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The Exploratory Role of AI-Assisted Modelling in the Assessment of Labour Progress: The Value of Ultrasound Parameters Compared to Clinical Evaluation

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Abstract: *This study analysed the potential of intrapartum ultrasound, enhanced by artificial intelligence (AI)-based interpretation, to optimise labour progress evaluation compared with standard clinical examination.*
Methods: *Two prospectively collected databases from Cuza Voda Clinical Hospital of Obstetrics and Gynecology were examined: one in the birth room (Eco in Birth Room, 2023-2024) and one during labour (Eco during Labour, 2021-2022). Ultrasound characteristics, namely the Head–Perineum Distance (HPD, cm), the Angle of Progression (AoP, °), the Head–Symphysis Distance (HSD, cm), and foetal station (clinically assessed) were retrieved and compared with clinical outcomes, particularly the mode of delivery (vaginal or caesarean). Data were analysed using R 4.4.2 using the packages tidyverse, readxl, janitor, and stats, logistic regression models were fitted with stats::glm(). No ultrasound images or comprehensive imaging datasets were utilized, and no segmentation algorithms were employed, as the model depended solely on manually acquired quantitative measurements. Predictive performance was measured using simple classification accuracy, which is based on the fraction of properly predicted delivery modes in the same dataset (no cross-validation). This accuracy metric is exploratory and meant to demonstrate the potential utility of AI-assisted quantitative modeling.The selection of logistic regression ensured enhanced transparency and clinical interpretability, thereby facilitating reproducibility and prospective applicability at the bedside.*
Results: *The Eco during labour dataset ($n = 124$) showed a mean HPD of 3.65 ± 1.29 and a mean AoP of $124.35 \pm 16.18°$. The Eco in Birth Room ($n = 10$) showed a mean HPD of 4.33 ± 1.48 and a mean AoP of $112.70 \pm 19.68°$. Logistic regression determined that increasing HPD was related with a significantly reduced probability of vaginal delivery and a higher probability of caesarean section ($\beta = -4.71$, $SE = 1.17$, $p < 0.001$). The AoP had a significant inverse correlation with caesarean delivery ($\beta = -0.25$, $SE = 0.10$, $p < 0.001$). Each one-degree increase in AoP was related with a 23% reduction in the odds of caesarean section (OR = 0.77, 95% CI 0.66-1.00), demonstrating its importance as a reliable indicator of labour progression.*
Conclusion: *Ultrasound-derived metrics, notably HPD, and AoP provide objective, quantitative indicators of foetal descent that surpass traditional clinical examination. AI-assisted ultrasound analysis may provide continuous, reproducible monitoring of labour dynamics, helping to individualised obstetric care.*

Keywords: *artificial intelligence; intrapartum ultrasound; labour progress; head-perineum distance; angle of progression; vaginal delivery; caesarean section.*

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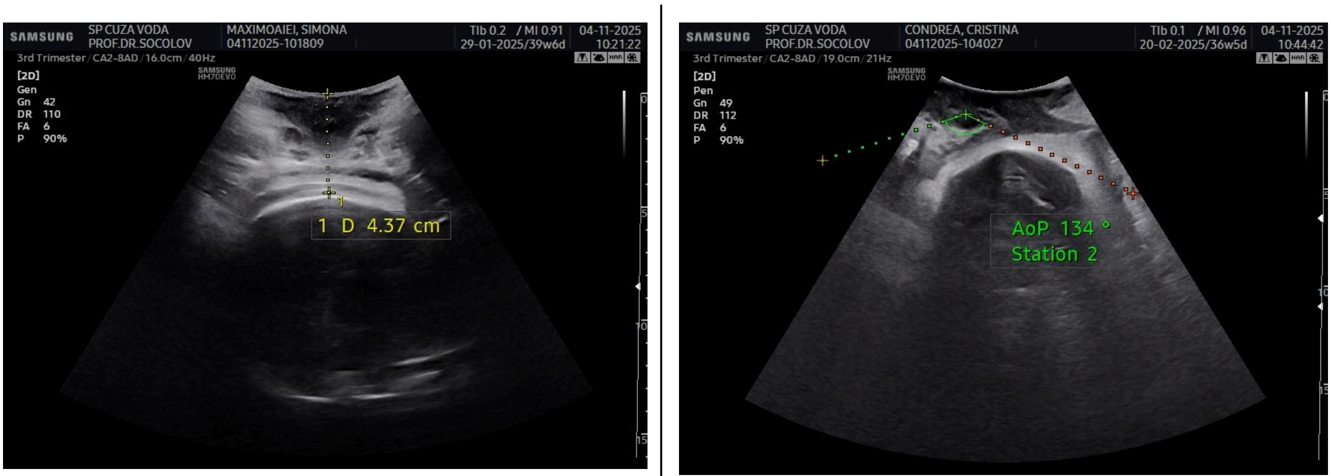
1. Introduction

Accurate assessment of labour progress is essential for making safe and timely obstetric decisions. Traditionally, labour progress has been assessed through digital vaginal examination to detect cervical dilatation, effacement, and foetal head position. However, these assessments are fundamentally subjective, differ between examiners, and may cause discomfort or increase the risk of infection for the mother (Coates et al., 2019). The partograph, endorsed by the WHO, is a labour monitoring tool intended to aid health professionals in tracking labour progress and ensuring timely interventions (World Health Organization, 2014). Despite over 40 years of use, it has faced criticism for not effectively preventing deaths from obstructed labour, as evidence of its effectiveness remains inconclusive (Lavender, Hart, & Smyth, 2013). Methodological limitations in trials and inconsistent usage raise concerns about its practical application (Ollerhead & Osrin, 2014). Understanding the barriers to its use is essential for improving its clinical effectiveness and ensuring it meets its intended purpose (Bedwell et al., 2017).

Modern intrapartum ultrasound is characterised as a real-time, imaging-based assessment of the foetal head position, station, and descent during labour, usually performed transabdominally or transperineally (Fouché et al., 2012). The Angle of Progression (AoP) indicates the angle between the pubic symphysis and the leading portion of the foetal skull, demonstrating a strong correlation with the probability of vaginal delivery (Ghi et al., 2018; Youssef et al., 2021); the Head–Perineum Distance (HPD) (see Figure 1) is an external perineal measurement linked to the engagement and descent of the foetal head (Eggebø et al., 2008); and the Head–Symphysis Distance evaluates the proximity of the foetal head to the maternal pubic symphysis, serving as an additional indicator of foetal station (Barber et al., 2010; Kahrs & Eggebø, 2021). Intrapartum ultrasound, despite its benefits, has limitations such as reliance on operator expertise, variability in probe placement, diminished acoustic windows in instances of maternal obesity, and restricted availability in resource-limited environments (Barber et al., 2010; Fouché et al., 2012).



A. *B.*

Figure 1. Ultrasounds images from HM70 EVO ultrasound scanner illustrating key intrapartum parameters: A) Head-Perineum Distance (HPD, cm),assessed in the mid-sagittal transperineal plane as the minimal distance between the outer foetal cranium and the inferior margin of the maternal pubic symphysis. B) Angle of Progression (AoP, °), evaluated in the same plane by measuring the angle between the longitudinal axis of the pubic symphysis and a tangent made along the foetal cranium.

The use of artificial intelligence (AI) in ultrasound interpretation represents a significant advancement. Artificial intelligence is increasingly being used in obstetric imaging, with applications ranging from automated foetal biometry and segmentation to machine-learning models trained to detect foetal head position, station, and descent. Contemporary AI systems, particularly deep-learning-based image classifiers and convolutional neural networks, have shown promising results in detecting key anatomical landmarks, assisting clinicians with real-time image interpretation, and reducing measurement subjectivity (Coronado-Gutiérrez et al., 2023; Patel et al., 2024).

Importantly, these methods have been demonstrated to significantly reduce both inter-observer and intra-observer variability, which has long been a drawback in traditional intrapartum ultrasound assessment, enhancing clinical measurements' repeatability and reliability. Machine learning algorithms can segment, measure, and analyse real-time ultrasound data, reducing operator variability and enabling dynamic tracking of labour progress (Gilboa & Perlman, 2021; Youssef et al., 2021). This context underscores why integrating AI-enhanced interpretation into intrapartum ultrasound is not only timely, but also crucial for improving objectivity in labour monitoring.

Despite the growing interest in artificial intelligence (AI) within obstetric imaging, its use in intrapartum care is still limited, with most research centred on antenatal applications such as anomaly detection and foetal biometry (Bellussi et al., 2017; Ramphul, Kennelly, & Murphy, 2012; Sherer, 2007). Few studies have assessed AI's role in interpreting intrapartum ultrasound and directly comparing it to traditional methods, which are subjective and vary between observers (Lucas & Elton, 2016; Ghi et al., 2018). Furthermore, current literature lacks evidence on the real-time reliability of AI measurements during labour, often relying on retrospective datasets (Ghi et al., 2018; Gilboa & Perlman, 2021). Key questions persist regarding AI's accuracy in dynamic labour conditions and its ability to reduce observer variability (Kahrs & Eggebø, 2021). Addressing these issues is essential for evaluating the safe integration of AI in labour management and enhancing decision-making in clinical practice.

This study aimed to investigate the integration of quantitative intrapartum ultrasonography parameters into an interpretable, AI-assisted analytical framework to enhance clinical evaluation of labour progression and delivery method. This approach prioritises transparent statistical modelling as an initial step toward future AI integration, rather than constructing automated image-based or deep-learning models.

2. Methods

Two clinical databases from *Cuza Voda Clinical Hospital of Obstetrics and Gynecology* were analysed. Ultrasound examinations were performed using *a Samsung Medison HM70 EVO ultrasound system (Samsung Medison Co., Ltd., South Korea)* equipped with *CA2-8AD Convex Array Transducer.* All examinations were conducted by an Obstetrics and Gynecology doctor, and the parameters of the birth mechanism were evaluated using the Labour-Assist software. Pregnant women aged 18 years or older who entered labour at a gestational age of ≥24 weeks or at term were eligible for inclusion in the study. All participants provided written informed consent, and only women without contraindications to vaginal delivery were enrolled. Labour assessment was performed after the onset of labour, at the time of entry into the active phase. The evaluation of labour progression was carried out in parallel using conventional clinical methods—vaginal examination (EVV and EVD) combined with abdominal palpation—and intrapartum ultrasound. Assessments were repeated at regular intervals of every 1–2 hours, according to the study protocol. At the completion of labour, maternal and neonatal outcomes were recorded. Maternal outcomes included the mode of delivery (vaginal or caesarean section), the presence of soft tissue injuries such as perineal, vaginal, or cervical ruptures, and the occurrence of postpartum haemorrhage. Neonatal outcomes comprised sex, birth weight, Apgar scores, evidence of intrapartum asphyxia, the presence of meconium-stained amniotic fluid, need for admission to the neonatal intensive care unit, requirements for respiratory support (free-flow oxygen, continuous positive airway pressure, or endotracheal intubation), duration of hospitalisation, and the occurrence of cerebral haemorrhage. The first database, *Eco in Birth Room*, contained ultrasound measures and obstetric results for ten individuals collected between 2023 and 2024. The second database, *Eco during Labour*, included serial ultrasonographic examinations and delivery outcomes for 124 individuals collected between 2021 and 2022. In both datasets, the principal variables identified for analysis included the

Head–Perineum Distance (HPD, cm), the Angle of Progression (AoP, °), the Head–Symphysis Distance (HSD, cm), foetal station (clinically assessed), and the mode of delivery (vaginal or caesarean section). The data were analysed using *R* version 4.4.2 using the packages *tidyverse, readxl, janitor*, and *stats*, logistic regression models were fitted with *stats::glm()*. No automated image analysis or machine-learning training was carried out; instead, an interpretable, AI-assisted analytical framework based on multivariable logistic regression was employed. Predictive performance was assessed using simple classification accuracy, which is based on the fraction of properly predicted delivery modes in the same dataset (no cross-validation or external validation). Descriptive statistics (mean ± SD and minimum-maximum values) were calculated. Independent t-tests were used to compare variables between delivery groups, and a logistic regression model was constructed to predict caesarean delivery using HPD, AoP, HSD, and foetal station. Statistical significance was defined as $p < 0.05$.

3. Results

A total of 134 records were analysed across the two datasets: 10 from *Eco in* Birth Room dataset and 124 from the *Eco during Labour* dataset (Table 1). In the *Eco in Birth Room* dataset, the mean Head–Perineum distance (HPD) was 4.33 ± 1.48 cm, consistent with a more advanced stage of labour in the majority of examinations. The mean Angle of Progression (AoP) was 112.70° ± 19.68°. The average foetal station was −0.20 ± 1.93, signifying considerable variability in foetal descent during the examination. The average Head–Symphysis Distance (HSD) for nine patients was 3.00 ± 1.00 cm. In the *Eco during Labour* dataset, the mean HPD was lower (3.65 ± 1.29 cm) with a larger AoP (124.35° ± 16.18°). The foetal station exhibited restricted dispersion (mean −0.20 ± 0.40), indicating clustering of data around engagement. The average HSD was 2.67 ± 0.96 cm. Most births (78.2%) were vaginal,while 21.8% required caesarean delivery. Caesarean births were more frequently associated with posterior occiput placements and slower foetal descent, which is consistent with previous research (Bellussi et al., 2017; Ghi & Youssef, 2014).

Table 1. Descriptive statistics

Dataset	Variable	N	Mean	SD	Min	Max
Eco in Birth Room	HPD (cm)	10	4.33	1.48	1.61	6.08
	AoP (°)		112.70	19.68	96.00	144.00
	Foetal station		-0.20	1.93	-2.00	3.00
	HSD (cm)	9	3.00	1.00	2.00	4.00
Eco during Labour	HPD (cm)	124	3.65	1.29	1.60	8.00
	AoP (°)		124.35	16.18	90.00	144.00
	Foetal station		-0.20	0.40	-1.00	0.00
	HSD (cm)		2.67	0.96	1.00	4.50

As indicated in Table 2, there were substantial differences between vaginal and caesarean deliveries in all ultrasonography and clinical parameters tested. Women who delivered vaginal had a substantially shorter Head-Perineum Distance (HPD) compared to those who had a caesarean section (3.41 ± 1.29 cm vs 4.49 ± 0.88 cm; t = −5.02, p = 4.8 × 10^{-6}). This study suggests that foetal head descent is more advanced after vaginal deliveries. The vaginal delivery group had a significantly wider Angle of Progression (AoP) (130.72° ± 10.93°) than the caesarean group (101.48° ± 10.17°), indicating a robust correlation between increasing AoP values and successful vaginal birth (t = 12.99, p = 1.09 × 10^{-16}). Foetal station also varies significantly between delivery modalities.

Vaginal deliveries resulted in greater foetal station (mean -0.06 ± 0.24) compared to caesarean deliveries (mean -0.70 ± 0.46; t = 6.92, p = 1.10 x 10^{-7}), indicating deeper engagement of the foetal head during evaluation. The Head-Symphysis Distance (HSD) was substantially shorter in the vaginal birth group compared to the caesarean group (2.33 ± 0.64 cm vs 3.92 ± 0.87 cm; t = −8.83, p = 2.29 × 10^{-10}), indicating its significance as an objective predictor of labour progress. Overall, these findings show that ultrasound-derived parameters of foetal head drop and engagement are highly related to mode of delivery and outperform subjective clinical assessment in discriminating between vaginal and caesarean births. Previous studies (Eggebø et al., 2008; Fouché et al., 2012; Ghi et al., 2018) have shown that AoP can accurately quantify head descent and predict delivery outcomes.

Table 2. Comparison by mode of delivery

Variable	Delivery	N	Mean	SD	t	p
HPD (cm)	Vaginal	97	3.41	1.29	−5.02	4.8×10^{-6}
	Caesarean	27	4.49	0.88		
AoP (°)	Vaginal	97	130.72	10.93	12.99	1.09×10^{-16}
	Caesarean	27	101.48	10.17		
Foetal station	Vaginal	97	−0.06	0.24	6.92	1.10×10^{-7}
	Caesarean	27	−0.70	0.46		
HSD (cm)	Vaginal	97	2.33	0.64	−8.83	2.29×10^{-10}
	Caesarean	27	3.92	0.87		

A logistic regression model (Table 3) was constructed using caesarean delivery (yes/no) as the dependent variable and HPD, AoP, Foetal station, HSD as predictors. HPD was a significant independent predictor of delivery method. Increasing HPD was related with a significantly reduced probability of vaginal delivery and a higher probability of caesarean section (β = -4.71, SE = 1.17, p < 0.001). The odds ratio showed a nearly-complete separation between delivery modes (OR = 0.00, 95% CI 0.00-0.09), demonstrating HPD's significant discriminatory potential in this group. The AoP had a significant inverse correlation with caesarean delivery (β = -0.25, SE = 0.10, p < 0.001). Each one-degree increase in AoP was related with a 23% reduction in the odds of caesarean section (OR = 0.77, 95% CI 0.66-1.00), demonstrating its importance as a reliable indicator of labour progression. Higher foetal station values were found to be a significant predictor of caesarean delivery (β = 2.90, SE = 1.64, p = 0.01). However, the broad confidence interval (OR = 18.38, 95% CI 1.00-620.02) demonstrates significant variability and suggests that this estimate has poor precision when compared to ultrasound-based assessments. HSD had an independent association with caesarean delivery (β = 3.75, SE = 2.44, p < 0.001). Larger HSD values were associated with a significantly increased risk of caesarean section (OR = 42.68), but the very broad confidence interval (95% CI 13.43-192,937.89) suggests model instability, most likely due to collinearity with other descent factors and sample size limits. Overall, the model shows that ultrasound-derived measures of foetal head descent—particularly head–perineum distance (HPD) and angle of progression (AoP)—demonstrate a stronger independent association with mode of delivery than clinically assessed foetal station.

Table 3. Logistic regression model

Predictor	β	SE	*p*	OR	95% CI for OR
HPD (cm)	−4.71	1.17	0.00	0.00	0.00– 0.09
AoP (°)	−0.25	0.10	0.00	0.77	0.66 – 1.00
Foetal station	2.90	1.64	0.01	18.38	1.00 – 620.02
HSD (cm)	3.75	2.44	0.00	42.68	13.43– 192,937.89

These correlations support the physiological relevance of the ultrasound measures. As cervical dilatation progresses, AoP increases due to head descent and flexion, while HPD shortens as the foetal head approaches the perineum—findings consistent with Fouché et al. (2012) and Simon, Arthuis, and Perrotin (2014).

4. Discussion

The present study highlights the exploratory potential of AI-assisted analytical methodologies for improving the interpretation of intrapartum ultrasonographic characteristics as predictors of labour outcomes. In this context, artificial intelligence was used as a conceptual and interpretative framework to help the future development of prediction models based on quantitative ultrasound measurements, rather than as an automated image-analysis or machine-learning system.

This approach demonstrates how AI-assisted modelling can supplement clinical assessment by increasing the objectivity and repeatability of intrapartum ultrasonography interpretation, particularly in assessing foetal head descent and engagement.

Our findings align with previous intrapartum ultrasound studies that have identified AoP and HPD as reliable indicators of foetal descent and engagement (Fouché et al., 2012; Ghi et al., 2018). Eggebø et al. (2008) reported that a broader AoP evaluated by transabdominal ultrasound predicts a vaginal birth, especially after 37 weeks in cases of prelabour rupture of membranes. Similarly, Simon, Arthuis, and Perrotin (2014) and Bellussi et al. (2017) demonstrated that intrapartum ultrasound is more accurate in detecting malpositions and cephalic malpresentations than vaginal examination. The research supports Barber et al. (2010) and Kahrs and Eggebø's (2021) findings that ultrasound is more reliable than clinical examinations for assessing head station. Furthermore, Molina and Nicolaides (2010) and Sherer (2007) argued for systematic sonographic evaluation in labour, citing its ability to reliably quantify foetal descent in real time, hence reducing interobserver variability, a weakness highlighted in conventional digital examination.

These results indicate that HPD was a significant independent predictor of delivery method. Increasing HPD was related with a significantly reduced probability of vaginal delivery and a higher probability of caesarean section. The AoP had a significant inverse correlation with caesarean delivery. This underscores the importance of interpreting AoP in conjunction with other parameters rather than in isolation. HSD had an independent association with caesarean delivery. Ghi and Youssef (2014) showed that the occiput position, when paired with AoP, could predict labour progress. The moderate association between AoP and cervical dilatation observed in our cohort lends support to Fouché et al. (2012)'s physiological model, in which AoP expansion corresponds to foetal descent and cervical effacement. Furthermore, ultrasonography has applications beyond foetal head station evaluation. Fukuda et al. (2016) established its role in assessing lower uterine segment thickness, adding an additional layer of safety to labour management, particularly in women with previous caesarean sections. Such objective imaging data, when paired with AI-based predictive algorithms, may help prevent uterine rupture by detecting abnormal distension patterns early on.

The fundamental innovation of this study lies in its exploratory use of AI to model labour outcomes based on ultrasound-derived metrics. AI's ability to analyse large, multidimensional datasets may also decrease the subjectivity inherent in obstetric decision-making. Ghi et al. (2018) and Gimovsky (2021) both advocated for structured , algorithm-assisted ultrasound interpretation to improve objectivity when diagnosing malpositions and forecasting delivery outcomes. In this context, AI augments rather than replaces clinical expertise, offering ongoing, data-driven insights that can be used to inform more precise interventions.

The current findings support routine use of ultrasonography during active labour, consistent with ISUOG Practice Guidelines (Ghi et al., 2018) and suggestions from Vintzileos, Chavez, and Kinzler (2010) and Ramphul, Kennelly, and Murphy (2012). Routine sonographic examination could standardise the measurement of foetal head descent and position, increasing both safety and confidence in intrapartum decision-making. Barber et al. (2010) underlined that using ultrasound in the labour ward not only improves diagnostic accuracy but also promotes communication across obstetric teams by providing a shared visual reference for complex cases. Furthermore, studies by Arzola et al. (2015) and Lucas and Elton (2016) extended this benefit to anaesthetic management, where ultrasound-guided epidural placement significantly increased success rates compared with traditional palpation methods, demonstrating ultrasound's cross-disciplinary value in peripartum care. From a patient-centred viewpoint, Coates et al. (2019) found that women undergoing induction of labour frequently experience uncertainty and anxiety owing to the unpredictability of progress. Objective sonographic data, combined with AI-powered predictive analytics, may improve counselling and shared decision-making, thereby empowering women during the birthing process.

Several large-scale studies have altered our understanding of induction timing and caesarean risk. Wennerholm et al. (2019) and Keulen et al. (2018), for example, found that induction at 41 weeks leads to improved neonatal outcomes while without raising caesarean rates. Similarly, Mishanina et al. (2014) and Magro-Malosso et al. (2017) concluded that well managed induction does not inherently increase surgical delivery risk. When viewed in the context of these findings, our study highlights the ability of objective, AI-supported ultrasound parameters to refine the timing and decision thresholds for interventions, thereby promoting real-time obstetric precision.

Several limitations to this study should be addressed. First, the Eco in the Birth Room dataset contains a small number of cases, limiting statistical power and the robustness of comparisons with this cohort. It is a pilot study and requires generalisation. Second, the analyses did not account for potentially significant clinical confounders such as parity, body mass index, epidural analgesia, or labour induction procedures, all of which may have an independent impact on labour progress and delivery. Third, data were collected at a single centre, which may limit the findings' applicability to other clinical settings with diverse patient groups or intrapartum care methods. Finally, while this work investigates the potential relevance of artificial intelligence in facilitating intrapartum assessment, the AI component remains exploratory. These findings should thus be regarded as hypothesis-generating, necessitating prospective, multicentric validation.

Future research should centre on prospective multicentre trials with greater datasets and real-time AI integration directly into ultrasound devices. Furthermore, extending the model to incorporate maternal pelvic characteristics, fetal biometric parameters, and intrapartum labour dynamics, as proposed by Youssef et al. (2021), may yield a more comprehensive predictive framework with the capacity to adapt dynamically to labour progression.

The combination of AI and intrapartum ultrasonography marks a shift in obstetric practice from qualitative judgement to quantitative prediction. As Molina and Nicolaides (2010) observed, ultrasonography in labour turns obstetrics into a measurable science. Clinicians can establish a hybrid decision support model by combining sonographic precision and AI interpretability-objective yet tailored, data-driven yet empathic. This transition is consistent with the global trend towards evidence-based, patient-centred, and technologically enabled obstetrics, providing a practical method to reduce unnecessary procedures and improve maternal–foetaloutcomes.

The study reveals that ultrasound metrics such as Head–Perineum Distance (HPD) and Angle of Progression (AoP) offer objective indicators of foetal descent, surpassing traditional examination reliability. HPD increases the likelihood of caesarean delivery, while each one-degree rise in AoP decreases caesarean odds by 23%, emphasizing its role in labour progression monitoring. Integrating AI-assisted ultrasound could enhance labour management through continuous, data-driven assessments, facilitating tailored interventions and improving maternal and neonatal outcomes by minimising subjective variability in decisions.

5. Conclusions

These findings suggest the prospective function of AI-assisted analysis of intrapartum ultrasonography parameters as an auxiliary decision-support instrument. HPD and AoP are reliable, quantifiable indicators of foetal descent that outperform traditional vaginal examination. This study examined the potential role of artificial intelligence (AI) in interpreting intrapartum ultrasound metrics. AI served as a conceptual framework to illustrate future AI-assisted analysis for assessing foetal descent. The findings indicate that ultrasound-derived HPD and AoP are reliable indicators, offering greater objectivity and precision compared to traditional vaginal examinations. These metrics can assist obstetric teams in identifying patients at risk for caesarean delivery and facilitating tailored interventions. Future research should involve multicentre studies with real-time AI analysis to validate predictive models and evaluate their effects on maternal and neonatal outcomes. The results highlight the importance of quantitative intrapartum ultrasound metrics as a basis for AI-assisted labour assessment, linking theoretical AI applications with practical obstetric care.

Patients Consent Statement

The participants provided informed consent for the use of their anonymised medical data for educational and research purposes. No medical actions were implemented based on the data obtained, and all care decisions were made by the obstetric care team.

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