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Torbjørn Moe Eggebø

Ultrasound and labour

Doctoral Thesis

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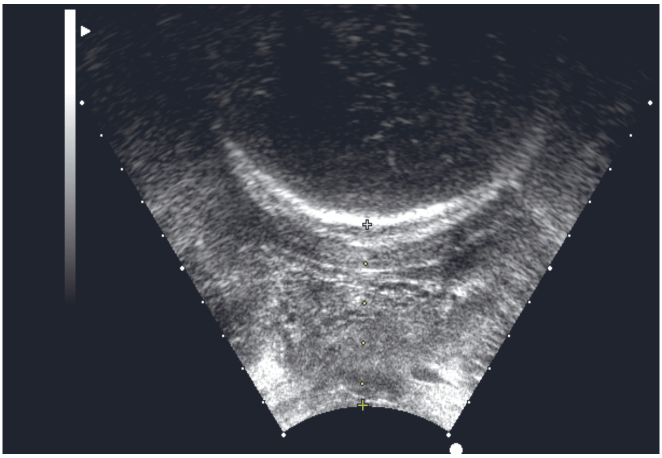

Thesis for the degree of philosophiae doctor

Stavanger, May 2009

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Ultralyd og fødsel

Fødselskanalen hos mennesket har en krum form, og den er trangest i midtpartiet. Fosteret må rotere for å passere. Fødselshjelpere bruker tradisjonelt hendene til å vurdere forholdet mellom foster og mor, men studier har vist stor variasjon mellom ulike undersøkere. Hensikten med avhandlingen var å vurdere nytten av ultralydmålinger like før fødselen starter.

Materiale og metode

Vi undersøkte 152 kvinner med vannavgang til termin (studie 1 og 2) og 275 kvinner der fødselen ble satt i gang (studie 3 og 4). Vi undersøkte fosterets posisjon og grad av fleksjon (bøying) i nakken med transabdominal ultralydundersøkelse, fosterhodets nivå i fødselskanalen (korteste avstand fra fosterhodet til perineum) med transperineal ultralydundersøkelse og livmorhalsens lengde, vinkel og åpning med transvaginal ultralydundersøkelse. En fødselshjelper som ikke kjente resultatene av ultralydundersøkelsene, utførte tradisjonell vurdering med hendene, såkalt Bishop score.

Studie 1

Occiput posterior posisjon (ansiktet fram) under fødselen er forbundet med økt risiko for stans i fødselen, operative forløsninger og rifter. 40 av 152 fostre hadde occiput posterior posisjon før fødselen, og hos 34 (85%) av disse roterte hodet til occiput anterior posisjon (ansiktet bak) i løpet av fødselen. 11 gravide hadde et foster med ekstendert (strukket) nakke før start av fødselen. Av disse fødte sju kvinner spontant, tre med keisersnitt og én med vakum. Det var ingen signifikant sammenheng mellom fosterhodets posisjon eller grad av nakkefleksjon før start av fødselen og utfallet. Vi konkluderte at transabdominal ultralydundersøkelse hos kvinner med vannavgang har liten nytteverdi.

Studie 2

Hensikten med studie 2 var å vurdere om fosterhodets nivå i fødselskanalen før start av riene hadde betydning for fødselsforløpet. Kvinner med kort avstand (< 45 mm) fra fosterhodet til perineum hadde signifikant færre keisersnitt, mindre bruk av epidural analgesi, kortere tid fra vannavgang til fødsel og kortere tid i aktiv fødsel enn de med lang avstand fra fosterhodet til perineum. Ultralydmåling av fosterhodets nivå kan være nyttig for å vurdere om kvinner med vannavgang bør vente på spontan fødsel eller tilbys tidlig igangsetting.

Studie 3

Hensikten med studie 3 var å vurdere om ultralydmålinger og kliniske undersøkelser kan predikere fødselsforløpet ved induserte fødsler. Paritet (tidligere fødsel) var den viktigste enkeltfaktoren. Fosterhodets nivå, lengden av livmorhalsen og livmorhalsens vinkel hadde også signifikant betydning for sannsynligheten for vaginal fødsel og for tiden fra induksjon til fødsel.

Studie 4

I studie 4 sammenlignet vi enkeltfaktorene i Bishop score med tilsvarende ultralydmålinger og vurderte om man kan kombinere ultralydmålinger og palpasjonsfunn. Vi fant moderat korrelasjon mellom palpasjon og ultralydmåling av lengden av livmorhalsen, svak korrelasjon for vurdering av åpning, vinkel og fosterhodets nivå. Bishop score er en subjektiv og komplisert metode. Vi foreslår en ny score der vi måler fosterhodets nivå og livmorhalsens lengde med ultralyd og livmorhalsens åpning med palpasjon.

Konklusjon

Ultralydundersøkelser kan være et nyttig supplement til klinisk undersøkelse før fødselen.

Kandidat: **Torbjørn Moe Eggebø**

Institutt: **Laboratoriemedisin, kvinne- og barnesykdommer,**
Norges teknisk naturvitenskapelige universitet (NTNU)

Veiledere: **Kjell Å. Salvesen (hovedveileder) og Pål R. Romundstad**

Avhandlingen er funnet verdig til å forsvares offentlig for graden philosophiae doctor i klinisk medisin.

Disputas finner sted i Aulaen, Stavanger Universitetssykehus, fredag 8.mai 2009 kl. 12.00

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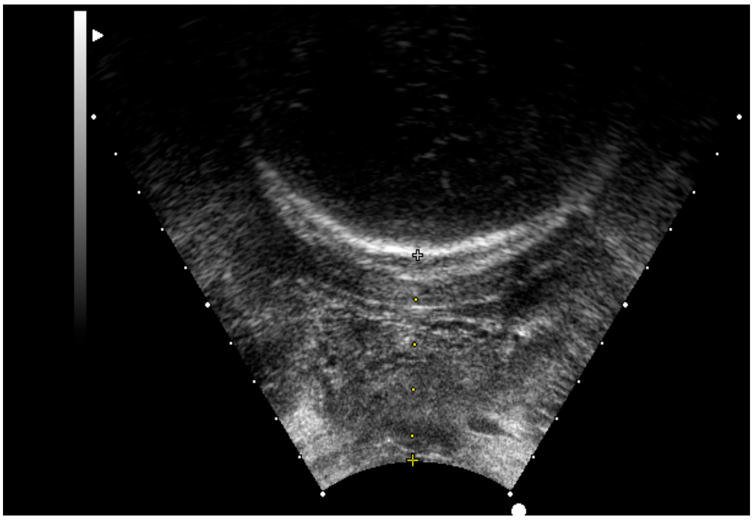

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Contents

Acknowledgements

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1 List of papers

1.1 Paper one

Eggebø TM, Heien C, Økland I, Gjessing LK, Smedvig E, Romundstad P, Salvesen KÅ.

Prediction of labour and delivery by ascertaining the fetal head position with transabdominal ultrasound in pregnancies with prelabour rupture of membranes after 37 weeks.

Ultraschall Med. 2008 Apr; 29(2): 179-83.

1.2 Paper two

Eggebø TM, Gjessing LK, Heien C, Smedvig E, Økland I, Romundstad P, Salvesen KÅ.

Prediction of labor and delivery by transperineal ultrasound in pregnancies with prelabor rupture of membranes at term. Ultrasound Obstet Gynecol. 2006 Apr; 27(4): 387-91.

1.3 Paper three

Eggebø TM, Heien C, Økland I, Gjessing LK, Romundstad P, Salvesen KÅ.

Ultrasound assessment of fetal head-perineum distance before induction of labor.

Ultrasound Obstet Gynecol 2008;32(2): 199-204.

1.4 Paper four

Eggebø TM, Økland I, Heien C, Gjessing LK, Romundstad P, Salvesen KÅ.

Ultrasound measurements or digital assessments before induction of labour?

Submittet June 11th 2008. Acta Obstetricia et Gynecologica Scandinavica - Manuscript ID AOGS-08-0351

2 Norwegian summary

2.1 Innledning

Alle kvinner ønsker seg en ukomplisert fødsel, men komplikasjoner kan oppstå plutselig og uventet. I følge Verdens Helseorganisasjon trenger 15% av de gravide kyndig hjelp under svangerskap eller fødsel.

Før fødselen starter er det viktig å vite hvordan fosteret er orientert i forhold til mor. Leiet vurderes som lengdeleie, tverrleie eller skråleie. Posisjonen beskriver hvordan fosteret er orientert fram, bak, til høyre eller venstre inne i livmoren, og presentasjon beskriver den delen av fosteret som er dypest i fødselskanalen. Nakken til fosteret kan være bøyd (flektert) eller strukket (ekstendert).

Fødselskanalen hos mennesket har en bøyd og uregelmessig form, og fosteret må derfor rotere for å kunne passere. De fire kardinalbevegelsene hos et foster med bakhodepresentasjon er fleksjon av hodet, rotasjon gjennom kanalen, ekstensjon i utskjæringen og rotasjon i det skuldrene passerer utgangen. Ved slutten av svangerskapet blir livmorhalsen kortere, og under fødselen blir den avflatet før den åpner seg. Fosterets nivå i fødselskanalen relateres vanligvis til prosessus spinosus. Fødselshjelperne bruker tradisjonelt hendene til å vurdere forholdet mellom foster og mor, men studier har vist stor variasjon mellom ulike undersøkere. Galileo Galilei har sagt: *«Mål det som er målbart, og prøv å gjøre målbart det som ennå ikke er det.»* Hensikten med denne avhandlingen er å vurdere nytten av ultralydmålinger like før fødselen starter.

2.2 Materiale og metode

Vi undersøkte to grupper gravide kvinner. Først undersøkte vi 152 kvinner med ett foster i hodeleie, ingen tidligere keisersnitt og vannavgang etter svangerskapsuke 37 (studie 1 og 2). Vi vurderte fosterhodets posisjon og grad av fleksjon i nakken med transabdominal ultralydundersøkelse. Deretter utførte vi en transperineal ultralydundersøkelse og målte avstanden til indre mormunn og lengden av livmorhalsen i sagittalplan. Vi brukte den korteste avstanden fra fosterhodet til perineum i frontalplan som et mål på fosterhodets nivå i fødselskanalen.

Andre gruppe bestod av kvinner som kom til fødselsinduksjon (studie 3 og 4). Inklusjonskriterier var ett foster i hodeleie, ingen tidligere keisersnitt og svangerskapslengde over 37 uker. 710 kvinner hadde indusert fødsel i studieperioden, og 275 ble inkludert i undersøkelsen. Fosterhodets posisjon og nivå ble vurdert på samme måte som beskrevet ovenfor. Vi målte livmorhalsens lengde og vinkel ved vaginal undersøkelse. En fødselshjelper som ikke kjente resultatene av ultralydundersøkelsene, utførte Bishop scoringen.

2.3 Studie 1

Occiput posterior posisjon under fødselen er forbundet med økt risiko for stans i fødselsforløpet, operative forløsninger og rifter. Det diskuteres om occiput posterior posisjon ved fødselen skyldes occiput posterior før start av fødselen eller en unormal rotasjon gjennom fødselskanalen. Hensikten med studien var å vurdere nytten av en transabdominal ultralydundersøkelse før start av fødselen hos kvinner med vannavgang etter uke 37.

40 av 152 foster hadde occiput posterior posisjon før fødselen, og hos 34 (85%) av disse roterte hodet til occiput anterior innstilling i løpet av fødselen. Fosterhodets posisjon før fødselen kunne predikere occiput posterior posisjon ved fødselen med sensitivitet 60%; 95% CI 26-88, falsk positiv rate 24%; 95% CI 17-32, positiv prediktiv verdi 15%; 95% CI 6-30, negativ prediktiv verdi 96%; 95% CI 91-99 og likelihood ratio (LR) 2,5.

11 gravide hadde foster med ekstendert nakke før start av fødselen. Av disse fødte sju spontant, tre kvinner med keisersnitt og én ble forløst med vakuum.

Det var ingen signifikant sammenheng mellom fosterhodets posisjon eller grad av nakkefleksjon før start av fødselen og utfallet av fødselen. Vi konkluderte med at en transabdominal ultralydundersøkelse hos kvinner med vannavgang har liten nytteverdi.

2.4 Studie 2

Transperineal ultralydundersøkelse er en lite brukt undersøkelsesmetode. Vi brukte utgangen av fødselskanalen som referanselinje for å vurdere fosterhodets nivå. Så vidt vi vet har ikke denne metoden vært evaluert tidligere. Hensikten med studien var å undersøke om resultatene av en transperineal ultralydundersøkelse kan predikere tid fra vannavgang til fødsel, og predikere sannsynligheten for en operativ forløsning.

Undersøkelse av livmorhalsens lengde i sagittalplanet var teknisk mislykket hos 16% av kvinnene og var derfor lite hensiktsmessig. Undersøkelse av fosterhodets nivå i frontalplanet var vellykket hos alle. Kvinner med kort avstand (< 45 mm) fra fosterhodet til perineum, hadde signifikant færre keisersnitt, mindre bruk av epiduralanalgesi, kortere tid fra vannavgang til fødsel og kortere tid i aktiv fødsel enn de med lang avstand fra fosterhodet til perineum. Lang avstand predikerte operativ forløsning (keisersnitt eller operativ vaginalforløsning) med sensitivitet på 83%; 95% CI 67-94, falsk positiv rate 59%; 95% CI 49-68, positiv prediktiv verdi 31%; 95% CI 22-41, negativ prediktiv verdi 89%; 95% CI 77-96 og LR 1,4. Ultralydmåling av fosterhodets nivå kan være nyttig for å vurdere om kvinner med vannavgang bør vente på spontan fødsel eller tilbys tidlig induksjon.

2.5 Studie 3

Hensikten med denne studien var å evaluere fosterhodets nivå, målt med ultralyd, som en prediktiv faktor for fødselsforløpet ved induserte fødsler. Vi sammenlignet målingen med paritet, BMI, Bishop score og ultralydundersøkelse av fosterhodets posisjon, livmorhalsens lengde og vinkel.

13% ble forløst med keisersnitt. Paritet var den beste faktoren for å predikere fødselsmåte. Den korteste avstanden fra fosterhodet til perineum predikerte vaginal fødsel med 62%; 95% CI 52-71% ($p = 0,03$) av arealet under kurven i en ROC (receiver-operating characteristics) kurve. Lengden av livmorhalsen predikerte vaginal fødsel med 61%; 95% CI 51-71% ($p = 0,03$), vinkelen til livmorhalsen med 63%; 95% CI 52-74% ($p = 0,02$) og Bishop score med 61%; 95% CI 52-70% ($p = 0,03$) av arealet under kurven. Best resultat fikk vi for cut-off verdiene: hode-perineum avstand ≤ 40 mm, lengde av livmorhalsen ≤ 25 mm og bakre vinkel av livmorhalsen > 90 grader. De samme faktorene hadde også signifikant betydning for sannsynligheten for å føde innen 24 timer etter induksjon. Fosterhodets posisjon hadde ingen prediktiv verdi for fødselsforløpet.

2.6 Studie 4

Bishop score består av faktorene lengde, åpning, posisjon og konsistens av livmorhalsen, og fosterhodets nivå i fødselskanalen. I denne studien sammenlignet vi enkeltfaktorene i Bishop score med tilsvarende ultralydmålinger, og hvordan man kan kombinere ultralydmålinger og palpasjonsfunn. Vi fant moderat korrelasjon mellom palpasjon og ultralyd til å vurdere lengden av livmorhalsen ($r = 0,54$), svak korrelasjon i vurdering av fosterhodets nivå i fødselskanalen ($r = 0,23$) og ingen korrelasjon i vurdering av livmorhalsens vinkel eller posisjon ($r = 0,03$).

Fosterhodets nivå og livmorhalsens lengde og åpning var de tre viktigste faktorene for å predikere fødselsforløpet. I klinisk praksis er det vanlig å kombinere faktorer i et scoringssystem. Bishop score er et subjektivt og komplisert system med score fra 0 til 13, og vi foreslår å bruke et nytt scoringssystem fra 0 til 3 der fosterhodets nivå og livmorhalsens lengde måles med ultralyd og åpningen vurderes med palpasjon.

Faktorer kan også kombineres ved hjelp av Bayes teorem. A priori sannsynlighet for vaginal fødsel etter induksjon er 88%. LR for vaginal fødsel var 3,5 hvis avstanden fra fosterhodet til perineum var ≤ 40 mm. A posteriori sannsynlighet for vaginal fødsel blir dermed 96%. Vi anbefaler å evaluere kombinasjon av prediktive faktorer i nye studier.

2.7 Tanker om framtida

I moderne medisinske forskning har metananalyser av randomiserte kontrollerte studier størst betydning. Humanistisk vitenskapsteori prioriterer erfaringskunnskap høyere. Erfaringskunnskap har lang tradisjon innenfor faget fødselshjelp, og det er viktig å ta vare på denne tradisjonen. Gammel og ny kunnskap må sammenlignes og evalueres. Pasientverdier har fått større betydning i moderne medisin. Klinikere kan ikke lenger bestemme for pasientene, men heller være rådgivere . God kunnskap er viktig for å kunne informere de fødende om sannsynlig forløp av fødselen.

Filosofen William of Ockham (1285-1349) har uttalt: *«Bruk alltid den enkleste av likeverdige metoder.»* Ressursene i helsevesenet er begrenset, og leger får ofte et etisk dilemma om de skal prioritere den enkelte pasient eller sykehusets økonomi. Det vil derfor bli viktig å finne undersøkelsesmetoder som er enkle å bruke, nyttige for pasientene og som samtidig er kostnadseffektive.

Ultralydundersøkelser har en sentral rolle i svangerskapsomsorgen. I denne avhandlingen har vi vurdert nytteverdien av ultralydmålinger like før fødselen starter. De samme undersøkelsesmetoder kan også brukes under fødselen. På dette området er det behov for mer forskning. Redaktøren i Ultrasound in Obstetrics and Gynecology har uttalt: *«We will move from obstetric ultrasound to ultrasonographic obstetrics.»* Kanskje vil ultralydundersøkelser i forbindelse med fødselen bli like viktige som de i dag er i svangerskapsomsorgen.

3 Abbreviations

3D	Three Dimensional
AFI	Amniotic Fluid Index
BMI	Body Mass Index
BPD	Biparietal Diameter
BPP	Biophysical Profile
CI	Confidence Interval
CTG	Cardiotocography
EFSUMB	European Federation of Societies for Ultrasound in Medicine and Biology
fFN	Fetal Fibronectin
IGFBP-1	Insulin-like Growth Factor Binding Protein-1
IOL	Induction of Labour
LOT	Left Occiput Transverse
LR	Likelihood Ratio
MCA	Middle Cerebral Artery
MRI	Magnetic Resonance Imaging
NCFM	National Center for Fetal Medicine
OA	Occiput Anterior
OP	Occiput Posterior
OR	Odds Ratio
PI	Pulsatility Index
PPROM	Preterm Prelabour Rupture of the Membranes
PROM	Prelabour Rupture of the Membranes
ROT	Right Occiput Transverse
RR	Relative Risk

TAU	Transabdominal Ultrasound
TPU	Transperineal Ultrasound
TVU	Transvaginal Ultrasound
UA	Umbilical Artery
US	Ultrasound
WHO	World Health Organization

4 Introduction

All women wish to experience an uncomplicated pregnancy and labour. Some women want to stay in low-risk obstetric units without technical interventions, whereas others prefer to take full advantage of available technology and analgesics. Most pregnancies and births are uneventful, but 15 % of pregnancies develop complications that calls for skilled care[1]. Labour is the time with highest risk of complications, and it is important to sort women into groups with high and low risk before labour. Only women at low risk should deliver in units intended for low-risk births or at home. Complications can arise acutely and unexpectedly in low-risk groups, and quick transfer to an operating theatre must be possible. In Norway, most obstetric units sort women into ‘red’ or ‘green’ groups, with the use of the obstetric history, problems during pregnancy and clinical examinations[2]. The aim of this thesis is to investigate whether ultrasound (US) examinations before the start of labour can predict the outcome of labour, and help clinicians to sort women correctly.

4.1 The normal labour

At the start of labour, it is important to know the orientation of the fetus within the uterine cavity. The fetal orientation relative to the mother is described in terms of fetal lie, position and presentation. The fetal lie is longitudinal, transverse or oblique. The position refers to a fetal part related to the mother's front, back, left or right side. The presenting part is the fetal part in the birth canal or closest to it. If the occipital fontanelle is the presenting part, it is referred to as a vertex or occiput presentation.

The maternal pelvis is irregular in shape, and the fetal head at term is large relative to the maternal pelvis. External compressive forces may act upon the fetal cranial vault and produce moulding. Still, not all diameters of the fetal head can pass through the birth canal, and movements of the head are necessary. The suboccipito-bregmatica (occiput anterior (OA) presentation) and submento-bregmatica (face presentation) diameters are shortest (around 9.5cm). The diameter occipito-frontalis (occiput posterior) is around 11.5 cm and diameter mento-verticalis is around 13.0 cm[3] (figure 1). The latter diameter makes a vaginal delivery impossible with a brow presentation.

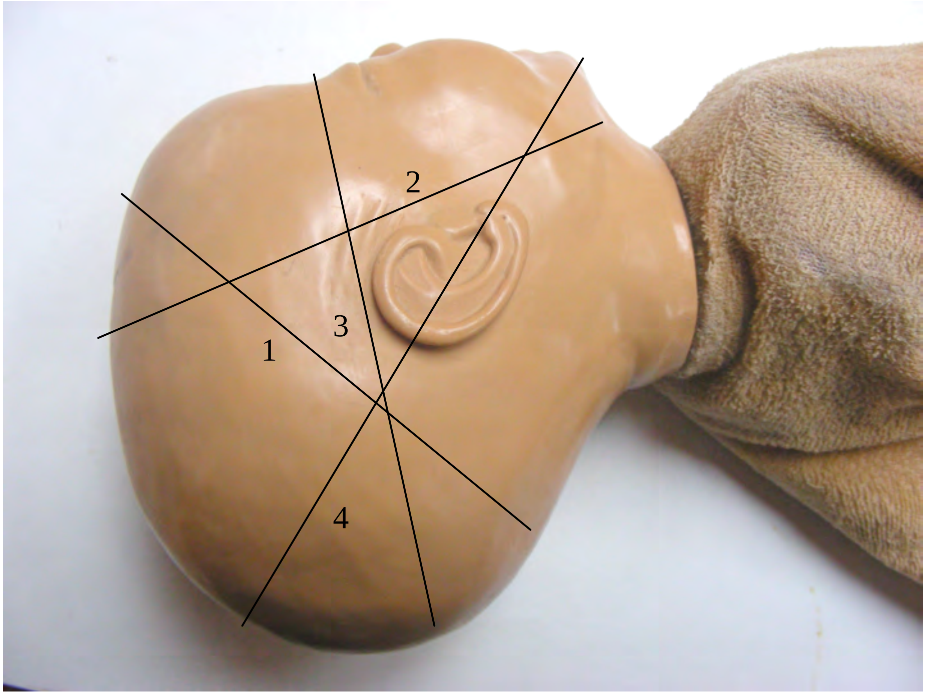


Figure 1. The different diameters of the fetal head[3], diameter suboccipito-bregmatica(1), diameter submento-bregmatica(2), diameter occipito-frontalis(3), diameter mento-verticalis(4).

4.1.1 The cardinal movements

The normal labour is described in textbooks[4-8]. The cardinal movements of labour of a fetus in occiput anterior presentation are flexion, internal rotation, extension and external rotation. The fetal head usually enters the birth canal transversely and engages in the pelvic inlet. The fetal head engages more often in the left occipitotransverse (LOT) position than in the right (figures 2 and 3) (59% versus 41%)[9].

Figure 2. Fetal head in left occiput transverse (LOT) position

Figure 3. Fetal head in right occiput transverse (ROT) position

Descent is brought about by pressure from uterine contractions. As soon as the descending head meets resistance, the fetal head flexes and rotates (figures 4 and 5).

Figures 4 and 5. Fetal head with occiput anterior presentation

When the flexed head reaches the vulva, it undergoes extension and external rotation, and delivery of the shoulders and the rest of the body follow. To see the first cardinal movements you will need imaging techniques (figures 6 and 7), but the final cardinal movements are visible (figures 8 and 9).

Figure 6. Sagittal abdominal ultrasound image after the first cardinal movement (flexion)

Figure 7. The internal rotation can be visualized by transverse abdominal ultrasound

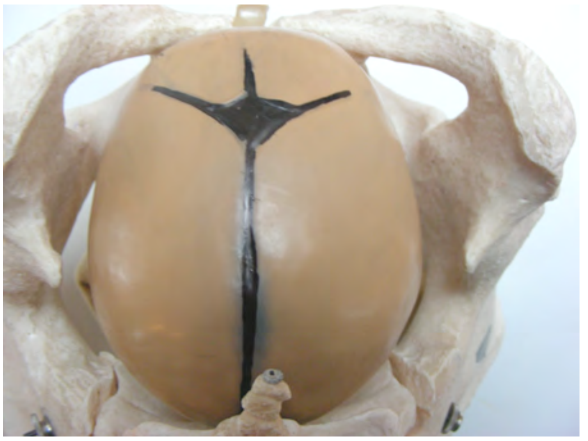
Figure 8. The third cardinal movement (extension)

Figure 9. The fourth cardinal movement (external rotation)

If the fetal head is in the occiput posterior position, the presenting part can be the occipital fontanelle (occiput presentation), the crown of the head (figures 10 and 11), frontal fontanelle (figures 12 and 13) (forehead presentation), brow presentation or face presentation depending on flexion or extension in the fetal neck.

Figures 10 and 11. Fetus in the occiput posterior position with the crown of the head as the presenting part

When the fetus is in occiput posterior presentation, the first cardinal movement is flexion, the second movement is internal rotation, the third movement is maximal flexion followed by extension and the fourth movement is external rotation.

Figures 12 and 13. Fetus with the frontal fontanelle (forehead) as the presenting part

A vaginal delivery is impossible when the brow is the presenting part. However, with further extension of the fetal neck, the face will be the presenting part and a vaginal delivery is possible (figures 14 and 15).

Figures 14 and 15. Fetus with face presentation

The cardinal movements are different when the fetal neck is extended. The first movement is extension (various extent), followed by internal rotation, flexion and external rotation.

4.1.2 Stages and phases of labour

Cervical effacement is the shortening and thinning of the cervix during labour, and cervical dilatation is the cervical opening measured in centimetres. The definitions from WHO are demonstrated in figures 16 and17 and table 1.

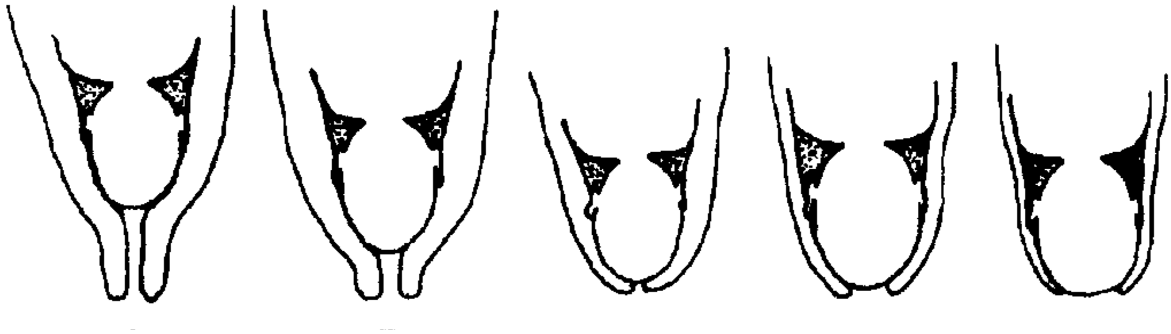


Figure 16. Effacement and dilatation of the cervix (from WHO)[1].

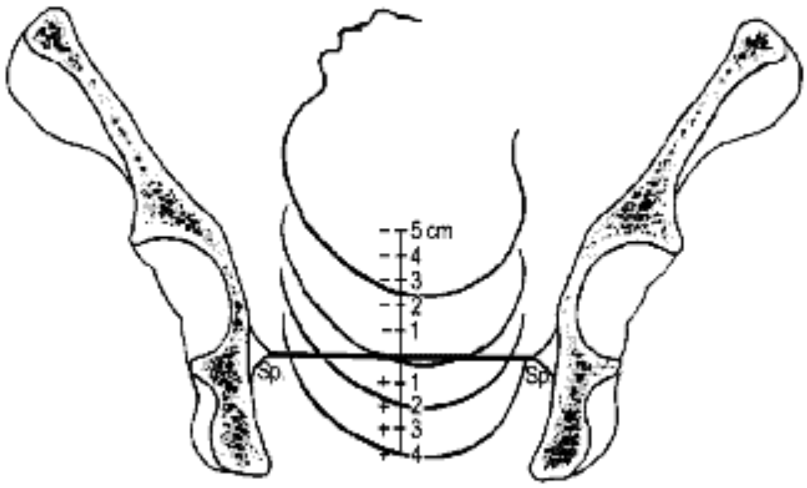


Figure 17. The descent of the fetal head in the birth canal is from stage -5 cm above the pelvic inlet, 0 at the level of the ischial spine and +4 cm at the level of the pelvic floor (from WHO)[1]

Cervix dilated less than 4 cm:	first stage and latent phase
Cervix dilated 4-9 cm:	first stage and active phase
Cervix fully dilated but presenting part above pelvic floor:	second stage and early phase
Cervix fully dilated and presenting part at the pelvic floor:	second stage and expulsive phase

Table 1. World Health Organization (WHO) definitions of the stages and phases of labour[1]

4.1.3 Leopold's manoeuvres

In 1894, Leopold described a systematical way of abdominal palpation. In the first manoeuvre the examiner will identify the fetal pole and in the second identify the back of the fetus. In the third manoeuvre the fingers of one hand are grasped just above the symphysis pubis to feel whether the presenting part is engaged and how deep it is descended in the maternal pelvis. In the fourth manoeuvre, the examiner faces the mother's feet, and with the tips of the first three fingers of each hand exerts pressure in the direction of the pelvic inlet.

4.1.4 Vaginal examination

A systematic way to do vaginal examination at the onset of labour and during labour is described as follows[4].

1. Two fingers are introduced into the vagina and the examiner will try to identify the presenting part
2. The next is to identify the course of the sagittal suture
3. The third is to identify the position of the fontanelles
4. The last is to describe the station or the extent to which the presenting part has descended into the pelvis

4.2 Labour dystocia

Labour dystocia may be a consequence of:

1. abnormalities of the power (contractions or pushing)
2. abnormalities of the fetus (size, presentation, position, flexion, malformations)
3. abnormalities of the maternal pelvis

Kolås et al. found fetal stress and failure to progress to be the most important indications for emergency caesarean section[10]. It has been asserted that dystocia leading to caesarean section is overdiagnosed[4]. In clinical practice it may be difficult to distinguish between the different reasons for labour dystocia, and a more precise diagnosis of labour progress would be important. In cases with maternal-fetal disproportions, a vaginal delivery is impossible. However, in cases with inadequate contractions, oxytocin augmentation should be the method of choice.

4.3 Occiput posterior position

The first objective studies regarding intrapartum fetal head position were done by Caldwell[9] and Calkins[11] in the 1930s. In the great majority of labours in the occiput posterior (OP) position, the mechanism of labour is almost identical to the normal labour except for a greater initial rotation. The majority of OP positions rotate before they reach the pelvic floor. In 5-10% the rotation may be incomplete or may not take place at all. Poor contractions or faulty flexion of the head may predispose to incomplete rotation and transverse arrest may occur. If no rotation occurs, the occiput will remain in persistent OP position[4]. In a study by Gardberg et al., 408 term pregnancies were investigated with sonography: most OP rotated to OA during labour and most OP positions at delivery were a consequence of a malrotation from initial OA (table 2)[12].

	OP at delivery	OA at delivery	
OP in early labour	8	53	61 (15%)
OA in early labour	13	334	347
	21 (5 %)	387	408

Table 2. Frequencies of fetuses in different positions in early labour and at delivery (from Gardberg et al.)

Souka et al[13]. and Akmal et al[14]. reached different conclusions. Souka reported that 80 of 106 OP deliveries were due to failure of rotation from an initial OP position[13]. Akmal investigated 918 women in active labour with transabdominal ultrasound (TAU). In this study, the majority of OP positions during labour rotated to the OA position, and the vast majority of OP positions at delivery were a consequence of persistence of this position during labour rather than malrotation from an initial OA or transverse position[14]. This topic is however debated. The conflicting results may be due to the timing of the US examinations.

The reasons for failure of spontaneous rotation are not known. Transverse narrowing of the midpelvis is a contributing factor. If the fetal head reaches the pelvic floor, a spontaneous delivery most certainly will occur. The late first stage and the second stage may be prolonged and an operative vaginal delivery may be necessary. Forceps rotation to OA can be done, but this procedure is seldom used nowadays. Manual rotation to OA is an alternative procedure. Correct diagnosis of the fetal head position is important in prolonged labour. TAU are of value in detecting the fetal head position and better than vaginal examinations[13, 15-20]. Dupuis et al. concluded that TAU is a simple, quick, and efficient way of increasing the accuracy of the assessment of fetal head position during the second stage of labour. In this study, the correlation between digital vaginal examination and TAU examination of the fetal head position during the second stage of labour was assessed. In 20% of the cases, ultrasonographic and clinical results differed significantly (i.e. > 45 degrees). This rate reached 50% for OP and transverse locations[21].

Pearl et al. performed a retrospective study of 564 OP deliveries and found an incidence of 4.2% persistent OP positions. Only 45% delivered spontaneously. They found more maternal lacerations in the OP than in an OA group and increased facial nerve and Erb's palsy in the newborn. They suggested vacuum extraction rather than forceps to avoid maternal lacerations[22]. Sizer et al. found an increase in OP with increased fetal weight (OR 1.18), epidural analgesia (OR 2.21) and oxytocin augmentation (OR 1.44)[23]. In a study by Fitzpatrick et al. only 29% of primiparas and 55% of multiparas with persistent OP position achieved spontaneous vaginal delivery, and OP was associated with a sevenfold higher incidence of anal sphincter disruption[24]. Ponkey et al. found similar results. The chance of a spontaneous vaginal delivery was 26% for primiparas and 57% for multiparas with persistent OP[25].

Akmal et al. investigated the value of ultrasonographically determined OP positions in the early stages of labour in predicting the likelihood of caesarean section. Delivery was vaginal in 514 (86%) cases and by caesarean section in 87 (14%). The fetal occiput position was posterior in 209 (35%) cases and in this group the incidence of caesarean section was 19% (40 cases), compared with 11% (47 of 392) in the non-OP group[26]. Rane et al. investigated the value of sonographic assessment of cervical length, posterior cervical angle and occipital position in 604 women. Prediction of the induction-to-delivery interval and the likelihood of vaginal delivery within 24 hours was provided by the occipital position[27]. Lieberman et al. evaluated epidural analgesia and the rate of abnormal fetal head positions at delivery. The final fetal position was established close to delivery. Women receiving epidural did not have more OP fetuses before the start of delivery (23% epidural versus 26% no epidural, $p = 0.9$), but they had more OP at delivery (13% epidural versus 3.3% no epidural, $p = 0.002$). This association remained in a multivariate model OR 4.0; 95% CI 1.4-11.1[28].

4.4 Deflected fetal neck

The second cardinal movement is flexion of the fetal head. Sometimes this movement does not occur and the fetal head enters the pelvis with the neck deflected. If the neck is hyperextended, the fetus has a face presentation. The incidence is from 1 in 500[8] to 1 in 1000[29] deliveries. The brow usually enters the pelvic canal and the position converts to a face presentation after further extension. The chin of the fetus must rotate under the symphysis pubis to enable vaginal delivery. If the neck does not hyperextend, the brow will be the presenting part. If a brow presentation persists, vaginal delivery is impossible, except for very small fetuses.

4.5 Engagement and station

The fetal head is engaged when the biparietal diameter (BPD) has traversed the antero-posterior diameter of the pelvic inlet. Flexion and descent contribute to engagement. In nulliparous women, engagement usually occurs during the last weeks of pregnancy. Clinically, engagement of the fetal head can be assessed by either abdominal or transvaginal digital examination[4]. With abdominal palpation, the fingers cannot reach the lowermost part of the fetal head. With vaginal examination, the fetal head is engaged when the presenting part is positioned at station 0. Sherer et al. compared transvaginal digital examination with TAU with a raw agreement rate of 86%[30]. Laencina et al. found fetal station to be the only factor in the Bishop score which could independently predict the probability of vaginal delivery within 60 hours in women with induced labours[31]. Dietz and Lanzarone used transperineal ultrasound (TPU) to evaluate engagement and related the fetal head to the symphysis pubis[32, 33]. Engagement and station are both evaluations of the descent of the fetal head. Engagement is a categorical evaluation (yes or no), and station is an example of numerical data, more precisely called ordered categorical data[34].

4.6 Assessment of labour progress

Progress of labour is measured in terms of advancing cervical dilatation and descent of the presenting part. The concept of station was first described by Müller in 1868. Friedman introduced the partogram in 1954[35]. In 1965, he reported a strong correlation between dilatation and station[36], and in 1976 he described an association between high station at arrest of labour and adverse labour outcome[37]. In 1982, Bersjø and Koss evaluated the interobserver agreement of digitally assessed dilatation and descent and found complete agreement or a difference of 1 cm in 90% [38]. Lewin et al. suggested using ultrasound to evaluate station in 1977 by measuring the distance from the fetal head to the sacral tip of the mother[39]. Various electromagnetic techniques and ultrasound ‘cervimetry’ for assessment of cervical dilatation have been tried[40]. However, in clinical practice assessment of the progress is still performed by subjective digital transvaginal examinations. Sherer argues in an editorial comment in Ultrasound in Obstetrics and Gynecology in 2007 for objective and repeatable methods for evaluating descent and dilataion[41].

Unfortunately the maternal ischial spines are not well depicted by TPU. Sherer has suggested measuring the distance from perineum to the fetal head, but he believes that this measure will be operator dependent and imprecise and no better than transvaginal examinations. The method has not been investigated in prospective studies. Salvesen suggested in an opinion in Ultrasound in Obstetrics and Gynecology in 2006 that three-dimensional ultrasound (3D) perhaps can document its value in assessment of the labour[42]. In a publication from 2008 Fuchs et al. demonstrate how the sutures and fontanelles can be visualized during labour using 3D ultrasound[43]. Recently Sharf et al. described a non-imaging US-based computerized system developed to provide continuous objective assessment of the progress of labour. The system is based on three-dimensional ultrasonic localization and consists of three external US transmitters/receivers. One of them is placed on the central lower abdomen and the other two at sites adjacent to the anterior superior iliac spines. The systematic error of the fetal head station measurement is estimated as 10-20%, depending on the anatomy of the mother. In addition, the clinical tests indicated that measurements of the changes of both cervix dilatation and fetal head station are feasible[44].

4.7 Rupture of the membranes

4.7.1 Preterm prelabour rupture of the membranes (PPROM)

In textbooks, PPROM is defined as the rupture of fetal membranes before 37 completed weeks and at least one hour before the onset of labour[4]. It is believed that choriodecidual infection or inflammation is an important predisposing event[45, 46]. PPROM is associated with significant maternal and fetal risks. Management requires an accurate diagnosis as well as evaluation of the risks and benefits of continued pregnancy. The treatment of pregnancies complicated by PPROM early in pregnancy should be directed towards conserving the pregnancy. Corticosteroid administration is recommended before 30-32 weeks of gestation[46]. Use of antibiotic therapy probably reduces infant morbidity[46-48]. It is not clear whether tocolysis reduces infant morbidity[46].

4.7.2 Prelabour rupture of the membranes (PROM)

The most commonly used definition of PROM is rupture of membranes after 37 weeks of pregnancy, but some use the term PROM from 34 weeks onwards. In a Swedish study, Ladfors et al. investigated risk factors for PROM from week 34-42. Risk factors were primiparity, premature contractions, PROM in a previous pregnancy and bleeding in the first trimester[49]. Ladfors et al. also investigated risk factors for neonatal sepsis. A total of 1385 women were randomized to induction the following morning after PROM (early induction group) or induction two days later (late induction group). In this study there was no difference in the incidence of neonatal infections between those with early and with late induction. Clinical neonatal sepsis was associated with time from PROM to delivery over 32 hours[50]. A higher rate of spontaneous deliveries was found among nulliparous women with prolonged latency as compared with brief latency prior to induction[51]. Tan and Hannah published a Cochrane review in 2000. The objective was to assess the effects of induction of labour with oxytocin versus expectant management for prelabour rupture of membranes at or near term (34 weeks or more). Compared to expectant management, induction of labour (IOL) by oxytocin was associated with decreased risk of maternal infection (OR for chorioamnionitis 0.63; 95% CI 0.51-0.78 and endometritis 0.72; 95% CI 0.52-0.99). There was also decreased risk of neonatal infection (OR 0.64; 95% CI 0.44-0.93). Caesarean section rates were not statistically different between groups, although the trend was towards fewer interventions with expectant management. Oxytocin was associated with more frequent use of pain relief and internal fetal heart rate monitoring[52]. The discussion continued and this Cochrane review was later withdrawn. In a new Cochrane review from 2006, planned early birth reduced the risk of some maternal infectious morbidity without increasing caesarean sections and operative vaginal births. Fewer infants went to neonatal intensive care although no differences were seen in neonatal infection rates. This review concluded that planned or expectant management was not very different, and that women need to have appropriate information to make informed choices[53].

There is no conclusion in the current Norwegian guidelines. The obstetrical department at Stavanger University Hospital has a routine policy of early IOL, that is, labour is usually induced the next morning. Thus, the usual time from PROM to induction may vary from 16 to 39 hours, depending on the time of PROM[54]. A review from 2005 concludes that misoprostol is an effective and safe agent for induction of labour in women with PROM[55].

4.8 Induction of labour (IOL)

IOL is defined as iatrogenic stimulation of uterine contractions prior to the onset of spontaneous labour. It is one of the most commonly performed obstetrical procedures. The induction rate in developed countries is now 15-20%[29, 56], and the frequency of induction is increasing[57]. IOL is associated with an increased risk of a caesarean section[58] from 14-25% in nulliparous women, and 3-5% in parous women[59]. A study from Stavanger University Hospital found the rate of operative deliveries to be almost 50% in nulliparous women with an unfavourable cervix[60], and elective labour induction for nonmedical indications is not recommended[61]. However, active management of a risk pregnancy may imply IOL, and one study has recommended induction of risk pregnancies at term, because it was associated with a significantly reduced rate of caesarean delivery[62]. Concerns about the risk of fetal demise with expectant management near term or post-term have contributed to an increased rate of induction. In general, induction should be undertaken when the benefits outweigh the risks of continuing the pregnancy[61].

The most common indications for IOL are preeclampsia, maternal diabetes, PROM, infection, fetal growth restriction, isoimmunization, post-term pregnancy, twins, suspected macrosomia and maternal request. The timing of IOL is controversial, and if a successful labour outcome could be predicted, IOL could be considered in cases with ‘soft indications’ or on maternal request[63]. Thus, any reliable methods of preinduction assessment would be valuable tools in counselling women before IOL.

A variety of maternal and fetal factors are found to predict successful IOL. These include parity[64-71], height[72], weight[72], body mass index (BMI)[27, 73-75], maternal age[74, 76, 77], Bishop score[27, 63, 65, 67, 72, 74, 78], cervical dilatation[66, 70, 72], transvaginal ultrasound (TVU) measurement of cervical length,[27, 63, 67-69, 72, 74], OP position before the start of labour[27] and biochemical markers, such as fetal fibronectin (fFN)[79] and insulin-like growth factor binding protein-1 (IGFBP-1)[80]. Rozenberg et al. emphasize that heterogeneous populations, lack of standardization of the methods of induction, different measurements and different endpoints can give conflicting results[81]. Some authors have suggested models with combinations of maternal factors and US measurements in assessment of women before the start of labour[27, 73, 82, 83].

4.8.1 Indications for induction of labour

In some clinical situations it may be necessary to terminate pregnancy. Delivery is recommended in women with preeclampsia, fetal growth restriction or when a prolonged pregnancy is considered to be dangerous for the mother or the fetus. IOL can be performed for suspected fetal growth restriction if Doppler measurements are normal, and the cervix is favourable[84]. In other situations such as diabetic women, twins or maternal request, the timing for IOL may be more difficult, and pros and cons must be balanced[61, 71]. The guidelines from the Norwegian Society of Gynaecology and Obstetrics recommend induction for diabetic pregnancies and twins at no later than 40 weeks[85, 86]. In Cochrane reviews, however, the timing for induction in the case of twins is uncertain[87], and there is no evidence to support elective delivery at term in pregnant women with insulin-requiring diabetes[88].

4.8.1.1 Prolonged pregnancy

In a randomized study from 1987 Augensen et al. compared early versus late induction of labour in post-term pregnancy[89]. They advocated a non-intervention policy. However, prolonged pregnancy is now one of the most frequent indications for labour induction[58]. In 2006, Heimstad et al. evaluated the timing of induction in prolonged pregnancies[90]. The primary aim was to compare IOL at 41 weeks with expectant management up to 43 weeks with neonatal morbidity as outcome. Secondary aims were to assess the effect on mode of delivery and maternal complications. There were no differences between induced and monitored groups regarding neonatal morbidity or mode of delivery[90]. Women preferred IOL to serial antenatal monitoring beyond 41weeks[91]. A Cochrane review from 2006 concluded that labour induction after 41 weeks compared to awaiting spontaneous labour was associated with fewer perinatal deaths. However, the absolute risk was extremely small[92].

4.8.1.2 Macrosomia

Peregrine et al. compared the accuracy of clinical and sonographic fetal weight estimation of birth weight prior to IOL[93]. The fetal weight was estimated clinically by the doctor and the woman herself. A transabdominal scan was then performed to estimate the fetal weight using the formulae from Shepard[94] and Hadlock 1984[95]. With all four methods, the estimated weight was significantly different from the actual birth weight. The corresponding proportion of the estimates within 10% of actual birth weight was 71% (doctor), 59% (woman), 62% (Shepard) and 42% (Hadlock). The sensitivity and specificity of detecting a fetus weighing > 4000 g were 16% and 99%, 29% and 96%, 48% and 92% and 40% and 94%, for the four methods respectively. US immediately prior to IOL was the best method to predict high birthweight fetuses[93].

Many women are afraid of delivering a macrosomic baby. The risk of delivering a baby weighing more than 4000 g is about 20%[96] and more than 4500 g around 5%[97]. Large fetuses are associated with increased risk of complications during labour and delivery, but IOL is not recommended[98]. In a study from Stavanger University Hospital, IOL did not change the Apgar score or diminish the frequency of shoulder dystocia. However, it did increase the frequency of operative deliveries and transfer to the neonatal intensive care unit[99]. Henriksen concluded in a meta-analysis from 2008 that current evidence shows no benefit of a policy of routine IOL because of suspected fetal macrosomia[100].

4.8.1.3 Maternal request

Modern women are used to taking control of life. Pregnancy and delivery are something a woman cannot control, and this may frighten her. Many women want to plan the delivery in relation to their own and their partner's work. Other women may feel uncomfortable towards the end of pregnancy. They may have sleeping problems or pelvic girdle pain[101]. Other women are afraid of delivery because of previous traumatic experiences, abuse or psychiatric disorders. The prevalence of serious fear of childbirth is around 6%[102]. Many women ask for a planned caesarean section without medical indication[103, 104], and the frequency of this request increases with increasing maternal age[105]. Women referred to a specialist service for fear of birth may become conscious of the causes of their fear and decide on a vaginal birth after all[106]. Often women want a timing of the delivery, and IOL may be an alternative to perform an elective caesarean section. The value of IOL as an alternative to a planned caesarean has not been scientifically evaluated[104].

4.8.2 Methods for induction of labour

Suggested methods for IOL include vaginal intercourse, heavy exercise, consumption of laxatives, nipple stimulation, homeopathy and acupuncture, but reviews conclude that there is little evidence of success of these methods[107-109]. Mechanical methods have been used for more than one hundred years and are still in use. A Foley catheter can be inserted in the cervical canal and gentle traction applied. A Cochrane review found insufficient evidence to evaluate the effectiveness of mechanical methods compared with prostaglandins, but the risk of hyperstimulation was reduced when compared with prostaglandins[110]. When the cervix is favourable, sweeping of membranes has proven effects in starting labour, but women often feel discomfort during the procedure[111].

Aksel P. Lange from Denmark evaluated IOL in a thesis from 1983. He compared the efficiency of three methods: oral prostaglandin E_2, buccal desaminooxytocin and intravenous administration of oxytocin after amniotomy[112]. In all, 21% of IOL attempts were unsuccessful. He suggested amniotomy when possible, followed by intravenous administration of oxytocin.

The effect of oxytocin was first described by Dale in 1906[113] and has been used for IOL from 1913 onwards[114]. In 1983 Sande et al. evaluated IOL with oxytocin between the 40th and 41st week of pregnancy and found it to be a safe procedure for the mother and the fetus[115]. It is still the most commonly used drug for IOL when cervix is favourable, but the drug has side effects. Ellen Blix has evaluated the use of oxytocin in a modern Norwegian delivery department[116]. A Cochrane review concluded that the effectiveness and safety of amniotomy and intravenous oxytocin in IOL are lacking, and no recommendations for clinical practice can be made on the basis of the review[117]. Hyperstimulation with use of oxytocin can generate fetal asphyxia[118] and uterine rupture[119].

When the cervix is unfavourable, the use of prostaglandins may have benefits[120]. Both prostaglandin E_2 and $F_{2\alpha}$ increase successful vaginal delivery rates within 24 hours without increasing operative deliveries[120]. However, prostaglandins increase the risk of uterine hyperstimulation[120]. Misoprostol (prostaglandin E_1 analogue) is cheap and effective, and misoprostol has no more side effects than other prostaglandins[121-124]. However, there is little interest from the manufacturer in promoting the use of this drug for IOL, and the drug will probably remain unlicensed for obstetric use. The company has declined to manufacture a 25 µg tablet (the recommended dosage for IOL), which means that the dose can only be obtained by cutting a 200 µg tablet into eight[121]. This means that the exact dose of 25 µg cannot be guaranteed. In Norway, 50% of delivery units used dinoprostone gel for IOL in 2003 and 25% used misoprostol[125].

The Norwegian Society of Gynaecology and Obstetrics has published guidelines for IOL and concluded that misoprostol has a similar effect and no increased risks compared to prostaglandin E2. However, the guideline recommends careful use in cases with previous caesarean section.[86]

At Stavanger University Hospital we recommend amniotomy and oxytocin as the method of choice for IOL if the cervix is favourable at the time of induction (Bishop score ≥ 6). When the cervix is unfavourable (Bishop score < 6), labour is induced with 25 µg misoprostol every 4th hour (maximum 100 µg in 24 hours and a total maximum dose of 200 µg) until regular contractions[54].

4.8.3 Predictive factors for labour induction

4.8.3.1 Parity

Parity is a positive predictive factor for IOL, and the importance of parity has been documented in many studies. Heffner et al. investigated 14409 women eligible for a vaginal delivery and found a caesarean delivery rate of 25% among nulliparous women and 5% among parous women after IOL[59]. In a study by Rane et al., the caesarean delivery rate was 28% versus 9% in nulliparous and parous women[68], and Tan et al. found in a multivariate logistic regression analysis that nulliparity was an independent predictor of caesarean delivery (adjusted OR 4.1; 95% CI 2.1-8.1, $p < 0.001$)[63]. Peregrine et al. found the OR for a caesarean delivery to be 20.6; 95% CI 7.97-53.05, $p < 0.001$ for nulliparous women[73]. In a study from 2007 Laencina et al., 87% of parous women delivered vaginally within 60 hours after IOL compared to 55% among nulliparous women ($p < 0.001$)[31].

4.8.3.2 Maternal age

In a study by Ecker et al. 3715 women were investigated for factors that increased the risk of caesarean delivery. Among women with spontaneous or induced labour, caesarean delivery rates increased with maternal age (8% in women < 25 years compared to 31% in women ≥ 40 years) and caesarean deliveries were more frequent in both spontaneous and induced labours[76]. In some other studies, maternal age was a predictive factor for IOL with a higher caesarean rate in older women [74, 77, 126]. In a study from Heffner et al., maternal age over 35 years was associated with an increased risk of caesarean delivery in nulliparous women, and maternal age over 40 years was associated with an increased risk in parous women[59].

4.8.3.3 Gestational age

Nassar et al. evaluated IOL in women with severe preeclampsia before 34 weeks of gestation and found a success rate of 48% for a vaginal delivery[127]. In a study from Wing et al. gestational age was an independent predicting factor for successful induction (OR 1.3; 95% CI 1.1-1.6, $p = 0.003$)[70]. Heffner et al. found that gestational age had little impact on the risk of having a caesarean delivery for either induced or spontaneously labouring parous women. However, gestational age was statistically significantly associated with caesarean deliveries among nulliparous women. Among induced nulliparous women the caesarean delivery rate was lowest between 36 and 38 weeks[59].

4.8.3.4 Body mass index (BMI)

In general, obese women are at increased risk of labour induction and a complicated labour. In a large cohort study from England, the risks of adverse outcome in obese women were studied in 287000 singleton pregnancies. In all, 62% had normal weight (BMI 20-25), 27% were moderately obese (BMI 25-30) and 11% were obese (BMI $\geq$ 30). Compared to women with normal BMI, IOL was more common in moderately obese women (OR 2.14; 99% CI 1.85-2.47), and in obese women (OR 1.70; 99% CI 1.64-1.76). Delivery by emergency caesarean section was also more common in moderately obese women (OR 1.30; 99% CI 1.25-1.34) and in obese women (OR 1.83; 99% CI 1.74-1.93). Maternal obesity carried significant risks for the mother and fetus. The risk increased with the degree of obesity and persisted after accounting for other confounding demographic factors[128].

In a study from Wales from 1990 to 1999, 60 000 women were examined. The study reported an increased risk of postdates, IOL, caesarean section, macrosomia and shoulder dystocia in obese women. The authors found IOL to be a starting point in the cascade of events[129].

Bhattacharya et al. found increasing BMI to be associated with increased incidence of pre-eclampsia, gestational hypertension, macrosomia, IOL and caesarean delivery. Underweight women had better pregnancy outcomes than women with normal BMI[130]. Doherty et al investigated the effect of maternal pre-pregnancy BMI on pregnancy outcomes and found pre-pregnancy obesity to be a risk factor for gestational diabetes, preeclampsia, labour induction, caesarean delivery for fetal distress, postpartum haemorrhage and neonatal hypoglycaemia and the need for resuscitation. Being underweight was a risk factor for fetal growth restriction[131].

In a study from Rane et al., the risk of caesarean delivery after IOL was higher in women with increased BMI (OR 1.85; 95% CI 1.24-2.74, $p = 0.0024$), but the induction to delivery interval was not increased[74]. Peregrine et al. found BMI to predict caesarean delivery in women with IOL (OR 6.17, 95% CI 2.10-18.13, $p < 0.001$)[73].

4.8.3.5 Fetal weight

In some studies fetal weight predicts a successful IOL. Crane et al. found birth weight to be an independent factor for duration of induced labours and the probability for a spontaneous vaginal delivery[126]. Vrouenraets et al. found birth weight > 3500 g to increase the risk of a caesarean delivery[75].

4.8.3.6 Cervical status

House and Socrate have described the cervix as a biomechanical structure[132]. Structural function was seen as a balance between structural strength and external loading. Cervical strength is the ability of the cervix to resist deformation or 'change' (funnelling, effacement and dilatation) and loading refers to the forces acting to cause deformation. The uterine cervix is composed of collagen, elastin, and glycosaminoglycans. The most important contributor to cervical softening is a rearrangement and realignment of the collagen, elastin, and smooth muscle cells. The cervix undergoes changes in two phases, softening and dilatation[133]. Terms applied for a strong cervix are 'unripe', 'firm' and 'unfavourable', whereas weak cervix is described as 'soft', 'ripe', 'mature' or 'favourable'. Clinically significant deformation would depend on the actual degree of deformation and the gestational age at which it occurs. The cervical status might be important when evaluating the risk of preterm delivery and when evaluating the probability for successful IOL[132].

Different types of matrix metalloproteinases are involved in the cervical ripening process[134], and successful prostaglandin E2-induced cervical ripening seems also to be related to an increase in cervical fetal fibronectin levels[79, 135].

The first cervical scoring system was suggested by Calkins et al in 1931[136]. They suggested that the intensity of contractions and the consistency, wall thickness and canal length of the cervix would predict the duration of labour. In 1941 Calkins suggested a new system based on cervical effacement, station and consistency[137]. In 1955, Cocks described five types of cervices, based on softness, effacement and dilatation[138]. Most of these assessments were by rectal examinations[72]. In 1960, Garrett characterized the cervix as ripe or unripe[139], and in 1962 Friedman assessed the cervical dilatation corresponding to the length of the latent phase of labour[140].

4.8.3.7 Bishop score

Bishop advised using vaginal examination instead of rectal examination, and in 1964 he published a scoring system based on cervical dilatation, effacement, consistency, cervical position and the station of the presenting part (table 3)[78]. Bishop concludes that elective induction may be safely and successfully performed when the score is ≥ 9.

Parameter\Score	0	1	2	3
Position	Posterior	Intermediate	Anterior	-
Consistency	Firm	Intermediate	Soft	-
Effacement	0-30%	40-50%	60-70%	80%
Dilatation	< 1 cm	1-2 cm	2-3 cm	> 3 cm
Fetal station	- 3	- 2	- 1, 0	+ 1, + 2

Table 3. Bishop's original scoring system[78]

In newer studies, a score < 6 is regarded as unfavourable and ≥ 6 as favourable[73, 75]. The Bishop score from 0-13 is an example of a biomechanical approach that incorporates both strength (consistency) and loading[132]. Many studies have demonstrated its value in predicting the outcome of labour. The induction to delivery interval, the likelihood of vaginal delivery within 24 hours and the likelihood of a successful vaginal delivery are predicted by the Bishop score[27, 63, 65, 67, 71, 72, 74, 75, 81, 141, 142]. However, the method is subjective and has limitations[67, 143-145]. An interobserver analysis showed perfect agreement in 28% of the cases. If a difference of one point between the observers was acceptable, the agreement was 66%. An informal evaluation of the cervix may be just as reliable as the Bishop score[146]. The different elements of the Bishop score have been analysed in several studies. Rane et al. found cervical dilatation, station and consistency to provide a significant contribution to the prediction of delivery within 24 hours[69]. Pandis et al. found that only the cervical length predicted the likelihood of a vaginal delivery within 24 hours[67]. Laencina et al. found that station was the only component of the Bishop score that was independently predictive of the probability of vaginal delivery within 60 hours[31]. Most studies emphasize that dilatation is the most important element of the Bishop score[64, 66, 70, 72, 147-149].

4.8.3.8 Modifications of the Bishop score

In 1966, Burnett suggested a modification of the Bishop score with a maximum score of 10 (two points per category), and found little hazard in IOL if the scoring was ≥ 6[150]. Friedman proposed a weighted scoring system with dilatation having twice the influence of effacement, station and consistency and four times that of cervical position[147]. Lange suggested using only effacement, dilatation and station[66]. Cervical effacement may be described as a percentage or as the residual cervical length in centimetres. Holcomb has recommended using the metric system for description of the cervix[151].

4.8.3.9 Ultrasound assessment of the cervix

Elghorori et al. modified the Bishop score by replacing the digital assessment of cervical length with US measured cervical length. The original Bishop score with cut-off level > 5 predicted a vaginal delivery with a sensitivity of 23 %; 95% CI 14.6-33.2 and specificity of 88%; 95% CI 63.5-98.5, while the modified Bishop score with cut-off level > 3 predicted a vaginal delivery with a sensitivity of 62%; 95% CI 51.0-72.3 and specificity of 82%; 95% CI 56.6-96.0[152].

Transabdominal, transperineal and transvaginal sonography can provide images of the cervix, but the transvaginal approach is superior to the others[153-155]. Hertzberg et al. have described the transperineal examination[155], and they suggested that hip elevation would improve the imaging quality of the cervix[156]. Some have found the agreement between the transperineal and transvaginal approach to be acceptable[157], whereas others disagree[158]. US measurements are probably more objective than digital examinations because a part of the cervix is above the vaginal fornices when the internal os is closed[72, 153].

The transvaginal examination has been described by Valentin et al.[159]. They found a substantial intra- and interobserver variability, even when experienced observers performed the measurements under standardized conditions, but they concluded that the differences were clinically acceptable[159]. The value of US has been evaluated in many studies with conflicting results. TVU performs better than the Bishop score in some studies[27, 67-69, 74], but not in others[65, 81, 109, 141]. Seven studies were included in a meta-analysis[64, 65, 68, 144, 160-162]. The author concluded that US measurements are equal to the Bishop score and called for more resarch[72]. (The most important studies will be described in detail later in this thesis: p 42-43.)

House described the cervix as a biomechanical structure and suggested using this approach. He suggested studying the cervical deformation with US[132]. A closed cervix corresponds to a ‘T’, changing to ‘Y’, ‘V’ and ‘U’ during the deformation process as described by Zilianti et al.[163]. Dynamic cervical changes during real-time ultrasound are common[164]. Cervical strength can also be evaluated by elastography, which is a promising technique that uses sonographic information to determine the mechanical properties of soft tissue. As early as 1973, Bakke suggested measuring cervical consistency with a mechanical device[165, 166]. Recently this idea has been evaluated in new studies. An ultrasound transducer can compresses the tissue, and image processing techniques can quantify this compression[132, 167].

4.8.3.10 Biochemical markers

Biochemical markers are suggested to be predictors of successful IOL. The most important markers are fetal fibronectin (fFN) and IGFBP-1.

fFN is a glycoprotein from the chorionic-decidual interface[168], and it is found to be a predictor of preterm birth[169]. fFN has also been evaluated as a predictor for IOL. In one study, an increased level of cervical fFN was found to indicate a favourable cervix[79], but other authors disagree[161]. A meta-analysis concluded that fFN was a predictor for IOL, but that it was not better than the Bishop score[72].

IGFBP-1 is released into the cervical secretions during cervical ripening, and it has been suggested as a bedside test for predicting successful labour induction in women with intact fetal membranes. The concentrations of IGFBP-1 are found to be four times higher in women with a favourable cervix (Bishop score ≥ 6)[80], but a review calls for more research[72].

4.8.4 Evaluation of labour outcome

The Cochrane database has a protocol for evaluation of IOL[170], and five primary outcomes have been chosen as the most representative of the clinically important measures of effectiveness and complications:

1. vaginal delivery not achieved within 24 hours
2. uterine hyperstimulation with fetal heart rate changes
3. caesarean delivery
4. serious neonatal morbidity or perinatal death
5. serious maternal morbidity or death

4.9 From obstetric ultrasound to ultrasonographic obstetrics

The editor in chief of Ultrasound in Obstetrics and Gynecology introduced this expression in an editorial in 2006 to emphasize the importance of the use of US in all perinatal units[171].

4.9.1 History of ultrasound

The use of US diagnostics in clinical medicine started with Ian Donald from Scotland in 1958[172] and in obstetrics and gynaecology in 1962[173]. In Scandinavia, Bertil Sundén presented the first thesis about the use of US in obstetrics and gynaecology in 1964[174]. Kratochwil from Austria used US to demonstrate fetal heart activity from the 7th gestational week in 1967[175], and Stuart Campbell (UK) measured the BPD and located the placenta by compound scanning in 1968[176, 177]. Anencephaly was the first fetal abnormality to be detected with US[174]. The University of Lund has been a leading centre for US diagnostics in Scandinavia, and they started to use US systematically in 1973.

4.9.2 Obstetrical ultrasound in Norway

Sturla Eik-Nes is the Norwegian pioneer of obstetrical US. He documented the value of routine use of ultrasound in pregnancies[178, 179]. His thesis was on the use of pulsed Doppler with combination of real-time B-mode ultrasonography for measurements of fetal blood flow [180]. He will be remembered for organizing the use of US in a rational way.

Lise Kvande has published a thesis about the history of ultrasound in Norway from 1970 to 1995[181]. She emphasized the importance of a scientific meeting in Ålesund in 1984 as a milestone in the introduction of routine US in Norway. The first Norwegian consensus conference was arranged in 1986[182]. A routine ultrasound examination around 18 weeks for dating of fetal age, diagnosing twins, locating placenta and examining fetal anatomy was recommended. Almost 98% of all pregnant women attended this examination in 1994[183]. An increasing number of fetal malformations were detected, and the ethical debate followed. A new consensus conference was arranged in 1995, and the recommendations were confirmed[184]. Midwives with special education usually perform the routine examinations.

Scientific documentation of medical technology is mandatory, and the National Center for Fetal Medicine (NCFM) in Trondheim has been the leading centre in Norway. Kjell Åsmund Salvesen evaluated the safety of ultrasound by comparing routine ultrasonography in utero and subsequent handedness and neurological development[185, 186], Torvid Kiserud published a thesis on the value of Doppler measurements of ductus venosus with fetal growth restriction[187], Katarina Tunon studied dating of pregnancies[188], Harm-Gerd Blaas studied sonoembryology[189], Christina Isaksen compared ultrasound findings and postmortem findings in fetuses and infants with anomalies[190, 191], Eva Tegnander studied fetal heart malformations[192], Anne Brantberg studied malformations in the fetal abdomen[193, 194], Runa Heimstad studied post-term pregnancies[90] and Kristin Offerdal studied prenatal ultrasound detection of anomalies in a non-selected population of almost 50 000 deliveries in Norway[195]. Researchers from other Norwegian Universities have also made important contributions. Trygve Bakke was a Norwegian pioneer who tried to evaluate the consistency of cervix as early as 1973[165, 166]. Guttorm Haugen studied the vasoactive effects of serotonin in human umbilical arteries and studied fetal liver circulation[196, 197], Ganesh Acharya studied the pulsatility index in different parts of the umbilical artery (UA)[198], Synnøve Lian Johnsen published longitudinal reference charts for growth[199], Jacob Nakling studied the use of obstetric US outside a university setting[200], Jörg Kessler studied the fetal portal vein[201], and Cathrine Ebbing studied the fetal splanchnic arteries and established longitudinal reference ranges for PI and blood flow velocities in MCA[202].

4.9.3 Safety

US in obstetrics may have side effects, and the safety of US will always remain a concern. Kjell Åsmund Salvesen published a thesis about safety, and he has participated in the ECMUS (European Committee for Medical Ultrasound Safety)[185, 203]. The possible association between US and handedness is still under debate[186]. As far as we know, US is a safe diagnostic tool in obstetrics. However, every operator should know indications for examinations, potential risks, and how to use the US devices in the safest possible way[204, 205].

4.9.4 Education

EFSUMB (European Federation of Societies for Ultrasound in Medicine and Biology) has proposed a minimum requirement for practising US in Europe[206] defined as skills at level one, two or three. In Norway, all obstetricians are educated corresponding to level one (one week theoretical course and 300 US examinations)[207].

The National Center for Fetal Medicine (NCFM) in Trondheim has a postgraduate educational programme in obstetric US for midwives which comprises theoretical and practical education (including a minimum of 800 US examinations). The skills of the first-line sonographers are essential for the quality of routine examination programmes. New methods and indications for US scanning increase the competence requirements for sonographers at all levels.

4.9.5 Ultrasound in early pregnancy

Early pregnancy failure is best diagnosed by US. It is possible to differentiate between anembryonic pregnancy, incomplete miscarriage or a missed miscarriage, and this is important for correct management[208]. US is also important to diagnose and manage ectopic pregnancies[209].

In many countries a first-trimester scan (11-13.6 weeks) is offered to all pregnant women as a routine[210]. The aim of this scan is to identify and classify multiple pregnancies, to date pregnancies, to estimate the risk of chromosomal abnormalities and to examine the fetal anatomy. In Norway, this examination is governed by a law (the Biotechnology Act)[211].

4.9.6 The routine ultrasound examination

In Norway, a routine scan is performed in the second trimester. The aims of this scan are to determine the estimated day of delivery, to diagnose multiple pregnancies and to locate the placenta. US dating has decreased the number of post-term pregnancies[178]. Today the second trimester scan also include a detailed examination of the fetal anatomy, and in a Norwegian study from 2005 about 40% of malformations were detected at the second trimester scan[200].

4.9.7 Ultrasound in the third trimester

McKenna et al. evaluated the effect of two US examinations in a low-risk antenatal population. Scans were performed at 30-32 weeks' gestation and again at 36-37 weeks' gestation. They found a reduced risk of growth-restricted infants and an increase in antenatal interventions[212]. Routine US examinations in the third trimester are not recommended in Norway[2]. However, US examinations are important in many clinical situations.

A common indication for US examination in the third trimester is to determine fetal presentation. In obese women it may be difficult to determine fetal presentation by manual examination. Sonography may also be used to examine fetal wellbeing by estimating growth[213], fetal movements and amniotic fluid volume in women with suspected fetal growth restriction, and the value of Doppler examinations in the UA, MCA, uterine arteries and ductus venosus is well established[84, 187, 214]. In women presenting with absent fetal movements, US helps to confirm or exclude fetal death.

4.9.8 Scanning for cervical incompetence

The likelihood of preterm delivery may be assessed by US examinations in the late second trimester[215, 216]. In an opinion in Ultrasound in Obstetrics and Gynecology in 2003 Valentin stated that there was no current evidence to support US screening of the cervix in early or mid-gestation pregnancies[217]. Crane and Hutchens published a systematic review in 2008. They concluded that cervical length measured by TUS in asymptomatic high-risk women predicted spontaneous preterm birth before 35 weeks gestation. Cervical length < 25 mm was the most commonly used cut-off level[218].

In women with short cervical length (≤ 15 mm at 23 weeks) a Shirodkar suture may reduce the risk of preterm delivery[219]. In one meta-analysis, cerclage prevented spontaneous preterm birth before 34 weeks of gestation[220]. However, a Cochrane review did not confirm this conclusion[221]. In a study from 2007, spontaneous delivery before 34 weeks of gestation was less frequent in women receiving vaginal progesterone from 23 to 34 weeks compared to a placebo group (19.2% vs. 34.4%; RR 0.56; 95% CI 0.36-0.86, p = 0.007). Progesterone was associated with a nonsignificant reduction in neonatal morbidity (8.1% vs. 13.8%; RR 0.59; 95% CI 0.26-1.25, p = 0.17). There were no serious adverse events associated with the use of progesterone[222]. In 2008 Smith et al. found a long cervix at mid-pregnancy to be an independent predictor of the risk of caesarean delivery at term in nulliparous women[223].

4.9.9 Ultrasound measurements as predictive factors of induction of labour

4.9.9.1 Fetal head position

Rane et al. investigated the value of OP position before IOL and found it to be a predictive factor for caesarean delivery, the induction to delivery interval, and the likelihood of delivering within 24 hours[27]. Peregrine et al. came to the opposite conclusion. They examined 289 women with US and found OP in 97 (36%) women before IOL. Only 8% of these fetuses were in OP at delivery. Of 25 fetuses in OP at delivery, 68% occurred due to a malrotation from a non-OP during labour. They concluded that there is sparse clinical value in determining the fetal head position before IOL[224].

4.9.9.2 Posterior cervical angle

Paterson-Brown et al. (1991) assessed 50 women with TVU and found a posterior cervical angle greater than 70 degrees to be a predictive factor for vaginal delivery[225]. Rane et al. found the posterior cervical angle to be predictive for the induction-to-delivery interval and the likelihood of delivering within 24 hours[27].

4.9.9.3 Cervical wedging

Bartha et al. compared TVU with the Bishop score for the choice of induction agent in 80 women. Prostaglandins were used if the cervix was unfavourable. In one group of 40 women, the cervix was classified as unfavourable if the Bishop score was < 6. In another group of 40 women, US classified the cervix as unfavourable if the cervical length was > 30 mm with cervical wedging of < 30% of the total cervical length. In the Bishop score group, 85% of women received prostaglandin due to an unfavourable cervix. In the US group, 50% of women received prostaglandins due to an unfavourable cervix (p = 0.001). The authors concluded that the use of TVU reduced the need for intracervical prostaglandin treatment without adversely affecting the success of induction[226]. Hatfield et al. found cervical wedging to be a useful predictor with positive LR of 2.64 and a negative LR of 0.64 for a successful IOL[227].

4.9.9.4 Cervical length

Seven studies were included in a meta-analysis (2006) to assess whether US measured cervical length was better than the Bishop score in predicting IOL[72].

1. Gonen et al. included 86 women. In a logistic regression model only the Bishop score and parity were significantly correlated with successful induction and the duration of labour. They concluded that transvaginal ultrasonographic evaluation of the cervix before IOL did not improve the prediction of cervical inducibility obtained by the Bishop score[65].
2. Chandra et al. compared TVU and digital cervical examination in predicting successful induction in post-term pregnancy in 122 women. The primary outcome was the rate of vaginal delivery, and no US characteristics had predictive value[64].
3. Gabriel et al. compared the Bishop score and transvaginal sonographic measurement of cervical length to predict the mode of delivery after IOL in 179 patients. Ultrasound-measured length of the cervix was a better predictor of the risk of caesarean delivery compared with the Bishop score. In women with an unfavourable Bishop score, a cervical length of < 26 mm was associated with a lower risk of caesarean delivery and shorter duration of labour[160].
4. Reis et al. included 134 women before IOL. Only obstetric history and digital examination predicted vaginal delivery within 24 hours, and both factors were independently associated with labour duration. US measurements failed to predict the outcome of induced labour[161].
5. Rane et al. examined the effect of parity and cervical length in 382 women undergoing IOL. Successful vaginal delivery within 24 hours of induction occurred in 67% of the women and the cervical length was significantly associated with the induction-to-delivery interval and the rate of vaginal delivery within 24 hours. Parity provided a significant independent factor. Sonographically measured cervical length was better than the Bishop score and vaginal examination of cervical length in predicting the outcome of induction[69].

6. Yang et al. evaluated 105 women undergoing IOL. Induction of labour was successful in 93 (89%) women. Cervical length was better than the Bishop score for predicting successful labour induction[162].
7. Roman et al. compared the Bishop score and US cervical parameters for predicting failed labour induction in 106 women when the cervix was unfavourable (Bishop score ≤ 5). Compared with the Bishop score, cervical length by US was not a better predictor for the outcome of IOL. The authors emphasized the limited value of the Bishop score[144].

Some recent studies from 2006 to 2008 are also important. Tan et al. compared transvaginal sonography for cervical length measurement and digital examination for Bishop score in 249 women undergoing IOL. Transvaginal sonography was significantly less painful than digital examination. Analyses of the ROC curves for cervical length and Bishop score indicated that both were predictors of caesarean delivery (61%; p = 0.012 under the curve area vs. 60.7%; p = 0.015; vs., respectively) with optimal cut-offs for predicting caesarean delivery of cervical length > 20 mm and Bishop score ≤ 5[63].

Laencina et al. compared the Bishop score and TVU to predict successful IOL in 177 women, and tried to estimate the most useful cut-off points for the two methods. Multiple regression analysis showed that the Bishop score and cervical length were predictive factors for the likelihood of delivering vaginally within 60 hours. Station was the only component of the Bishop score that provided an independent contribution in the prediction of a vaginal delivery within 60 hours. The best cut-off points for predicting successful induction using ROC curves were 24 mm for cervical length and 4 for the Bishop score. Cervical length was a better predictor than the Bishop score (sensitivity and specificity of 66 and 77% versus 77 and 56%, respectively)[31].

Vankayalapati et al. studied ultrasound-measured cervical length as a predictive factor in prolonged labours. They found cervical length to be a independent predictor of the likelihood of the onset of spontaneous labour in nulliparous women, and of successful vaginal delivery in both nulliparous and parous women[228]. Strobel et al. found the Bishop score and ultrasound-measured cervical length to have similar ability to predict the time to spontaneous onset of labour in prolonged pregnancies[229].

In a review from 2007, Hatfield et al. found cervical length to predict successful IOL (LR 1.66; 95% CI 1.20-2.31) and failed induction (LR 0.51; 95% CI 0.39-0.67). However, they concluded that sonographically measured cervical length was not an effective predictor of successful IOL[227].

4.9.9.5 Cervical volume and vascularization

In the future, 3D ultrasound during labour may become an important diagnostic tool[42]. Reference data regarding the cervix has been published, but no clinical value has yet been determined[230]. Rovas et al. examined women undergoing IOL with prostaglandin in prolonged pregnancies. Sonographically measured cervical length, Bishop score, and parity were related to the success of labour induction, whereas cervical volume and 3D power Doppler examination were not[231]. They also investigated the predictive value of 3D ultrasound with power Doppler examination to predict time to spontaneous onset of labour or time to delivery in prolonged pregnancies. Vascularization of the cervix was related to cervical ripening, but the examination was a complex method with no substantial improvement in prediction compared with use of the Bishop score or ultrasound-measured cervical length[232]. In a new study using 3D US in women with prolonged pregnancy the same authors did not find any cervical changes during the last week before spontaneous start of labour[233].

4.9.10 Scanning at the labour ward

Even during labour it may be difficult to determine the fetal presentation. US examination will easily give the correct answer. The presentation of the second twin can also be confirmed by US, and US is essential in the process of leading the second twin into a longitudinal lie during labour.

In women with vaginal bleeding, US is useful to localize the placenta[234]. The incidence of placenta accreta is increasing, and both US and magnetic resonance imaging (MRI) can confirm the diagnosis preoperatively. In one study, US predicted placenta accreta in 30 of 39 of women, and ruled out placenta accreta in 398 of 414 without placenta accreta (sensitivity 77% and specificity 96%)[235]. Placental abruption is a clinical diagnosis, but sometimes a retroplacental haematoma may be seen on US examinations[236].

There are only a few studies on the value of US scanning in the labour ward, and there is a danger in extending US use to new situations and indications before its value has been evaluated in studies[236].

Saito et al. investigated whether the change in cervical length during a uterine contraction could predict the progress of labour. They used TVU in the first stage of labour and described the degree of cervical shortening during the contraction relative to the cervical length before contraction. The cervix was shortened in length by about 50% on average during a uterine contraction in the normal course of labour. The degree of cervical shortening was significantly greater in the normal latent and active phases than it was in the prolonged latent phase. US observation of the cervix during uterine contractions helped to differentiate between inefficient and normal uterine contractions and could predict the course of labour[237].

4.9.10.1 Amniotic fluid volume

Moses et al. estimated the amniotic fluid volume as an admission test in 499 women. Women were randomized to have the amniotic fluid assessed by amniotic fluid index (AFI) or by the presence of a 2 x 1cm single pocket. Oligohydramnios was diagnosed in 25% in the AFI group compared to 8% in the single deepest pocket group ($p < 0.001$). Both techniques failed to identify patients who later underwent amnioinfusion for fetal distress ($p = 0.86$), had variable decelerations ($p = 0.21$) or late decelerations ($p = 0.21$) during delivery, fetal distress in labour ($p = 0.22$), caesarean delivery for fetal distress ($p = 0.13$) or admission to the neonatal intensive care unit ($p = 0.69$). Neither the AFI group nor the single deepest pocket technique could identify pregnancies at risk for adverse outcome[238].

4.9.10.2 Biophysical profile

Manning et al. described a biophysical profile (BPP) score including five fetal biophysical variables: fetal breathing movements, fetal movements, fetal tone, qualitative amniotic fluid volume and the non-stress test (CTG)[239]. Kim et al. investigated its value during labour. The BPP was examined prospectively in 100 normal singleton pregnancies in active labour. The BPP was not influenced by the use of oxytocics, prostaglandins or epidural analgesia. Fetal breathing movements (95% vs 71%; $p = 0.002$) and gross fetal movements (98% vs 84%; $p = 0.04$) decreased with the rupture of amniotic membranes. A BPP score of 6/10 or less in labour was associated with a RR for caesarean delivery of 8.0; 95% CI 2.4-26.5. In a multivariate analysis, fetal movements and amniotic fluid volume were the two most important variables in predicting the need for caesarean delivery. Kim et al. concluded that the BPP score was better than cardiotocography (CTG) for predicting the need for caesarean section and admission to the neonatal intensive care unit[240]. A Cochrane review from 2008 concluded that there is insufficient evidence from randomized trials to support the use of BPP as a test of fetal wellbeing in high-risk pregnancies[241].

4.9.10.3 Position

Sherer et al. compared digital examination with US to detect fetal head position during first and second stages of labour. In these studies, the examiners failed to determine the position of the fetal head in 76% of women by digital assessment during the first stage of labour and 65% during the second stage[19, 20]. The clinical value of determining fetal head position is probably not important during a normal labour, but it may be of value in labours with failure to progress.

Kreiser et al. used both transabdominal and transperinal US to detect the fetal head position in the second stage and compared the results with digital examination. The error rate in detecting fetal occiput position was significantly lower using the US technique (6.8%) compared to vaginal examination (29.6%, p = 0.01). Parity, BMI and fetal weight did not influence the error rate[18].

Souka et al. assessed the feasibility of US for determining the fetal head position during labour and compared it to digital examinations. Assessment of the fetal head position by digital examination was not possible in 122 (61%) of 201 cases in the first stage of labour and 41 (31%) of 133 cases in the second stage of labour. In cases where assessment by vaginal examination was possible, the correlation with US was fair in the first stage of labour (kappa = 0.59) and good in the second stage of labour (kappa = 0.77). Overall, the digital fetal head position assessment was accurate in 31% of the cases in the first stage and 66% of the cases in the second stage of labour. Rotation of the fetal head was highly unlikely when labour started in the OA position. Persistent OP position developed through failure to rotate from an initial OP or transverse position[13].

Akmal et al. investigated the accuracy of determining fetal head position by digital examination before instrumental delivery. US was considered to be the ‘gold standard’. The digital examination was considered to be correct if the fetal head position was within + /- 45 degrees of the US findings. Digital examinations failed to identify the correct position in about one quarter of cases[15]. An exact knowledge of the fetal head position is important before the use of forceps.

US may also help the obstetricians to place the vacuum cup close to the flexion point of the fetal head. Wong et al. investigated whether the accuracy of vacuum cup placement could be improved by intrapartum US assessment. The distance from the flexion point to the position of the vacuum cup was 2.1+ /- 1.3 cm in the group with digital examination and US assessment and 2.8+ /- 1.0 cm in the group with digital examination alone. The difference in the mean distance between the two groups was statistically significant (p = 0.04)[242].

Rozenberg et al. compared the learning curve for TAU with digital examination in determining the fetal head position and found that the learning curve and accuracy of determination were easier and better with TAU[243].

4.9.10.4 Engagement and station

In 1977, Lewin et al. described a US measuring of the distance from the head to the sacral tip. They obtained 453 examinations before and during labour. The aims were to make the Bishop's score more precise, permit a more accurate check of trial of labour and help to recognize a low station correctly before an application of forceps[39].

Grischke, Dietz and coworkers described the method of TPU in 1986[244]. Dietz and Lanzarone evaluated two different TPU methods in evaluating engagement. They assessed 139 women before the start of labour between week 35 + 3 and 40 + 4. In the first proposed method, they employed a line through the inferioposterior symphyseal margin parallel to the main transducer axis as a reference, and measured the minimum distance between this line and the presenting part. In their second method, they used a line vertical to the central axis of the symphysis pubis as a reference point, and measured the distance between this line and the presenting part (figures 28 and 29). US measurements correlated with abdominal palpation, the Bishop score and vaginal assessment ($p < 0.001$). Reproducibility was highest for the second method[33], and head engagement ($p < 0.0001$) was significantly associated with delivery mode[83].

Sherer et al. compared transvaginal digital assessment of fetal head engagement with TAU. They considered the head to be engaged if the leading part of the fetal head was positioned at station 0 or lower by digital examination. The head was considered to be engaged if the BPD was below the pelvic inlet by TAU examination. Digital examinations were consistent with US in 86% of cases[30].

Henrich et al. defined maternal and fetal landmarks sonographically and evaluated the use of US in twenty women immediately before a vacuum extraction. Landmarks were[245]:

1: The ‘infrapubic line’ perpendicular to the long axis of the pubic joint and extending dorsally from its inferior margin in a mid-sagittal plane.

2: The widest fetal head diameter and its movement with regard to the infrapubic line during pushing, and

3: The ‘head direction’ with respect to the long axis of the symphysis.

Eleven of the 20 vacuum deliveries had the fetal head below the infrapubic line, and resulted in successful (‘simple’ or ‘moderately difficult’) operative deliveries. Lack of descent or lack of passage below the infrapubic line and horizontal or downward head direction were poor prognostic signs. They concluded that US provided objective information on the dynamics of the second stage of labour, head station and head direction and may be useful to assess the prognosis for successful operative vaginal delivery[245].

4.9.10.5 Caput succedaneum

The sonographic detection of caput succedaneum (subcutaneous edema) was described in 1986[246]. The occurrence of caput succedaneum is more common in cases with oligohydramnios and prolonged labour, but the clinical value of detection of caput succedaneum is still unclear[41].

4.9.10.6 Nuchal cord

A nuchal cord is defined as an umbilical cord that can be visualized 360 degrees around the fetal neck. In a study from Peregrine et al. a nuchal cord did not increase the risk of caesarean section or poor neonatal outcome in women with IOL[247]. Ghosh et al. evaluated post-term pregnancies with nuchal cord and found no increased risk of fetal distress or operative interventions[248]

4.9.10.7 Myometrical thickness

Buhimischi et al. used TAU in 52 pregnant women at term to investigate any dynamic changes in myometrical thickness during the second stage of labour and immediately after delivery. They found a significant and widespread thinning of the myometrium during active labour. Descent of the fetal head during the second stage of labour was associated with a relative thickening of the anterior and fundal myometrium. After delivery this relationship was reversed[249].

4.9.10.8 Intrapartum Doppler measurements

Doppler examinations during labour are not used in clinical practice. Maesel et al. examined blood flow velocity waveforms in the middle cerebral artery (MCA) during labour. The maximum velocity waveforms were recorded before, during and after uterine contractions and analysed for pulsatility index (PI). No differences in the PI were found with regard to uterine contractions. The results suggested an unchanged peripheral resistance in the fetal cerebral vascular bed during the first stage of normal labour[250]. Yagel et al., on the other hand, found a 40% reduction of MCA blood flow impedance among fetuses in labour compared with control fetuses who were not in labour[251]. Li et al. investigated 82 term pregnancies with possible fetal growth restriction. They recorded simultaneous electronic fetal heart rate (CTG) and Doppler measurements of PI in the UA and the MCA during basal conditions and during uterine contractions and relaxations. During acute hypoxic stress, the fetuses developed a centralization of blood flow to the brain at expense of the umbilicoplacental blood flow[252]. Tadmor et al. investigated UA velocity waveforms before, during, and after 20 episodes of variable decelerations during the active stage of labour in 8 women. During 50% of the decelerations, the UA resistance increased significantly ($p < 0.01$). They suggested that it could be possible to differentiate between two groups of decelerations: decelerations caused by UA occlusion and decelerations caused by fetal hypoxia[253]. Krapp et al. demonstrated significant differences in fetal ductus venosus blood flow waveforms during and between labour contractions in 78 women[254]. Fu and Olofsson compared blood flow velocities in ductus venosus with blood flow in UA and brain-sparing in MCA during uterine contractions[255]. However, the use of Doppler measurements has not yet found a role during labour[41].

4.9.10.9 The third stage of labour

The use of US during the third stage of labour has not been sufficiently evaluated. In an editorial, Herman recommended that clinicians turn on the scanner in cases with complicated third stages[256]. The normal third-stage labour has four phases[257]:

1: latent phase, characterized by thick, placenta-free wall and thin, placenta-site wall

2: contraction phase, with thickening of placenta-site wall (from < 1 cm to > 2 cm)

3: detachment phase, in which the placenta completes its separation and detaches

4: expulsion phase, with a sliding movement of the placenta

Mo and Rogers used ultrasound imaging to visualize the uteroplacental separation[258]. The visualized sliding of the placenta may be important. In cases of a prolonged third stage, traction of the cord should only be applied when a sliding movement of the placenta is observed[257]. Krapp et al. described the normal and abnormal third stages of placental separation using colour Doppler sonography. In 57 cases with clinically normal placental separation, blood flow between placenta and myometrium ceased immediately after delivery of the fetus. In four cases with placenta accreta, they observed maternal blood flow from the myometrium deep into the placenta beyond the latent phase[259].

5 Aims

5.1 Study one

The aim of the study was to examine the value of TAU in a group of women with prelabour rupture of membranes (PROM). We wanted to evaluate the proportion of fetal head rotation from OP to OA during labour and to study whether OP before labour was associated with a higher risk of operative deliveries and a longer duration of labour.

5.2 Study two

The aim of the study was to evaluate whether TPU measurements (fetal head-perineum distance, cervical length and distance from internal os to perineum) after PROM were associated with time from PROM to delivery and operative deliveries.

5.3 Study three

The aims of the study were to evaluate fetal head-perineum distance measured by transperineal ultrasound as a predictive factor for IOL and to compare this distance with maternal factors, the Bishop score and ultrasound measurements of cervical length, posterior cervical angle and OP.

5.4 Study four

The aims of this study were to correlate the elements of the Bishop score with sonographical measurements and to discuss how predictive factors for IOL can be combined in a clinical setting.

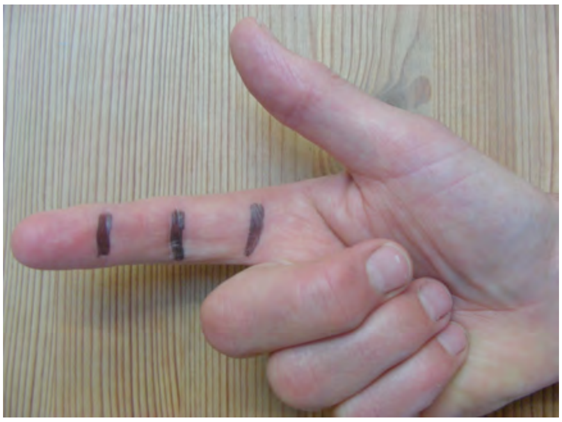
6 Subjects and methods

6.1 Subjective or objective methods

Galileo Galilei stated: *'Measure everything possible and try to measure what is not possible yet.'* The metric system is well established among carpenters (figure 18), but in obstetrics and gynaecology subjective palpation has a long tradition. Few years ago, the size of cysts were described as mandarins, oranges, grapefruits or melons (figure 19), but the value of US in evaluating adnexal tumours is well established today[260].

Figures 18 and 19. Subjective or objective methods?

US has not yet established a position during labour. Almost all assessments are done by digital examinations. When will US find its place in the delivery room (figures 20 and 21)?



Figures 20 and 21. Digital examination or ultrasound measurements?

Data were collected prospectively in two different groups of women. The studies were observational studies.

6.2 Women with prelabour rupture of membranes

TAU and TPU examinations were performed in 154 women who presented at the delivery unit from October 1st 2003 to January 31st 2005. During this 16-month period, 415 (7.7%) of 5391 term deliveries presented with PROM. Women were eligible for the studies if they had a live singleton pregnancy with cephalic presentation and a gestational age longer than 37 completed pregnancy weeks according to a mid-trimester scan. Two women were excluded because of breech presentation. In all, 152 (37%) of 415 eligible women were included.

In this period the obstetrical department had a routine policy of early IOL, that is, labour was usually induced the next morning. Thus, the usual time from PROM to induction varied from 16 to 39 hours depending on the time of PROM. If the cervix was favourable (Bishop score $\geq$ 6), labour was routinely induced with oxytocin. If the cervix was unfavourable (Bishop score < 6), labour was induced with 50 µg misoprostol every 6th hour until regular contractions or with a slow-release vaginal device with 10 mg dinoproston (PGE2) / 24 hours in women with previous caesarean section. The methods of IOL were according to the management protocol of the hospital introduced in 1999.

6.3 Induction of labour

In all, 5487 women delivered at Stavanger University Hospital from January 2006 to March 2007. Women were eligible if they had a live singleton pregnancy with cephalic presentation and a gestational age of more than 37 completed pregnancy weeks according to a mid-trimester scan. Women with a previous caesarean section were not eligible. In the study population 710 (14%) of 4918 women had IOL, and 275 (39%) of them were included in the study. The main reason for non-inclusion was unwillingness to participate.

The routine method of induction in women with an unfavourable cervix was changed in the department (October 1st 2005) before the start of the study. The decision to change induction methods was independent of the ongoing research.

Labour was induced with amniotomy followed by oxytocin if the cervix was favourable (Bishop score $\geq$ 6). If the cervix was unfavourable, labour was induced with 25 µg misoprostol applied vaginally every 4th hour (maximum 100 µg in 24 hours and a total maximum dose of 200 µg) until regular contractions.

6.4 Ultrasound methods

6.4.1 Transabdominal ultrasound (TAU)

A suprapubic US examination was done before the women with PROM had regular contractions (study one) and before IOL (study three). All examinations were performed with the woman in the supine position with empty bladder. Three obstetricians and five specially trained midwives did the sonographic measurements with EUB Hitachi or B & K Medical Hawk devices with 3.5-7.5 MHz multifrequency transducers.

6.4.1.1 Fetal head position

In a transverse US view, the mid-cerebral echo, cerebellum, the orbits, thalamus or the cavum septum pellucidum were located to determine the position of the head. The fetal head position was classified as occiput anterior (OA), left occiput transverse (LOT), occiput posterior (OP) or right occiput transverse (ROT) according to Akmal et al.[16] and Rane et al.[27]. A clock-like circle was used, and the results were stratified in groups of ‘half an hour’ instead of ‘15 minutes’ as used in Akmal's study. LOT was from 02.30 to 03.30, OP from 04 to 08, ROT from 08.30 to 09.30 and OA from 10 to 02 (figure 22). Examples are demonstrated in figures 23 and 24. Determination of fetal head position was successfully performed in all women. Movements of the fetal head were observed in 30% of cases in the PROM study.

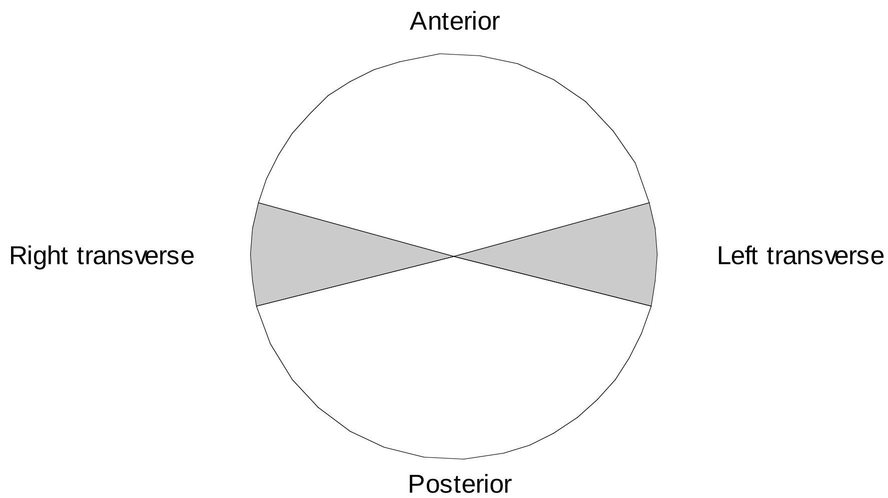
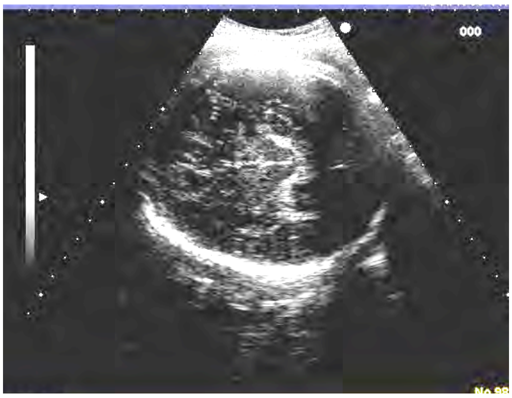


Figure 22. Description of occipital position

Figures 23 and 24. Fetuses in left occiput transverse position (left) and occiput posterior position (right).

Akmal et al. investigated the interobserver agreement in 60 pregnancies. The observers had complete agreement of the fetal occipital position in 22 (37%) of 60 cases and disagreement by 15 degrees and 30 degrees in 31 (52%) and seven (12%) cases, respectively. The 95% limits of agreement were -28.9 degrees (-32.2 to -25.6) to 29.4 degrees (26.1 to 32.7)[17].

6.4.1.2 Flexion of the neck

In a longitudinal view the degree of flexion of the neck was determined by drawing a line through the cervical spine from C1 to C7 and a line through the occipital bone (study one). A flexion angle ≥ 90 degrees was defined as indicating a flexed neck, and angle < 90 degrees as a deflected neck. A fetus with 90 degrees of neck flexion is demonstrated in figure 25.

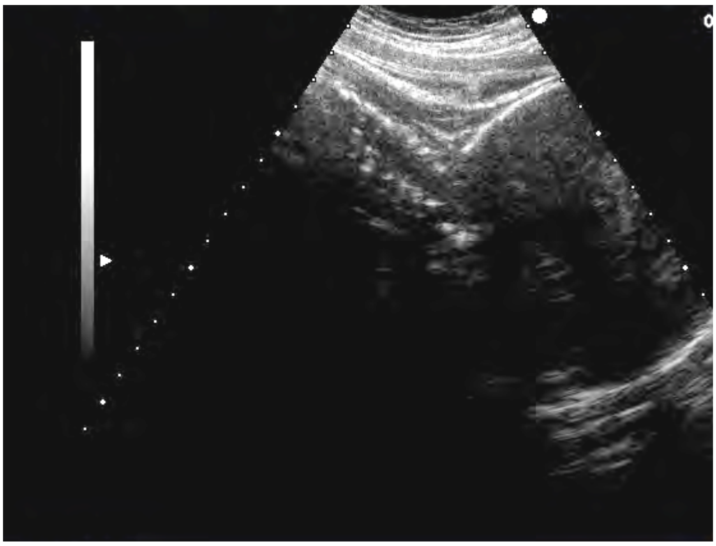


Figure 25. Fetus with 90 degrees flexion in the neck

Measurements were successfully performed in all women. This method had not been previously published, and we assessed the interobserver agreement in 23 cases. The classification of neck flexion was within 10 degrees in 87 % of cases. Limits of agreement of interobserver variation of neck flexion was + 16.5 to - 21.3 degrees.

6.4.2 Transperineal ultrasound (TPU)

Three obstetricians and five specially trained midwives did the sonographic measurements with EUB Hitachi or B & K Medical Hawk devices with 3.5-7.5 MHz multifrequency transducers. TPU examinations were performed with the woman in supine position and with empty bladder. All measurements were repeated three times, and the mean value was calculated. In the PROM study, movements of the fetal head were observed in 50% of cases.

6.4.2.1 Sagittal examination

The cervical length and the distance from the internal cervical os to the perineum were measured in a sagittal view (study two) (figure 26). The exact localization of the internal and the external cervical os in the sagittal view was not possible to determine in 16% of women because of shadowing from gas in the rectum, even though a hip elevation technique was used[156].

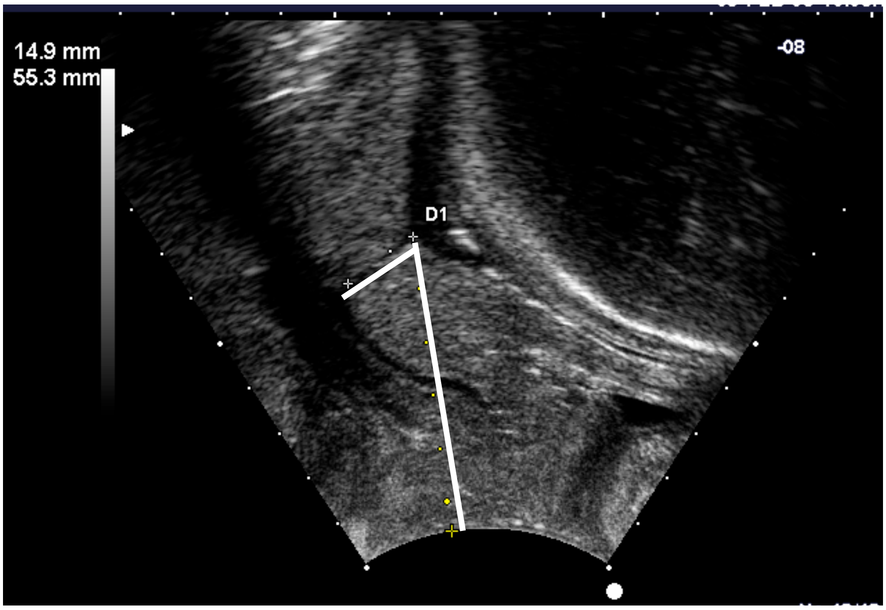


Figure 26. Transperineal examination of the cervical length and the distance from the internal cervical os to the perineum

6.4.2.2 Transverse examination

The distance from the outer bony limit of the fetal skull to the skin surface of the perineum was measured in a transverse view (study two, three and four) (figure 27). In the transverse view the probe was held over the ischial tuberosity with a firm pressure without creating any discomfort for the woman. The probe was positioned to measure the shortest distance from the fetal head to the perineum (fetal head-perineum distance). This distance was successfully measured in all women.

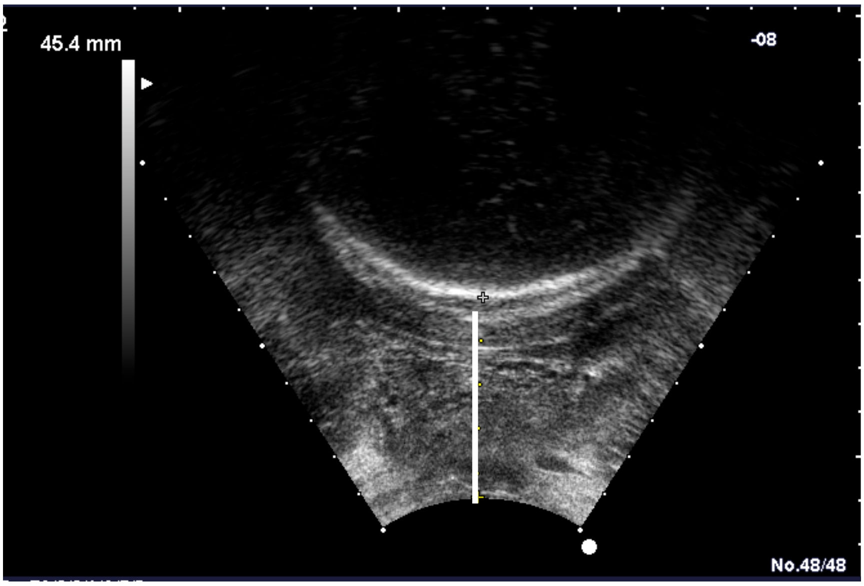


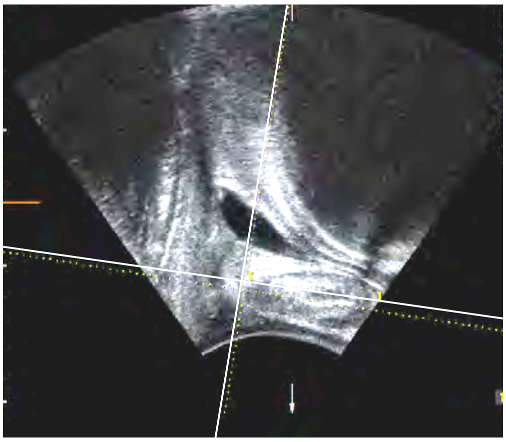
Figure 27.Transperineal measurement of the fetal head-perineum distance.

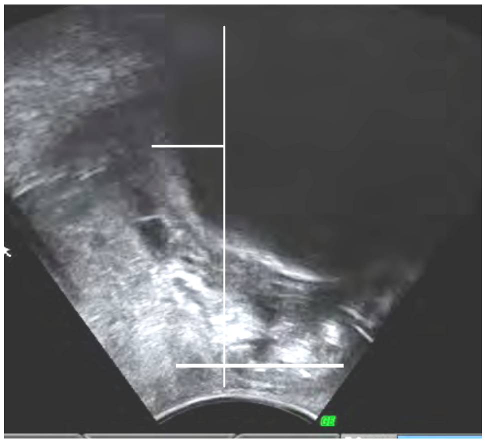
This method was not previously published, and the intra- and interobserver agreements were assessed in 23 cases. The intraobserver variation was within 3 mm in 20 of 23 (87%) women, and the interobserver variation was within 3 mm in 14 of 23 (61%) women**.** Limits of agreement for intraobserver variation were -3.0 to +5.3 mm, and for interobserver agreement -8.5 to +12.3 mm.

6.4.2.3 Engagement related to the symphysis pubis

Dietz and Lanzarone evaluated fetal head engagement by relating the fetal head engagement to the symphysis pubis. They used a line vertical to the central axis of the symphysis pubis placed through the inferioposterior symphyseal margin as a reference, and measured the distance between this line and the presenting part (figures 28 and 29). They investigated the intra- and interobserver variability in 30 women and found the intraobserver interclass correlation to be 0.93, and the interobserver interclass correlation to be 0.80[32].

We tried to use this method, but found it difficult to visualize the entire symphysis pubis and the presenting part simultaneously, and it was difficult to place an exact line through the symphysis pubis. The touching point of the line vertical to the inferioposterior symphyseal margin was far from the symphysis, and a small inaccuracy in the angle resulted in large variability of the results. We believe that our proposed measurement of fetal head-perineum distance to evaluate fetal head engagement or descent is easier to perform for non-experts.





Figures 28 and 29. The distance between the fetal head and a line vertical to the central axis of the symphysis pubis placed through the inferoposterior symphyseal margin is measured. In the left picture the distance is zero, and in the right picture the short line illustrates the distance (the fetal head is below the reference line and at a lower level than in the right picture).

6.4.3 Transvaginal ultrasound (TVU)

The TVU examinations (study three and four) were performed with EUB Hitachi devices with 5.0-9.0 MHz multifrequency transducers. Two obstetricians and three specially trained midwives did the sonographic measurements. All measurements were repeated three times, and the mean value was calculated. Neither fundal nor suprapubic pressures were applied.

6.4.3.1 Cervical length

The cervix was evaluated by TVU without applying pressure to the cervix. The cervical length was measured as described by Valentin et al. (figure 30)[159]. Only the segment of the cervical canal that was bordered by the endocervical mucosa was included. We did not measure cervical width or cervical wedging.

Valentin and Bergelin have evaluated the intra- and interobserver reproducibility of cervical length measurements in 20 women. The repeatability coefficient was + /- 5.4 mm for observer one and + /- 5.9 mm for observer two. The intraclass correlation coefficient was 0.93 for both observers. The interclass correlation coefficient was 0.76, the mean interobserver difference was 0.4 mm, and the limits of agreement were - 10.0 mm to + 10.8 mm. There was no systematic difference between the first, second and third cervical length measurements. The authors conclude that there was substantial intra- and interobserver variability in the results of measurements of cervical length, even when experienced observers performed the measurements under standardized conditions[159].

Figure 30. Transvaginal measurement of the cervical length

6.4.3.2 Posterior cervical angle

The posterior cervical angle was assessed as described by Rane et al.[27]. The angle was measured with a protractor applied to a hard copy of a picture taken in a sagittal plane at the level of the internal os and approximated to the nearest 10 degrees (figure 31). In the case of funnelling or a curved cervix, the angle was assessed at the junction of the line measuring the cervical length and posterior uterine wall.

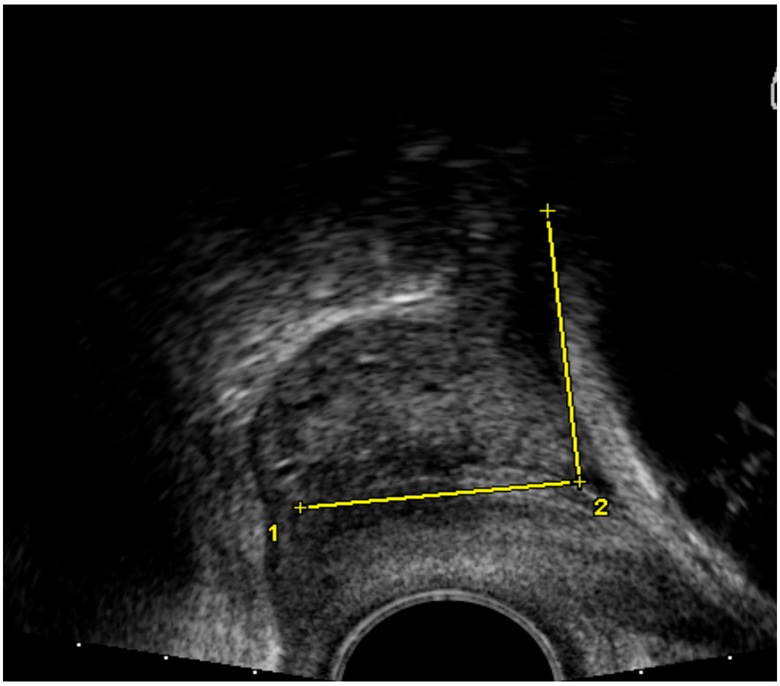


Figure 31. Transvaginal measurement of the posterior cervical angle

6.4.3.3 Cervical dilatation

The cervix was considered to be dilated at US examination if the cervical mucosa on the anterior and posterior part of cervix were separated. The shortest distance between the borders was measured. The cervical length was measured on the anterior border (figure 32).

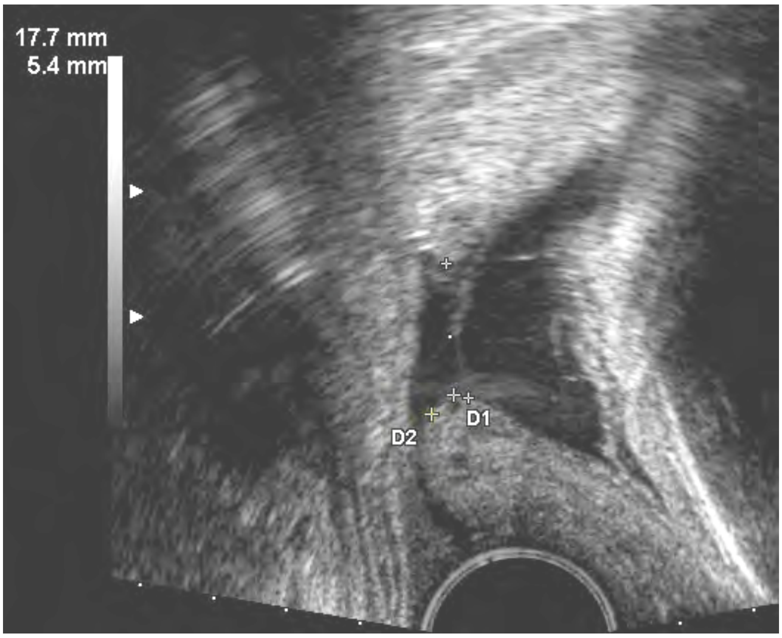


Figure 32. Transvaginal measurement of cervical dilatation and length

6.5 Statistics

6.5.1 Methods

In study 1 and 2, Mann Whitney U test, chi-square test, Fisher's test of exact probability, Pearson correlation, Kaplan-Meier survival analysis and Cox regression analysis were used for comparisons. P-values < 0.05 were considered significant. Limits of agreement were estimated based on the procedure described by Bland and Altman[261].

The time from PROM to delivery was the dependent variable in a Kaplan-Meier survival analysis and a Cox regression analysis. Women experiencing induction, operative delivery or a time to delivery > 36 hours were censored. In the multivariable Cox regression analysis US measurements, parity, maternal age, BMI, gestational age, birth weight and head circumference were investigated as potential predictive or confounding factors.

In study 3, Mann Whitney U tests, chi-square tests, Fisher's test of exact probability and Pearson's correlation test were used. The predictive value for vaginal delivery from maternal factors, US measurements and the Bishop score was evaluated using receiver operating characteristics (ROC) curves, and the area under the curve was used as the discriminator. Area of 100% implies a perfect test (100% sensitivity and specificity), whereas area of 50% describes a useless test, equal to flipping a coin. The induction-to-delivery interval within 24 hours was evaluated using Kaplan-Meier survival analyses and Cox regression analyses. In the Cox regression analyses, fetal head-perineum distance, cervical length, cervical angle, OP, parity and BMI were tested as possible predictive factors. In additional analyses, we also adjusted for maternal age, gestational age, birth weight, and head circumference as possible confounders. The assumptions for the Cox regression analyses were checked graphically using log-log plots and with Schoenfeld residuals for the proportional hazards assumptions[262]. P-values < 0.05 were considered significant.

In study 4, ultrasound measurements and digital assessments were compared with Spearman's correlation coefficients. The predictive value for vaginal delivery was evaluated using ROC curves. Ultrasound measurements and digital assessments were transformed to Z-scores, and ROC curve analyses of the sum of Z-scores were performed. The Stavanger University Hospital database from 1999-2005 was used to determine the prior probability of vaginal delivery after IOL. The caesarean delivery rate among women scheduled for IOL in 1999-2005 was 12%. Thus, the prior odds for vaginal delivery after IOL was 88:12. Bayes theorem and likelihood ratios (LRs) were used to calculate posterior probabilities (Prior odds x LR = posterior odds)[263]

Data were entered into the statistical software package SPSS version 13.0 and 14.0 and 16.0 (SPSS Inc., Chicago, IL, USA).

6.5.2 Sample size estimation

In women with PROM, we wanted to evaluate a new US method, the fetal head-perineum distance, as a predictive factor for labour outcome. We were unable to calculate a sample size before the study.

In study 2, we found caesarean delivery rates of 4% among women with a short distance and 15% among women with a long fetal head-perineum distance. For study 3 we used an alpha of 0.05 and a power of 0.8 and assumed a ratio of 2:1 for a long and short distance. We calculated that 250 women were needed for an adequately powered study.

7 Discussion and interpretation of the results

7.1 Paper 1

This paper examined the value of TAU in a group of women with PROM. We studied the proportion of fetal head rotations from OP to OA during labour and whether OP or a deflected neck before labour was associated with a higher risk of operative deliveries and a longer duration of labour.

Malposition and malrotation can arrest the delivery process. It is well known that OP is associated with labour complications[24]. It has been debated whether OP at delivery is a consequence of OP before the start of labour or a consequence of malrotation during labour. When I first started as an obstetrician, midwives instructed me not to break the waters too early, because it could stop the rotation of the fetal head and increase the risk for persistent OP. We found 40 (26%) of 152 fetuses in OP before labour, 27 (18%) were in ROT, 41 (27%) were in OA and 44 (29%) were in LOT. At the time of delivery, only 10 (7%) fetuses were in OP. Thus, 34 (85%) of 40 fetuses with OP rotated to OA during labour. Four fetuses in other positions rotated to OP, and six fetuses in OP were still in this position at the time of delivery (table 4).

	OP at delivery	OA at delivery	
OP before start of labour	6	34	40 (26%)
Other positions before start of labour	4	108	112
	10 (7 %)	142	152

Table 4. Frequencies of fetuses in different positions before start of labour and at delivery

The fetal head position before the start of labour predicted OP delivery with a sensitivity of 60%; 95% CI 26-88, false positive rate of 24%; 95% CI 17-32, positive predictive value of 15%; 95% CI 6-30, negative predictive value of 96%; 95% CI 91-99 and LR of 2.5.

The second question was whether OP before the start of labour in women with PROM could predict a caesarean section. The null hypothesis was that OP before labour could not predict labour outcome.

Akmal et al. found a statistically significant association between OP in the early stage of labour and the risk of caesarean section (19% vs 11%) [15]. We found a similar association

(15% vs 10%), but the difference did not reach levels of statistical significance. We could not reject the null hypothesis. This may be due to small numbers (type II error). We did not know the paper of Akmal et al. when we planned the study, and our study was underpowered to demonstrate a statistically significant difference between head position before labour and caesarean section. We can estimate from calculations after the study that we would need a sample size of n = 1820 to demonstrate an association between caesarean delivery and OP after PROM before the start of contractions with a statistical power of 80%.

We evaluated the duration from PROM to delivery with survival analyses. In a multivariable Cox regression model, multiparity was the only statistically significantly contributing factor to the model. A Kaplan-Meier survival plot demonstrated that OP could not predict the duration (figure 33). The difference between the two groups was not statistically significant (p = 0.39, log rank test).

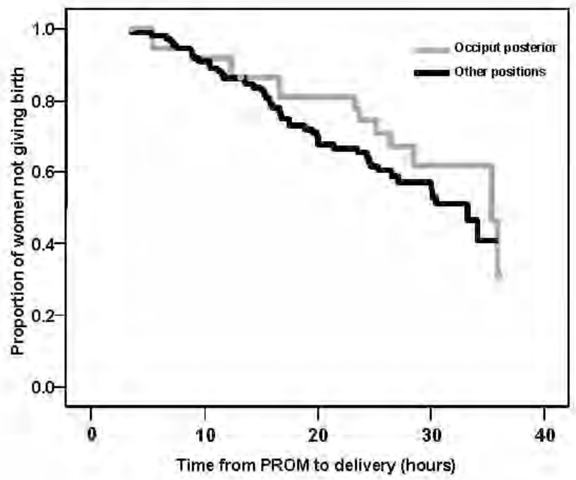


Figure 33. Kaplan-Meier estimates of proportions of women not delivered within 36 hours, according to fetal head in occiput posterior or other positions before the start of labour (log rank test p = 0.39). Women experiencing induction, operative delivery or a time to delivery > 36 hours were censored

The last question of study 1 was whether deflection of the fetal neck before the start of labour was related to labour outcome. Eleven fetuses (7%) had a deflected neck before the start of labour. Ten were in OP before labour, but only three were in OP at delivery. Three of the 11 babies were delivered by caesarean section, and one was delivered by vacuum. Seven babies (64%) were delivered spontaneously. Deflexion of fetal neck before the start of labour did not seem to be an important prognostic factor for operative delivery.

Most fetuses in OP before the start of labour rotate to OA during labour even after PROM. Our study did not show any significant associations between fetal head position or neck flexion before labour and operative deliveries or duration of labour. The value of a TAU in women with PROM is uncertain.

A later study from 2007 (Peregrine et al.) reached similar conclusions[224]:

1: Two thirds of OP positions at delivery occur due to a malrotation during labour from a non-OP position

2: Ultrasonography is an easy method to assess fetal head position before IOL

3: In clinical practice its usefulness is limited because contrary to conventional teaching, OP position before IOL does not appear to be associated with an increased risk of caesarean delivery.

7.2 Paper 2

This paper studied whether TPU measurements after PROM were associated with time from PROM to delivery and operative deliveries.

Engagement of the fetal head has occurred when the largest transverse diameter of the fetal head has traversed the pelvic inlet[4]. Assessment of the fetal head engagement and the pelvic station is essential in the management of labour, and the traditional examination is a transvaginal digital examination[4].

US examinations during labour must be easy for non-experts to perform. The aim was to evaluate a simple transperineal US method that can be used at the labour ward.

TVU measurement of the cervical length is a well-established method, and it is documented that the transvaginal approach is the best method to measure cervical length[155]. However, the risk of infection may increase with transvaginal examinations in women with PROM. Thus, we decided to examine cervical length by transperineal US. The sagittal US examination may be distorted by gas in the rectum or difficulties in localizing the internal cervical os. The quality of examinations will improve with elevation of the hip[156]. Still we found that sagittal TPU examinations were unsuccessful in 16% of women. We found that measurement of the cervical length could predict time to delivery, but this association disappeared when head engagement was included in the regression model. We found no statistically significant associations between the distance from internal os to perineum and the outcomes of labour. In our model the sagittal TPU examination was of little value.

We found, however, that the evaluation of fetal head descent by measuring the fetal head-perineum distance was a valuable method. This was a new technique, and we did not specify any cut-off values in advance. The mean distance from the outer bony part of the skull to the skin of the perineum was 47.7 mm (median 47 mm, range 28-85mm). We decided to use cut-off levels close to the median value (45mm).

Women with a short distance (< 45 mm) had statistically significantly fewer caesarean sections, less use of epidural analgesia, shorter time from PROM to delivery and a shorter time in active labour. Their babies had a higher pH in the UA.

The relation between fetal head-perineum distance and operative deliveries is demonstrated in table 5.

	Operative delivery		Spontaneous delivery	
Long fetal head-perineum distance	30	(31%)	68	98
Short fetal head-perineum distance	6	(11%)	48	54
	36		116	152

Table 5. Frequencies of delivery mode related to fetal descent before start of labour

A long fetal head-perineum distance could predict operative delivery with sensitivity 83%; 95% CI 67-94, false positive rate 59%; 95% CI 49-68, positive predictive value 31%; 95% CI 22-41, negative predictive value 89%; 95% CI 77-96 and LR 1.4.

The time from PROM to delivery was evaluated in a Cox regression analysis and short head-perineum distance and multiparity were statistically significant contributing factors in the Cox regression model. A Kaplan-Meier survival plot demonstrates the induction-to-delivery interval stratified in groups of fetal head-perineum distance (figure 34). The difference between groups was statistically significant ($p < 0.001$, log rank test).

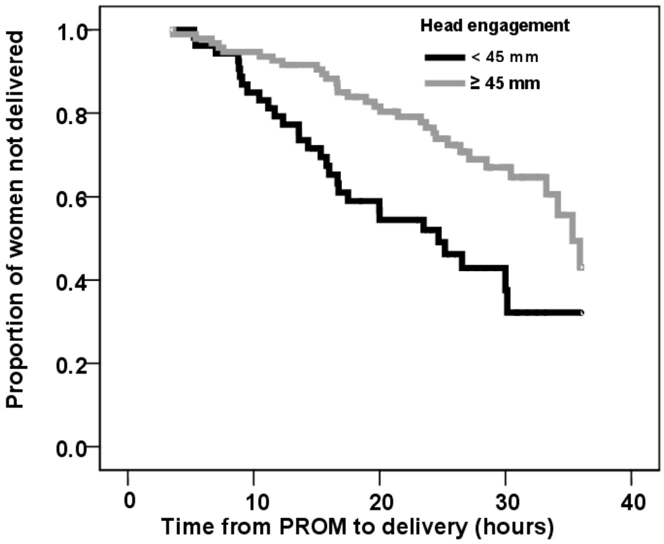


Figure 34. Kaplan-Meier estimates of proportions of women not delivered within 36 hours, according to sonographically measured distance from the fetal head to perineum (log rank test, p < 0.001). Women experiencing induction, operative delivery or a time to delivery > 24 hours were censored

The treatment of choice for term pregnancies with PROM is debated[52, 53, 264, 265]. Our department had a routine policy of expectant management, but not for more than 39 hours. The present study demonstrated that 32%; 95% CI 15-49 of women with a short distance from head to perineum and 43%; 95% CI 24-62 of women with a long distance were still in labour after 36 hours. IOL may increase the risk of a caesarean section, and expectant care may increase the risk of infection. US evaluation of fetal head engagement may help the clinician to sort women for expectant management or early induction, e.g. parous women with a short fetal head-perineum distance have a high probability of a quick labour without obstetrical interventions and can be offered expectant management when presenting with PROM.

7.3 Paper 3

This paper studied fetal head descent measured by TPU as a predictive factor for successful IOL, and compared fetal head-perineum distance with maternal factors, the Bishop score and US measurements of cervical length, cervical angle and occiput position.

Ultrasound-measured fetal head-perineum distance was found to be a predictor for vaginal delivery after IOL. The Bishop score, BMI and ultrasound-measured fetal head-perineum distance, cervical length and posterior cervical angle all predicted a vaginal delivery with around 60% under the ROC curve area. The predictive values of maternal factors, ultrasound measurements and the Bishop score are presented in table 6.

	Sensitivity (95% CI)	FPR (95% CI)	PPV (95% CI)	LR
Fetal head-perineum distance ≤ 40 mm	29.3 (23.6-35.5)	8.3 (1.7-22.5)	95.9 (88.5-99.1)	3.5
Fetal head-perineum distance ≤ 45 mm	49.4 (42.9-55.9)	41.7 (25.5-59.3)	88.7 (82.1-93.6)	1.2
Fetal head-perineum distance ≤ 50 mm	67.4 (61.0-73.3)	47.2 (30.4-64.5)	90.4 (85.2-94.3)	1.4
Cervical length ≤ 20 mm	26.4 (20.9-32.4)	13.9 (4.7-29.5)	92.6 (83.7-97.6)	1.9
Cervical length ≤ 25 mm	43.1 (36.7-49.6)	25.0 (12.1-42.2)	92.0 (85.3-96.3)	1.7
Cervical length ≤ 30 mm	62.3 (55.9-68.5)	44.4 (27.1-61.9)	90.3 (84.7-94.4)	1.4
Cervical angle > 90 degrees	87.9 (83.0-91.7)	61.1 (43.5-76.9)	90.5 (86.0-94.0)	1.4
Cervical angle ≥ 120 degrees	37.7 (31.5-44.1)	27.8 (14.2-45.2)	90.0 (82.4-95.1)	1.4
Para 1+	57.7 (51.2-64.1)	19.4 (8.2-36.0)	95.2 (90.3-98.0)	3.0
BMI < 30	84.9 (79.8-89.2)	77.8 (60.8-89.9)	87.9 (83.0-91.8)	1.1
Bishop score ≥ 6	43.5 (37.1-50.1)	25.0 (12.1-42.8)	92.0 (85.4-96.3)	1.7

Table 6. Test characteristics with 95% confidence intervals of ultrasound measurements, maternal characteristics and Bishop score in predicting a vaginal delivery (FPR = false positive rate; PPV = positive predictive value; LR = likelihood ratio)

Parity and US measurements (figure 35) were contributing factors in predicting delivery within 24 hours in the survival analyses. The Bishop score was not tested in the survival analyses because the induction methods were stratified according to the Bishop score.

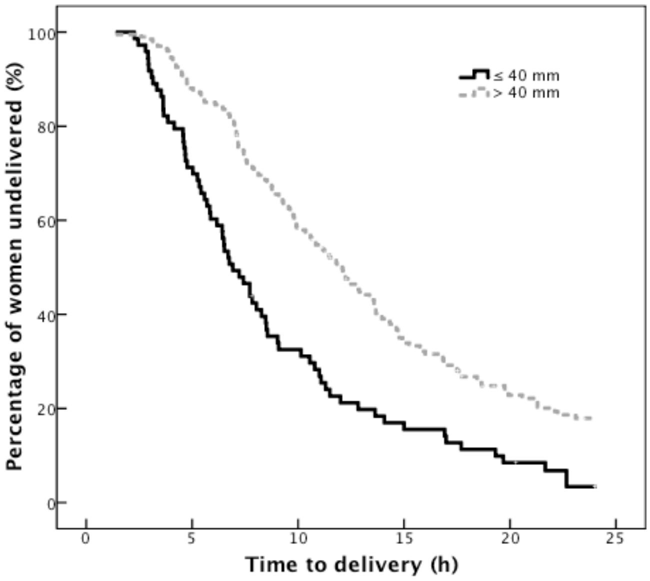


Figure 35. Kaplan-Meier estimates of proportions of women not delivered within 24 hours, according to sonographically measured fetal head-perineum distance (grey line: ultrasound-measured distance > 40mm; black line: distance ≤ 40mm). Women experiencing caesarean section or a time to delivery > 24 hours were censored.

In study 2, we divided women into two groups according to the fetal head-perineum distance. We used a cut-off point below, but close to the expected level of the ischial spines (approximately 5 cm from the outlet of the birth canal)[1]. The cut-off level was set at 45 mm. Below this fetal head-perineum distance, we anticipated that the fetal head had passed the narrowest part of the birth canal.

In study 3, we used ROC-curve analyses for a continuous evaluation of the fetal head-perineum distance to predict vaginal delivery. The results indicated that a cut-off level at 40-42 mm was the best predictor of the mode of delivery. In table 6, we present LR at different cut-off points close to the level of the ischial spines. We decided to use a cut-off level at 40 mm in the multivariate analysis.

Parity was, as expected, the best predictor for vaginal delivery, and this was in accordance with other studies. Maternal age was not a predictive factor in our study. This may be due to a type II error because of a rather low caesarean delivery rate in our department.

The predictive value of OP position is debated. In paper 1, OP position had no statistically significant predictive value, but we did not reject the hypothesis of its value because of a possible statistical type II error. In study 3, the results contrasted with the results from study

1, with a lower caesarean rate and quicker deliveries in the OP group. Most fetuses were in the OP position close to the limit values (four o'clock or eight o'clock). In study 1, we found that with 30% of cases the fetal head moved during the US examination. We conclude that fetal head position before start of labour has no predictive value for labour outcome.

Even if ultrasound-measured fetal head-perineum distance, cervical length and cervical angle can predict labour outcome, neither of the factors are good enough in a clinical setting when used alone. A combination of factors should be evaluated.

7.4 Paper 4

In this study we compared the components of the Bishop score with corresponding sonographical measurements, and we performed correlation analyses. Because the residuals did not show a normal distribution, we used Spearman's correlation coefficient. The results are presented in table 7.

	Ultrasound-measured			digitally assessed				
	length	position	dilatation	station	length	position	dilatation	consistency
ultrasound descent	0.42**	0.21**	0.05	0.23**	0.31**	0.06	0.23**	0.15*
ultrasound cervical length		0.21**	0.37**	0.30**	0.54**	0.15*	0.32**	0.31**
ultrasound position			0.14*	0.05	0.12*	0.03	0.07	0.14*
ultrasound dilatation				0.12*	0.17**	0.10	0.16**	0.16**
digital station					0.23**	0.16**	0.25**	0.11
digital cervical length						0.25**	0.43**	0.30**
digital position							0.42**	0.18**
digital dilatation								0.47**

*Table 7. Spearman's correlation coefficient (**p < 0.01, *p < 0.05).*

The ultrasound and digital assessments of cervical length were moderately correlated (r = 0.54). The ultrasound and digital assessments of descent were weakly correlated (r = 0.23), and the ultrasound and digital assessments of position were not correlated at all (r = 0.03).

Digital assessment of cervical dilatation was the best ‘stand alone’ element in the Bishop score for predicting delivery mode with 61%; 95% CI 51-71%, (p = 0.03) under the ROC curve area. In fact, this component was as predictive as the Bishop score itself (61%; 95% CI 52-70% (p = 0.03) under the curve area).

In study 3, we concluded that neither of the evaluated factors used alone was good enough in predicting labour outcome, and in study 4 we evaluate three different ways to combine factors.

1. Combination of ultrasound measurements can be evaluated in ROC-curve analyses by transforming the results to Z-scores and analysing a sum of the Z-scores. However, this method is not very useful in every day life. Figure 36 presents our best predictive model with a combination of ultrasound-assessed fetal head descent, cervical length, posterior cervical angle and digitally assessed cervical dilatation. This combination predicted a vaginal delivery with 68%; 95% CI 58-78%, (p < 0.01) under the ROC curve area (figure 36). The predictive value was 65%; 95% CI 55-75%, (p < 0.01) when the posterior cervical angle was omitted from the model.

   A similar ROC-curve can be made from a multiple regression analysis.

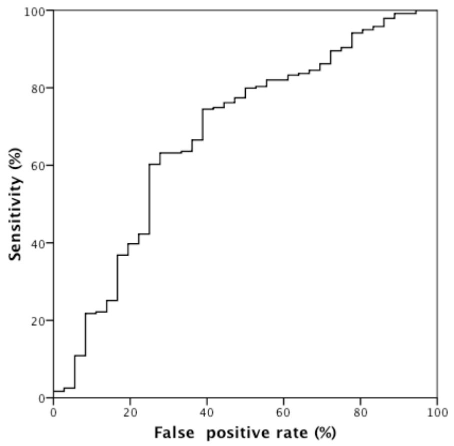


Figure 36. Receiver operating characteristics (ROC) curve for the combination of ultrasound-measured fetal head descent, cervical length, posterior cervical angle and digitally assessed cervical dilatation.

2. Factors can be combined in a scoring system like the Bishop score. Numerical scoring implies that a difference from 0 to 1 or from 1 to 2 is equally important, and that the different elements are considered equally important[34]. A scoring system is easy to use in clinical practice.

The Bishop score is a rather complicated and subjective scoring system with scores from 0-13, and we think a simpler system will be more practical, objective and reliable. In 1982, Lange et al. suggested a scoring system depending only on fetal station, cervical length and cervical dilatation[66]. Digital assessment of cervical dilatation performed much better than ultrasound. During the ultrasound examination the vaginal probe is placed in the anterior vaginal fornix, whereas digital assessment implies that one or two fingers are placed into the cervical canal. If the cervical consistency is soft, the cervical canal will dilate during this procedure. Assessment of dilatation and consistency might therefore be parts of the same evaluation, and we found the two elements to be correlated (r = 0.47). We did not find ultrasound measurements of cervical dilatation to be reliable. In cases with a curved posterior uterine segment, curved cervix or with cervical wedging we found it difficult to measure the posterior cervical angle exactly. Thus, we suggest to omit the two factors cervical position and consistency, and we suggest a scoring model as presented in table 8.

Score	0	1
Digitally assessed dilatation	Closed cervix	Dilated cervix
Ultrasound-measured fetal head-perineum distance	> 40 mm	≤ 40mm
Ultrasound-measured cervical length	> 25 mm	≤ 25mm

Table 8. Scoring system with combination of digital and ultrasound assessments.

We tested this model on the study population and found that 29/41 (71%) women with score 0, 93/108 (86%) women with score 1, 77/84 (92%) women with score 2 and 40/42 (95%) women with score 3 had a successful vaginal delivery. In a ROC curve analysis the scoring model predicted vaginal delivery with 67%; 95% CI 57-76% ($p < 0.01$) under the curve area. However, this model should be evaluated in new prospective studies before it can be recommended for clinical practice.

3. Individual risk estimates can be calculated with the use of Bayes theorem[263]. This concept has gained wide acceptance in fetal medicine in counselling women after an 11-14 week scan with regards to the risk of Down syndrome. In 2008, Celik et al. recommended the same concept in counselling women at high risk of preterm labour[266]. The prior probability of a successful IOL can be modified by the LRs of ultrasound measurements (Posterior odds = Prior odds X LR). The probability of a vaginal delivery rate among women scheduled for IOL at Stavanger University Hospital from 1999-2005 was 88%. Thus, the prior odds of vaginal delivery were 88:12 (= 7.33). LR for a vaginal delivery was 3.5 if the fetal head-perineum distance was ≤ 40 mm. Posterior odds can be computed and will be 25.7 (= 96.25/3.75; ≈ 96/4). Thus, the post-test probability for a vaginal delivery is 96%. The shift in probability can be more easily visualized/performed with the use of Fagan's nomogram (figure 37)[267]. Similar examples can be made for a Bishop score ≥ 6 with LR 1.7 (change from 88% to 92%) and cervical length ≤ 25 mm with LR 1.7 (change from 88% to 92%). Correlation between factors should be considered before several factors are combined. Likelihood ratios must be reliable and based on a large dataset. Thus, we suggest new studies before likelihood ratios are applied to predict success of IOL.

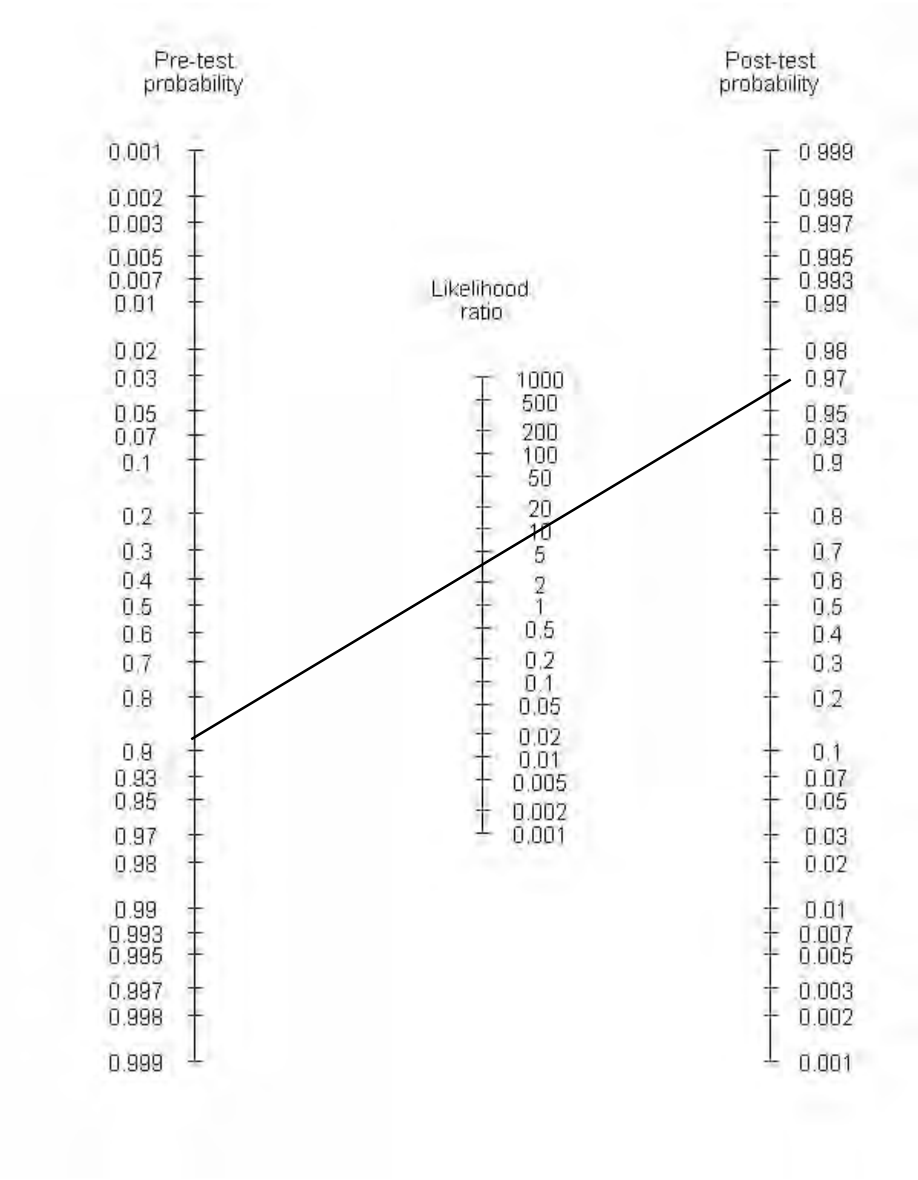


Figure 37. Calculation of post-test probability with Fagan's nomogram

8 Reflections on the future

8.1 Evidence-based medicine

In medical research evidence-based medicine is usually synonymous with meta-analysis of randomized controlled trials. Labour is a complex process and many different factors are important. It is not easy to perform randomized controlled trials to demonstrate solutions to all problems. Medical knowledge is more than facts. Clinical expertise is the ability to use clinical skills and past experience in clinical practice. David Sackett et al. define evidence-based medicine as the integration of best research evidence with clinical expertise and patient values[268]. Clinical expertise and patient values are not codifiable. They depend instead on skilled judgement and personal experience. This is called tacit knowledge or the silent knowledge, which is understood and implied without being stated. Tim Thornton claims that tacit knowledge is a unifying factor in science[269].

Thomas Kuhn discusses the value of tacit knowledge in research in his book Structure of Scientific Revolutions[270]. He suggests that the main activity of normal science is 'puzzle solving', which he compares to crossword and jigsaw puzzles. According to Karl Popper, a scientific hypothesis cannot be verified, only falsified[271]. If not falsified, it is not a fact, only the best knowledge yet.

In this thesis the value of ultrasound measurements is compared with obstetricians' clinical experience in digital examinations, and hopefully it will put a new piece in place in the research puzzle of how to perform obstetrics.

8.2 Patient values and patient rights

Traditionally, obstetricians made decisions on behalf of women. Modern obstetricians are more like guides. Women of today want to plan their lives, and many women want to plan the date of delivery. Still, they want midwives and obstetricians to take the responsibility for their labour. Patient rights in Norway are governed by a law[272] (Patients' Rights Act). Paragraph 3.1 states: *'The patient is entitled to participate in the implementation of his or her health care. This includes the patient's right to participate in choosing between available and medically sound methods of examination and treatment. The form of participation shall be adapted to the individual patient's ability to give and receive information.'*

In the future, midwives and obstetricians will inform women of treatment options, and women will make informed choices[53, 273]. Thus, there is a need for new methods for risk evaluations. If a successful labour outcome can be predicted, it will be easier to recommend induced labour in cases with 'soft indications' or on maternal request[63]. Any reliable methods of preinduction assessment will be valuable tools in counselling women before IOL.

The frequencies of induced labour are increasing[29, 57], and this will probably continue in the years to come. The cost of delivery is higher with IOL than with spontaneous labour[274]. Outpatient management of induction may however be cheaper and a reasonable option for selected low-risk women[275].

Ethics in obstetrics may be individual, or may reflect act utilitarianism, i.e. to promote the best for the greatest number. Patients would like obstetricians to practice individual ethics, but politicians demand act utilitarianism. Future obstetricians have to do the best for the patient and spend as little money as possible. This balance is difficult and will remain a challenge.

8.3 Simple methods

After extensive literature search I could not find any previous publication of the proposed method to measure fetal head descent with TPU. It is a simple method and easy to perform for non-experts. Labours occur through day and night, and ultrasound examination cannot wait until the opening hours of an ultrasound laboratory. Labour is a complicated process, and the fetus rotates through a curved birth canal. The proposed method has been criticized with the argument that measuring fetal head descent is too simple for evaluating such a complex process. Others have suggested using the maternal symphysis pubis and the pelvic inlet as reference points. However, we believe that the pelvic outlet is the finish line of the delivery process and a valuable reference line. The fetal head-perineum distance will be shorter when the fetal head passes through the birth canal even though the canal is curved as illustrated in figure 38.

Ockham's razor is a philosophical principle often attributed to William of Ockham (1285-1349): '*One should not make more assumptions than the minimum needed such that we should choose from a set of otherwise equivalent models of a given phenomenon the simplest one.'*

8.4 Limitations

In this thesis I have evaluated maternal characteristics, clinical examinations and ultrasound measurements as predicting factors of labour outcome. None of them are reliable alone, and a combination of factors is necessary. I have suggested some combinations of factors and how to use them in clinical practice. However, it seems to be difficult to predict a successful IOL. The predictive values for vaginal delivery in the ROC curve analyses in this study were quite low. A good predictive test has a positive LR ≥ 10 or a negative LR ≤ 0.1. Fetal head-perineum distance predicted a vaginal delivery only with positive LR = 3.5 and negative LR 0.77. This is probably because we try to predict outcome (delivery mode) of a process (labour) that has not yet started, and the process may be influenced by many factors unknown at the time of induction. Another factor contributing low predictive values is the fact that most women in high-risk groups deliver vaginally. Thus, it will probably be impossible to find good and reliable tests predicting labour outcome.

8.5 Ultrasound during labour

This thesis evaluates ultrasound measurements before the start of labour. The methods may also be of value in evaluating the labour process.

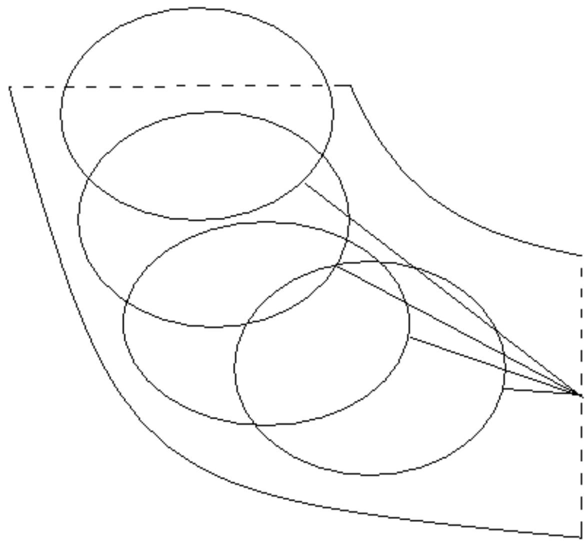


Figure 38. Illustration of how the fetal head perineum distance diminishes as the fetal head descends through the birth canal.

Ultrasound examinations will probably not be necessary for women during a normal labour. In obstructed labours, however, we believe that ultrasound may be an important tool in the future. Exact descriptions of the fetal head position and descent before operative vaginal deliveries will probably be important. Practitioners should use US as a complementary tool for investigation rather than a replacement for their clinical skills[276]. It is easier to learn to determine fetal head position by ultrasound than by digital examination[243]. Some papers and editorials have emphasized the importance of ultrasound examinations in labours[41, 236, 245]. However, the use in clinical practice is limited. Because ultrasound measurements are more objective methods than digital assessments, we think that ultrasound will be the method of choice in evaluating labour progress. Ultrasound will probably be our most important tool in the surveillance of pregnancies from the very early beginning to the end. Thus, Yves Ville may be correct in his statement that we will move from '*obstetric ultrasound to ultrasonographic obstetrics*'[171].

Index

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Apply the background theories to new cases

Thomas Kuhn

Paper one

Eggebø TM, Heien C, Økland I, Gjessing LK, Smedvig E, Romundstad P, Salvesen KÅ.

Prediction of labour and delivery by ascertaining the fetal head position with transabdominal

Ultrasound in pregnancies with prelabour rupture of membranes after 37 weeks. Ultraschall Med. 2008 Apr; 29(2): 179-83. DOI: 10.1055/s-2007-963017

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Paper two

Eggebø TM, Gjessing LK, Heien C, Smedvig E, Økland I, Romundstad P, Salvesen KÅ.

Prediction of labor and delivery by transperineal ultrasound in pregnancies with prelaborrupture of membranes at term.

Ultrasound Obstet Gynecol. 2006 Apr; 27(4): 387-91.
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Paper three

Eggebø TM, Heien C, Økland I, Gjessing LK, Romundstad P, Salvesen KÅ.

Ultrasound assessment of fetal head-perineum distance before induction of labor.

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Ultrasound measurements and digital assessments

Ultrasound measurements or digital assessments before induction of labour?

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KEYWORDS:

Bishop score, fetal head–perineum distance, cervical length, posterior cervical angle, cervical dilatation.

ABSTRACT

Objective *To compare the elements of the Bishop score and sonographical measurements before induction of labour and to evaluate combinations of predictive factors.*

Methods *The study included 275 women scheduled for induction of labour. The fetal head descent was assessed with transperineal ultrasound as the shortest distance from the fetal skull to the perineum, compared with digital assessment of the fetal head station. Cervical length, angle and dilatation were evaluated with transvaginal ultrasound. Ultrasound measured posterior cervical angle was compared with digital assessed cervical position. The Bishop score was assessed without knowledge of the ultrasound measurements, immediately after the scans.*

Results *Digital and sonographic assessments were moderately correlated for cervical length (r =0.54, p <0.01) and weakly correlated for fetal head descent (r =0.23, p <0.01). Ultrasound measured posterior cervical angle was not correlated with digital assessment of cervical position (r =0.03). The cervix was determined as closed in 219 (80%) of cases with the use of ultrasound and in 58 (21%) by digital assessment. A combination of ultrasound measured fetal head–perineum distance, cervical length and digitally assessed cervical dilatation predicted vaginal delivery with 65%; 95% CI [55–75%](p <0.01) under the ROC curve area.*

Conclusion *The elements of the Bishop score and the corresponding ultrasound measurements were weakly to moderately correlated. A combination of ultrasound measured fetal head station, cervical length and digitally assessed cervical dilatation may be useful in counselling women prior to induction of labour.*

INTRODUCTION

Induction of labour (IOL) is a commonly performed obstetrical intervention, and the frequency is increasing. The current induction rate in developed countries is 13–20% (1,2). The procedure is associated with increased risk of Cesarean delivery (3). Timing of induction for indications such as twins, diabetes, post–term pregnancy and preeclampsia is debated, and many women ask for induction without medical indications. Objective methods for assessment of cervix and fetal head descent would be useful when counselling women prior to IOL. Maternal characteristics, Bishop score and ultrasound measurements used alone have limitations, and combinations of factors have been suggested (4-6).

The Bishop score includes five elements; the station of the presenting part, cervical dilatation, effacement, consistency and position (7). It is a subjective evaluation, and the predictive value for successful IOL is limited (8,9). In one study an informal evaluation of the cervix was as reliable as the Bishop score (10). Other studies emphasize the importance of fetal station (11) or cervical dilatation (12,13). It has been suggested to replace digital assessments with ultrasound measurements (14,15). Four elements of the Bishop score can be compared with corresponding ultrasound measurements in a clinical setting. Cervical consistency can only be addressed by ultrasound elastography, and this method is not in clinical use (16).

In some studies, transvaginal ultrasound measurements of cervical length perform better than the Bishop score in predicting outcome of IOL (6,9,11), but not in others (17,18). Ultrasound measured posterior cervical angle (6) and fetal head engagement (4,19) have been found to predict labour outcome. A recent meta–analysis called for more research (20).

The aims of this study were to correlate the elements of the Bishop score with sonographical measurements and to discuss how predictive factors for IOL can be combined in a clinical setting.

METHODS

In all, 275 women scheduled for IOL at Stavanger University Hospital were included in a prospective clinical study. Women were eligible if they had a live singleton pregnancy with cephalic presentation and a gestational age of more than 37 completed pregnancy weeks according to a mid–trimester scan. Women with previous Cesarean section were not eligible. We defined successful IOL as a vaginal delivery, spontaneous or operative. The local Ethics Committee approved the study, and all women gave written informed consent. Characteristics of the study population have been published previously (21).

Labour was induced with amniotomy followed by oxytocin if the cervix was favourable (Bishop score $\geq$6). If the cervix was unfavourable, labour was induced with 25 microgram misoprostol applied vaginally every 4th hour (maximum 100 microgram in 24 hours and a total maximum dose of 200 microgram) until regular contractions.

Two obstetricians and three trained midwives did the ultrasound measurements with EUB Hitachi 5500 (Kashiwa, Japan) devices with a 3.5–7.5 mHz multifrequency transabdominal transducer and a 5.0–9.0 mHz multifrequency transvaginal transducer. The Bishop score was assessed after the scan and immediately before induction by the obstetrician on call, who was blinded for the ultrasound measurements. In all, approximately 20 different doctors with more than three years of obstetric experience assessed the Bishop score. All examinations were performed with the woman in a supine position and with an empty bladder.

The cervical length was measured by ultrasound as described by Valentin et al. (22), and compared with digital evaluation of the cervical length stratified into four categories; three, two, one centimetre (cm) or effaced. The posterior cervical angle was measured by ultrasound as described by Rane et al. (6). The sonographically measured angles were compared with digital assessments of the cervical position, classified as posterior (score 0), centred (score 1) or anterior position (score 2). The shortest distance from the outer bony limit of the fetal skull to the skin surface of the perineum was measured by transperineal ultrasound as described in a previous study (19), and the measurements were compared with digital assessments of the fetal head station according to WHO classification (23). The mean of three measurements was used for all three ultrasound methods.

We used a transvaginal sagittal scan to assess cervical dilatation. The cervix was considered dilated if the cervical mucosa on the anterior and posterior part of cervix was separated at the time of the scan, and dilatation was measured in millimetres (mm). The ultrasound assessments were compared with digital assessments of cervical dilatation in centimetres (cm). The cervical consistency was not evaluated by ultrasound in this study.

We used the results from the present study to develop a new scoring model from 0 to 3 depending on ultrasound measured fetal head descent, cervical length and digital assessment of cervical dilatation (table 1). The cut off levels for ultrasound measurements in the proposed score were chosen based on previous publications (9,11,12,21).

Data were entered into the statistical software package SPSS version 16.0 (SPSS Inc., Chicago, IL, USA). The Spearman's correlation coefficient was used for statistical analyses. The predictive values of the elements of the Bishop score were evaluated using receiver–operating characteristics (ROC) curves, and the area under the curve was used as discriminator. Ultrasound measurements and digital assessments were transformed to Z–scores, and a ROC curve analysis of the sum of Z–scores was performed to evaluate combination of factors. P–values < 0.05 were considered significant.

The Stavanger University Hospital database from 1999–2005 was used to determine the prior probability of vaginal delivery after IOL (2). The Cesarean delivery rate among women scheduled for IOL in 1999–2005 was 12%. Thus, the prior odds for vaginal delivery after IOL was 88:12. Posterior odds (and post–test probability) can be calculated with the use of Bayes theorem (Prior odds x likelihood ratio = Posterior odds) or Fagan`s nomogram (24,25).

RESULTS

Figures 1–3 present boxplots of the associations between ultrasound measurements of the fetal head–perineum distance and the digital assessments of fetal head descent, ultrasound and digital assessments of cervical length, and ultrasound measured posterior cervical angle related to digital assessments of cervical position. The cervix was classified as closed in 58 (21%) women by digital palpation and in 219 (80%) women by ultrasound. Table 2 presents correlation coefficients between the elements of the Bishop score, and table 3 presents correlation coefficients between elements of the Bishop score and ultrasound measurements.

ROC curve analyses demonstrated that digital assessment of cervical dilatation was the single element of the Bishop score with best predictive value (61%; 95% CI [51–71%] p =0.03) under the curve area. The predictive values of the elements in the Bishop score are presented in table 4. A combination of ultrasound measured fetal head–perineum distance, cervical length, posterior cervical angle and digital assessed dilatation predicted a vaginal delivery with 68%; 95% CI [58–78%] (p <0.01) under the ROC curve area. The predictive value was 65%; 95% CI [55–75%] (p <0.01) when posterior cervical angle was omitted from the model (figure 4).

We tested our proposed scoring model (table 1) on the study population and found that 29/41 (71%) women with score 0, 93/108 (86%) women with score 1, 77/84 (92%) women with score 2 and 40/42 (95%) women with score 3 had a successful IOL. In a ROC curve analysis the scoring model predicted vaginal delivery with 67%; 95% CI [57–76%] (p <0.01) under the curve area.

We have previously published likelihood ratios at different cut off values for ultrasound measurements (21). The probability of vaginal delivery changed from 88% to 96% if the fetal head–perineum distance was ≤40 mm (figure 5) and from 88% to 92% if the cervical length was ≤25 mm.

DISCUSSION

Ultrasound measurements were weakly to moderately correlated with the elements of the Bishop score. A combination of ultrasound measured fetal head descent, cervical length and digital assessed cervical dilatation predicted a successful labour induction with 65% under the ROC curve area.

Digital assessments have been considered to be subjective, whereas ultrasound measurements are regarded as objective methods (26). We found ultrasound measurements of fetal head descent, cervical length and posterior cervical angle to perform better than the corresponding digital assessments. A possible limitation of the present study was that many different obstetricians (> 20) performed the Bishop score, whereas only 5 doctors and midwives did the ultrasound measurements. This may have biased the results in favour of the ultrasound assessments.

Ultrasound measured cervical length in the mid-trimester (27) and before IOL (5,6,9) predicts the risk of a Cesarean section. Cervical length can be more accurately assessed by ultrasound than by digital examination, and the interobserver reproducibility of ultrasound is clinically acceptable (22). Sonek et al. found a moderate correlation between ultrasound and digitally assessed cervical length (r =0.49) (28). We found similar results (r =0.54). Digital assessment of cervical length was generally shorter than ultrasound measurements (figure

2), probably because one third of the cervix is supravaginal and inaccessible to the examining fingers when the cervix is closed (29). Elghorori et al. has suggested to modify the Bishop score by replacing the digital assessment of cervical length with ultrasound measured cervical length (15).

Digitally assessed cervical position had no predictive value for a successful IOL, and we found no correlation between ultrasound measurements of the posterior cervical angle and digital assessments of cervical position (r =0.03). Ultrasound measurement of the posterior cervical angle as described by Rane et al. (6) is probably a more objective method than digital assessment of cervical position. However, in cases with a curved posterior uterine segment, a curved cervix or a cervical wedging we found it difficult to measure the angle exactly. Thus, we found this measurement to be difficult to perform in a clinical setting.

Fetal head station is assessed by digital examination of the relationship between the fetal head and the maternal ischial spine (23). However, the ischial spine is difficult to visualize with ultrasound. As early as in 1977 Lewin et al. suggested to use ultrasound to assess fetal head station by measuring the distance between the fetal head and the sacral tip (14). We have measured the shortest distance from the fetal head to the perineum using the outlet of the birth canal as a reference line (19,21). This measurement is easy to perform. Since the birth canal is curved, there will be an association, but not a direct relationship between fetal head–perineum distance and fetal head station. The measurements may vary with the degree of compression of soft tissue, but the intra– and interobserver variability of the method has been found acceptable (19). In this study, digital assessments were weakly correlated to the ultrasound measurements (r =0.23). Digital assessment of station was a poor predictor of delivery mode (54% under the ROC curve area), and we found the ultrasound measured fetal head–perineum distance to be a better predictor (21).

Cervical dilatation was the single item in the Bishop score with best predictive value. In fact, the predictive capacity of this component was as good as the Bishop score itself (21). Current ultrasound technology fails to provide precise, objective assessment of cervical dilatation (30). We used a non–validated ultrasound method, measuring the distance between the anterior and posterior parts of the cervix in a sagittal view. Digital assessment of cervical dilatation performed much better than ultrasound. During the ultrasound examination the vaginal probe is placed in the anterior vaginal fornix, whereas digital assessment implies that one or two fingers are placed into the cervical canal. If the cervical consistency is soft, the cervical canal will dilate during this procedure. Assessment of dilatation and consistency might therefore be parts of the same evaluation, and we found the two elements to be correlated (r =0.47, table 2). Thus, we decided to include only dilatation in our scoring model.

None of the factors used alone are good enough to predict a successful IOL in a clinical setting. Combination of factors can be analysed using ROC curve analyses as illustrated in figure 4. However, such analyses are not useful in every day life. The predictive values for vaginal delivery in the ROC curve analyses in this study were quite low. This is probably because we predict outcome (delivery mode) of a process (labour) that has not yet started, and the process may be influenced by many factors unknown at the time of induction.

Different factors can be combined in a scoring system. An advantage of such a score is that it is useful in clinical practice. The Bishop score is a complicated and subjective scoring system with score from 0 to 13, and the interobserver agreement of the Bishop score has been regarded as ‘fair to substantial’ (10). We believe that a simpler score may be more practical, objective and reliable. In 1982, Lange et al. proposed a scoring model based on fetal station, cervical length and cervical dilatation (12). We suggest a scoring model based on the same factors (table 1), but we have replaced the digital assessments of station and cervical length with ultrasound measurements. Since this model was retrospectively created from the data collected in the present study, it should be prospectively evaluated in new studies before it is recommended for clinical use.

Individual risk estimates can also be calculated with the use of Bayes theorem (25). This concept has gained wide acceptance in fetal medicine in counselling women after an 11–14 week scan, calculating the risk of Down Syndrome. The prior probability of a successful IOL can be modified by the likelihood ratios of ultrasound measurements. Calculations are easy to perform using Fagans nomogram (figure 5). The example in figure 5 may be interpreted as a change in the probability of vaginal delivery from 88% before the scan to 96% after the scan if the ultrasound examination reveals a short fetal head perineum distance. However, it is important to know how factors are correlated if several factors are combined. The likelihood ratios have to be reliable and based on a large dataset. Thus, new studies are necessary before likelihood ratios are applied to predict success of IOL. We found parity to be the best predictor of vaginal delivery (21); this being in accordance with other studies (3,5,12,20). Thus, parity must be taken into account in a future prediction model based on likelihood ratios.

The elements of the Bishop score and the corresponding ultrasound measurements were weakly to moderately correlated. Combination of factors improves prediction of labour outcome. We suggest a new scoring model including ultrasound measurements of fetal head descent, cervical length and digital assessment of cervical dilatation. This model should be tested in new prospective studies.

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Table 1. A proposed score combining ultrasound measurements and digital assessments of cervix and fetal head station

Score	0	1
Ultrasound measured fetal head–perineum distance	> 40 mm	≤ 40mm
Ultrasound measured cervical length	> 25 mm	≤ 25mm
Digitally assessed dilatation	Closed cervix	Dilated cervix

Table 2. Correlations between the elements of the Bishop score

	Cervical			
	length	position	dilatation	consistency
Fetal station	0.23**	0.16**	0.25**	0.11
Cervical length		0.25**	0.43**	0.30**
Cervical position			0.42**	0.18*
Cervical dilatation				0.47**

*Spearman's correlation coefficient, ** correlation is significant at the 0.01 level,*
** correlation is significant at the 0.05 level*

Table 3. Correlations between ultrasound (US) measurements and digital assessments

	Digitally assessed fetal station and cervical (cx):				
	station	cx length	cx position	cx dilatation	cx consistency
US fetal head-perineum distance	**0.23****	0.31**	0.06	0.23**	0.15*
US cervical length	0.30**	**0.54****	0.15*	0.32**	0.31**
US posterior cervical angle	0.05	0.12*	**0.03**	0.07	0.14*
US dilatation	0.12*	0.17**	0.10	**0.16****	0.16**

*Spearman's correlation coefficient, ** correlation is significant at the 0.01 level, * correlation is significant at the 0.05 level*

Table 4. Prediction of successful vaginal delivery after induction of labour with the use of single elements of the Bishop score

	Area under ROC–curve	[95% CI]	p–value
Digital assessment:			
fetal head station	54%	[44–64]	0.47
cervical length	60%	[51–69]	0.06
cervical position	53%	[42–63]	0.62
cervical dilatation	61%	[51–71]	0.03
cervical consistency	56%	[46–65]	0.28

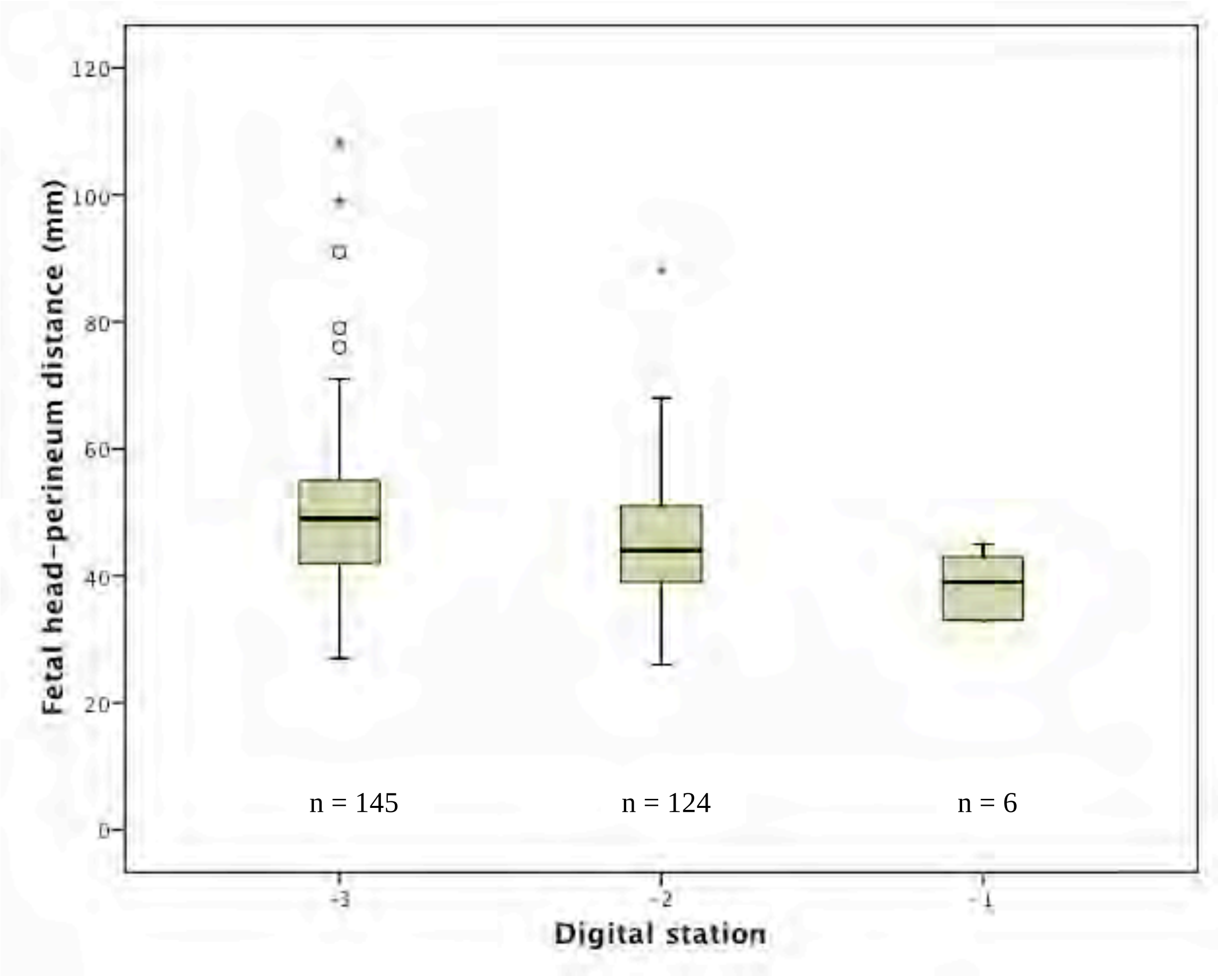

Figure 1 Boxplot of sonographically measured fetal head–perineum distance and digitally assessed fetal station.

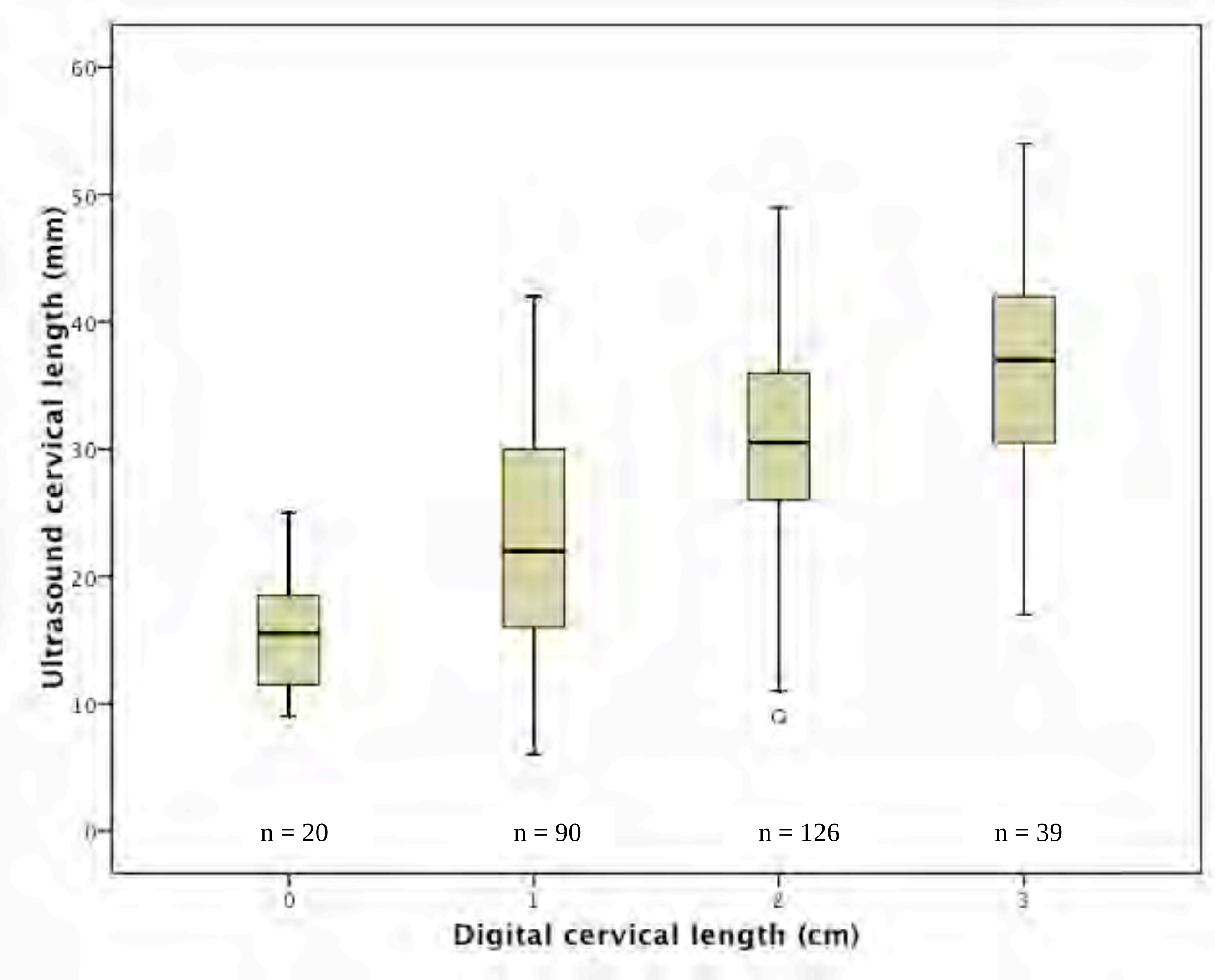

Figure 2 Boxplot of sonographically measured and digitally assessed cervical length.

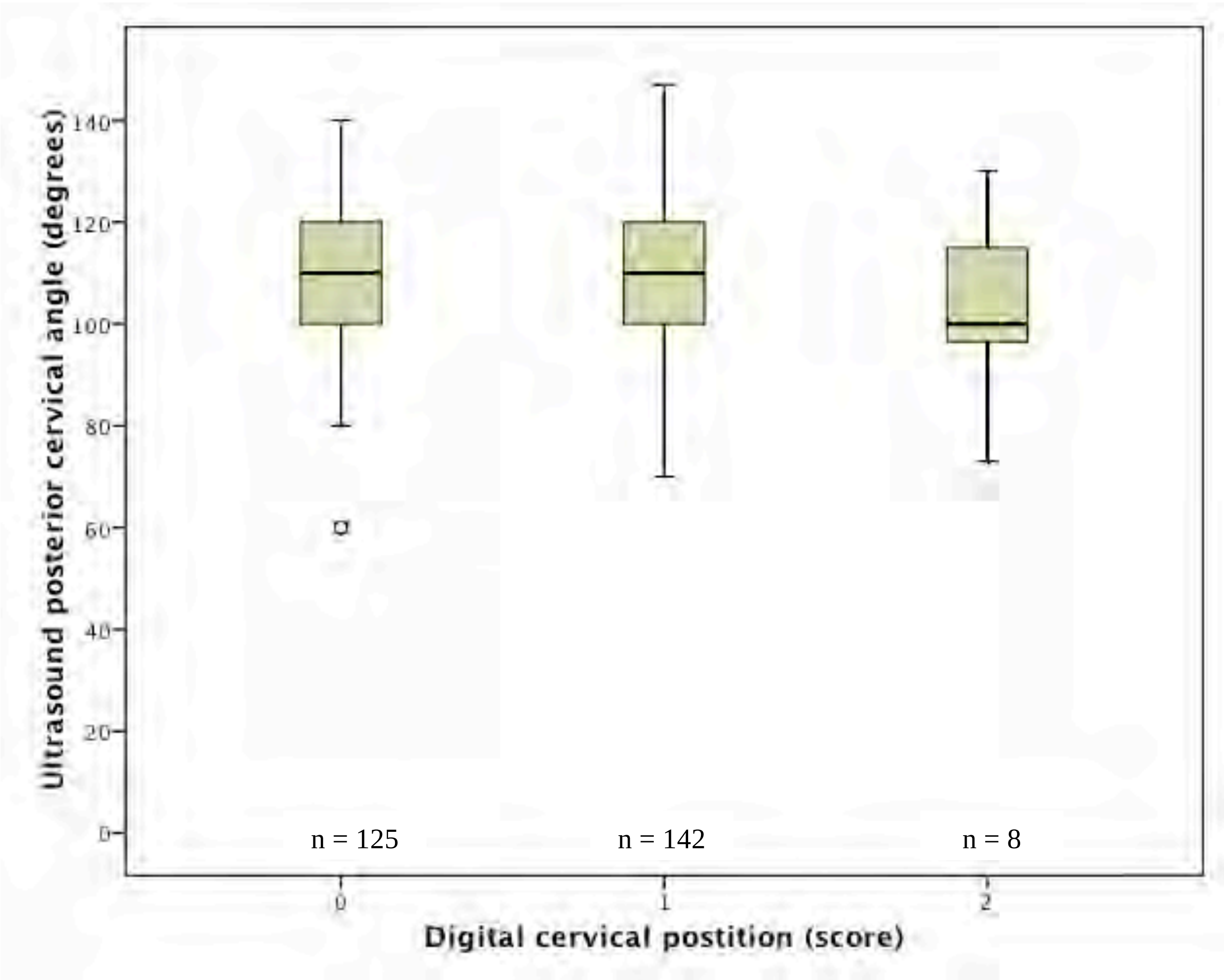

Figure 3 Boxplot of sonographically measured posterior cervical angle and digitally assessed cervical position.

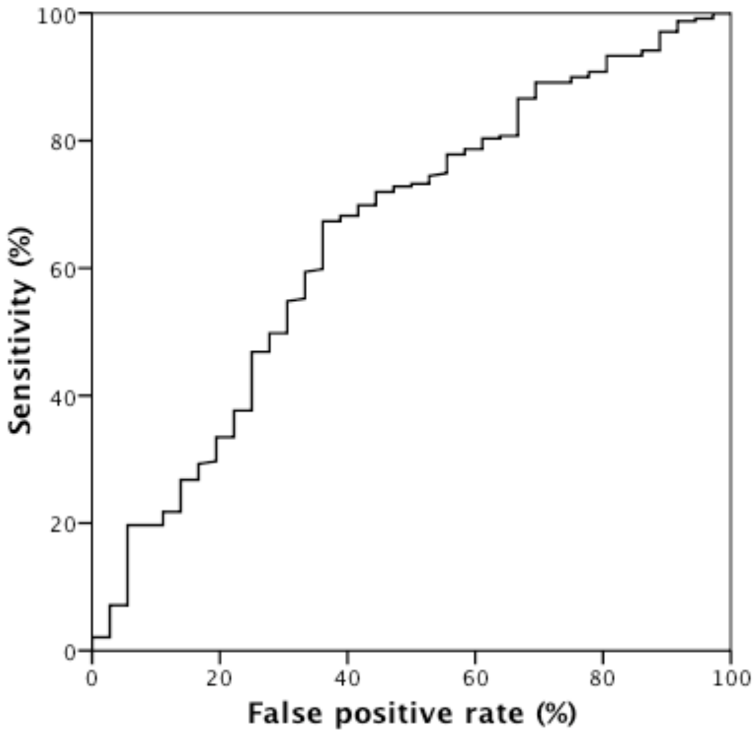

Figure 4 Receiver–operating characteristics (ROC) curve for the combination of ultrasound measured fetal head–perineum distance, cervical length and digitally assessed cervical dilatation in predicting vaginal delivery (239 vaginal and 36 Cesarean deliveries).

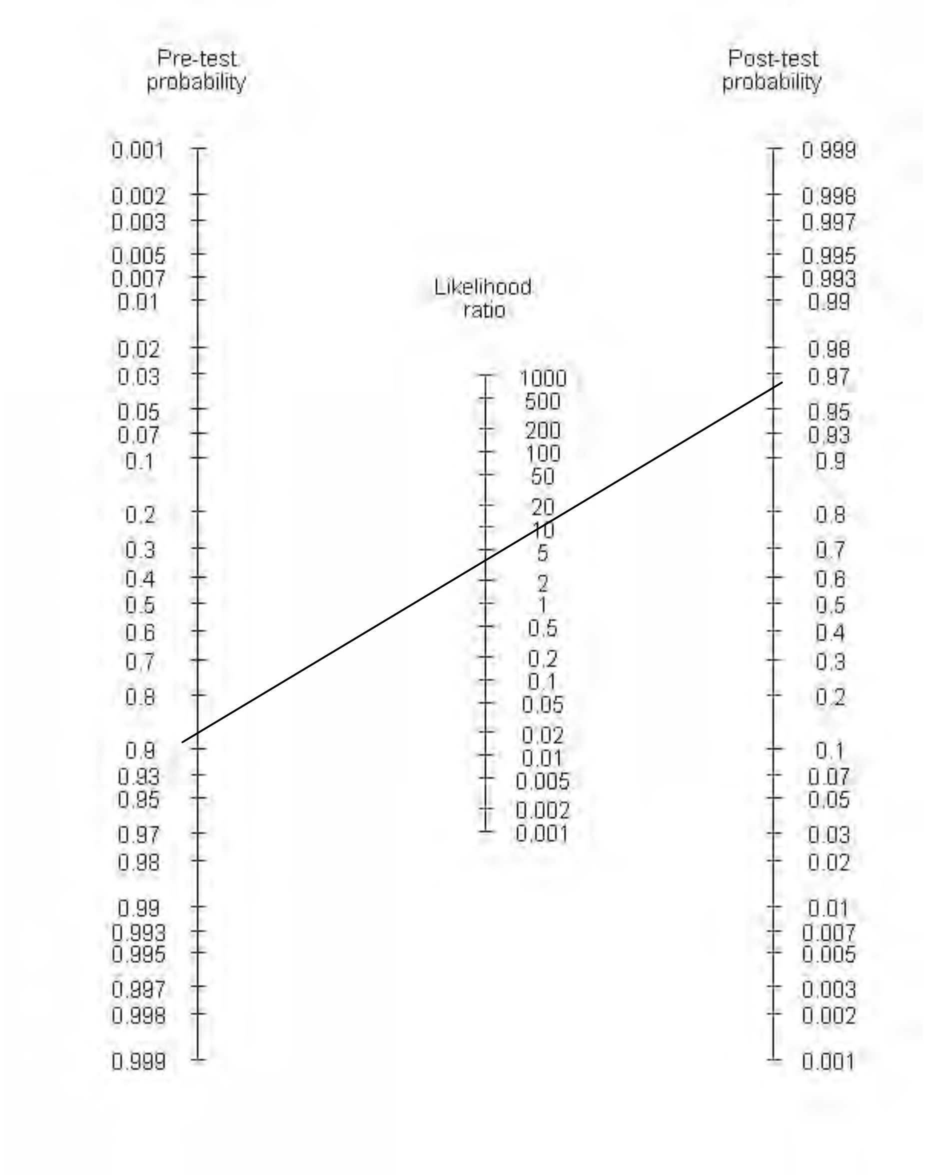

Figure 5 Calculation of post–test probability with Fagan's nomogram.

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114. Hans Stifoss-Hanssen: SEEKING MEANING OR HAPPINESS?
115. Anne Kvikstad: LIFE CHANGE EVENTS AND MARITAL STATUS IN RELATION TO RISK AND PROGNOSIS OF CANCER.
116. Torbjørn Grøntvedt: TREATMENT OF ACUTE AND CHRONIC ANTERIOR CRUCIATE LIGAMENT INJURIES. A clinical and biomechanical study.
117. Sigrid Hørven Wigers: CLINICAL STUDIES OF FIBROMYALGIA WITH FOCUS ON ETIOLOGY, TREATMENT AND OUTCOME.
118. Jan Schjøtt: MYOCARDIAL PROTECTION: Functional and Metabolic Characteristics of Two Endogenous Protective Principles.
119. Marit Martinussen: STUDIES OF INTESTINAL BLOOD FLOW AND ITS RELATION TO TRANSITIONAL CIRCULATORY ADAPATION IN NEWBORN INFANTS.
120. Tomm B. Müller: MAGNETIC RESONANCE IMAGING IN FOCAL CEREBRAL ISCHEMIA.
121. Rune Haaverstad: OEDEMA FORMATION OF THE LOWER EXTREMITIES.
122. Magne Børset: THE ROLE OF CYTOKINES IN MULTIPLE MYELOMA, WITH SPECIAL REFERENCE TO HEPATOCYTE GROWTH FACTOR.
123. Geir Smedslund: A THEORETICAL AND EMPIRICAL INVESTIGATION OF SMOKING, STRESS AND DISEASE: RESULTS FROM A POPULATION SURVEY.

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124. Torstein Vik: GROWTH, MORBIDITY, AND PSYCHOMOTOR DEVELOPMENT IN INFANTS WHO WERE GROWTH RETARDED *IN UTERO*.
125. Siri Forsmo: ASPECTS AND CONSEQUENCES OF OPPORTUNISTIC SCREENING FOR CERVICAL CANCER. Results based on data from three Norwegian counties.
126. Jon S. Skranes: CEREBRAL MRI AND NEURODEVELOPMENTAL OUTCOME IN VERY LOW BIRTH WEIGHT (VLBW) CHILDREN. A follow-up study of a geographically based year cohort of VLBW children at ages one and six years.
127. Knut Bjørnstad: COMPUTERIZED ECHOCARDIOGRAPHY FOR EVALUTION OF CORONARY ARTERY DISEASE.
128. Grethe Elisabeth Borchgrevink: DIAGNOSIS AND TREATMENT OF WHIPLASH/NECK SPRAIN INJURIES CAUSED BY CAR ACCIDENTS.
129. Tor Elsås: NEUROPEPTIDES AND NITRIC OXIDE SYNTHASE IN OCULAR AUTONOMIC AND SENSORY NERVES.
130. Rolf W. Gråwe: EPIDEMIOLOGICAL AND NEUROPSYCHOLOGICAL PERSPECTIVES ON SCHIZOPHRENIA.
131. Tonje Strømholm: CEREBRAL HAEMODYNAMICS DURING THORACIC AORTIC CROSSCLAMPING. An experimental study in pigs.

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132. Martinus Bråten: STUDIES ON SOME PROBLEMS REALTED TO INTRAMEDULLARY NAILING OF FEMORAL FRACTURES.
133. Ståle Nordgård: PROLIFERATIVE ACTIVITY AND DNA CONTENT AS PROGNOSTIC INDICATORS IN ADENOID CYSTIC CARCINOMA OF THE HEAD AND NECK.

134. Egil Lien: SOLUBLE RECEPTORS FOR **TNF** AND **LPS**: RELEASE PATTERN AND POSSIBLE SIGNIFICANCE IN DISEASE.
135. Marit Bjørgaas: HYPOGLYCAEMIA IN CHILDREN WITH DIABETES MELLITUS
136. Frank Skorpen: GENETIC AND FUNCTIONAL ANALYSES OF DNA REPAIR IN HUMAN CELLS.
137. Juan A. Pareja: SUNCT SYNDROME. ON THE CLINICAL PICTURE. ITS DISTINCTION FROM OTHER, SIMILAR HEADACHES.
138. Anders Angelsen: NEUROENDOCRINE CELLS IN HUMAN PROSTATIC CARCINOMAS AND THE PROSTATIC COMPLEX OF RAT, GUINEA PIG, CAT AND DOG.
139. Fabio Antonaci: CHRONIC PAROXYSMAL HEMICRANIA AND HEMICRANIA CONTINUA: TWO DIFFERENT ENTITIES?
140. Sven M. Carlsen: ENDOCRINE AND METABOLIC EFFECTS OF METFORMIN WITH SPECIAL EMPHASIS ON CARDIOVASCULAR RISK FACTORES.

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141. Terje A. Murberg: DEPRESSIVE SYMPTOMS AND COPING AMONG PATIENTS WITH CONGESTIVE HEART FAILURE.
142. Harm-Gerd Karl Blaas: THE EMBRYONIC EXAMINATION. Ultrasound studies on the development of the human embryo.
143. Noèmi Becser Andersen:THE CEPHALIC SENSORY NERVES IN UNILATERAL HEADACHES. Anatomical background and neurophysiological evaluation.
144. Eli-Janne Fiskerstrand: LASER TREATMENT OF PORT WINE STAINS. A study of the efficacy and limitations of the pulsed dye laser. Clinical and morfological analyses aimed at improving the therapeutic outcome.
145. Bård Kulseng: A STUDY OF ALGINATE CAPSULE PROPERTIES AND CYTOKINES IN RELATION TO INSULIN DEPENDENT DIABETES MELLITUS.
146. Terje Haug: STRUCTURE AND REGULATION OF THE HUMAN UNG GENE ENCODING URACIL-DNA GLYCOSYLASE.
147. Heidi Brurok: MANGANESE AND THE HEART. A Magic Metal with Diagnostic and Therapeutic Possibilites.
148. Agnes Kathrine Lie: DIAGNOSIS AND PREVALENCE OF HUMAN PAPILLOMAVIRUS INFECTION IN CERVICAL INTRAEPITELIAL NEOPLASIA. Relationship to Cell Cycle Regulatory Proteins and HLA DQBI Genes.
149. Ronald Mårvik: PHARMACOLOGICAL, PHYSIOLOGICAL AND PATHOPHYSIOLOGICAL STUDIES ON ISOLATED STOMACS.
150. Ketil Jarl Holen: THE ROLE OF ULTRASONOGRAPHY IN THE DIAGNOSIS AND TREATMENT OF HIP DYSPLASIA IN NEWBORNS.
151. Irene Hetlevik: THE ROLE OF CLINICAL GUIDELINES IN CARDIOVASCULAR RISK INTERVENTION IN GENERAL PRACTICE.
152. Katarina Tunòn: ULTRASOUND AND PREDICTION OF GESTATIONAL AGE.
153. Johannes Soma: INTERACTION BETWEEN THE LEFT VENTRICLE AND THE SYSTEMIC ARTERIES.
154. Arild Aamodt: DEVELOPMENT AND PRE-CLINICAL EVALUATION OF A CUSTOM-MADE FEMORAL STEM.
155. Agnar Tegnander: DIAGNOSIS AND FOLLOW-UP OF CHILDREN WITH SUSPECTED OR KNOWN HIP DYSPLASIA.
156. Bent Indredavik: STROKE UNIT TREATMENT: SHORT AND LONG-TERM EFFECTS
157. Jolanta Vanagaite Vingen: PHOTOPHOBIA AND PHONOPHOBIA IN PRIMARY HEADACHES

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158. Ola Dalsegg Sæther: PATHOPHYSIOLOGY DURING PROXIMAL AORTIC CROSS-CLAMPING CLINICAL AND EXPERIMENTAL STUDIES
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160. Christina Vogt Isaksen: PRENATAL ULTRASOUND AND POSTMORTEM FINDINGS – A TEN YEAR CORRELATIVE STUDY OF FETUSES AND INFANTS WITH DEVELOPMENTAL ANOMALIES.
161. Holger Seidel: HIGH-DOSE METHOTREXATE THERAPY IN CHILDREN WITH ACUTE LYMPHOCYTIC LEUKEMIA: DOSE, CONCENTRATION, AND EFFECT CONSIDERATIONS.
162. Stein Hallan: IMPLEMENTATION OF MODERN MEDICAL DECISION ANALYSIS INTO CLINICAL DIAGNOSIS AND TREATMENT.

163. Malcolm Sue-Chu: INVASIVE AND NON-INVASIVE STUDIES IN CROSS-COUNTRY SKIERS WITH ASTHMA-LIKE SYMPTOMS.
164. Ole-Lars Brekke: EFFECTS OF ANTIOXIDANTS AND FATTY ACIDS ON TUMOR NECROSIS FACTOR-INDUCED CYTOTOXICITY.
165. Jan Lundbom: AORTOCORONARY BYPASS SURGERY: CLINICAL ASPECTS, COST CONSIDERATIONS AND WORKING ABILITY.
166. John-Anker Zwart: LUMBAR NERVE ROOT COMPRESSION, BIOCHEMICAL AND NEUROPHYSIOLOGICAL ASPECTS.
167. Geir Falck: HYPEROSMOLALITY AND THE HEART.
168. Eirik Skogvoll: CARDIAC ARREST Incidence, Intervention and Outcome.
169. Dalius Bansevicius: SHOULDER-NECK REGION IN CERTAIN HEADACHES AND CHRONIC PAIN SYNDROMES.
170. Bettina Kinge: REFRACTIVE ERRORS AND BIOMETRIC CHANGES AMONG UNIVERSITY STUDENTS IN NORWAY.
171. Gunnar Qvigstad: CONSEQUENCES OF HYPERGASTRINEMIA IN MAN
172. Hanne Ellekjær: EPIDEMIOLOGICAL STUDIES OF STROKE IN A NORWEGIAN POPULATION. INCIDENCE, RISK FACTORS AND PROGNOSIS
173. Hilde Grimstad: VIOLENCE AGAINST WOMEN AND PREGNANCY OUTCOME.
174. Astrid Hjelde: SURFACE TENSION AND COMPLEMENT ACTIVATION: Factors influencing bubble formation and bubble effects after decompression.
175. Kjell A. Kvistad: MR IN BREAST CANCER – A CLINICAL STUDY.
176. Ivar Rossvoll: ELECTIVE ORTHOPAEDIC SURGERY IN A DEFINED POPULATION. Studies on demand, waiting time for treatment and incapacity for work.
177. Carina Seidel: PROGNOSTIC VALUE AND BIOLOGICAL EFFECTS OF HEPATOCYTE GROWTH FACTOR AND SYNDECAN-1 IN MULTIPLE MYELOMA.

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178. Alexander Wahba: THE INFLUENCE OF CARDIOPULMONARY BYPASS ON PLATELET FUNCTION AND BLOOD COAGULATION – DETERMINANTS AND CLINICAL CONSEQUENSES
179. Marcus Schmitt-Egenolf: THE RELEVANCE OF THE MAJOR hISTOCOMPATIBILITY COMPLEX FOR THE GENETICS OF PSORIASIS
180. Odrun Arna Gederaas: BIOLOGICAL MECHANISMS INVOLVED IN 5-AMINOLEVULINIC ACID BASED PHOTODYNAMIC THERAPY
181. Pål Richard Romundstad: CANCER INCIDENCE AMONG NORWEGIAN ALUMINIUM WORKERS
182. Henrik Hjorth-Hansen: NOVEL CYTOKINES IN GROWTH CONTROL AND BONE DISEASE OF MULTIPLE MYELOMA
183. Gunnar Morken: SEASONAL VARIATION OF HUMAN MOOD AND BEHAVIOUR
184. Bjørn Olav Haugen: MEASUREMENT OF CARDIAC OUTPUT AND STUDIES OF VELOCITY PROFILES IN AORTIC AND MITRAL FLOW USING TWO- AND THREE-DIMENSIONAL COLOUR FLOW IMAGING
185. Geir Bråthen: THE CLASSIFICATION AND CLINICAL DIAGNOSIS OF ALCOHOL-RELATED SEIZURES
186. Knut Ivar Aasarød: RENAL INVOLVEMENT IN INFLAMMATORY RHEUMATIC DISEASE. A Study of Renal Disease in Wegener’s Granulomatosis and in Primary Sjögren’s Syndrome
187. Trude Helen Flo: RESEPTORS INVOLVED IN CELL ACTIVATION BY DEFINED URONIC ACID POLYMERS AND BACTERIAL COMPONENTS
188. Bodil Kavli: HUMAN URACIL-DNA GLYCOSYLASES FROM THE UNG GENE: STRUCTRUAL BASIS FOR SUBSTRATE SPECIFICITY AND REPAIR
189. Liv Thommesen: MOLECULAR MECHANISMS INVOLVED IN TNF- AND GASTRIN-MEDIATED GENE REGULATION
190. Turid Lingaas Holmen: SMOKING AND HEALTH IN ADOLESCENCE; THE NORD-TRØNDELAG HEALTH STUDY, 1995-97
191. Øyvind Hjertner: MULTIPLE MYELOMA: INTERACTIONS BETWEEN MALIGNANT PLASMA CELLS AND THE BONE MICROENVIRONMENT
192. Asbjørn Støylen: STRAIN RATE IMAGING OF THE LEFT VENTRICLE BY ULTRASOUND. FEASIBILITY, CLINICAL VALIDATION AND PHYSIOLOGICAL ASPECTS

193. Kristian Midthjell: DIABETES IN ADULTS IN NORD-TRØNDELAG. PUBLIC HEALTH ASPECTS OF DIABETES MELLITUS IN A LARGE, NON-SELECTED NORWEGIAN POPULATION.
194. Guanglin Cui: FUNCTIONAL ASPECTS OF THE ECL CELL IN RODENTS
195. Ulrik Wisløff: CARDIAC EFFECTS OF AEROBIC ENDURANCE TRAINING: HYPERTROPHY, CONTRACTILITY AND CALCUIM HANDLING IN NORMAL AND FAILING HEART
196. Øyvind Halaas: MECHANISMS OF IMMUNOMODULATION AND CELL-MEDIATED CYTOTOXICITY INDUCED BY BACTERIAL PRODUCTS
197. Tore Amundsen: PERFUSION MR IMAGING IN THE DIAGNOSIS OF PULMONARY EMBOLISM
198. Nanna Kurtze: THE SIGNIFICANCE OF ANXIETY AND DEPRESSION IN FATIQUE AND PATTERNS OF PAIN AMONG INDIVIDUALS DIAGNOSED WITH FIBROMYALGIA: RELATIONS WITH QUALITY OF LIFE, FUNCTIONAL DISABILITY, LIFESTYLE, EMPLOYMENT STATUS, CO-MORBIDITY AND GENDER
199. Tom Ivar Lund Nilsen: PROSPECTIVE STUDIES OF CANCER RISK IN NORD-TRØNDELAG: THE HUNT STUDY. Associations with anthropometric, socioeconomic, and lifestyle risk factors
200. Asta Kristine Håberg: A NEW APPROACH TO THE STUDY OF MIDDLE CEREBRAL ARTERY OCCLUSION IN THE RAT USING MAGNETIC RESONANCE TECHNIQUES

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201. Knut Jørgen Arntzen: PREGNANCY AND CYTOKINES
202. Henrik Døllner: INFLAMMATORY MEDIATORS IN PERINATAL INFECTIONS
203. Asta Bye: LOW FAT, LOW LACTOSE DIET USED AS PROPHYLACTIC TREATMENT OF ACUTE INTESTINAL REACTIONS DURING PELVIC RADIOTHERAPY. A PROSPECTIVE RANDOMISED STUDY.
204. Sylvester Moyo: STUDIES ON STREPTOCOCCUS AGALACTIAE (GROUP B STREPTOCOCCUS) SURFACE-ANCHORED MARKERS WITH EMPHASIS ON STRAINS AND HUMAN SERA FROM ZIMBABWE.
205. Knut Hagen: HEAD-HUNT: THE EPIDEMIOLOGY OF HEADACHE IN NORD-TRØNDELAG
206. Li Lixin: ON THE REGULATION AND ROLE OF UNCOUPLING PROTEIN-2 IN INSULIN PRODUCING ß-CELLS
207. Anne Hildur Henriksen: SYMPTOMS OF ALLERGY AND ASTHMA VERSUS MARKERS OF LOWER AIRWAY INFLAMMATION AMONG ADOLESCENTS
208. Egil Andreas Fors: NON-MALIGNANT PAIN IN RELATION TO PSYCHOLOGICAL AND ENVIRONTENTAL FACTORS. EXPERIENTAL AND CLINICAL STUDES OF PAIN WITH FOCUS ON FIBROMYALGIA
209. Pål Klepstad: MORPHINE FOR CANCER PAIN
210. Ingunn Bakke: MECHANISMS AND CONSEQUENCES OF PEROXISOME PROLIFERATOR-INDUCED HYPERFUNCTION OF THE RAT GASTRIN PRODUCING CELL
211. Ingrid Susann Gribbestad: MAGNETIC RESONANCE IMAGING AND SPECTROSCOPY OF BREAST CANCER
212. Rønnaug Astri Ødegård: PREECLAMPSIA – MATERNAL RISK FACTORS AND FETAL GROWTH
213. Johan Haux: STUDIES ON CYTOTOXICITY INDUCED BY HUMAN NATURAL KILLER CELLS AND DIGITOXIN
214. Turid Suzanne Berg-Nielsen: PARENTING PRACTICES AND MENTALLY DISORDERED ADOLESCENTS
215. Astrid Rydning: BLOOD FLOW AS A PROTECTIVE FACTOR FOR THE STOMACH MUCOSA. AN EXPERIMENTAL STUDY ON THE ROLE OF MAST CELLS AND SENSORY AFFERENT NEURONS

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216. Jan Pål Loennechen: HEART FAILURE AFTER MYOCARDIAL INFARCTION. Regional Differences, Myocyte Function, Gene Expression, and Response to Cariporide, Losartan, and Exercise Training.
217. Elisabeth Qvigstad: EFFECTS OF FATTY ACIDS AND OVER-STIMULATION ON INSULIN SECRETION IN MAN

218. Arne Åsberg: EPIDEMIOLOGICAL STUDIES IN HEREDITARY HEMOCHROMATOSIS: PREVALENCE, MORBIDITY AND BENEFIT OF SCREENING.
219. Johan Fredrik Skomsvoll: REPRODUCTIVE OUTCOME IN WOMEN WITH RHEUMATIC DISEASE. A population registry based study of the effects of inflammatory rheumatic disease and connective tissue disease on reproductive outcome in Norwegian women in 1967-1995.
220. Siv Mørkved: URINARY INCONTINENCE DURING PREGNANCY AND AFTER DELIVERY: EFFECT OF PELVIC FLOOR MUSCLE TRAINING IN PREVENTION AND TREATMENT
221. Marit S. Jordhøy: THE IMPACT OF COMPREHENSIVE PALLIATIVE CARE
222. Tom Christian Martinsen: HYPERGASTRINEMIA AND HYPOACIDITY IN RODENTS – CAUSES AND CONSEQUENCES
223. Solveig Tingulstad: CENTRALIZATION OF PRIMARY SURGERY FOR OVARAIN CANCER. FEASIBILITY AND IMPACT ON SURVIVAL
224. Haytham Eloqayli: METABOLIC CHANGES IN THE BRAIN CAUSED BY EPILEPTIC SEIZURES
225. Torunn Bruland: STUDIES OF EARLY RETROVIRUS-HOST INTERACTIONS – VIRAL DETERMINANTS FOR PATHOGENESIS AND THE INFLUENCE OF SEX ON THE SUSCEPTIBILITY TO FRIEND MURINE LEUKAEMIA VIRUS INFECTION
226. Torstein Hole: DOPPLER ECHOCARDIOGRAPHIC EVALUATION OF LEFT VENTRICULAR FUNCTION IN PATIENTS WITH ACUTE MYOCARDIAL INFARCTION
227. Vibeke Nossum: THE EFFECT OF VASCULAR BUBBLES ON ENDOTHELIAL FUNCTION
228. Sigurd Fasting: ROUTINE BASED RECORDING OF ADVERSE EVENTS DURING ANAESTHESIA – APPLICATION IN QUALITY IMPROVEMENT AND SAFETY
229. Solfrid Romundstad: EPIDEMIOLOGICAL STUDIES OF MICROALBUMINURIA. THE NORD-TRØNDELAG HEALTH STUDY 1995-97 (HUNT 2)
230. Geir Torheim: PROCESSING OF DYNAMIC DATA SETS IN MAGNETIC RESONANCE IMAGING
231. Catrine Ahlén: SKIN INFECTIONS IN OCCUPATIONAL SATURATION DIVERS IN THE NORTH SEA AND THE IMPACT OF THE ENVIRONMENT
232. Arnulf Langhammer: RESPIRATORY SYMPTOMS, LUNG FUNCTION AND BONE MINERAL DENSITY IN A COMPREHENSIVE POPULATION SURVEY. THE NORD-TRØNDELAG HEALTH STUDY 1995-97. THE BRONCHIAL OBSTRUCTION IN NORD-TRØNDELAG STUDY
233. Einar Kjelsås: EATING DISORDERS AND PHYSICAL ACTIVITY IN NON-CLINICAL SAMPLES
234. Arne Wibe: RECTAL CANCER TREATMENT IN NORWAY – STANDARDISATION OF SURGERY AND QUALITY ASSURANCE

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235. Eivind Witsø: BONE GRAFT AS AN ANTIBIOTIC CARRIER
236. Anne Mari Sund: DEVELOPMENT OF DEPRESSIVE SYMPTOMS IN EARLY ADOLESCENCE
237. Hallvard Lærum: EVALUATION OF ELECTRONIC MEDICAL RECORDS – A CLINICAL TASK PERSPECTIVE
238. Gustav Mikkelsen: ACCESSIBILITY OF INFORMATION IN ELECTRONIC PATIENT RECORDS; AN EVALUATION OF THE ROLE OF DATA QUALITY
239. Steinar Krokstad: SOCIOECONOMIC INEQUALITIES IN HEALTH AND DISABILITY. SOCIAL EPIDEMIOLOGY IN THE NORD-TRØNDELAG HEALTH STUDY (HUNT), NORWAY
240. Arne Kristian Myhre: NORMAL VARIATION IN ANOGENITAL ANATOMY AND MICROBIOLOGY IN NON-ABUSED PRESCHOOL CHILDREN
241. Ingunn Dybedal: NEGATIVE REGULATORS OF HEMATOPOIETEC STEM AND PROGENITOR CELLS
242. Beate Sitter: TISSUE CHARACTERIZATION BY HIGH RESOLUTION MAGIC ANGLE SPINNING MR SPECTROSCOPY
243. Per Arne Aas: MACROMOLECULAR MAINTENANCE IN HUMAN CELLS – REPAIR OF URACIL IN DNA AND METHYLATIONS IN DNA AND RNA
244. Anna Bofin: FINE NEEDLE ASPIRATION CYTOLOGY IN THE PRIMARY INVESTIGATION OF BREAST TUMOURS AND IN THE DETERMINATION OF TREATMENT STRATEGIES

245.Jim Aage Nøttestad: DEINSTITUTIONALIZATION AND MENTAL HEALTH CHANGES AMONG PEOPLE WITH MENTAL RETARDATION
246.Reidar Fossmark: GASTRIC CANCER IN JAPANESE COTTON RATS
247.Wibeke Nordhøy: MANGANESE AND THE HEART, INTRACELLULAR MR RELAXATION AND WATER EXCHANGE ACROSS THE CARDIAC CELL MEMBRANE

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248.Sturla Molden: QUANTITATIVE ANALYSES OF SINGLE UNITS RECORDED FROM THE HIPPOCAMPUS AND ENTORHINAL CORTEX OF BEHAVING RATS
249.Wenche Brenne Drøyvold: EPIDEMIOLOGICAL STUDIES ON WEIGHT CHANGE AND HEALTH IN A LARGE POPULATION. THE NORD-TRØNDELAG HEALTH STUDY (HUNT)
250.Ragnhild Støen: ENDOTHELIUM-DEPENDENT VASODILATION IN THE FEMORAL ARTERY OF DEVELOPING PIGLETS
251.Aslak Steinsbekk: HOMEOPATHY IN THE PREVENTION OF UPPER RESPIRATORY TRACT INFECTIONS IN CHILDREN
252.Hill-Aina Steffenach: MEMORY IN HIPPOCAMPAL AND CORTICO-HIPPOCAMPAL CIRCUITS
253.Eystein Stordal: ASPECTS OF THE EPIDEMIOLOGY OF DEPRESSIONS BASED ON SELF-RATING IN A LARGE GENERAL HEALTH STUDY (THE HUNT-2 STUDY)
254.Viggo Pettersen: FROM MUSCLES TO SINGING: THE ACTIVITY OF ACCESSORY BREATHING MUSCLES AND THORAX MOVEMENT IN CLASSICAL SINGING
255.Marianne Fyhn: SPATIAL MAPS IN THE HIPPOCAMPUS AND ENTORHINAL CORTEX
256.Robert Valderhaug: OBSESSIVE-COMPULSIVE DISORDER AMONG CHILDREN AND ADOLESCENTS: CHARACTERISTICS AND PSYCHOLOGICAL MANAGEMENT OF PATIENTS IN OUTPATIENT PSYCHIATRIC CLINICS
257.Erik Skaaheim Haug: INFRARENAL ABDOMINAL AORTIC ANEURYSMS – COMORBIDITY AND RESULTS FOLLOWING OPEN SURGERY
258.Daniel Kondziella: GLIAL-NEURONAL INTERACTIONS IN EXPERIMENTAL BRAIN DISORDERS
259.Vegard Heimly Brun: ROUTES TO SPATIAL MEMORY IN HIPPOCAMPAL PLACE CELLS
260.Kenneth McMillan: PHYSIOLOGICAL ASSESSMENT AND TRAINING OF ENDURANCE AND STRENGTH IN PROFESSIONAL YOUTH SOCCER PLAYERS
261.Marit Sæbø Indredavik: MENTAL HEALTH AND CEREBRAL MAGNETIC RESONANCE IMAGING IN ADOLESCENTS WITH LOW BIRTH WEIGHT
262.Ole Johan Kemi: ON THE CELLULAR BASIS OF AEROBIC FITNESS, INTENSITY-DEPENDENCE AND TIME-COURSE OF CARDIOMYOCYTE AND ENDOTHELIAL ADAPTATIONS TO EXERCISE TRAINING
263.Eszter Vanky: POLYCYSTIC OVARY SYNDROME – METFORMIN TREATMENT IN PREGNANCY
264.Hild Fjærtoft: EXTENDED STROKE UNIT SERVICE AND EARLY SUPPORTED DISCHARGE. SHORT AND LONG-TERM EFFECTS
265.Grete Dyb: POSTTRAUMATIC STRESS REACTIONS IN CHILDREN AND ADOLESCENTS
266.Vidar Fykse: SOMATOSTATIN AND THE STOMACH
267.Kirsti Berg: OXIDATIVE STRESS AND THE ISCHEMIC HEART: A STUDY IN PATIENTS UNDERGOING CORONARY REVASCULARIZATION
268.Björn Inge Gustafsson: THE SEROTONIN PRODUCING ENTEROCHROMAFFIN CELL, AND EFFECTS OF HYPERSEROTONINEMIA ON HEART AND BONE

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269.Torstein Baade Rø: EFFECTS OF BONE MORPHOGENETIC PROTEINS, HEPATOCYTE GROWTH FACTOR AND INTERLEUKIN-21 IN MULTIPLE MYELOMA
270.May-Britt Tessem: METABOLIC EFFECTS OF ULTRAVIOLET RADIATION ON THE ANTERIOR PART OF THE EYE
271.Anne-Sofie Helvik: COPING AND EVERYDAY LIFE IN A POPULATION OF ADULTS WITH HEARING IMPAIRMENT
272.Therese Standal: MULTIPLE MYELOMA: THE INTERPLAY BETWEEN MALIGNANT PLASMA CELLS AND THE BONE MARROW MICROENVIRONMENT

273. Ingvild Saltvedt: TREATMENT OF ACUTELY SICK, FRAIL ELDERLY PATIENTS IN A GERIATRIC EVALUATION AND MANAGEMENT UNIT – RESULTS FROM A PROSPECTIVE RANDOMISED TRIAL
274. Birger Henning Endreseth: STRATEGIES IN RECTAL CANCER TREATMENT – FOCUS ON EARLY RECTAL CANCER AND THE INFLUENCE OF AGE ON PROGNOSIS
275. Anne Mari Aukan Rokstad: ALGINATE CAPSULES AS BIOREACTORS FOR CELL THERAPY
276. Mansour Akbari: HUMAN BASE EXCISION REPAIR FOR PRESERVATION OF GENOMIC STABILITY
277. Stein Sundstrøm: IMPROVING TREATMENT IN PATIENTS WITH LUNG CANCER – RESULTS FROM TWO MULITCENTRE RANDOMISED STUDIES
278. Hilde Pleym: BLEEDING AFTER CORONARY ARTERY BYPASS SURGERY - STUDIES ON HEMOSTATIC MECHANISMS, PROPHYLACTIC DRUG TREATMENT AND EFFECTS OF AUTOTRANSFUSION
279. Line Merethe Oldervoll: PHYSICAL ACTIVITY AND EXERCISE INTERVENTIONS IN CANCER PATIENTS
280. Boye Welde: THE SIGNIFICANCE OF ENDURANCE TRAINING, RESISTANCE TRAINING AND MOTIVATIONAL STYLES IN ATHLETIC PERFORMANCE AMONG ELITE JUNIOR CROSS-COUNTRY SKIERS
281. Per Olav Vandvik: IRRITABLE BOWEL SYNDROME IN NORWAY, STUDIES OF PREVALENCE, DIAGNOSIS AND CHARACTERISTICS IN GENERAL PRACTICE AND IN THE POPULATION
282. Idar Kirkeby-Garstad: CLINICAL PHYSIOLOGY OF EARLY MOBILIZATION AFTER CARDIAC SURGERY
283. Linn Getz: SUSTAINABLE AND RESPONSIBLE PREVENTIVE MEDICINE. CONCEPTUALISING ETHICAL DILEMMAS ARISING FROM CLINICAL IMPLEMENTATION OF ADVANCING MEDICAL TECHNOLOGY
284. Eva Tegnander: DETECTION OF CONGENITAL HEART DEFECTS IN A NON-SELECTED POPULATION OF 42,381 FETUSES
285. Kristin Gabestad Nørsett: GENE EXPRESSION STUDIES IN GASTROINTESTINAL PATHOPHYSIOLOGY AND NEOPLASIA
286. Per Magnus Haram: GENETIC VS. AQUIRED FITNESS: METABOLIC, VASCULAR AND CARDIOMYOCYTE ADAPTATIONS
287. Agneta Johansson: GENERAL RISK FACTORS FOR GAMBLING PROBLEMS AND THE PREVALENCE OF PATHOLOGICAL GAMBLING IN NORWAY
288. Svein Artur Jensen: THE PREVALENCE OF SYMPTOMATIC ARTERIAL DISEASE OF THE LOWER LIMB
289. Charlotte Björk Ingul: QUANITIFICATION OF REGIONAL MYOCARDIAL FUNCTION BY STRAIN RATE AND STRAIN FOR EVALUATION OF CORONARY ARTERY DISEASE. AUTOMATED VERSUS MANUAL ANALYSIS DURING ACUTE MYOCARDIAL INFARCTION AND DOBUTAMINE STRESS ECHOCARDIOGRAPHY
290. Jakob Nakling: RESULTS AND CONSEQUENCES OF ROUTINE ULTRASOUND SCREENING IN PREGNANCY – A GEOGRAPHIC BASED POPULATION STUDY
291. Anne Engum: DEPRESSION AND ANXIETY – THEIR RELATIONS TO THYROID DYSFUNCTION AND DIABETES IN A LARGE EPIDEMIOLOGICAL STUDY
292. Ottar Bjerkeset: ANXIETY AND DEPRESSION IN THE GENERAL POPULATION: RISK FACTORS, INTERVENTION AND OUTCOME – THE NORD-TRØNDELAG HEALTH STUDY (HUNT)
293. Jon Olav Drogset: RESULTS AFTER SURGICAL TREATMENT OF ANTERIOR CRUCIATE LIGAMENT INJURIES – A CLINICAL STUDY
294. Lars Fosse: MECHANICAL BEHAVIOUR OF COMPACTED MORSELLISED BONE – AN EXPERIMENTAL IN VITRO STUDY
295. Gunilla Klensmeden Fosse: MENTAL HEALTH OF PSYCHIATRIC OUTPATIENTS BULLIED IN CHILDHOOD
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