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THE PREDICTIVE ABILITY OF CLINICAL PALPATION FOR ESTIMATING AMNIOTIC FLUID VOLUME IN SUSPECTED PROLONGED PREGNANCY

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Science in Epidemiology in the field of Biostatistics and Epidemiology

Johannesburg

30 October 2012

DECLARATION

I, Eckhart Johannes Buchmann, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Epidemiology in the field of Biostatistics and Epidemiology in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

.....

.....day of 2012

DEDICATION

I dedicate this work to my father, Klaus Buchmann

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GLOSSARY OF OBSTETRIC TERMS

Amniocentesis: Needling of the uterine cavity during pregnancy through the skin and the uterus, to obtain amniotic fluid or to inject dye or medication into the amniotic cavity.

Apgar score: A scoring system to evaluate newborn babies' condition just after birth. A high score indicates newborn well-being (named after Dr Virginia Apgar, an anaesthesiologist).

Ballottable: The ability, on feeling the abdomen of a pregnant women, to bounce fetal parts from one hand to the other. This can be done for the presenting parts above the pelvic brim, or for fetal parts higher up (in the fundus) of the uterus.

Biophysical profile: A scoring system to evaluate fetal condition before birth, based on ultrasound criteria. A high score indicates fetal well-being.

Cardiotocography: Fetal heart rate and uterine contraction recording to assess fetal well-being. The result is presented as a tracing on a screen or on a paper strip.

Cephalopelvic disproportion: The disproportion that arises when the fetal head is too large to pass easily through the maternal pelvis during birth.

Fetal distress: Fetal hypoxaemia before birth, usually indicating risk of death.

Forewaters: Amniotic fluid contained in front of the presenting fetal part at the pelvic inlet.

Hysterotomy: Incision of the uterus to deliver a fetus or to perform procedures on a fetus. Caesarean section is a form of hysterotomy, but implies that the fetus is viable (>28 weeks).

Intrapartum: Synonym for 'during labour'.

Meconium: Sterile fetal intestinal discharge (faeces) passed before, at, or just after birth.

Nullipara: A woman who has given birth to her first baby.

Oligohydramnios: Below-normal total amniotic fluid volume.

Palpation: Feeling with the hands as part of clinical physical examination of a patient.

Parity: The number of viable births (>28 weeks) that a woman has had.

Perinatal: Referring to events that occur at or just after delivery; for example, perinatal death refers to death of a baby, either stillborn or within the first seven days after birth.

Polyhydramnios: Above-normal amniotic fluid volume.

Pre-eclampsia: Hypertension with protein in the urine, developing after 20 weeks of pregnancy.

Shoulder dystocia. Difficulty or delay with delivery of the shoulders of a baby, after delivery of the head, usually associated with above-normal size of the baby.

Symphysis-fundal height. A measure of the height of the uterus, being the distance in cm on the maternal skin, from the symphysis pubis to the highest palpated point of the uterus.

Term. The traditionally accepted gestational age interval at which normal birth is said to occur spontaneously – 37 to 41 weeks.

LIST OF ABBREVIATIONS

AF	Amniotic fluid
AFI	Amniotic fluid index
BMI	Body-mass index
BP	Blood pressure
CHBAH	Chris Hani Baragwanath Academic Hospital
CI	Confidence interval
CS	Caesarean section
GA	Gestational age
HAART	Highly active antiretroviral therapy
HIV	Human immunodeficiency virus
IQR	Interquartile range
LMP	Last menstrual period
MAS	Meconium aspiration syndrome
MOU	Midwife obstetric unit
MRI	Magnetic resonance imaging
MVP	Maximum vertical pool
NST	Non-stress test
PLR	Positive likelihood ratio
PND	Perinatal death
PP	Presenting part
RCOG	Royal College of Obstetrics and Gynaecology
RCT	Randomised controlled trial
ROC	Receiver operator characteristic
SD	Standard deviation
SFH	Symphysis-fundal height
SR	Systematic review

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ABSTRACT

Background and objectives

In low resource settings, ultrasound scans may not be available for amniotic fluid volume (AFV) assessment as part of fetal evaluation for suspected prolonged pregnancies (≥41 weeks' gestation). The objectives of this study were: 1) to describe AFV measurements using ultrasound in women with suspected prolonged pregnancies, and to relate these measurements to maternal and fetal factors; 2) to evaluate different clinical palpation methods for estimating AFV; and 3) to determine the ability of clinical palpation to estimate AFV and predict oligohydramnios, using ultrasound-based amniotic fluid index (AFI) as a gold standard, accounting for the influence of maternal and fetal factors.

Methods

The study included women referred to Chris Hani Baragwanath Academic Hospital from midwife-run antenatal clinics because of concern about prolonged pregnancy (gestational age ≥41 weeks). On arrival at hospital, the women had real-time ultrasound assessment of AFI by an experienced ultrasonographer. The researcher, blinded to the AFI result, estimated AFV by abdominal palpation using ballottability of fetal parts, uterine fluctuance, uterine irritability, easily felt fetal parts, and a general impression of AFV. After recording the palpation findings, the researcher made a best estimate of gestational age for each woman based on the last menstrual period, early pregnancy ultrasound scans if available, or other relevant clinical information. Oligohydramnios was defined as an AFI <5 cm.

Results

One hundred women participated, of whom 45 had a best estimate gestational age ≥41 weeks. The mean AFI was 8.1±4.3 cm; 23 women had an AFI <5 cm. Twenty women were HIV

infected. In univariable and multivariable linear regression analysis, HIV infection and gestational age were inversely associated with AFI at a P value <0.05. On abdominal palpation, the symphysis-fundal height, uterine fundal fetal parts ballottement, and presenting part ballottement were significantly positively associated with AFI on univariable and multivariable linear regression analysis. For the binary outcome of oligohydramnios, only presenting part ballottement was associated with an AFI <5 cm (negatively), both crudely, and adjusted for gestational age and HIV infection using logistic regression analysis. For women with a fetal head fully palpable ('five fifths') above the pubic symphysis (n=55), an inability to ballot the presenting part had a sensitivity of 73%, specificity of 64%, and a negative predictive value of 90% for an AFI <5 cm.

Conclusion

While fetal part ballottement and symphysis-fundal height measurement showed significant associations with AFI, the predictive value of clinical palpation for oligohydramnios was poor. However, in settings where real-time ultrasound technology is unavailable, the assessment of presenting part ballottement may be of value in women with suspected prolonged pregnancy. In clinical settings similar to those in this study, a ballottable fetal head gives 90% assurance of normal AFV.

1. INTRODUCTION

The risk of poor pregnancy outcome increases significantly after 40 weeks of gestation, the so-called expected date of delivery. Current management of prolonged pregnancy (gestation≥41 weeks) is induction of labour or close fetal surveillance, based on reliable gestational age assessment usually obtained from early pregnancy ultrasound.[1] In the absence of reliable information on pregnancy dating, it may be difficult to decide on a correct management plan. Such a dilemma can be resolved by assessing markers of fetal condition, including amniotic fluid volume (AFV). Reduced AFV (oligohydramnios) will sound a warning to possible adverse outcome for the baby. The acceptable response to such a finding is admission for delivery, usually by inducing labour. Conversely, a normal AFV, usually with good fetal movements perceived by the pregnant woman and a normal fetal heart rate (fetal cardiotocographic non-stress test), should allow ongoing close surveillance of the pregnancy.

Ultrasound imaging is the standard method for assessing AFV, by measuring the depth of amniotic fluid (AF) pools. There is still debate about the best method of measurement, the two alternatives being the deepest or maximum vertical pool (MVP) found in the whole uterus, or a sum of the deepest pools in each quadrant of the uterus, termed the amniotic fluid index (AFI).[2]

1.1. Statement of problem

What about low resource settings where ultrasound equipment and skills are in short supply? In such settings, many pregnancies are wrongly classified as prolonged, as they may be unreliably dated using only the last menstrual period. This may result in unnecessary inductions of labour. Also, AFV assessment using ultrasound may not be available to provide reassurance about fetal condition. This dilemma confronts many clinicians who care for

pregnant women with suspected prolonged pregnancy in low resource settings. Given the risks and expense of induction of labour, it would be understandable to ignore prolonged pregnancy and allow nature to take its course and hope for the best in each case. This might seem untenable to modern clinicians.

To provide the reassurance that clinicians and pregnant women need, the seemingly obvious alternative to AFV assessment using ultrasound is clinical examination of the pregnant woman's abdomen. Clinical teachers and obstetric textbooks continue to describe findings associated with increased, normal and reduced AFV. On clinical examination, fluid can be distinguished from solid, and in the obstetric patient a fetus in the uterus can be made to bounce (ballot) from side to side if there is sufficient AF.[3,4] Reduced AFV may give the impression of a fetus cramped for movement,[3,5] or make it easy to feel separate fetal parts.[3,6]

1.2. Justification for this research

While modern clinicians may dismiss clinical palpation for assessing AFV, there is little data to support such a dismissal. The researcher found only two studies, from 1972 and 1984, that evaluated clinical examination for AFV assessment.[7,8] Both reported that clinical assessment was unreliable and of no value. Since the two studies had significant limitations, there is a need for further research on clinical methods in AFV assessment, especially in the context of prolonged pregnancy where AFV assessment is frequently called for. Of course, this does not apply in high-income settings, where shortage of ultrasound equipment is not an issue. The potential importance of clinical assessment of AFV in low resource settings remains, and needs to be evaluated.

2. LITERATURE REVIEW

2.1. Amniotic fluid volume

Amniotic fluid and its functions

Amniotic fluid (AF) is the fluid contained by the amniochorionic membranes in the uterus. It provides the watery environment in which the fetus develops. The fluid allows musculo-skeletal, gastrointestinal and respiratory system development, and also protects the fetus from traumatic injury.[9] AF also has antibacterial properties, and may provide short-term fluid and nutrient supplementation to the fetus.[9,10]

Physiology of amniotic fluid volume

During the embryonic phase of development (<8 weeks of gestation), AF is no more than an ultrafiltrate of maternal plasma. In later weeks the fluid reflects the composition of fetal extracellular fluid, with free diffusion of water and solutes though the fetal skin and other epithelial surfaces into the amniotic cavity.[11] Then, in the second half of pregnancy, the fetal skin becomes cornified and no longer allows diffusion of fluid. Brace, in an excellent review, described the mechanisms of AFV regulation as they are understood in the second half of pregnancy.[12] Briefly, there are four main routes of AF movement at advanced gestation, two that produce AF and two that remove AF. The following are daily volumes for a term fetus:

- AF production: the fetus passes about 800-1200 mL of urine. This is greater than the average total AFV (about 800 mL), suggesting a high and rapid turnover of AF.
- AF production: the fetal lungs secrete about 340 mL of fluid of which about half is swallowed and half is delivered to the AF through breathing movements.
- AF removal: the fetus swallows 500-1000 mL of AF, and this is absorbed in the gastrointestinal system.

- AF removal: 200-500 mL of AF is absorbed from the fetal surface of the placenta into the placental circulation each day, through the intermembranous pathway. This movement is favoured by AF having a relatively low osmolality (about 10 mOsmol/mL less than fetal plasma)[10]

Additional but insignificant exchanges occur from the fetal nose and throat into the AF (about 25 mL), and through the fetal membranes into the maternal circulation, by the trans-membranous pathway (about 10 mL).

While some of these exchanges are regulated by fluid and solute status for intermembranous transfer, and by fetal kidney perfusion and related mechanisms, it is unlikely that AFV *per se* is regulated. AFV in the second half of pregnancy is highly variable, and in view of the turnover of fluid volumes as noted above, can change rapidly.

2.2. Gestational age and amniotic fluid volume

It makes intuitive sense that as the uterus enlarges with ongoing pregnancy, AFV will increase; the larger the baby, the greater the amount of water in the bag. However, traditional obstetric teaching holds that AFV increases to a maximum at about 36 weeks' gestation, and declines thereafter. This is based on a frequently quoted review by Brace and Wolf, published in 1989.[13] The authors combined results from 12 studies in which AFV was measured, either directly at hysterotomy or caesarean section, or by dye-dilution techniques. The studies were done between 1961 and 1978, on a total of 705 pregnancies. However, in 1997, Magann et al. found that AFV increases consistently up to 40 weeks' gestation, after performing an aminohippurate sodium dye-dilution technique on 144 pregnancies from 15-40 weeks of gestation.[14] Their technique involved injection of dye at the time of amniocentesis in 'normal' pregnancies that had a clinical indication for amniocentesis. After injecting dye and waiting for the AF to mix with the dye, they withdrew a specimen which reflected the volume of AF

by the dilution of dye obtained. The aminohippurate sodium dye dilution technique was later validated by the same team.[15] The authors of the 1997 study criticized the Brace and Wolf combined analysis, based on small numbers in individual studies, heterogeneity of methods used, and inherent inaccuracies with some of the dye-dilution and AF collection methods. Their own study had limitations too: the difficulty in being able to sample entirely normal pregnancies, the cross-sectional study design, and the absence of pregnancies of more than 40 weeks' gestation. However, it now seems reasonable to believe that AF increases with gestation, at least up to 40 weeks, as suggested by Magann et al.[14]

2.3. Determinants of amniotic fluid volume

The physiological increase in AFV with advancing gestation has already been discussed. Deviations from the norm will result from changes in any of the four main routes of AF movement mentioned earlier. Changes in urine output and the fetus's ability to swallow have the greatest effect. A clinically significant increase in amniotic fluid volume is termed polyhydramnios, and a decrease oligohydramnios. There are no useful upper and lower limits of AFV respectively to define these entities, although gestational age-specific readings can be derived from the graphics in published articles.[13,14] For example, about 95% of measurements of AFV at 30 weeks of gestation will be between 100 mL (upper limit for oligohydramnios) and 2750 mL (lower limit for polyhydramnios).[14] Measurement of AFV, including direct measurement, dye-dilution methods, noninvasive semiquantitative measurements and qualitative estimates, will be discussed later.

Increase in amniotic fluid volume

Polyhydramnios is most often associated with fetal abnormalities, related to inability to swallow or absorb AF. Examples are gastrointestinal atresias (blockages), mass effects of organ enlargements in the neck and chest, and brain defects affecting swallowing reflexes.

Other causes include maternal gestational diabetes mellitus, multiple pregnancy, and hydrops fetalis.[16] Increased AFV will not be discussed further in this research report.

Decrease in amniotic fluid volume

Oligohydramnios most frequently results from rupture of the membranes during or before labour. Oligohydramnios or anhydramnios (no discernible AF) without membrane rupture may occur in association with fetal kidney and urine outflow tract abnormalities. Certain medications, especially non-steroidal anti-inflammatory drugs, may cause reduced fetal urine output resulting in oligohydramnios.[17] Of most concern to clinicians is oligohydramnios caused by reduced uteroplacental perfusion with fetal hypoxaemia. This may result from pre-eclampsia, fetal infections, chronic placental insufficiency, nicotine use, prolonged pregnancy, and maternal dehydration or hypoxaemia.[16,18] It has been shown that reduced fetal oxygenation causes redistribution of oxygenated blood to vital organs, away from the kidneys and thus reducing urine output, as evidenced by the demonstration of reduced renal artery blood flow on Doppler investigation.[19] In addition, increased fetal plasma osmolality related to reduced uterine perfusion causes a rise in antidiuretic hormone levels and reduced urine output, further reducing urine volume and therefore AFV.[9] The decrease in AFV after 40 weeks' gestation is thought to be related, at least in part, to placental insufficiency and fetal hypoxaemia. Evidence for this has been provided by the finding of increased erythropoietin levels in fetuses at more than 41 weeks' gestation.[20] Concern about failing placental function has made AFV measurement an essential component of fetal monitoring in the management of pregnancies beyond 41 weeks of gestation.

The clinical significance of oligohydramnios is not only related to it being a marker of fetal hypoxaemia. Oligohydramnios can itself have consequences for the fetus. Early in gestation (before 22 weeks), reduced AFV may result in lung hypoplasia and defects in intestinal tract

development.[9,16] Closer to delivery, oligohydramnios may allow umbilical cord compression resulting in fetal hypoxaemia, and also contribute to meconium aspiration syndrome (MAS) where the fetus aspirates undiluted irritant meconium into the lungs.[19]

2.4. Measurement of amniotic fluid volume

Precise measurement of AFV is only possible by direct or dye-dilution methods, used in research settings. In practice, clinicians use ultrasonographic vertical depth measurements of AF pools to provide indirect non-invasive semiquantitative measures of AFV. Less frequently, qualitative estimates of AFV may also be done using a variety of methods, including clinical palpation.

Invasive 'gold standard' measurement

Direct measurement of AFV can only be achieved at hysterotomy or caesarean section, where all AF is collected and measured. Intrauterine fluid is sucked out at the time of incision of the uterus, and all remaining fluid is collected in custom-made drapes with pockets. This method is well described by Magann et al.[14] Where there is no clinical indication for hysterotomy or caesarean section, the best gold standard measurement of AFV is dye-dilution. At amnio-centesis (needling of the uterus to remove AF), dye is injected into the amniotic cavity and allowed to mix with the AF by external agitation of the uterus or repeatedly withdrawing and injecting fluid with the needle still in the uterus. After a certain time, AF is withdrawn and AFV is calculated based on the dilution of the dye and the assumption of even mixing of dye in the AF. Indigocarmine, aminohippurate and radioactive technetium have all been used as dyes,[13] but aminohippurate is currently the most favoured.[14] Dye-dilution techniques give measurements of reasonable precision for only a short time. Using direct collection at caesarean section as a gold standard, Magann et al. showed that dye-dilutions gave erroneous

measurements of AF if the dye-dilution amniocentesis preceded the caesarean section by more than four hours.[15]

Non-invasive qualitative and semiquantitative measurements using ultrasound

The sonolucent 'waters' in the uterus can be easily identified on ultrasound imaging, and it is possible to express estimates of AFV from the depth of pools of AF. In 1980, Manning et al. described the biophysical profile (BPP) for evaluating fetal health.[21] The authors had recognised that AFV (among other criteria such as fetal heart rate and fetal activity) was an indicator of fetal health, and described qualitative measurement of the vertical depth of AF pools as a component of the BPP. Normal AFV was assumed if the ultrasound scan showed 'fluid evident throughout the uterine cavity. Largest pocket of fluid greater than 1 cm in vertical diameter'. Decreased AFV was assumed if 'fluid absent in most areas of uterine cavity. Largest pocket of fluid measures 1 cm or less in vertical axis. Crowding of fetal small parts'. These rather arbitrary definitions were backed up by the authors in their series of 216 high-risk pregnancies, as part of the composite BPP, which was correlated with neonatal outcome. The BPP remains to this day an accepted method of fetal evaluation. In 1984, an observational study by Chamberlain et al., in which Manning was a co-investigator, showed a significant inverse relationship between ultrasonographic AFV estimation and perinatal outcome in a sample of 7583 high-risk pregnancies. The increased perinatal mortality rate associated with oligohydramnios was related to fetal deaths from intrauterine growth restriction and major congenital anomalies.[22] The authors provided a semi-quantitative (admittedly arbitrary) method of expressing AFV: 'The depth of a pocket (i.e., <1.0 cm, 1.0 to 2.0 cm, >2.0 to <8.0 cm) was used for classification of cases into decreased, marginal, or normal groups, respectively.' These measurements referred, as in the case of Manning et al.,[21] to the maximum vertical pool (MVP) of AF found in each pregnancy ultrasound scan.

In 1987, to improve on the qualitative and crude semiquantitative measurements of MVP as described in the previous paragraph, Phelan et al. introduced the amniotic fluid index (AFI).[23] Referring to the MVP measurements, they wrote that 'these techniques do not permit the clinician to follow the progressive changes in the AFV during the course of pregnancy, nor do they facilitate total evaluation of the fluid within the intra-uterine cavity'. The AFI relied (and still relies) on measuring the vertical diameter of the MVP in each of four quadrants of the uterus, as follows:[23]

'The approach... begins by first dividing the maternal abdomen into four quadrants. Using the umbilicus as the reference point, the uterus is divided into upper and lower halves. The linea nigra is then used as the midline, with the uterus divided into right and left halves. The (ultrasound) transducer head is then placed on the maternal abdomen along the longitudinal axis. With the transducer head perpendicular to the floor, the largest amniotic fluid pocket in each quadrant is identified. Then the vertical diameter of the largest pocket in each quadrant is measured. The numbers obtained from each quadrant are summed. This sum is the amniotic fluid index, in centimetres, for each patient.'

The authors found that AFI declined significantly after 40 weeks. Using an arbitrary lower cut-off of 5 cm for oligohydramnios, they found that 2.4% of women of 36-40 weeks' gestation had an AFI $\leq$5 cm, while 24% of women at 41-42 weeks had an AFI $\leq$5 cm. Current definitions of oligohydramnios as an AFI <5 cm are derived from this study. In a subsequent study, the same group of authors showed, from data in 197 pregnant women, that the AFI increased up to 26 weeks (mean AFI = 19.7 cm) and stabilized, then showed a gradual decline from 38 weeks (mean AFI = 16.1 cm) to 42 weeks (mean AFI = 14.1 cm).[24] It is notable that the findings of these studies were not compared to a gold standard AFV, yet the AFI was accepted by the authors as creating 'an adequate impression of the AFV and (correlating) well with the changes in AFV during pregnancy'. It seemed to make sense that four MVPs from different parts of the uterus should be more helpful than just one. With two more articles from the same group correlating the AFI with perinatal outcome, and showing

good inter- and intra-observer variability for AFI,[25,26] the obstetric community was more than happy to accept these results. The AFI rapidly came into widespread use around the world as a tool for measuring AFV and pregnancy risk. The intuitive appeal and widespread adoption of the AFI spawned numerous studies to better define AFI normal limits and the relationship of the AFI with AFV. Strong et al. in 1990 showed how AFI increased quite predictably after infusion of measured volumes of saline into the amniotic cavity.[27] Moore and Cayle provided one of the first nomograms for AFI in 1990, finding mean AFI measurements of 11.5 cm at term (37-41 weeks), and 10.8 cm at 41.1-42 weeks.[28] They found that an AFI of 5 cm corresponded to less than the first centile value at term. Studies of AFI normal ranges according to gestation are summarised in Table 1.

Table 1. Studies of normal values and percentiles of amniotic fluid index (AFI).

Author	Country	Number of women	Gestational ages	Findings and remarks
Moore and Cayle (1990)[28]	USA	791	16-44	5th centile at term = 68 mm. AFI <5 cm in <1% of scans at term
Marks and Divon (1992)[29]	USA	511	≥41 weeks	AFI ≤5 cm in 11.5% of scans, 25% reduction in AFI for each week beyond 41 weeks
Alley et al. (1998)[30]	Bulgaria	750	≥24 weeks	Maximal AFI at 28-32 weeks. 5th centile at 37-41 weeks = 5.4 cm, at >41 weeks = 4.2 cm
Chauhan et al. (1999)[31]	USA	56	≥24 weeks	No significant differences in AFI from 24-40 weeks. Significant decrease in AFI from 40 weeks
Locatelli et al. (2004)[32]	Italy	3049	≥40 weeks	AFI ≤5 cm found in 11.5% of scans
Hinh and Ladinsky (2005)[33]	Vietnam	117	≥28 weeks	Longitudinal study, but no statistical techniques used to handle repeated measures. Mean AFI at 29 weeks (maximum) = 15.1 cm. Mean AFI at 41 and 42 weeks = 10.3 and 9.3 cm respectively
Machado et al. (2007)[34]	Brazil	2868	≥20 weeks	50th centile AFI the same from 20 to 33 weeks. 10th centile at 40, 41 and 42 weeks = 6.2, 5.3 and 4.4 respectively.

While the nomograms from different studies give different ranges, consistent findings are a peak in AFI at around 26 to 30 weeks and a sharp decline in AFI after 40 weeks of gestation. It has been pointed out that the range of normal values for AFI is very wide, although less so for below-normal AFVs. Recently, Machado et al. from Brazil used rigorous methodology to measure AFI in 2868 low-risk pregnant women with reliable last menstrual periods confirmed by first-trimester ultrasound dating.[34] Only one AFI was reported per woman, thus avoiding any clustering effect of repeated measures. The 10th centile AFIs for women at 40, 41 and 42 weeks were 6.2, 5.3 and 4.4 cm respectively, providing support for the arbitrary 5 cm cut-off for oligohydramnios assigned by Phelan et al. in 1987.[23]

Reproducibility in measurement of AFI has been reported from several studies. In 1990, Moore and Cayle showed that measurements were repeatable within 3-7% of an AFI measurement, but with higher errors in the oligohydramnios range.[28] Williams et al. showed better intra-observer repeatability with AFI for oligohydramnios at 5th centile cut-offs for gestational age (kappa = 0.60) than with one MVP alone at a 2 cm cut-off (kappa = 0.33).[35] Alley et al. found mean percentage errors of 2.4% for intra-observer and 3.4% for inter-observer comparisons,[30] and Hinh and Ladinsky reported mean percentage errors of 4.8% for intra-observer and 12.3% for inter-observer comparisons.[33] There is general consensus in the literature that the AFI is a reproducible measurement, although less so in the setting of oligohydramnios. It has justifiably been suggested that measurements in the low range of AFV should be repeated to improve precision and reproducibility.[10]

Amniotic fluid index versus single maximum vertical pool

With AFI measurement becoming part of routine care of high-risk pregnancies, a number of studies, including a meta-analyses, were done to correlate AFI with perinatal outcome.[36,37] The overwhelming finding was that AFI was a poor predictor for poor perinatal outcome,

leading to re-evaluation of the method and its utility. A large number of studies compared MVP (one pool for the whole uterus) with the AFI (MVP in each of the four uterine quadrants, added together) for both prediction of AFV and for clinical endpoints. Most studies settled on AFI <5 cm or ≤5 cm and MVP <2 cm or ≤2 cm as their definitions of oligohydramnios (Table 2). AFI performs marginally better than MVP, which is expected since the AFI samples more AF pockets. However, Dildy et al. made the important point that both tests gave good correlations with gold standard AFV in the normal range of AFV, but with overestimation of AFV in oligohydramnios, and underestimation of AFV in polyhydramnios.[38] Therefore, predetermined cut-offs at low levels may prove more useful for assessment of oligohydramnios, rather than assuming correlation based on a full range of values.[39]

Table 2. Studies that compared correlation of maximum vertical pocket (MVP) and amniotic fluid index (AFI) with gold standard AF volume.

Author	Country	Number of women	Gold standard	Pearson's correlation coefficient (r)
Croom et al. (1992)[40]	USA	50	Dye dilution	MVP: 0.60 AFI: 0.75
Dildy et al. (1992)[38]	USA	50	Dye dilution	MVP: R^2=0.74* AFI: R^2=0.71
Horsager et al (1994)[41]	USA	40	Fluid collection at caesarean section	MVP: 0.76 AFI: 0.74
Magann et al. (2000)[39]	USA	197	Dye dilution	PLR for MVP = 2.5† PLR for AFI = 2.4
Zaretsky et al. (2004)[42]	USA	80	Fluid collection at caesarean section	MVP: 0.71 AFI: 0.77

*Coefficient of determination R^2 from a scale of log-transformed AFI and MVP against log-transformed AFI

†PLR = positive likelihood ratio, for oligohydramnios at MVP<2 cm and AFI <5 cm.

When AFI was compared with MVP for prediction of poor perinatal outcome, most studies found an MVP cut-off of 2 cm as having less false positive results than an AFI cut-off of 5 cm.[2,43,44] While AFI may correlate better with AFV as noted above, MVP is currently favoured as the standard screening method for fetuses at risk, because of its superior predictive value for poor perinatal outcome.[2, 43-47]

Other imaging methods for AFV assessment

In 1998, Sherer et al. from the USA considered that the amniotic forewaters might provide a significant reservoir of AF, not detectable by measuring vertical pockets on transabdominal scans.[48] Using transvaginal ultrasound, the investigators measured the maximum longitudinal distance between the internal cervical os and the presenting fetal scalp. AFI was used as the gold standard. Thirty women with normal AFI (>5 cm) and 30 women with reduced AFI (≤5 cm) participated. The mean depth of forewaters was 0.2 cm in the women with reduced AFI, and 0.4 cm in those with normal AFI, a difference that was not statistically significant. Also, if the forewaters depth was added to the AFI as a fifth measurement, there was no difference in the recalculated AFI. It is possible that the study was underpowered and may have delivered a type II statistical error.

In 2004, Zaretsky et al., from the USA, performed magnetic resonance imaging (MRI) scans for AFV in 80 women and compared the results with AFI and MVP by ultrasound scanning, against a gold standard of directly collected AFV at caesarean section immediately after the scans.[42] The MRI scans were done before the ultrasound scans, favouring the ultrasound scans in terms of time interval to direct collection of AFV. Nevertheless, the MRI measurements performed best ($r = 0.84$), better than AFI ($r = 0.77$) and significantly better than MVP ($r = 0.71$; $p = 0.046$). All three methods however had poor accuracy in detecting oligohydramnios (defined as AFV <200 mL on direct collection). In view of cost,

inconvenience and only marginal improvement over AFI and MVP, MRI scanning is not currently favoured for AFV assessment.

2.5. Clinical assessment of AFV by abdominal palpation

Obstetric teachers and textbooks frequently describe methods of assessing AFV on clinical abdominal palpation. This implies a belief that such assessment will lead to decisions to improve pregnancy outcome. Presumably, palpation can detect, or at least suspect, oligo-hydramnios or polyhydramnios. In its latest edition, the Myles Text Book for Midwives describes the clinical signs of increased AFV as ballottable fetal parts (examiner able to bounce the parts in the AF from one hand to the other, or between fingers and thumb) and a fluid thrill. It describes signs of decreased AFV as being easily felt fetal parts, a small-for-dates uterus, and a compact feel about the baby.[3] In his classic text Practical Obstetric Problems, Donald wrote that, in examining the abdomen in prolonged pregnancy, oligo-hydramnios could be appreciated by an impression of 'ramrod rigidity' in the fetus.[5] A recent textbook on clinical signs suggests that clinicians 'assess liquor volume: is it normal, reduced (fetal parts abnormally easy to palpate) or increased (tense with difficulty in distinguishing fetal parts)?'[6] In South Africa, the popular Perinatal Education Programme Maternal Care Manual cautions that AF volume is 'not always easy to feel' but that 'the amount of liquor is assessed clinically by feeling the way that the fetus can be moved (ballotted) while being palpated'.[4] An internet-based clinical teaching guide has a rather sarcastic take on clinical AFV estimation and advises students who report on AFV on abdominal palpation that 'some obstetricians may ask about your liquor volume devining (sic) abilities: "Really? The liquor volume is normal? Perhaps we should toss out our expensive ultrasound and pay you instead".[49]

Evidence from research

Despite these appeals to our clinical skill, there is almost no scientific work to validate clinical impressions of AFV. Only two studies were found that evaluated clinical palpation for assessing AFI, both done in the UK. The first, by Barnes et al., was published in 1972 in the pre-ultrasound era.[7] Ninety-six pregnant women were palpated, and the obstetricians' impression of either 'reduced' or 'normal' AFV was recorded. The gold standard AFV was calculated in each case using a radioactive Technetium dye-dilution technique. Oligo-hydramnios was defined as AFV <500 mL, a higher cut-off than used in most subsequent studies. Dye-dilution results were available for 83 women. The obstetricians' impressions of AFV were found to be unreliable and no better than would be expected by chance. Seventy-three per cent of pregnancies that turned out to have oligohydramnios were passed off as normal on abdominal palpation (Table 3). The problem with this study is that the clinicians used only a subjective feel of the abdomen, rather than systematic palpation for ballottability, ease of palpation of fetal parts, fetal rigidity, uterine compaction, and uterine fluctuance (feeling of fluid in the uterus). Also, the study did not consider factors that could affect accurate assessment of AFV, such as maternal body-mass index, level of the fetal head above the brim, fetal size and fetal position.

The second study to evaluate clinical palpation was published by Crowley at al. in 1984.[8] The primary aim was to correlate ultrasound-derived AFV estimates with clinical outcome in prolonged pregnancies. The authors briefly mentioned the results for clinical palpation. In 227 women a 'senior obstetrician' was found to have a false positive rate of 25% and a false negative rate of 43% for the outcomes of meconium-stained AF and/or absent AF at delivery. This corresponds to a sensitivity of 56% and a specificity of 75%, giving an acceptable likelihood ratio of 2.2, still less impressive, however, than the likelihood ratio of 7.6 obtained

with ultrasound. The authors' only comment was that clinical examination alone was a 'poor predictor of fetal postmaturity syndrome'.

Table 3. Results of clinical palpation to assess amniotic fluid volume (AFV), against a gold standard Technetium radioactive dye test from which oligohydramnios was defined as AFV <500 mL (n=83).[7]

	Oligohydramnios	Normal amniotic fluid volume	Totals
Assessed as reduced on palpation	8	14	22
Assessed as normal on palpation	22	39	61
Totals	30	53	83

Sensitivity = 27%, specificity = 74%, positive likelihood ratio = 1.04.

The potential value and place of clinical palpation

There clearly is doubt about clinicians' ability to detect AFV abnormalities by abdominal palpation. However, there is not enough evidence from research to dismiss the clinical method, nor is there enough evidence to confirm it as useful. Ultrasound technology, so easily available in high-income countries, may not be accessible in low resource regions. What of clinical situations where AFV assessment is needed and ultrasound is not available? One such situation is prolonged pregnancy, which is associated with increased risks of intrapartum asphyxia and stillbirth, meconium aspiration syndrome and postmaturity syndrome. Recognition or exclusion of oligohydramnios in prolonged pregnancies facilitates decisions on whether to continue with such pregnancies or induce labour, as will be discussed later. There is certainly a place for research into the predictive ability of clinical palpation for AFV in a low resource setting, with attention to eliminate the methodological deficiencies of previous studies.

2.6. Prolonged pregnancy

Definitions

Current beliefs on the normal duration of pregnancy have not changed since Naegele, a 19th century German obstetrician, held that a pregnancy should last for 280 days (40 weeks) from the first day of the woman's last menstrual period (LMP).[50] The definition of what is prolonged has had little refinement over the last 50 years, with most texts still quoting an arbitrary 42 weeks or more as being significantly prolonged, or 'post-term'.[50] The American College of Obstetrics and Gynaecology, for example, continues to use this definition.[51] In recent decades, concern about increased pregnancy risks at 41 weeks has prompted definition of pregnancy ≥41 weeks as 'prolonged pregnancy', while keeping a gestation ≥42 weeks as 'post-term'.[52] In a recent review, Clark and Fleischman suggested that these risks are significant enough to assign pregnancies ≥41 weeks as 'post-term'.[50] The terminology is further confused by occasional use of the word 'post-dates'. For this research report, further use of the word 'post-term' will refer to a gestational age ≥42 weeks. The words 'prolonged pregnancy' will be used as a deliberately vague hold-all term for pregnancies considered by clinicians or researchers to have proceeded significantly beyond their expected duration. 'Post-dates' will not be used except where quoted from the literature.

Pregnancy dating and diagnosis of prolonged pregnancy

It is clearly not possible to identify a prolonged pregnancy if there is no certainty about the gestational age, just as milk from a dairy cannot be stamped with a 'use-by' date if the date of milking is not known. Naegele's rule demands good recall of menstrual dates and relies on the assumption that conception takes place 14 days after the first day of the LMP in a regular 28-day cycle. Use of ultrasound scanning in the first and early second trimester has since allowed much better estimation of gestational age.[53,54] In 2002, regarding dating of

pregnancies at term and post-term, Savitz et al. from the USA compared early ultrasound scans with LMP information in 5052 women.[53] The authors found a tendency for pregnancies to be reported as longer using the LMP, by an average of 3 days. The proportion of post-term pregnancies by LMP was 12.1%, but only 3.4% by early ultrasound scan. There was poor agreement (kappa = 0.16) between LMP and ultrasound to agree on term versus post-term pregnancy classification. The authors concluded that the LMP is fallible, for three main reasons: 1) delayed ovulation, which is more frequent than early ovulation (notably in women with oligo-ovulation and women who have recently used hormonal contraception), resulting in the expectation of an earlier date of delivery and a higher chance of apparent post-term pregnancy; 2) digit preference, with women systematically choosing the 15th, followed by the 1st, 5th, and 20th day of months; and 3) problems with recall of menstrual dates. Taipale et al. reported similar results from Finland in 17721 pregnancies, where the proportion of post-term pregnancies was 10.3% by LMP, and 2.7% using ultrasound scanning.[54] The earlier in the pregnancy that scans were done, with fetal crown-rump length used in the first 10 weeks, the lower the prediction error rate. In 2005, Van Dyk from Johannesburg reported on 416 women who had LMP information and early second-trimester ultrasound scans.[55] Unpublished data from that study showed that the proportion of post-term pregnancies by LMP was 6.5%, and by ultrasound scans, 2.6%.[56] Gardosi et al were likely correct in 1997 when they suggested that most post-term pregnancies ascertained by menstrual dates were in fact not post-term and were simply cases of wrong dates.[57] This emphasizes the need, wherever possible, to use routine early pregnancy ultrasound scanning if misclassification of term pregnancies as post-term pregnancies is to be avoided. Indeed, one of the few substantive benefits of routine early ultrasound scanning is a decrease in the proportion of inductions of labour for prolonged pregnancy, as demonstrated in a Cochrane review by Neilson.[58]

Epidemiology of prolonged pregnancy

The true frequency of prolonged pregnancy is difficult to determine. Joseph et al. showed that differential methods resulted in spurious differences in post-term pregnancy frequencies between the USA (6.6%) and Canada (1.0%), because of greater use of early ultrasound scanning in Canada.[59] Therefore, the reported proportions of pregnancies ≥41 weeks (14%) and ≥42 weeks (6%) in the USA may be an overestimate.[60] In South Africa, Van Dyk found that 10.3% of pregnancies reached gestations ≥41 weeks, and 2.6% gestations ≥42 weeks, using early second-trimester ultrasound.[56]

Another artefactual reason for different frequencies of prolonged pregnancies in different communities lies in obstetric practices around induction and delivery.[61-63] For example, where it is routine practice to induce labour at 41 weeks, the proportion of pregnancies ≥42 weeks may be close to zero. Where there are high frequencies of labour induction or primary elective caesarean section at term, the proportion of pregnancies ≥41 weeks will be relatively low. The frequency of post-term pregnancy may be declining in high-income countries, because of these therapeutic practices as well as the almost universal use of early pregnancy ultrasound for pregnancy dating.[61]

A number of maternal, fetal and obstetric conditions predispose to prolonged pregnancy. Rare but well-recognised causes include anencephaly and placental sulphatase deficiency, where fetal-placental stimuli to the onset of labour are poorly developed.[61] Large obstetric databases from high-income countries have provided opportunities to do retrospective cohort studies to determine associations with prolonged pregnancy. In 2009, Caughey et al. reported on a cohort of over 110000 pregnancies in the USA, and in a multivariable logistic regression model found post-term pregnancy to be significantly associated with obesity, primigravidity (first pregnancy), white race, and maternal age >35 years.[64] In 2010, Roos et al. reported on a

Swedish cohort of over one million births and found similar results although the authors did not examine the influence of racial group.[65] Kistka et al., in 2007, added previous postterm pregnancy as another predisposing factor.[66] Two further studies added valuable information on the association between obesity and post-term pregnancy.[67,68] Based on their data and good causal evidence, Stotland et al. suggested that for every 14 women brought down one body-mass index category, one post-term pregnancy could be prevented.[67] If this is so, post-term pregnancy could be prevented by pre-pregnancy weight loss programmes.

While large databases provide statistical power, and the facility to examine rare outcomes and exposures, they are usually derived from routinely collected clinical or registration data. There is considerable potential for systematic error in data collection and the retrospective cohorts mentioned above are no exception. The most serious potential error is in the detail of how the pregnancies were dated. For example, The Swedish post-term frequency was 8.9%, much higher than expected in studies where gestational age is measured using early pregnancy ultrasound.[65]

Complications of prolonged pregnancy

There are undoubted risks related to continuing with prolonged pregnancies. The magnitude of these risks was not appreciated until relatively recently. This is because in the pre-ultrasound era, most 'prolonged' pregnancies were simply wrong dates, or normal-length pregnancies, as discussed earlier. With more precise dating, much cleaner samples of prolonged pregnancies can be analysed. In addition, Hilder et al. pointed out in 1998 that analysis of mortality rates per gestational age was inappropriate, and showed that the number of ongoing pregnancies should rather be used as a denominator.[69] The authors, from a database of 171527 births, showed that stillbirth rates for London at term (37-41 weeks) were 2.3 per 1000 term births and at post-term (≥42 weeks) were 1.9 per 1000 post-term births.

Yet, when the same data set was used with stillbirth rates per ongoing pregnancies, the stillbirth rate was 0.35 per 1000 ongoing pregnancies at 37 weeks, and 1.27, 1.55 and 2.12 per 1000 ongoing pregnancies at 41, 42 and ≥43 weeks respectively. While these differences are small in absolute terms, there is a more than 6-fold increased mortality risk at 43 weeks compared to 37 weeks. Similar findings were reported by Smith from Scotland.[70]

Why the increased risks? Large databases from Scandinavia and the USA have shown post-term pregnancy to be associated with umbilical cord compression, meconium aspiration syndrome, cephalopelvic disproportion, fetal injury, and peripartum asphyxia.[71,72] Interestingly, perinatal mortality in post-term babies was highest in those with a birth weight <2.5 kg, suggesting that placental insufficiency and growth restriction were likely causal factors.

Part of the explanation for these hazards is found in the extremes of birth weight. The babies that grow large because of prolonged pregnancy are more likely to need delivery by caesarean section for cephalopelvic disproportion or to be injured at vaginal birth. At the lower extreme are infants who are poorly grown and chronically oxygen-deprived. These babies are more likely to die in utero, or to suffer asphyxia during labour contractions.

Oligohydramnios in prolonged pregnancy

The relative reduction in AFV after 40 weeks of gestation has been discussed earlier. This assumes clinical significance, not only as a marker of prolonged pregnancy and diminishing placental function, but also as a factor favouring umbilical cord compression and meconium aspiration, as mentioned in previous paragraphs. With failing placental function, the fetus responds by shunting oxygenated blood away from the kidneys thus reducing urine output and therefore AFV. Indeed, low birth weight in prolonged pregnancies has been associated with reduced AFI, confirming the mechanisms suggested here.[32] Crowley et al. in 1984,[8] and

Phelan et al. in 1985,[73] were among the first to suggest that AFV reduction in prolonged pregnancies, as a marker of fetal risk, could be measured by ultrasound, and be used to guide clinical management. Prolonged pregnancies with reduced AFV could then be identified as being at risk for adverse fetal outcome, and terminated by induction of labour. Crowley et al. showed in their small series that prolonged pregnancies with reduced AFV had increased frequencies of intrapartum meconium passage, fetal growth restriction, caesarean section for fetal distress, and fetal acidemia.[8] They concluded that assessing AFV was an 'effective discriminatory test in post-term pregnancy'. These early studies set the stage for the current management of prolonged pregnancy.

Management of prolonged pregnancy

By the late 1980s, easier diagnosis of post-term pregnancy, the emotional impact of prolonged pregnancy on women,[61,62] as well as the clearly defined associated risks, posed a management dilemma to obstetricians. Would the risks be avoided completely by inducing labour at 41-42 weeks at the cost of the supposed complications of labour induction? Or could a middle road be taken by monitoring pregnancies for early signs of trouble using discriminatory tests and inducing only where necessary? Randomised controlled trials have suggested little difference between the two approaches, although showing a trend to less stillbirths and to reduced caesarean section rates with induction of labour.[74] The results of three recent systematic reviews (SRs), with meta-analyses, are summarised in Table 4.[1,75,76] The most recent of the SRs suggests that 328 inductions would need to be done to prevent one perinatal death, and recommends a policy of induction of labour from 41 weeks.

Guidelines, most of which pre-dated the two most recent SRs, are available from several sources. The UK's Royal College of Obstetricians and Gynaecologists (RCOG),[77] and Canadian guidelines, recommend that labour induction be offered between 41 and 42 weeks,

with at least twice-weekly antenatal monitoring (AFV and NST) for women declining induction.[78] The World Association of Perinatal Medicine has suggested that 'both management strategies (are) acceptable' after exclusion of high-risk groups.[79]

Table 4. Summary of important findings of three recent systematic reviews and meta-analyses of randomized controlled trials comparing management strategies for prolonged pregnancy: induction of labour v. expectant care.

Systematic review	Number of trials in meta-analysis	Important outcomes reported with relative risk (95% confidence interval)
Cochrane review (2006)[1]	19	MAS: 0.39 (0.09 – 0.99) PND: 0.30 (0.09 – 0.99) CS (41 weeks): 0.92 (0.76 – 1.12) CS (42 weeks): 0.97 (0.72 – 1.31)
Wennerholm et al. (2009)[75]	13	MAS: 0.43 (0.23 – 0.79) PND: 0.33 (0.10 – 1.09) CS: (41 and 42 weeks): 0.87 (0.80 – 0.96)
Hussain et al. (2011)[76]	15	MAS: 0.43 (0.23 – 0.79) PND: 0.31 (0.11 – 0.88) CS: (41 and 42 weeks): 0.87 (0.80 – 0.96)

MAS = meconium aspiration syndrome, PND = perinatal death, CS = caesarean section.

The role of amniotic fluid volume estimation in prolonged pregnancy

It is clear from the above discussion that there is a place for expectant care in prolonged pregnancy, with AFV assessment universally recommended along with NST. This is based on the expected reduction of AFV after 40 weeks of pregnancy, and also on the reported associations between reduced AFV and perinatal complications in prolonged pregnancy, as first pointed out by Crowley et al. and Phelan et al.[8,73] There have been concerns that AFV assessment has poor sensitivity and predictive value for poor perinatal outcomes, as discussed earlier in this review and acknowledged in the World Association of Perinatal Medicine guideline.[79] Yet, in the absence of a more suitable replacement, the practice of measuring AFI or MVP will continue. The RCOG guideline expressed its preference for MVP in line with

published evidence, as discussed earlier.[2] A Cochrane review on the topic did not find 'enough evidence to evaluate tests of fetal well-being'.[80] Umbilical and uterine artery Doppler studies have proved disappointing for risk assessment in prolonged pregnancies.[81,82]

Prolonged pregnancy in low resource settings

Reduction of high perinatal mortality rates has emerged as a priority for low resource settings such as in sub-Saharan Africa.[83,84] Global advocates for improved perinatal care have noted that routine induction of labour at ≥41 weeks may be of value, and have incorporated this clinical policy into pregnancy care recommendations that include less-developed countries.[85] This is inherently problematic because the evidence base for routine induction at ≥41 weeks is derived from research done mostly in high-income settings where: 1) early pregnancy antenatal care is the norm; 2) ultrasound scanning is easily available; and 3) induction of labour is closely monitored and considered safe. It is likely that most maternity services in sub-Saharan Africa do not fulfil even one of these three conditions, which are all essential to detection of post-term pregnancy and its evidence-based management.

Post-term pregnancy certainly occurs in low resource settings. Data is scarce for sub-Saharan Africa. Geerts et al., in an RCT on early pregnancy ultrasound in Cape Town, found post-term pregnancy rates of 2.0% and 8.4% in women having and not having early pregnancy ultrasound respectively.[86] In similar work from Johannesburg cited earlier, van Dyk found corresponding rates of 2.6% and 6.5%.[56] A Nigerian study on outcomes in elderly nulliparas found a post-term pregnancy rate of 17% in under-35 nulliparas, presumably in the absence of early pregnancy ultrasound dating.[87] It is thus likely that most post-term pregnancies detected in the absence of early pregnancy ultrasound are not post-term at all, as observed earlier.[57] Therefore, a policy of induction of labour would, using menstrual dates alone, affect 6.5 to 17% of pregnancies. The current South African national guideline recommends,

without mentioning ultrasound, that after ensuring that the gestational age has been correctly calculated, labour should be induced at ≥41 weeks.[88] This can only bring additional strain to struggling health services and may result in a burden of complications related to unnecessary and poorly monitored induction of labour.[89] A reasonable local response in South Africa has been to screen women with AFV measurement if they present with suspected prolonged pregnancy,[90] to replicate expectant management groups in RCTs for post-term induction of labour.[1] While this approach seems a sensible way of reducing the number of inductions, it has not been scientifically evaluated. Moreover, it again relies on ultrasound scanning to assess AFV, and may not be available in low resource settings. Only clinical palpation, currently of no proven value, presents an alternative to ultrasound assessment of AFV.

A comprehensive search of published scientific literature could find only one article that addressed management of post-term pregnancy in sub-Saharan Africa. Otoide and Okonofua described their experiences of induction of labour at 41-42 weeks in a Nigerian teaching hospital, and found that outcomes were generally good.[91] Gestational age was determined by certain dates or early ultrasound if available. The study's results reflect practice in a teaching centre and do not really address low resource settings in sub-Saharan Africa, from which there appears to be no data. An unpublished report by Brand et al. from Cape Town in 1993 found that women referred for 'post dates pregnancy' often had uncertain dates and, in general, did not require induction of labour.[92] Amniotic fluid volume was inversely related to need for caesarean section. Perhaps, in Africa, post-term pregnancies are wished away by women and their caregivers, in the certain knowledge that all gestations will come to a spontaneous end, usually (but not always) with pleasing outcomes. This approach should not be surprising, given late initiation of antenatal care, the difficulties with pregnancy dating, and the risks of unnecessary inductions. Yet, post-term pregnancy in these settings presents a compelling dilemma, worthy of research.

3. RESEARCH QUESTION

There remains a gap in knowledge about the value of clinical palpation in assessing AFV. Should clinical palpation be sufficiently predictive of AFV, it could offer a simple, cheap and rapid method of assessing whether a suspected prolonged pregnancy should be considered for labour induction. This may not have value in high-income settings with easy access to ultrasound scanning, but could prove useful in low resource settings.

3.1. Aim of this study

This study attempted to find out whether AFV estimation by clinical palpation correlated well with AFV estimation by ultrasound in pregnancies suspected to be prolonged.

3.2. Objectives

The specific objectives of the study were:

1. To describe the maternal, fetal and obstetric characteristics, and clinical outcomes, of suspected prolonged pregnancies in women presenting at Chris Hani Baragwanath Academic Hospital antenatal clinic from July to September 2011.
2. To describe AFV measurements using ultrasound methods, in women with suspected prolonged pregnancies, and to investigate how these measurements are related to maternal and fetal factors.
3. To describe and evaluate clinical palpation methods for estimating AFV.
4. To determine the predictive ability of clinical palpation to estimate AFV and predict oligohydramnios, using the ultrasound method as a gold standard, accounting for the influence of maternal and fetal factors.

4. METHODS

4.1. Study design

This was a cross-sectional analytic study. All data, except for the ultrasound scan, was collected by one researcher, who is an experienced clinical specialist on the staff of the Department of Obstetrics and Gynaecology at Chris Hani Baragwanath Academic Hospital.

4.2. Setting

Chris Hani Baragwanath Academic Hospital (CHBAH) is a referral centre for midwife-run antenatal services in the surrounding areas of Soweto, Orange Farm and Lenasia. Routine antenatal care is conducted at these services, and problem cases are referred to the unit at CHBAH. All pregnancies suspected to have reached 41 completed weeks of gestation are referred. From experience of working in the antenatal clinic, the suspicion of prolonged pregnancy is most frequently based on a menstrual history, or an estimate based on fetal size at an earlier gestation. The gestational age is therefore frequently in doubt. Hospital clinicians may request an ultrasound scan in such cases to look for oligohydramnios (AFI <5 cm), and such a finding will likely result in a decision to induce labour. Where the gestational age is ≥41 weeks based on good evidence such as early pregnancy ultrasound or reliable dates based on certain LMP, induction is offered irrespective of AFI findings, in line with evidence from randomized trials and South African guidelines.[1,88] Close surveillance with twice-weekly antenatal monitoring (AFV and non-stress testing) is rarely done.

4.3. Study population

The study population was all women referred to CHBAH from midwife-run clinics with a suspicion of prolonged pregnancy (≥41 weeks' gestation), irrespective of age or parity. If women were found on assessment at CHBAH to be <41 weeks pregnant, they were still

included because they represented the clinical problem of suspected prolonged pregnancy. Only singleton pregnancies with live babies were included in this study. Women under the age of 18 years, as well as those referred for hypertension in pregnancy, breech presentation, diabetes mellitus and prelabour rupture of the membranes, and those with previous caesarean section, were excluded. Those found incidentally to be hypertensive (two readings of systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg), or with breech presentation, were included as they had been referred only for prolonged pregnancy.

4.4. Sampling

A sample of eligible women was drawn on days that the researcher was able to be at the antenatal clinic at CHBAH. Depending on the time available, up to four women were recruited on a morning, almost always the first four that presented themselves. This was done so that the women could have ultrasound scans early before long queues developed.

No data from research was available to inform a sample size calculation. The researcher estimated, from experience of working at CHBAH, that the frequency of oligohydramnios determined by AFI in suspected prolonged pregnancies would be about 10%. In such a population, to show statistical significance for clinical palpation to detect oligohydramnios with a sensitivity of 75% and a specificity of 75%, with 80% power (1-β) and at a significance level (α) of p=0.05, a sample of 101 women was required.

4.5. Data collection

The researcher asked the attending nurses in the antenatal clinic to point out which women had been referred for suspected prolonged pregnancy. After confirming the reason for referral by reading the referral note in the appropriate block on the antenatal card, the researcher

informed the woman of the reason for the study, and directed her to the ultrasound scanning room.

The ultrasound scan

All ultrasound scans were performed with a Siemens Sonoline G50 ultrasound scanner using a 3.5 MHz curvilinear transducer. The ultrasonographer was an experienced Health Professions Council of South Africa-certified professional with a bachelor's degree in ultrasound scanning. She was aware of the research, and in each case completed a custom-made ultrasound report (Appendix A). This included estimated fetal weight using the Hadlock formula based on biparietal diameter, abdominal circumference and femur length,[94] and deepest AF pool depth in each of the four uterine quadrants, summed to an AFI, according to the method of Phelan et al.[23] The deepest pool found was noted as the MVP. If the AFI was less than 10 cm, the ultrasonographer repeated the measurements immediately, and the mean of the two AFI measurements was then used. If there was a multiple pregnancy or any major fetal abnormality, the woman was excluded from the study at that stage. The ultrasonographer did not discuss the AFI findings with the woman, and folded up the report and inserted it into the woman's file. The woman was then sent back to the researcher for clinical assessment.

Explanatory variables

Within one hour after the ultrasound scan, a full clinical assessment, blinded to the ultrasound report, was made by the researcher. The only difference from the normal routine was that the physical examination was done first and data entered, followed by the history and reading of the antenatal card. This reversal of the usual order was done to prevent biased clinical palpation assessments related to the history, especially the gestational age. The woman's

height was measured using a calibrated tape-measure attached to the wall. This was followed by a general physical and obstetric examination.

The primary explanatory variables were various clinical methods of assessing AFV. These included eliciting ballottement (present or absent) of the fetus or fetal parts inside the uterus in: 1) the uterine fundus, and 2) the lower pole of the uterus, where the presenting part is situated. In addition, 3) presence or absence of fetal compaction or rigidity was determined, as well as 4) ease of palpating fetal parts (yes or no), and 5) presence or absence of fluctuance (impression of fluid content) of the uterus including a fluid thrill.

Further clinical observations on abdominal examination included symphysis-fundal height (SFH) measurement, from the upper edge of the pubic symphysis in the midline to the highest palpated point on the uterus, not necessarily in the midline, according to the method described in the Perinatal Education Programme.[4] This was measured twice with a soft tape-measure and averaged. Also assessed were abdominal circumference (measured once from the small of the back to include the widest part of the abdomen), uterine irritability (binary variable defined as a contraction developing during the palpation), and level of fetal head felt above the pelvic brim in fifths (from five fifths being the highest, to zero fifths being not palpable at all and fully descended, using the fingerbreadths method described by Notelowitz).[94] Finally, the researcher noted his general impression of AFV, either normal, or reduced (oligohydramnios) based on the whole abdominal examination.

The researcher then made a cervical assessment (Bishop score, out of possible maximum of 13) to determine favourability for induction of labour. Whenever the cervix admitted at least a finger-tip, irrespective of gestational age assessment, sweeping of the membranes was performed to facilitate the onset of labour.[95]

Following his examination, the researcher called a consultant colleague from a neighbouring examination room in the antenatal clinic to estimate AFV by abdominal palpation, using whatever criteria the colleague might find useful. The colleague was asked to give a general impression of AFV, stating if this felt reduced or not. The colleague was aware that the woman was referred for prolonged pregnancy, but did not have access to any other information on gestational age.

Other explanatory variables were collected by the researcher, including possible confounders or effect modifiers, and included maternal age in completed years on the day of referral, parity (number of previous pregnancies carried to 28 weeks or more), HIV status and smoking. The maternal weight at first antenatal care visit was recorded, as the closest available measure to pre-pregnancy weight. Gestational age was calculated after palpation findings were noted, as follows: 1) an early ultrasound scan (≤24 weeks) from private or public providers was accepted as the correct gestational age; 2) if no early ultrasound scan was available, the first day of the last menstrual period (LMP) was used as the reference point of zero weeks; if there was uncertainty about LMP, a late ultrasound scan (>24 weeks) was used; in the absence of any of these findings, estimates based on palpation and/or SFH measurement at antenatal clinic were used. The study data sheet is attached as Appendix B.

Outcome variables

After entering all explanatory variable data, the researcher unfolded the ultrasound report and entered the AFI and MVP findings onto the data sheet. The primary outcome measure was AFV determined by AFI. Oligohydramnios was defined as an AFI <5 cm. AFI was chosen over MVP because intuitively and from evidence AFI shows slightly better correlation with AFV,[38,40-42] and has previously been used as a gold standard measure for AFV.[48]

The researcher was then able to use the information from the ultrasound report to plan management for the woman. While management plans were individualized, they followed the clinical protocols in the department. The protocol on prolonged pregnancy recommends induction of labour for women considered to be at ≥41 weeks' gestation, and in cases of doubt about gestation, induction if AFV is reduced. The decision to admit for induction, or to discharge home, was noted in the data sheet.

All women were followed up to delivery. Delivery dates and outcomes (induced or spontaneous labour, place of delivery, mode of delivery, birth weight, five-minute Apgar score, neonatal admission, baby's sex, neonatal unit admission with reasons, and perinatal death) were extracted from the birth registers in Chris Hani Baragwanath labour ward as well as MOUs in Soweto, Orange Farm and Lenasia. The MOUs were visited regularly to determine final outcomes of all participants. Full in-patient files were not requested from the records department unless there was doubt about caesarean section indication or whether induction of labour occurred.

4.6. Data analysis

Data management and analysis was done using STATA version 11 (STATA Corp, College Station, Texas, USA) software. Frequencies and percentages for counts, and means ± standard deviations, or medians with interquartile ranges for continuous variables as appropriate were used to describe the data. Pearson's correlation co-efficient was used to determine correlations of continuous variables. Inter- or intra-observer variation in clinical and ultrasound observations was determined using Cohen's kappa statistic for categorical measures, and intraclass correlation for continuous measures. The McNemar test with exact p value calculation was done for paired binary observations.

To investigate the association between maternal and fetal factors on continuous levels of AFI obtained by ultrasound, univariable linear regression was used. For dichotomized levels of ultrasound-obtained AFI (oligohydramnios) as the outcome variable, univariable logistic regression was performed for continuous and categorized explanatory variables. Multivariable linear and logistic regressions for continuous and categorized AFI respectively were used to identify independent maternal and fetal predictors for AFV after adjustment for the influence of covariates. Explanatory variables with p-values <0.2 in univariable models were included for consideration in the multivariable models.

The associations between AFI and potentially predictive elements of clinical palpation were then investigated using univariable linear regression analysis for the continuous AFI outcome variable. For categorized binary levels of AFI (oligohydramnios) as the outcome, univariable logistic regression was used. Elements of clinical palpation found to be significantly associated with oligohydramnios were then placed alongside statistically significant maternal and fetal predictors for AFI, as described in the previous paragraph, in multivariable models to determine their predictive value after adjustment for the maternal and fetal predictors.

Linear regression analysis was done considering all assumptions with appropriate testing, such as normally distributed continuous outcome (histograms and tests for normality), linearity of association (‘qnorm’ and ‘pnorm’ in STATA), normal distribution of variance (histograms), homogeneity of variance (homoskedasticity) and the influence of outliers with sensitivity analysis, using dfbeta analysis. Interaction terms were tested and included where appropriate. Logistic regression analysis included interaction terms where necessary, and nested models were compared with larger models using the likelihood ratio test.

For clinical observations found to have predictive value for oligohydramnios at a cut-off level of AFI, sensitivity, specificity, positive and negative predictive values, and positive and

negative likelihood ratios were computed. ROC curves were drawn for predictive observations with area under the curve calculated. Unadjusted and adjusted (for maternal and fetal factors after logistic regression analysis) curves were drawn.

Statistical comparisons, when not done using regression analysis, were made using Fisher's exact test for categorical variables, and Wilcoxon's rank sum test for continuous variables.

In all statistical comparisons, p-values <0.05 were used to define statistical significance.

4.7. Ethics

This was an observational study with the clinical examination for AFV not influencing clinical decisions, as all participants underwent ultrasound assessments. No additional examinations or ultrasound scans other than those done routinely in the clinical situation of suspected prolonged pregnancy were done. Informed consent was obtained from all participants who were assured that all data would be anonymized on the data sheets. The information and consent form is attached as Appendix C. Approval for conduct of this study was obtained from University of the Witwatersrand's Human Research and Ethics Committee (approval number M110111, dated 28 January 2011, attached as Appendix D).

5. RESULTS

5.1. Maternal, fetal and obstetric characteristics and outcomes

One hundred women participated in the study. Their mean age was 25.7 ± 6.0 years. Forty-four percent were nulliparous. There were 11 women with incidental hypertension, of whom 1 had severe pre-eclampsia. Twenty women were HIV infected, with 13 on highly active antiretroviral therapy (HAART). The names of the drugs in the HAART regimens were recorded. The mean maternal weight (available for 96 women) was 72.3 ± 12.4 kg, and height was 160.5 ± 5.1 cm; 24 women (25%) were classified as obese (BMI ≥30 kg/m^2).

Based on LMP, available in 86 women, the mean gestational age was 40.2 ± 2.2 weeks. The best estimate of gestational age was based on LMP in 52 women, and on early ultrasound (≤24 weeks) in 26 (Table 5). The mean gestational age by best estimate was 39.9 ± 1.5 weeks; 45 women had a best estimate gestational age ≥41 weeks, determined by LMP in 20, early pregnancy ultrasound in 10, later ultrasound in 4, and other methods in 11 women.

Table 5. Gestational age estimation in women referred for suspected prolonged pregnancy (n=100).

Gestational age in weeks by best estimate (median with range)		40 (34 – 43)
Gestational age in weeks by best estimate:	<37 37-38 39-40 41 ≥42	4 11 40 40 5
Method of obtaining best estimate:	ultrasound ≤24 weeks last menstrual period ultrasound >24 weeks first clinical palpation	26 52 9 13
Ultrasound scans during antenatal care:	none private provider public provider both public and private	47 37 14 2

The researcher admitted 44 of the 100 women for delivery. The most frequent reasons for admission were gestation ≥41 weeks (n=25), hypertension (n=6), gestation ≥41 weeks with hypertension (n=5), and oligohydramnios (AFI <5 cm) at <41 weeks (n=7). Forty-two of the admitted women underwent induction of labour. A further 8 women required induction of labour section after further follow-up by other clinicians. Thirty-five women required caesarean section, the most frequent indication being fetal distress (n=24; 69%). Fifteen of the 56 women not admitted (27%) went on to deliver at MOUs. The mean birth weight was 3305 ± 414 g. There were 53 male infants (54%; one newborn's sex was not recorded). There were no stillbirths, no neonatal deaths, and no cases of MAS or neonatal encephalopathy.

5.2. Ultrasound estimation of amniotic fluid volume

The mean AFI was 8.1 ± 4.4 cm, with a median of 7.9 cm and a range of 0-22.5 cm. Twenty-three women had an AFI <5 cm. The ultrasonographer took two measurements of AFI where the AFI was <10 cm, and in those instances (n=64) a mean of the two measurements was taken. The intraclass correlation between the first and second AFI measurements was 0.96 (95% CI 0.92; 0.99). The AFI measurements were normally distributed (Figure 1).

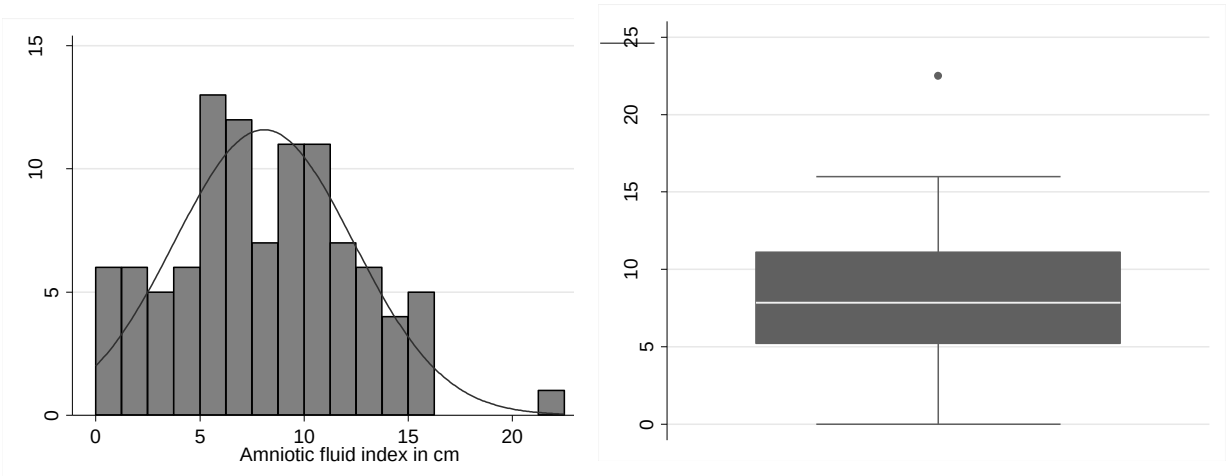


Figure 1. Histogram and box-and-whisker plot, showing frequency distribution of amniotic fluid indices (n=100)

5.3. Clinical examination

The findings of the researcher's clinical examination are shown in Table 6. The mean symphysis-fundal height (SFH) was 37.9 cm (range 31.5-43.5 cm). The fetal head was felt at five fifths above the brim in 55 women (56%). Using Fisher's exact test, there was no statistically significant association between level of the head in fifths and gestational age ≥41 weeks (p=0.08, data not shown). The presenting part could not be ballotted in the uterus in 66 women.

Table 6. Findings on clinical abdominal measurement and palpation. All observations were made without knowledge of the ultrasound scan results (n=100).

Finding	**n (%)***
Symphysis-fundal height in cm (mean ± SD)	37.9 ± 2.6
Abdominal circumference in cm (mean ± SD)	101.9 ± 6.8
Level of the fetal head in fifths (n=99):† 5 4 3	55 (56%) 31 (31%) 13 (13%)
Uterine irritability	28
Fetal parts not ballottable in the uterine fundus	75
Presenting part not ballottable suprapubically	66
Impression of fetal compaction	13
Fetal parts easy to feel	41
Failure to elicit uterine fluctuance	18
General impression of oligohydramnios by researcher	28
General impression of oligohydramnios by colleague	37

*Percentages not shown if n=100. †There was one breech presentation

The colleague who was asked to give a general estimate of AFV was a consultant (specialist) in 95 cases and a registrar (trainee specialist) in 5 cases when a consultant was not available.

The colleagues made up 15 consultants and 3 registrars. The kappa statistic for inter-observer agreement between the researcher and the colleagues was 0.03 (standard error=0.10; p=0.38), indicating no agreement in assessment of AFV by general impression. The McNemar test for paired observations showed no significant trend to over- or under-estimation of AFV by researcher or colleagues relative to each other (p=0.22) (Table 7).

Table 7. Inter-observer agreement for general impression of AFV by researcher and by consultants (n=100)

	Reduced AFV by colleague	**Normal AFV by colleague**
Reduced AFV by researcher	11	17
Normal AFV by researcher	26	46

When the researcher considered the AFV to be reduced (n=28), the mean AFI was 7.0 ± 3.5 cm, and when he considered the AFV to be normal (n=72), the mean AFI was 8.5 ± 4.5 cm (p=0.11). The corresponding values for the colleagues were an AFI of 8.3 ± 4.5 cm for reduced AFV (n=37) and 8.0 ± 4.2 cm for normal-feeling AFV (n=63) (p=0.75).

The researcher correctly predicted reduced AFV in 7 out of 23 women (sensitivity of 30%) who were found to have an AFI <5 cm, and the colleagues correctly predicted reduced AFV in 8 women (sensitivity 35%) (Table 8). Corresponding specificities were 73% (56/77) for the researcher and 62% (48/77) for the colleagues.

Table 8. Association between researcher and colleagues' impression of amniotic fluid volume (AFV) and finding of amniotic fluid index (AFI) <5 cm on ultrasound (oligohydramnios) (n=100).

	AFI on ultrasound		p value
	<5 cm (n=23)	≥ 5 cm (n=77)	
Researcher impression of reduced AFV	7 (30%)	21 (27%)	0.80
Colleagues' impression of reduced AFV	8 (35%)	29 (38%)	1.00

5.4. Maternal and fetal characteristics and amniotic fluid index

Univariable (unadjusted) linear regression for the continuous outcome of AFI showed no statistically significant associations with antenatally measured maternal and fetal predictors, except for inverse correlations with gestational age ($p<0.01$) and HIV infection ($p=0.01$) (Table 9). The univariable statistical trend for maternal weight ($p=0.18$) in the univariate model was not confirmed in a multivariable linear regression model. The multivariable model for AFI included only gestational age and HIV status as independent predictors of AFI (Table 10). The result for gestational age suggests that for each increased week of gestation in the ranges measured in this study, the AFI reduces by 0.80 cm, with a 95% confidence interval of 0.27 to 1.33 cm after adjustment for HIV status. The association with HIV status prompted an examination of the influence of highly active antiretroviral therapy (HAART). The median AFI for women on HAART (n=13) was 4.9 cm and the median AFI for women not on HAART (n=7) was 5.8 cm. Using the Wilcoxon ranksum test, this difference was not statistically significant ($p=0.50$).

Table 9. Univariable linear regression analysis for amniotic fluid index (AFI) against maternal and fetal characteristics (n=100).

Explanatory variable	Constant	Beta-coefficient	Standard error	95% CI	P value
Maternal age in years	9.70	-0.06	0.07	-0.21; 0.08	0.38
Parity ≥1 (reference para 0)	8.61	-0.96	0.87	-2.68; 0.76	0.27
Gestational age in weeks	43.53	-0.89	0.27	-1.43; -0.35	<0.01
HIV infected (reference HIV negative)	8.60	-2.64	1.05	-4.72; -0.56	0.01
Maternal height in cm	9.72	-0.01	0.09	-0.18; 0.16	0.91
Maternal weight in kg	11.42	-0.05	0.04	-0.12; 0.02	0.18
Body-mass index	10.88	-0.10	0.09	-0.28; 0.07	0.25
Estimated fetal weight in g	5.75	0.001	0.001	-0.001; 0.002	0.46
Male fetal sex (reference female)	8.72	-1.22	0.87	-2.94; 0.50	0.16

Table 10. Multivariable linear regression model for amniotic fluid index (AFI) (n=100).

Explanatory variable	Beta-coefficient	Standard error	95% CI	P value
Gestational age in weeks	-0.80	0.27	-1.33; -0.27	<0.01
HIV infected (reference HIV negative	-2.18	1.02	-4.20; -0.16	0.04

Equation: AFI = 40.47 – 0.80(gestation in weeks) – 2.18 (HIV infected); $R^2 = 0.14$.

For the measure of oligohydramnios at an AFI cut-off <5 cm, maternal and fetal characteristics were compared with respect to oligohydramnios and normal AFV using univariable logistic regression (Table 11). Only gestational age (40.7 weeks with oligohydramnios v. 39.7 weeks with normal AFV; p=0.01), HIV status (35% positive v. 16% positive; p=0.05) and mean maternal weight (75.4 kg v. 71.3 kg; p=0.18) showed trends towards an association with reduced AFI.

Table 11. Comparison of maternal and fetal characteristics in women with oligo-hydramnios (amniotic fluid index <5 cm) and normal amniotic fluid index, by univariable logistic regression (n=100).

Explanatory variable	**Oligo-hydramnios (n=23)**	**Normal AFV (n=77)**	**Odds ratio (95% CI)**	**P value**
Maternal age in years (mean ± SD)	26.5 ± 6.3	25.5 ± 5.9	1.03 (0.95; 1.11)	0.47
Parity ≥1 (reference para 0)	14 (61%)	42 (55%)	1.30 (0.50; 1.84)	0.59
Gestational age in weeks (mean ± SD)	40.7 ± 1.0	39.7 ± 1.6	1.84 (1.13; 3.00)	0.01
HIV infected (reference HIV negative)	8 (35%)	12 (16%)	2.89 (1.01; 8.31)	0.05
Maternal height in cm (mean ± SD)	161.0 ± 4.4	160.3 ± 5.2	1.03 (0.93; 1.13)	0.59
Maternal weight in kg (mean ± SD)	75.4 ± 13.6	71.3 ± 12.0	1.03 (0.99; 1.07)	0.18
Body-mass index (mean ± SD)	29.1 ± 5.0	27.8 ± 4.9	1.05 (0.96; 1.15)	0.30
Estimated fetal weight in g (mean ± SD)	3682 ± 477	3630 ± 520	1.00 (1.00; 1.00)	0.67
Male fetal sex (reference female)	15 (65%)	38 (50%)	1.88 (0.71; 4.94)	0.20

In a multivariable logistic regression model for the binary outcome of oligohydramnios, only gestational age showed a statistically significant association (adjusted odds ratio 1.90; 95% CI 1.09-2.97) (Table 12). Although removal of HIV status from the model with gestational age showed no statistically significant difference using the likelihood ratio test, HIV status was retained in the model because of its clinical significance given the findings in the linear regression analysis for AFV in Tables 9 and 10.

Table 12. Multivariable logistic regression model for oligohydramnios (amniotic fluid index < 5 cm) versus normal amniotic fluid index for maternal and fetal characteristics (n=100).

Explanatory variable	Adjusted odds ratio	Standard error	95% CI	P value
Gestational age in weeks	1.80	0.46	1.09; 2.97	0.02
HIV positive status	2.47	1.39	0.82; 7.43	0.11

5.5. Association of clinical assessments with amniotic fluid index

The association of each of the clinical measurements and assessments with AFI was tested in univariable linear regression analysis (Table 13). SFH (p=0.03), fundal ballottability (p<0.01) and presenting part ballottability (p<0.01) showed statistically significant negative associations with AFI. A trend to significance was shown with level of head five fifths (p=0.05). A composite measure of non-ballottability of the fetal parts in the fundus, non-ballottability of the presenting part, and an SFH <39 cm was tested as a marker of oligohydramnios. There were 43 women in whom this combination was found. The composite measure was significantly associated with AFI (p<0.01). These four elements of physical examination were each placed in separate multivariable linear regression models alongside gestational age and HIV, which were the maternal and fetal characteristics found to

be significant in regression for AFI. Symphysis-fundal height, fundal ballottability, presenting part ballottability and the composite measure all remained statistically significantly associated with AFI after adjustment for gestational age and HIV status (Table 14). A level of head of five fifths or more did not attain statistical significance in a multivariable model (p=0.10) (data not shown).

Table 13. Univariable linear regression analysis for amniotic fluid index, for clinical signs on abdominal and vaginal examination (n=100).

	Constant	**Beta co-efficient**	**Standard error**	**95% CI**	**P value**
Symphysis-fundal height (SFH) in cm	-5.52	0.36	0.16	0.04; 0.68	0.03
Abdominal circumference in cm	13.08	-0.49	0.06	-0.18; 0.08	0.44
Head five fifths palpable*	7.16	1.67	0.85	-0.03; 3.36	0.05
Uterine irritability†	8.00	0.26	0.96	-1.65; 2.17	0.79
Fundal parts not ballottable†	10.32	-2.99	0.95	-4.88; -1.10	<0.01
Presenting part (PP) not ballottable†	9.75	-2.54	0.88	-4.28; -0.80	<0.01
Fetal compaction†	8.24	-1.29	1.28	-3.83; 1.24	0.31
Fetal parts easy to feel†	7.32	1.28	0.87	-0.45; 3.00	0.14
Failure to elicit uterine fluctuance†	8.29	-1.21	1.12	-3.43; 1.01	0.28
Composite measure: PP and fundal parts not ballottable, SFH <39 cm†	9.28	-2.81	0.83	-4.45; -1.17	<0.01

Binary explanatory variables: *reference is head 4 fifths or less; †reference is opposite or absence of that finding

Table 14. Multivariable regression models for amniotic fluid index (AFI), against: i. symphysis-fundal height (SFH); ii. uterine fundal ballottability; iii. presenting part (PP) ballottability; and iv. a composite of no fundal and no PP ballottability and SFH<39 cm; in each case adjusting for gestational age (GA) and HIV status (n=100).

	Beta co-efficient	Standard error	95% CI	P value
i. SFH:*				
GA in weeks	-0.84	0.26	-1.37; -0.32	<0.01
HIV infected	-1.96	1.00	-3.95; 0.24	0.05
Symphysis-fundal height in cm	0.36	0.15	0.06; 0.66	0.02
ii. Fundal ballottability:†				
GA in weeks	-0.61	0.27	-1.15; -0.07	0.03
HIV infected	-2.29	0.99	-4.26; -0.32	0.02
Fundal parts not ballottable	-2.42	0.94	-4.29; -0.55	0.01
iii. PP ballottability:‡				
GA in weeks	-0.68	0.27	-1.21; -0.16	0.01
HIV infected	-2.28	0.99	-4,24; -0.31	0.02
Presenting part not ballottable	-2.30	0.84	-3.86; -0.53	0.01
iv. Composite of SFH and ballottability:§				
GA in weeks	-0.75	0.26	-1.26; -0.24	<0.01
HIV infected	-2.14	0.97	-4.06; -0.22	0.03
Composite of SFH and no ballottability	-2.64	0.77	-4,17; -1.10	<0.01

Equations:

*AFI = 28.48 – 0.84 (GA in weeks) – 1.96 (HIV infected) + 0.36 (SFH in cm); $R^2 = 0.19$.

†AFI = 34.77 – 0.61 (GA in weeks) – 2.29 (HIV infected) – 2.42 (fundal non-ballottability); $R^2 = 0.19$.

‡AFI = 37.22 – 0.68 (GA in weeks) – 2.28 (HIV infected) – 2.20 (PP non-ballottability); $R^2 = 0.20$.

§AFI = 39.56 – 0.75 (GA in weeks) – 2.14 (HIV infected) – 2.64 (composite); $R^2 = 0.23$.

Tests were performed for model assumptions in the four multivariable linear regression models shown in Table 14. The assumptions of linearity, approximately normal distribution of y-residuals, homoskedasticity, and the influence of outliers using dfbeta plots with sensitivity analysis, provided reassurance of the appropriateness and applicability of the models (Appendix E).

The association of each of the measurements and clinical signs with the binary outcome of oligohydramnios (AFI <5 cm) was investigated using univariable logistic regression (Table 15). In this analysis, only presenting part ballottability was associated with oligohydramnios.

Table 15. Comparison of clinical signs for amniotic fluid volume on abdominal and vaginal examination, in women with oligohydramnios (amniotic fluid index <5 cm) and normal amniotic fluid volume (amniotic fluid index ≥5 cm), by univariable logistic regression (n=100).

Explanatory variable	Oligo-hydramnios (n=23)	Normal AFV (n=77)	Odds ratio (95% CI)	P value
Mean symphysis-fundal height (cm)	37.4 ± 3.0	38.0 ± 2.5	0.91 (0.76; 1.10)	0.34
Mean abdominal circumference (cm)	103.4 ± 7.9	101.5 ± 6.4	1.04 (0.97; 1.12)	0.22
Head five fifths palpable (n=99)*	11 (50%)	44 (57%)	0.69 (0.27; 1.75)	0.43
Uterine irritability†	7 (30%)	21 (27%)	1.17 (0.42; 3.24)	0.77
Parts not ballottable in uterine fundus†	19 (83%)	56 (73%)	1.78 (0.54; 5.85)	0.34
Presenting part not ballottable†	20 (87%)	46 (60%)	4.49 (1.23; 16.42)	0.02
Fetal compaction†	3 (13%)	10 (13%)	1.00 (0.25; 4.01)	0.99
Fetal parts easy to feel†	12 (52%)	47 (61%)	0.70 (0.27; 1.78)	0.45
Failure to elicit uterine fluctuance†	5 (22%)	13 (17%)	1.37 (0.43; 4.35)	0.60

Binary explanatory variables:

*reference is head four fifths or less; †reference is opposite finding of that given in table

Presenting part ballottability was then placed in a multivariable logistic regression model alongside the significant predictors (gestational age and HIV status) obtained from the analyses shown in Tables 11 and 12. Presenting part ballottability remained a statistically significant predictor after adjustment for gestational age and HIV status (Table 16). Again, as for Table 12, removal of HIV status from the model with gestational age showed no statistically significant difference using the likelihood ratio test, but HIV status was retained because of its clinical significance. The data here show that the odds of oligohydramnios increase by a factor of 4.58 (95% CI 1.13-18.5) if the presenting part is not ballottable, as opposed to it being ballottable, after adjustment for gestational age and HIV status.

Table 16. Multivariable logistic regression model for AFI <5 cm, against presenting part ballottability, adjusting for gestational age and HIV status (n=100).

Explanatory variable	**Adjusted odds ratio**	**Standard error**	**95% CI**	**P value**
Gestational age in weeks	1.77	0.48	1.04; 3.01	0.04
HIV infected (reference HIV negative)	2.81	1.64	0.89; 8.80	0.08
Presenting part not ballottable (reference ballottable)	4.58	3.27	1.13; 18.58	0.03

5.6. Predictive ability of clinical palpation for oligohydramnios

Presenting part non-ballottability had a sensitivity of 87% for oligohydramnios, with a specificity of 40%, and a positive likelihood ratio of 1.46 (Table 17). The receiver-operator characteristic (ROC) curve showed an area under the curve of 0.64 (Figure 2). After adjustment for gestational age and HIV, presenting part non-ballottability showed an area under the curve of 0.76 in a receiver operator characteristic curve for oligohydramnios (Figure 3).

It is known from clinical experience that ballottability of the presenting part is only rarely elicited with a fetal head below five fifths palpable above the pelvic brim. Therefore, a similar calculation was made including only women where the presenting part was five fifths palpable (n=55). The sensitivity of non-ballottability was 73% with a specificity of 64% and a positive likelihood ratio of 1.96 for oligohydramnios (p=0.04) (Table 18).

Table 17. Predictive value of presenting part ballottability for oligohydramnios (amniotic fluid index <5 cm) (n=100)

	Oligo-hydramnios	Normal AFV	Totals
Presenting part not ballottable	20	46	66
Presenting part ballottable	3	31	34
Totals	23	77	100

Sensitivity = 87%, specificity = 40%, positive predictive value = 30%, negative predictive value = 91%, positive likelihood ratio = 1.46, negative likelihood ratio = 0.32.

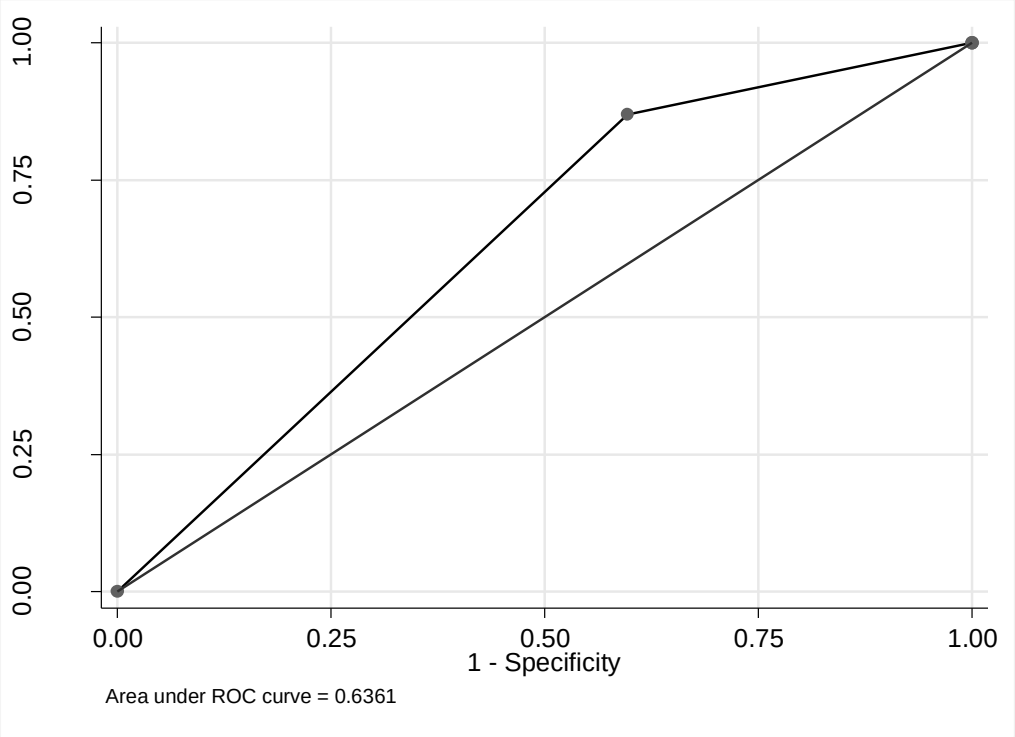


Figure 2. Receiver-operator characteristic curve for presenting part non-ballottability for oligohydramnios (amniotic fluid index <5 cm)

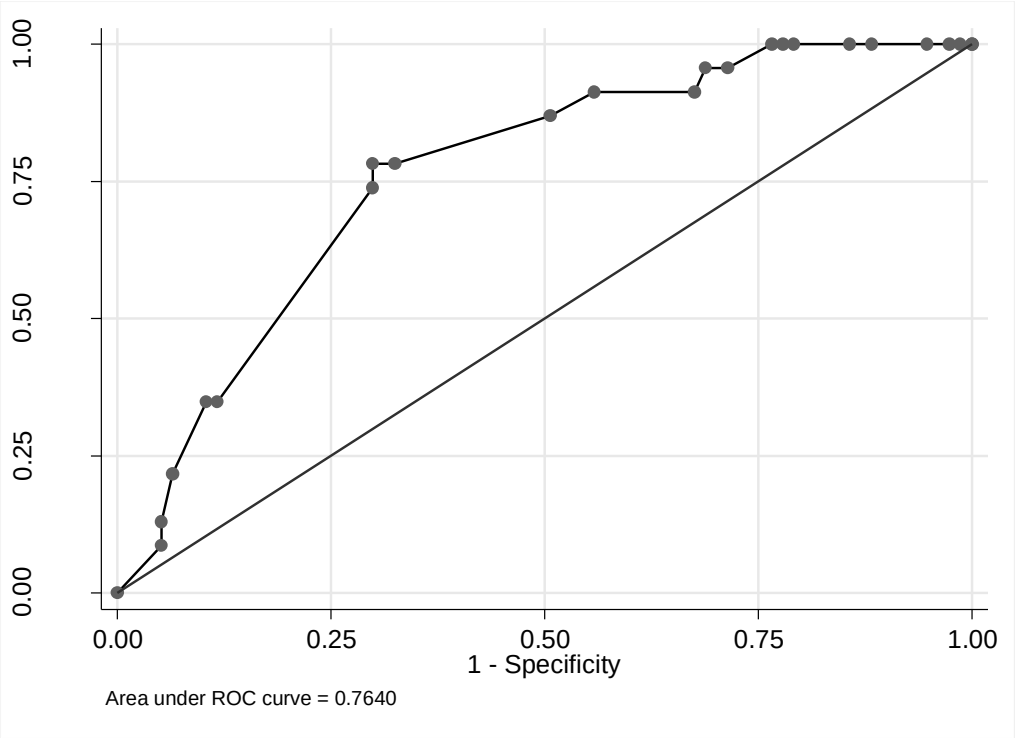


Figure 3. Receiver-operator characteristic (ROC) curve for presenting part non-ballottability adjusted for gestational age and HIV infection, for oligohydramnios (amniotic fluid index <5 cm), derived from logistic regression model.

Table 18. Predictive value of presenting part ballottability for oligohydramnios (amniotic fluid index <5 cm) if fetal head five fifths palpable above the pelvic brim (n=55).

	Oligo-hydramnios	Normal AFV	Totals
Presenting part not ballottable	8	16	24
Presenting part ballottable	3	28	31
Totals	11	44	55

Sensitivity = 73%, specificity = 64%, positive predictive value = 33%, negative predictive value = 90%, positive likelihood ratio = 1.96, negative likelihood ratio = 0.43.

6. DISCUSSION

6.1. Maternal, fetal and obstetric characteristics and outcomes

The mean and range of gestational age of women referred for suspected prolonged gestation reflected the uncertainty of MOU midwives in making decisions based on gestational age. The approximately normal distribution of AFIs is suggestive of a term, rather than post-term population of pregnancies. One should expect post-term pregnancies to show a positively (left) skewed distribution of AFIs, with values clustered towards low AFI measurements. Less than half of the 100 referred women had a best estimate gestational age ≥41 weeks. In retrospect, therefore, more than half of these women need not have been referred, since the information used by the researcher to determine gestational age was also available to the referring midwives. Only 26 women had gestational age information from early ultrasound scans, and in 16 of these, the gestational age was ≤41 weeks, yet even those 16 women were referred. These findings will back up efforts to improve antenatal care and referral. In-service training and triage clinics with experienced midwives could be introduced, to reduce unnecessary referrals and anxiety for pregnant women.

The neonatal outcomes were good in this small series of 100 pregnancies, with no deaths and no serious morbidity. A limitation of this study was the absence of detailed intrapartum information such as length of labour, intrapartum fetal heart rate abnormalities and meconium-staining of the AF. The caesarean section rate of 46% for labour inductions was high, even higher than the 38% recently reported for inductions of labour for prolonged pregnancy in a teaching hospital in Cape Town.[96]

6.2. Amniotic fluid index related to maternal and fetal factors

The statistically significant inverse association between gestational age and AFI was expected, showing similar results to previous work.[24,34] The frequency of AFI <5 cm was much higher than in most studies that measured AFI at advanced gestations,[28,34] but similar to findings by Phelan et al. for pregnancies ≥41 weeks.[23] It must however be remembered that in this study less than half of the women were estimated to be ≥41 weeks pregnant. The ultrasonographer showed good intra-observer variability, although the women were re-measured immediately after their first measurement, making it likely that the ultrasonographer would sample the same AF pockets, and make very similar measurements.

The association between HIV infection and AFI was a surprise. No hypothesis on HIV had been proposed and the variable was included only as an essential clinical factor, along with parity, height, weight and others. A literature search for an association between HIV and oligohydramnios did not reveal any similar results. Low birth weight has been associated with HIV infection,[97] and if this is related to placental insufficiency, the association with oligohydramnios can be explained. But if so, the mechanism through which HIV infection may result in placental insufficiency is not known, although chronic inflammation could play a role. A possible explanation may be found in the HAART drug regimen, which includes tenofovir, known to be nephrotoxic in adults.[98] One could speculate on whether the tenofovir reduced fetal urine output, but that, and the role of HIV in oligohydramnios, needs to be the subject of further research.

The association of gestational age and HIV with AFI, both remaining in adjusted statistical models, and the absence of influence of any of the other maternal and fetal factors, meant that gestational age and HIV were included as factors for adjustment in assessing the role of clinical palpation for AFI.

6.3. Clinical palpation for amniotic fluid volume

The general impressions of AFV, given by the researcher and by the colleagues, were no better than chance in predicting oligohydramnios as defined by an AFI <5 cm. Also, the researcher's and the colleagues' findings on the same women showed no agreement using the kappa test. This method of AFV estimation was similar to that described in the studies by Barnes et al. and Crowley at al.[7,8] In terms of sensitivities and specificities, the findings were very similar to those of Barnes et al., suggesting likelihood ratios close to 1, equivalent to a useless test. The findings cannot be compared directly with those of Crowley et al., who used clinical outcomes (meconium-stained AF and absent AF at delivery) as their endpoint. The lack of agreement between the researcher and the clinician colleagues cannot be explained by the data, but it is possible that different clinicians do not use uniform methods for estimating AFV. One might find better agreement in a study where specific aspects of AFV estimation, e.g. ballottability, are examined for inter-observer variability.

This study showed, by separate evaluation of different elements of palpation, that ability to ballot fetal parts was predictive for AFI, as previously suggested, without evidence from research, in a number of texts.[3,4] In the hands of the researcher, ease of palpation of fetal parts, and the impression of a fetus cramped for space,[3,6] did not correlate well with oligohydramnios. The researcher's own ideas, that uterine fluctuance or uterine irritability could perhaps predict AFI, were also not borne out. Ballottability, both in the fundus and of the presenting part, remained predictive for AFI after adjustment for gestational age and HIV. When oligohydramnios was the endpoint, only presenting part ballottability, generally associated with a head at five-fifths above the brim, was significantly associated, both in crude and adjusted analysis. It should be noted that ballottability refers to back-and-forth movement of parts felt inside the uterus, not back-and-forth movement of the uterus in the abdominal cavity. SFH was also associated with AFI, as suggested in the Myles midwifery

textbook, where reference was made to ‘small-for-dates’ uterus in prediction of oligo-hydramnios.[3] The composite of fundal ballottability, presenting part ballottability and reduced SFH provided a better co-efficient of determination (R^2=0.23) for AFV than each of the measures on their own, although the coefficient did not differ much from that found with each of the measures individually.

6.4. Predictive ability of presenting part ballottability for oligohydramnios

This study sought a simple clinical method, not for estimating AFV, but for identifying oligohydramnios as part of screening for fetal well-being in suspected prolonged pregnancy. The one promising physical sign was presenting part ballottability, as shown by its sensitivity and specificity and performance on ROC curves, both unadjusted, and adjusted, for gestational age and HIV. The positive likelihood ratio improved to 2.0 when women with fetal heads not five-fifths palpable were excluded, but this reduced the applicability of the test to only about half of the study population. The most important finding was in the negative predictive value of 90%, irrespective of the level of the head. The practical significance is as follows. If a woman from this community presents with a suspected prolonged pregnancy and the presenting part can be ballotted in the uterus, there is a 90% probability of finding an AFI ≥5 cm. While this may sound impressive, the fact remains that even without palpating the uterus at all, there is a 77% probability that a randomly selected woman from this study has an AFI ≥5 cm. Negative predictive value is dependent on prevalence of a condition in a community, and therefore the 90% finding can only be generalized to pregnant populations similar to the one studied here.

Presenting part ballottability is only a weak predictor of oligohydramnios, and can probably not replace ultrasound scanning if AFV is to be a part of assessment of women with suspected prolonged pregnancy. Where, however, there is no ultrasound facility for AFI

assessment, presenting part ballottability could be used to obtain reassurance about AFV in pregnancies suspected to be prolonged.

6.5. Limitations

A number of limitations must be acknowledged. The women recruited for the study was a sample determined by whoever arrived earliest at the antenatal clinic. This study was primarily designed to investigate clinical palpation to predict oligohydramnios, and was not intended as an epidemiological study of prolonged or post-term pregnancy in the Chris Hani Baragwanath referral area. Therefore, the maternal, fetal and obstetric characteristics of this group of women should not be assumed to represent all women in this area with suspected prolonged pregnancy. It is not known if the women arriving early could have been a selected subgroup of prolonged pregnancies, for example where there was greater concern about the pregnancy. No data is available for women who arrived later at the antenatal clinic.

The sample size of 100, based on clinical experience from work at the hospital, was adequate for demonstrating an association between abdominal palpation and oligohydramnios, but left little room for analysis of subgroups, such as only those women who were considered to be ≥41 weeks pregnant, and the influence of multiple covariates. The association between oligohydramnios and HIV, for example, could have been better defined using a larger sample. Any further research, whether on presenting part ballottability, or on HIV and AFV, can make use of the findings in this study for its sample size calculations.

A valid criticism would be the use of AFI as a gold standard for AFV. Dye-dilution or direct measurement of AF at caesarean section or hysterotomy are the current gold standards. Dye dilution would have presented ethical problems because of the need for non-essential amniocentesis. An ultrasound scan followed immediately by caesarean section and AF collection would have been possible in theory, but was not a practical option. AFI remains

the best non-invasive measure, with reasonable correlation, for AFV.[38,40-42] AFI has been used as a gold standard in at least one published study, on transcervical ultrasound estimation of AFV.[48]

The elements of palpation for AFV, such as presenting part ballottement, were performed by a single researcher, with no evaluation of intra-observer variability, or even of inter-observer variability by asking the colleagues to repeat the elements of palpation. The CHBAH antenatal clinic is just too busy to allow for this type of distraction, which would have inconvenienced other women waiting to be consulted. It was considered sufficient and not too time-consuming just to ask the colleagues if they considered AFV to be normal or reduced, as was done in the study by Barnes et al.[7] If a study is ever done to validate presenting part ballottement, then the consultant colleagues could be asked only to feel for this clinical sign, again without wasting too much time on multiple different palpation methods.

The blinding process made it impossible for the researcher or the colleagues to know the gestational age or the AFV before palpating each woman's abdomen. This was the strength of the study. What was impossible to blind was the initial finding on first abdominal palpation. Whatever impression was gained at that point may have influenced subsequent systematic palpation. For example, if the first feel of the abdomen suggested reduced AF, then the researcher might have decided that ballottability was absent or fetal parts were easily felt, based on preconceptions or textbook knowledge. Such information bias, if it occurred, would have biased the systematic palpation findings, such as presenting part ballottability, towards the null, in view of the negative eventual result of general impression on palpation, thus favouring a type II rather than a type I statistical error.

6.6. Conclusion

To the best of the researcher's knowledge, this is the first study to show which of the elements of clinical abdominal palpation are able, and which are unable, to predict AFV at and beyond term. The ability to ballot fetal parts, as suggested in some textbooks, can predict AFV. The study has also dismissed the composite guess of AFV on general abdominal palpation as little more than useless.

In terms of the practical application of clinical palpation for AFV in prolonged pregnancy, the study offered mixed results. Although presenting part ballottability was significantly inversely related to reduced AFI (oligohydamnios), the test characteristics (sensitivity, specificity, positive likelihood ratio) were too weak to allow such palpation to dictate clinical management. If AFV needs to be measured as part of management of suspected prolonged pregnancy, ultrasound scanning remains the method of choice. One should only venture a prediction of AFV based on ballottability of the presenting part if ultrasound scanning is unavailable. In such circumstances, ballottability increases the probability of the AFV being normal, and may assist in the clinical decision to admit a woman for induction or to continue with pregnancy surveillance.

Further research should focus on the significance of ballottability, using a larger sample size, based on this study's findings, and a more refined hypothesis. The predictive value of this clinical sign needs to be tested in a group of obstetric clinicians and midwives, standardizing the method and testing also for intra- and inter-observer repeatability. Favourable results would allow use of this simple method of palpation to assist clinical decision-making in cases of suspected prolonged pregnancy where ultrasound is unavailable.

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Appendix A: Ultrasound form

Postdates pregnancy: ultrasound assessment

Name..... Date.....

BPD ..... = ... weeks

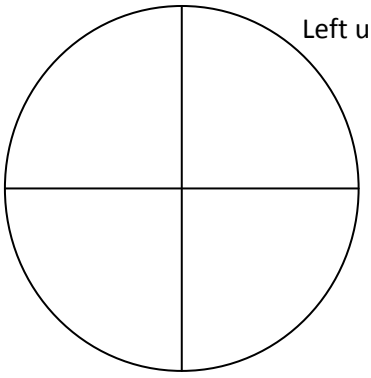
FL ..... = ... weeks

AC ..... = ... weeks

} EFW ..... g

FH ..... Other .....

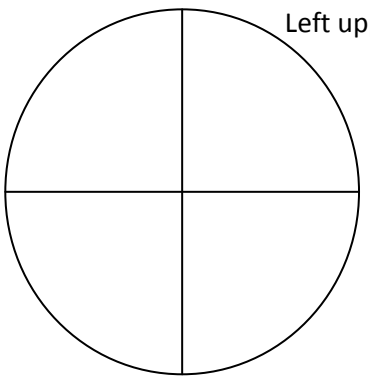
AFI 1:



AFI 1 = ... cm

Please repeat AFI if AFI1 is less than 10 cm

AFI 2:



AFI 2 = ... cm

Appendix B: Data sheet

Date..... Study no……. Age…… Parity…… Prev CS……

Gestation (LMP)……..…Best gestation…..….. by early scan(1), dates(2), late scan(3), other (4)……..

Public scan..... Private scan.....

Smoking …… Per day..... HPT ..... HIV ….. CD4 ……. HAART…..... Weight…....… kg

Height……. cm MUAC.....cm AC……. cm SFH…… cm

Head in fifths……..... Irritability ……

Fundal ballottement…….

Suprapubic ballottement……..

Fetus free.....

Fetal parts obscured.....……

Uterine compressibility.……

Cervical forewaters…..……..

General impression…… Colleague impression..... Rank..... (1,2)

Cervix (Bishop):

Dilatation……=……. Length……=…….

Consistency……=……. Position……=……

Station……=……. **TOTAL.....**

	0	1	2	3
Dil	0	1-2	3-4	5
Length	5	3-4	1-2	0
Cons	Firm	Med	Soft	
Pos	Post	Mid	Ant	
Stat	-3	-2	-1,0	+1

MVP1……. MVP2..... **MVP**..... cm

AFI1……..... AFI2……..….. **AFI**.....cm

EFW..... g

Labour spontaneous……. Date of birth..... Interval ..... Hospital.....

Caesarean section…… Birthweight…… g Indication.....

Stillbirth…….. 5-minute Apgar……..

Neonatal admission…….. Neonatal death……

Admitted for IOL.....

1 = CPD/poor progress
2= Fetal distress
3=Failed IOL
4=Elective CS
5=Other

Appendix C: Information and consent form

Information and consent form

GOOD DAY. My name is Dr Eckhart Buchmann. I am a specialist obstetrician doctor working at Chris Hani Baragwanath Hospital. I am doing a research project to achieve a master's degree (MSc) with Wits University. I am inviting you to participate in this project because you were referred by your clinic because your pregnancy seems to have gone past its expected dates. This form has information to help you decide if you want to take part. Read it carefully and feel free to ask me or any staff member for assistance.

What is the project about?

We have a problem with women whose pregnancies have gone (or are thought to have gone) past their expected delivery dates. This can be dangerous for the unborn baby because 1) the baby may be big, and 2) the baby may have a shortage of water (amniotic fluid) around it, allowing the baby's umbilical cord to be squeezed, and also allowing the baby's faeces (meconium) to become very thick if the baby passes faeces in the womb.

Research has found that if we do a sonar (ultrasound scan) in women who have gone past their expected delivery dates, we can find out which babies have enough water around them and should be safe, and which babies don't and could be in danger. Those in danger can be admitted to hospital for us to induce labour and monitor the baby's condition during labour. The problem in many places (not here) is that there is not always sonar available to measure the amount of water around the baby. My research will try to find out if a doctor (me) can estimate the amount of water in the womb by feeling women's tummies without doing a sonar but you will be sent for a sonar anyway because that is the way we measure the water around the bay at this time.

Why have I been chosen to participate?

You have been chosen because you have been sent by your clinic to the hospital, for the reason that the clinic sisters think that your pregnancy might have gone past its expected delivery date. We at the hospital need to see if we agree that your pregnancy has gone past its expected delivery data, and we need to find out if your baby is safe or in danger.

What exactly will be done to me?

I will examine you and do all the tests that are necessary to determine whether you more than 41 weeks and send you for a sonar. I will take information from your card, and I will then feel your tummy and try to work out if there is enough water around your baby. I will also feel in your vagina if your womb is open or not so that we can decide whether or how we should induce labour, and how much water I can feel Then you will have a sonar done to measure the amount of water around the baby. I will write down all this information on a special form. Your name and hospital number will not be written on the form. All of these examinations and sonar are part of the normal care that you would have got in pregnancy, except for the findings from my feeling your tummy for water. After having the sonar, one of our specialist doctors or me will talk with you about what we found, and decide on how to treat your pregnancy further. Your treatment has nothing to do with my research. We will not use the finding from my examination to decide how to treat you. But we will use the sonar findings.

Do I gain by participating in this project?

You do not gain directly. What I am doing will not affect the way you are treated. This is a research project where we want to find out how to improve care of women like you in the future. The measurements that I get from feeling your tummy will not be used to treat you, and will not be known to nurses and doctors treating you. Also, you will not receive any reward for agreeing to participate in this project.

Will there be any harm to my baby or me if I participate?

Feeling your tummy and making my findings will not harm you or your baby in any way, as the information from that will not be used to treat you. Whether or not you take part in this research project, I have to tell you that there can be problems with the pregnancy or birth. So, I cannot promise that you or your baby will be fine during the pregnancy or during labour or after birth.

Could the information obtained in my file end up in the wrong hands?

No. Everything I find out about you is strictly confidential. All the information will go on to my special form that will not have your name or hospital number on. The form contains only a study number and I will be the only person who knows that the study number is yours.

What will happen if I do not want to participate?

You are free to refuse to take part in the project. It will not affect the way you are treated by nurses and doctors here. Even if you sign the consent form to participate, and you change your mind later, you may withdraw from the project. That is your decision and I will respect that.

Who can I speak to if I have a question regarding the research?

If you have any questions about the research, you may ask the doctor or nurse who is attending to you in the hospital, or you can speak to me directly on 0834087777 or 0119338155 or 0119338156, even after you have left the hospital. This research has also been approved by the University of the Witwatersrand's Human Research and Ethics Committee. If you have any queries about whether this study is safe or allowed to be done, you may call the committee's secretary, Ms Anisa Keshav, at 0117171234 during working hours.

Consent

I agree to participate in this project. Dr Buchmann will take information from my card, feel my tummy, do a vaginal/internal examination, write down the sonar findings and write down what happened to me and my baby.

The forms he uses in this project will not include my name or hospital number. I understand that I am not entitled to any gain for me taking part in the project. I also understand that I may withdraw my consent for participation at any time, even after I have signed this form.

Participant..... Witness.....

Researcher..... Date.....

Appendix D: HREC approval

M110111

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Professor EJ Buchmann

CLEARANCE CERTIFICATE	**M110111**
PROJECT	The Predictive Ability of Clinical Palpation for Estimating Amniotic Fluid Volume in Suspected Prolonged Pregnancy (New title)
INVESTIGATORS	Professor EJ Buchmann.
DEPARTMENT	Department of Obstetrics & Gynaecology
DATE CONSIDERED	28/01/2011
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 28/01/2011 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Dr Yasmin Adam

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

Appendix E:

Linear regression diagnostics for amniotic fluid index for the model containing the predictors of gestational age, HIV infection and presenting part ballottability.

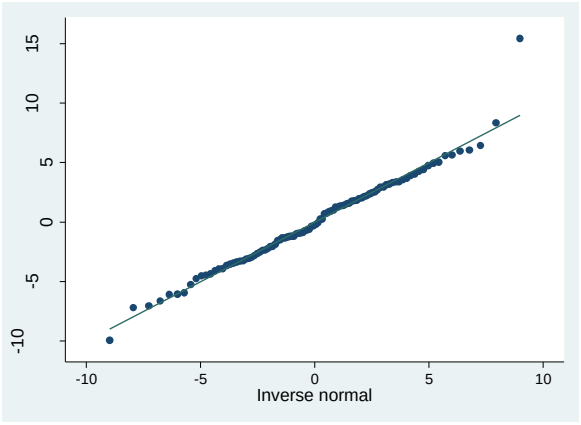


Figure 3 a. q-q for regress AFI bestgest hiv ppballot

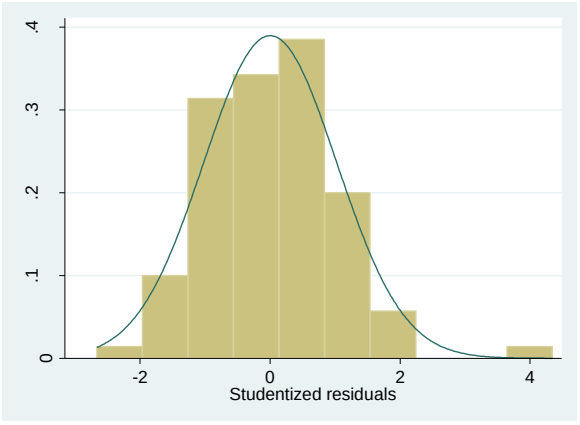


Figure 3 b. Histogram of residuals

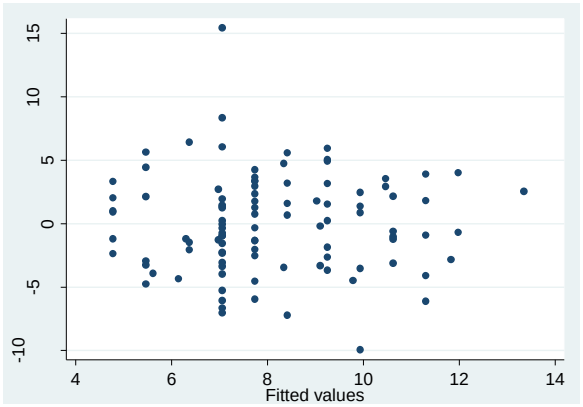


Figure 3 c. RVF plot

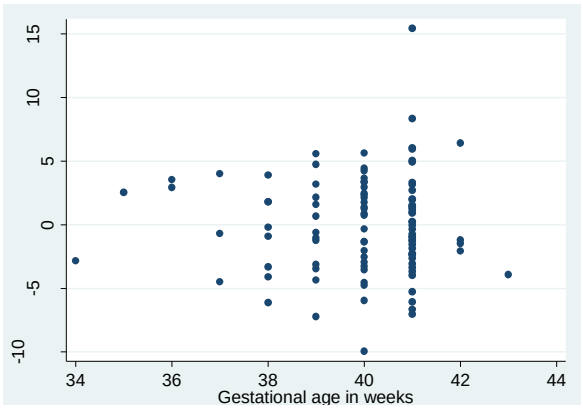


Figure 3 d. RVP plot gestation

Figure 3. Tests for assumptions in multiple linear regression with AFI as the outcome, and gestational age, hiv status positive, and presenting part ballottability as the exposure variables: a) linearity assumption:....; b) normal distribution of residuals....; c) RVF (residual v. fitted) plot to confirm homoskedasticity; Cook-Weisberg test; p=0.61; d) residual v. plotted (RVP) plot for variance of residuals for gestational age.

Outlier = woman with AFI of 22 cm – not removed from analysis

Also did tables for hiv and ppballot residuals, and did dfbetas with sensitivity analysis for 0.2 and 0.4 – results essentially the same.