
Moulding score (occipito-parietal)	Grade 0	202	27 (17.2%)	2 (4.4%)	0.052*
	Grade 1		35 (22.3%)	8 (17.8%)	
	Grade 2		89 (56.7%)	27 (60.0%)	
	Grade 3		6 (3.8%)	8 (17.8%)	
Caput score	None	305	145 (64.4%)	32 (40.0%)	0.0005
	Grade 1		50 (22.2%)	27 (33.8%)	
	Grade 2		30 (13.3%)	21 (26.3%)	
Position	Occipitoanterior	300	72 (32.3%)	23 (29.9%)	0.91
	Occipitotransverse		65 (29.1%)	24 (31.2%)	
	Occipitoposterior		86 (38.6%)	30 (39.0%)	
Fetal head flexion	Good	300	47 (21.2%)	22 (28.2%)	0.11
	Moderate		96 (43.2%)	38 (48.7%)	
	Poor		79 (35.6%)	18 (23.1%)	
Partogram lines crossed	None	306	55 (24.3%)	0 (0.0%)	<0.0001
	Alert		84 (37.2%)	13 (16.3%)	
	4-hour action		87 (38.5%)	67 (83.8%)	
Mean duration of active phase of labour in hours		306	8.3 ±4.7	12.8 ±5.5	<0.0001
Oxytocin augmentation used		306	123 (54.5%)	59 (73.8%)	0.002

*Chi-squared test: grade 2 and grade 3 moulding were combined as one grade

Table 7.5. Association of maternal demographics and measurements with CPD in multiparae (n=178)

	Number	No CPD (n=145)	CPD (n=33)	P value
Mean age in years	178	29.6 ±5.5	29.8 ±6.0	0.79
HIV positive	139	33/112 (29.5%)	8/27 (29.6%)	0.99
Mean weight in kg	174	74.4 ±13.4	73.3 ±14.2	0.69
Mean supine height in cm	178	163.5 ±6.6	160.3 ±5.6	0.01
Mean body mass index in kg/m^2	174	27.8 ±5.2	28.5 ±5.4	0.44
Mean shoe size (British)	178	5.8 ±1.1	5.4 ±1.1	0.052
Mean foot length in cm	178	23.9 ±1.1	23.5 ±0.9	0.07
Mean gestational age in weeks	178	39.0 ±1.6	39.9 ±1.4	0.003

Table 7.6. Association of intrapartum clinical observations with CPD in multiparae (n=178)

		Number	No CPD (n=145)	CPD (n=33)	P value
Mean estimated fetal weight by author in kg		175	3256 ±361	3418 ±307	0.018
Mean symphysis-fundal height in cm		175	37.2 ±3.6	39.3 ±3.1	0.001
Mean level of head above brim in fifths (Crichton)		177	3.2 ±1.3	3.5 ±1.0	0.21
Mean level of head above brim in fifths (Notelowitz)		177	3.2 ±1.3	3.7 ±0.9	0.06
Mean symphysis to sinciput distance in cm		177	9.9 ±3.1	11.0 ±1.8	0.042
Mean cervical dilatation in cm		178	6.0 ±1.8	5.7 ±1.7	0.37
Discomfort at examination		178	11 (7.6%)	2 (6.1%)	0.55
Mean station of head		166	–0.9 ±1.5	–1.3 ±1.3	0.11
Moulding score (parieto-parietal)	Grade 0 Grade 1 Grade 2 Grade 3	178	74 (51.0%) 51 (35.2%) 18 (12.4%) 2 (1.4%)	8 (24.2%) 13 (39.4%) 11 (33.3%) 1 (3.0%)	0.003*
Moulding score (occipito-parietal)	Grade 0 Grade 1 Grade 2 Grade 3	136	15 (13.8%) 29 (26.6%) 54 (49.5%) 11 (10.1%)	2 (7.4%) 6 (22.2%) 18 (66.7%) 1 (3.7%)	0.53*
Caput score	None Grade 1 Grade 2	178	107 (73.8%) 26 (17.9%) 12 (8.3%)	17 (51.5%) 10 (30.3%) 6 (18.2%)	0.038
Head position	Occipitoanterior Occipitotransverse Occipitoposterior	177	45 (31.3%) 60 (41.7%) 39 (27.1%)	13 (39.4%) 10 (30.3%) 10 (30.3%)	0.47
Flexion	Good Moderate Poor	175	26 (18.3%) 63 (44.4%) 53 (37.3%)	5 (15.2%) 13 (39.4%) 15 (45.5%)	0.68
Partogram lines crossed	None Alert 4-hour action	178	48 (33.1%) 63 (43.4%) 34 (23.4%)	1 (3.0%) 8 (24.2%) 24 (72.7%)	<0.0001
Mean duration of active phase of labour in hours		178	6.3 ±3.8	11.2 ±5.2	<0.0001
Oxytocin augmentation used		178	46 (31.7%)	16 (48.5%)	0.07

*Chi-squared test: grade 2 and grade 3 moulding were combined as one grade

7.2.3. Multivariate analysis

To study and compare the influence of abdominal (fifths) and transvaginal (station) estimation of head descent, separate analyses were performed, one including fifths by Notelowitz (Tables 7.7 and 7.8), the other including station (Tables 7.9 and 7.10). The Notelowitz method was chosen because of its marginally stronger association with CPD than both the Crichton method and the symphysis-to-sinciput measurement. Occipito-parietal moulding was excluded from the analysis because scores were only available for 338 (69.8%) of subjects, and because of the lack of statistical association with CPD in the crude analysis for nulliparae and multiparae.

In the multivariate analysis that included level of head above the brim in fifths, significant associations with CPD were found with shorter maternal stature, increased SFH, decreased cervical dilatation, parieto-parietal moulding, caput succedaneum and increased duration of labour (Table 7.7). Variables that were significant on univariate but not multivariate analysis were gestation, level of the head in fifths, and time from examination to delivery. When cervical dilatation was removed from the analysis (not shown), level of the head in fifths became significantly associated (adjusted odds ratio 1.55; 95% CI 1.14-2.10; P=0.006).

A stepwise logistic regression model showed that height, SFH, cervical dilatation, parieto-parietal moulding, caput succedaneum and duration of labour were independent clinical predictors for CPD (Table 7.8). The model shows, for example, that the odds for CPD are 0.95 times less (5% less) for a woman who is 1 cm taller than another woman.

In the multivariate analysis that included station, SFH was excluded to show the influence of gestation as a predictor for CPD. SFH and gestation were significantly correlated in this study (r=0.33; 95% CI 0.14-0.43). Significant independent predictors for CPD were short stature, gestation, decreased cervical dilatation, parieto-parietal moulding, caput succedaneum and increased duration of labour (Table 7.9). Variables that were significant on univariate but not multivariate analysis were station and time interval from examination to delivery. When cervical dilatation was removed from the analysis (not shown), station became an independent predictor for CPD (adjusted odds ratio 0.63; 95% CI 0.48-0.83; P=0.0005).

A stepwise logistic regression model showed that height, gestation, station, cervical dilatation, parieto-parietal moulding, caput succedaneum and duration of labour were independent clinical predictors for CPD (Table 7.10). The model shows, for example, that the odds for CPD are 2.33 times greater (133% greater) for each increased degree of parieto-parietal moulding.

Table 7.7. Univariate (crude) analysis and multivariate (adjusted) logistic regression for clinical predictors of CPD using fifths (Notelowitz) as the measure of head descent.

Variable	Crude odds ratio (95% CI)	P value	Adjusted odds ratio (95% CI)	P value
Maternal age	1.06 (0.96-1.03)	0.76	1.02 (0.95-1.090)	0.65
Parity	0.71 (0.50-1.00)	0.05	0.76 (0.43-1.33)	0.34
HIV status	0.98 (0.92-1.05)	0.56	0.99 (0.90-1.08)	0.77
Maternal weight	1.00 (0.98-1.01)	0.61	0.99 (0.96-1.02)	0.45
Supine height	0.94 (0.91-0.97)	0.0004	0.95 (0.90-0.99)	0.02
Gestation	1.33 (1.16-1.52)	<0.0001	1.13 (0.93-1.37)	0.23
SFH	1.21 (1.14-1.29)	<0.0001	1.21 (1.09-1.35)	0.0004
Level of head in fifths	1.58 (1.28-1.94)	<0.0001	1.28 (0.92-1.78)	0.14
Cervical dilatation	0.76 (0.66-0.86)	<0.0001	0.67 (0.53-0.85)	0.0009
State of the membranes	1.05 (0.76-1.45)	0.75	1.14 (0.71-1.82)	0.59
Fetal head position	1.02 (0.79-1.33)	0.87	0.84 (0.57-1.24)	0.84
Moulding (parieto-parietal)	2.38 (1.82-3.11)	<0.0001	2.32 (1.59-3.39)	<0.0001
Caput succedaneum	2.77 (1.80-4.26)	<0.0001	2.31 (1.17-4.55)	0.016
Head flexion	0.82 (0.61-1.09)	0.18	0.88 (0.58-1.33)	0.88
Duration of labour	1.21 (1.15-1.27)	<0.0001	1.23 (1.14-1.33)	<0.0001
Interval from examination to delivery	1.19 (1.12-1.27)	<0.0001	0.97 (0.87-1.09)	0.63

Table 7.8. Stepwise logistic regression model showing independent predictors of CPD with fifths (Notelowitz) as the measure of head descent.

Predictor	Adjusted odds ratio (95% CI)	P value
Supine height (cm)	0.95 (0.90-0.99)	0.02
SFH (cm)	1.21 (1.11-1.31)	<0.0001
Cervical dilatation (cm)	0.64 (0.53-0.77)	<0.0001
Parieto-parietal moulding (degree)	2.41 (1.67-3.46)	<0.0001
Caput succedaneum (degree)	2.29 (1.23-4.26)	0.009
Duration of labour (hours)	1.23 (1.16-1.30)	<0.0001

Table 7.9. Univariate (crude) analysis and multivariate (adjusted) logistic regression for clinical predictors of CPD using station as the measure of head descent.

Variable	Crude odds ratio (95% CI)	P value	Adjusted odds ratio (95% CI)	P value
Maternal age	1.06 (0.96-1.03)	0.76	1.02 (0.96-1.09)	0.52
Parity	0.71 (0.50-1.00)	0.05	0.72 (0.41-1.28)	0.27
HIV status	0.98 (0.92-1.05)	0.56	0.99 (0.91-1.09)	0.96
Maternal weight	1.00 (0.98-1.01)	0.61	1.01 (0.98-1.03)	0.63
Supine height	0.94 (0.91-0.97)	0.0004	0.93 (0.89-0.98)	0.003
Gestation	1.33 (1.16-1.52)	<0.0001	1.30 (1.09-1.56)	0.005
Station of head	0.69 (0.59-0.82)	<0.0001	0.74 (0.56-1.00)	0.053
Cervical dilatation	0.76 (0.66-0.86)	<0.0001	0.69 (0.58-0.83)	<0.0001
State of the membranes	1.05 (0.76-1.45)	0.75	1.05 (0.65-1.69)	0.84
Fetal head position	1.02 (0.79-1.33)	0.87	0.93 (0.63-1.37)	0.70
Moulding (parieto-parietal)	2.38 (1.82-3.11)	<0.0001	2.79 (1.96-3.96)	<0.0001
Caput succedaneum	2.77 (1.80-4.26)	<0.0001	2.25 (1.12-4.53)	0.023
Head flexion	0.82 (0.61-1.09)	0.18	0.91 (0.61-1.37)	0.66
Duration of labour	1.21 (1.15-1.27)	<0.0001	1.23 (1.16-1.31)	<0.0001
Interval from examination to delivery	1.19 (1.12-1.27)	<0.0001	0.98 (0.87-1.09)	0.67

Table 7.10. Stepwise logistic regression model showing independent predictors of CPD with station as the measure of head descent.

Predictor	Adjusted odds ratio (95% CI)	P value
Supine height (cm)	0.94 (0.90-0.98)	0.009
Gestation (weeks)	1.29 (1.08-1.55)	0.0065
Station (cm)	0.76 (0.58-0.99)	0.046
Cervical dilatation (cm)	0.73 (0.59-0.90)	0.003
Parieto-parietal moulding (degree)	2.33 (1.61-3.39)	<0.0001
Caput succedaneum (degree)	2.28 (1.19-4.37)	0.013
Duration of labour (hours)	1.23 (1.15-1.30)	<0.0001

To explain why the addition of cervical dilatation to the multivariate analysis removed level of head as a predictor for CPD, it became necessary to explore the relationship between cervical dilatation and level of head. Stratified analysis was done first for unengaged vs. engaged heads in fifths, and then for unengaged vs. engaged heads by station, at low and high cervical dilatation, with respect to CPD (Tables 7.11 and 7.12).

Both stratified analyses showed that an unengaged head at advanced cervical dilatation (>6 cm) was more predictive for CPD than one at a lower cervical dilatation. This suggests that the predictive value of level of head is partly dependent on cervical dilatation at the time of clinical assessment.

Table 7.11. CPD rates with percentages for unengaged vs. engaged heads by fifths estimation, at cervical dilation <7 cm and ≥7 cm, with relative risks given for CPD with unengaged heads (n=482).

Level of head	Cervix <7 cm dilated	Cervix ≥7 cm dilated
Unengaged (≥three fifths)	82/271 (30.2%)	16/83 (16.2%)
Engaged (<three fifths)	8/39 (20.5%)	7/89 (7.3%)
Relative risk for CPD with unengaged head (95% CI)	1.48 (0.77-2.81)	2.45 (1.06-5.66)

Table 7.12. CPD rates with percentages for unengaged vs. engaged heads by estimation of station, at cervical dilation <7 cm and ≥7 cm, with relative risks given for CPD with unengaged heads (n=434).

Level of head	Cervix <7 cm dilated	Cervix ≥7 cm dilated
Unengaged (station -1 or higher)	59/175 (33.7%)	10/35 (28.6%)
Engaged (station 0 or lower)	18/104 (17.3%)	11/120 (9.2%)
Relative risk for CPD with unengaged head (95% CI)	1.95 (1.22-3.11)	3.12 (1.44-6.73)

7.2.4. Maternal supine height

Maternal supine height was shown in multivariate analysis to be an independent predictor for CPD. Examination of rates of CPD according to height showed that no women with a height greater than 172 cm (n=28) had CPD, while CPD occurred in 12 out of 28 women with a height less than 153 cm (Table 7.13). A supine height of 172 cm corresponds to a standing height of about 166 cm (Table 7.1). The lower and upper limits of 153 and 172 cm were chosen to illustrate these differences clearly. The equivalence of 153 cm with five feet is coincidental.

Table 7.13. Intrapartum maternal supine height and CPD (n=484).

Height (cm)	No CPD (n=371)	CPD (n=113)	CPD rate (95% CI)
<153	16	12	42.9% (25.0 – 62.6)
153-172	327	101	23.6% (19.7 – 28.0)
>172	28	0	0.0% (0.0 – 15.0)

7.2.5. Symphysis-fundal height

The independent association of SFH with CPD has been demonstrated in the multivariate analysis. Comparison of cut-off intervals of SFH measurements with respect to CPD found a 75.0% probability of CPD (9/12) when SFH was 45 cm or more, and an 8.4% probability of CPD (10/119) when SFH was less than 35 cm (Table 7.14).

Table 7.14. Intrapartum symphyis-fundal height (SFH) measurement and CPD (n=480). This excludes four women with multiple pregnancies.

SFH (cm)	No CPD (n=367)	CPD (n=113)	CPD rate (95% CI)
<35	109	10	8.4% (4.3 – 15.3)
35-39	191	63	24.8% (19.7 – 30.7)
40-44	64	31	32.6% (23.6 – 43.1)
≥45	3	9	75.0% (42.8 – 93.3)

7.2.6. Combination of maternal height and symphysis-fundal height

The influence of short stature in combination with a large SFH was tested using cut-off values of less than 160 cm, and 40 cm and greater respectively. With such a combination, the positive predictive value for CPD was 42.4% (Table 7.15). Conversely, the combination of tall stature (165 cm or greater) with a small SFH (less than 35 cm) resulted in a positive predictive value of 10% (Table 7.16). This analysis excludes the four women with twin pregnancies.

Table 7.15. Positive predictive value (PPV) and likelihood ratio (LR) for CPD, for a combination of short stature (<160 cm supine height) and high SFH (≥40 cm) (n=480).

<table>
<tr><th></th><th>CPD
(n=113)</th><th>No CPD
(n=367)</th><td rowspan="3">PPV = 42.4%
(95% CI 25.9-60.6)

LR = 2.39
(95% CI 1.24-4.62)</td></tr>
<tr><td>Height <160 cm and SFH ≥40 cm</td><td>14</td><td>19</td></tr>
<tr><td>Height ≥160 cm and/or SFH <40 cm</td><td>99</td><td>348</td></tr>
</table>

Table 7.16. Positive predictive value (PPV) and likelihood ratio (LR) for CPD, for a combination of tall stature (≥165 cm supine height) and small SFH (<35 cm) (n=480).

<table>
<tr><th></th><th>CPD
(n=113)</th><th>No CPD
(n=367)</th><td rowspan="3">PPV = 10.0%
(95% CI 3.3-24.6)

LR = 0.36
(95% CI 0.13-0.99)</td></tr>
<tr><td>Height ≥165 cm and SFH <35 cm</td><td>4</td><td>36</td></tr>
<tr><td>Height <160 cm and/or SFH ≥35 cm</td><td>109</td><td>331</td></tr>
</table>

7.2.7. Combination of moulding and level of fetal head

The influence of moulding in combination with level of head was tested using engagement by Notelowitz method (two-fifths or less palpable) and parieto-parietal moulding. With an unengaged head in the presence of moulding of grade 2 or greater, the positive predictive value for CPD was 48.6% (Table 7.17). Conversely, engagement in the absence of such moulding resulted in a positive predictive value of 7.9% (Table 7.18). The latter calculation is equivalent to a probability for vaginal delivery of 92.1%. This analysis excludes five women in whom moulding or level of head, or both, could not be determined by the author.

Table 7.17. Positive predictive value (PPV) and likelihood ratio (LR) for CPD, for a combination of parietoparietal moulding ≥grade 2 and unengaged fetal head (≥3 fifths palpable) (n=479).

<table>
<tr><th></th><th>CPD
(n=112)</th><th>No CPD
(n=367)</th><td rowspan="3">PPV = 48.6%
(95% CI 36.6-60.7)

LR = 3.09
(95% CI 2.04-4.70)</td></tr>
<tr><td>Moulding ≥grade 2
and head ≥3 fifths</td><td>34</td><td>36</td></tr>
<tr><td>Moulding <grade 2
and/or head <3 fifths</td><td>78</td><td>331</td></tr>
</table>

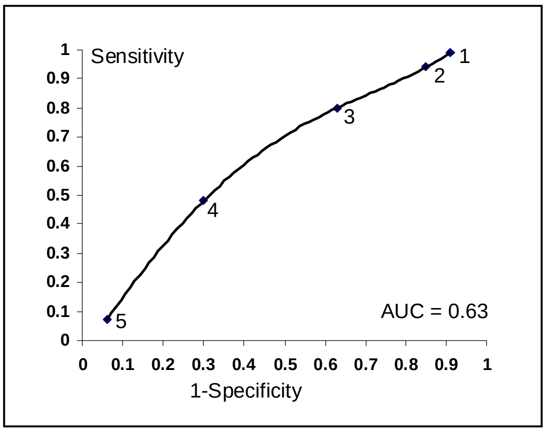
Table 7.18. Positive predictive value (PPV) and likelihood ratio (LR) for CPD, for a combination of parietoparietal moulding <grade 2 and engaged fetal head (<3 fifths palpable) (n=479).

<table>
<tr><th></th><th>CPD
(n=112)</th><th>No CPD
(n=367)</th><td rowspan="3">PPV = 7.9%
(95% CI 3.9-14.9)

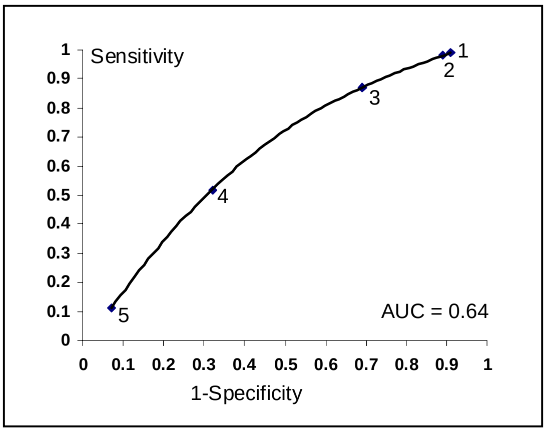
LR = 0.28
(95% CI 0.15-0.54)</td></tr>
<tr><td>Moulding <grade 2
and head <3 fifths</td><td>9</td><td>105</td></tr>
<tr><td>Moulding ≥grade 2
and/or head ≥3 fifths</td><td>103</td><td>262</td></tr>
</table>

7.2.8. Comparison of methods of estimating head descent

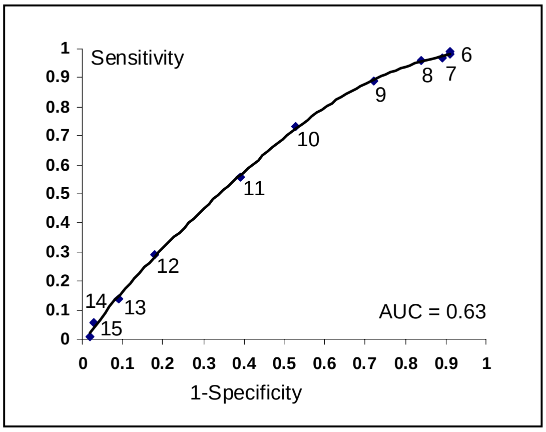
The associations of CPD with level of head in fifths and station have been shown in the multivariate analyses. Comparison of univariate association of different methods of estimating head descent is presented here using receiver operated characteristic plots. These show sensitivity plotted against (1-specificity) for CPD at each measure for each method (Figure 7.1). For each plot, a curve is drawn and the area under the curve (AUC) is calculated. The composite predictive value of each method can be determined by the area under the curve. The four methods performed similarly, with station being marginally better (AUC=0.66) than fifths by the Notelowitz method (0.64), fifths by the Crichton method (0.63), and symphysis-to-sinciput measurement (0.63). Examination of the plot for symphysis-to-sinciput measurement showed that a cut-off of 10 cm vs. 9 cm corresponded best to the estimate for head engagement (conventionally three-fifths vs. two-fifths, or station -1 vs. station 0).



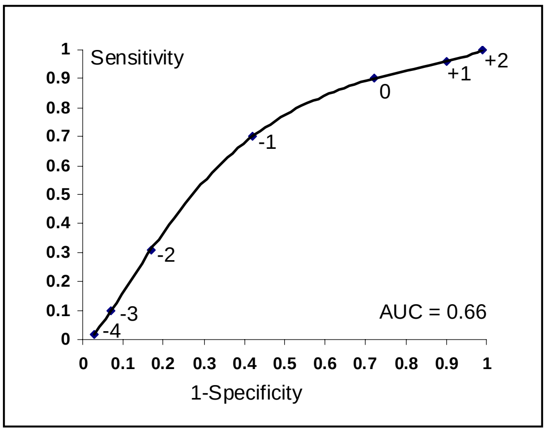
A: Level of head in fifths (Crichton) (n=482)



B. Level of head in fifths (Notelowitz) (n=482)



C. Symphysis-sinciput distance in cm (n=482)



D. Station of head (n=434)

Figure 7.1. Receiver operated characteristic plots for four methods of estimating head descent in the prediction of CPD. Each measurement shown next to the curve represents a cutoff of that measurement against one unit lower of head descent, e.g. in D, station –1 is the cutoff vs. station 0. AUC = area under the curve.

At the point of head engagement, station was the best predictor for CPD, with a greater positive predictive value and likelihood ratio than fifths or symphysis-to-sinciput measurement. Station could however only be assessed in 434 cases (89.7%). All three abdominal methods performed similarly, with symphysis-to-sinciput being a marginally better predictor than either of the fifths methods (Table 7.19).

Table 7.19. Sensitivity, specificity, prevalence of CPD and likelihood ratio for fifths, symphysis-to-sinciput measurement and station at the point of fetal head engagement (n=482).

	≥3 fifths (Crichton)	≥3 fifths (Notelowitz)	Symphysis to sinciput ≥10 cm	Station above 0 (n=434)
Sensitivity for CPD	0.80	0.87	0.73	0.70
Specificity for CPD	0.37	0.31	0.47	0.58
Prevalence of CPD*	28.0%	27.7%	29.5%	32.3%
Likelihood ratio (95% CI)	1.28 (1.13-1.44)	1.26 (1.13-1.38)	1.37 (1.18-1.58)	1.68 (1.40-2.01)

*Prevalence of CPD = positive predictive value

7.3. DISCUSSION

It must be born in mind that the sample of women used for this study did not represent a normal obstetric population. The women encountered during a round in the Chris Hani Baragwanath Labour Ward are necessarily high risk pregnancies and labours, because this is a referral centre. Furthermore, the recruitment process was time consuming and tended to exclude women with rapid labour. The author can recall many instances where eligible women agreed to participate in the study, but by the time the clinician's round had started, they had given birth. The result is a sample of women with prolonged labours. There was a preponderance of nulliparae (63%). Only 21% of women in the study achieved delivery before crossing the partogram alert line. The caesarean section rate was high (27%), with the majority of operations being done for CPD. This is far higher than the primary caesarean section rate for CPD (4.7%) at Chris Hani Baragwanath and its satellite clinics in Soweto.[19] The high risk profile was however advantageous for the investigation of risk factors for CPD, and allowed the examination of multiple predictors using a relatively small number of women.

The recording and reporting of HIV serostatus was necessary because of the possibility of a confounding influence on the major outcome variable – caesarean section for poor progress. Clinicians may have had a lower threshold for caesarean section in HIV positive women. Reassuringly, however, the results showed that HIV seropositivity had no influence at all on caesarean section for this indication.

Did all women who had caesarean sections for poor progress truly have CPD? While the answer to this question has to be no, it is likely that most of these women had at least a moderate degree of disproportion. Of 80 nulliparae requiring caesarean section for poor progress, all crossed the partogram alert line, and 67 (84%) crossed the action line. Seventy-four per cent had oxytocin augmentation. Of 33 such multiparae, 32 (97%) crossed the alert line and 24 (73%) crossed the action line, with 49% receiving oxytocin. The author believes that the definition of CPD used for this study was robust and mostly correct. Clinicians at Chris Hani Baragwanath Maternity Hospital generally have a high threshold for caesarean section and allow a long trial of labour before intervening surgically.

7.3.1. Blinded non-participant observation

The study methodology was unique in its demand for blinded intrapartum clinical assessment by the author. It did not allow reading of the mothers' notes or knowledge of any previous or concurrent findings by doctors or nurses attending to the mothers. In addition, the author did not divulge his findings to the attending clinicians, and made no obstetric decisions. This ensured that the author's findings were not biased by previous observations, and that the critical outcome, caesarean section for poor progress, was not influenced by his findings.

The non-participant element of the methodology was achieved in all cases. Blinding was generally successful, but it was impossible to blind the author to characteristics such as short maternal stature or very large baby on examination, which could have resulted in lower thresholds for reporting the presence of putative predictors for CPD such as moulding or caput. The author however believes that any such bias was absent or insignificant.

7.3.2 Parity

Nulliparous and multiparous women did not differ much beyond what was expected. Nulliparae were younger and weighed less than multiparae. They had longer labours, and tended to experience more discomfort at vaginal examination. They received oxytocin augmentation more frequently, and had a higher rate of CPD. This was not surprising, as a number of multiparae with CPD would have had caesarean sections in their previous pregnancies, a group that was excluded in this study. Notably, no multipara required an assisted vaginal delivery. The most striking difference was the higher level of head found in multiparae, and the statistical non-significance of measures of head descent (fifths and station) in prediction of CPD in these women. This attests to the tendency of the head to remain high in multiparae, even in normal labour.[109,110]

7.3.3. Maternal weight, height and shoe size

Maternal weight had no influence on the development of CPD. The data on weight must be interpreted with caution as it was based on routine weighing at the first antenatal clinic visit. It was not possible to verify these weights, and the influence of gestational age at first visit on weight was not considered. Supine height proved to be a consistent significant predictor for CPD. This was a novel way of measuring stature, not previously described in the obstetric literature. An interesting finding was that vaginal delivery occurred in all 28 women with a supine height greater than 172 cm, probably corresponding to a standing height of about 166 cm. This is made more remarkable in that the study sample was already a select group of women at high risk for CPD. A tentative conclusion would be that CPD is most unlikely in a woman who is taller than 166 cm standing or 172 cm supine with a normal sized baby. This does not however invalidate standard care in a trial of labour. Conversely, women measuring less than 153 cm supine had a CPD rate of 43%, but this still meant that 57% gave birth vaginally, even in this select high-risk sample. If supine height is to be used in clinical practice, clinicians must ensure that this measurement is not confused with standing height measured at some antenatal clinics. Duplicate outcome tables could be constructed to convert standing to supine heights or vice versa, based on the findings shown in table 7.1.

Small shoe size and foot length were weakly predictive for CPD. Among nulliparae, foot length showed greater statistical significance, while in multiparae both displayed only a non-significant trend. This is the largest study yet done on shoe size and foot-length related to CPD, strengthened by prospective recording in a population at risk. The results confirm the conclusions of two previous South African studies that shoe size is of little value in prediction of CPD.[34,40] Shoe size and foot length should not be used to predict outcome of labour or to direct obstetric decision making.

7.3.4. Estimates of fetal size, and gestational age

CPD was significantly associated with increased estimated fetal weight and SFH. This is the first prospective study to report this relationship. This finding is strengthened by the methodology of blinding and non-participation. One retrospective study has found an association between fetal weight estimation and CPD.[95] Symphysis-fundal measurement was marginally more predictive than fetal weight estimation, and has the advantage of being potentially more repeatable and easy to teach. SFH was therefore used as the measure of fetal size in the multivariate analysis. The finding that an SFH of 45 cm or greater was 75% predictive for CPD may have clinical value, although the number of women with these measurements was small. Conversely, CPD was infrequent (8%) when the SFH was less than 35 cm. Calculation of the predictive value of a combination of maternal height and SFH did not appear to add much SFH alone as a predictor. SFH measurements should however not be interpreted in isolation or even in combination with one or two other observations. Primarily, there has to be poor progress in labour before

SFH, or a combination of SFH with other factors, can be used to justify a diagnosis of CPD.

In crude analyses, increased gestational age was associated with CPD, but this association disappeared in multivariate analysis that included SFH. Gestational age was clearly not an intrapartum clinical observation, but was obtained retrospectively from the notes. Within the gestational age range allowed for this study (37 weeks or greater), fetal weight estimation by SFH or palpation was more predictive for CPD than gestation. Clinicians should estimate fetal weight or measure SFH rather than make decisions based on weeks of gestation when considering obstetric decisions related to possible CPD.

7.3.5. Position and flexion of the fetal head

The high frequency of occipitoposterior (OP) position, and the absence of association between OP position and CPD in univariate and multivariate analyses were surprising findings. Several studies have pointed out significant associations between the OP position and CPD or caesarean section.[78,79,91,92] It is almost 70 years since Calkins' landmark work[89] on the OP position, and this study is the only one since then to have found similar results. The studies are however not directly comparable, because Calkins' study population did not have such a high risk profile. What this study has in common with that of Calkins is the sense that OP position is no more than a variant of normal labour, with no increased risk for CPD. The results probably confirm the suggestion of work done in Durban by Cowan, *et al*.,[94] where OP position was frequent in women with first-stage delay. However, in that study, such labours usually culminated in vaginal delivery following augmentation or expectant management. Clinicians should not use the OP position to justify a diagnosis of CPD. CPD may occur with OP position, but this is incidental rather than causal.

Flexion or deflexion of the fetal head has not been studied as a predictor for CPD. It is known that brow presentation, representing extreme deflexion, is a cause of CPD. In this study however, small degrees of deflexion associated with vertex presentation were not found to be associated with CPD. Most likely, deflexion is overcome by efficient contractions, if necessary in the second stage of labour. Deflexion may therefore be a marker of inefficient uterine activity or early labour. As with OP position, deflexion should not be used as a reason to justify a diagnosis of CPD.

7.3.6. Fetal head descent

As briefly discussed earlier, there was a difference between nulliparae and multiparae in terms of level of head assessment and prediction for CPD. This study showed that there was a strong association in unadjusted univariate analysis between a high head and CPD in nulliparae but not in multiparae. This is in keeping with the findings of Friedman and Sachtleben.[111] Stewart and Philpott,[50] in their work on nulliparae in Zimbabwe, also showed this association. What the author did not expect here was that the association disappeared or weakened when cervical dilatation was added to the multivariate analysis. Only station was shown in the regression model to be a weak predictor of CPD. Stratified analysis confirmed that there was a trend to higher probability of caesarean section with an unengaged head if the cervix was dilated 7 cm or more, than if the cervix was less than

7 cm dilated. The significance of a high head for the prediction of CPD is therefore greater at high cervical dilatation, and probably greatest at full dilatation, a phenomenon well recognized by Sizer, Evans, Bailey, *et al*.[200] in their description of a second stage partogram.

Many studies discussed in Chapter 3 have suggested that non-engagement of the head in the active phase of the first stage of labour is usually not indicative of CPD. This study strengthens these conclusions. The multivariate analysis, which controlled for the influence of numerous explanatory variables, further excluded level of the head as a strong independent predictor for CPD. The importance of level of the head in the first stage of labour has perhaps been overestimated. Philpott's contention,[1] that CPD could be diagnosed by observation of failure of descent with increasing moulding, could however not be tested, as the author only did one-off estimations of head descent in each case, and did not do follow-up estimations. However, analysis of the predictive value of a combination of parieto-parietal moulding and non-engagement did show a moderately increased risk of CPD. What is probably true is that failure of head descent on its own, especially in the early active phase, is not a reason to suspect CPD.

Comparison of the four methods of estimating head descent – fifths by Crichton, fifths by Notelowitz, symphysis-to-sinciput, and station – provided no clear answers. All were predictive for CPD in nulliparae in unadjusted analysis, and none were predictive in multiparae, except, curiously, symphysis-to-sinciput measurement. In general, station performed marginally better than the other methods as a predictor for CPD, although the author was unable to assess station in over 10% of women. Estimation of station increased the duration of vaginal examination, and palpation of the ischial spines was sometimes uncomfortable for the mothers. In the author's opinion, station does not have sufficient advantage over fifths for it to be recommended as the method of choice for estimating level of head. However, the converse may also be true. The results provide no basis for a change in clinical practice among experienced practitioners. Obstetricians and midwives should continue to use the method with which they are most comfortable, be it fifths or station. Those in training might consider employing fifths as their method of choice, because of the ease of abdominal assessment and lesser discomfort for the mothers. Descent by fifths can also be re-assessed frequently without subjecting women to repeated vaginal examinations.

The three abdominal methods of estimating head descent differed only slightly from each other in terms of association with CPD. Symphysis-to-sinciput is a measurement that introduces a degree of repeatability to the estimation, but it offered no clear advantage over fifths. The Notelowitz method was marginally more predictive for CPD than the Crichton method, but this difference was insignificant.

There can be no dogmatism about which method to use in assessing head descent in the first stage of labour. However, this may not be true in the second stage, where head descent is critical to a good outcome. There is a need for prospective blinded and non-participant research along the lines of the retrospective study done by Knight, *et al.*[125]

This would clarify whether abdominal or vaginal assessment of head descent is preferable.

7.3.7. Moulding and caput succedaneum

The study provided good evidence that parieto-parietal moulding, rather than occipito-parietal moulding, was predictive for CPD. This confirmed the X-ray observations of Borell and Fernstrom,[132] and the clinical observations of Stewart and Philpott.[50] Again, the strength of this study was in the blinded non-participant methodology, that did not allow the author's observations to influence the outcome – caesarean section for poor progress. It was notable that occipito-parietal moulding did not reach statistical significance in unadjusted analysis for prediction of CPD. This also confirmed the observations of those who considered occipito-parietal moulding to be a sign of normal labour.[88, 129-131] Furthermore, occipito-parietal moulding could often not be assessed due to inaccessibility of the lambdoidal sutures as a result of deflexion. This contrasts with the findings of Stewart and Philpott,[50] who were able to report degrees of occipito-parietal moulding in every one of their women in labour.

The clinical implications are clear. Parieto-parietal moulding is a strong independent predictor of CPD, and should always be assessed during intrapartum clinical assessment. Occipito-parietal moulding is a sign of normal labour and its assessment has no role in the prediction of CPD. The practice of adding the occipito-parietal to the parieto-parietal moulding score to give a composite score, as suggested by Stewart and Philpott,[50] should be discouraged. For assessment of parieto-parietal moulding to be reliable, obstetric clinicians must distinguish the sagittal suture from the lambdoidal sutures. This implies a need for development of clinical skills to identify these suture lines. The simple finding of an overlapping suture line on vaginal examination is meaningless unless the involved bones can be clearly identified.

Surprisingly, caput succedaneum was also found to be an independent predictor for CPD. This contradicts the suggestion by Stewart and Philpott[50] that caput is more a marker of prolonged labour than of CPD. It supports the concept, mentioned by the same authors, that there may be a form of 'pelvic caput' associated with CPD. This is the first study that has shown an association in multivariate analysis between caput succedaneum and CPD. Caput may therefore be used by clinicians to assist in the diagnosis of CPD, especially where moulding is difficult to feel or sutures are not easily identified. At times, it may be the caput itself that hampers assessment of the suture lines.

7.3.8. Cervical dilatation

Lesser cervical dilatation was a predictor for CPD in this study. This was somewhat artefactual, because all labours must go through all measures of dilatation before vaginal delivery is achieved. The significance lies in the fact that labours with CPD probably spend more time at low cervical dilatations, because of either protraction or arrest disorders. The finding of a cervix that is, for example, 4 cm dilated, is not by itself a risk factor for CPD. However, if there are two women, one 4 cm dilated and another 7 cm dilated with all other variables equal, it can be said that the woman who is 4 cm dilated is the more likely to have CPD. A better measure of progress would have been to note change in cervical dilatation over time, but this could not be done. Careful estimation of cervical dilatation entered correctly on a labour graph remains the cornerstone of measuring labour progress.

7.3.9. Duration of labour

Duration of labour was a strong predictor for CPD, and would have been even stronger statistically if the women with CPD did not have their prolonged labours truncated by caesarean section. This truncation was not considered in the statistical analysis. Duration of labour was not assessed at the time of examination but was entered retrospectively, along with the progress of labour according to the partogram action and alert lines. Progress according to these lines was not included in the multivariate analysis because such progress was considered to be equivalent to duration of labour.

The significance of labour duration in the prediction of CPD emphasizes the importance of a trial of labour in the diagnosis. Findings such as short mother, large baby, caput, moulding, or combinations of these are not meaningful if labour progresses well. CPD never results in a labour of short duration. As shown by Philpott and Castle,[21,22] a properly completed labour graph allows easy and early identification of prolonged labour, and facilitates diagnosis of CPD.

7.4. LIMITATIONS

The study had several limitations which must be considered when interpreting the results. The assumption that CPD was present in women who had caesarean sections for poor progress is reasonable, but this was not verified with another method. Postnatal X-ray pelvimetry was used in such studies in the 1970s, and would have provided a verification tool to provide assurance that CPD was truly present. This investigation is however no longer done at Chris Hani Baragwanath Hospital.

It has also been stated that the diagnosis of CPD requires an assurance of adequate uterine contractions.[6,9] This is best done using intrauterine pressure transducers. These are expensive and are rarely used in South African government hospitals. This study did not have the resources to employ such equipment. Clinical palpation of contractions has been found to be unreliable,[201] and was not done by the author in this study. It is possible that a number of women with prolonged labour did not have CPD, but had inadequate uterine activity. However, the majority of women designated as having CPD did receive oxytocin augmentation, assuring at least some degree of uterine work. The author accepts that some women who had caesarean sections for poor progress may not have had CPD. The converse, that some women who had vaginal deliveries may have had absolute CPD, is however false. The outcome of vaginal delivery (no CPD) is therefore robust and not subject to error.

Certain clinical observations which could have been predictors for CPD were not included in this analysis. While maternal height, foot size and fetal size were correctly considered as possible predictors, maternal pelvic capacity was not. This would have been an opportunity to investigate the value of intrapartum clinical pelvic assessment in a blinded non-participant fashion. The author acknowledges that a chance was missed here, but he undertook the study to examine commonly performed intrapartum observations, not measurements that almost all modern clinicians have abandoned. In a pilot for this study, the author attempted to measure the diagonal conjugates of a number of women in labour, but found this uncomfortable, and probably one examination too many, for the women. Clinical pelvic assessment was therefore omitted from the data collection.

The study design may be criticized for its one-off single assessment of each case. It might have been better to observe progress of labour in each woman, with the author doing at least two vaginal examinations and observing differences in, for example, level of head and moulding. This was not logistically possible, because the author had to do all examinations himself and did not have sufficient time to return to each of these women. A second research vaginal examination might also have been ethically unacceptable. In any case, many women would have delivered by the time the author returned in two or four hours. In a sense, follow-up did occur, because the author noted the time and mode of delivery and was able to reconstruct a partogram with action and alert lines for every labour.

Chapter 7: Summary points

- Five hundred and eight women were examined. After excluding 24 who had caesarean sections for fetal distress, 484 women remained for analysis of predictors for CPD
- One hundred and thirteen women (23.3%) had caesarean sections for poor progress (CPD) and 371 had vaginal deliveries (no CPD)
- In univariate analysis, high fetal head, by fifths or station, was associated with CPD in nulliparae but not in multiparae. High head was more frequent in multiparae
- Multivariate analysis identified supine height, SFH, cervical dilatation, parieto-parietal moulding, caput, and duration of labour as independent predictors for CPD
- Occipitoposterior position and deflexion of the head were not associated with CPD in univariate or multivariate analysis
- Estimating the level of head has limited value in the first stage of labour, and is likely to have greater importance in the assessment of progress of the second stage of labour
- Comparison of methods of estimating fetal head descent showed little difference between fifths by Crichton, fifths by Notelowitz and symphysis-to-sinciput measurement
- Assessment of station was slightly more predictive for CPD than the other three methods, but was only possible in 89.7% of women
- The choice of method for estimation of head descent should remain the clinician's choice. This study provided insufficient evidence for a change of practice

- Parieto-parietal moulding was a strong independent predictor for CPD, as opposed to occipito-parietal moulding, which appears to be a feature of normal labour. The finding of occipito-parietal moulding should not be used to support a diagnosis of CPD
- Caput succedaneum was predictive for CPD and may be useful as a clinical sign in combination with moulding, or where moulding is difficult to assess

CHAPTER 8

INTEROBSERVER AGREEMENT: RESULTS AND DISCUSSION

This chapter describes the ranks of the attending clinicians with whom the author performed intrapartum assessments. It presents interobserver agreement between the author and the clinicians in the estimation of cervical dilatation, fetal head descent by fifths and station, fetal position, and moulding. Factors influencing agreement, including clinician rank, are identified.

8.1. THE ATTENDING CLINICIANS

The author did his examinations on the labour ward rounds at the same time as the clinicians on duty. The clinicians comprised 17 registrars and nine consultants. Their names were not entered on the data sheets. If they were registrars, their levels of training were noted. The ranks of the doctors who did the clinician examinations are shown in Table 8.1. The large proportion of junior registrars (less than two years' experience) can be explained by the departmental culture of allocating junior rather than senior registrars to do rounds in labour ward.

8.2. FETAL WEIGHT ESTIMATION

Detailed comparison of the author's and the clinicians' fetal weight estimations is described and discussed in Chaper 9.

Table 8.1. Rank of clinicians that did the intrapartum examinations at the same time as the author (n=508).

Rank	Years of experience as a registrar	Number of examinations
Junior Registrar	<1	98 (19.3%)
	1-2	108 (21.3%)
Senior Registrar	2-3	37 (7.3%)
	3-4	43 (8.5%)
Consultant	4	222 (43.7%)

8.3. CERVICAL DILATATION

The author and the clinicians agreed exactly on the cervical dilatation in 250 instances (49.2%), differed by 1 cm in 202 (39.8 %), and differed by 2 cm or more in 56 (11.0%). The overall Kappa statistic for interobserver agreement between the author and the clinicians was 0.40 (95% confidence interval 0.34-0.45). Disagreement with the author was greater for registrar than for consultant assessments, but there was no significant difference between junior and senior registrar assessments. Among registrars, there was a greater tendency to overestimate cervical dilatation compared with consultants (Table 8.2). Using the author as the standard for each cervical dilatation from 3 cm to 10 cm, there was a tendency to overestimation by the clinicians (Table 8.3).

Table 8.2. Agreement, underestimation and overestimation for cervical assessments by clinicians, compared to the author's assessments.*

	Underestimation		Agree	Overestimation		
	2 cm	1 cm		1 cm	2 cm	3 cm
Junior registrar (n=206)	3 (1%)	26 (13%)	101 (49%)	49 (24%)	25 (13%)	2 (1%)
Senior registrar (n=80)	1 (1%)	10 (13%)	34 (43%)	24 (30%)	8 (10%)	3 (4%)
Consultant (n=222)	5 (2%)	49 (22%)	115 (52%)	44 (20%)	8 (4%)	1 (0%)
All (n=508)	9 (2%)	85 (17%)	250 (49%)	117 (23%)	41 (8%)	6 (1%)

*Junior registrar vs. senior registrar: P=0.51; all registrars vs. consultants: P=0.0004 (Fisher's exact test).

Table 8.3. Clinicians' mean observed cervical dilatation, with standard deviation, using the author's estimated dilatation as the standard (n=508).

Cervix (cm) by the author	Number of women	Mean (95% confidence interval)	Standard deviation	Range
3	12	3.21 (3.06-3.36)	0.26	3-4
4	121	4.16 (4.10-4.22)	0.34	3-6
5	123	5.15 (5.06-5.24)	0.51	3-8
6	77	6.16 (6.03-6.29)	0.58	4-9
7	68	6.99 (6.86-7.12)	0.54	5-10
8	46	8.16 (8.04-8.28)	0.40	6-10
9	24	9.04 (8.91-9.17)	0.33	8-10
10	37	9.88 (9.80-9.96)	0.25	8-10

Table 8.4 shows the percentage of examinations where the author and the clinicians agreed, at each dilatation from 3 to 10 cm, with the percentage of under and overestimations at each measure of dilatation. Agreement was best at the extremes, being 58% at 3, 4 and 9 cm, and 78% at 10 cm. Agreement was poorest in the mid-range, being 36% at 6 cm, and 40% at 7 cm.

Table 8.4. Percentage agreement in estimation of cervical dilatation between the author and the clinicians, using the author's estimation as the standard. At each measure of dilatation, differences of 1 cm or more are shown as under and overestimations in percentages.

Cervix (cm) by the author	Number of women	Underestimation by clinicians (%)	Agreement (%)	Overestimation by clinicians (%)
3	12		58	42
4	121	7	58	35
5	123	21	43	36
6	77	25	36	40
7	68	34	40	27
8	46	11	48	41
9	24	17	58	25
10	37	21	78	

Multivariate ordinal regression analysis was done to determine independent predictors for disagreement in estimation of cervical dilatation. There was no association with parity, body mass index, membrane rupture, occipitoposterior position and mother discomfort, although univariate analysis suggested significantly greater disagreement with lower parity (odds ratio 0.78; 95% confidence interval 0.62-0.97). Independent predictors for disagreement were greater gestation (odds ratio 1.14; 95% CI 1.02-1.27), lower station of the fetal head (1.21; 95% CI 1.05-1.39) and lower rank of clinician (0.73; 95% CI 0.60-0.88) (Table 8.5).

Table 8.5. Univariate (crude) and multivariate (adjusted) ordinal regression analysis showing influence of independent variables on disagreement in estimation of cervical dilatation between the author and the clinicians.

Variable	Crude odds ratio	95% CI	P value	Adjusted odds ratio	95% CI	P value
Parity	0.78	0.62-0.97	0.03	0.82	0.64-1.08	0.17
Body mass index	1.01	0.97-1.04	0.74	1.02	0.98-1.06	0.42
Gestational age	1.13	1.02-1.25	0.02	1.14	1.02-1.27	0.02
State of membranes	0.88	0.69-1.13	0.31	0.82	0.62-1.07	0.14
Station of head	1.19	1.04-1.36	0.01	1.21	1.05-1.39	0.008
Position of head	0.92	0.75-1.13	0.41	0.97	0.78-1.21	0.80
Mother discomfort	0.87	0.53-1.44	0.60	1.09	0.51-2.35	0.82
Clinician experience	0.71	0.60-0.85	<0.001	0.73	0.60-0.88	0.001

8.4. LEVEL OF THE HEAD

8.4.1. Fifths of head

Both the author and the clinicians were able to estimate the level of head in 506 women (99.6%). This institution usually teaches the Crichton method of estimating fifths, so comparison was made between the author's fifths estimation by the Crichton method and the clinicians' fifths estimation. The author and clinicians agreed on the level of head in 217 cases (42.9%), disagreed by one fifth in 223 (44.1%) and disagreed by two fifths or more in 66 (13.0%). Agreement was best (64%) when the author found the head to be three-fifths above the brim (Table 8.6). The Kappa statistic for interobserver agreement was 0.22 (95% CI 0.17-0.27). The most frequent level of head was three-fifths, found by the author in 167 women (33.0%) and by the clinicians in 246 (48.6%). In terms of whether engagement had occurred (head three-fifths or higher vs. two-fifths or lower), the author and clinicians agreed that engagement had not occurred in 305 cases (60.3%), and that it had occurred in 84 (16.6%). They did not agree on engagement in 117 cases (23.1%). The Kappa statistic was 0.43 (95% CI 0.35-0.52) (Table 8.7).

Logistic regression analysis (not shown) was done to identify clinical predictors for disagreement in determining engagement by fifths. The analysis included maternal age, parity, gestation, height, weight, cervical dilatation, state of the membranes, fetal position, head flexion, parieto-parietal moulding, discomfort on examination, and rank of examining clinician. Not one of these variables was shown to be a significant independent predictor of disagreement.

Table 8.6. Clinicians' estimates of level of the head according to fifths against the author's estimates as the standard, showing percentage of underestimation, agreement, or overestimation (n=506). Kappa = 0.22 (95% CI 0.17-0.27).

Fifths of head above brim by author	Number	Clinician underestimate of descent in fifths (%)			Agree (%)	Clinician overestimate of descent in fifths (%)		
		By 3	By 2	By 1		By 1	By 2	By 3
5	31				32	52	16	0
4	144			1	44	47	6	1
3	167		0	20	64	13	2	1
2	100	0	8	49	29	12	2	
1	30	10	30	40	10	10		
0	34	32	35	21	12			

Table 8.7. Interobserver agreement in terms of engagement of the head in fifths between author and clinicians (n=506). Kappa = 0.43 (95% CI 0.35-0.52)

Level of head by author	Level of head by clinician	
	Unengaged (≥three-fifths)	Engaged (<three-fifths)
Unengaged (≥three-fifths)	305 (60.3%)	37 (7.3%)
Engaged (<three-fifths)	80 (15.8%)	84 (16.6%)

8.4.2. Station

Station could be estimated by both the author and clinicians in 446 women (87.8%). There was agreement on station in 166 cases (37.2%), disagreement by 1 cm in 208 (46.6%), and disagreement by 2 cm or more in 72 (16.1%). Agreement was best (50%) when the author found the head to be at station -1 (Table 8.8). The Kappa statistic for agreement was 0.23 (95% CI 0.17-0.29). The most frequent level of head was station -1, found by the author in 136 women (30.5%) and by the clinicians in 153 (34.3%). In terms of engagement of the head (station 0 defined as engaged and station -1 as unengaged), the author and clinicians agreed that engagement had not occurred in 166 cases (37.2%) and that it had occurred in 149 (33.4%). They did not agree on station in 131 women (29.3%), The Kappa statistic was 0.33 (95% CI 0.24-0.43) (Table 8.9).

Logistic regression analysis was performed to identify predictors for disagreement in determining engagement by station. This included maternal age, parity, gestation, height, weight, cervical dilatation, state of the membranes, fetal position, head flexion, parieto-parietal moulding, discomfort on examination, and rank of examining clinician. Not one of these variables was shown to be an independent predictor of disagreement.

Table 8.8. Clinicians' estimates of level of the head by station against the author's estimates as the standard, showing percentage of underestimation, agreement, or overestimation (n=446). Kappa = 0.23 (95% CI 0.17-0.29).

Station of head by author	Number	Clinician underestimate of descent in cm (%)			Agree (%)	Clinician overestimate of descent in cm (%)		
		By 3	By 2	By 1		By 1	By 2	By 3
Minus 3 or higher	35				20	51	17	11
Minus 2	56			9	36	34	14	7
Minus 1	136		4	13	50	26	7	0
Zero	117	2	5	38	38	18	2	0
Plus 1	67	3	19	45	22	10	0	
Plus 2	31	6	26	29	32	6		
Plus 3 or lower	4	0	25	25	50			

Table 8.9. Interobserver agreement in terms of engagement of the head by station between author and clinicians (n=446). Kappa = 0.33 (95% CI 0.24-0.43).

Level of head by author	Level of head by clinician: Unengaged (station -1 or higher)	Level of head by clinician: Engaged (station 0 or lower)
Unengaged (station -1 or higher)	166 (37.2%)	61 (13.7%)
Engaged (station 0 or lower)	70 (15.7%)	149 (33.4%)

8.5. FETAL POSITION

Both the author and the clinicians were able to identify a fetal position in 452 cases (89.0%). When the author identified an occipitoanterior position, the clinicians agreed in 76.8% of examinations. When the author identified an occipitotransverse or occipitoposterior position, the clinicians agreed in 26.0% and 34.6% of cases respectively. The Kappa statistic for interobserver agreement was 0.18 (95% CI 0.14-0.23) (Table 8.10).

Table 8.10. Comparison of the author's and the clinicians' findings of fetal position (n=452). Kappa = 0.18 (95% CI 0.14-0.23)

		Clinicians' findings			Percentage agreement (95% CI)
		Occipito-anterior	Occipito-transverse	Occipito-posterior	
Author's findings	Occipito-anterior	109	14	19	76.8 (68.8-83.3)
	Occipito-transverse	87	40	27	26.0 (19.4-33.8)
	Occipito-posterior	79	23	54	34.6 (27.3-42.7)

Separate comparisons were made for position identification between the author and consultants (n=207), senior registrars (n=70) and junior registrars (n=175). The comparison between the author and junior registrars provided the highest Kappa statistic (0.21; 95% CI 0.14-0.29). The Kappa statistic for the comparison with consultants was 0.19 (95% CI 0.12-0.26), and that for senior registrars was 0.11 (0.04-0.23).

During the latter part of the study, a convenience sample of 30 women underwent intrapartum suprapubic ultrasound scanning by the author a few minutes after abdominal and vaginal examination. The objective was to determine the fetal position on ultrasound, in an attempt to verify or refute his and the clinicians' findings. The author's findings were found to be exactly correct in 22 cases (73.3%), incorrect by 45 degrees in five (16.7%) and incorrect by 90 degrees or more, or could not be assessed, in three (10.0%). The clinicians' findings were exactly correct in seven cases (23.3%), incorrect by 45 degrees in five (16.7%) and incorrect by 90 degrees or more, or could not be assessed, in 18 (60.0%) (Table 8.11). Transposition of occipitoanterior and occipitoposterior by 180 degrees did not occur with the author, but was observed in 10 clinician examinations, eight of them right occipitoposterior positions identified by the clinicians as left occipitoanterior.

Further statistical testing to investigate predictors of disagreement in position was not done because of the low Kappa statistic for agreement, inconsistency in agreement related to clinician rank, and the frequent failure of clinicians to identify non-occipitoanterior positions as shown on ultrasound scans.

Table 8.11. Fetal position findings of the author and clinicians in 30 women who had suprapubic ultrasound scans to identify fetal position. Errors are shown in degrees of rotation.

Position on ultrasound scan	Number	Author's findings with errors	Clinicians' findings with errors
Left occipitoanterior (LOA)	8	5 correct, 2 LOT (45), 1 ROA (90)	3 correct, 1 direct OA (45), 1 LOT (45), 1 DOP (135), 2 ROP (180)
Left occipito-transverse (LOT)	6	5 correct, 1 LOA (45)	1 correct, 2 LOA (45), 1 LOP (45), 1 ROA (135), 1 ROP (135)
Left occipitoposterior (LOP)	3	2 correct, 1 LOT (45)	2 correct, 1 ROT (135)
Right occipitoanterior (ROA)	1	None correct, 1 LOT (135)	None correct, 1 LOA (90)
Right occipito-transverse (ROT)	2	1 correct, 1 ROP (45)	1 correct, 1 could not be assessed
Right occipito-posterior (ROP)	9	8 correct, 1 could not be assessed	None correct, 8 LOA (180), 1 could not be assessed
Direct occipito-posterior (DOP)	1	1 correct	1 ROA (135)

8.6. MOULDING

Early on in the study the author observed that the clinicians frequently did not specify the suture lines when they described moulding. This continued throughout. Analysis of interobserver agreement for parieto-parietal and occipito-parietal moulding between author and clinicians therefore became impractical and was not attempted.

8.7. CAPUT SUCCEDANEUM

The grade of caput succedaneum was estimated by the author and attending clinicians in 506 cases. The author and clinicians agreed on the grade of caput in 370 cases (73.1%)

and differed by a degree of one in 120 (23.7%). Agreement was best with a caput grade of 0 (88.6%). The Kappa statistic for agreement was 0.48 (95% CI 0.42-0.55) (Table 8.12). Where the clinicians were registrars (n=285) there was agreement on the grade of caput in 216 cases (75.8%), with a Kappa statistic of 0.52 (95% CI 0.44-0.61). With consultants (n=221), there was agreement in 154 cases (69.7%) with a Kappa statistic of 0.43 (95% CI 0.33-0.53).

Table 8.12. Comparison of the author's and the clinicians' findings of caput succedaneum in grades (n=506). Kappa = 0.48; 95% CI 0.42-0.55.

		Clinicians' findings			Percentage agreement (95% CI)
		Grade 0	Grade 1	Grade 2	
Author's findings	Grade 0	279	31	5	88.6 (84.4-91.8)
	Grade 1	45	58	17	48.3 (39.2-57.6)
	Grade 2	11	27	33	46.5 (34.7-58.6)

8.8. DISCUSSION

8.8.1. Cervical dilatation

This is the first study to investigate interobserver agreement in estimation of cervical dilatation in parturient women. It was done on a large number of subjects across the full range of cervical dilatations in the active phase of labour. The author was used as a standard against which the attending clinicians' assessment could be measured. It may be reassuring that there was exact agreement in 49% of observations, with a 2 cm or greater difference occurring in only 11%. The improving agreement with increasing rank of clinicians suggests that cervical assessment is a skill that develops with training and experience. It appears that junior staff members frequently overestimate cervical dilatation. The better agreement at smaller (3 to 5 cm) and greater (8 to 10 cm) dilatations is interesting and has a possible explanation. At 3 to 5 cm, the examining index and middle fingers are either closely opposed or slightly apart, making estimation relatively easy. At 8 to 10 cm, it has been suggested that clinicians estimate the remaining length of cervix on each side of the head and multiply by two, and then subtract from 10 (full dilatation).[87] For example, a 1 cm remaining length of cervix equates to a dilatation of 8 cm, while a thin rim equates to 9 cm. At 6 and 7 cm, proprioceptive skill comes into play, requiring an estimate of distance between the examining fingertips. This is presumably more difficult. Regarding poorer agreement at lower stations of head, this could be the artefactual result of stronger contractions or maternal bearing down efforts during examination, with an engaged head. This would cause a transient stretch of the cervix to a greater dilatation, perhaps encountered by only one of the two observers. Although every effort was made to do examinations only between contractions, this may not have happened in every case. The weak association of disagreement in cervical assessment with gestational age cannot be readily explained and may be a chance finding.

Previous research using hard models with known gold standard dilatations showed similar results.[85,86] More recently, the study by Huhn and Brost,[87] which used soft models to make examinations more realistic, found correct estimates in only 19% of 360 examinations, although they reported 54% accuracy with hard models. Perhaps the soft models were less realistic than they should have been. Comparison with research that used models must take into account that this study did not have a known gold standard dilatation, only the author’s ‘expert’ estimate in each case. There is currently no reliable test or instrument that can provide exact cervical dilatation measurements *in vivo*.

8.8.2. Level of the head

Interobserver agreement has not been investigated previously, neither using fifths nor station as the estimate. In the majority of examinations, the author and the clinicians did not agree on the level of descent. Agreement was best in the mid-range, unlike with cervical dilatation where it was best at the extremes of measurement. It was notable that the clinicians found the head to be three-fifths palpable in almost half of the women examined. This tendency to assign a mid-range or average value may be related to uncertainty with the palpation, in the hope of not committing too gross an error. This suspicion cannot be confirmed from the data, but if true, indicates a serious lack of confidence with clinical skills.

The Kappa statistics (0.22 and 0.23 respectively) for assessment of descent by fifths and station are poor. These scores improved somewhat (0.43 and 0.33 respectively) when assessment of engagement alone was studied, although agreement on station was still poor. If the author’s assessment of engagement is considered correct (an untested assumption), 13.7% of unengaged heads were found to be engaged by the clinicians. This figure is very close to the 12% found by Dupuis, *et al.*[127] in a study of clinicians examining a mannequin fetus placed at various pre-set stations in a birth simulator. This confirms the concern of Roshanfekr, *et al.*[116] that station is a difficult clinical observation.

Clinical assessment of head descent appears to be inexact and poorly reproducible, by either method. No predictors for disagreement could be found on logistic regression analysis. It is therefore difficult to identify areas to direct training of clinicians to improve clinical skill. It is tempting to suggest that measurement of descent with a tape-measure (symphysis-to-sinciput) may provide a more reproducible measure of descent, especially by inexperienced clinicians. This would however require validation in a separate study.

This study was concerned mainly with the first stage of labour where assessment of descent is not as critical as in the second stage, when instrumental vaginal delivery may be considered. Prospective research on assessment of descent in the second stage of labour would contribute greatly to the understanding of these clinical observations.

8.8.3. Fetal position

Agreement on position was poor, with the Kappa statistic of 0.18 probably an overestimate because only anterior-transverse-posterior positions were investigated without consideration of right or left orientation. Agreement was inconsistent across the ranks of clinicians, with junior registrars showing the best agreement with the author, followed by consultants and then senior registrars.

Ultrasound confirmation of position was not included in the initial study protocol, and was added in the light of recent publications showing that this was a useful ‘gold standard’ for fetal position.[96-102] Although only 30 ultrasound scans were done, it was clear that clinicians frequently erred in identifying fetal position. This is not peculiar to doctors at Chris Hani Baragwanath. Several studies have demonstrated similar uncertainties.[97-101] There was a tendency among the clinicians to assume occipitoanterior positions. The author performed rather better, and this was reassuring for interpretation of position findings in prediction of CPD (Chapter 7).

In general, fetal position is poorly reproducible clinically, although the necessary skills for accurate assessment can probably be developed. It could be argued that fetal position has little importance in the first stage of labour other than causing a small increase in duration.[89] While this study was restricted mainly to observations in the first stage of labour, the correct identification of fetal position is most importance in the second stage when instrumental vaginal delivery may considered. This has been investigated in a number of studies, with the recommendation that all instrumental deliveries should be preceded by ultrasound scan to identify fetal position.[99-101,104]

8.8.4. Moulding and caput succedaneum

The author was unable to test interobserver agreement in assessment of moulding, owing to the frequent reporting by clinicians of moulding without specifying the sutures involved. This suggests failure on their part to identify the sutures with confidence. This is linked to the uncertainty of clinicians in identifying fetal position. Appreciation of moulding and position appears to be more difficult than most textbooks would admit. Acquiring proficiency probably takes time, with the necessary interest by the student or registrar, and similar commitment on the part of the teacher.

In contrast, caput succedaneum proved to be the intrapartum clinical observation with the best Kappa statistic for interobserver variation between the author and the clinicians. This has not been studied previously. In the author's experience, caput is quite easy to feel on the fetal head, and the findings confirm that it is a robust clinical sign that has more value than may have been appreciated.

8.9. LIMITATIONS

An obvious limitation to this analysis is the implied assumption that the author could be a 'gold standard' against which the other clinicians could be measured. This potential flaw is acknowledged. What can be stated is that the author is an experienced labour ward clinician who for many years has taught intrapartum clinical skills to students, midwives and registrars. Also in favour of his being the standard is that he was always one of the two examiners in each case. His findings on fetal position, which were mostly correct, provide some reassurance of his skill in clinical assessment.

Comparison with the clinicians has its problems, because data capture did not allow identification of individual doctors. It was therefore impossible to measure the effect on the results of one or a few clinicians who may consistently have agreed or disagreed with the author's assessments.

Estimation of latent phase cervical dilatation and effacement was not investigated, and the study was restricted to term mothers with vertex presentations, without previous caesarean sections. The findings of this study cannot be generalized to women excluded from the study population. Due to resource constraints, epidural analgesia is not offered at Chris Hani Baragwanath Hospital and the influence of this analgesic modality on clinical assessment could not be investigated.

It is possible that the reported interobserver agreements are actually better than what would be found in normal clinical practice. This is because of the possibility of a Hawthorne effect, the phenomenon of experimental subjects differing from the study population because of the circumstances of the study itself. The clinicians may have made unusually thorough and careful clinical assessments while under research scrutiny by the author. In addition, the findings of this study cannot necessarily be generalized to situations in which obstetric and midwifery staff have less intensive exposure to intrapartum obstetrics than is available at this institution.

Chapter 8: Summary points

- The author examined 508 women, accompanied in 286 cases by registrars and in 222 cases by consultants
- The author and clinicians agreed on cervical dilatation in 49% of examinations, and differed by 1 cm in 40% (Kappa = 0.40)
- Agreement in assessment of cervical dilatation was best at extremes (3-4 cm and 8-10 cm)
- Independent predictors for disagreement in estimation of cervical dilatation were gestation, lower station of the fetal head, and lower rank of clinician
- The author and clinicians agreed on fifths of head above brim in 43% of examinations, and differed by one-fifth in 44% (Kappa = 0.22)
- The author and clinicians agreed on station of head in 37% of examinations, and differed by 1 cm in 47% (Kappa = 0.23)
- Clinician rank did not contribute to agreement in estimation of level of the fetal head
- There was poor agreement between the author and clinicians in identification of fetal position (Kappa=0.18)
- In comparison with the author's and ultrasound findings of position, it was evident that clinicians frequently assumed fetal occipitoposterior positions to be occipitoanterior
- The research findings have to be interpreted with caution, as the author cannot necessarily be assumed to provide a 'gold standard' against which clinician estimates should be judged

CHAPTER 9

ESTIMATION OF FETAL WEIGHT: RESULTS AND DISCUSSION

This chapter presents the results of fetal weight estimation by palpation in terms of the correlation co-efficient and mean percentage accuracy, and by symphysis-fundal height measurement in terms of the correlation co-efficient. The influence of other clinical variables on birth weight prediction is also presented. The significance of the results is discussed with reference to the literature, and limitations are acknowledged.

9.1 DISTRIBUTION OF BIRTH WEIGHTS

There were 504 singleton cephalic term infants. The mean birth weight was 3190 g, with a standard deviation of 436 g. The median birth weight was 3200 g, with a range of 1880 to 4890 g. The 90th centile was 3700 g. The distribution of birth weights, in intervals of 500 g, is shown in Table 9.1.

Table 9.1. Distribution of birth weights, in intervals of 500 g (n=504).

Birth weight interval (g)	Number	Percentage
<2500	20	4.0
2500 - 2999	128	25.4
3000 - 3499	250	49.6
3500 - 3999	84	16.7
4000 - 4499	16	3.2
≥4500	6	1.2

9.2 FETAL WEIGHT ESTIMATION BY PALPATION

9.2.1 Percentage error

Percentage error was calculated as the difference between the author's or clinician's estimated fetal weight (EFW) and the birth weight, divided by the birth weight:

Percentage error = 100 × (EFW – birth weight) / birth weight

The author's mean percentage error was 8.7%. His greatest underestimate was 37.6% and greatest overestimate 44.8%. Estimates were correct to within 10% or less of the birth weight in 344 (68.3%) of examinations. The clinicians' mean percentage error was 10.2%, with the greatest underestimate being 42.7% and the greatest overestimate 50.9%. Clinicians' estimates were correct to within 10% or less of the birth weight in 285 (56.5%) of examinations (Tables 9.2 and 9.3). A number of estimates were 'exact'. This reflects approximation of scale readings, especially those of the analogue scale which gave readings to the nearest 50 g.

Table 9.2. Percentage error of intrapartum estimated fetal weight (EFW) with respect to birth weight, for author and attending clinicians.

	Mean percentage error (95% CI)	Standard deviation	Median
Author's EFW	8.7 (8.0-9.3)	7.4	6.8
Clinicians' EFW	10.2 (9.5-11.0)	8.3	8.7

Table 9.3. Distribution of percentage error showing underestimation and over-estimation of fetal weight (EFW) with respect to birth weight by the author and clinicians.

	Error range (percentage)	Author's EFW		Clinicians' EFW	
		Number	Percentage	Number	Percentage
Under-estimation	>40	0	0.0	1	0.2
	30.1-40.0	1	0.2	1	0.2
	20.1-30.0	7	1.4	19	3.8
	10.1-20.0	52	10.3	74	14.7
	0.1-10.0	140	27.8	139	27.6
	'Exact'	22	4.4	19	3.8
Over-estimation	0.1-10.0	182	36.1	127	25.2
	10.1-20.0	63	12.5	89	17.7
	20.1-30.0	28	5.6	21	4.2
	30.1-40.0	8	1.6	10	2.0
	>40	1	0.2	4	0.8

Mean percentage errors for both the author and the clinicians' EFW were greatest at the extremes of birth weight in this sample of term pregnancies. This was especially so for infants weighing less than 2500 g. In this group, the author's mean error was 22.0% and the clinicians' mean error was 26.4%. For birth weights above 4000 g, the author's mean error was 15.4%, and that of the clinicians was 18.3%. Mean errors were below 10% for both the author and clinicians when the birth weight was between 3000 and 4000 g (Table 9.4).

Table 9.4. Mean percentage error in estimation of fetal weight for the author and clinicians for birth weight categories in intervals of 500 g.

Birth weight interval (g)	Number	Author's mean percentage error (95% CI)	Clinicians' mean percentage error (95% CI)
<2500	20	22.0 (16.9-27.1)	26.4 (20.7-32.1)
2500 - 2999	128	10.2 (8.8-11.6)	11.9 (10.5-13.4)
3000 - 3499	250	6.6 (5.9-7.3)	7.8 (7.0-8.5)
3500 - 3999	84	7.7 (6.5-8.9)	9.0 (7.7-10.4)
≥4000	22	15.4 (12.9-17.9)	18.3 (16.3-20.3)

9.2.2. Simple linear regression

Scatter plots for EFW (independent variable) as a predictor for birth weight (dependent variable) were drawn for the author and the clinicians (Figures 9.1 and 9.2). The Pearson correlation co-efficient (r) for the author's EFW was 0.62 (95% CI 0.55-0.67). This means that the fetal weight estimate by the author, in this univariate regression analysis, could explain 38% of the relationship between EFW and birth weight. For the clinicians, r was 0.45 (95% CI 0.35-0.54). When the clinicians were divided into registrars (n=285) and consultants (n=219), no difference was observed. The Pearson correlation co-efficients were 0.46 (95% CI 0.32-0.57) and 0.45 (95% CI 0.26-0.57) for registrars and consultants respectively.

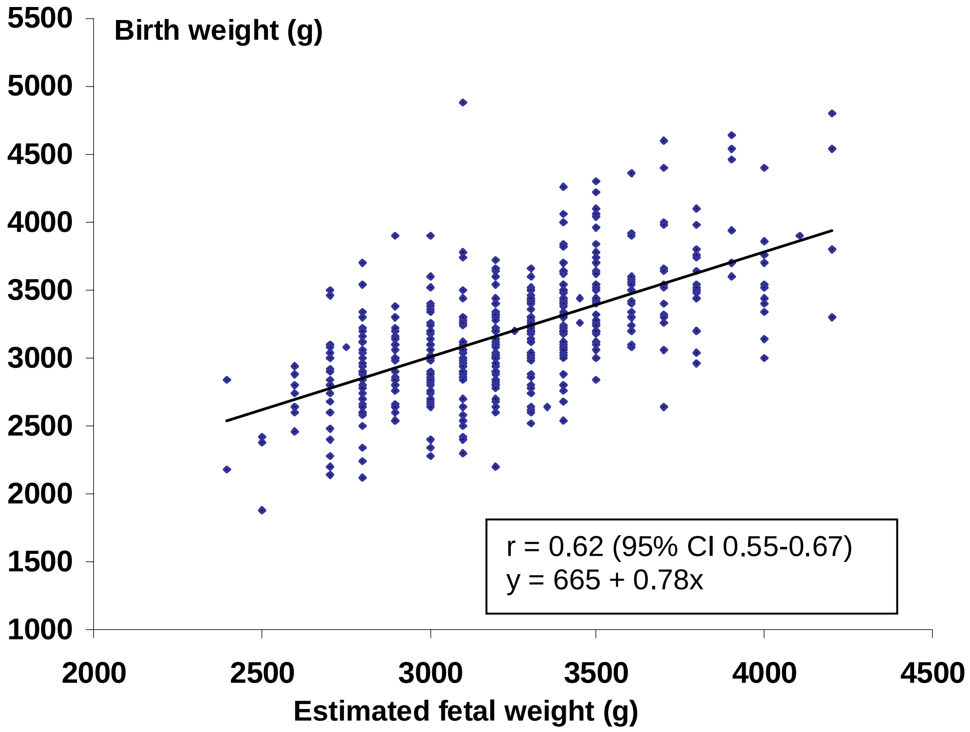


Figure 9.1. Scatter plot for estimated fetal weight by the author as a predictor for birth weight, with regression line.

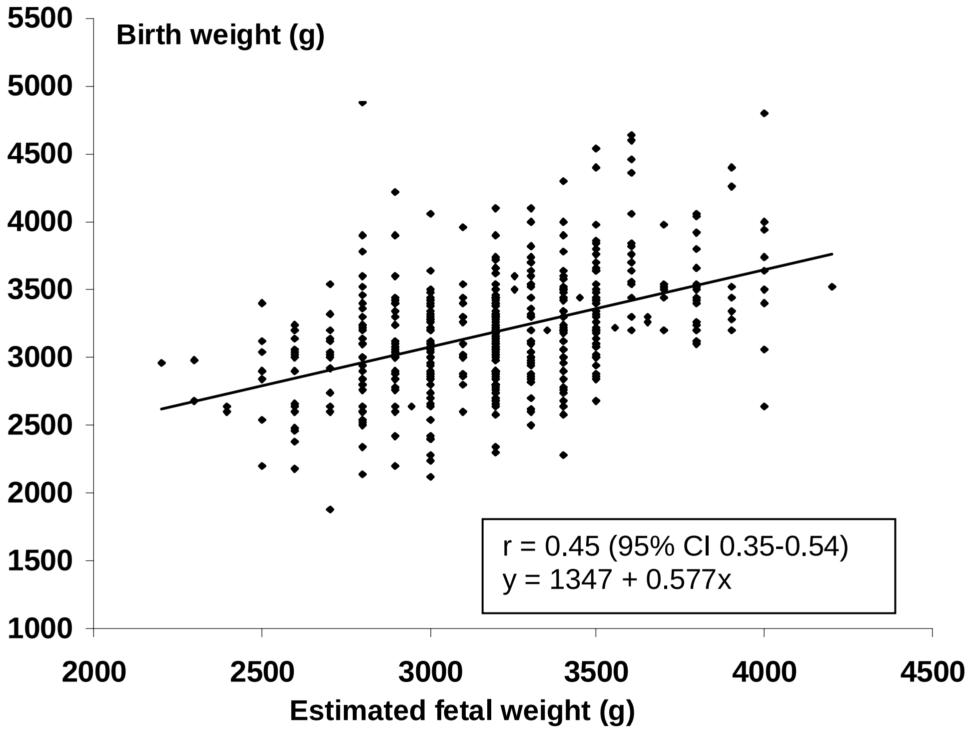


Figure 9.2. Scatter plot for estimated fetal weight by the clinicians as a predictor for birth weight, with regression line.

9.3 SYMPHYSIS-FUNDAL HEIGHT MEASUREMENT

After performing and noting fetal weight estimation by palpation, the author measured symphysis-fundal height (SFH). A scatter plot was drawn for SFH as a predictor for birth weight (Figure 9.3). The Pearson correlation co-efficient r for SFH was 0.64 (95% CI 0.57-0.69). The regression line in the figure indicates that an SFH measurement of 35 cm corresponds approximately to a birth weight of 3000 g. The gradient of the line (0.78) represents an increase in birth weight of approximately 80 g for each cm increase in SFH.

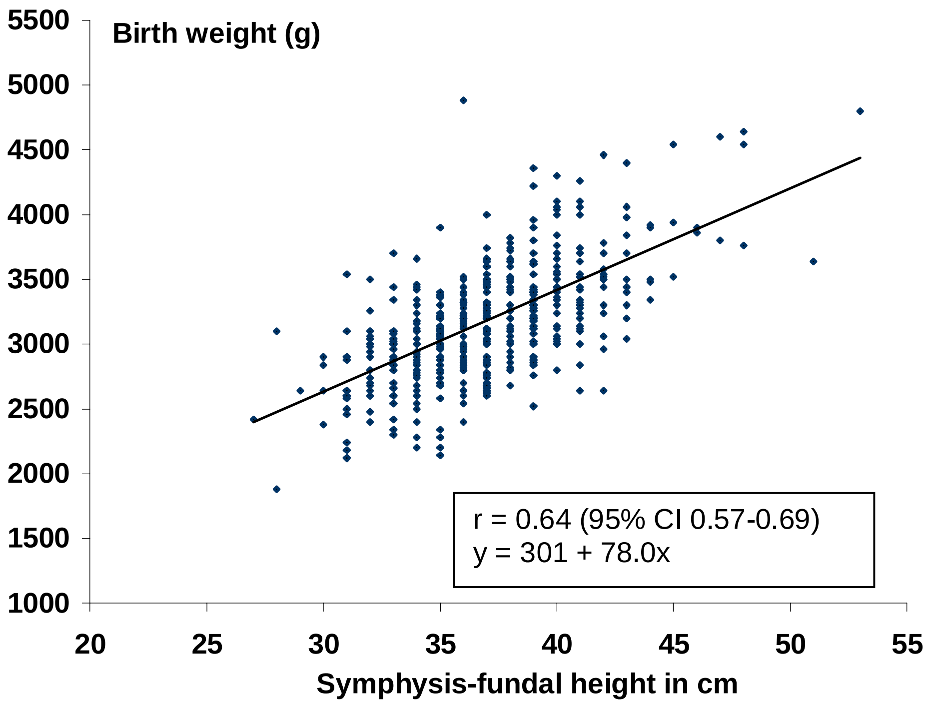


Figure 9.3. Scatter plot for symphysis-fundal height as a predictor for birth weight, with regression line.

9.4 ADDITIONAL PREDICTORS OF BIRTH WEIGHT

The influence of other clinical variables in birth weight prediction was investigated in addition to EFW and SFH. Univariate and multivariate linear regression for birth weight was performed with respect to maternal age, parity, height and weight, HIV serostatus, gestation, state of the membranes, level of head in fifths by the author, and cervical dilatation. This was done in two separate models, one including EFW and the other SFH.

In univariate and multivariate analysis that included the author's EFW, univariate analysis showed that birth weight was significantly associated with age, parity, height, weight, gestation and EFW. There was no association with level of the fetal head and status of the membranes. In multivariate analysis, the association remained for height, gestation, and EFW, with cervical dilatation becoming significant (Table 9.5). Stepwise linear regression, with generation of partial correlation co-efficients r^2, found that the greatest contribution to fetal weight prediction in this model was EFW (37%), followed by maternal height (2.7%), gestation (1.3%), parity (0.7%) and cervical dilatation (0.7%). All of these variables were positively correlated with birth weight. This means that as the variable measure increased, birth weight increased. The R^2 for the model was 0.429, meaning that these variables together contributed 42.9% to the prediction of birth weight (Table 9.6).

Table 9.5. Univariate and multivariate linear regression for birth weight with independent variables including estimated fetal weight (EFW) by the author. SEM = standard error of the mean.

Variable	Univariate analysis		Multivariate analysis	
	Estimate ± SEM	P value	Estimate ± SEM	P value
Age	15.88 ± 3.29	<0.0001	2.59 ± 3.64	0.48
Parity	100.53 ± 29.45	0.0002	33.03 ± 28.61	0.25
Height	12.48 ± 3.01	<0.0001	11.70 ± 2.56	<0.0001
Weight	9.13 ± 1.36	<0.0001	-0.90 ± 1.37	0.51
HIV serostatus	1.09 ± 5.61	0.85	5.16 ± 4.51	0.25
Gestation	87.60 ± 11.59	<0.0001	37.06 ± 10.13	0.0003
State of membranes	10.70 ± 29.45	0.72	4.45 ± 23.28	0.85
EFW	0.78 ± 0.54	<0.0001	0.71 ± 0.05	<0.0001
Level of head (fifths)	17.98 ± 16.10	0.26	24.73 ± 15.40	0.11
Cervical dilatation	16.22 ± 10.38	0.12	27.62 ± 9.73	0.0047

Table 9.6. Stepwise linear regression showing partial r^2 (percentage contribution) of each clinical variable, including estimated fetal weight (EFW) by the author.

Independent variable	P value	Partial r^2
EFW	<0.0001	37.0
Height	<0.0001	2.7
Gestation	0.0004	1.3
Parity	0.019	0.7
Cervical dilatation	0.0127	0.7
Model: R^2 = 0.429, P<0.0001 Birth weight = -2384.0 + 0.71 (EFW in g) + 10.7 (height in cm) + 35.8 (gestation in weeks) + 50.3 (parity) + 20.2 (cervical dilatation in cm).		

In a similar analysis that included SFH instead of the author's EFW, univariate analysis showed that birth weight was significantly associated with age, parity, height, weight, gestation and SFH. There was no association with level of the fetal head and status of the membranes. In multivariate analysis, the association remained for height, weight, gestation, and SFH, with cervical dilatation becoming significant (Table 9.7). Stepwise linear regression found that the greatest contribution to fetal weight prediction was SFH (40%), followed by maternal height (4%), gestation (1%), cervical dilatation (0.8%), parity (0.5%) and maternal weight (0.5%). All of these variables, with the exception of maternal weight, were positively correlated with birth weight. The R^2 for the model was 0.472, meaning that these variables together contributed 47.2% of the prediction of birth weight (Table 9.8).

Comparison of beta-coefficients in the two models (one including EFW vs. the other including SFH) showed that SFH was a better predictor for birth weight than the author's fetal weight prediction (P<0.0001).

Table 9.7. Univariate and multivariate linear regression for birth weight with independent variables including symphysis-fundal height (SFH). SEM = standard error of the mean

Variable	Univariate analysis		Multivariate analysis	
	Estimate ± SEM	P value	Estimate ± SEM	P value
Age	16.65 ± 3.32	<0.0001	2.78 ± 3.50	0.43
Parity	107.08 ± 27.17	<0.0001	35.49 ± 27.56	0.20
Height	11.65 ± 3.03	0.0001	15.26 ± 2.50	<0.0001
Weight	9.13 ± 1.36	<0.0001	-2.78 ± 1.35	0.041
HIV serostatus	1.96 ± 5.76	0.73	3.91 ± 4.34	0.37
Gestation	84.54 ± 11.82	<0.0001	32.09 ± 9.78	0.0011
State of membranes	2.53 ± 30.29	0.93	-12.46 ± 22.48	0.58
SFH	76.99 ± 4.24	<0.0001	75.95 ± 4.94	<0.0001
Level of head (fifths)	19.56 ± 16.33	0.23	14.62 ± 14.90	0.33
Cervical dilatation	14.23 ± 10.57	0.18	25.29 ± 9.37	0.0072

Table 9.8. Stepwise linear regression showing partial r^2 (percentage contribution) of each clinical variable, including symphysis-fundal height (SFH).

Independent variable	P value	Partial r^2
SFH	<0.0001	40.0
Height	<0.0001	4.0
Gestation	0.0015	1.0
Cervical dilatation	0.0056	0.8
Parity	0.012	0.5
Maternal weight	0.039	0.5
Model: R^2 = 0.472, P<0.0001 Birth weight = -3282.7 + 76.9 (SFH in cm) + 15.1 (height in cm) + 30.9 (gestation in weeks) + 21.6 (cervical dilatation in cm) + 53.9 (parity) – 2.7 (weight in kg).		

9.5 PREDICTING THE MACROSOMIC BABY

The ability of palpation and measurement in predicting high birth weight was tested. Macrosomia was defined as a birth weight of 4000 g or more.

9.5.1 The author's estimation of fetal weight

A two-by-two contingency table was constructed for the author's prediction of birth weight based on abdominal palpation. His prediction of birth weight of 4000 g or more had a sensitivity of 0.14, a specificity of 0.97, a positive predictive value of 0.18, and a positive likelihood ratio of 4.73 (Table 9.9).

9.5.2 Symphysis-fundal height measurement

For prediction of infants weighing 4000 g or more, an SFH of 40 cm or more had a sensitivity of 0.82, a specificity of 0.80, a positive predictive value of 0.16, and a negative predictive value of 0.99. The positive and negative likelihood ratios were 4.2 and 0.23 respectively (Table 9.10).

Table 9.9. Two-by-two table for estimated fetal weight (EFW) in the prediction of birth weight at a 4000 g cut-off.

	Birth weight ≥4000 g	Birth weight <4000 g	Total
EFW ≥4000 g	3	14	17
EFW <4000 g	19	468	487
Total	22	482	504

		95% confidence interval
Sensitivity	0.14	0.04-0.36
Specificity	0.97	0.95-0.98
Positive predictive value	0.18	0.05-0.44
Negative predictive value	0.96	0.94-0.98
Positive likelihood ratio	4.7	1.5-15.2
Negative likelihood ratio	0.89	0.75-1.05

Table 9.10. Two-by-two table for symphysis-fundal height (SFH) measurement of 40 cm in the prediction of birth weight at a 4000 g cut-off.

	Birth weight ≥4000 g	Birth weight <4000 g	Total
SFH ≥40 cm	18	95	113
SFH <40 cm	4	387	391
Total	22	482	504

		95% confidence interval
Sensitivity	0.82	0.59-0.94
Specificity	0.80	0.76-0.84
Positive predictive value	0.16	0.10-0.24
Negative predictive value	0.99	0.97-1.00
Positive likelihood ratio	4.2	3.2-5.4
Negative likelihood ratio	0.23	0.09-0.55

A receiver-operated characteristic plot was made for prediction of birth weight of 4000 g or more, for SFH measurements from 35 to 45 cm (Figure 9.4). A measurement of 40 cm appears to provide the best combination of sensitivity and specificity, with greater measurements showing poor sensitivity and lesser measurements poor specificity.

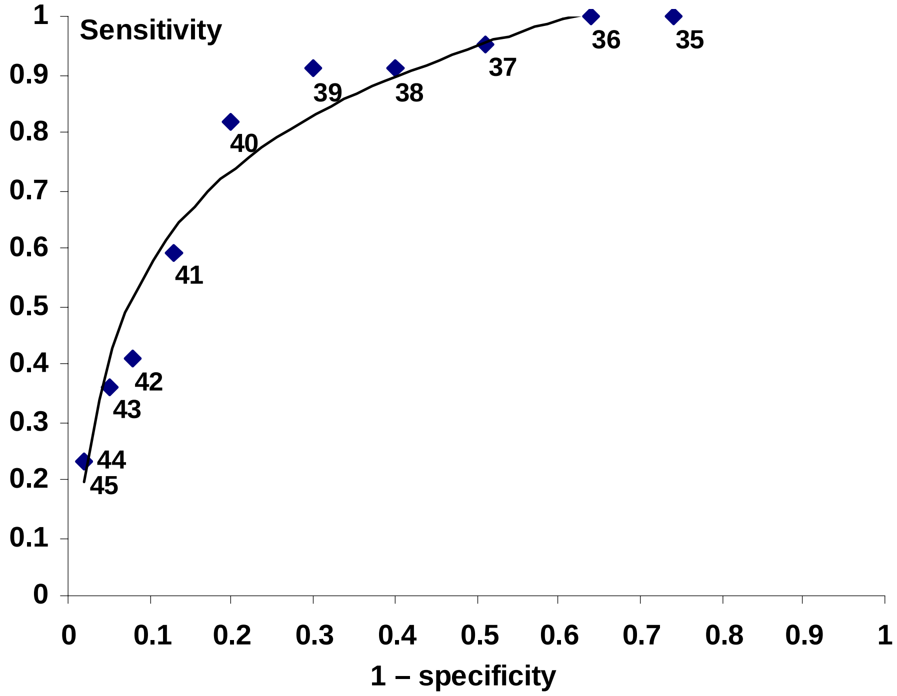


Figure 9.4. Receiver-operated characteristic plot for symphysis-fundal height as a predictor for birth weight ≥4000 g, for symphysis-fundal height measurements from 35 cm to 45 cm.

9.6 DISCUSSION

The author's ability to estimate fetal weight by palpation was in the mid to upper range of published work (Table 4.1). However, most if not all such studies quoted fetal weight estimations probably based on more than simple palpation. Those observers had access to the pregnant women's clinical notes, while the author here was blinded to all clinical detail with the exception of maternal height and weight. The clinicians in this study made significantly poorer estimates than the author, even though they had prior clinical knowledge of the women, for example gestational age and previous birth weight estimates. The author noticed that a significant number of clinicians performed no more than a cursory one-handed palpation of the abdomen, sometimes while doing a vaginal examination with the other hand. Good estimations cannot be expected from such examinations. The lack of difference in accuracy between registrars and consultants is consistent with findings from other studies.[191,195,196]

Fetal weight estimation was least accurate at the extremes of weight, especially for low birth weight infants. This has little significance in terms of predicting CPD. Birth weight estimates were moderately good in the range of 2500 to 4000 g birth weight, which includes most of the larger-than-average babies. The reduced accuracy at extremes of birth weight is in agreement with the observations of Loeffler[161] and Ong and Sen.[162]

The performance of SFH measurement as a predictor of birth weight was impressive (correlation co-efficient r=0.64), significantly better than the author's EFW. The correlation co-efficient falls in the upper range of that reported by other researchers.[147,148,150-153] This is the first study to make direct comparison between intrapartum SFH and EFW by palpation. The findings suggest that an inexperienced but trained clinician who measures SFH will be able to make fetal weight estimations as good as those of an accomplished obstetrician or midwife. However, for SFH to be translated easily to an EFW, a simple formula is needed. The results show that a 1 cm increase in SFH is equivalent to an 80 g increase in fetal weight for this range of weights. A tempting formula would be one based on rounding up 80 g to 100 g, with birth weight in g = (SFH × 100) – 500 (Figure 9.5). This would give predictions based on a subtraction of 5, for example, 35 cm = 3000 g, or 41 cm = 3600 g. However, a validation study needs to be done, preferably using a different observer or observers, before any recommendations can be made regarding SFH-based formulae for birth weight. The frequently quoted Johnson formula[143] was found to be unworkable in this study. A regression line based on that formula is included in Figure 9.5.

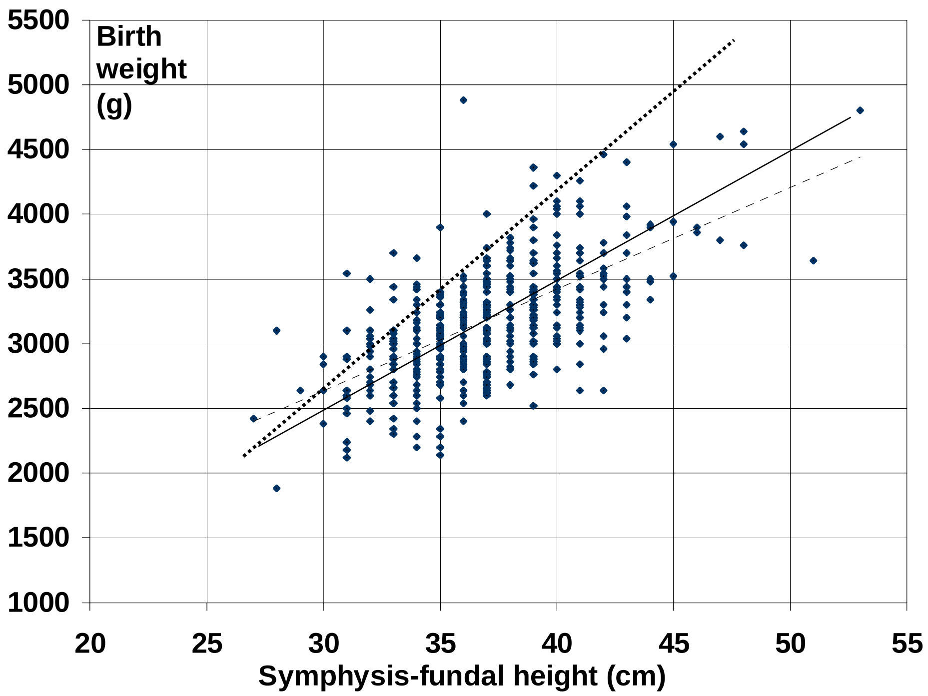


Figure 9.5. Scatter plot for symphysis-fundal height (SFH) as a predictor for birth weight in this study, with regression line (dashed). The solid line corresponds to a fetal weight increase of 100 g per cm SFH, where birth weight in g = (SFH × 100) – 500. The dotted line corresponds to the Johnson formula,[143] where birth weight in g = (SFH – 13) × 155.

Multiple linear regression identified other clinical factors in the prediction of birth weight, although the contribution of these did not approach that of EFW by palpation or SFH measurement. Maternal height was the most significant, related either to genetic transmission of maternal size, or underestimation of fetal weight in tall women, or both. Maternal weight was a significant negative predictor in the model that included SFH, but not in association with EFW. This may reflect overestimation of birth weight when measuring SFH in women with large amounts of abdominal subcutaneous fat. The contributions of parity and gestational age were not unexpected, as birth weight is known to increase with parity and gestation. Why a greater degree of cervical dilatation should correlate with increasing birth weight or fetal weight underestimation, is difficult to explain. Status of the membranes did not contribute to the prediction, in agreement with several other studies.[150,153,185] Level of the head in fifths above the brim also did not contribute to prediction of birth weight. It had been expected, as observed by Bothner, *et al*.,[153] that a high head would result in overestimation, but no correlation was found. A possible explanation is that a high head did in fact result in overestimation, but that this was balanced by a tendency for such fetuses to be larger, resulting in underestimation, and ultimately, no effect. Alternatively, an engaged fetal head may displace the uterine corpus upwards, resulting in an unchanged SFH measurement. While the regression model was able to explain 47% of birth weight prediction, this left 53% unaccounted for. One can only speculate on what factors may have been important but were missed in this study. Variables that may play a role include abdominal girth, lumbar lordosis, pelvic depth, previous large baby, maternal weight gain, maternal nutritional status, maternal smoking, socio-economic factors, altitude, race, and clinical conditions such as maternal diabetes or hypertension. Most of these were not measured in this study.

Clinical prediction of the macrosomic fetus (birth weight 4000 g or more) was generally poor. The author's EFW by palpation had a sensitivity of 16%, much lower than those described from other studies (Tables 9.10 and 4.2). It is possible that he was reluctant to estimate high fetal weights, in view of the scarcity of macrosomic babies in this institution. Even SFH measurement performed poorly, with a sensitivity of little more than 20% for SFHs of 44 and 45 cm. A receiver-operated characteristic plot suggested that the most valuable SFH measurement with respect to macrosomic infants was 40 cm (Figure 9.4). This measurement gave a negative predictive value of 99% for a 4000 g birth weight (Table 9.10). This means that, while sensitivity and positive predictive value were poor, an SFH of less than 40 cm was able to give 99% assurance that the newborn infant would weigh less than 4000 g. Sensitivity and positive predictive value here should be interpreted with caution, because of the small numbers of macrosomic infants and the resultant wide 95% confidence intervals.

9.7 LIMITATIONS

Some study limitations have already been acknowledged. These include the non-inclusion of certain variables or measurements as contributors to birth weight prediction, the small number of macrosomic infants, and the apparently cursory EFW by the attending clinicians.

Another limitation relates to the author being a single observer of both SFH and EFW. A team of trained and enthusiastic clinicians may have delivered results more typical of a normal clinical setting. With only one observer, the study has strength in consistency, although intraobserver variation was not assessed, neither for the author's EFW, nor for his SFH measurements. A further study, drawing on hypotheses related to an SFH-based formula for birth weight, should include other or multiple observers, with measurement of intraobserver variation.

An important limitation is in the applicability of results obtained here from a high risk labour ward serving mostly working class African women. The study design did not allow for SFH measurement and EFW in a random sample of women in normal labour. Any validation study based on the results found here, should attempt to include a more 'normal' labour ward population. If not, the results will be applicable only to environments similar to Chris Hani Baragwanath Labour Ward.

Chapter 9: Summary points

- The author's EFW by palpation had a mean percentage error of 8.7%, with 68.3% of estimates within 10% or less of the birth weight. The correlation co-efficient r for EFW by palpation was 0.62.
- Accuracy of the author's EFW by palpation was best at birth weights between 2500 and 4000 g, and worst at less than 2500 g (mean percentage error 22.0%) and at greater than 4000 g (15.4%)
- The correlation co-efficient r for SFH measurement was 0.64. Fetal weight increased by approximately 80 g for every cm of SFH in the weight range studied, according to the formula $y = 301 + 78.0x$.
- A stepwise linear regression model for birth weight found EFW by the author and SFH to be strong predictors, with statistically significant contributions made by maternal height and weight, parity, gestational age and cervical dilatation at the time of examination
- Level of head in fifths above the brim, and state of the membranes, did not contribute to prediction of birth weight by SFH or by palpation
- The author's EFW by palpation had poor sensitivity (14%) and a poor positive predictive value (18%) for a macrosomic newborn (birth weight ≥4000 g)
- An SFH measurement <40 cm had a negative predictive value of 99% for a birth weight ≥4000 g
- Both the author's EFW by palpation, and SFH measurement, had accuracy similar to previously published studies

- To date, no study has directly compared EFW by palpation and SFH measurement in the prediction of birth weight. This study has shown that SFH measurement appears to be superior to palpation by an experienced obstetrician
- Validation studies are needed to confirm the value of derived formulae for birth weight based on SFH measurement

CHAPTER 10

CONCLUSION

This chapter reviews the history of research into the prediction and diagnosis of CPD. It reminds the reader of significant weaknesses and gaps in current knowledge, and motivates why the study was done, with reflection on the study design. The most significant findings are discussed, with an opinion on how these should influence future research and practice.

The observation of labour progress and detection of CPD is an entirely clinical activity. With X-ray cephalopelvimetry failing in the 1950s and 1960s, clinicians began to understand that a trial of labour noting clinical observations on a partogram was the best way of identifying CPD. This is as appropriate now as it was in the 1970s. Indeed, labour management has not changed in the last three decades. No technology has been able to improve on clinical assessment in fetal weight estimation at term, and in the assessment of cervical dilatation, head descent, moulding and caput. It is only in identification of fetal position where ultrasound has recently gained a foothold, and that is likely to be of value only in the second stage of labour.

It may come as no surprise that there is little new research on clinical observations in labour, and on diagnosis of CPD. This is not because CPD is a condition of the past. In Africa, it is prevalent and pervasive, causing crippling disability and death to hundreds of thousands of women and infants. When Africa's health services start to meet the obstetric needs of their populations, CPD will be recognized by midwives and doctors using simple clinical methods. These methods however need evaluation and refinement, so that labour ward decisions can be based on evidence from research. This applies to clinical methods just as it does to new diagnostic technologies.

The lack of new research is perhaps related to the assumption that all is known about labour. However, a reading of the literature revealed that almost all research on intrapartum clinical methods is retrospective, and subject to significant bias. Unfortunately, a number of clinical observations have been incorporated into obstetric practice without any proof of their value. An example is level of the head, where methods of estimating fifths above the brim were presented with no supporting evidence of predictive value. The same can be said about station as a marker of head descent. Little is known about the true significance of different types and degrees of moulding and caput, because no prospective studies have investigated these commonly reported clinical observations.

Furthermore, interobserver variation is known to be a significant problem in clinical and laboratory practice. However, not one of the important clinical observations in labour, with the exception of SFH measurement, has been subjected to *in vivo* evaluation of inter-observer variation.

These gaps in knowledge about intrapartum observations needed to be filled and resolved. The author felt well placed to do this, given the frequency of CPD in African populations, and the high risk profile of women treated in the Chris Hani Baragwanath Labour Unit. The study design had to be prospective, with mechanisms to prevent bias. To this end, the author as an observer had to be blinded to earlier clinical observations and ultrasound findings. He also could not be involved in the obstetric management, nor could his findings be used to direct obstetric care. This meant that his observations could not be divulged to clinicians caring for these women.

This ‘fly on the wall’ approach of making clinical observations provided a fascinating insight into their predictive value and reliability. The blinded non-participant study design has never been applied in this type of setting, and the author believes that the results provide the best evaluation yet of intrapartum clinical methods. A weakness in this cross-sectional research was perhaps the lack of a longitudinal element in that each woman was examined only once, the only follow-up being time and mode of delivery. Some may feel that the diagnosis of CPD, defined as caesarean section for poor labour progress, was not sufficiently verified. However, this criterion was measurable and robust, with most of these women having prolonged labour with failure to progress on augmentation.

The core of this study’s contribution is in the description of independent clinical predictors of CPD. The results delivered a number of surprises, and confirmed some well established truths.

There was convincing evidence of the important role of parieto-parietal moulding, and the lack of predictive value of occipito-parietal moulding, in the prediction of CPD. Fifty year old radiographic studies of moulding were proved correct in a clinical setting. The results found fault with the current illogical text-book approach that moulding at either suture is equally significant, or that moulding at the two sutures can be added as a composite score. Caput succedaneum, dismissed by many clinicians as a sign of normal labour, was shown to be a predictor of CPD. Moulding and caput can be easily assessed by trained doctors or midwives, although identification of the parieto-parietal suture line may be difficult, especially if fetal position is not known. Caput is easier to appreciate, and of all the clinical observations evaluated, it showed the best interobserver agreement.

Estimation of level of the head, by any method, was disappointing as a predictor of CPD, especially in multiparous women. Numerous studies had already shown that a non-engaged head in the first stage was usually followed by normal delivery. The first stage of labour is probably not the best time to study assessment of level of the head as a clinical method. Comparison of abdominal and vaginal methods of estimating head descent showed that there is little to choose between fifths and station. The findings suggest that dogmatic ideas on using one or other method are inappropriate, and that clinicians may do or teach the method with which they are most comfortable. The disappointing predictive value of level of head in the first stage was compounded by the finding of poor interobserver agreement for both fifths and station. A new method, symphysis-to-sinciput distance, did not provide any significant improvement, but at least offered a degree of objectivity.

There were no surprises in the findings of maternal height, length of labour, and dilatation of the cervix. These proved to be significant predictors, the latter two confirming the importance of cervical assessment and trial of labour in detection of CPD. Cervical assessment was found to be moderately reliable in terms of interobserver agreement, with improved agreement with more senior grades of staff.

SFH and, to a lesser extent, gestation, are indicators of birth weight. These were found to be independent predictors for CPD. In the hands of the author, SFH measurement correlated slightly better with birth weight than fetal weight estimation by palpation. This was encouraging for clinical practice, because SFH should be more objective and repeatable than guesswork by different practitioners.

It was notable that parity did not have an independent influence on prediction of CPD, despite assertions that multiparae may obstetrically be a ‘different species’. CPD is a simple mechanical problem and it is logical to presume that the same clinical findings will prevail in both nulliparae and multiparae if there is mismatch between the fetal head and maternal pelvis.

Other clinical observations that did not contribute to prediction of CPD were maternal weight, occipitoposterior position and deflexion of the fetal head. Occipitoposterior position was surprisingly frequent, and could be considered a normal finding in the population studied. The difficulty with identifying fetal position was demonstrated in the ultrasound-verified group of women, although the author was correct in most cases. As has been stated before, the occipitoposterior position may co-exist with CPD, but is never likely to be the cause.

No single independent predictor, nor even a combination of predictors, is diagnostic of CPD. It would have been possible to develop from the study data a composite ‘CPD score’ made up of these observations. This could have been manipulated to produce a high positive predictive value for CPD. The author considers this inappropriate, as such a score would only apply in high risk conditions similar to those at Chris Hani Baragwanath Labour Ward. The study also was not designed to produce, nor did it include in its objectives, a ‘CPD score’. More important, intrapartum observations should be seen as adjuncts to, and not replacements for, a trial of labour using a partogram. Women with CPD in this study almost always crossed to the right of the partogram alert line. In a woman with normal labour progress, her height, the estimated fetal weight, and the presence of caput and moulding, are of little consequence. The ideal place for using these observations is in situations where labour progress is subnormal and the clinician is in some doubt about whether to continue with a trial of labour. This is especially true for multiparae where, for fear of causing uterine rupture, there might be reluctance to augment labour with oxytocin.

The findings have implications for obstetric practice. The independent clinical predictors for CPD identified in this study – maternal height, SFH, parieto-parietal moulding, and caput – should be noted at every intrapartum clinical examination, along with cervical dilatation and level of the head. Height and SFH need to be measured only once, probably on admission in the active phase of labour. Fetal position may be recorded, but should not be used to justify a diagnosis of CPD. Senior clinicians need to teach basic intrapartum assessment, especially SFH, level of the head, cervical dilatation, moulding and caput, to students and inexperienced doctors. This can be done on models and in parturient women.

The study raised some new questions, offering opportunities for further research. Whether descent is better measured by fifths or by station was not resolved. This question can only be answered by a prospective non-participant study done in the second stage of labour. Such a study could include evaluation of interobserver agreement of fifths and station. Regarding fetal weight estimation, an obvious follow-up study would involve the testing of a formula for birth weight estimation based on the SFH. This could verify a simple calculation suggested here, and allow it to be applied in clinical practice. The problems with interobserver agreement could prompt research into clinical teaching of observations such as level of the head, position, moulding and caput. These are just a few of the areas that might justify further investigation.

In a world that is increasingly technological, there are still activities that require the essentially human skills of observing, feeling, and estimating. Assessment of labour progress is such an area. Intrapartum clinical palpation and assessment has been shown to be valuable in prediction of CPD, and must continue to be developed as an essential skill in obstetrics and midwifery.

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