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IMPLEMENTACIÓN CLÍNICA DE LA ECOGRAFÍA PERIPARTO PARA LA MEJORA DE LOS RESULTADOS PERINATALES

Ana María Fidalgo Conde

Directoras:

María Mar Gil Mira

Adriana Aquise Pino

Madrid, febrero de 2026

Directora de tesis: María del Mar Gil Mira
Universidad Francisco de Vitoria
Hospital Universitario de Torrejón
Madrid, España

Confirmo que Dña. Ana Mª Fidalgo Conde ha llevado a cabo, bajo mi supervisión, los estudios presentados en la Tesis: ***Implementación clínica de la ecografía periparto para la mejora de los resultados perinatales.***

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He leído la Tesis y estoy de acuerdo en que se presente en el programa de Doctorado en Biotecnología, Medicina y Ciencias biosanitarias de la Universidad Francisco de Vitoria.

María del Mar Gil Mira
Madrid, febrero de 2026

Directora de tesis: Adriana Aquise Pino
Hospital Universitario de Torrejón
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Adriana Aquise Pino
Madrid, febrero de 2026

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ÍNDICE DE ABREVIATURAS

ADP: ángulo de progresión

ALM: ángulo de línea media

CRL: *crown-rump length*, longitud cráneo-caudal

DBP: diámetro biparietal

DC: dirección de la cabeza

DCE: dilatación cervical por ecografía

DCP: distancia cabeza-periné

FIV: fecundación *in vitro*

IMC: índice de masa corporal

IVF: *in vitro fertilization*

PS-ADP: ángulo de progresión parasagital

TV: tacto vaginal

VPP: valor predictivo positivo

Δ-ADP: delta ángulo de progresión

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RESUMEN

Introducción

Clásicamente la valoración del trabajo de parto se ha realizado mediante tactos vaginales periódicos que se registraban en forma de partograma. Este es un método limitado debido a su subjetividad e incluso a la incomodidad para la paciente. La ecografía intraparto surge como una herramienta alternativa, más objetiva y reproducible y menos invasiva, que nos permite realizar una valoración del parto desde la consulta de urgencia hasta la tercera fase del parto, e incluso ayudar a decidir el mejor momento, modo y lugar en el que este tenga lugar

Objetivo

El objetivo último es el de evaluar la implementación clínica de la ecografía periparto en términos de reproducibilidad, factibilidad y aceptación y analizar posibles parámetros de mejora del resultado perinatal.

Para concretarlo se propusieron los siguientes objetivos específicos:

1. Evaluar la reproducibilidad y concordancia en la medición de parámetros ecográficos durante el parto entre matronas y obstetras;
2. Determinar la factibilidad y aceptabilidad del sonopartograma; y valorar si la ecografía puede reducir el dolor de la paciente durante la exploración;
3. Evaluar la reproducibilidad del ángulo de progresión de la nalga como parámetro objetivo en la presentación de nalgas y estandarizar su medida mediante la creación y aplicación de una lista de comprobación basada en imágenes;
4. Comparar la datación de la gestación mediante DBP con la tradicional basada en CRL y evaluar cómo su implementación afectaría a la tasa de inducción de parto.

Métodos

Para dar respuesta a ello se diseñaron los siguientes cuatro estudios clínicos que conforman esta tesis por compendio de publicaciones:

1. El primero de ellos se trata de un estudio prospectivo realizado en dos maternidades en Madrid entre marzo de 2018 y diciembre de 2019 en el que participaron 109 pacientes en primera fase de parto. Se realizó ecografía transperineal y transabdominal de forma independiente por una matrona entrenada previamente y por un obstetra. Se obtuvo un par de mediciones por

examen, por matrona y obstetra respectivamente del ángulo de progresión (ADP) (n = 107), la distancia cabeza-periné (DCP) (n = 106), la dilatación cervical ecográfica (DCE) (n = 97) y la posición de la cabeza fetal (n = 79). Se analizó el nivel de correlación mediante el coeficiente de correlación intraclase (CCI).

2. El segundo es un estudio de cohortes longitudinal prospectivo cuyas 100 participantes eran gestantes entre 37 + 0 y 41 + 6 semanas de gestación que iban a someterse a una inducción de parto, en tres maternidades diferentes de Madrid y Hong-Kong. Se les realizó una ecografía basal transabdominal y transperineal, que incluyó una biometría fetal, Doppler de la arteria umbilical y la arteria cerebral media fetal, el índice de líquido amniótico, la determinación de la posición de la columna y el occipucio fetales, el ADP parasagital (PS-ADP), la DCP, la DCE y la longitud cervical. Se realizaron ecografías intraparto seriadas en lugar de tactos vaginales, a menos que existiera una indicación clínica para realizarla, según el protocolo. Se pidió a las participantes que nos indicaran su nivel de dolor durante la exploración mediante una puntuación verbal de 0 a 10 (donde 0 representa ausencia de dolor). Los datos de las mediciones se analizaron utilizando modelos de efectos mixtos para identificar factores importantes que afectaran a la relación entre PS-ADP, DCP, DCE y modo de parto.
3. El tercer estudio es observacional y multicéntrico en el que se proporcionaron dieciocho volúmenes tridimensionales (3D) de ecografía transperineal de gestantes entre de 36 y 40 semanas de gestación con un feto único en presentación de nalgas a ocho operadores de cuatro maternidades distintas en España e Italia. Todos los operadores midieron el ángulo de progresión de la nalga utilizando un programa informático de procesamiento de volúmenes ecográficos 3D y se evaluó la reproducibilidad interobservador utilizando el CCI. Después de una revisión de todas las mediciones mediante una reunión *online* de por parte de los operadores y de la identificación de causas de discordancia, se desarrolló una lista de comprobación para la correcta medición del ángulo de progresión de la nalga. Las mediciones del ángulo de progresión de la nalga se repitieron utilizando esta lista y se reevaluó la reproducibilidad.
4. El cuarto es un estudio de cohortes retrospectivo multicéntrico realizado en cinco maternidades en España, Reino Unido, Bélgica y Bulgaria entre enero de 2011 y diciembre de 2019. Se incluyó a todas las gestantes que asistieron a una ecografía rutinaria entre las 11 + 0 y las 13 + 6 semanas con gestación única intrauterina viable sin malformaciones y con mediciones de la longitud cráneo-

ráquis (*Crown rump length* o CRL) como del diámetro biparietal (DBP), junto con un registro completo de los resultados del embarazo. Se desarrolló una fórmula para la datación del embarazo basada en DBP utilizando datos de embarazos concebidos mediante fecundación in vitro mediante la aplicación de una regresión lineal simple. Validamos esta fórmula tanto interna como externamente y la comparamos con las fórmulas más utilizadas (fórmulas basadas en CRL de Robinson y fórmulas basadas en DBP de Kustermann) mediante el uso de la distancia euclídea, el error absoluto relativo y el error cuadrático medio. También se examinó la tasa de inducción del parto para el embarazo prolongado en función de la datación utilizando cada una de las fórmulas.

Resultados

1. Se encontró una buena correlación entre obstetras y matronas en la medida del ADP (CCI = 0,85; intervalo de confianza [IC] del 95%: 0,80-0,89). Hubo una correlación moderada en la DCP (CCI = 0,75; IC del 95%: 0,68-0,82). Hubo una muy buena correlación en la medida de la CDE (CCI = 0,94; IC del 95%: 0,91-0,96). Hubo un muy buen nivel de concordancia en la clasificación de la posición de la cabeza fetal (κ de Cohen = 0,89; IC del 95%: 0,80-0,98).
2. De las 100 pacientes que participaron, el 20% dio a luz por cesárea, el 65% mediante parto eutócico y el 15% con un parto instrumental. No hubo resultados adversos fetales o maternos. Se realizaron un total de 223 ecografías intraparto en 87 participantes (13 mujeres dieron a luz antes de que se les realizara la ecografía intraparto seriada), con una mediana de dos ecografías por participante (rango intercuartílico, RIC, 1-3). De ellas, 76 mujeres se sometieron a un total de 151 tactos vaginales, con una mediana de un tacto vaginal por participante (RIC 0-2), sin diferencias significativas entre los grupos de parto vaginal o por cesárea. Excluidas las paciente con analgesia epidural, la mediana de la puntuación de dolor para las ecografías intraparto fue de 0 (RIC: 0-1) y para el tacto vaginal fue de 3 (RIC: 0-6). En aquellos partos que acabaron en cesárea se observó una menor tasa de cambio en el PS-ADP, la DCP y la DCE.
3. Cuando los ocho operadores analizaron los dieciocho volúmenes inicialmente lograron una reproducibilidad moderada (CCI: 0,70; IC del 95 %: 0,48 a 0,86). Tras desarrollar la escala de verificación descrita previamente, se reevaluaron los mismos dieciocho volúmenes utilizándola, y se observó que mejoró considerablemente la reproducibilidad (CCI: 0,81; IC del 95 %: 0,66 a 0,92).
4. Se incluyó en el estudio a un total de 49 492 gestantes, de las cuales 47 223 (95,4%) fueron gestaciones espontáneas y 2 269 (4,6%) concibieron mediante

FIV. En la validación interna realizada con datos de embarazos por FIV, nuestra fórmula recién desarrollada no mostró diferencias significativas en comparación con la edad gestacional real calculada a partir de la fecha de concepción, con una diferencia de medias 0,0006 (IC del 95 %, -0,09 a 0,09) días. Por el contrario, la diferencia de medias de la fórmula basada en la DBP de Kustermann fue de -0,31 (IC del 95 %, -0,46 a -0,17) días y la diferencia de medias de la fórmula basada en el CRL de Robinson fue de -1,78 (IC del 95 %, -1,88 a -1,68) días. En la validación externa utilizando datos de embarazos concebidos espontáneamente, datados mediante la fórmula de Robinson como referencia para la edad gestacional "real", tanto nuestra fórmula como la de Kustermann resultaron en una subestimación de la edad gestacional, con diferencias de medias significativas de -1,25 (IC del 95 %, -1,28 a -1,22) días y -0,96 (IC del 95 %, -0,98 a -0,93) días, respectivamente. Las mayores diferencias en comparación con los resultados de datación basados en la fórmula de Robinson se observaron entre las semanas 11 + 0 y 12 + 0. Datar el embarazo utilizando la fórmula de Robinson identificaba a un 8,1 % de embarazos que requerían inducción tras la 41 + 3 semanas, en comparación con el 6,8 % ($P < 0,001$) y el 7,0 % ($P < 0,001$) al aplicar nuestra fórmula y la fórmula de Kustermann, respectivamente.

Conclusiones

1. La evaluación ecográfica de la posición de la cabeza fetal y el progreso del trabajo de parto puede ser realizada de manera precisa por matronas asistentes sin experiencia previa en ecografía.
2. La evaluación ecográfica transabdominal y transperineal permite evaluar la evolución del trabajo de parto y reduce el dolor durante la exploración.
3. La medición del BPA es posible y reproducible al utilizar una escala estandarizada basada en imágenes.
4. La datación del embarazo basada en la medición ecográfica del DBP fetal entre las 11 + 0 y las 13 + 6 semanas de gestación es una alternativa fiable a la datación basada en el CRL.

ABSTRACT

Introduction

Traditionally, labor assessment has been performed through periodic vaginal examinations recorded in a partogram. However, this method is limited due to its subjectivity and even discomfort for the patient. Intrapartum ultrasound emerges as an alternative tool, more objective, reproducible, and less invasive, that allows assessment of labor from the emergency visit through the third stage of labor, and even helps determine the optimal timing, mode, and place of delivery.

Objectives

The main objective was to evaluate the clinical implementation of peripartum ultrasound in terms of reproducibility, feasibility, and acceptance, and to analyze potential parameters for improving perinatal outcomes.

To achieve this, the following specific objectives were proposed:

1. To evaluate the reproducibility and agreement in the measurement of ultrasound parameters during childbirth between midwives and obstetricians;
2. To determine the feasibility and acceptability of sonopartogram; and to assess whether ultrasound can reduce patient pain during the examination;
3. To evaluate the reproducibility of the breech progression angle (BPA) as an objective parameter in breech presentation and standardize its measurement by creating and applying an image-based checklist;
4. To compare pregnancy dating using DBP with traditional CRL-based dating and evaluate how its implementation would affect the rate of labor induction.

Methods

To address this, the following four clinical studies were designed, which together form this thesis as a compendium of publications:

1. The first study is a prospective study conducted in two maternity units in Madrid between March 2018 and December 2019, involving 109 patients in the first stage of labor. Transperineal and transabdominal ultrasounds were performed independently by a previously trained midwife and an obstetrician. Two pairs of measurements were obtained for comparison in 107 cases for the angle of progression (AoP), 106 cases for head-to-perineum distance (HPD), 97 cases for ultrasound cervical dilation (SCD), and 79 cases for fetal head position. Level of agreement was assessed using the intraclass correlation coefficient (ICC).

2. The second study is a prospective longitudinal cohort study involving 100 participants, women between 37 + 0 and 41 + 6 weeks of gestation undergoing induction of labor in three different labor wards. First, an initial transabdominal and transperineal ultrasound was performed, including fetal biometry, Doppler of the umbilical and middle cerebral arteries, amniotic fluid index, determination of fetal spine and occiput position, PS-AoP, HPD, SCD, and cervical length. Serial intrapartum ultrasounds were performed instead of vaginal examinations, unless there was a clinical indication for it, according to the protocol. Participants were asked to indicate their level of pain during the examination using a verbal score from 0 to 10 (where 0 represents no pain). The measurement data were analyzed using mixed-effects models to identify important factors affecting the relationship between ps-AoP, HPD, SCD, and mode of delivery.
3. The third study was a multicenter observational study in which eighteen three-dimensional (3D) transperineal ultrasound volumes of pregnant women between 36- and 40-weeks' gestation with a singleton fetus in breech presentation were provided to eight operators from four different maternity wards in Spain and Italy. All operators measured BPA using 3D ultrasound volume processing software, and interobserver reproducibility was assessed using the intraclass correlation coefficient (ICC). After reviewing all measurements via an online meeting with the operators and identifying causes of discordance, a checklist for correct BPA measurement was developed. BPA measurements were repeated using this checklist, and reproducibility was reassessed.
4. The fourth study was a retrospective multicenter cohort study performed in five maternity units in Spain, the UK, Belgium and Bulgaria between January 2011 and December 2019. We included all women who attended a routine ultrasound examination at 11 + 0 to 13 + 6 weeks who had a singleton pregnancy with a viable non-malformed fetus/neonate and ultrasound-derived measurements for both CRL and BPD, along with a comprehensive record of pregnancy outcomes. We developed a formula for pregnancy dating based on BPD using data from pregnancies conceived via in-vitro fertilization (IVF) by applying a simple linear regression. We validated this formula both internally and externally and compared it with the most commonly used formulae (Robinson's CRL-based and Kustermann's BPD-based formulae) through utilization of the Euclidean distance, relative absolute error and mean squared error. We also examined the rate of induction of labor for post-term pregnancy based on dating using each of the formulae.

Results

1. We found a good correlation between the AoP measured by obstetricians and midwives (ICC = 0.85; 95% confidence interval [CI] 0.80–0.89). There was a moderate correlation between the HPD (ICC = 0.75; 95% CI 0.68–0.82). There was a very good correlation between the CD measured (ICC = 0.94; 95% CI 0.91–0.96). There was a very good level of agreement in the classification of the fetal head position (Cohen's κ = 0.89; 95% CI 0.80–0.98).
2. A total of 100 women were included in the study. Of these, 20% delivered by Cesarean section, 65% vaginally and 15% by instrumental delivery. There were no adverse fetal or maternal outcomes. A total of 223 intrapartum ultrasound scans were performed in 87 participants (13 women delivered before intrapartum ultrasound was performed), with a median of two scans per participant (interquartile range (IQR), 1–3). Of these, 76 women underwent a total of 151 vaginal examinations with a median of one VE per participant (IQR, 0–2), with no significant difference between vaginal- or Cesarean-delivery groups. After excluding those with epidural anesthesia during examination, the median pain score for intrapartum scans was 0 (IQR, 0–1) and for VE it was 3 (IQR, 0–6). Cesarean delivery was significantly associated with a slower rate of change in PS-AOP, HPD and SCD.
3. Eighteen volumes were analyzed by the eight operators, achieving a moderate reproducibility (ICC: 0.70, 95% CI: 0.48 to 0.86). A score was developed to include a series of landmarks for the appropriate assessment of BPA. Subsequently, the same eighteen volumes were reassessed using the new score, resulting in improved reproducibility (ICC: 0.81, 95% CI: 0.66 to 0.92).
4. A total of 49 492 women were included in the study, comprising 47 223 (95.4%) who conceived spontaneously and 2 269 (4.6%) who conceived via IVF. In the internal validation performed using data from IVF pregnancies, our newly developed formula showed no significant difference when compared with the true gestational age calculated using conception date, with a mean difference of 0.0006 (95% CI, -0.09 to 0.09) days. In contrast, the mean difference of Kustermann's BPD-based formula was -0.31 (95% CI, -0.46 to -0.17) days and the mean difference of Robinson's CRL-based formula was -1.78 (95% CI, -1.88 to -1.68) days. In the external validation using data from spontaneously conceived pregnancies, with dating using Robinson's formula as the reference for 'true' gestational age, both our formula and Kustermann's formula resulted in underestimation of gestational age, with significant mean differences of -1.25 (95% CI, -1.28 to -1.22) days and -0.96 (95% CI, -0.98 to -0.93) days,

respectively. The largest differences compared with Robinson's formula-based dating results were observed between 11 + 0 and 12 + 0 weeks. Dating the pregnancy using Robinson's formula led to 8.1% of pregnancies identified as requiring induction after 41 + 3 weeks, compared with 6.8% ($P < 0.001$) and 7.0% ($P < 0.001$) when applying our formula and Kustermann's formula, respectively.

Conclusions

1. Ultrasound assessment of fetal head position and progress of labor can effectively be performed by attending midwives without previous experience in ultrasound.
2. Comprehensive transabdominal and transperineal ultrasound assessment can be used to assess progress in labor and can reduce the level of pain experienced during examination. Ultrasound assessment may be able to replace some transabdominal and vaginal examinations during labor.
3. The measurement of BPA is feasible and reproducible when using a standardized image-based score.
4. Pregnancy dating based on ultrasound measurement of fetal BPD between 11 + 0 and 13 + 6 weeks' gestation is a reliable alternative to dating based on fetal CRL.

INTRODUCCIÓN

1 INTRODUCCIÓN

1.1 Contextualización del parto y la evaluación del progreso del trabajo de parto

A principios del siglo XX a nivel mundial y tras la década de los 60 y 70, en España, el trabajo de parto se trasladó desde los domicilios hasta los centros sanitarios, pasando a ser las matronas o comadronas quienes, a través de tactos vaginales seriados, evaluaran la correcta evolución del mismo.[1]

La exploración vaginal y la partograma, como representación de esta a lo largo de las horas, aún a día de hoy sigue siendo la herramienta de referencia que permite valorar la progresión del parto y diagnosticar signos precoces de distocia.[2]

1.2 Limitaciones del tacto vaginal y del partograma clásico

Conocemos que la exploración vaginal es una valoración subjetiva y con una reproducibilidad interobservador baja, presentando una gran discordancia en la valoración cervical en todas las fases del trabajo de parto. Previo al trabajo de parto se muestran concordancias de tan solo el 28% en el test de Bishop;[3] en la primera fase la concordancia en la dilatación oscila entre el 19% y el 54% (según se usen modelos anatómicos blandos o duros respectivamente);[4] y en la segunda fase del parto algunos estudios sugirieron una alta concordancia entre la exploración vaginal y la ecográfica (85,6%),[5] mientras que otros describieron un error de en torno al 30% en el diagnóstico de la estación de Lee en la que se encontraba la presentación.[6]

Además, es sabido que el tacto vaginal aumenta el riesgo de infecciones, tanto maternas como fetales[7] y puede resultar incómodo e intrusivo para la paciente.[8]

1.3 Surgimiento y validación de la ecografía transperineal periparto como herramienta objetiva

El uso de la ecografía para el diagnóstico prenatal ha contribuido significativamente a mejorar los resultados perinatales. Por ejemplo, la correcta datación de la gestación en primer trimestre de embarazo, la detección de anomalías fetales o de los anejos ovulares y la estimación de peso fetal que han permitido optimizar el modo, momento y sitio en los que el parto tiene lugar.[9,10]

Por lo tanto, la incorporación de la ecografía transperineal intraparto en el manejo del parto supone un avance lógico y natural, al tratarse de un método no invasivo, objetivo, seguro y bien tolerado por la paciente.[11–13]

Su aprendizaje es rápido, y constituye un instrumento fiable no solo para el seguimiento del parto eutócico sino también para la identificación de los posibles signos de distocia [14,15] y, por lo tanto, apto para su universalización en el paritorio. Sin embargo, para conseguir que su uso sea rutinario, este no debe limitarse a obstetras con mayor o menor experiencia en ecografía, sino también extenderse a matronas u obstetras sin formación ecográfica a priori.

1.4 Evaluación de la estática fetal y la progresión del parto por ecografía

Existen una serie de parámetros ecográficos que correlacionan puntos anatómicos de la pelvis materna con la cabeza fetal que nos van a permitir describir la estática fetal y el progreso del parto con mayor precisión que el examen físico mediante palpación abdominal o tacto vaginal. Algunos de estos parámetros se obtienen mediante abordaje transabdominal y otros transperinealmente.

1.4.1 VÍA TRANSABDOMINAL

1.4.1.1 Posición del dorso fetal

La posición fetal hace referencia a la orientación de la presentación respecto a la pelvis y puede ser anterior, posterior o transversa. En los partos de vértice la presentación o punto guía es el occipucio, que actúa como punto de referencia en el examen vaginal, mientras que en la exploración abdominal, es el dorso el que define la posición. Tiene importancia la identificación de la posición posterior pura (dorso fetal junto a la espalda materna) puesto que es aquella que menos frecuentemente rota tanto en maniobra de versión cefálica externa como en el trabajo de parto.[16] En este sentido, la identificación de la columna vertebral fetal mediante ecografía abdominal resulta una tarea sencilla y altamente precisa.

1.4.1.2 <u>Posición de la cabeza (también valorable mediante el abordaje transperineal)</u>

Mediante la identificación de las órbitas (posición occípito-posterior), la línea media interhemisférica (occípito-transversa), o el cerebelo, columna o plexos coroideos (occípito-anterior) por ecografía transabdominal, podemos conocer la posición precisa de la cabeza fetal en relación a la pelvis materna (**Figura 1**).[17,18] El abordaje transperineal también permite esta evaluación empleando las mismas referencias anatómicas.

La identificación precisa del punto guía, sobre todo en aquellas presentaciones occípitosacras persistentes (alrededor del 5% en la segunda fase del parto), es de máxima importancia para el manejo del expulsivo, para aplicación de instrumentos para la extracción fetal y para indicar una cesárea en segunda fase del parto. La posición occípitosacra persistente aumenta por cuatro el riesgo de parto instrumental y por doce el de cesárea.[19–21]

Figura 1. Visualización ecográfica transabdominal de a) las órbitas, determinando una posición occípito posterior; b) la línea interhemisférica, determinando una posición occípito transversa; y c) la línea interhemisférica y los plexos coroideos, determinando una posición occípito anterior.

1.4.1.3 <u>Actitud de la cabeza fetal</u>

La actitud fetal hace referencia a la relación que tienen entre sí las diferentes partes fetales. En las presentaciones cefálicas corresponde al grado de flexión o extensión de la cabeza. Para la valoración de la actitud de la cabeza mediante ecografía transabdominal, Ghi et al describió en 2016 el ángulo occípito-cervical (*occiput-spine angle*); definido como el ángulo formado entre una línea que discurre tangencialmente por el occipucio fetal y otra por las apófisis espinosas de las primeras vértebras cervicales (**Figura 2**).[22] Este ángulo es útil para valorar el grado de flexión en posiciones no-occípitosacras y se ha considerado que si es menor 125º la cabeza no se encuentra flexionada sino extendida. Ángulos < 109º se han asociado a mayor índice de cesáreas por no progresión de parto.[23]

Figura 2. Medición ecográfica del ángulo occípito-cervical. En este ejemplo se objetiva la cabeza fetal en extensión (ángulo 63º).

En aquellos casos en los que el dorso fetal está en posición posterior, DiPasquo et al definieron en 2019 el ángulo barbilla-esternón *(chin-to-chest angle*) como aquel que surge entre la línea que discurre tangencialmente por el borde inferior mandibular fetal y aquella que lo hace por al esternón fetal (**Figura 3**).[24] Estos autores describieron que los ángulos mayores de 33º se consideraban una actitud en extensión de la cabeza.

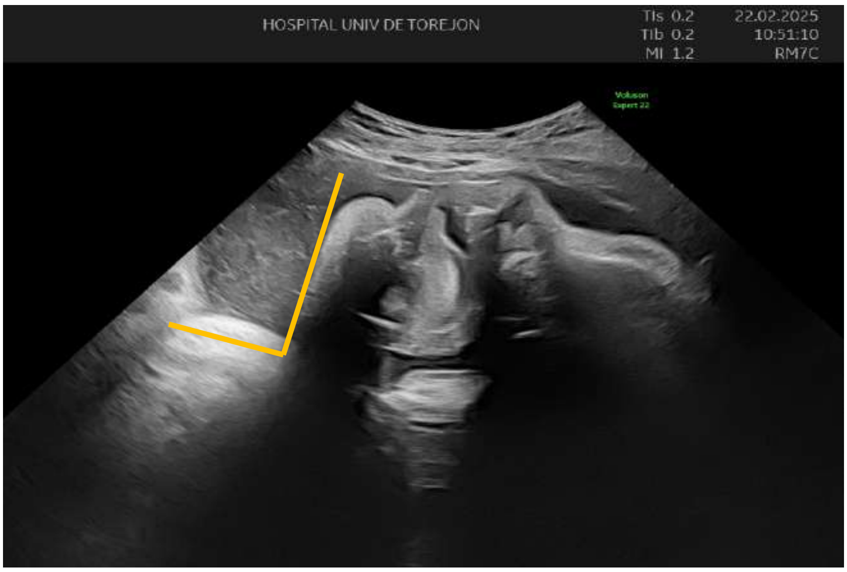


Figura 3. Medición ecográfica del ángulo barbilla-esternón. En este ejemplo se objetiva la cabeza fetal en extensión (ángulo 33º).

1.4.2 VÍA TRANSPERINEAL

1.4.2.1 Ángulo de progresión

El ángulo de progresión (ADP) fue descrito por Barbera et al en 2009, quien lo definió como el ángulo obtenido al trazar una línea que atraviese el eje longitudinal de la sínfisis del pubis y otra línea que discurra tangencialmente a la cara externa de calota fetal, en su porción más descendida, hasta la porción más inferior de la sínfisis del pubis (**Figura 4**).[25]

Para obtener el ADP, se debe colocar el transductor entre los labios vulvares en posición medio sagital, identificando la línea media de la sínfisis del pubis materno y la posición más descendida de la calota fetal (**Figura 5**).

El ADP es un indicador del descenso de la cabeza fetal en la pelvis materna. Se ha descrito que las espinas ciáticas se corresponden con un ADP de 120º, el cual ha demostrado ser un buen predictor del éxito de parto vaginal.[26–28]

La variación entre el ADP en reposo y con pujo es define como Δ- ADP; siendo un buen predictor de parto vaginal cuando es mayor de 18º.[29]

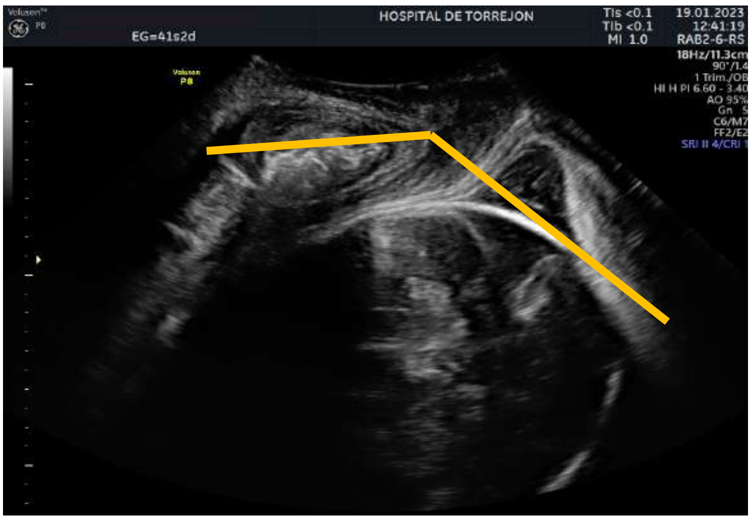


Figura 4. Medición ecográfica del ángulo de progresión. Los puntos anatómicos de referencia son la "almendra" dibujada por la sínfisis del pubis en plano medio sagital puro, el borde más inferior de la misma y la línea hiperecogénica que dibuja la calota fetal en su parte más descendida.

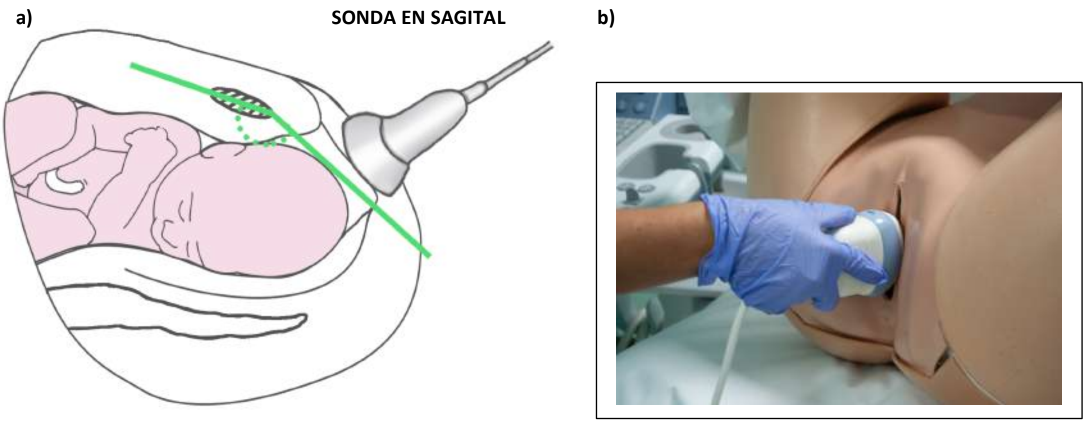


Figura 5. Representación esquemática de la posición de la sonda en un corte medio sagital materno (a) y demostración en maniquí de simulación (b) para la medición del ángulo de progresión.

Si el ADP se mide sobre cualquiera de las dos ramas óseas del pubis en un plano parasagital, en vez de sobre la sínfisis, recibe el nombre de ADP parasagital (PS-ADP) (**Figura 6**). Por su mayor simplicidad, este ángulo puede ser empleado en lugar del ADP, pero teniendo en cuenta que mide unos 11° más que este.[30]

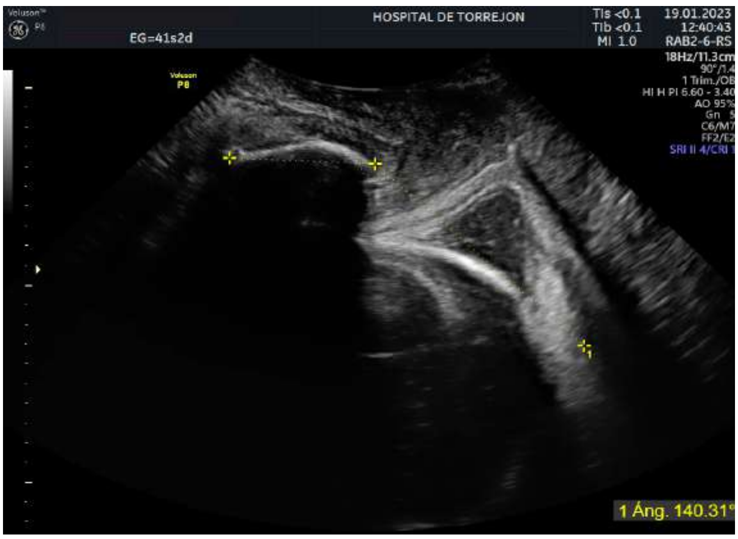


Figura 6. Medición ecográfica del ángulo de progresión parasagital, donde la línea púbica se sitúa en los extremos superior e inferior de la rama ósea del pubis materno.

1.4.2.2 Ángulo de progresión de la nalga

El ángulo de progresión de la nalga (*breech progression angle,* BPA) fue descrito por Youssef et al en 2021 como aquel que se forma entre la línea que discurre por el eje longitudinal de la sínfisis del pubis, dividiéndola en dos partes iguales (como para la medición del ADP), y otra que discurre tangencialmente por la parte fetal que se presenta más caudal, ya sea la nalga o el pie (**Figura 7**).[31] Dado a que hace referencia al grado de encajamiento de la nalga (o pie/s), se propone como un parámetro que podría aportar información a la hora de predecir el éxito de la maniobra de versión cefálica externa o del parto de nalgas.

Figura 7. Medición ecográfica del ángulo de progresión de la nalga. Los puntos anatómicos de referencia son la "almendra" dibujada por la sínfisis del pubis en plano medio sagital puro, el borde más inferior de la misma y la nalga fetal en su parte más descendida.

1.4.2.3 Distancia cabeza-periné

La distancia cabeza-periné (DCP) fue descrita por Eggebo et al en 2006 como la distancia más corta entre el límite óseo externo de la calota fetal hasta el periné materno (Figura 8). Para obtener este ángulo, se colocar el transductor en posición transversa a nivel de la horquilla vulvar posterior, y se aplica una presión firme pero no dolorosa en sentido cefálico, comprimiendo el tejido blando completamente (Figura 9).32

De manera similar a lo que hemos descrito para el ADP, estos autores describieron que la presentación fetal se encontraba al nivel de las espinas ciática cuando la DCP es de 35 mm. Cuando la calota fetal se sitúa a menos de 35mm ocurre el encajamiento y, en estos casos, sólo un 2% de las presentaciones no-occípitosacras terminarán en cesárea. Por lo tanto, la DCP al igual que el ADP, es un parámetro que, nos habla del descenso de la cabeza en el canal del parto y, como tal, es un buen predictor de parto vaginal en aquellos casos de trabajo de parto prolongado.[33–37]

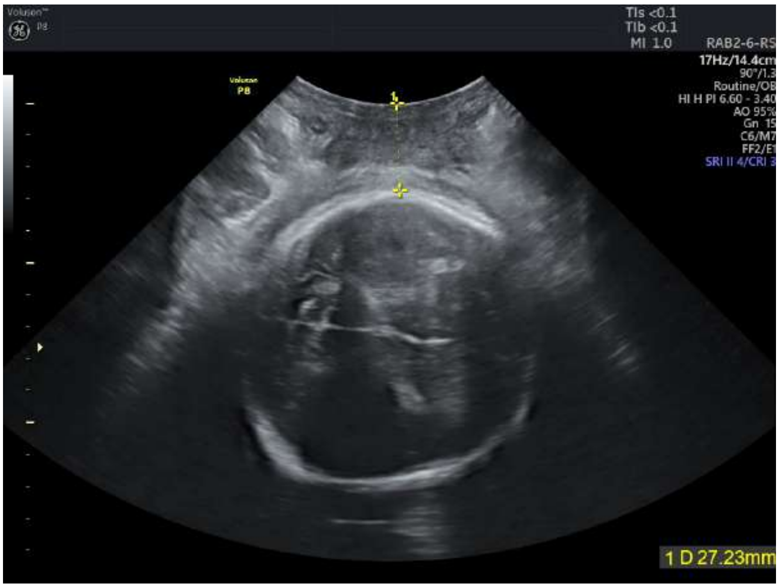
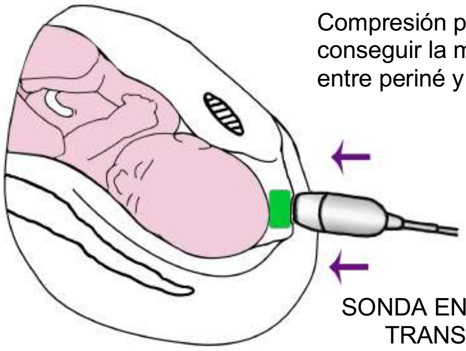


Figura 8. Medición ecográfica de la distancia cabeza periné, o distancia entre el periné materno y la parte más descendida de la calota fetal. En el ejemplo se demuestra una DCP de 27° y, por tanto, la posibilidad de parto vaginal es superior al 98%.

a)



b)

Figura 9. Representación esquemática de la posición de la sonda en un corte medio sagital materno (a) y demostración en maniquí de simulación (b) para la medición de la distancia cabeza-periné.

1.4.2.4 Dilatación cervical por ecografía

La técnica para la medición de la dilatación cervical por ecografía (DCE) fue descrita por Hassan et al en 2013. Los autores describieron que para su realización, primero se debía colocar el transductor en posición medio-sagital y, mediante movimientos finos de lateralización para identificar el orificio cervical interno y colocarlo en el centro de la imagen, se debía a continuación girar el transductor 90º hasta colocarlo en posición transversa. Entonces se debía realizar pequeños movimientos de inclinación, hasta identificar la imagen circular del cuello uterino, midiendo la dilatación cervical como la distancia entre el labio anterior y el posterior (**Figura 10**, **Figura 11**).[38]

Figura 10. Medición ecográfica de la dilatación cervical, o distancia entre el labio anterior y posterior del cérvix en un corte axial del mismo.

a)

b)

Figura 11. Representación esquemática (a) y sobre el maniquí de simulación (b) de la posición de la sonda para la medición de la dilatación cervical: en posición transversa cerca del clítoris materno y perpendicular al eje del cérvix, para lo que se requiere la inclinación de la sonda hacia anterior.

Se ha reportado que la diferencia entre la DCE y el tacto vaginal es de 1,24 cm a favor del tacto vaginal (menor la DCE).[38]

Sin embargo, su medición puede resultar más difícil cuando la dilatación cervical es mayor de 7cm, debido a la interposición de la cabeza sobre el labio posterior del cérvix. Por tanto es un parámetro especialmente útil en la monitorización de la primera fase del parto.[39]

1.4.2.5 Rotación de la cabeza

El ángulo de la línea media (ALM), descrito por primera vez por Ghi et al en 2009, evalúa el grado de rotación de la cabeza al descender en la pelvis, utilizándolo como indicador del progreso del parto. Para obtener el ALM, se colocará el transductor en posición axial materna entre los labios vulvares, de manera similar a la medición de la DCE, y se trazará una línea siguiendo la línea media interhemisférica y una segunda línea siguiendo el eje anteroposterior de la pelvis materna. El ángulo obtenido entre ambas líneas es el ALM (**Figura 12**).

a) **b)** **c)** **d)**

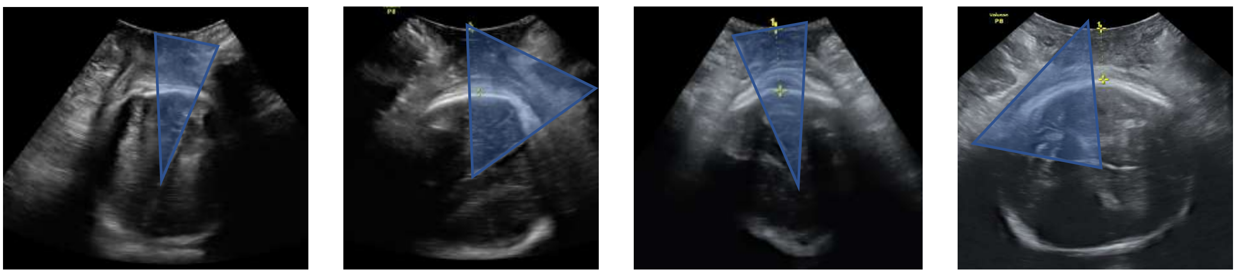


Figura 12. Medición ecográfica del ángulo de la línea media (ALM). Los ejemplos muestran un feto en posición occípito izquierda anterior con un ALM menor de 45º (a) y mayor de 45º (b), un feto en posición occípito derecha anterior con un ALM menor de 45º (c), y un feto en posición occípito derecha transversa (d).

El ALM va disminuyendo según la cabeza desciende por el canal del parto. En presentaciones no-occípitosacras se los autores observaron que un ALM ≥45° se correspondía a una estación de la cabeza de ≤+2cm en el 98,6% de los casos y un ALM <45° se correspondía a una estación de la cabeza de ≥+3cm en el 83,7% de los casos (P <0.001). Ellos estimaron que la probabilidad de éxito de la extracción fetal es mayor cuando el ALM es <45°.[18] Estos hallazgos fueron validados posteriormente por Sainz et al que mostraron como un ALM >35º se asociaba con un 85% de ventosas difíciles que requirieron >4 tracciones.[40]

1.4.2.6 Dirección de la cabeza

La dirección de la cabeza (DC) correlaciona la sínfisis púbica con la cabeza fetal para determinar la dirección de la misma y relacionarla con su flexión y descenso en la pelvis. La DC fue descrita por primera vez por Henrich et al en 2006, como el ángulo entre el eje mayor de la cabeza fetal y el eje mayor de la sínfisis del pubis, tomado en el plano medio sagital (**Figura 13**).[41]

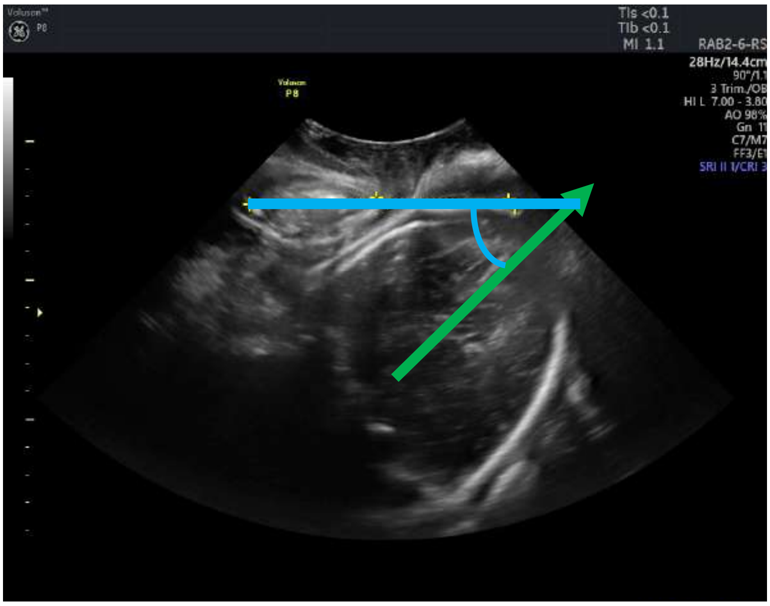


Figura 13. Valoración ecográfica de la dirección de la cabeza mediante el ángulo delimitado por la línea que transcurre por el eje mayor de la cabeza fetal y la línea que transcurre por el eje mayor de la sínfisis del pubis.

Estos autores clasificaron la dirección de la cabeza como hacia abajo (*head-down*), cuando el ángulo es menor de 0 º, horizontal, cuando el ángulo es entre 0 º y 30 º, o hacia arriba (*head-up*), cuando el ángulo en mayor de 30 º (**Figura 14**). La dirección de la cabeza hacia arriba demostró ser un predictor del parto vaginal.[18,41]

a) b)

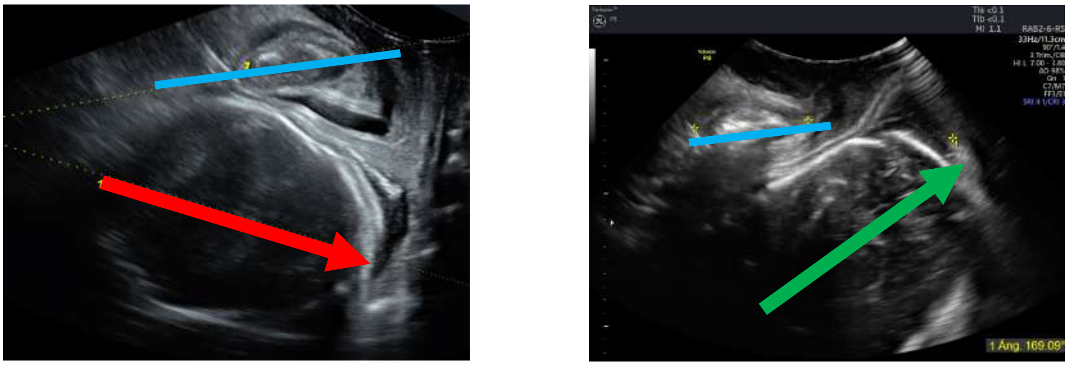


Figura 14. Ejemplos de dirección de la cabeza hacia abajo (a) y hacia arriba (b) determinados por ecografía transperineal.

En este punto es necesario remarcar la diferente manera que tiene de descender la cabeza en la pelvis en las posiciones no-occípitosacras (anteriores) y en la occípitosaccra (posteriores). Los fetos en posición occípitosacra mantienen la dirección hacia abajo durante mucho más tiempo, hasta que la frente ha superado el hueso púbico, para entonces cambiar directamente a una dirección hacia arriba (**Figura 15**).

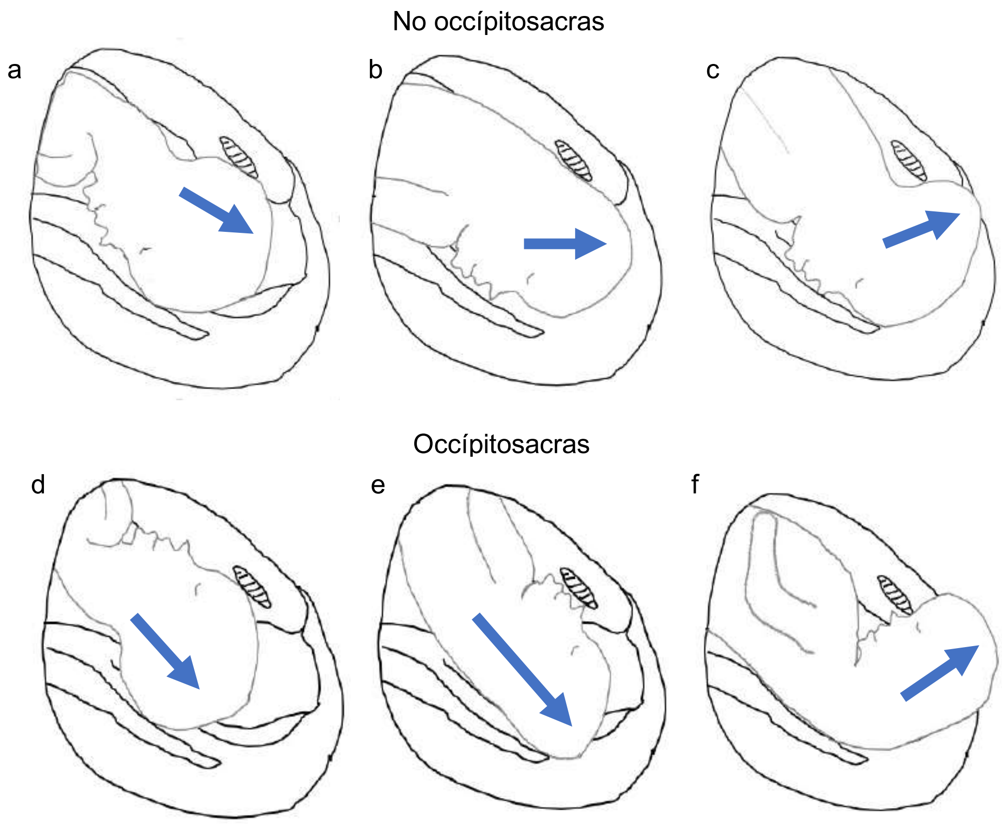


Figura 15. Representación esquemática de la dirección de la cabeza en el canal del parto: hacia abajo (a), horizontal(b) y hacia arriba (c) en las presentaciones no occipito sacras (imágenes superiores), y la dirección reiterada hacia abajo (d y e) y finalmente hacia arriba (f) en las occipito sacras (imágenes inferiores).

1.4.2.7 Valoración ecográfica del asinclitismo, cáput y acabalgamiento

La ecografía intraparto nos permite valorar algunos signos que podrían indicar una distocia de descenso. Por ejemplo, si existe cáput y acabalgamiento de suturas, el riesgo de desproporción cefalopélvica aumenta.[42,43]

1.5 Relevancia clínica del reemplazo o complementariedad de la ecografía frente a los métodos clásicos

Los sistemas ecográficos ya están casi siempre disponibles en la sala de partos pues son de gran ayuda y, en ocasiones, fundamentales en la valoración de los casos de sangrado anormal durante el trabajo de parto, cuando hay una sospecha de desprendimiento prematuro de placenta normoinserta o de rotura uterina.

Además de estas indicaciones clásicas, la ecografía puede ayudar, complementar o incluso potencialmente llegar a sustituir a la exploración tradicional en muchos de los momentos del parto.

1.5.1 Ecografía en la atención obstétrica de urgencia

En la urgencia obstétrica la ecografía nos ayuda a la hora de diagnosticar un embarazo intrauterino viable,[44] situaciones emergentes como un embarazo ectópico accidentado o una placenta previa que sangra,[45] así como a confirmar la presentación fetal,[18] o para medir la longitud cervical en el diagnóstico de la amenaza de parto prematuro.[46]

Además, la ecografía en la urgencia obstétrica permite realizar una estimación relativamente precisa del peso fetal en una paciente que ingresa de parto y en la que no se ha realizado un control previo adecuado de la gestación, en pacientes obesas o ante la sospecha de macrosomía o restricción de crecimiento.[47]

En la admisión de parto, la ecografía transperineal ha demostrado ser igual de válida que el tacto vaginal para indicar ingreso por trabajo de parto (indicando trabajo de parto si dilatación cervical ecográfica es ≥ 3cm o el ADP es >128º, lo que se correspondería con estación +1 de Lee.[48]

Previo a una inducción de parto, si la longitud cervical medida por ecografía es ≤ 30 mm la probabilidad de parto vaginal será muy alta (VPP para parto vaginal del 75%).[49] Además, presentar un ADP >95 º y una DCP ≤ 40 mm aumentan la probabilidad de éxito en la inducción de parto.[33,49,50] Se han creado modelos predictivos de parto que combinan los diferentes parámetros ecográficos, como la longitud cervical, la posición occípitosacra, el peso fetal estimado, el ADP y la DCP, con otros demográficos como la edad materna, el IMC, la paridad o la edad gestacional.[51]

1.5.2 Ecografía en la primera fase del parto

La primera fase de parto comprende desde el comienzo del trabajo de parto hasta la dilatación completa. Se subdivide en una primera fase latente y una fase activa (cuando la dilatación cervical ya es ≥ 6 cm) y su duración va a depender de la paridad (**Figura 16**).[52,53]

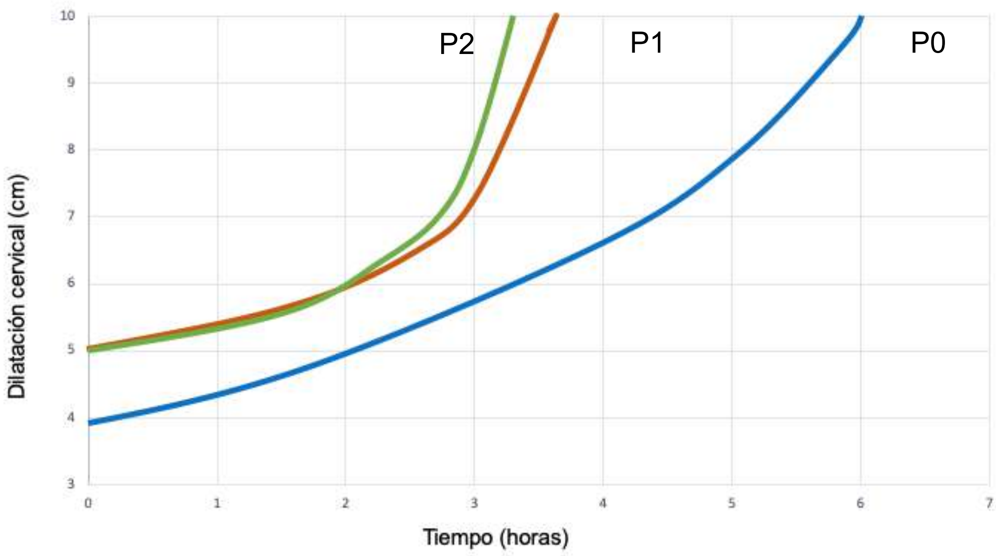


Figura 16. Curvas de dilatación en función de la paridad (P0 = sin partos previos; P1 = un parto previo; P2 = dos partos previos o más. Adaptado de Zhang et al. [52]

El diagnóstico de prolongación de primera fase de parto se hace cuando, habiéndose roto las membranas amnióticas y estimulado adecuadamente con oxitocina (objetivando dinámica uterina regular), no existe una progresión en la dilatación cervical en 4 horas o en 6 horas cuando las contracciones han sido irregulares.[53] La guía del *National Institute for Health and Care Excellence* (NICE) lo define como una dilatación cervical < 2 cm en 4 horas.[54]

Clásicamente, mediante el tacto vaginal en la primera fase del parto valoramos el borramiento, la dilatación cervical, el plano Hodge o la estación de Lee, la posición de la cabeza o la flexión de la cabeza. Tal y como se ha descrito anteriormente, mediante ecografía intraparto podremos tener una valoración objetiva de los mismos parámetros. A continuación, introduciremos la utilidad clínica de los mismos.

1.5.2.1 Utilidad clínica de la dilatación cervical por ecografía

La medición de la DCE es útil en la valoración del cérvix en la primera fase del parto, así como en casos de amenaza de parto prematuro, rotura prematura de membranas pretérmino y a término o previo a realizar una amniorrexis artificial.[55]

Como ya se ha explicado, siempre deberemos tener en cuenta que DCE es 1,24 cm menor que mediante tacto vaginal (TV).[38,56]

Se ha observado que el descenso rápido de la presentación ocurre a los 7-8 cm de dilatación cervical y esto tiene lugar aproximadamente 4h previo al parto en mujeres primíparas.[57] Es a partir de este momento cuando la medición de la DCE se hace más compleja y por ello nuestras guías españolas no lo recomiendan.[39]

1.5.2.2 Utilidad clínica de la evaluación ecográfica del descenso fetal

Los parámetros que han demostrado ser más útiles para la valoración del descenso de la cabeza fetal son el ADP y la DCP, incluso por delante de la exploración vaginal.

En un parto vaginal espontáneo el ADP y la DCP se mantienen inicialmente estables y progresan rápidamente em las últimas 4 horas de trabajo de parto, observando un tiempo hasta el parto menor de 5,5 horas cuando la DCP es de 40 mm, o < 5,2 horas cuando el ADP es de 110º.[57] En partos instrumentales este descenso es más pausado y en aquellos casos que terminan en cesárea por no progresión de parto apenas existe descenso objetivable.[57]

En esta misma línea, otros autores han descrito que un ADP ≥ 110 º se sigue de apenas un 12% de cesáreas por no progresión de parto, mientras que un ADP <110º conllevaría un 62% de cesáreas.[34,58] Por tanto, a mayor ADP menor riesgo de cesárea por este motivo.[30]

Por otro lado, objetivar una DCP > 50mm conlleva un riesgo del 82% de acabar en una cesárea ;[34] sin embargo, si vemos una DCP ≤ 40mm, sólo el 7% terminarían en cesárea por esta misma indicación.[34,59]

En estos mismos estudios se comparó la capacidad predictiva del ADP y la DCP con el tacto vaginal para la predicción de la cesárea por no progresión de parto, con resultados muy favorecedores para la ecografía.[34,58] Estos autores demostraron que en los casos que finalizaban con cesárea por esta indicación había una menor tasa de modificación del ADP, del ADP-ps , de la DCP y de la

DCE respecto al grupo que finalmente tenía un parto vaginal (menor grado de descenso).[60,61]

1.5.2.3 Utilidad clínica de la evaluación ecográfica de la posición de la cabeza fetal

Al inicio del parto, la posición occípitosacra es frecuente, persistiendo únicamente un 20% de ellas en dicha posición en la segunda fase del parto. Además se ha visto que la rotación de occípitosaca a occípito-anterior se lleva a cabo al final del trabajo de parto, cuando la presentación está a nivel de espinas ciáticas y la dilatación es completa.[62] La presentación dorso posterior reduce la probabilidad de rotación espontánea hacia anterior.[16] Sólo en torno al 5% del total de presentaciones será una occípitosacra persistente.

En casos de prolongación de la primera fase del parto, se ha observado que la posición occípitosacra asocia un 38% de riesgo de cesárea, mientras que en la no occípitosacra la probabilidad de cesárea es prácticamente la mitad, de alrededor del 17%.[63] En aquellos casos con posición occipitosacra persistente existe un riesgo de parto instrumental cuatro veces mayor y hasta doce veces mayor de cesárea.[19,20]

1.5.2.4 Utilidad clínica de la evaluación ecográfica de la flexión de la cabeza fetal

Una adecuada flexión de la cabeza fetal se asocia con parto vaginal exitoso, tanto en posiciones occípitosacras[64] como en no occípitosacras. En estas últimas se ha observado que una menor flexión asocia mayor tasa de parto instrumental.[22]

Existe asociación entre la flexión de la cabeza, el encajamiento y la progresión del parto.[65] La flexión se asocia con la estación de Lee en posiciones no occípitosacras, sugiriendo que un plano alto podría ser indicador de una inadecuada flexión. En este sentido, un ángulo occípito-cervical < 109 º o un ángulo barbilla-esternón > 33º se asocian con cesárea por no progresión de parto.[23]

1.5.2.5 Creación de un sonopartograma

El sonopartograma consiste en la representación gráfica de todos los parámetros ecográficos descritos anteriormente, medidos durante la primera fase del parto, junto con otros datos clínicos como son la amniorrexis, la perfusión de oxitocina, la presencia de epidural o la valoración del líquido amniótico, así como las constantes maternas si se considera útil el registro conjunto (**Figura 17**). El sonopartograma fue descrito por Hassan et al en 2014, demostrando una adquisición de datos del trabajo de parto más exitosa que en partograma.[66]

Estudios posteriores apoyan la idea de que la ecografía intraparto puede ser usada para valorar el trabajo de parto mediante su representación en un sonopartograma y que podría reducir los niveles de dolor durante la exploración.[67]

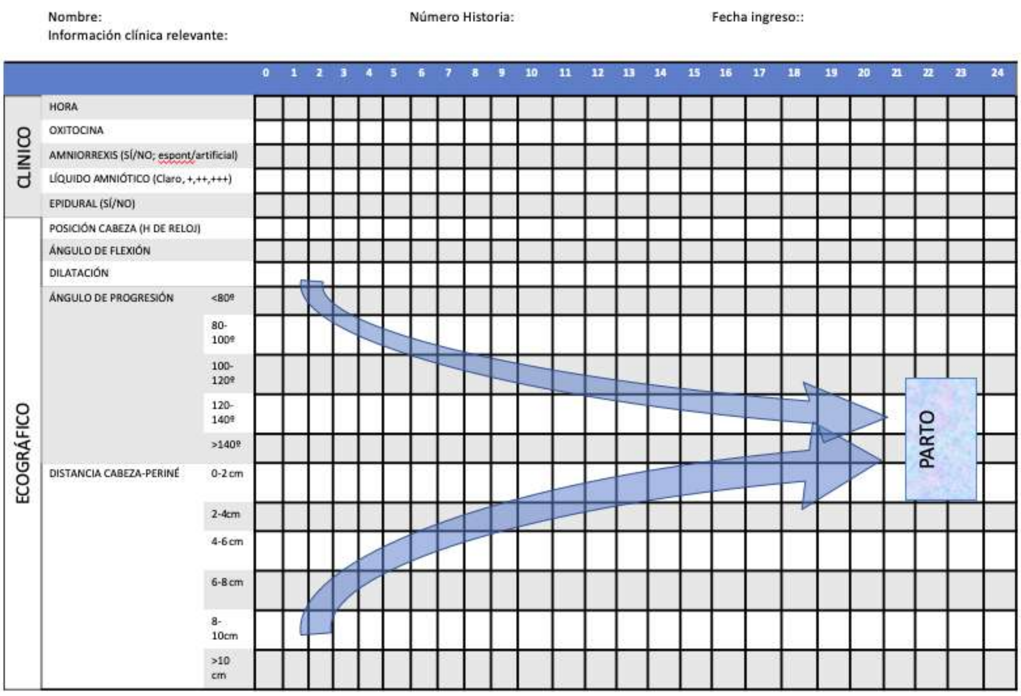


Figura 17. Propuesta de sonopartograma.

1.5.3 Ecografía en la segunda fase del parto

La segunda fase del parto se define como aquel periodo que va desde la dilatación completa hasta el nacimiento fetal. Ya se ha comentado que la dilatación cervical completa es difícil de valorar ecográficamente dada la interposición de la cabeza fetal entre labio anterior y posterior del cérvix cuando la dilatación en 6-7cm. Sin embargo, la fase de descenso rápido de la presentación ocurre en las últimas cuatro horas en la mujer primípara y esto tiene lugar cuando la presentación está próxima a las espinas ciáticas. Por lo tanto, realizar una medición de la DCE puede no ser necesaria llegado este punto.

El encajamiento de la presentación se define como el paso de la misma por la estación 0 de Lee o el III plano de Hodge (espinas ciáticas) y, ecográficamente, se correspondería con un ADP de 120º [26] y una DCP de 35mm.[36] Estudios posteriores han confirmado que un ADP > 120 º es predictor de parto vaginal[26–28] y, si el ADP se encuentra entre 120-140º predice el parto vaginal eutócico fehacientemente (sensibilidad del 81% y especificidad del 73%).[68] Si realizamos un seguimiento ecográfico del trabajo de parto, podemos asumir que la segunda fase del parto comienza cuando el ADP supera los 120º y la DCP disminuye por debajo de 35mm, aunque no seamos capaces de observar el cérvix en la ecografía transperineal.

En la segunda fase del parto, la ecografía intraparto nos sirve de ayuda en los siguientes escenarios:

1.5.3.1 Previa a la instrumentación

En un parto eutócico encontramos que el ADP está entre 120 y 140º, el Δ-ADP es aproximadamente 15º (cuando ADP basal es >140º) y la dirección de la cabeza hacia arriba son buenos predictores de parto espontáneo.[68,69]

A la hora de instrumentar, un ADP basal > 140º se asocia con un parto asistido no complicado.[13] El ADP, ángulo de rotación o ALM y la distancia de progresión con pujo son los mejores predictores de parto instrumental no complicado.[70,71] En las posiciones occípitosacras, debido a la distinta biomecánica del parto, se debe considerar la medición de la DCP además del ADP, como predictor de encajamiento. En las posiciones no occípitosacras, si la DCP es <35mm, tan solo un 2% de los partos acabarán en cesárea.[33–37]

Existen una serie de predictores de parto instrumental complicado, como son un ADP <120º sin pujo (la tasa de parto instrumental no complicado se reduce del

85% a 57%),[71] un ALM ≥ 35º o una dirección de la cabeza horizontal o hacia abajo, que se asocian en un 85% de los casos con instrumentación difícil (ventosas que requieren más de cuatro aplicaciones).[40]

Si la instrumentación se va a realizar mediante el uso de fórceps para rotar la cabeza fetal, hay evidencia de que la ecografía intraparto nos puede ser de ayuda como "doble comprobación" antes de la colocación de ramas o para ver la rotación de la línea media durante el procedimiento.[72] Si la instrumentación la vamos a realizar con una ventosa, la ecografía nos ayuda en su adecuada colocación en el punto de flexión, a 3 cm de fontanela menor (**Figura 18**).[73]

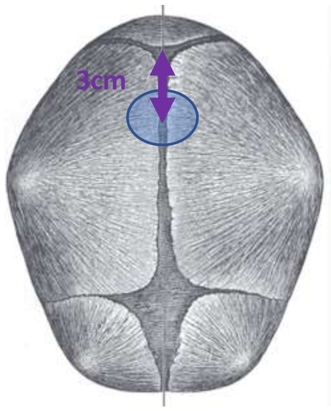


Figura 18. Identificación del punto de flexión.

1.5.3.2 Encontrar causas de distocia de descenso

La ecografía es una herramienta útil para identificar causas de distocia de segunda fase del parto como son la malrotación, el asinclitismo, la deflexión de la cabeza o la posición occípitosacra persistente (**Figura 19**).

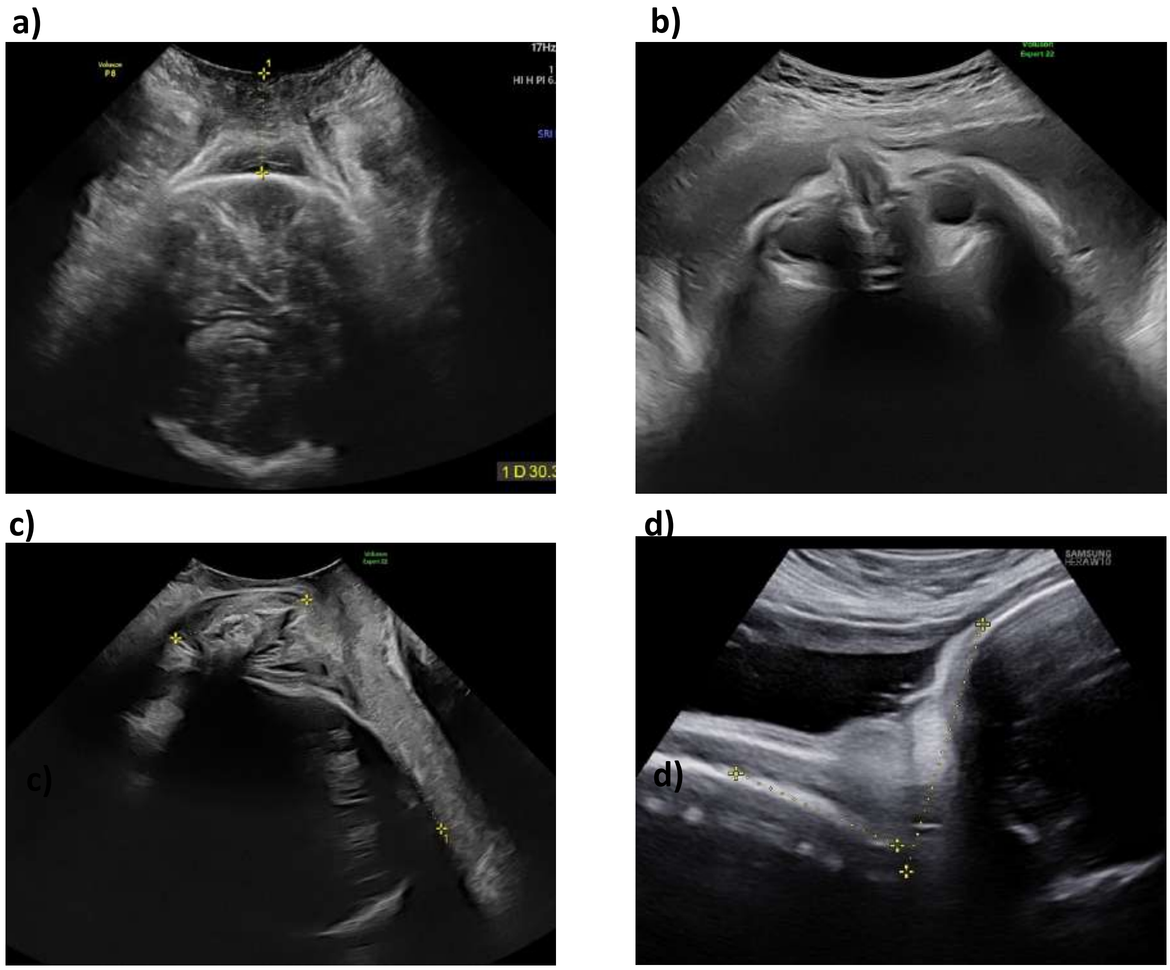


Figura 19. Causas de distocia detectables por ecografia: a) asinclitismo anterior, visualizando la línea media inter-hemisférica desplazada anteriormente y exponiendo el hemisferio posterior; b) posición posterior del vértex, visualizando las órbitas anteriormente; c) dirección de la cabeza hacia abajo, evaluando la relación entre el eje longitudinal de la cabeza fetal y el de la sínfisis púbica materna; d) cabeza fetal en extensión, visualizando un ángulo occípito-espinal < 125º.

1.5.3.3 Retroalimentación en los pujos activos

En los últimos cinco años, la ecografía intraparto se está convirtiendo en una herramienta fundamental para el trabajo de las matronas. Tanto en la admisión de urgencias de partos, como en el propio paritorio, el uso de la ecografía constituye un apoyo importante. Su uso como “retroalimentación” o estimulación visual del pujo por ecografía optimiza los pujos maternos y reduce la duración de la segunda fase de parto.[74,75]

Además se ha visto que la coactivación de músculo elevador del ano se asocia con prolongación de la segunda fase por lo que la ecografía podría servir de ayuda para ayudar a la paciente a relajar este músculo mediante retroalimentación visual.[76]

1.5.3.4 Parto del segundo gemelo

La ecografía también es un instrumento fundamental en los partos gemelares, especialmente para el parto del segundo gemelo en presentación no cefálica y realización de la maniobra de gran extracción.[77]

1.5.4 Ecografía en la tercera fase del parto

Tras el nacimiento del bebé, la ecografía nos puede ayudar en el diagnóstico de sospecha del acretismo placentario no detectado prenatalmente (visualización de lagunas vasculares, no visualización de línea hipoecoica que separa placenta de miometrio, vascularización aumentada, etcétera) o en casos de atonía uterina para valorar la cavidad endometrial (presencia de coágulos, restos placentarios).[65]

1.6 La correcta datación del embarazo y la mejoría en los resultados perinatales

Muchos de los resultados adversos perinatales vienen derivados de las complicaciones de la prematuridad o de la gestación prolongada. Además, la mayoría de las decisiones en relación al momento, lugar y vía del parto están condicionadas por la edad gestacional. En este sentido, si la finalización se ha programado demasiado pronto o demasiado tarde por un error de datación, este error se perpetuará hasta el nacimiento ya que no existe datación fiable en ese momento. Por lo tanto, la correcta datación de la gestación es fundamental para minimizar las posibles complicaciones que conllevan tanto el embarazo pretérmino como el postérmino.[78] En gestaciones obtenidas mediante fecundación *in-vitro* en las que sabemos qué día ha ocurrido la fecundación exactamente, la datación es fácil y se calcula según la fecha de concepción.[79] En gestaciones espontáneas, la datación más fiable es aquella que ocurre durante la ecografía del primer trimestre mediante la medición de la longitud cráneo-raquis (del inglés *crown-rump lenght*, CRL)[80,81] mediante el uso de las tablas de Robinson, las cuales han demostrado tener un margen de error de 3-8 días.[82,83]

Sin embargo, la obtención de una buena longitud cráneo-caudal (CRL, *crown-rump length)*, es a veces complicada, sobre todo en gestaciones cercanas a las 13-14 semanas en las que la posición fetal no suele ser tan neutra como previamente y, además, el feto suele rotar sobre sí mismo. Por estos motivos, además de por lo pequeño que es el espacio en el que se puede obtener un plano medio sagital óptimo a esta edad gestacional, se ha demostrado que la curva de aprendizaje es larga.[84] En consecuencia, muchos centros desestiman la importancia de esta medida y datan el embarazo por fecha de última regla o por un CRL obtenido más precozmente por personal poco entrenado en ecografía. En este contexto, la datación mediante la medición del diámetro biparetal (DBP) fetal se ha postulado como una alternativa fácil y reproducible,[85–87] que puede ser realizada por profesionales con menos experiencia. Sin embargo, la literatura existente comparando ambos métodos es limitada, lo que ha impedido su generalización.

HIPÓTESIS Y OBJETIVOS

2 HIPÓTESIS Y OBJETIVOS

2.1 HIPÓTESIS

La implementación sistemática de la ecografía periparto, realizada por profesionales entrenados, mejora la calidad de la evaluación del trabajo de parto y puede traducirse en una atención más objetiva y reproducible, menos tactos vaginales, reducción de tactos vaginales y una mayor aceptación por parte de las mujeres, todo ello enfocado a la mejora de los resultados perinatales.

2.2 OBJETIVO GENERAL

Evaluar la implementación clínica de la ecografía periparto en términos de reproducibilidad, factibilidad y aceptación y analizar posibles parámetros de mejora del resultado perinatal.

2.3 OBJETIVOS ESPECÍFICOS

1. Evaluar la reproducibilidad y concordancia en la medición de parámetros ecográficos durante el parto entre matronas y obstetras;

2. Determinar la factibilidad y aceptabilidad del sonopartograma;

3. Evaluar la reproducibilidad del ángulo de progresión de la nalga como parámetro objetivo en la presentación de nalgas y estandarizar su medida;

4. Comparar la datación de la gestación mediante DBP con la tradicional basada en CRL y evaluar cómo su implementación afectaría a la tasa de inducción de parto.

MÉTODOS

3 MÉTODOS

Esta tesis doctoral se presenta como un compendio de cuatro artículos científicos que se corresponden con cuatro estudios clínicos diseñados para responder a los objetivos planteados anteriormente. A continuación, se presentan los métodos empleados en cada uno de ellos.

3.1 Estudio 1: *“Level of agreement between midwives and obstetricians performing ultrasound examination during labor”*

3.1.1 Diseño y población del estudio

Este es un estudio prospectivo comparativo y multicéntrico llevado a cabo en dos maternidades en Madrid (Hospital Universitario de Torrejón y Hospital Universitario La Paz), España. Por conveniencia clínica, se invitó a participar a aquellas embarazadas con gestación única cefálica a término que se encontraran en primera fase de parto en nuestras unidades entre marzo de 2018 y diciembre de 2019. El único criterio de exclusión fue que tuviera una cesárea programada.

3.1.2 Procedimientos del estudio

Tras la firma del consentimiento, se registraron las características maternas y de la gestación. A continuación, un obstetra y una matrona, de manera ciega entre sí respecto a los hallazgos ecográficos y también respecto a las exploraciones clínicas, llevaron a cabo las exploraciones ecográficas en orden aleatorio. Durante la exploración ecográfica se evaluaron la posición de la cabeza fetal, el ADP, la DCP y la dilatación DCE. Cada mujer fue evaluada sólo una vez por el obstetra y por la matrona.

Antes de empezar el estudio, un obstetra experto en ecografía intraparto impartió un curso corto práctico a un grupo seleccionado de matronas que atienden partos, pero sin experiencia previa en ecografía y a obstetras con amplia experiencia en ecografía pero que nunca habían realizado ecografía transperineal durante el parto.

Para el análisis estadístico, se calculó la diferencia absoluta de los pares, el coeficiente de correlación intraclase (ICC) y el índice Kappa de Cohen ponderado. Finalmente, también usamos los diagramas de Bland and Altman para mostrar gráficamente las diferencias entre los pares de medidas

3.2 Estudio 2: *"Implementation of sonopartogram: multicenter feasibility study"*

3.2.1 Diseño y población del estudio

Se trata de un estudio de cohortes prospectivo longitudinal en mujeres con gestación única sometidas a inducción de parto a las ≥ 37 semanas de gestación, llevado a cabo en una unidad de maternidad en Hong Kong y dos unidades en Madrid, entre el 1 de diciembre de 2021 y el 31 de julio de 2023.

3.2.2 Procedimientos del estudio

Tras obtener el consentimiento informado, se registraron los antecedentes maternos y demográficos y se realizó una ecografía inicial antes de la inducción de parto. Se realizó un tacto vaginal para la valoración cervical y determinar el método de inducción. En todas las participantes se reemplazaron los tactos vaginales destinados a evaluar la progresión del parto por exploraciones ecográficas, salvo indicación clínica. Se realizó una ecografía cada doce horas hasta que la participante tuvo contracciones regulares espontáneas o cuando comenzó la perfusión de oxitocina y tras ello, las exploraciones ecográficas se realizaron cada cuatro horas durante la fase latente y cada dos horas tras la fase activa. En la exploración ecográfica inicial se realizó una biometría fetal, el índice de pulsatilidad de arteria umbilical y la arteria cerebral media, y el índice de líquido amniótico. Las siguientes ecografías se destinaron a evaluar la posición de la cabeza fetal, el PS-ADP, la DCP y la DCE. El manejo obstétrico fue el indicado por protocolo clínico.
A todas las participantes se les preguntó verbalmente a las participantes por el nivel de dolor con la exploración en una escala entre 0 y 10.

Las variables categóricas se compararon usando el test de χ-cuadrada o el test de Fisher exacto. Para la comparación de las variables continuas se usó el test de Mann–Whitney U o el test de “t de Student” para los datos no paramétricos y paramétricos, respectivamente. Para el análisis de medidas repetidas del ADP-ps, DCP y DCE, se realizó un análisis de modelo lineal mixto, incluyendo los efectos fijos y los efectos aleatorios. Los modelos finales se seleccionaron basándose en el Criterio de Información Bayesiano (BIC) más bajo.

3.3 Estudio 3: *“Reproducibility of Breech Progression Angle: Standardization of Transperineal Measurements and Development of Image-Based Checklist for Quality Control”*

3.3.1 Diseño y población del estudio

Este es un estudio multicéntrico observacional llevado a cabo entre enero y mayo de 2023 en dos hospitales españoles y dos italianos.
Se incluyeron gestantes de 36-40 semanas con gestación única de nalgas.

3.3.2 Procedimientos del estudio

Se obtuvieron veinte ecografías tridimensionales (3D). Después de las adquisiciones el equipo central del estudio revise la calidad de las imágenes y dos de los volúmenes fueron excluidos por presentar una visualización subóptima, manteniendo dieciocho volúmenes para el análisis final. Estos fueron distribuidos a ocho obstetras senior, dos de cada centro participante. Para reducir la variabilidad en los conocimientos de base, los operadores fueron seleccionados entre obstetras con experiencia en ecografía obstétrica y aquellos que usaban ecografía intraparto habitualmente, pero sin experiencia en la medición del ángulo de progresión de la nalga sin realizar ningún entrenamiento previo. Los operadores midieron el BPA usando un programa informático para procesamiento de volúmenes. Tras la primera ronda de valoraciones, se analizaron las discordancias y sus posibles causas para elaborar una lista de comprobación que sirviera para estandarizar la medición y hacerla más reproducible.

Seis meses después, todos los operadores repitieron la medición de los BPA en los mismos volúmenes pero usando la lista de comprobación en su valoración.

Se evaluó la reproducibilidad interobservador de los volúmenes en dos ocasiones: antes de la implementación de la lista de comprobación y después, usando el CCI. Se estimó la concordancia general entre todos los operadores, así como la concordancia por pares entre cada par de operadores. La variabilidad de las mediciones también se evaluó visualmente mediante la representación gráfica de las mediciones obtenidas para cada volumen. Se realizó un análisis de potencia a posteriori para verificar que el estudio tuviera la potencia estadística suficiente para evaluar la reproducibilidad.

3.4 Estudio 4: *"Biparietal diameter for first-trimester pregnancy dating: multicenter cohort study"*

3.4.1 Diseño y población del estudio

Este es un estudio de cohortes multicéntrico retrospectivo desarrollado en dos maternidades en España, una en Reino Unido, una en Bélgica y una en Bulgaria entre enero de 2011 y diciembre de 2019. Se incluyeron todas las mujeres que asistieron a consulta de rutina, con un embarazo único y una ecografía entre las semanas 11+0 y 13+6 de gestación sin malformaciones fetales, y mediciones ecográficas del CRL y del DBP, junto con un registro completo del de todo el embarazo hasta el parto.

3.4.2 Procedimientos del estudio

Se registraron las mediciones ecográficas del CRL y del DBP así como las características maternas y del embarazo. En la práctica clínica, solamente se habían usado el CRL, o la fecha de concepción para embarazos de FIV, para la datación del embarazo y la medición del DBP se realizó para otros fines, de acuerdo con los protocolos locales.

Para validar las fórmulas en diversas poblaciones, se organizaron los datos por centro y se analizó cada conjunto de datos en el orden en que fueron recibidos. El conjunto de datos se dividió en tres subgrupos.

- El grupo 1 incluyó todas las gestaciones FIV de dos maternidades y se usó para desarrollar nuestra fórmula de datación de la gestación por DBP y fue usado para la validación interna.
- El grupo 2 representaba todas las gestaciones espontáneas de todos los centros participantes y fue usado para la validación externa del modelo en gestaciones espontáneas.
- El grupo 3 fue un subgrupo del grupo 2 que comprendía gestaciones espontáneas que iban a someterse a inducción de parto más allá de semana 41+3 y aquellas que se pusieron de parto de manera espontánea entre las 34+0 y 42+6 semanas, y fue usado para calcular la tasa de inducción debido a gestación cronológicamente prolongada.

Al representar gráficamente el DBP como variable dependiente y la edad gestacional en días como variable independiente, se observó una relación completamente lineal. Por lo tanto, se optó por ajustar un modelo de regresión lineal simple para desarrollar una ecuación que estimara la edad gestacional basándose en el DBP.

Durante el desarrollo de la fórmula y la validación interna (es decir, para el Grupo 1), la edad gestacional calculada a partir de la fecha de concepción se consideró la referencia. Para la validación externa (es decir, para el Grupo 2) y la evaluación de la tasa de inducción (es decir, para el Grupo 3), la edad gestacional calculada mediante la fórmula de Robinson basada en el CRL se consideró el estándar de oro.

Para comparar la edad gestacional estimada en las distintas fórmulas, se calculó la distancia euclídea, el error absoluto relativo (RAE), el error cuadrático medio (MSE), la comparación de medias mediante la prueba t pareada y la comparación de los valores mediante la prueba de Wilcoxon.

Se realizó una comparación final entre las fórmulas basada en el número de embarazos identificados que requirieron inducción del parto por embarazo prolongado, definido como aquellos casos en los que no ha ocurrido un trabajo de parto espontáneo dentro de las 41+3 semanas/290 días, según cada fórmula. Se utilizó la prueba de McNemar para evaluar la diferencia en la tasa de inducción al utilizar cada método de datación del embarazo.

RESULTADOS

4 RESULTADOS: ARTÍCULOS CIENTÍFICOS

ARTÍCULOS PUBLICADOS

Estudio 1.- Level of agreement between midwives and obstetricians performing ultrasound examination during labor.

Fidalgo AM, Miguel R, Fernández-Buhigas I, Aguado A, Cuerva MJ, Corrales E, Rolle V, Santacruz B, Gil MM, Poon LC.Int J Gynaecol Obstet. 2024 Jan;164(1):131-139. doi: 10.1002/ijgo.14956. Epub 2023 Jul 4.PMID: 37401541

Estudio 2.-Implementation of sonopartogram: multicenter feasibility study.

Lee NMW, Lau SL, Yeung YK, Chiu CPH, Liu F, Lau YY, Fidalgo AM, Cuerva MJ, Aquise A, Nguyen-Hoang L, Gil MM, Poon LC.Ultrasound Obstet Gynecol. 2024 Aug;64(2):214-221. doi: 10.1002/uog.27634. Epub 2024 Jul 5.PMID: 38456522

Estudio 3.- Reproducibility of Breech Progression Angle: Standardization of Transperineal Measurements and Development of Image-Based Checklist for Quality Control.

Fidalgo AM, Aquise A, Molina FS, Youssef A, González-Vanegas O, Brunelli E, Cataneo I, Segata M, Cuerva MJ, Rolle V, Gil MM.Diagnostics (Basel). 2025 Jul 11;15(14):1757. doi: 10.3390/diagnostics15141757.PMID: 40722507

Estudio 4.- Biparietal diameter for first-trimester pregnancy dating: multicenter cohort study.

de Paco Matallana C, Rolle V, Fidalgo AM, Sánchez-Romero J, Jani JC, Chaveeva P, Delgado JL, Santacruz B, Nicolaides KH, Gil MM.Ultrasound Obstet Gynecol. 2025 May;65(5):560-566. doi: 10.1002/uog.29216. Epub 2025 Apr 3.PMID: 40179227

4.1 Estudio 1.- <u>Level of agreement between midwives and obstetricians performing ultrasound examination during labor.</u>

Fidalgo AM, Miguel R, Fernández-Buhigas I, Aguado A, Cuerva MJ, Corrales E, Rolle V, Santacruz B, Gil MM, Poon LC.Int J Gynaecol Obstet. 2024 Jan;164(1):131-139. doi: 10.1002/ijgo.14956. Epub 2023 Jul 4.PMID: 37401541

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CLINICAL ARTICLE

Obstetrics

Level of agreement between midwives and obstetricians performing ultrasound examination during labor

Ana M. Fidalgo[1] | Raquel Miguel[1] | Irene Fernández-Buhigas[1] | Asunción Aguado[1] | Marcos J. Cuerva[2] | Elisa Corrales[1] | Valeria Rolle[3] | Belén Santacruz[1,4] | María M. Gil[1,4] | Liona C. Poon[5]

[1]Department of Obstetrics and Gynecology, Hospital Universitario de Torrejón, Madrid, Spain

[2]Department of Obstetrics and Gynecology, Hospital Universitario La Paz, Madrid, Spain

[3]Biostatistics and Epidemiology Platform at Fundación para la Investigación e Innovación Biosanitaria del Principado de Asturias, Oviedo, Spain

[4]School of Health Sciences, Universidad Francisco de Vitoria, Pozuelo de Alarcón, Madrid, Spain

[5]Department of Obstetrics and Gynaecology, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong

Correspondence
María M. Gil, Universidad Francisco de Vitoria, Carretera Pozuelo a Majadahonda, Km 1.800, 28223 Pozuelo de Alarcón, Madrid, Spain.
Email: mariadelmar.gil@ufv.es

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Abstract

Objective: To evaluate the level of agreement between ultrasound measurements to evaluate fetal head position and progress of labor by attending midwives and obstetricians after appropriate training.

Methods: In this prospective study, women in the first stage of labor giving birth to a single baby in cephalic presentation at our Obstetric Unit between March 2018 and December 2019 were invited to participate; 109 women agreed. Transperineal and transabdominal ultrasound was independently performed by a trained midwife and an obstetrician. Two paired measurements were available for comparisons in 107 cases for the angle of progression (AoP), in 106 cases for the head-to-perineum distance (HPD), in 97 cases for the cervical dilatation (CD), and in 79 cases for the fetal head position.

Results: We found a good correlation between the AoP measured by obstetricians and midwives (intra-class correlation coefficient [ICC]=0.85; 95% confidence interval [CI] 0.80–0.89). There was a moderate correlation between the HPD (ICC=0.75; 95% CI 0.68–0.82). There was a very good correlation between the CD measured (ICC=0.94; 95% CI 0.91–0.96). There was a very good level of agreement in the classification of the fetal head position (Cohen's κ=0.89; 95% CI 0.80–0.98).

Conclusions: Ultrasound assessment of fetal head position and progress of labor can effectively be performed by attending midwives without previous experience in ultrasound.

KEYWORDS
cervical dilatation, cervical examination, childbirth, labor, midwives, ultrasound

1 | INTRODUCTION

Serial vaginal examinations constitute the routine intervention to assess the progress of labor. Together with the partogram, they provide a graphical view of the process and allow identification of early signs of labor dystocia.[1] Despite being considered the reference standard method, it lacks good evidence of effectiveness and is not exempt from potential risks.[2] Vaginal examination is a subjective approach; the reproducibility between operators is suboptimal and increases the risk of infection for both mother and baby.[3] Some women perceive vaginal examination as uncomfortable, painful or even abusive.[3,4] For all these reasons, ultrasound has emerged as a well-tolerated, complementary and valuable non-invasive technique for assessing labor progress objectively, reproducibly, confidently, and safely.[5–7] In addition, ultrasound can objectively assess fetal presentation, placenta localization, and is also a helpful tool for evaluating fetal heart rate, evaluating cervical dilatation (CD), or assisting the vaginal birth of the second twin.[8,9]

Labor progress by ultrasound is assessed with parameters that correlate the anatomical landmarks of the pelvis with the fetal head.[10] Visualizing the fetal head and the pubis makes it possible to evaluate the fetal head station and flexion through the angle of progression (AoP), the head direction, and the progression distance.[9,11,12] AoP is the most widely used sonographic parameter; it is defined as the angle between the long axis of the pubic symphysis and a line from the inferior border of the symphysis tangential to the fetal skull. The AoP can be easily converted into head station, and different cut-offs have been established with significant prognostic value. For example, 120 degrees equals a head station of 0 and either a successful vacuum extraction or spontaneous vaginal delivery.[5,9,11] Another widely used sonographic parameter to observe the fetal head station is the head-to-perineum distance (HPD), which does not depend on the visualization of the maternal pubis and may be a predictor for vaginal delivery or the success of labor induction.[13] The position of the fetal head can be evaluated by transperineal and transabdominal ultrasound, observing cranial structures (orbits, interhemispheric midline, or cerebellum).[14] Finally, CD is evaluated by transperineal ultrasound by measuring the anteroposterior diameter of the cervical opening.[8]

In many countries, the management of labor for low-risk women is midwifery-led. Midwives accompany the women throughout their pregnancy, during the birth and the postpartum period, unless there are complications. Therefore, if any new tool is meant to be introduced into the routine clinical management of labor and delivery, midwives must be involved. It has previously been demonstrated that trained midwives can effectively acquire ultrasound skills to visualize fetal heartbeat and movements and identify placental location.[15] However, only two studies evaluating the role of ultrasound in labor have included a small number of midwives to perform the assessments.[13,16] Only one small study ($n=30$) has compared results from ultrasound examinations carried out by midwives with those performed by obstetricians, and the authors only found a moderate agreement between them.[17]

The main objective of our study was to evaluate the level of agreement between the ultrasound measurements taken for the evaluation of fetal head position and progress of labor between attending midwives and obstetricians.

2 | MATERIALS AND METHODS

This was a prospective comparative study carried out at two maternity units (Hospital Universitario de Torrejón and Hospital Universitario La Paz) in Madrid, Spain. Women in the first stage of labor giving birth to a singleton term baby in cephalic presentation in our Obstetric Units between March 2018 and December 2019 were invited to participate in the study, regardless of their previous risk for delivery, parity, labor onset, or the status of the amniotic membranes. The only exclusion criterion was planned cesarean section. The study was approved by the local research ethics committee (Hospital Universitario de Getafe, reference A10/17), and written informed consent was obtained.

We recorded the following maternal and pregnancy characteristics: maternal age, pre-pregnancy weight, and pregnancy weight gain, method of conception (natural/assisted conception), cigarette smoking during pregnancy (yes/no), parity (parous or nulliparous if no previous pregnancy at 24 weeks or more of gestation), diabetes mellitus and chronic hypertension (yes/no), and gestational age at admission. All variables and results of the ultrasound investigations and pregnancy outcome were recorded in a secure computer database (ViewPoint software, GE Healthcare, Chicago, IL, USA).

After obtaining informed consent, one obstetrician and one midwife, blinded to each other's ultrasound findings and the findings of the clinical examination, carried out the ultrasound scan in random order. Examinations performed more than onehour apart between the two operators were excluded from the analysis. During the ultrasound scan, the fetal head position and the AoP, HPD, and CD were assessed with a Voluson S8 (GE Healthcare, Chicago, IL, USA) ultrasound machine with convex transducers (RAB6-RS or 4C-RS) and SonoL&D software. Each woman was assessed only once by the obstetrician and midwife. The position of the fetal head was classified using the number of the quadrant in which the lambda fontanelle was located, following the scheme represented in Figure 1.

Before any ultrasound assessment, urinary bladder was emptied. The women were requested to lie in a semi-recumbent position with their legs flexed. First, the fetal head position was evaluated transabdominally, and then the ultrasound transducer was placed on the vulva to measure the AoP, HPD, and CD as previously described.[5,8] Figure 2 provides a visual explanation of how to measure those.

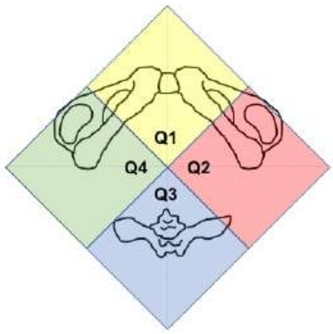

FIGURE 1 Quadrants representing the position of the fetal head attending to the location of the lambda fontanelle.

Before starting the study, the most experienced obstetrician in labor ultrasound provided a short training course to a selected group of attending midwives with no experience in ultrasound and to obstetricians with extensive experience in ultrasound but who had never performed transperineal ultrasound during labor. First, it consisted of a 1-h theoretical introduction on how to use the ultrasound machine, complete the assessment, and take the relevant measurements. We used the International Society of Ultrasound in Obstetrics and Gynecology guidelines to standardize the measurement of AoP, HPD, and CD by transperineal ultrasound.[10] The second part of the course consisted of hands-on training on consenting pregnant women, supervised by an experienced fetal medicine specialist. To complete the training process, both midwives and obstetricians were requested to take at least five satisfactory ultrasound measurements.[13]

For statistical analysis, descriptive data were expressed as median and interquartile range and in proportions (absolute and relative frequencies). The absolute paired differences were calculated.

Intra-class correlation coefficients (ICC) were calculated to analyze the inter-observer variability of the numerical variables (AoP, HPD, and CD).[18] The weighted Cohen's (κ_w) was computed based on a two-way random-effects model to assess the level of agreement between the two operators classifying the fetal head position. To favor correct identification of the fetal sagittal suture, disagreements in one position (adjacent quadrant) were penalized more strongly than those in two positions (opposed quadrant) by assigning the former 0% of the total agreement weight and the latter 50% of the total agreement weight; in a more technical way, all diagonal cells had weight 1, all adjacent cells weight 0.5 and all the others weight 0. The values for both statistics, ICC and κ_w, ranged from zero (the agreement is likely to have occurred by chance) to one (perfect arrangement). The level of agreement was considered very good when the κ_w was more than 0.80, good between 0.60 and 0.80, moderate between 0.40 and 0.60, fair between 0.20 and 0.40, and poor if κ_w was less than 0.20.[19] For the ICC assessment, greater than 0.90 was considered very good; between 0.80 and 0.90, it was considered good, and between 0.60 and 0.80, moderate, and poor if less than 0.60. 95% confidence intervals (CI) were also obtained. Finally, we also used Bland and Altman figures to graphically assess the differences between the paired measurements (y-axis) and their mean (x-axis).[20] When there is a good agreement, the values tend to group close to the horizontal line, representing complete agreement. Mean of differences, limits of agreement, and 95% CI are reported. Analyses were run on a complete case basis, and the number of pregnancies included in each analysis was reported wherever necessary.

The statistical software package R version 4.2.2 and its packages "Psych",[21] "BlandAltmanLeh",[22] and "ggplot2"[23] were used for data analyses.

3 | RESULTS

During the study period, 109 women agreed to participate in the study, and only four women declined. Maternal and pregnancy characteristics are reported in Table 1. Thirty-one attending midwives and 10 obstetricians were trained before the start of the study. Paired measurements were available for comparisons in 107 (98.17%) cases for the AoP, 106 (97.25%) cases for the HPD, 97 (88.99%) cases for the CD; and 79 (72.45%) cases for fetal head position. Results from ultrasound examinations are summarized in Table 2.

We found a good correlation between the AoP measured by midwives and obstetricians (ICC=0.85; 95% CI 0.80–0.89, Figure 3). There was a moderate correlation between the HPD measured by midwives and obstetricians (ICC=0.75; 95% CI 0.68–0.82; Figure 4).

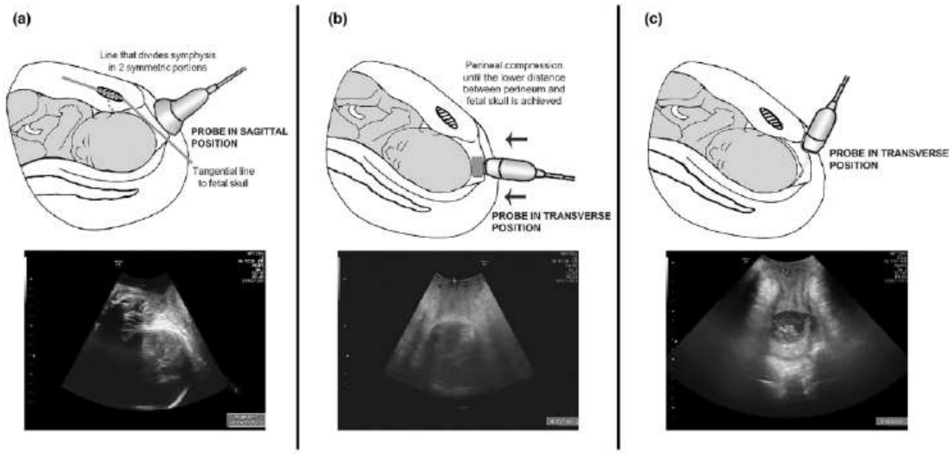

FIGURE 2 Ultrasound measurements of (a) angle of progression; (b) head-to-perineum distance; and (c) cervical dilatation.

There was a very good correlation between the CD measured by midwives and obstetricians (ICC = 0.94; 95% CI 0.91–0.96, Figure 5). Finally, there was a very good level of agreement in the classification of the fetal head position between midwives and obstetricians (κ_w = 0.89; 95% CI 0.80–0.98). The results were visually confirmed by analysis of both correlation and Bland–Altman graphs.

According to the Bland–Altman method, for AoP, the mean of differences (bias) was −2.21 (95% CI −4.37 to −0.04). The upper limit of agreement was 19.96 (95% CI 16.2–23.71) and lower limit of agreement was −24.37 (95% CI −28.12 to −20.61). For HPD, the mean of differences was −0.02 (95% CI −0.19 to 0.15). The upper limit of agreement was 1.7 (95% CI 1.41–2.00) and lower limit of agreement was −1.75 (95% CI −2.04 to −1.45). For CD, the mean of differences was 0.23 (95% CI 0.07–0.38). The upper limit of agreement was 1.73 (95% CI 1.47–2) and lower limit of agreement was −1.28 (95% CI −1.55 to −1.01).

TABLE 1 Maternal and pregnancy characteristics of the study population.[a]

Variable	Values
Age, year	34.8 (30.8–38.4)
Gestation, week	40.0 (38.9–41.2)
Pre-pregnancy weight, kg	64.0 (57.0–72.0)
Increase in weight, kg	13.0 (9.4–16.5)
Parity	
Nulliparous	67 (61.5)
Multiparous	42 (38.5)
Previous cesarean section	10 (23.8)
Method of conception	
Spontaneous	99 (90.8)
Assisted	10 (9.2)
Diabetes mellitus	
Gestational	9 (8.3)
Pre-gestational	1 (0.9)
Cigarette smoking	11 (10.1)
Less than 3 cm dilatation	72 (66.1)
Rupture of membranes before assessment	56 (51.4)
Epidural anesthesia at examination	31 (28.4)
Mode of delivery	
Cesarean section	20 (18.3)
Normal vaginal	63 (57.8)
Instrumental vaginal	26 (23.9)

[a]Data are given as median (interquartile range) or number (percentage).

4 | DISCUSSION

In the present study, we found that, following a training course that included a short theoretical description of the techniques and hands-on training, attending midwives and obstetricians with very different levels of experience in ultrasound could acquire the necessary skills to perform transperineal/transabdominal ultrasound to assess fetal head position and labor progress. Second, there was good to very good agreement between ultrasound examinations performed by midwives and those performed by obstetricians.

Two previous studies have evaluated the level of agreement between midwives and obstetricians when measuring the AoP.[17,22] The first study[17] was designed to evaluate AoP and the head-to-symphysis distance. To measure these, the fetal head must reach the inferior border of the pubic symphysis. Therefore, the cases were in more advanced stages of labor than in our study. In this study, 11 different midwives performed 30 assessments of the AoP and compared their measurements to those obtained by obstetricians. They only found a moderate agreement between the two groups of operators (ICC 0.76, 95% CI 0.55–0.88). Training was provided as a 1-h slideshow presentation, but only one supervised assessment was undertaken to complete the training.

In comparison, we provided individualized hands-on training, and only when the trainer considered that the operator was ready were the five mandatory ultrasound examinations requested. In another study,[24] one single experienced obstetrician performed 44 transperineal ultrasound examinations of women in prolonged second stage of labor with the fetus in the occiput anterior position and the stored images were subsequently evaluated by three midwives without ultrasound experience, three junior

TABLE 2 Results from examinations performed by each group.[a]

Examination	n	Midwives	Obstetricians	Pairwise absolute differences
Angle of progression, degrees	107	102 (92–116)	102 (89–110)	7 (3.5–11.5)
Head to perineum distance, cm	106	4.3 (3.7–5)	4.3 (3.5–5.1)	0.5 (0.3–0.9)
Cervical dilatation, cm	97	1.3 (0.7–2.9)	1.5 (0.7–3)	0.3 (0.1–0.7)
Fetal head position	79			
Quadrant 1		18 (22.8)	18 (22.8)	
Quadrant 2		23 (29.1)	23 (29.1)	
Quadrant 3		15 (19.0)	14 (17.7)	
Quadrant 4		23 (29.1)	24 (30.4)	

[a]Data are given as median (interquartile range) or number (percentage).

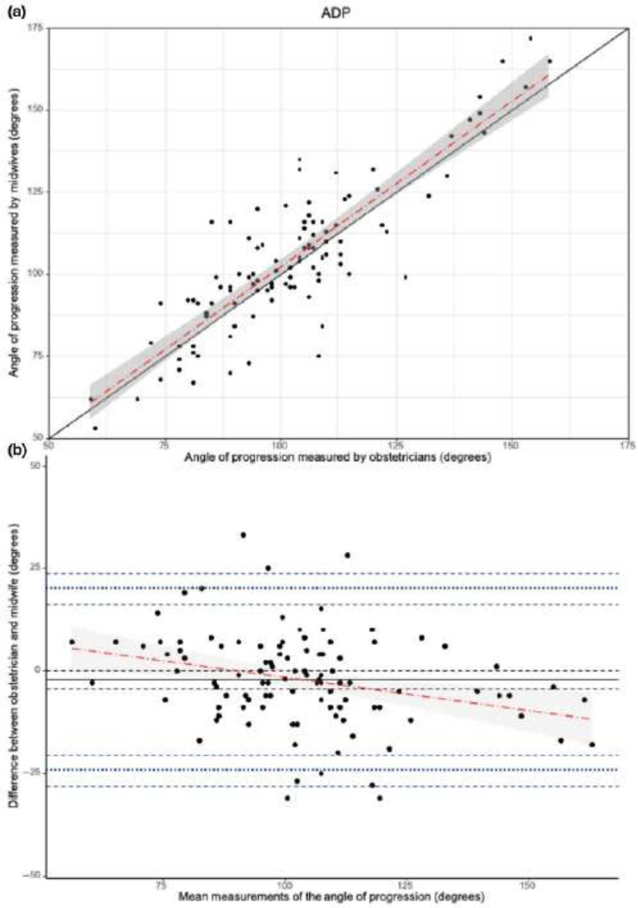

FIGURE 3 (a) Bland–Altman plot for the angle of progression. Solid line represents the mean of the differences, dotted lines are limits of agreement, dashed lines are 95% confidence intervals, and dot-dashed line is the regression line. (b) Scatter plot for the angle of progression from obstetricians and midwives. Dot-dashed line is the regression line and diagonal represents the perfect agreement.

obstetricians, and three senior obstetricians. Although not statistically different, the authors reported lower reliability when the measurements were performed by the midwives (ICC 0.61, 95% CI 0.43–0.74) than by the junior (ICC 0.81, 95% CI 0.71–0.88) or senior (ICC 0.82, 95% CI 0.70–0.89) obstetricians. Although the assessment of still images eliminates any variations merely due to the time passed between assessments, it inevitably implied a major limitation because it did not consider variability related to different acquisitions.

The main limitation of our study is that most of the assessments (n=72) were carried out during the latent phase of labor when cervical dilatation is less than 3cm; therefore, our results may not be applicable when labor progression is greater. Although ultrasound examination during the early stages of labor may indeed overestimate the reliability of the measurement of the CD by ultrasound,[16,25] the opposite effect is expected for the measurement of the AoP or HPD because the anatomical landmarks are difficult to see when the fetal head is high. We also acknowledge that the paired classifications of the fetal head position were unavailable in about 25% of the cases. As this is the most easily obtained variable, we believe that the reason why this was not recorded was that the researchers forgot to do so and not because they could not determine it. However, because the confidence interval of the κ_w was still very narrow, it is unlikely that this is affecting the results.

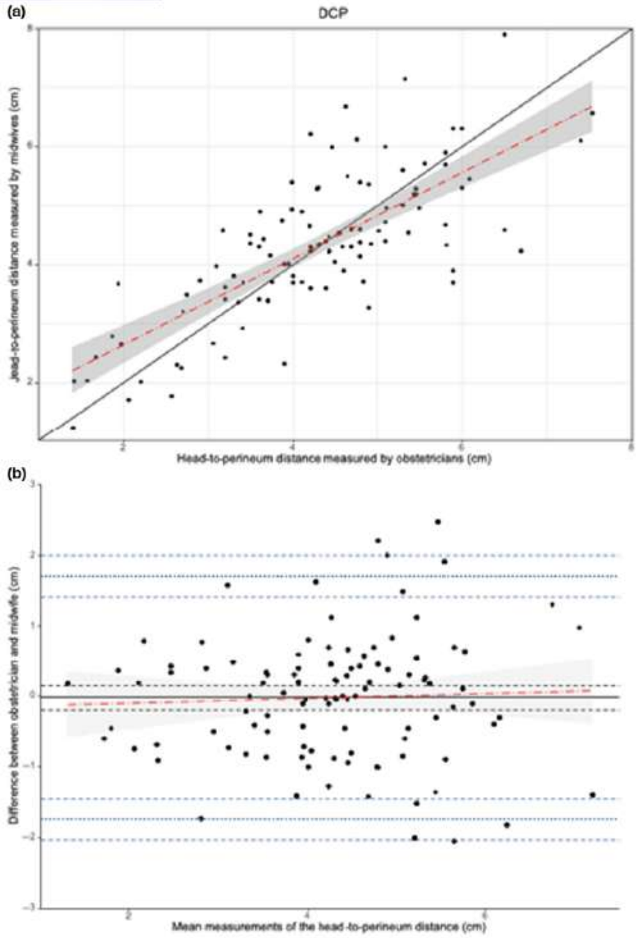

FIGURE 4 (a) Bland–Altman plot for the head-to-perineum distance. Solid line represents the mean of the differences, dotted lines are limits of agreement, dashed lines are 95% confidence intervals, and dot-dashed line is the regression line. (b) Scatter plot for the head-to-perineum distance from obstetricians and midwives. Dot-dashed line is the regression line and diagonal represents the perfect agreement.

Regarding the time between ultrasound scans performed by obstetricians and midwives, although a difference of up to 1 h between the examinations can be very long, more than 20 minutes was exceptional and only happened in nulliparous women who were in the latent phase of labor, so its impact would be minimal.[26]

The main strength of our study derives from being a large prospective study involving attending midwives and obstetricians with no previous experience in transperineal ultrasound in labor in a real clinical setting. This allows fair conclusions to be drawn concerning the feasibility of using transperineal ultrasound for routine monitoring of labor progress, irrespective of the type of healthcare professionals managing the labor. In addition, our comparison groups not only differed in their position but also in their level of expertise with ultrasound, which might have allowed indirect evaluation of experience as a limiting factor.

We have demonstrated that following appropriate training, ultrasound assessment of the fetal head position and the progress of labor can be effectively performed by attending midwives without previous experience in ultrasound. This may help to change the perception that ultrasound is a tool reserved for clinicians. The

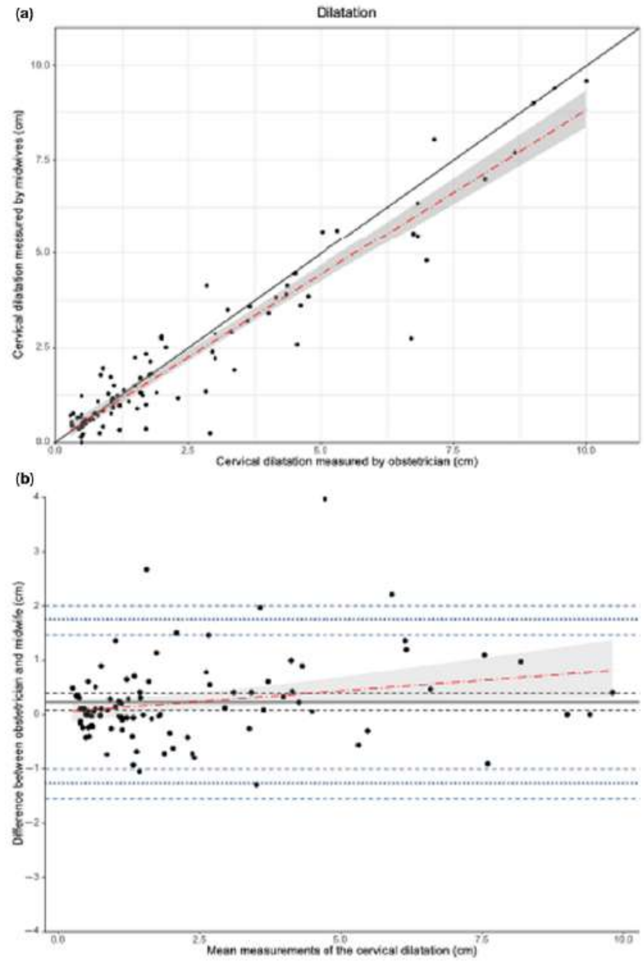

FIGURE 5 (a) Bland–Altman plot for the cervical dilatation. Solid line represents the mean of the differences, dotted lines are limits of agreement, dashed lines are 95% confidence intervals, and dot-dashed line is the regression line. (b) Scatter plot for the cervical dilatation from obstetricians and midwives. Dot-dashed line is the regression line and diagonal represents the perfect agreement.

introduction of ultrasound for managing labor and birth by midwives may help to reduce the number of vaginal examinations and, therefore, secondary infection. In addition, ultrasound allows a more objective and visual way of assessing the progress of labor, which may help prospective parents better understand deviations from normal directly from their caring midwife before the doctor is called into the room and takes any action.

In conclusion, following appropriate training, ultrasound assessment of the fetal head position and the progress of labor can be effectively performed by attending midwives with no previous experience in ultrasound. The level of agreement between the attending midwives and obstetricians with more experience in ultrasound is either good or very good.

AUTHOR CONTRIBUTIONS.

Conceptualization: Ana M. Fidalgo, Raquel Miguel, María M. Gil, Liona C. Poon conceptualized the study, performed the formal analysis, designed the methodology, and wrote the original draft; María

M. Gil and Liona C. Poon performed the project administration and supervision. Ana M. Fidalgo, Raquel Miguel, Irene Fernández-Buhigas, Asunción Aguado, Marcos J. Cuerva, Elisa Corrales, Valeria Rolle, Belén Santacruz, María M. Gil, and Liona C. Poon curated the data and contributed to validation and investigation, and to review and editing of the article.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Ana M. Fidalgo https://orcid.org/0000-0001-8218-7339
Irene Fernández-Buhigas https://orcid.org/0000-0003-4354-5273
Marcos J. Cuerva https://orcid.org/0000-0002-8013-4732
Valeria Rolle https://orcid.org/0000-0002-1793-7049
Belén Santacruz https://orcid.org/0000-0003-1817-3092
María M. Gil https://orcid.org/0000-0002-9993-5249
Liona C. Poon https://orcid.org/0000-0002-3944-4130

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4.2 Estudio 2.-**Implementation of sonopartogram: multicenter feasibility study.**

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Implementation of sonopartogram: multicenter feasibility study

N. M. W. LEE[1], S. L. LAU[1], Y. K. YEUNG[1], C. P. H. CHIU[1], F. LIU[1], Y. Y. LAU[1], A. M. FIDALGO[2,3], M. J. CUERVA[4,5], A. AQUISE[2], L. NGUYEN-HOANG[1], M. M. GIL[2,3] and L. C. POON[1]

[1]*Department of Obstetrics and Gynecology, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong SAR;* [2]*Obstetrics and Gynecology Department, Hospital Universitario de Torrejón, Torrejón de Ardoz, Madrid, Spain;* [3]*School of Medicine, Universidad Francisco de Vitoria, Madrid, Spain;* [4]*Department of Obstetrics, Hospital Universitario La Paz, Madrid, Spain;* [5]*School of Medicine, Universidad Autónoma de Madrid, Madrid, Spain*

KEYWORDS: angle of progression; AOP; caput succedaneum; cervical dilatation; feasibility; fetal head station; head–perineum distance; HPD; parasagittal angle of progression; SCD; sonographic cervical dilation; transperineal ultrasound

CONTRIBUTION

What are the novel findings of this work?
We have shown that transabdominal and transperineal ultrasound measurements can be performed successfully to monitor progress in labor, and may reduce the level of pain experienced during examination.

What are the clinical implications of this work?
Ultrasound parameters for monitoring progress in labor are known to be reliable and reproducible, and full integration of ultrasound into intrapartum care would represent a paradigm shift towards objective assessment of the progress of labor and improved care for women.

ABSTRACT

Objectives *Well-established clinical practice for assessing progress in labor involves routine abdominal palpation and vaginal examination (VE). However, VE is subjective, poorly reproducible and painful for most women. In this study, our aim was to evaluate the feasibility of systematically integrating transabdominal and transperineal ultrasound assessment of fetal position, parasagittal angle of progression (psAOP), head–perineum distance (HPD) and sonographic cervical dilatation (SCD) to monitor the progress of labor in women undergoing induction of labor (IOL). We also aimed to determine if ultrasound can reduce women's pain during such examinations.*

Methods *Women were recruited as they presented for IOL in three maternity units. Ultrasound assessments were performed in 100 women between 37 + 0 and 41 + 6 weeks' gestation. A baseline combined transabdominal and transperineal scan was performed, including assessment of fetal biometry, umbilical artery and fetal middle cerebral artery Doppler, amniotic fluid index, fetal spine and occiput positions, psAOP, HPD, SCD and cervical length. Intrapartum scans were performed instead of VE, unless there was a clinical indication to perform a VE, according to protocol. Participants were asked to indicate their level of pain by verbally giving a pain score between 0 and 10 (with 0 representing no pain) during assessment. Repeated measures data were analyzed using mixed-effect models to identify significant factors that affected the relationship between psAOP, HPD, SCD and mode of delivery.*

Results *A total of 100 women were included in the study. Of these, 20% delivered by Cesarean section, 65% vaginally and 15% by instrumental delivery. There were no adverse fetal or maternal outcomes. A total of 223 intrapartum ultrasound scans were performed in 87 participants (13 women delivered before intrapartum ultrasound was performed), with a median of two scans per participant (interquartile range (IQR), 1–3). Of these, 76 women underwent a total of 151 VEs with a median of one VE per participant (IQR, 0–2), with no significant difference between vaginal- or Cesarean-delivery groups. After excluding those with epidural anesthesia during examination, the median pain score for intrapartum scans was 0 (IQR, 0–1) and for VE it was 3 (IQR, 0–6). Cesarean delivery was significantly associated with a slower rate of change in psAOP, HPD and SCD.*

Correspondence: Prof. L. C. Poon, Department of Obstetrics and Gynaecology, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong SAR (e-mail: liona.poon@cuhk.edu.hk)

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ORIGINAL PAPER

Conclusions *Comprehensive transabdominal and transperineal ultrasound assessment can be used to assess progress in labor and can reduce the level of pain experienced during examination. Ultrasound assessment may be able to replace some transabdominal and vaginal examinations during labor.* *© 2024 The Authors. Ultrasound in Obstetrics & Gynecology published by John Wiley & Sons Ltd on behalf of International Society of Ultrasound in Obstetrics and Gynecology.*

INTRODUCTION

Abdominal palpation and vaginal examination (VE) are standard practice for assessing progress in labor. However, VEs have significant inter- and intraobserver variability[1,2], are painful for women[3] and can cause infection[4,5]. An objective, reliable, non-invasive method of accurately assessing progress in labor would be a major step forward in obstetrics.

A number of techniques have been described using ultrasound to assess the progress of labor[1,6–12]. Ultrasound can be used to determine fetal position, descent, head rotation, flexion and cervical dilatation[8–14]. Transperineal ultrasound parameters include the angle of progression (AOP), head–perineum distance (HPD) and sonographic cervical dilatation (SCD). The AOP is the angle from the leading part of the fetal skull to the maternal symphysis pubis in the sagittal plane[7]. It correlates with fetal head descent (station) and flexion[15–18]. The SonoL&D software (GE Healthcare, Zipf, Austria) measures the parasagittal AOP (psAOP) because the pubic rami visualized in a parasagittal view are more echogenic than in the midsagittal plane, and there is good correlation between AOP and psAOP[19]. HPD is the distance from the fetal skull to the perineum[6] and is correlated with head station[20–22]. SCD is the diameter of the cervix in a transverse plane[23]. Fetal position can be evaluated by both transperineal and transabdominal ultrasound by observing the position of the spine and cranial structures, such as orbits, interhemispheric midline or cerebellum[10].

The use of ultrasound to monitor the progress of labor is not standard practice. An ultrasound 'sonopartogram' was first conceptualized and shown to be feasible in 2014[8]. Intrapartum transperineal scanning measurements have been shown previously to be reliable, reproducible and have good agreement between fetal head descent and cervical dilatation determined by VE[8,16,17,24–27]. Our group has shown previously, in a study involving 308 women undergoing induction of labor (IOL), that the measurement of psAOP, HPD and SCD has high interobserver intraclass correlation coefficients of > 0.8[28]. Subsequently, we reported 1139 paired vaginal and transperineal ultrasound measurements in 326 women and showed high reproducibility in psAOP, HPD and SCD[24]. It has also been shown that the level of agreement in measurements obtained by consultant obstetricians and attending midwives is high[29].

In this study, our aim was to evaluate the feasibility of systematically integrating transabdominal and transperineal ultrasound assessment of fetal position, psAOP, HPD and SCD to monitor the progress of labor in women undergoing IOL. We also aimed to determine if ultrasound can reduce women's pain during such examinations.

METHODS

This was a prospective longitudinal cohort study in women with a singleton pregnancy undergoing IOL at or after 37 weeks' gestation, carried out in one maternity unit in Hong Kong SAR, China (Department of Obstetrics and Gynecology, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin), and two units in Madrid, Spain (Department of Obstetrics, Hospital Universitario La Paz, and Obstetrics and Gynecology Department, Hospital Universitario de Torrejón, Torrejón de Ardoz), between 1 December 2021 and 31 July 2023. Inclusion criteria for the study were pregnant women with a live fetus in cephalic presentation and intact membranes undergoing IOL between $37+0$ and $41+6$ weeks' gestation. Exclusion criteria included women who were unconscious or severely ill, those with learning difficulties or serious mental illness, breech presentation or age < 18 years. Written informed consent was obtained from the women agreeing to participate in the study, which was approved by the institutional review board of each recruiting center (Joint Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee, Reference Number CRE-2021.247; Ethics Committee of Hospital Universitario La Paz, Reference number PI-5448 ACTA: 20/2022; Hospital Universitario de Torrejón local ethics committee, Reference Number CPMP/ICH/135/95, 2021.036).

After obtaining written informed consent, maternal history and demographics were recorded from the patient's medical records and an initial ultrasound assessment was performed immediately prior to IOL. VE was performed to assess the cervix using a modified Bishop score, and the method of IOL was determined. Labor was induced using either artificial rupture of membranes (ARM), prostaglandin E2, oxytocin, Cook Balloon® (Cook Cervical Ripening balloon; Cook Medical LLC, IN, USA) or misoprostol.

The participants were managed according to standard care, apart from replacing VE by ultrasound assessment. Ultrasound was performed every 12 h until the participant was spontaneously contracting regularly or when oxytocin infusion was commenced. Thereafter, ultrasound assessment was performed every 4 h during the latent phase and every 2 h after the active phase of labor, until the SCD could no longer be assessed, which most commonly occurs when cervical dilatation is ≥ 8 cm[27,30]. Cesarean section or instrumental delivery was performed as clinically indicated.

During labor, VE was performed when: (1) there was a non-reassuring cardiotocogram pattern; (2) there was a need to confirm ultrasound findings of slow progress of labor and Cesarean section was potentially indicated; (3) there was antepartum hemorrhage; and (4) procedures such as fetal scalp electrode application or ARM were required. Participants were asked to indicate their level of pain by verbally giving a pain score between 0 and 10 (with 0 representing no pain) during assessment.

The mode of delivery, timing of delivery, umbilical cord arterial pH and neonatal outcome were recorded immediately following delivery.

Ultrasound assessment

Trained midwives or obstetricians performed the ultrasound scans. Examinations were performed with the woman in a supine position and with an empty bladder. A GE HealthCare Voluson™ SWIFT or Voluson S8 ultrasound machine (GE Healthcare) with a wide-band, convex transducer (RAB6-RS or 4C-RS) was used. Fetal lie and head and spine position were determined through transabdominal ultrasound using the method described by Akmal *et al.*[9], with results recorded at half-hourly intervals. During the baseline transabdominal ultrasound examination, fetal biometry was measured and umbilical artery pulsatility index, middle cerebral artery pulsatility index and amniotic fluid index were recorded. Subsequent scans did not include fetal growth and Doppler assessment.

The participant was then asked to flex and abduct her hips. The transducer was placed between the labia majora at the level of the posterior fourchette to obtain a sagittal view including the symphysis pubis and the fetal head. Small lateral movements of the transducer were made to align the ultrasound beam in a parasagittal orientation to include the whole length of the parasagittal pubic bone and the fetal skull[28]. The psAOP was measured between the longitudinal axis of the pubic bone and the lowest convexity of the fetal skull. The SCD was then measured by identifying the anterior edge of the cervix in the sagittal plane and turning the transducer 90° to acquire a full view of the cervix, as described by Hassan *et al.*[23] in 2021. The SCD was measured in the anteroposterior plane with the cursors placed on the inner part of the cervical tissue anteriorly and the inner part of the cervical tissue posteriorly ('inner-to-inner')[31]. In the same transverse view, the HPD was then measured as the shortest distance from the outer bony limit of the fetal skull to the skin surface of the perineum. The transducer was moved and angled until the shortest distance to the fetal head was visualized. The soft tissue was compressed with firm pressure without causing discomfort[7]. Examples of the measurement of psAOP, HPD and SCD can be seen in Figure 1. Fetal head and spine position were assessed by both transabdominal and transperineal ultrasound, with results recorded at half-hourly intervals as previously described.

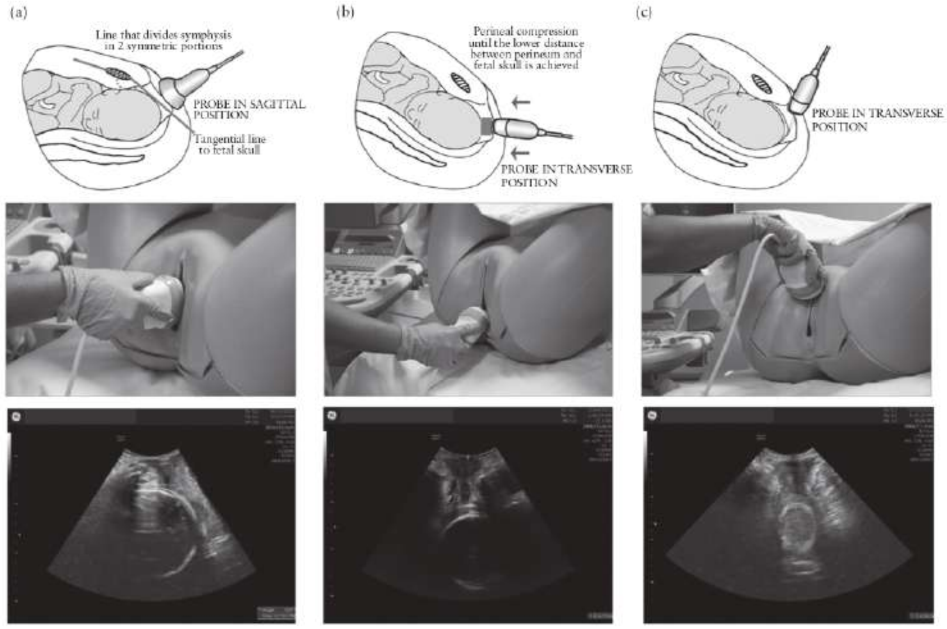

Figure 1 Diagrams (top) and simulation models (middle) showing probe positioning and resulting ultrasound images (bottom) for measurement of: (a) parasagittal angle of progression, (b) head–perineum distance and (c) sonographic cervical dilatation. Reproduced with permission from GE Healthcare Austria GmbH & Co OG.

The participants' data and ultrasound measurements were anonymized, stored locally in a secure electronic file and transferred to Hong Kong for analysis. Data on pregnancy and labor outcomes were retrieved from computerized medical records and stored in a secure database.

Induction of labor

IOL was performed according to a standardized protocol. The modified Bishop score was determined, and labor was induced if the cervix was favorable (Bishop score = 6) with ARM followed by oxytocin infusion. Oxytocin infusion was also administered if spontaneous rupture of membranes had occurred.

If the cervix was unfavorable, a 10-mg dinoprostone slow-release vaginal pessary (Propess®; Ferring Pharmaceuticals, Saint-Prex, Switzerland) was inserted vaginally and removed 24 h later. If spontaneous rupture of membranes had occurred, either 25-mg misoprostol was administered orally followed by oxytocin infusion 4 h later, or direct oxytocin infusion was commenced.

In women who had had a previous Cesarean delivery, a Cook cervical ripening balloon was inserted and removed 12 h later. The women were then reassessed and, if the cervix remained unfavorable, a further 10 mg of Propess was given. If the cervix was favorable, ARM was then performed.

Following ARM, if a woman remained in the latent phase after 12 h of oxytocin infusion, or if there were two or more episodes in which the cervix failed to dilate at a rate of at least 1 cm/h after the cervix was > 3 cm dilated, labor was considered to not be progressing and a Cesarean delivery was performed.

Statistical analysis

We included 100 women from three different settings to ensure that there would be a sufficient number of examinations to encounter all possible implementation problems, and to show a significant difference in pain level in those women without epidural anesthesia[32].

Quantitative data are presented as median (interquartile range (IQR)) while categorical data are expressed as *n* (%). Categorical variables were compared using the χ-square test or Fisher's exact test. For comparison of continuous data, the Mann–Whitney *U*-test or Student's *t*-test was used for non-parametric and parametric data, respectively.

For the repeated-measures analysis of psAOP, HPD and SCD, a linear mixed-effects analysis, including fixed effects and random effects, was performed. The fixed-effect component included maternal height, parity, epidural status, number of intrapartum scans and mode of delivery. The random-effect component included the intercept (patient identity number) and slope (number of intrapartum scans). The Bayesian information criterion (BIC) was used to select the best model among fixed intercept–fixed slope model, fixed intercept–random slope model, random intercept–fixed slope model and random intercept–random slope model. The final models were selected based on the lowest BIC[33]. The values of the estimated marginal mean of each sonographic parameter assessed across the duration of labor are presented. Data were analyzed using SPSS version 23.1 (IBM Inc., Armonk, NY, USA); $P < 0.05$ was considered to indicate statistical significance.

RESULTS

A total of 106 women were recruited, of whom six were excluded owing to incomplete assessments, leaving 100 women included in the study. Maternal characteristics, labor details and pregnancy outcomes are shown in Table 1. Cesarean sections performed during IOL were considered to be emergency Cesarean deliveries. Women delivering vaginally were significantly taller than women undergoing Cesarean section ($P = 0.04$), but there were no other significant differences between the groups.

The median modified Bishop score was 6 (range, 3–6). Induction methods included ARM (53%), Propess (33%), Cook cervical ripening balloon (9%), misoprostol (3%) and oxytocin (2%) (Table 1). Of the 100 women, 20% delivered by Cesarean section, 65% by vaginal delivery and 15% by instrumental delivery. There were no adverse fetal or maternal outcomes.

Intrapartum assessment of pain score

A total of 223 intrapartum ultrasound scans were performed in 87 participants, and of these, 76 had a total of 151 intrapartum VEs performed. Thirteen women delivered soon after commencing IOL, before an intrapartum scan could be performed. The median number of intrapartum scans (excluding the baseline scan) performed per participant was two (IQR, 1–3) and that of VEs was one (IQR, 0–2), with no significant difference between vaginal- or Cesarean-delivery groups.

The median pain score was 0 (IQR, 0–2) for the baseline assessment scan, and 6 (IQR, 4–7) for the baseline VE ($P < 0.001$). After excluding those who had epidural anesthesia during examination, a total 118 scans and 120 VEs were included in the analysis. For intrapartum VE, the pain score was 3 (IQR, 0–6) and for ultrasound it was 0 (IQR, 0–1) ($P < 0.001$).

Baseline and intrapartum ultrasound measurements

The posterior fontanelle position and fetal biometry measurements (biparietal diameter, head circumference, abdominal circumference, femur length) were recorded successfully in all women, while the spine position, psAOP, HPD and SCD were recorded successfully in ≥ 95% of women (Table 2).

Out of the 223 intrapartum scans, posterior fontanelle position was recorded in 215 (96.4%) scans, spine position in 217 (97.3%), psAOP in 209 (93.7%), HPD in 214 (96.0%) and SCD in 184 (82.5%) cases. Out of

Table 1 Demographic and baseline characteristics and pregnancy outcomes in 100 women undergoing induction of labor at ≥ 37 weeks, overall and according to delivery mode

Parameter	*Total* (n = *100)*	*Vaginal delivery* (n = *80)*	*Cesarean delivery* (n = *20)*	P
Maternal age (years)	33 (30–35)	33 (30–35)	34 (28–38)	0.604
Racial origin				0.711
Afro-Caribbean	3 (3.0)	3 (3.8)	0 (0)	
Asian	58 (58.0)	45 (56.3)	13 (65.0)	
Caucasian	31 (31.0)	26 (32.5)	5 (25.0)	
South American	8 (8.0)	6 (7.5)	2 (10.0)	
Height (cm)	160 (156–165)	162 (156–166)	158 (156–160)	0.036
Weight (kg)	59 (53–70)	59 (53–70)	62 (53–73)	0.756
Body mass index (kg/m^2)	23 (21–27)	23 (20 –27)	24 (22–30)	0.238
Parity				0.180
Nulliparous	58 (58.0)	42 (52.5)	16 (80.0)	
Parous	42 (42.0)	38 (47.5)	4 (20.0)	
GA at induction (weeks)	39.3 (38.1–41.6)	39.3 (38.1–40.4)	39.2 (37.7–41.2)	0.779
Induction method				0.465
ARM	53 (53.0)	42 (52.5)	11 (55.0)	
Cook balloon	9 (9.0)	9 (11.3)	0 (0)	
Misoprostol	3 (3.0)	3 (3.8)	0 (0)	
Oxytocin	2 (2.0)	2 (2.5)	0 (0)	
Propess	33 (33.0)	24 (30.0)	9 (45.0)	
Birth weight (g)	3110 (2698–3440)	3122 (2745–3482)	3050 (2636–3390)	0.418
1-min Apgar score	9 (9–9)	9 (9–9)	9 (6–9)	0.032
5-min Apgar score	10 (10–10)	10 (10–10)	10 (10–10)	0.994
Umbilical cord arterial pH	7.25 (7.2–7.3)	7.2 (7.2–7.3)	7.3 (7.2–7.3)	0.579
Total number of VEs	1 (0–2)	1 (0–2)	1 (1–2)	0.633
Total number of intrapartum scans	2 (1–3)	2 (1–3)	2 (1–4)	0.762

Data are given as median (interquartile range) or *n* (%). ARM, artificial rupture of membranes; GA, gestational age; VE, vaginal examination.

Table 2 Baseline ultrasound measurements in 100 women undergoing induction of labor at ≥ 37 weeks, overall and according to delivery mode

Measurement	*Failed to capture*	*Total* (n = *100)*	*Vaginal delivery* (n = *80)*	*Cesarean delivery* (n = *20)*	P
Posterior fontanelle position	0				0.847
Occiput anterior		28 (28.0)	22 (27.5)	6 (30.0)	
Occiput posterior		26 (26.0)	21 (26.3)	5 (25.0)	
Left occiput transverse		24 (24.0)	20 (25.0)	4 (20.0)	
Right occiput transverse		22 (22.0)	17 (21.3)	5 (25.0)	
Spine position	3				0.684
Anterior		25/97 (25.8)	20 (25.0)	5/17 (29.4)	
Posterior		17/97 (17.5)	13 (16.3)	4/17 (23.5)	
Transverse left		34/97 (35.1)	29 (36.3)	5/17 (29.4)	
Transverse right		21/97 (21.6)	18 (22.5)	3/17 (17.6)	
BPD (cm)	0	9.2 (8.9–9.6)	9.2 (8.6–9.7)	9.2 (8.9–9.7)	0.569
HC (cm)	0	32.6 (31.7–33.5)	32.5 (31.6–33.5)	32.9 (32.3–33.5)	0.552
AC (cm)	0	34.2 (32.4–35.5)	34.2 (31.9–35.3)	34.3 (33.0–35.6)	0.632
FL (cm)	0	7.1 (6.8–7.4)	7.2 (6.9–7.4)	7.0 (6.6–7.3)	0.174
AFI (cm)	35	12 (10–15)	12 (10–15)	12 (12–15)	0.872
psAOP (°)	1	100 (90–112)	102 (90–112)	90 (89–106)	0.365
HPD (mm)	5	47 (40–55)	47 (40–55)	50 (45–55)	0.262
SCD (mm)	1	7.6 (4.6–10.9)	8.0 (5.0–12.0)	4.9 (4.2–8.3)	0.084
Cervical length (cm)	3	2.1 (1.6–2.6)	2.1 (1.6–2.6)	2.1 (1.4–2.6)	0.810
Modified Bishop score	0	6 (3–6)	5 (3–6)	6 (3–6)	0.648

Data given as *n*, *n* (%), *n*/*N* (%) or median (interquartile range). AC, abdominal circumference; AFI, amniotic fluid index; BPD, biparietal diameter; FL, femur length; HC, head circumference; HPD, head–perineum distance; psAOP, parasagittal angle of progression; SCD, sonographic cervical dilatation.

the 39 (17.5%) cases in which SCD was not recorded, 22 (56.4%) had cervical dilatation of $\geq$ 8 cm.

Reasons for intrapartum vaginal examination

The most frequent reason for VE was to perform ARM ($n = 33$ (21.9%)), followed by suspicion of full dilatation or the woman experiencing the urge to push ($n = 30$ (19.9%)), a cardiotocography concern ($n = 29$ (19.2%)), or suspected no progress in labor ($n = 25$ (16.6%)) (Table 3).

Repeated time measures of ultrasound parameters of labor progress

The best-fit model (Table S1 and Appendix S1) showed that the estimated marginal mean of psAOP across the duration of labor adjusted for number of intrapartum scans and the interaction between number of intrapartum scans and delivery outcomes was significantly lower in the Cesarean-section group compared with the vaginal-delivery group (110.6° *vs* 126.8°; $P = 0.029$) (Table 4, Figure 2a). Conversely, the Cesarean-section group had a higher estimated marginal mean of HPD across the duration of labor adjusted for number of intrapartum scans compared with the vaginal-delivery group (46.4 mm *vs* 38.2 mm; $P = 0.008$) (Table 4, Figure 2b). The estimated marginal mean of SCD across duration of labor adjusted for the number of intrapartum scans and delivery outcomes was significantly higher for those in the vaginal-delivery group *vs* those in the Cesarean-section group (28.3 mm *vs* 19.1 mm; $P = 0.025$) (Table 4, Figure 2c).

Table 3 Reason for intrapartum vaginal examination ($n = 151$ total examinations in 87 women)

Reason	n (%)
Artificial rupture of membranes	33 (21.9)
Suspicion of full dilatation/urge to push	30 (19.9)
Cardiotocography concern	29 (19.2)
No progress of labor	25 (16.6)
Could not see sonographic cervical dilatation	9 (6.0)
Suspected antepartum hemorrhage	5 (3.3)
Patient request	3 (2.0)
Not documented	17 (11.3)

Table 4 Estimated marginal means of ultrasonographic parameters of labor progress adjusted for number of scans, according to mode of delivery

	Estimated marginal mean (95% CI)		
Variable	*Vaginal delivery*	*Cesarean section*	P
psAOP (°)	126.84 (120.49–133.19)	110.57 (97.33–123.81)	0.029
HPD (mm)	38.15 (34.94–41.35)	46.39 (40.67–52.12)	0.008
SCD (mm)	28.25 (23.94–32.57)	19.14 (11.58–26.70)	0.025

HPD, head–perineum distance; psAOP, parasagittal angle of progression; SCD, sonographic cervical dilatation.

DISCUSSION

Combined abdominal examination and VE has long been established as normal practice, therefore, integrating the use of ultrasound on the labor ward into routine clinical practice may mean overcoming various obstacles and barriers. The first step is to identify which ultrasonographic measurements are the most useful, accurate and reproducible. The development of an ultrasound-based intrapartum examination, known as a 'sonopartogram', was conceptualized in 2014 and was shown to be feasible[8]. To the best of our knowledge, this is the first attempt to fully integrate ultrasound to monitor the progress of labor, and replace some VEs with ultrasound assessment. Our study has demonstrated that using combined transabdominal and transperineal ultrasound measurements instead of abdominal palpation and VEs to monitor labor is feasible, and can reduce women's pain during such examinations.

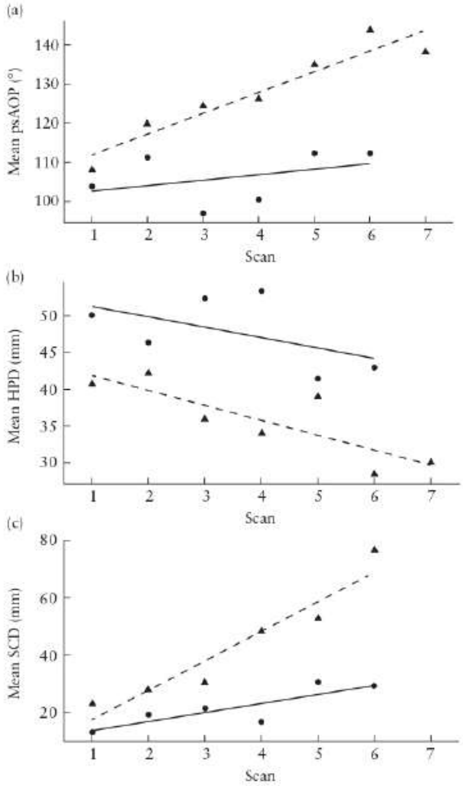

Figure 2 Change in mean parasagittal angle of progression (psAOP) (a), head–perineum distance (HPD) (b) and sonographic cervical dilatation (SCD) (c) according to number of intrapartum scans across duration of labor in women who delivered vaginally (- ▲ -) and those who delivered by Cesarean section (—●—).

There is a lack of consensus in the literature with regard to which intrapartum ultrasound parameter is the most useful for monitoring progress in labor. Our data shows that spine position, psAOP and HPD were successfully captured during the majority of scans. The lower number of SCD measurements could be explained by the fact that SCD can be difficult to visualize once cervical dilatation is ≥ 8 cm, as reported in previous studies[8,34]. As the cervix effaces, the head is pressed against the thinning dilated cervix, and therefore it becomes increasingly difficult to visualize a cervix that is in close approximation to the fetal scalp. Further, the fetal skull bone may also obscure a thin cervix, and the presence of caput succedaneum can further hinder the measurement of SCD[34]. In our study, 56% of unrecorded SCDs resulted when the participants had cervical dilation of ≥ 8 cm. This is in agreement with the results of previous studies[7,28].

The concept underpinning the use of a partogram is to improve maternal and fetal outcomes and allow timely intervention to ensure safe progress in labor and delivery. The sonopartogram is an extension of this concept, with the additional benefit of objective serial measurements rather than subjective assessment with poor inter- and intraobserver reliability. Usman *et al.*[35] published a recent review of the sonopartogram and its relevance in modern obstetric care. With the trend towards individualized risk prediction model-based care, for example in pre-eclampsia or trisomy screening, there is interest in developing a labor-outcome prediction model that could improve delivery management and allow informed decision-making for women.

Pre-existing maternal factors, clinical assessments and ultrasound measurements can allow reliable prediction of the mode of delivery[12,35–37]. Intrapartum ultrasound can also be used to predict the duration of labor. A longer labor is associated with the need for operative delivery and poorer fetal outcomes. The development of a reproducible sonopartogram that has predictive capability and has been validated in different populations would represent a paradigm shift in modern obstetrics, providing better quality of information to facilitate counseling and shared decision-making between healthcare providers and patients.

More research is required for the further development and implementation of a sonopartogram, with the aim of providing improved labor management, patient experience and delivery outcomes.

Strengths and limitations

Strengths of the current study include its longitudinal design with repeated ultrasonographic measurements from the commencement of IOL until full cervical dilatation or when delivery occurred, and the inclusion of multiple transabdominal and transperineal ultrasound measurements (fetal spine and head positions, psAOP, HPD, SCD) obtained in a single clinical encounter. Although multiple sonographers across different sites performed the ultrasound assessments, it has previously been shown that intersonographer variability is low[29,38].

Limitations of this study include its small sample size and findings that might not be generalizable, as we included mainly Chinese and Spanish women who underwent IOL at term. We included only women undergoing IOL in this study as we wanted to capture ultrasound measurements from the onset of labor. Further work will be needed to evaluate the relationship between serial intrapartum ultrasound measurements in women undergoing spontaneous labor.

Conclusions

Comprehensive transabdominal and transperineal ultrasound assessment can be successfully used to assess progress in labor and can reduce the level of pain experienced during examination. It may be possible to replace some transabdominal and vaginal examinations during labor with ultrasound assessment.

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SUPPORTING INFORMATION ON THE INTERNET

The following supporting information may be found in the online version of this article:

Appendix S1 Best-fit model for repeated time measures of ultrasound parameters of labor progress

Table S1 Estimated marginal means of parasagittal angle of progression (psAOP), head–perineum distance (HPD) and sonographic cervical dilatation (SCD) across duration of labor, adjusted for number of intrapartum scans and interaction between number of intrapartum scans and delivery outcomes

4.3 Estudio 3.- Reproducibility of Breech Progression Angle: Standardization of Transperineal Measurements and Development of Image-Based Checklist for Quality Control.

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Reproducibility of Breech Progression Angle: Standardization of Transperineal Measurements and Development of Image-Based Checklist for Quality Control †

Ana M. Fidalgo [1,2], Adriana Aquise [1,2], Francisca S. Molina [3,4], Aly Youssef [5], Otilia González-Vanegas [3,4], Elena Brunelli [5], Ilaria Cataneo [6], Maria Segata [6], Marcos J. Cuerva [7], Valeria Rolle [8,9,*] and Maria M. Gil [1,2,10,*]

1 Department of Obstetrics and Gynecology, Hospital Universitario de Torrejón, 28850 Madrid, Spain; anamariafidalgoconde@gmail.com (A.M.F.); adriana.aquise@gmail.com (A.A.)
2 School of Medicine, Universidad Francisco de Vitoria, Pozuelo de Alarcón, 28223 Madrid, Spain
3 Department of Obstetrics and Gynecology, Hospital Universitario San Cecilio, 18016 Granada, Spain; fsoniamolina@gmail.com (F.S.M.); otigonzalez16@gmail.com (O.G.-V.)
4 Instituto de Investigación Biosanitaria ibs.GRANADA, 18012 Granada, Spain
5 Obstetrics Unit, IRCCS Azienda Ospedaliero-Universitaria di Bologna, 40138 Bologna, Italy; aly.youssef78@gmail.com (A.Y.); elenabrunelli23@gmail.com (E.B.)
6 UOC Ginecologia ed Ostetricia, Ospedale Maggiore Bologna, 40133 Bologna, Italy; cataneo.ilaria@gmail.com (I.C.); m.segata@ausl.bologna.it (M.S.)
7 Department of Obstetrics and Gynecology, Hospital Universitario La Paz, 28046 Madrid, Spain; marxichos@hotmail.com
8 Statistics and Data Management Unit, iMaterna Foundation, Alcalá de Henares, 28806 Madrid, Spain
9 Biostatistics and Epidemiology Platform, Fundación para la Investigación y la Innovación Biosanitaria del Principado de Asturias (FINBA), 33011 Asturias, Spain
10 Vicerrectorado de Investigación, Facultad de Medicina, Universidad Francisco de Vitoria, Carretera Pozuelo a Majadahonda, Km 1.800, Pozuelo de Alarcón, 28223 Madrid, Spain
* Correspondence: valeria.rolle@ispasturias.es (V.R.); mariadelmar.gil@ufv.es (M.M.G.)

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Highlights

What are the main findings?

- The breech progression angle is a feasible and highly reproducible transperineal parameter when an image-based checklist is used for its evaluation.

What is the implication of the main finding?

- Image-based checklists can be useful for the standardization of transperineal ultrasound and improve reproducibility of intrapartum parameters.
- This contributes to increase diagnostic accuracy when performing an External Cephalic Version maneuver or a breech delivery.

Abstract

Objectives: To evaluate the reproducibility of measurements of breech progression angle (BPA) by transperineal ultrasound (US) before and after its standardization by applying an image-based checklist. **Methods:** Eighteen 3-dimensional (3D) volumes of transperineal US from women at 36–40 weeks of gestation with a singleton fetus in breech presentation were provided to eight operators from four maternity units in Spain and Italy. All operators measured the BPA using 3D US volume processing software, and interobserver reproducibility was evaluated using the intraclass correlation coefficient (ICC). Following an online live review of all measurements by the operators, and the identification of sources of disagreement, an image-based scoring system for BPA measurement was collaboratively developed. The checklist included the following: (1) acquisition in the midsagittal plane, avoiding the posterior shadow of the pubic ramus; (2) visualization of the complete "almond-shaped" pubic symphysis; (3) drawing a first line along the longitudinal axis of the symphysis, dividing it equally; (4) extending this line to the inferior edge of the bone; and (5) drawing a second line tangentially from the lower edge of the symphysis to the lowest recognizable fetal part. The BPA measurements were then repeated using this checklist, and reproducibility was reassessed. **Results:** Eighteen volumes were analyzed by the eight operators, achieving a moderate reproducibility (ICC: 0.70, 95% confidence interval (CI): 0.48 to 0.86). A score was developed to include a series of landmarks for the appropriate assessment of BPA. Subsequently, the same eighteen volumes were reassessed using the new score, resulting in improved reproducibility (ICC: 0.81, 95% CI: 0.66 to 0.92). **Conclusions:** The measurement of BPA is feasible and reproducible when using a standardized image-based score.

Keywords: breech presentation; reproducibility; transperineal ultrasound; intrapartum ultrasound; cephalic external version

1. Introduction

Breech presentation occurs in 3–4% of singleton term pregnancies [1,2]. Over the past decades there has been an increase in elective cesarean sections performed for this reason, driven largely by concerns surrounding the safety of vaginal breech delivery. This shift was particularly catalyzed by the results of the Term Breech Trial, which reported higher rates of neonatal morbidity and mortality associated with planned vaginal birth in breech presentations [3]. As a consequence, there has been a decline in clinical experience with breech deliveries and an associated rise in maternal morbidity and mortality related to cesarean birth [4], together with longer recovery times, and complications in subsequent pregnancies, such us placenta accreta spectrum [4,5]. Therefore, there is a renewed interest in exploring safe strategies to reduce unnecessary cesareans in breech presentations. One such strategy is the promotion of external cephalic version (ECV), a procedure aimed at rotating the fetus into cephalic presentation before the onset of labor [6]. The success of ECV, however, is highly dependent on several factors, including the engagement of the fetal breech within the maternal pelvis [7].

Traditionally, the evaluation of fetal descent and engagement has relied heavily on digital vaginal examination or abdominal palpation. These methods are inherently subjective and can vary significantly between practitioners [8]. In recent years, intrapartum ultrasound (US) has emerged as a valuable tool for providing more objective and reproducible information about fetal position, descent, and engagement [9–16]. Among various US parameters, the angle of progression (AoP) has gained prominence as a reliable measure in cephalic presentations [17–21]. In cases of breech presentation, the breech progression angle (BPA) represents an analogous parameter, providing quantifiable insight into the descent of the breech within the maternal birth canal [21].

The BPA was first described by Youssef et al. in 2021, as the angle between a line running along the long axis of the pubic symphysis and another line extending from the most inferior portion of the pubic symphysis tangentially to the surface of the lowest recognizable fetal part in the maternal pelvis (whether the buttock or the lowest fetal foot), as obtained by transperineal US [21]. The authors reported high reproducibility in a limited single-center study. However, the generalizability of BPA across different clinical settings and among various practitioners has not been extensively evaluated.

The main objective of this study was to assess the reproducibility of the US measurement of the BPA before and after its standardization by applying a newly developed image-based checklist to ensure homogeneity and quality.

2. Methods

2.1. Study Design and Population

This was a multicenter, observational study carried out between January and May 2023 in four hospitals: Azienda Ospedaliero-Universitaria Policlinico S. Orsola-Malpighi (Bologna) and Ospedale Maggiore di Bologna (Bologna) in Italy, and Hospital Universitario de Torrejón (Madrid) and Hospital Clínico San Cecilio (Granada) in Spain.

The study was approved by the local research ethics committee (Comité de Ética de la Investigación con Medicamentos de los Hospitales Universitarios Torrevieja y Elche-Vinalopó on 29 October 2020 and approved in all participating centers), and written informed consent was obtained from all the participants after providing detailed information about the study.

Twenty transperineal 3-dimensional (3D) US volumes were acquired from pregnant women at 36–40 weeks of gestation with a singleton fetus in breech position. For volume acquisition, participants were assessed in the lithotomy position with empty bladder to ensure consistency in image conditions. The US examinations were performed using either a Voluson SWIFT (GE Healthcare, Zipf, Austria) or Voluson P8 (GE Healthcare, Zipf, Austria) US machine, equipped with a convex transducer covered by a sterile glove. The transducer was positioned in the midsagittal plane visualizing the pubic symphysis, the urethra, the vagina, and the fetal breech or foot as previously described [21].

Following acquisition, the image quality was reviewed by the central study team, and two 3D volumes (volumes 7 and 14) were excluded due to suboptimal visualization, leaving eighteen for final analysis. These were then distributed to eight senior obstetricians, two from each participating unit. To reduce the influence of baseline skill variability, operators were selected among obstetricians with expertise in obstetric US and those who routinely used intrapartum US in their clinical practice but without any previous experience measuring BPA. Although the original publication was reviewed by each operator, no specific training was provided. The operators measured the BPA using a 3D US volume processing software (4D View$^{\mathrm{TM}}$, version 5.0, GE Medical, Kretz Ultrasound, Zipf, Austria).

Following the first round of measurements, A.M.F. reviewed all measurements from all operators to identify sources of disagreement, which were subsequently discussed during a live, interactive online session. All investigators collaboratively analyzed the six volumes with the greatest inter-operator variability, as well as those that best illustrated the most common conflicts. The session focused on identifying anatomical landmarks and clarifying interpretation challenges. Based on this discussion, an image-based checklist was developed to standardize the BPA measurement. The checklist included five key criteria: (1) correct midsagittal plane identification, (2) complete delineation of the pubic symphysis, (3) accurate bisecting of the symphysis, (4) precise extension of the first line to the lower edge of the bone, and (5) consistent application of the second line tangent to the fetal breech (Figure 1, Table 1).

Table 1. Image-based score for correct evaluation of breech progression angle.

Score	Image Acquisition Criteria
1	**Midsagittal plane**: not seeing the posterior shadow of the pubic ramus
2	Accurately identify the whole limits of the oval-shaped symphysis (**"almond" shape**), not just the white hyperechogenic cartilage
3	1st line: line along the longitudinal axis of the symphysis, dividing it into **two equal parts**
4	1st line: take it **to the edge of the bone**
5	2nd line: from the edge of the bone, **tangentially to the lowest recognizable fetal part** in the maternal pelvis

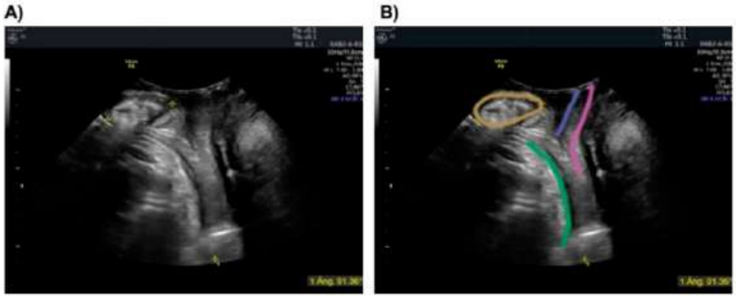

Figure 1. Measurement of the breech progression angle (BPA). Panel (**A**) shows the acquired image, which is labeled in panel (**B**). The orange line outlines the pubic symphysis ("almond" shape); the green line traces the fetal buttock; the blue line represents the urethra; and the pink line indicates the vagina. The yellow lines represent the BPA: the first line bisects the pubic symphysis down to its lower edge, and the second line extends tangentially from the lower edge of the pubic symphysis to the lowest recognizable fetal part.

Six months later, all operators repeated the BPA measurements using this checklist. This interval was intended to minimize recall bias and assess long-term adherence to standardized procedures.

2.2. Statistics

The interobserver reproducibility of the volumes was assessed on two occasions: first before the implementation of the checklist and again after. This allowed us to evaluate the impact of the checklist on improving the consistency of the measurements. The intraclass correlation coefficient (ICC) with 95% confidence intervals (CIs) was used both times to quantify the reproducibility.

Each rater was asked to rate every sample independently, to obtain one measurement from each operator. We computed the ICC2, which, according to the classification of Shrout and Fleiss, is appropriate to accommodate a random sample of judges rating each sample [22]. This approach assumes that both the operators and samples are obtained randomly from their populations. The overall agreement between all operators, as well as paired agreement between every two operators, were estimated. The ICC was categorized as very good (>0.90), good (0.90 to 0.80), moderate (0.80 to 0.60), or poor (<0.60).

Additionally, Bland–Altman plots were generated for each pair of operators to illustrate the mean difference between measurements (bias) and the limits of agreement, along with their 95% CI [23]. The variability in the measurements was also visually assessed by plotting the measurements obtained for each volume.

A post hoc power analysis was conducted to verify that the study was adequately powered to assess reproducibility.

Analyses were performed using the statistical software R (version 4.4.1) [24]. The DescTools package [25] was used to calculate the ICCs, dplyr for data wrangling, table1 for the tables, BlandAltmanLeh for Bland–Altman stats and plots [26], ICC.Sample.Size for the power analysis [27], and the ggplot2 package [28] to generate the plots.

3. Results

Prior to the implementation of the checklist, the overall interobserver reproducibility was moderate, with an ICC of 0.70 (95% CI 0.48 to 0.86), and paired agreement between operators varied substantially, ranging from 0.46 to 0.92, with better agreement between operators from the same center, as shown in Table 2. Figure 2 (panel A) represents the individual measurements of each operator for each volume. After applying the checklist, the reassessment of BPA across all volumes by all operators showed a good overall reproducibility, increasing the ICC to 0.81 (95% CI 0.66 to 0.92). Agreement between paired operators also improved, ranging from 0.72 to 0.97, as well as reproducibility between operators from different centers (Table 2 and Figure 2, panel B).

Table 2. Intraclass correlation coefficient and its 95% confidence interval for each pair of operators before (gray cells) and after (white cells) application of the image-based checklist.

	Site 1, operator 1	Site 1, operator 2	Site 2, operator 1	Site 2, operator 2	Site 3, operator 1	Site 3, operator 2	Site 4, operator 1	Site 4, operator 2
Site 1, operator 1		0.89 (0.74 to 0.96)	0.61 (−0.06 to 0.89)	0.49 (−0.04 to 0.84)	0.69 (−0.06 to 0.91)	0.71 (−0.07 to 0.92)	0.61 (0.11 to 0.84)	0.54 (−0.09 to 0.84)
Site 1, operator 2	0.75 (0.20 to 0.92)		0.58 (−0.10 to 0.86)	0.46 (−0.08 to 0.81)	0.63 (0.10 to 0.86)	0.69 (0.06 to 0.89)	0.57 (0.17 to 0.81)	0.49 (−0.03 to 0.78)
Site 2, operator 1	0.73 (−0.06 to 0.93)	0.87 (0.68 to 0.95)		0.85 (0.22 to 0.96)	0.90 (0.68 to 0.97)	0.92 (0.39 to 0.98)	0.63 (0.26 to 0.84)	0.74 (0.46 to 0.89)
Site 2, operator 2	0.75 (−0.07 to 0.94)	0.87 (0.70 to 0.95)	0.97 (0.93 to 0.99)		0.73 (−0.02 to 0.92)	0.74 (−0.07 to 0.93)	0.57 (−0.04 to 0.84)	0.73 (0.41 to 0.89)
Site 3, operator 1	0.93 (0.81 to 0.97)	0.74 (0.26 to 0.91)	0.72 (−0.08 to 0.93)	0.74 (−0.05 to 0.93)		0.90 (0.77 to 0.96)	0.66 (0.31 to 0.85)	0.68 (0.36 to 0.86)
Site 3, operator 2	0.77 (−0.02 to 0.94)	0.88 (0.70 to 0.95)	0.94 (0.85 to 0.98)	0.94 (0.85 to 0.98)	0.77 (0.05 to 0.93)		0.74 (0.46 to 0.89)	0.72 (0.42 to 0.88)
Site 4, operator 1	0.91 (0.78 to 0.97)	0.73 (0.37 to 0.90)	0.76 (−0.05 to 0.94)	0.80 (−0.003 to 0.95)	0.88 (0.70 to 0.95)	0.83 (0.17 to 0.95)		0.63 (0.27 to 0.83)
Site 4, operator 2	0.83 (0.61 to 0.93)	0.78 (0.49 to 0.91)	0.77 (0.16 to 0.93)	0.78 (0.31 to 0.92)	0.80 (0.54 to 0.92)	0.82 (0.47 to 0.93)	0.85 (0.64 to 0.94)	

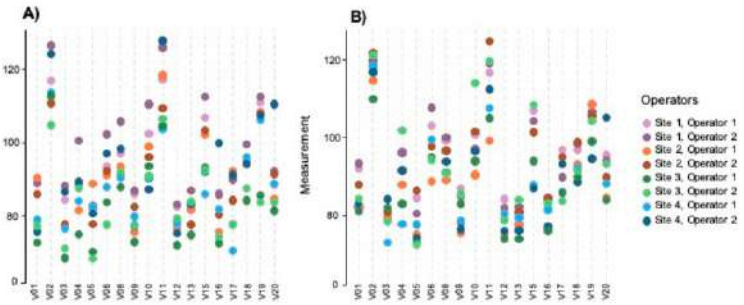

Figure 2. Individual BPA measurements by each operator (colored dots) for the different volumes. Panels show the first round of measurements before (panel (**A**)) and after (panel (**B**)) the development of the image-based checklist. The x-axis represents the evaluated volumes; volumes V07 and V14 were not analyzed due to poor image quality.

The Bland–Altman plots can be seen in Figure 3 and their statistics in Table 3.

Assuming an expected ICC of 0.8 and a minimum acceptable ICC of 0.4, the post hoc power analysis indicated a statistical power of 79.5%, suggesting that the study was adequately powered to detect acceptable levels of agreement.

Operators reported that the checklist was intuitive and facilitated a more confident interpretation of anatomical landmarks.

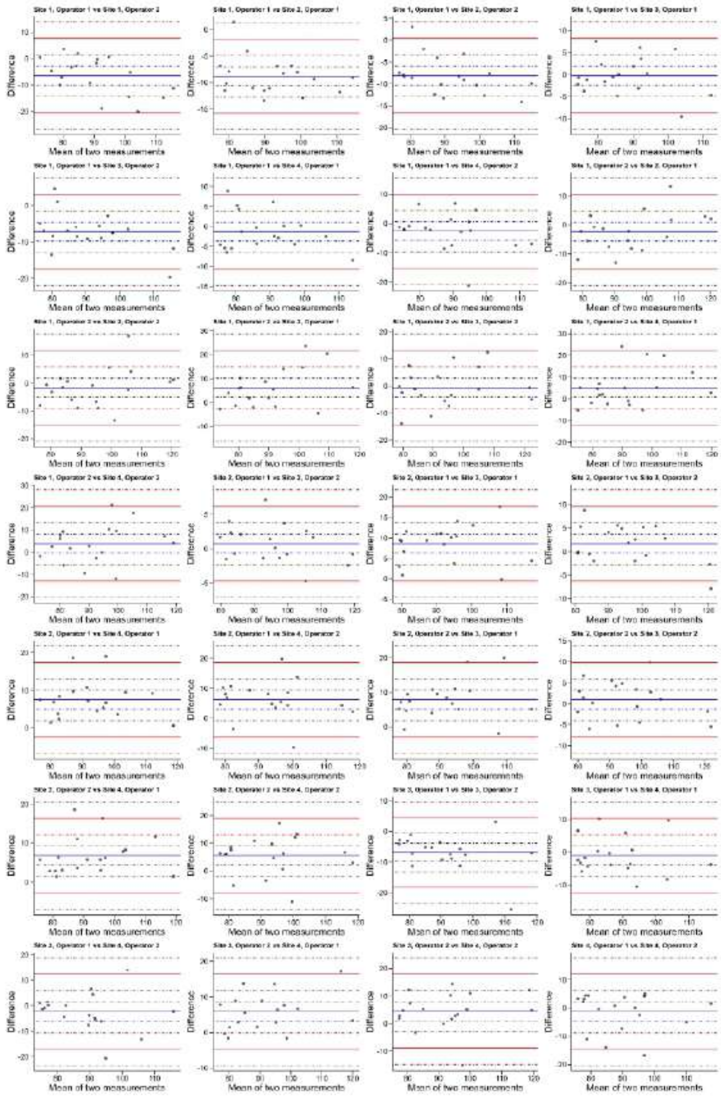

Figure 3. Bland–Altman plots for all pairwise comparisons of operators. Blue lines refer to mean difference, and red lines to the limits of agreement. Solid lines are point estimates and dotted lines are 95% confidence intervals.

Table 3. Bland–Altman statistics (mean difference, limits of agreement, and confidence intervals) for all pairs of operators.

Comparison	Mean Difference (95% CI)	Lower LoA (95% CI)	Upper LoA (95% CI)
Site 1, Operator 1 vs. Site 1, Operator 2	−6.47 (−10.05 to −2.89)	−20.59 (−26.8 to −14.39)	7.65 (1.44 to 13.85)
Site 1, Operator 1 vs. Site 2, Operator 1	−8.84 (−10.6 to −7.08)	−15.79 (−18.84 to −12.73)	−1.9 (−4.95 to 1.15)
Site 1, Operator 1 vs. Site 2, Operator 2	−8.12 (−10.28 to −5.95)	−16.66 (−20.42 to −12.91)	0.43 (−3.33 to 4.18)
Site 1, Operator 1 vs. Site 3, Operator 1	−0.26 (−2.41 to 1.89)	−8.73 (−12.45 to −5.01)	8.21 (4.49 to 11.94)
Site 1, Operator 1 vs. Site 3, Operator 2	−7.16 (−9.76 to −4.55)	−17.43 (−21.94 to −12.92)	3.11 (−1.4 to 7.63)
Site 1, Operator 1 vs. Site 4, Operator 1	−1.33 (−3.7 to 1.04)	−10.67 (−14.77 to −6.57)	8.01 (3.9 to 12.11)
Site 1, Operator 1 vs. Site 4, Operator 2	−2.63 (−5.83 to 0.56)	−15.24 (−20.77 to −9.7)	9.97 (4.43 to 15.51)
Site 1, Operator 2 vs. Site 2, Operator 1	−2.37 (−5.64 to 0.9)	−15.27 (−20.93 to −9.6)	10.53 (4.86 to 16.19)
Site 1, Operator 2 vs. Site 2, Operator 2	−1.64 (−5.06 to 1.77)	−15.09 (−21.01 to −9.18)	11.8 (5.89 to 17.72)
Site 1, Operator 2 vs. Site 3, Operator 1	6.21 (2.24 to 10.18)	−9.43 (−16.31 to −2.56)	21.86 (14.99 to 28.74)
Site 1, Operator 2 vs. Site 3, Operator 2	−0.69 (−4.2 to 2.83)	−14.53 (−20.61 to −8.44)	13.15 (7.07 to 19.24)
Site 1, Operator 2 vs. Site 4, Operator 1	5.14 (0.76 to 9.52)	−12.12 (−19.71 to −4.54)	22.41 (14.82 to 29.99)
Site 1, Operator 2 vs. Site 4, Operator 2	3.84 (−0.42 to 8.1)	−12.96 (−20.34 to −5.58)	20.64 (13.25 to 28.02)
Site 2, Operator 1 vs. Site 2, Operator 2	0.72 (−0.65 to 2.1)	−4.71 (−7.09 to −2.32)	6.16 (3.77 to 8.54)
Site 2, Operator 1 vs. Site 3, Operator 1	8.58 (6.26 to 10.91)	−0.58 (−4.61 to 3.45)	17.75 (13.72 to 21.77)
Site 2, Operator 1 vs. Site 3, Operator 2	1.68 (−0.33 to 3.7)	−6.27 (−9.76 to −2.77)	9.64 (6.14 to 13.13)
Site 2, Operator 1 vs. Site 4, Operator 1	7.51 (4.99 to 10.03)	−2.41 (−6.77 to 1.95)	17.43 (13.07 to 21.79)
Site 2, Operator 1 vs. Site 4, Operator 2	6.21 (3.05 to 9.37)	−6.25 (−11.72 to −0.77)	18.66 (13.19 to 24.13)
Site 2, Operator 2 vs. Site 3, Operator 1	7.86 (5.12 to 10.6)	−2.95 (−7.7 to 1.8)	18.67 (13.92 to 23.42)
Site 2, Operator 2 vs. Site 3, Operator 2	0.96 (−1.3 to 3.22)	−7.94 (−11.85 to −4.03)	9.86 (5.95 to 13.77)
Site 2, Operator 2 vs. Site 4, Operator 1	6.79 (4.36 to 9.21)	−2.78 (−6.99 to 1.42)	16.35 (12.15 to 20.56)
Site 2, Operator 2 vs. Site 4, Operator 2	5.48 (2.06 to 8.91)	−8.01 (−13.94 to −2.08)	18.97 (13.04 to 24.9)
Site 3, Operator 1 vs. Site 3, Operator 2	−6.9 (−9.8 to −4)	−18.34 (−23.37 to −13.31)	4.54 (−0.49 to 9.57)
Site 3, Operator 1 vs. Site 4, Operator 1	−1.07 (−3.96 to 1.81)	−12.43 (−17.43 to −7.44)	10.29 (5.3 to 15.28)
Site 3, Operator 1 vs. Site 4, Operator 2	−2.38 (−6.1 to 1.35)	−17.06 (−23.51 to −10.61)	12.31 (5.85 to 18.76)
Site 3, Operator 2 vs. Site 4, Operator 1	5.83 (3.16 to 8.49)	−4.68 (−9.3 to −0.06)	16.33 (11.72 to 20.95)
Site 3, Operator 2 vs. Site 4, Operator 2	4.52 (1.12 to 7.93)	−8.89 (−14.79 to −3)	17.94 (12.04 to 23.83)
Site 4, Operator 1 vs. Site 4, Operator 2	−1.3 (−4.67 to 2.06)	−14.57 (−20.4 to −8.74)	11.96 (6.13 to 17.79)

CI: confidence interval; LoA: limit of agreement.

4. Discussion

4.1. Main Findings

This study has demonstrated that the BPA is a reproducible sonographic parameter when measured according to well-standardized criteria. The implementation of the image-based checklist developed for this study improved interobserver reproducibility, both within individual centers and across different institutions. These findings reinforce the importance of structured training and methodological standardization in US assessment, especially when introducing new sonographic parameters into clinical practice.

4.2. Comparison with Previous Studies

The original study by Youssef et al., first introducing the BPA, reported good inter-operator reproducibility, with an ICC of 0.83 (95% CI, 0.71–0.90) [21]. However, that study was limited to only two operators from a single center. In contrast, our study involved eight operators from four different institutions, introducing variability that better represents real-world clinical settings. In our study, the maternal pubic symphysis and fetal parts were always identifiable, allowing BPA measurements by all operators in 90% (18 out of 20) of the volumes. Nevertheless, in our first round of measurements, conducted after critically reviewing the original article on a personal basis, the overall ICC was only 0.70 (95% CI 0.48 to 0.86). Notably, agreement tended to be higher among operators from the same center despite blinding, likely due to shared interpretations and informal discussion of the original methodology. Similar limitations in interobserver reproducibility have been observed in other studies [29]. After the introduction of the image-based checklist and structured consensus-building, reproducibility improved markedly, with an ICC of 0.81 (95% CI, 0.66–0.92), consistent with the findings of Youssef et al. These results support the conclusion that the BPA is a feasible parameter for clinical application, provided it is used within a standardized framework and guided by clear protocols.

Operator experience is another well-known factor influencing reproducibility. Duckelman et al. investigated whether clinical US experience affected the reliability of the AoP measurements [18]. In their study, 44 images were acquired by a senior obstetrician with over 10 years of experience from women during their second stage of labor. The images were later analyzed offline, and the AoP was measured by nine examiners with varying levels of US experience: three senior obstetricians (>10 years of experience), three fellows (<five years of experience), and three midwives with no prior US experience in US), using standardized criteria. The overall ICC for the nine operators was 0.72 (95% CI 0.63 to 0.81). Although greater experience was associated with higher ICC values, the difference was not statistically significant. They concluded that while US experience influences performance in the measurement of the AoP, standardized criteria can mitigate this effect. Similarly, Sainz et al. reported significant variability in subjective intrapartum ultrasound assessments, even among experienced operators [29]. In our study, all operators were senior obstetricians with more than five years of ultrasound experience. The improvement in interobserver agreement following implementation of the image-based score highlights the importance of standardized methodology regardless of operator expertise.

Other sonographic parameters for assessing breech progression and predicting delivery outcome have been explored. Jennewein et al. conducted a prospective study showing that sonographic confirmation of fetal breech engagement (termed the intrapartum ultrasound breech engagement sign, or IPUBES) was associated with a significantly lower rate of cesarean delivery. However, because this sign relies solely on qualitative interpretation of sagittal ultrasound images depicting the maternal pubic bone and fetal buttocks, it remains subjective and potentially limits its reproducibility and clinical utility [30]. In contrast, our study contributes to the development of measurable, objective ultrasound parameters, such as the BPA, enabling consistent interobserver comparisons and offering a practical framework for use across diverse clinical settings.

Similarly, other ultrasound parameters have also been investigated to assess the likelihood of success in ECV. Among these, the volume of amniotic fluid is one of the most extensively studied. Noteworthy is the measurement of the volume of amniotic fluid beneath the presenting fetal part (fore-bag), which serves as an indirect but meaningful predictor. Isakov et al. demonstrated that a larger fore-bag significantly increased the probability of successful ECV, incorporating this measurement into a multivariable predictive model with high discriminative capacity (C-index = 0.933) alongside maternal body mass index and parity [31]. Other studies have also emphasized the importance of overall amniotic fluid volume in predicting ECV outcomes [32–34]. Despite its utility, the assessment of amniotic fluid volume is subject to certain limitations, particularly concerning reproducibility. Although interobserver variability in ultrasound-based measurements such as the amniotic fluid index (AFI) or the single deepest pocket is generally considered low, discrepancies may still arise depending on factors such as ultrasound technique, fetal position, and operator expertise [35]. Furthermore, the measurement of the fore-bag volume is not routinely standardized across clinical settings, thereby limiting its generalizability. These issues highlight the need for refined protocols and potential automation to enhance consistency and clinical applicability when incorporating sonographic assessments into predictive models for ECV.

Previous studies have also focused on non-sonographic methods to assess both the likelihood of a successful ECV and the progression of a vaginal breech birth. The problem is that all these methods involve some degree of subjectivity. Thus, in the case of evaluating ECV, clinical parameters such as abdominal wall tone, uterine relaxation, maternal discomfort, and palpability of the fetal head during the maneuver are frequently considered [36]. Multiparity has consistently been shown to be a strong predictor of ECV success, as prior births often result in a more distensible uterus and compliant abdominal wall, facilitating the maneuver. Moreover, the absence of maternal pain during ECV has been independently associated with significantly higher success rates (one study found that women reporting no pain had up to 14 times higher odds of a successful version) [37]. In respect to the palpability of the fetal head, in a retrospective study by Correia Costa et al., involving 324 ECVs, a non-palpable fetal head was identified as an independent predictor of failure, with an odds ratio of 0.20 (95% CI: 0.06–0.60) [38].

Similarly, during labor progression in breech presentation, several non-sonographic clinical findings are used, such as cervical dilatation, fetal station, pelvic adequacy, and type of breech presentation, but these too are prone to observer variability. For instance, interobserver agreement in estimating fetal station is notoriously poor, and clinical pelvimetry remains subjective with limited reproducibility and uncertain predictive value [8,15,39]. Although these parameters are still considered to be essential for intrapartum decision-making, particularly in determining whether to continue with a vaginal breech birth or proceed to cesarean section, their inherent variability underscores the need for structured protocols and objective methods to enhance reliability, such as BPA measurements.

4.3. Strengths and Limitations

The main strength of our study lies in its multicenter and international nature, incorporating the expertise of eight obstetricians from four distinct centers across two different countries. This diversity enhances the external validity and generalizability of our results. Additionally, by having all participants analyze the same pre-acquired US volumes, we eliminated the variability in image acquisition and focused solely on interpretation, providing a strong rationale for the need to unify the measurement criteria. This process ultimately informed the development of the image-based checklist.

One limitation is that all BPA measurements were performed offline, unlike the real-time evaluations typical in clinical practice. While this may create minor discrepancies with live assessments, we argue that offline analysis offers a controlled environment for the development and refinement of standardized criteria without the external pressure characteristic of the labor ward. Notably, we have previously demonstrated that real-time assessments can achieve comparable accuracy, even among operators without prior US experience, when supported by clear criteria and appropriate training [14]. Therefore, the use of offline measurements is unlikely to have significantly affected the results. Another limitation is that all US volumes were acquired by a single expert obstetrician and also analyzed by senior clinicians, which likely resulted in a higher image quality and more accurate measurements than might be expected from less experienced operators. However, previous studies have shown that clinicians without prior US experience can be effectively trained in intrapartum ultrasound and reach performance levels similar to those of expert practitioners [14]. In addition to homogenizing the level of expertise among operators, we aimed to ensure that the results primarily reflect the impact of the intervention itself.

Clinical Implications

This study highlights the importance of standardizing criteria when introducing new diagnostic tools, such as intrapartum US in clinical practice. The BPA, when measured using well-defined criteria, may serve as a valuable parameter in predicting the outcomes of ECV and vaginal breech delivery. By demonstrating reproducibility among multiple experienced clinicians, our findings support the integration of BPA into routine obstetric evaluation, thereby enhancing the reliability of decision-making during labor.

Recent evidence highlights the role of ECV in reducing cesarean rates in breech pregnancies. A systematic review by Devold Pay et al. confirmed that attempting ECV at or near term significantly reduces the likelihood of cesarean delivery, affirming its value as a first-line intervention recommended by major international guidelines [6]. The effectiveness of ECV, however, hinges on the accurate ultrasonographic assessment of fetal positioning and descent. The present study strengthens the case for BPA as a clinically relevant and reproducible metric to guide such assessments. By offering objective benchmarks for breech engagement, BPA may improve the precision of decision-making by providing more accurate odds of success to the patient, increase rates of successful vaginal delivery by appropriate selection of cases undergoing ECV, and ultimately reduce unnecessary cesarean sections. Therefore, following this study, further research should therefore explore the implementation of BPA measurement in predicting labor outcomes and optimizing breech delivery management.

Finally, our findings reinforce the clinical relevance of promoting standardized, objective US-based evaluation during labor not only for BPA measurement but also to reduce variability for other parameters.

5. Conclusions

The BPA is a feasible and reproducible US parameter. The use of an image-based checklist supports the standardization of intrapartum US measurements, enhancing their clinical applicability and potential integration into quality control programs. Further studies are warranted to assess the predictive value of BPA in the context of ECV and vaginal breech delivery, as well as to evaluate training requirements, including the time and feasibility for broader clinical implementation.

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4.4 Estudio 4.- **Biparietal diameter for first-trimester pregnancy dating: multicenter cohort study.**

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Biparietal diameter for first-trimester pregnancy dating: multicenter cohort study

C. DE PACO MATALLANA[1,2#], V. ROLLE[3,4#], A. M. FIDALGO[5,6], J. SÁNCHEZ-ROMERO[1,2], J. C. JANI[7], P. CHAVEEVA[8], J. L. DELGADO[1,2], B. SANTACRUZ[5,6], K. H. NICOLAIDES[9] and M. M. GIL[5,6,9,10]

[1]*Department of Obstetrics and Gynecology, Hospital Clínico Universitario 'Virgen de la Arrixaca', El Palmar, Murcia, Spain; Institute for Biomedical Research of Murcia, IMIB-Arrixaca, El Palmar, Murcia, Spain;* [2]*Faculty of Medicine, Universidad de Murcia, Murcia, Spain;* [3]*Statistics and Data Management Unit, iMaterna Foundation, Alcalá de Henares, Madrid, Spain;* [4]*Biostatistics and Epidemiology Platform, Fundación para la Investigación y la Innovación Biosanitaria del Principado de Asturias (FINBA), Asturias, Spain;* [5]*Department of Obstetrics and Gynecology, Hospital Universitario de Torrejón, Torrejón de Ardoz, Madrid, Spain;* [6]*Faculty of Medicine, Universidad Francisco de Vitoria, Pozuelo de Alarcón, Madrid, Spain;* [7]*Department of Obstetrics and Gynecology, University Hospital Brugmann and Université Libre de Bruxelles, Brussels, Belgium;* [8]*Fetal Medicine Unit, Shterev Hospital, Sofia, and Medical University, Pleven, Bulgaria;* [9]*Harris Birthright Research Centre for Fetal Medicine, King's College Hospital, London, UK;* [10]*Department of Obstetrics and Gynecology, Hospital Universitario La Paz, Madrid, Spain*

KEYWORDS: biparietal diameter; crown–rump length; first trimester; gestational age; pregnancy dating

ABSTRACT

Objective *To evaluate the accuracy of fetal biparietal diameter (BPD) measurement in comparison with crown–rump length (CRL) measurement for pregnancy dating at 11–13 weeks' gestation.*

Methods *This was a retrospective multicenter cohort study performed in five maternity units in Spain, the UK, Belgium and Bulgaria between January 2011 and December 2019. We included all women who attended a routine ultrasound examination at 11 + 0 to 13 + 6 weeks who had a singleton pregnancy with a viable non-malformed fetus/neonate and ultrasound-derived measurements for both CRL and BPD, along with a comprehensive record of pregnancy outcomes. We developed a formula for pregnancy dating based on BPD using data from pregnancies conceived via* in-vitro *fertilization (IVF) by applying a simple linear regression. We validated this formula both internally and externally and compared it with the most commonly used formulae (Robinson's CRL-based and Kustermann's BPD-based formulae) through utilization of the Euclidean distance, relative absolute error and mean squared error. We also examined the rate of induction of labor for post-term pregnancy based on dating using each of the formulae.*

Results *A total of 49 492 women were included in the study, comprising 47 223 (95.4%) who conceived spontaneously and 2269 (4.6%) who conceived via IVF. In the internal validation performed using data from IVF pregnancies, our newly developed formula showed no significant difference when compared with the true gestational age calculated using conception date, with a mean difference of 0.0006 (95% CI, −0.09 to 0.09) days. In contrast, the mean difference of Kustermann's BPD-based formula was −0.31 (95% CI, −0.46 to −0.17) days and the mean difference of Robinson's CRL-based formula was −1.78 (95% CI, −1.88 to −1.68) days. In the external validation using data from spontaneously conceived pregnancies, with dating using Robinson's formula as the reference for 'true' gestational age, both our formula and Kustermann's formula resulted in underestimation of gestational age, with significant mean differences of −1.25 (95% CI, −1.28 to −1.22) days and −0.96 (95% CI, −0.98 to −0.93) days, respectively. The largest differences compared with Robinson's formula-based dating results were observed between 11 + 0 and 12 + 0 weeks. Dating the pregnancy using Robinson's formula led to 8.1% of pregnancies identified as requiring induction after 41 + 3 weeks, compared with 6.8%* ($P < 0.001$) *and 7.0%* ($P < 0.001$) *when applying our formula and Kustermann's formula, respectively.*

Correspondence: Dr M. M. Gil, Vicerrectorado de Investigación, Facultad de Medicina, Universidad Francisco de Vitoria, Carretera Pozuelo a Majadahonda, Km 1.800, 28223 Pozuelo de Alarcón, Madrid, Spain (e-mail: mariadelmar.gil@ufv.es); Prof. K. H. Nicolaides, Fetal Medicine Research Institute, King's College Hospital, 16–20 Windsor Walk, Denmark Hill, London SE5 8BB, UK (e-mail: kypros@fetalmedicine.com)

#C.D.P.M. and V.R. contributed equally to this study.

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ORIGINAL PAPER

Conclusion *Pregnancy dating based on ultrasound measurement of fetal BPD between 11 + 0 and 13 + 6 weeks' gestation is a reliable alternative to dating based on fetal CRL. © 2025 International Society of Ultrasound in Obstetrics and Gynecology.*

INTRODUCTION

Pregnancy dating is essential to mitigate potential complications associated with either preterm or post-term birth[1]. Pregnancy lasts on average 280 days from the first day of the mother's last menstrual period (LMP)[2]. While Naegele's rule[3] is a widely utilized method owing to its simplicity, it tends to be inaccurate, even in women with regular menstrual periods. In comparison with ultrasound measurement of the fetal biparietal diameter (BPD) taken during the second trimester, the LMP method typically underestimates the expected date of delivery (EDD) by approximately 2–3 days[4]. Theoretically, the most accurate method for calculating the EDD involves determining the exact day of conception – an approach applicable exclusively to pregnancies conceived via *in-vitro* fertilization (IVF)[5].

In the case of natural conception, ultrasound assessment has been shown to be the most effective means for dating the pregnancy and estimating the EDD[6,7]. Crown–rump length (CRL) measurement in the first trimester is now recognized universally as the 'gold standard' for pregnancy dating[8,9], providing greater accuracy compared with other biometric parameters such as head circumference or abdominal circumference[10], with a margin of error ranging from 3 to 8 days according to the most commonly used chart, the Robinson chart[11–13]. In the case of IVF pregnancy, the Robinson method tends to overestimate gestational age by 3 days when compared with the true date of conception[14]. When considering other sonographic methods for pregnancy dating in the first trimester, such as measurement of head circumference, abdominal circumference or femur length, BPD appears to be the best alternative to CRL[8,10,11,15,16]. Obtaining a precise CRL measurement requires an extended learning curve and can be particularly challenging in pregnancies at around 13–14 weeks' gestation[17]. In contrast, BPD measurement is reproducible and does not typically need extensive training[10,18,19].

The aim of this study was to evaluate the accuracy of BPD in comparison with CRL for pregnancy dating at 11–13 weeks' gestation.

METHODS

This was a retrospective multicenter cohort study performed at two maternity units in Spain (Hospital Clínico Universitario 'Virgen de la Arrixaca', Murcia and Hospital Universitario de Torrejón, Madrid), one in the UK (King's College Hospital, London), one in Belgium (Brugmann University Hospital, Brussels) and one in Bulgaria (Dr Shterev Hospital, Sofia) between January 2011 and December 2019. Approval for the study and a waiver of consent were obtained from the relevant research ethics committee of each participating center.

We included all women who attended for a routine ultrasound examination at 11 + 0 to 13 + 6 weeks' gestation, who had a singleton pregnancy with a live non-malformed fetus/neonate and ultrasound-derived measurements for both CRL and BPD, along with a comprehensive record of pregnancy outcome. Cases of spontaneous or elective termination or intrauterine death were excluded from the study. Ultrasound measurements and maternal characteristics (weight, height, ethnicity (White, Black, East Asian, South Asian or mixed), method of conception (natural or assisted conception with ovulation drugs or IVF), smoking status during pregnancy, parity, medical history and pregnancy outcome) were obtained from the hospital's electronic clinical database (ViewPoint® Software, GE Healthcare, Munich, Germany; or Astraia® Software, Astraia GmbH, Munich, Germany).

To calculate gestational age, CRL was measured in the midline sagittal section of the whole fetus, oriented horizontally in a neutral position. The maximum distance from the top of the head to the rump of the fetus was measured as a straight line, obtained by placing ultrasound calipers at the outer edges (Figure 1). According to standard recommendations[8,9], three measurements were taken, and the average was considered the final CRL measurement. BPD was measured in the largest symmetrical axial view of the fetal head, demonstrating the skull, midline echo and choroid plexuses, by placing the calipers outer-to-outer, perpendicular to the midline

Figure 1 Crown–rump length (a) and biparietal diameter (b) measurements, illustrating the simplicity of obtaining the latter.

falx (Figure 1)[8]. As recommended by the Fetal Medicine Foundation, this view was chosen for BPD measurement owing to its simplicity in early gestation compared with the transthalamic view[9]. Pregnancy dating using BPD was calculated using the formula derived from this study and that published by Kustermann *et al.*[20]. Only CRL, or conception date for IVF pregnancies, was used for pregnancy dating in clinical practice and the BPD measurement was undertaken for other purposes, according to local protocols. Conception date was calculated as the transfer day minus the age of the embryo (i.e. 3 or 5 days). Ultrasound examinations were performed by sonographers or obstetricians certified for nuchal translucency measurement by the Fetal Medicine Foundation.

To validate the formulae across diverse populations, we organized the data by center and analyzed each dataset in the order they were received. The generated dataset was divided into three subgroups. Group 1 ($n = 2269$) included all IVF pregnancies in the maternity units in London and Murcia. This dataset was used to develop the BPD formula for pregnancy dating and was used for internal validation. Group 2 ($n = 47\,223$) included all spontaneous pregnancies in the maternity units in London and Murcia (2013–2017), Brussels (2011–2018), Sofia (2017–2018) and Madrid (2017–2019), and was used for external validation of the model in spontaneously conceived pregnancies. Group 3 ($n = 5256$) was a subset of Group 2, comprising spontaneous pregnancies undergoing induction of labor beyond 41 + 3 weeks ($n = 275$ (5.2%)) and those undergoing spontaneous labor between 34 + 0 and 42 + 6 weeks ($n = 4981$ (94.8%)) in Brussels, Sofia and Madrid (2011–2019), and was used to assess the induction rate due to post-term pregnancy. The cut-off for induction of labor was chosen based on local protocols, which consistently recommended induction of labor by 41 + 3 weeks at the latest for post-term pregnancy, in all participating centers.

Statistical analysis

Continuous data are given as median (interquartile range) and categorical data as n (%). To plan the analysis, we visually analyzed the distribution of the two variables. When plotting BPD as the dependent variable and gestational age in days as the independent variable, a completely linear relationship became apparent. Therefore, we chose to fit a simple linear regression model to develop an equation to estimate gestational age based on BPD. All hypotheses of the model were graphically corroborated. When developing the formula and during internal validation (i.e. for Group 1), gestational age calculated using the date of conception was regarded as the gold standard. For external validation (i.e. for Group 2) and assessment of induction rate (i.e. for Group 3), gestational age calculated using Robinson's CRL-based formula was regarded as the gold standard.

To compare gestational age estimation between formulae, the Euclidean distance, relative absolute error (RAE), mean squared error (MSE), mean comparison using the paired t-test and range comparison using the Wilcoxon signed-rank test were calculated. For RAE, MSE and Euclidean distance, a smaller value indicates better prediction (i.e. it is closer to the gold standard). In the case of the Wilcoxon signed-rank test and the paired t-test, better prediction is indicated when the estimate and 95% CI are closer to 0. The RAE, MSE, t-test and Wilcoxon signed-rank test for our formula were estimated by 10-fold cross-validation using data from Group 1. Each parameter was calculated in each fold and their results were averaged. 95% CIs were obtained with 1000 bootstrap replicates. Since Euclidean distance depends on the sample size, it was calculated for the whole sample.

We conducted a final comparison between formulae based on the number of pregnancies identified as requiring induction of labor owing to post-term pregnancy, defined as cases in which spontaneous labor did not commence within 41 + 3 weeks/290 days, according to each formula. We used the McNemar test to assess the difference in induction rate when using each pregnancy-dating method.

All analyses were carried out using R software version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria)[21]. 'Car' package was used to clean the data[22], 'caret' package was used to create the folds for the cross validation[23], 'lubridate' package was used to manage the dates[24] and 'ggplot2' package was used for plots and figures[25]. $P < 0.05$ was considered to indicate statistical significance.

RESULTS

A total of 49 492 women were included in the study, comprising 47 223 (95.4%) women in Group 2 who conceived spontaneously and 2269 (4.6%) women in Group 1 who conceived via IVF. Group 3 comprised 5256 women from Group 2 who conceived spontaneously, of whom 275 (5.2%) underwent induction of labor after 41 + 3 weeks and 4981 (94.8%) underwent spontaneous labor between 34 + 0 and 42 + 6 weeks. Maternal and pregnancy baseline characteristics are presented in Table 1.

Development of BPD formula

Group 1 data were used initially to derive a formula for predicting gestational age (in days) using BPD measurement, using a cross-validated linear regression model: gestational age (days) = (BPD (mm) + 16.33798) / 0.4299. Subsequently, we compared the gestational age prediction derived from our formula with that derived from the formula of Kustermann[20] (using BPD) and that of Robinson[12] (using CRL) (Table 2). While Robinson's formula had the smallest global error, our newly developed formula showed the smallest mean and range differences compared with the true gestational age (based on date of conception), closely followed by Kustermann's formula. Our formula did not demonstrate a statistically significant difference from the gold standard, differing by a mean of 0.0006 (95% CI, −0.09 to 0.09) days. Kustermann's and Robinson's formulae showed a mean difference of −0.31

Table 1 Maternal and pregnancy baseline characteristics of study cohort

Characteristic	Group 1 (n = 2269)	Group 2 (n = 47 223)	Group 3 (n = 5256)
Maternal age (years)	37.0 (34.0–40.0)	32.0 (28.0–36.0)	29.4 (25.7–33.4)
Maternal ethnic origin			
Black	49 (2.2)	6995 (14.8)	679 (12.9)
East Asian	50 (2.2)	1111 (2.4)	15 (0.3)
Mixed	31 (1.4)	1166 (2.5)	9 (0.2)
South Asian	116 (5.1)	2086 (4.4)	76 (1.4)
White	2023 (89.2)	35 865 (75.9)	4477 (85.2)
Maternal body mass index (kg/m^2)	23.3 (21.3–26.2)	23.9 (21.4–27.5)	24.6 (21.8–28.1)
Nulliparous	1617 (71.3)	20 914 (44.3)	1754 (33.4)
Smoker	63 (2.8)	2442 (5.2)	407 (7.7)
Conception			
In-vitro fertilization	2269 (100)	0 (0)	0 (0)
Spontaneous	0 (0)	47 223 (100)	5256 (100)
Chronic hypertension	13 (0.6)	400 (0.8)	53 (1.0)
Diabetes mellitus	9 (0.4)	309 (0.7)	32 (0.6)
Gestational age at ultrasound (days)*	87.0 (85.0–90.0)	89.0 (86.3–91.6)	89.1 (86.0–92.1)

Data are given as median (interquartile range) or *n* (%). *Estimated according to routine clinical practice i.e. conception date for pregnancies conceived by *in-vitro* fertilization and crown–rump length for spontaneously conceived pregnancies.

Table 2 Internal validation of our formula, Kustermann's formula[20] and Robinson's formula[12] for pregnancy dating, using Group 1 data (conception via *in-vitro* fertilization)

Formula	RAE	MSE	Euclidean distance	Mean difference from gold standard (days)	Range difference from gold standard (days)*
Our formula	1.02 (0.99–1.04)	14.94 (14.19–15.92)	184 (179–190)	0.0006 (−0.09 to 0.09)	−0.02 (−0.12 to 0.06)
Kustermann[20]	0.94 (0.91–0.98)	12.83 (12.07–13.67)	170 (165–176)	−0.31 (−0.46 to −0.17)	−0.34 (−0.48 to −0.20)
Robinson[12]	0.80 (0.77–0.83)	9.30 (8.68–9.99)	145 (140–151)	−1.78 (−1.88 to −1.68)	−1.73 (−1.83 to −1.64)

Data are given as estimate (95% CI), unless stated otherwise. *Data are given as pseudomedian (95% CI). In all cases, gold standard is true gestational age calculated using conception date. MSE, mean squared error; RAE, relative absolute error.

(95% CI, −0.46 to −0.17) days and −1.78 (95% CI, −1.88 to −1.68) days, respectively, with respect to the true gestational age calculated using the date of conception. While the MSE and RAE highlight occasional large errors in the BPD formulae, the mean difference and range difference show that most BPD predictions are closer to the observed values, indicating less systematic bias (Table 2).

Figure 2 provides a visual representation of the predicted gestational age calculated using each formula compared with the true gestational age based on date of conception. Both of the formulae that use BPD provided similar estimates, especially after 13 weeks, and showed excellent concordance with the true gestational age. In contrast, the CRL formula overestimated gestational age, particularly at 11–12 weeks.

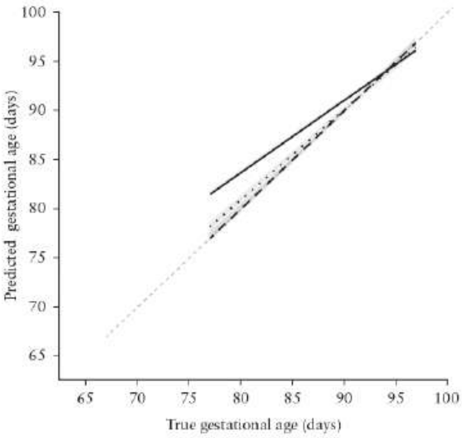

Figure 2 Gestational age calculated using our formula (– –), Kustermann's formula[20] (····) and Robinson's formula[12] (——) for pregnancy dating, in comparison with true gestational age calculated based on conception date, using Group 1 data. Gray dashed line represents maximum possible agreement between true and predicted gestational age. Gray shaded areas are 95% CI.

External validation in spontaneously conceived pregnancies

Group 2 data were used for the external validation of our formula and comparison with Robinson's and Kustermann's formulae, applied to spontaneously conceived pregnancies. In this analysis, we regarded gestational age calculated using Robinson's CRL-based dating as the 'true' gestational age (Table 3, Figure 3), as the conception date in spontaneous pregnancies is unknown. Both

Table 3 External validation of our formula and Kustermann's formula[20] for pregnancy dating, using Group 2 data (spontaneous conception)

Formula	*RAE*	*MSE*	*Euclidean distance*	*Mean difference from gold standard (days)*	*Range difference from gold standard (days)**
Our formula	0.87 (0.86–0.88)	11.27 (11.11–11.43)	730 (724–734)	−1.25 (−1.28 to −1.22)	−1.31 (−1.34 to −1.29)
Kustermann[20]	0.76 (0.75–0.77)	8.72 (8.60–8.85)	641 (637–647)	−0.96 (−0.98 to −0.93)	−1.01 (−1.04 to −0.99)

Data are given as estimate (95% CI), unless stated otherwise. *Data are given as pseudomedian (95% CI). In all cases, gold standard is 'true' gestational age estimated from crown–rump length using Robinson's formula[12]. MSE, mean squared error; RAE, relative absolute error.

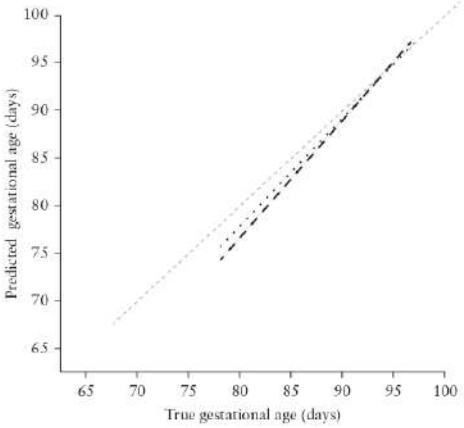

Figure 3 Gestational age calculated using our formula (– –) and Kustermann's formula[20] (- - - -) for pregnancy dating, in comparison with 'true' gestational age calculated based on Robinson's crown–rump-length-based dating formula[12], using Group 2 data. Gray dashed line represents maximum possible agreement between 'true' and predicted gestational age. Gray shaded areas are 95% CI.

BPD-based formulae showed a statistically significant underestimation of gestational age when compared with gestational age calculated using Robinson's formula, with a mean difference of −1.25 (95% CI, −1.28 to −1.22) days and −0.96 (95% CI, −0.98 to −0.93) days using our formula and Kustermann's formula, respectively. The largest differences compared with Robinson's formula were observed between 11 + 0 and 12 + 0 weeks, but the differences diminished thereafter. Bland–Altman plots for dating using our formula and Kustermann's formula are given in Figures S1 and S2, respectively.

Rate of induction of labor for post-term pregnancy

Group 3 data were used to estimate the induction rate after 41 + 3 weeks, derived using each of the three abovementioned formulae. When pregnancy dating was performed using Robinson's CRL-based formula, there were 426 (8.1%) cases identified as requiring subsequent induction of labor. Dating using our BPD-based formula resulted in 355 (6.8%) cases identified as requiring induction, and dating using Kustermann's BPD-based formula resulted in 366 (7.0%) cases identified as requiring induction. The number of cases identified as requiring induction of labor using our formula and Kustermann's formula was significantly different from that identified using Robinson's formula, with the former requiring fewer inductions ($P < 0.001$ for both). There was no difference between the number of cases identified as requiring induction of labor using our formula and that using Kustermann's formula ($P = 0.1$).

DISCUSSION

Main findings

There were four main findings of this study. First, pregnancy dating based on ultrasound measurement of fetal BPD during the first-trimester scan, especially when performed after 12 weeks' gestation, provided a reliable alternative to dating based on ultrasound measurement of fetal CRL. Second, BPD-based dating presented a closer concordance with the true gestational age (calculated from conception date in IVF pregnancies) when compared with CRL-based dating. Third, EDD calculated using BPD-based or CRL-based dating methods differed by less than a day on average. Fourth, pregnancy dating using first-trimester BPD measurements did not result in a higher rate of post-term induction of labor in comparison with dating using CRL measurements.

Comparison with results of previous studies

Many studies have examined potential methods for pregnancy dating in the first trimester, with a focus not only on accuracy but also on measurement reproducibility. However, these studies were small and lacked external validation. Two studies[10,26] found that CRL and BPD were equally accurate in predicting the EDD. Chalouhi *et al.*[10] developed dating formulae for CRL and BPD using data from 331 IVF pregnancies, which were subsequently validated in 3667 pregnancies, most of which were spontaneous. Similar to our findings, they concluded that both CRL and BPD measurements were highly reproducible and could predict the EDD with great accuracy. Wu *et al.*[26] investigated BPD as an alternative to CRL for the determination of gestational age in 167 IVF pregnancies. They found that the BPD-based dating formula had a significantly smaller mean difference from conception date-based estimates compared with the CRL formula (0.013 *vs* 0.746; $P < 0.01$), with a lower SD (2.414 *vs* 3.008; $P < 0.05$). Consequently, they suggested that BPD might offer similar accuracy to CRL in pregnancy dating[26].

Two other studies[14,27] reported that BPD measurement is preferable to CRL for pregnancy dating. Knight *et al.*[14] analyzed 178 pregnancies conceived via IVF at 11 + 2 to 14 + 1 weeks' gestation and compared dating using Robinson's CRL-based formula with dating based on conception date. Similar to our findings, they observed a mean overestimation of 3.0 (95% CI, 2.70–3.36) days when using Robinson's formula[14]. Sladkevicius *et al.*[27] evaluated the accuracy of 21 CRL-based dating formulae and three BPD-based dating formulae using data from 167 singleton IVF pregnancies. They reported that the three BPD formulae outperformed all 21 CRL formulae, as they presented smaller random errors. All but two CRL-based dating formulae displayed systematic overestimation or underestimation of gestational age, with SDs ranging from 2.25 to 4.86 days[27].

Strengths and limitations

The main strength of this study lies in the large sample size, which allowed us to divide the dataset into different subgroups and perform different validations across different populations. The importance of external validation is that, before a predictive model can be considered for use in clinical practice, its performance must be evaluated in populations distinct from those used in its development[28]. This extends beyond evaluation at a different point in time; external validation in a different geographical area serves as a robust measure of the model's generalizability and transportability. Furthermore, the large number of included IVF pregnancies enabled us to develop a precise formula and validate the two formulae that are most commonly used for pregnancy dating.

The main limitations of this study are related to its retrospective design. We were unable to evaluate other factors that may have been of interest after obtaining the results, such as operator experience or reproducibility. Another limitation to consider is that, as BPD was not the standard method for pregnancy dating in any of the participating centers, the measurements may not have been performed as meticulously as were CRL measurements, which is the clinical standard for dating. This could have led potentially to an underestimation of the accuracy of the BPD methods. A common limitation of validation studies is that they do not allow for distinguishing differences due to population-specific characteristics or different measurement techniques for the validation of the model itself. Therefore, each population may require specific adjustments once its characteristics are known[29].

Implications for clinical practice

Measuring fetal BPD is a relatively straightforward procedure, as reference points or landmarks for BPD are readily identifiable and do not necessitate advanced ultrasound expertise or high-resolution equipment. Owing to its simplicity and accessibility, employing BPD measurement for pregnancy dating in areas with limited ultrasound training opportunities could enhance its widespread use, potentially reducing complications arising from inaccurate dating. Furthermore, although it is not typically required in routine clinical protocols, BPD measurement may be useful in clinical situations such as persistent inadequate fetal positioning, which is relatively common by the end of the 13th week of pregnancy. In this case, using BPD for pregnancy dating with either our formula or Kustermann's formula can shorten the examination time and thus improve clinical efficiency.

Conclusions

This study has demonstrated that pregnancy dating based on ultrasound measurement of fetal BPD between 11 + 0 and 13 + 6 weeks' gestation is a reliable alternative to dating based on fetal CRL. Dating using BPD differs by less than a day from dating using CRL, with no increase in the rate of induction of labor due to prolonged gestation.

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SUPPORTING INFORMATION ON THE INTERNET

The following supporting information may be found in the online version of this article:

Figure S1 Bland–Altman analysis of our newly developed biparietal-diameter-based dating formula *vs* Robinson's crown–rump-length-based dating formula, using Group 2 data. Red line represents mean difference (days) between the two methods and blue lines represent 95% CI.

Figure S2 Bland–Altman analysis of Kustermann's biparietal-diameter-based dating formula *vs* Robinson's crown–rump-length-based dating formula, using Group 2 data. Red line represents mean difference (days) between the two methods and blue lines represent 95% CI.

RESUMEN DE RESULTADOS Y DISCUSIÓN

5 RESUMEN Y DISCUSIÓN

5.1 Estudio 1: *“Level of agreement between midwives and obstetricians performing ultrasound examination during labor”*

5.1.1 Resumen

El objetivo de este estudio era el evaluar el nivel de concordancia entre las mediciones ecográficas para evaluar la posición de la cabeza fetal y la progresión del trabajo de parto por parte de matronas que atienden partos y obstetras, después del entrenamiento adecuado. Para ello se diseñó un estudio prospectivo, en el que se invitó a participar a gestantes en primera fase de parto con gestación única en cefálica en dos unidades de maternidad en Madrid, España (Hospital Universitario de Torrejón y Hospital Universitario La Paz), entre marzo de 2018 y diciembre de 2019; 109 mujeres aceptaron participar. Se realizó ecografía transperineal y transabdominal de forma independiente por una matrona capacitada y por un obstetra. Se obtuvieron dos pares de mediciones para poder compararlas en 107 casos para el ADP, en 106 casos para la DCP, en 97 casos para la DCE y en 79 casos para la posición de la cabeza fetal. Como resultado encontramos una buena correlación entre obstetras y matronas en la medida del ADP (CCI = 0,85; IC del 95%: 0,80-0,89). Hubo una correlación moderada en la DCP (CCI = 0,75; IC del 95%: 0,68-0,82). Hubo una muy buena correlación en la medida de la CDE (CCI = 0,94; IC del 95%: 0,91-0,96). Hubo un muy buen nivel de concordancia en la clasificación de la posición de la cabeza fetal (κw de Cohen = 0,89; IC del 95%: 0,80-0,98).

5.1.2 Discusión

Este estudio muestra que, tras un entrenamiento teórico y práctico estructurado, matronas sin experiencia previa en ecografía pueden adquirir las competencias necesarias para realizar ecografía transperineal y transabdominal para evaluar la posición de la cabeza fetal y la progresión del parto. La concordancia entre matronas y obstetras fue buena o muy buena para ADP, DCP, CDE y para la clasificación de la posición de la cabeza fetal. Estos resultados pueden contribuir a superar la idea de que esta técnica es exclusiva de los médicos y su incorporación en la práctica clínica habitual por parte de matronas puede disminuir el número de exploraciones vaginales y, con ello, el riesgo de infecciones, a la vez que ofrece una evaluación más objetiva y visual que facilita a los futuros padres comprender mejor cualquier desviación de la normalidad antes de que se tomen decisiones clínicas.

Nuestros resultados mejoran los obtenidos en estudios previos. En el trabajo de Van Adrichem et al., que incluyó 11 matronas y 30 mediciones en fases más avanzadas del parto, la concordancia para ADP fue solo moderada (CCI 0,76), posiblemente por un entrenamiento limitado a una presentación de una hora y una única evaluación supervisada.[88] En nuestro caso, el entrenamiento fue individualizado, con práctica supervisada hasta lograr competencia y la obtención de cinco ecografías obligatorias, lo que probablemente explica la mayor reproducibilidad. En el estudio de Ducklemann et al., las imágenes fueron adquiridas por un único obstetra y evaluadas después por matronas y obstetras junior y senior.[27] Aunque no se hallaron diferencias significativas, la fiabilidad fue menor en las matronas (ICC 0,61) frente a obstetras junior (ICC 0,81) o senior (ICC 0,82). Además, el análisis de imágenes fijas eliminó la variabilidad temporal, pero no reflejó la dificultad de la adquisición en tiempo real, un aspecto clave abordado en nuestro diseño.

Entre las limitaciones de nuestro estudio destaca que la mayoría de las exploraciones se realizaron en fase latente, cuando la dilatación cervical es <3 cm, lo que puede limitar la extrapolación a fases más avanzadas. Sin embargo, en esta fase se esperaría una menor visibilidad de los puntos de referencia para ADP o DCP, por lo que la concordancia podría incluso estar infraestimada. Aproximadamente un 25 % de las mediciones de la posición de la cabeza no se registraron, probablemente por olvido más que por imposibilidad, dado el estrecho intervalo de confianza de κw. El tiempo entre exploraciones raramente superó los 20 minutos, por lo que su impacto es mínimo.

La principal fortaleza radica en su diseño prospectivo y en condiciones clínicas reales, incluyendo a matronas y obstetras sin experiencia previa en ecografía intraparto. Este enfoque permite valorar de forma robusta la viabilidad de la ecografía transperineal como herramienta rutinaria para monitorizar el parto, con independencia del perfil profesional del operador, y proporciona evidencia adicional frente a estudios anteriores en contextos más limitados o con menor entrenamiento.

5.2 Estudio 2: *"Implementation of sonopartogram: multicenter feasibility study"*

5.2.1 Resumen

El objetivo de este estudio fue evaluar la viabilidad de integrar la valoración ecográfica transabdominal y transperineal de la posición fetal, el PS-ADP, la DCP y la DCE para monitorizar el trabajo de parto en mujeres que van a ser sometidas a una inducción de parto. También buscamos determinar si la ecografía puede reducir el dolor de las mujeres durante estos exámenes.

Para ello diseñamos un estudio de cohortes longitudinal prospectivo cuyas participantes eran gestantes que iban a someterse a una inducción de parto en tres maternidades.

Se realizaron evaluaciones ecográficas a mujeres entre 37 + 0 y 41 + 6 semanas de gestación. Se realizó una ecografía basal transabdominal y transperineal, que incluyó una biometría fetal, Doppler de la arteria umbilical y la arteria cerebral media fetal, el índice de líquido amniótico, la determinación de la posición de la columna y el occipucio fetales, el ADP-ps, la DCP, la DCE y la longitud cervical. Se realizaron ecografías intraparto seriadas en lugar de tacto vaginal, a menos que existiera una indicación clínica para realizarla, según el protocolo. Se pidió a las participantes que indicaran su nivel de dolor durante la exploración mediante una puntuación verbal de 0 a 10. Los datos de las mediciones se analizaron utilizando modelos de efectos mixtos para identificar factores importantes que afectaran a la relación entre el PS-ADP, la DCP, la DCE y el modo de parto.

Se incluyeron en el estudio un total de 100 mujeres. De estas, el 20% tuvo un parto mediante cesárea, el 65% mediante parto eutócico y el 15% con un parto instrumental. No hubo resultados adversos fetales o maternos. Se realizaron un total de 223 ecografías intraparto en 87 participantes (13 mujeres dieron a luz antes de que se les realizara la ecografía intraparto seriada), con una mediana de dos ecografías por participante (rango intercuartílico, RIC, 1-3). De ellas, 76 mujeres se sometieron a un total de 151 tactos vaginales, con una mediana de un tacto vaginal por participante (RIC 0-2), sin diferencias significativas entre los grupos de parto vaginal o por cesárea.

Tras excluir a las pacientes con anestesia epidural durante la exploración, la mediana de la puntuación de dolor para las ecografías intraparto fue de 0 (RIC: 0-1) y para el tacto vaginal fue de 3 (RIC: 0-6). En aquellos partos que acabaron en cesárea se observó una menor tasa de cambio en el PS-ADP, la DCP y la DCE.

5.2.2 Discusión

La integración de ecografía transabdominal y transperineal en la monitorización del parto supone un avance frente al enfoque clásico basado en exploración abdominal y tacto vaginal. Nuestro estudio confirma su factibilidad en inducciones a término y muestra que reduce de forma significativa el dolor percibido, hallazgo coherente con series previas que destacan la incomodidad de la exploración vaginal como una de las principales preocupaciones de las gestantes.

El concepto de sonopartograma, propuesto en 2014, busca objetivar la dinámica del parto y superar la baja reproducibilidad interobservador del partograma clásico.[66] Hasta donde sabemos, este es el primer intento de integrar completamente la ecografía para el seguimiento del trabajo de parto y reemplazar algunos tactos vaginales con una evaluación ecográfica. Revisiones como la de Usman et al. han enfatizado su potencial predictivo para el tipo y la duración del parto, así como para la identificación precoz de partos con riesgo de instrumentación o cesárea. Nuestros hallazgos, que evidencian una menor tasa de cambio en PS-ADP, DCP y DCE en los partos terminados en cesárea, se alinean con trabajos que exploran su valor pronóstico y apoyan el desarrollo de modelos multivariable que integren factores maternos, datos clínicos y mediciones ecográficas.

Existe falta de consenso en la literatura sobre qué parámetro ecográfico intraparto es el más útil para monitorizar el progreso del trabajo de parto. En nuestro estudio, la posición de la columna, el PS-ADP-ps a y la HPD se registraron correctamente en la mayoría de las ecografías. El menor número de mediciones de DCE podría explicarse por la dificultad de visualización del cérvix una vez que hay ≥8 cm de dilatación por la interposición de la cabeza, como se ha descrito en estudios previos.[66,89] Además, el la calota fetal también puede hacer sombra sobre cérvix delgado, y la presencia de cáput succedaneum puede dificultar aún más la medición de la DCE. [89] En nuestro estudio, el 56 % de las DCE no registradas se produjeron cuando las participantes tenían una dilatación cervical ≥8 cm. Esto concuerda con los resultados de estudios previos. [25,90]

Entre las fortalezas de este estudio destacan el diseño prospectivo longitudinal y multicéntrico y la obtención seriada de parámetros ecográficos clave, con baja variabilidad interecografista documentada en la literatura. Como limitaciones, el tamaño muestral y la inclusión exclusiva de gestantes sometidas a inducción podrían limitar la generalización a partos espontáneos, un aspecto que otros grupos también han señalado como paso necesario para validar el sonopartograma en poblaciones diversas.

Pese a lo alentador de estos resultados, se requieren más estudios para evaluar el desarrollo e implementación de un sonopartograma, con el objetivo de mejorar la gestión del trabajo de parto, la experiencia de la paciente y los resultados del parto.

5.3 Estudio 3: *"Reproducibility of Breech Progression Angle: Standardization of Transperineal Measurements and Development of Image-Based Checklist for Quality Control"*

5.3.1 Resumen

El objetivo fue evaluar la reproducibilidad en la medición del ángulo de progresión de la nalga antes y después de la aplicación de una lista de comprobación para estandarizar su medición. Este ángulo que hace referencia a la relación que existe entre nalga (o pie) fetal y la pelvis materna, podría ser un parámetro importante para valorar el grado de encajamiento de la nalga en casos de parto de nalgas o previo a realizar una maniobra de versión cefálica externa.
Este es un estudio multicéntrico observacional en el que se analizaron dieciocho volúmenes tridimensionales (3D) de ecografía transperineal de gestantes entre de 36 y 40 semanas de gestación con un feto único en presentación de nalgas a ocho operadores de cuatro maternidades distintas en España e Italia. Todos los operadores midieron el ángulo de progresión de la nalga utilizando un programa informático de procesamiento de volúmenes ecográficos 3D y se evaluó la reproducibilidad interobservador utilizando el CCI. Después de una reunión con todos los operadores para revisar todas las mediciones y de la identificación de causas de discordancia, se desarrolló de forma colaborativa una lista de comprobación de características de la imagen para la correcta medición del ángulo de progresión de la nalga. Esta lista consistía en cinco puntos: (1) obtención de plano medio sagital, evitando la sombra posterior de la rama púbica; (2) visualización de la sínfisis púbica completa, en "forma de almendra"; (3) trazar una primera línea a lo largo del eje longitudinal de la sínfisis, dividiéndola en dos partes iguales; (4) que esta línea se extendiera hasta el borde

inferior del hueso púbico; y (5) trazar una segunda línea desde este último punto, que discurriera tangencialmente hasta la parte fetal más baja reconocible (nalga o pie). Las mediciones del ángulo de progresión de la nalga se repitieron utilizando esta lista de comprobación y se reevaluó la reproducibilidad.
Cuando los ocho operadores analizaron los dieciocho volúmenes inicialmente lograron una reproducibilidad moderada (CCI: 0,70; IC al 95 %: 0,48 a 0,86). Tras desarrollar la escala de verificación descrita previamente, se reevaluaron los mismos dieciocho volúmenes utilizándola, y se observó que mejoró considerablemente la reproducibilidad (CCI: 0,81; IC del 95 %: 0,66 a 0,92).

5.3.2 Discusión

Este estudio demuestra que la medición del ángulo de progresión de la nalga es reproducible cuando se siguen criterios estandarizados. En la primera ronda, únicamente tras revisar críticamente el artículo original de Youssef et al., pero sin entrenamiento previo, la reproducibilidad fue moderada (CCI 0,70), pero mejoró de forma notable (CCI 0,81) tras implementar una lista de comprobación consensuada, reforzando la importancia de una metodología uniforme en la introducción de nuevos parámetros ecográficos. Cabe destacar que, en la primera ronda, la concordancia tendió a ser mayor entre los operadores del mismo centro a pesar de realizar la medición a ciegas uno del otro, probablemente debido a interpretaciones compartidas y discusión informal de la metodología original, algo que ya ha sido discutido en otros estudios.[91]

Nuestros hallazgos se sitúan en la misma línea que el estudio de Youssef et al., que describió una buena reproducibilidad (CCI 0,83) pero en un contexto más restringido, con solo dos operadores de un único centro.[31] Al incorporar ocho operadores de cuatro instituciones en dos países, nuestro trabajo refleja mejor la variabilidad del entorno clínico real. Coincidiendo con otros estudios de ecografía intraparto, observamos una concordancia más alta entre operadores del mismo centro, lo que sugiere interpretaciones compartidas aun cuando las mediciones se realizaron a ciegas.

La experiencia del operador es un factor reconocido. Duckelman et al. demostraron que la formación estandarizada puede mitigar el efecto de la experiencia, al no encontrar diferencias significativas en la reproducibilidad del ADP entre obstetras experimentados, fellows y matronas sin experiencia previa.[27] De modo similar, Sainz et al. describieron variabilidad interobservador incluso en operadores expertos, lo que respalda la necesidad de protocolos precisos.[91] La mejora observada en nuestro estudio tras la introducción de la lista de comprobación confirma este punto.

En el ámbito de la presentación de nalgas, se han descrito otros parámetros como el signo IPUBES, propuesto por Jennewein et al., que relaciona el encajamiento de la nalga con menor tasa de cesáreas, pero basado en una interpretación cualitativa y, por tanto, con menor fiabilidad.[92] Asimismo, se han explorado predictores del éxito de la versión cefálica externa, como el volumen de líquido amniótico o el "saco previo", que han mostrado valor pronóstico en modelos multivariables, aunque con limitaciones de reproducibilidad y escasa implementación rutinaria.[93] Frente a estos métodos, el BPA ofrece una medición cuantitativa objetiva, que puede integrarse en protocolos clínicos con mayor consistencia interobservador.

Como principales fortalezas, destaca el diseño multicéntrico e internacional, la participación de ocho obstetras de cuatro centros y la revisión de los mismos volúmenes por todos los operadores, eliminando la variabilidad en la adquisición de imágenes y focalizando el análisis en la interpretación. Entre las limitaciones, las mediciones se realizaron offline a partir de volúmenes obtenidos por un único operador experto, lo que pudo favorecer la calidad de las imágenes; sin embargo, estudios previos muestran que la precisión alcanzable en tiempo real es comparable cuando se dispone de criterios claros y formación adecuada.[94]

Nuestros hallazgos refuerzan la importancia clínica de promover una evaluación ecográfica estandarizada y objetiva durante el parto, no solo para la medición del ángulo de progresión de la nalga, sino también para reducir la variabilidad de otros parámetros. Tras los resultados de este estudio, se debe evaluar el papel que el ángulo de progresión de la nalga puede tener en la predicción de los resultados del parto y la optimización del manejo del parto de nalgas.

5.4 Estudio 4: *“Biparietal diameter for first-trimester pregnancy dating: multicenter cohort study”*

5.4.1 Resumen

El objetivo de este estudio fue evaluar la precisión de la medición del DBP en comparación con la medición del CRL para la datación del embarazo a las 11-13 semanas de gestación. Para ello se diseñó un estudio de cohortes retrospectivo multicéntrico realizado en cinco maternidades de España, Reino Unido, Bélgica y Bulgaria entre enero de 2011 y diciembre de 2019. Se incluyeron todas las mujeres con feto único viable sin malformaciones que se sometieron a una ecografía de rutina entre las 11+0 y 13+6 semanas y que tuvieran realizada medición del CRL y del DBP, así como un registro completo del embarazo y parto. Mediante una regresión lineal simple se desarrolló una fórmula para la datación de la gestación basada en el DBP, utilizando datos de embarazos concebidos mediante fecundación in vitro (FIV).

Esta fórmula fue validada interna y externamente, y comparada con las fórmulas más utilizadas (la de Robinson basada en el CRL y la de Kustermann basada en el DBP) mediante la distancia euclídea, el error absoluto relativo y el error cuadrático medio. También estudiamos la tasa de inducción del parto en embarazos prolongados según la datación mediante cada una de las fórmulas.

Un total de 49 492 mujeres fueron incluidas en el estudio, de las cuales 47 223 (95,4%) tuvieron un embarazo espontáneo y 2 269 (4,6%) se obtuvo mediante FIV.

En la validación interna utilizando datos de embarazos por FIV, nuestra fórmula nueva no mostró diferencias significativas en comparación con la edad gestacional real calculada utilizando la fecha de concepción, con una diferencia de medias de 0,0006 (IC del 95%, -0,09 a 0,09) días. Por el contrario, la diferencia de medias de la fórmula basada en el BPD de Kustermann fue de -0,31 (IC del 95%, -0,46 a -0,17) días y, de basada en CRL de Robinson fue de -1,78 (IC del 95%, -1,88 a -1,68) días.

En la validación externa, utilizando datos de los embarazos espontáneos datados mediante la fórmula de Robinson como referencia de edad gestacional "real", tanto nuestra fórmula como la fórmula de Kustermann subestimaron de la edad gestacional, con diferencia de medias medias significativa de -1,25 (IC del 95 %, -1,28 a -1,22) días y -0,96 (IC del 95 %, -0,98 a -0,93) días, respectivamente. Las mayores diferencias en comparación con la datación por fórmula de Robinson se observaron entre las 11+0 y las 12+0 semanas. Datar el embarazo mediante la fórmula de Robinson indicaba que un 8,1 % de los embarazos requerían inducción de parto tras las 41+3 semanas, en comparación con el 6,8 % (P < 0,001) y el 7,0 % (P < 0,001) al aplicar nuestra fórmula y la fórmula de Kustermann, respectivamente.

5.4.2 Discusión

Este estudio, el mayor hasta la fecha que evalúa la datación gestacional basada en el DBP, confirma que la medición del DBP en la ecografía de las 11–13 semanas, especialmente a partir de la semana 12, ofrece una precisión al menos comparable a la obtenida con la obtenida con el CRL, pues la fecha probable de parto estimada por DBP o CRL difirió de media menos de un día, y una mejor concordancia con la edad gestacional real calculada a partir de embarazos por FIV. Además, la utilización de fórmulas basadas en DBP no supuso un incremento de la tasa de inducción por gestación prolongada, lo que refuerza su seguridad clínica.

Estos resultados se alinean con estudios previos de menor tamaño. Chalouhi et al. y Wu et al. demostraron que las mediciones de DBP y CRL predicen con gran precisión la fecha probable de parto, incluso con menor desviación estándar para el DBP.[85,95] Knight et al. y Sladkevicius et al. encontraron una sistemática sobreestimación de la edad gestacional con fórmulas basadas en CRL y menor error aleatorio con DBP, respaldando su uso preferente.[96,97] Nuestra cohorte multicéntrica de casi 50 000 gestaciones amplía esta evidencia al permitir una validación interna y externa rigurosa en distintos países y poblaciones.

La validación externa es esencial para trasladar un modelo a la práctica clínica.[98] En nuestro trabajo, tanto la nueva fórmula como la de Kustermann subestimaron discretamente la edad gestacional en comparación con Robinson, sobre todo entre las semanas 11+0 y 12+0, hallazgo que podría reflejar diferencias metodológicas o de población, tal como han señalado revisiones recientes. Sin embargo, la ausencia de incremento en las inducciones por gestación prolongada confirma la robustez de la datación por DBP en escenarios clínicos reales.

Entre las principales fortalezas figuran el gran tamaño muestral, la inclusión de un número elevado de embarazos por FIV con fecha de concepción conocida y la validación en diversos contextos geográficos. Como limitaciones, el carácter retrospectivo impidió analizar la reproducibilidad intra e interobservador o la influencia de la experiencia del operador, y el DBP, al no ser método estándar, pudo medirse con menor rigor que el

CRL, lo que tendería a infraestimar su precisión. Además, como ocurre en todo estudio de validación, cada población puede requerir ajustes específicos una vez conocidas sus características.[99]

En términos de práctica clínica, la medición del DBP es una técnica sencilla y de rápida ejecución, que se basa en referencias anatómicas fácilmente identificables y no requiere equipos de alta gama ni amplia experiencia ecográfica. Por su accesibilidad, puede ser especialmente valiosa en entornos con recursos limitados, reduciendo el riesgo de errores en la datación. Además, resulta útil en situaciones específicas, como la persistencia de una posición fetal inadecuada al final de la semana 13, en las que permite acortar el tiempo de exploración y mejorar la eficiencia, ya sea aplicando la nueva fórmula o la de Kustermann. A la luz de estos resultados, su integración progresiva en protocolos de datación gestacional y su evaluación en diferentes sistemas sanitarios se perfilan como pasos clave para su adopción rutinaria y para ampliar su potencial de impacto clínico en el futuro.

CONCLUSIONES

6 CONCLUSIONES

6.1 Estudio 1: *“Level of agreement between midwives and obstetricians performing ultrasound examination during labor”*

Tras una formación teórica y práctica adecuada, las matronas sin experiencia previa en ecografía pueden evaluar de manera eficaz la posición de la cabeza fetal y la progresión del parto mediante ecografía intraparto. La concordancia con obstetras con mayor experiencia fue buena o muy buena, lo que respalda la viabilidad de incorporar esta técnica en su práctica asistencial.

6.2 Estudio 2: *“Implementation of sonopartogram: multicenter feasibility study”*

La monitorización del trabajo de parto mediante ecografía intraparto transabdominal y transperineal es factible y se asocia a una menor percepción de dolor en comparación con el tacto vaginal. Nuestros resultados sugieren que parte de las exploraciones vaginales rutinarias podrían sustituirse por evaluación ecográfica, avanzando hacia un “sonopartograma” más objetivo y reproducible.

6.3 Estudio 3: *“Reproducibility of Breech Progression Angle: Standardization of Transperineal Measurements and Development of Image-Based Checklist for Quality Control”*

El ángulo de progresión de la nalga es un parámetro ecográfico objetivo y reproducible cuando se mide con criterios estandarizados. La implantación de una lista de comprobación de calidad mejora de forma significativa la concordancia interobservador, facilitando su integración en programas de control de calidad y su uso clínico en diferentes contextos como la predicción de resultados en la versión cefálica externa y el parto vaginal de nalgas.

6.4 Estudio 4: *"Biparietal diameter for first-trimester pregnancy dating: multicenter cohort study"*

La datación gestacional basada en el diámetro biparietal fetal entre las semanas 11+0 y 13+6 es una alternativa fiable a la medición del CRL, con una diferencia media inferior a un día en relación a la datación por CRL, y sin aumento de inducciones por gestación prolongada. Su sencillez técnica y accesibilidad la hacen especialmente útil en contextos con recursos limitados o en situaciones en las que la medición del CRL es difícil, como ocurre al final de la semana 13, lo que podría potencialmente acortar el tiempo de exploración y mejorar la eficiencia clínica.

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