INTERDISCIPLINARY DOCTORAL SCHOOL

Faculty of Medicine

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Particularities of pregnancy and the analysis of obstetric risk in adolescents

SUMMARY

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Thessis

CHAPTER 1. INTRODUCTION

Adolescent pregnancy represents a major public health problem on a global scale, with implications for demographics, economics, and healthcare systems. According to data provided by the World Health Organization (WHO), the global prevalence of pregnancy among adolescents (aged 10-19 years) is estimated at 17.9%, indicating that nearly one in five adolescent girls worldwide becomes a mother before reaching full maturity [1,2].

Within the context of the European Union, Romania occupies an unfavorable position, consistently recording one of the highest rates of adolescent births. Statistical data indicate a rate of 39.3 births per 1,000 adolescents (aged 15-19 years) in 2009, a figure substantially higher than the European average 12. Although a downward trend has been observed in the last decade, recent statistics remain problematic. Despite the high prevalence of this phenomenon in Romania, current clinical practice reveals an acute lack of differentiated obstetric management protocols adapted to the specific needs of adolescents. Presently, pregnant adolescents are assessed and monitored using the same clinical criteria and predictive tools as the adult population, an approach that disregards the anatomical and physiological particularities described previously. There are no validated risk stratification instruments dedicated exclusively to this age group within the context of the national healthcare system, which may lead to underestimation of risks or inadequate obstetric interventions. This uniformization of medical practice constitutes a major problem that requires a rigorous scientific approach to optimize maternal-fetal outcomes.

1.1. Justification for the Need for the Present Study

The present study is necessary and timely given the specific geographical and demographic context of Brașov County, an area characterized by a mixed urban-rural profile and by the presence of vulnerable communities with an increased incidence of early pregnancy. Regional particularities necessitate local data for the adaptation of intervention strategies, as models imported from other healthcare systems are not always directly applicable. The study addresses an acute need for knowledge regarding the epidemiological and clinical reality in the central region of the country, providing a factual basis for the development of public health policies at the county and regional levels.

1.2. Anticipated Novelty and Original Contribution

This doctoral thesis represents the first systematic analysis conducted on an extensive cohort of 1,322 adolescent births, monitored over a seven-year period (2018-2024). The sample size and duration of follow-up permit the formulation of valid conclusions. The element of novelty consists in the systematic introduction and evaluation of advanced ultrasound parameters (AoP, CRUI, CCUR) specifically in the adolescent population, thereby establishing reference values that can subsequently be utilized in current clinical practice.

The original contribution of this work is materialized through the development and proposal of the ADOLESRISK score, an obstetric risk stratification instrument designed specifically for adolescents, adapted to local factors such as ethnic background, rural origin, and limited access to prenatal care.

CHAPTER 2. AIM AND OBJECTIVES OF THE RESEARCH

2.1. Foundation of the Objectives Based on the Identified Research Problem

Critical analysis of the literature has revealed the following major problems that justify the necessity of the present study. Advanced ultrasound parameters, such as the angle of progression (AoP), cervical ripening ultrasound index (CRUI), cervico-cephalic ratio (CCUR), fetal-pelvic adaptation index (FPAI), and lower uterine segment thickness (LUST), have demonstrated clinical utility in predicting obstetric outcomes in the adult population, but have not been systematically evaluated in pregnant adolescents. Within the Romanian national context, there is a lack of a validated obstetric risk stratification system that integrates both specific demographic and socio-economic factors (ethnicity, rural origin, limited access to medical services) and clinical and ultrasound parameters, adapted to the realities of the adolescent population in Romania.

2.2. General Aim of the Research

The aim of the present research is to conduct a comprehensive analysis of the obstetric and clinical particularities of adolescent births in Brașov County, with a view to optimizing medical management and developing prevention strategies adapted to this vulnerable population.

2.3. Specific Objectives of the Research

2.3.1. General Objective

To characterize the obstetric, clinical, and social profile of pregnant adolescents in Brașov County and to develop predictive instruments for risk stratification and optimization of clinical management.

2.3.2. Secondary Objectives

Objective 1 consists of the demographic and socio-economic characterization of the pregnant adolescent population in Brașov County, with descriptive analysis of the following variables: maternal age at birth, age at menarche, ethnic background, environment of origin (urban/rural), level of education, and access to prenatal medical services.

Objective 2 aims to identify and analyze specific risk factors associated with adolescent pregnancy and to establish their degree of impact on maternal and neonatal obstetric outcomes, through multivariate statistical analysis methods.

Objective 3 refers to the evaluation of the type and frequency of maternal obstetric complications (preeclampsia, eclampsia, antepartum and postpartum hemorrhage, anemia, urogenital infections) and fetal complications (intrauterine growth restriction, prematurity, acute fetal distress, low birth weight) in the study cohort.

Objective 4 concerns the analysis of the particularities of labor and delivery modes in adolescents, including the duration of labor phases, frequency of dystocia, necessity for labor induction or augmentation, and indications for operative delivery (cesarean section, instrumental vaginal delivery).

Objective 5 seeks to determine the predictive value of advanced ultrasound parameters, specifically the angle of progression (AoP), cervical ripening ultrasound index (CRUI), cervico-cephalic ratio assessment (CCUR), fetal-pelvic adaptation index (FPAI), and lower uterine segment thickness (LUST), in assessing obstetric risk and predicting the mode of delivery in adolescents.

Objective 6 consists of comparing obstetric and neonatal outcomes among different subgroups of adolescents, classified according to ethnic, age, and environmental origin criteria, in order to identify categories at maximum risk and changes in access to care and pregnancy evolution.

Objective 7 aims to evaluate access to prenatal care, taking into account the number of consultations, gestational age at first consultation, prenatal care according to national and international criteria, as well as its impact on the incidence of maternal and fetal complications and on neonatal outcomes.

Objective 8 aims to develop and internally validate the ADOLESRISK score, which integrates demographic, clinical, and ultrasound parameters, as well as to evaluate its diagnostic performance through ROC curve analysis.

Objective 9 consists of developing evidence-based recommendations for clinical management protocols adapted to the particularities of pregnant adolescents and for prevention and intervention strategies at the community and public health levels.

2.4. Research Hypotheses

2.4.1. Main Hypothesis

Pregnant adolescents present specific obstetric particularities and an increased risk for maternal and fetal complications compared to the young adult population (20–24 years), which justifies the necessity for developing and implementing differentiated clinical management protocols adapted to this vulnerable population.

2.4.2. Secondary Hypotheses

Hypothesis 1 posits that socio-economic factors, rural origin, and low educational level significantly influence pregnancy evolution and obstetric outcomes in adolescents. It is anticipated that adolescents of Roma ethnicity and from rural environments present higher rates of obstetric and neonatal complications compared to those of Romanian ethnicity and from urban environments.

Hypothesis 2 posits that very young maternal age (under 15 years) is associated with an increased risk of dystocia, prolonged labor, failure of labor induction, and the need for obstetric interventions (cesarean section, instrumental vaginal delivery), independent of other socio-economic or clinical factors.

Hypothesis 3 affirms that adolescents present a specific profile of obstetric complications, characterized by increased incidence of anemia, hypertensive disorders of pregnancy, and preterm birth compared to the young adult population, reflecting both biological vulnerabilities and socio-economic determinants.

Hypothesis 4 assumes that advanced ultrasound parameters, specifically the angle of progression (AoP), cervical ripening ultrasound index (CRUI), cervico-cephalic ratio (CCUR), fetal-pelvic adaptation index (FPAI), and lower uterine segment thickness (LUST), have superior predictive value compared to classic clinical parameters (including the Bishop Score) in assessing obstetric risk and predicting the mode of delivery in adolescents.

Hypothesis 5 posits that reduced access to prenatal care (fewer than 4 prenatal consultations or absence of consultations in the first trimester) correlates directly with increased incidence of maternal and fetal complications (severe anemia, preeclampsia, preterm birth, low birth weight) and with adverse neonatal outcomes (low Apgar scores, need for admission to Neonatal Intensive Care).

Hypothesis 6 posits that an integrated multifactorial risk score (ADOLESRISK), which combines demographic, socio-economic, clinical, and ultrasound parameters, can stratify the risk of obstetric complications in adolescents, with an area under the ROC curve (AUC) superior to classic evaluation instruments (Bishop Score), anticipating a diagnostic performance of AUC > 0.75.

Structure of the Thesis

The present doctoral thesis is structured into seven main chapters that reflect the entire scientific approach, from theoretical foundation to final conclusions and original contributions.

Chapter 1 - INTRODUCTION places the research topic in the global and national context of adolescent pregnancy, highlighting the prevalence of the phenomenon, obstetric impact, and specific vulnerabilities of this age group. The chapter identifies the research problem, justifies the necessity of the study in Brașov County, and presents the anticipated scientific novelty through the development of predictive instruments adapted to the biological specificity of the pregnant adolescent.

Chapter 2 - AIM AND OBJECTIVES OF THE RESEARCH defines the general aim of the study - analysis of obstetric and clinical characteristics of adolescent births for optimization of medical management - and details the nine specific objectives, such as demographic characterization, identification of risk factors, evaluation of maternal-fetal complications, analysis of labor and delivery, validation of advanced ultrasound parameters, and development of the ADOLESRISK score. The chapter formulates the main hypothesis and six secondary hypotheses of the research.

Chapter 3 - MATERIAL AND METHOD describes the study design (retrospective-prospective cohort over 7 years, 2018-2024), the study population (1,322 adolescents aged 12-16 years), inclusion and exclusion criteria, analyzed variables (demographic, clinical, ultrasound, intrapartum, neonatal), and evaluation instruments (AoP, CRUI, CCUR, FPAI, LUST, CRPI, FHMI, SFUD, ADOLESRISK score). The chapter details the statistical methodology used for data analysis and validation of predictive instruments.

Chapter 4 - CURRENT STATE OF KNOWLEDGE presents a comprehensive analysis of the specialized literature regarding the anatomical and physiological particularities of the pregnant adolescent, obstetric complications documented internationally, classic and modern instruments for predicting labor progression, as well as limitations of current methods in application to the adolescent population.

Chapter 5 - RESULTS AND DISCUSSIONS constitutes the core of the thesis and presents the primary results of the study: demographic and socio-economic characteristics of the cohort, profile of maternal complications (anemia 45.0%, preeclampsia 8.0%, preterm birth 18.0%, IUGR 12.0%), neonatal outcomes (mean birth weight 2,947 ± 512 g, LBW 33.7%, NICU admission 13.8%, perinatal mortality 13.6‰), labor and delivery characteristics (mean duration 11.4 hours, cesarean rate 28.5%), as well as the performance of advanced ultrasound parameters. The chapter analyzes in detail the performance of the CRUI score (AUC 0.88 in training, 0.85 in validation) and the ADOLESRISK score (AUC 0.85 in training, 0.82 in validation), comparing them with classic instruments and data from international literature. The clear superiority of the new instruments over the traditional Bishop score (AUC 0.503) is demonstrated.

Chapter 6 - SYNTHESIS OF RESULTS integrates the main findings of the study, highlighting the epidemiological profile of adolescent pregnancy in Brașov County (73.4% Roma ethnicity, 82.8% rural environment, 38.2% without prenatal consultation), independent risk factors identified through multivariate analysis (absence of prenatal care OR=8.73, birth weight <1,000 g OR=22.15, maternal age <14 years OR=3.24 for severe preeclampsia), and the diagnostic performance of the developed instruments.

Chapter 7 - CONCLUSIONS AND ORIGINAL CONTRIBUTIONS synthesizes the theoretical and practical implications of the research, highlighting the eight major original contributions: development of the CRUI index as the first multidimensional ultrasound score for cervical maturity in adolescents, introduction of the CRPI parameter for evaluation of pouch of Douglas depth, creation of the ADOLESRISK score as the first multifactorial stratification instrument adapted to the Romanian context, validation of the integrated predictive model (AUC 0.908), development of a standardized ultrasound evaluation protocol, identification of the LUST-labor duration correlation (r=-0.998), and detailed characterization of the local epidemiological profile. The chapter proposes future research directions, including multicenter external validation, integration of artificial intelligence, and extension to multiple pregnancies.

CHAPTER 3. RESEARCH METHODOLOGY

3.1. Type and Design of the Study

The present research represents an observational cohort study with a mixed retrospective-prospective design, conducted over a period of 7 consecutive years (January 2018 – December 2024), at the "Dr. I.A. Sbârcea" Clinical Hospital of Obstetrics and Gynecology in Brașov, Romania.

The mixed design was chosen to combine the advantages of an extensive retrospective analysis (access to a large volume of clinical data for general characterization of the population) with those of standardized prospective collection of advanced ultrasound parameters.

3.1.1. Retrospective Component

The retrospective component aimed at identifying and completely characterizing all cases of pregnant adolescents (12–16 years) who gave birth at the "Dr. I.A. Sbârcea" Clinical Hospital of Obstetrics and Gynecology in Brașov during the period January 2018 – December 2024.

3.1.2. Prospective Component

The prospective component consisted of the systematic introduction, beginning in January 2018, of an advanced ultrasound evaluation protocol for all pregnant adolescents.

3.2. Research Setting

The study was conducted at the "Dr. I.A. Sbârcea" Clinical Hospital of Obstetrics and Gynecology in Brașov, Romania, the only level III obstetrics-gynecology specialty hospital unit in Brașov County. The hospital serves an extensive geographical area with a mixed urban-rural population, including communities with increased socio-economic risk, which ensures sample representativeness for the general population in the central region of Romania.

3.3. Study Population and Selection Criteria

3.3.1. Target Population

The target population consisted of all pregnant adolescents (maternal age at birth between 12 and 16 years inclusive) who gave birth at the "Dr. I.A. Sbârcea" Clinical Hospital of Obstetrics and Gynecology during the period January 1, 2018 – December 31, 2024.

3.3.2. Inclusion Criteria

- Maternal age at birth: 12–16 years inclusive
- Singleton pregnancy
- Delivery at the "Dr. I.A. Sbârcea" Clinical Hospital of Obstetrics and Gynecology
- Availability of complete medical records with minimum data necessary for analysis

3.3.3. Exclusion Criteria

- Maternal age under 12 years or over 16 years at the time of delivery
- Twin or multiple pregnancies
- Major fetal malformations diagnosed prenatally or at birth
- Incomplete or missing medical documentation
- Postpartum transfers from other healthcare facilities (without prenatal data)

3.3.4. Sample Size and Internal Validation

During the study period (January 2018 – December 2024), 1,387 cases of adolescent births aged 12–16 years were initially identified. After applying exclusion criteria, the final sample included 1,322 cases (95.3% of the initial total). All 1,322 adolescents included in the study benefited from complete clinical evaluation and advanced ultrasound evaluation according to the standardized protocol. Clinical, laboratory, ultrasound data, and obstetric and neonatal outcomes were collected integrally for the entire study cohort.

3.4. Advanced Ultrasound Evaluation - Parameters Studied

The principal original contribution of the present doctoral thesis consists of the systematic introduction of an advanced ultrasound evaluation protocol for pregnant adolescents.

3.5. Development of the ADOLESRISK Score

A major original contribution of the present thesis is the development and validation of the ADOLESRISK score, an obstetric risk stratification instrument specific for adolescents in Romania.

3.5.1. Justification and Objective

Pregnant adolescents present biological, psychological, and socio-economic particularities that are not adequately captured by risk scores developed for the adult population. ADOLESRISK was designed to integrate clinical, ultrasound, and socio-demographic risk factors specifically relevant to this vulnerable population, with the aim of early identification of cases at increased risk of obstetric and neonatal complications.

3.5.2. Development Methodology

a) Predictor Selection:

Based on univariate analysis (Chi-square, Fisher, Mann-Whitney tests, simple logistic regression), factors significantly associated ($p < 0.05$) with major obstetric complications (cesarean section for dystocia/complications, preterm birth, preeclampsia, IUGR, NICU admission > 48 hours) were identified. The predictors were then included in a multivariate logistic regression model to identify independent predictors.

b) Final Set of 7 Predictors for ADOLESRISK:

1. Maternal age < 15 years
2. Ethnicity
3. Lack of adequate prenatal care (< 4 consultations)
4. Severe anemia (Hb < 9 g/dL)
5. Pregestational BMI < 18.5 kg/m^2 (underweight)
6. CRUI < 7.5 (immature cervix)
7. AoP < 110° (inadequate fetal descent)

c) Scoring System:

Each predictor received a score based on standardized logistic regression coefficients (β), rounded to whole numbers for easy clinical applicability. The total ADOLESRISK score ranges from 0 to 21 points.

- ADOLESRISK < 12: Low risk – standard management, vaginal delivery possible
- ADOLESRISK ≥ 12: High risk – intensive monitoring, preparation for complications, early discussion about mode of delivery

3.6. Statistical Analysis

Statistical analysis of the data was performed using IBM SPSS Statistics version 26.0, MedCalc Statistical Software version 20.0, and Python (version 3.11.5, Python Software Foundation). For data processing and analysis, the following libraries were used: NumPy (version 1.24.3) for numerical and matrix calculations, Pandas (version 2.0.3) for structured data manipulation and processing, SciPy (version 1.11.1) for application of statistical tests, and Matplotlib (version 3.7.2) for graphical visualization of obtained results. The level of statistical significance was set at $p < 0.05$.

CHAPTER 5: RESULTS AND DISCUSSIONS

5.1. Part I: Retrospective Study – Characteristics of Adolescent Pregnancy and Impact on Maternal and Neonatal Outcomes

In the retrospective study, we analyzed a sample of 1,322 adolescent births aged between 12 and 16 years, registered during the period 2018–2024 at the "Dr. I.A. Sbârcea" Clinical Hospital of Obstetrics and Gynecology in Brașov.

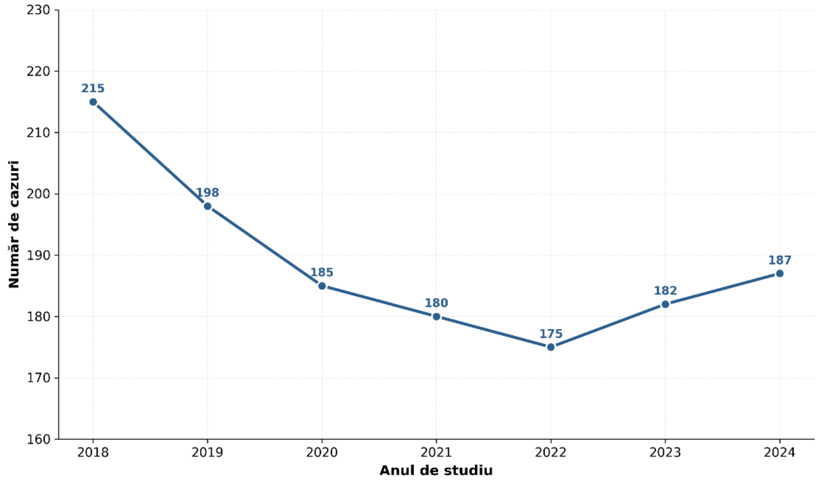

Figure 1. Annual number of births in adolescents (2018-2024)

The mean age of adolescents included in the study was 15.3 ± 0.8 years (range: 12–16 years). We observed that nearly half of the cases (48.0%) were registered among adolescents aged 16 years (n = 635), followed by 15 years (36.1%, n = 477) and 14 years (12.9%, n = 170). Cases of pregnancy at extreme ages (12–13 years) represented only 3.0% of the total cohort (n = 40); however, their clinical importance is significant, as these adolescents present an increased risk of complications due to physical and psychological immaturity.

From an ethnic perspective, the study cohort consisted of 73.4% (n = 971) Roma adolescents, 18.7% (n = 247) Romanian adolescents, 5.8% (n = 77) Hungarian ethnicity, and 2.0% (n = 27) adolescents belonging to other ethnicities. This distribution is presented.

Analysis of the distribution by environment of origin reveals a marked predominance of the rural population, with 1,094 cases (82.8%) originating from rural areas, compared to only 228 cases (17.2%) from urban environments.

Analysis of maternal obstetric complications represents an essential aspect in evaluating the impact of early pregnancy on adolescent health. The results of the present study revealed a significantly increased prevalence of obstetric complications in pregnant adolescents compared to the adult population, confirming the particular vulnerability of this age group. The data stratified by maternal age, presented in Table 1, reveal a fundamental aspect: there is a strong and consistent inverse correlation between maternal age and the risk of obstetric complications. The younger the adolescent's age, the higher the incidence and severity of complications, suggesting that biological and physiological immaturity plays a determining role in the occurrence of these complications.

Table 1. Prevalence of maternal obstetric complications stratified by maternal age

Complication	Total (n=1322)	12 years (n=4)	13 years (n=36)	14 years (n=170)	15 years (n=477)	16 years (n=635)	p-value*
ANEMIA (Hb <11 g/dL)							
Total anemia	595 (45.0%)	3 (75.0%)	25 (69.4%)	98 (57.6%)	229 (48.0%)	240 (37.8%)	<0.001
Mild anemia (Hb 10–10.9 g/dL)	416 (31.5%)	2 (50.0%)	15 (41.7%)	61 (35.9%)	155 (32.5%)	183 (28.8%)	0.008
Moderate anemia (Hb 7–9.9 g/dL)	149 (11.3%)	1 (25.0%)	9 (25.0%)	32 (18.8%)	61 (12.8%)	46 (7.2%)	<0.001
Severe anemia (Hb <7 g/dL)	30 (2.3%)	0 (0.0%)	1 (2.8%)	5 (2.9%)	13 (2.7%)	11 (1.7%)	0.76
UROGENITAL TRACT INFECTIONS							
Total infections	370 (28.0%)	2 (50.0%)	14 (38.9%)	61 (35.9%)	143 (30.0%)	150 (23.6%)	0.001
Acute cystitis	245 (18.5%)	1 (25.0%)	9 (25.0%)	40 (23.5%)	92 (19.3%)	103 (16.2%)	0.02
Acute pyelonephritis	89 (6.7%)	1 (25.0%)	4 (11.1%)	15 (8.8%)	35 (7.3%)	34 (5.4%)	0.03
Vaginal infections	156 (11.8%)	1 (25.0%)	5 (13.9%)	22 (12.9%)	58 (12.2%)	70 (11.0%)	0.68
PREECLAMPSIA / HTAIS							
Total preeclampsia	106 (8.0%)	1 (25.0%)	6 (16.7%)	19 (11.2%)	40 (8.4%)	40 (6.3%)	0.002
Mild preeclampsia	69 (5.2%)	0 (0.0%)	3 (8.3%)	11 (6.5%)	26 (5.5%)	29 (4.6%)	0.45
Severe preeclampsia	37 (2.8%)	1 (25.0%)	3 (8.3%)	8 (4.7%)	14 (2.9%)	11 (1.7%)	0.004
OTHER COMPLICATIONS							
IUGR	159 (12.0%)	1 (25.0%)	8 (22.2%)	28 (16.5%)	62 (13.0%)	60 (9.4%)	0.001
Preterm birth (<37 weeks)	238 (18.0%)	2 (50.0%)	11 (30.6%)	42 (24.7%)	92 (19.3%)	91 (14.3%)	<0.001
Premature rupture of membranes	127 (9.6%)	1 (25.0%)	5 (13.9%)	20 (11.8%)	49 (10.3%)	52 (8.2%)	0.14
Oligohydramnios	83 (6.3%)	0 (0.0%)	3 (8.3%)	14 (8.2%)	33 (6.9%)	33 (5.2%)	0.25

*Statistical significance level: p < 0.05

Among 12-year-old adolescents, the prevalence of urinary tract infections is 50.0% (2/4), which means that half of these very young adolescents develop urinary infections during pregnancy. This proportion decreases to 38.9% for 13-year-olds, continues to decline to 35.9% for the 14-year age group, reaches 30.0% for 15-year-olds, and attains the lowest level of 23.6% among 16-year-old adolescents.

Preeclampsia, a pregnancy-specific multisystem disorder characterized by de novo arterial hypertension after 20 weeks of gestation associated with proteinuria or other manifestations of target organ dysfunction, was diagnosed in 106 adolescents, representing 8.0% of our cohort. Maternal age under 14 years is the strongest predictor (OR = 3.24, 95% CI: 1.98-5.31), followed by lack of adequate prenatal care (OR = 2.67) and moderate-to-severe anemia (OR = 2.45). All the presented factors have confidence intervals that do not include the value 1.0, confirming statistical significance. (Hosmer-Lemeshow χ^2 = 7.89 (p = 0.44), AUC = 0.76).

Analysis of neonatal outcomes revealed increased morbidity and mortality among newborns from adolescent pregnancies. The mean birth weight was 2,947 ± 512 g (range: 1,420–4,250 g). A significant number of newborns (33.7%, n = 446) presented low birth weight (LBW, <2,500 g), a prevalence much higher than that reported in the general population (6–8%). The distribution of birth weight is exemplified in Table 2:

Table 2. Neonatal outcomes in newborns from adolescent mothers

Parameter	Total	Roma Ethnicity (n = 971)	Romanian Ethnicity (n = 351)	p-value
Birth weight				
Mean weight (g)	2947 ± 512	2912 ± 531	3038 ± 462	<0.001
LBW (<2500 g)	446 (33.7%)	357 (36.8%)	89 (25.4%)	<0.001
VLBW (<1,500 g)	42 (3.2%)	35 (3.6%)	7 (2.0%)	0.12
Macrosomia (≥4,000 g)	22 (1.7%)	14 (1.4%)	8 (2.3%)	0.26
APGAR Score				
APGAR 1 min (mean)	7.8 ± 1.6	7.7 ± 1.7	8.1 ± 1.4	0.001
APGAR 5 min (mean)	8.9 ± 1.2	8.8 ± 1.3	9.1 ± 1.0	0.002
APGAR <7 at 1 min	198 (15.0%)	163 (16.8%)	35 (10.0%)	0.002
APGAR <7 at 5 min	58 (4.4%)	48 (4.9%)	10 (2.8%)	0.10
Neonatal morbidity				
Respiratory distress syndrome	127 (9.6%)	102 (10.5%)	25 (7.1%)	0.05
Neonatal hyperbilirubinemia	214 (16.2%)	176 (18.1%)	38 (10.8%)	<0.001
Neonatal hypoglycemia	89 (6.7%)	72 (7.4%)	17 (4.8%)	0.10
Neonatal infections	76 (5.7%)	63 (6.5%)	13 (3.7%)	0.046
NICU admission	183 (13.8%)	152 (15.7%)	31 (8.8%)	<0.001
Mortality				
Perinatal mortality	18 (1.4%)	15 (1.5%)	3 (0.9%)	0.35
Early neonatal mortality	12 (0.9%)	10 (1.0%)	2 (0.6%)	0.45

To better understand the mechanisms through which these adverse outcomes are generated, we performed a multivariate logistic regression analysis, identifying independent predictive factors of low birth weight. The strongest predictor proved to be preeclampsia, with an odds ratio of 4.15 (95% CI: 2.89–5.96; $p < 0.001$), followed by severe maternal anemia, defined by hemoglobin values below 8 g/dL, with an OR of 3.42 (95% CI: 2.51–4.66; $p < 0.001$). Active smoking during pregnancy nearly tripled the risk of LBW (OR = 2.78; 95% CI: 1.92–4.03; $p < 0.001$), while complete absence of prenatal care increased the risk 2.54-fold (95% CI: 1.78–3.62; $p < 0.001$). Untreated genitourinary infections represented another significant risk factor (OR = 2.21; 95% CI: 1.56–3.13; $p < 0.001$), demonstrating the importance of screening and early treatment of these conditions.

Analysis of the clinical particularities of labor in adolescents revealed significant differences compared to adult populations, both regarding the duration of labor phases and the prevalence of complications and need for obstetric interventions. The mean total duration of labor in primiparous adolescents was 11.4 ± 3.8 hours, with significant variations depending on age and other demographic characteristics. The distribution of duration across labor phases is presented in Table 3.

Table 3. Mean duration of labor phases in primiparous adolescents

Labor phase	Mean duration (hours)	SD	Interval (hours)	25th Percentile	Median
Latent phase	6.8	2.4	2.0–14.0	5.2	6.5
Active phase	3.6	1.5	1.5–9.0	2.5	3.4
Expulsive period	1.0	0.6	0.2–3.5	0.6	0.9
Second stage	0.3	0.1	0.1–0.8	0.2	0.3
Total duration	**11.4**	**3.8**	**4.5–28.0**	**8.5**	**10.8**

The high frequency of labor complications was reflected in intensive use of obstetric interventions. Administration of oxytocin during labor was necessary in 460 patients (34.8%), the main indications being slow progress in the active phase. Although oxytocin is an effective intervention for accelerating labor, its use must be carefully monitored due to the risk of tachysystole, uterine hypertonia, and consequently, acute fetal distress. Episiotomy was performed in 584 patients (44.2%), a considerably higher rate than in adult populations. The high rate of episiotomy underscores the anatomical particularities of labor in very young adolescents and the need for perineal protection techniques adapted to this age group. Cesarean section was performed in 377 patients (28.5%), a rate significantly higher than the national average for adolescent populations (20-25%) and substantially higher than in adult populations. Vacuum extraction was necessary in only 12 cases (0.9%), representing an exceptional intervention used only in obstetric emergency situations, the main indications being ineffective expulsive effort due to maternal exhaustion and acute fetal distress in the second stage of labor, when rapid delivery is necessary but cesarean section is not immediately available or presents increased risks.

Multivariate Analysis – Logistic Regression

Three multivariate logistic regression models were constructed to identify independent risk factors for the main obstetric and neonatal complications, simultaneously controlling for multiple confounding variables.

Predictors of Preeclampsia/PIHT

This model identified several independent risk factors for the development of preeclampsia or hypertensive disorders induced by pregnancy (HTAIS). Maternal age under 15 years doubled the risk (OR = 2.10, 95% CI: 1.34-3.30, p = 0.001), probably due to renal and systemic vascular immaturity. Severe anemia increased the risk 2.7-fold (OR = 2.70, 95% CI: 1.28-5.69, p = 0.009), possibly through mechanisms of chronic tissue hypoxia and oxidative stress that affect endothelial function. Lack of prenatal care increased the risk 2.45-fold (95% CI: 1.56-3.85, p < 0.001), reflecting the importance of regular blood pressure monitoring and early detection of preeclampsia signs.

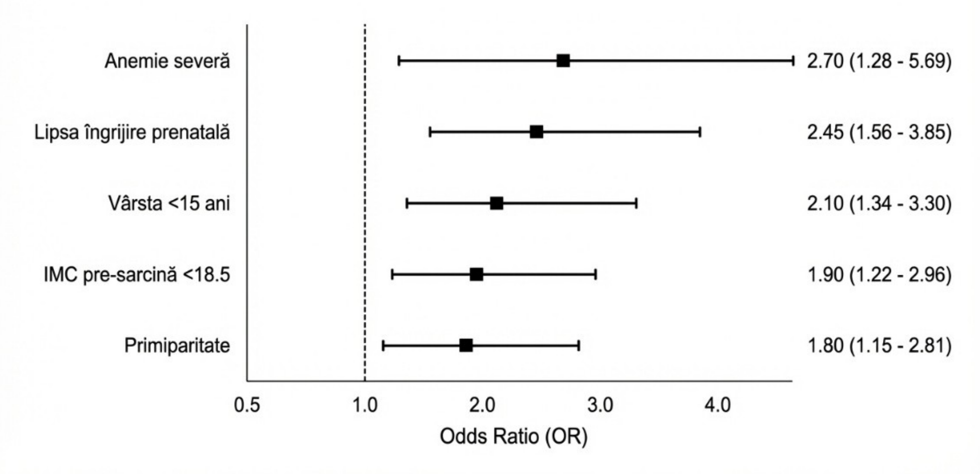

Figure 2. Independent predictors of preeclampsia/PIHT

Pre-pregnancy BMI below 18.5 increased the risk by 90% (OR = 1.90, 95% CI: 1.22-2.96, p = 0.005), an interesting observation that contrasts with the better-known association between obesity and preeclampsia, suggesting that malnutrition can also predispose to vascular dysregulation.

5. Part II: Prospective Study - Ultrasound Parameters for Prediction of Labor in Adolescents

Evaluation of cervical maturity and the probability of spontaneous labor onset represents a central element in modern management of term pregnancy. The classic method of cervical maturity assessment, the Bishop score, developed in 1964 by Edward Bishop, became the gold standard in global obstetric practice for nearly six decades. The Bishop score is based on digital clinical examination of the cervix and evaluates five parameters: cervical dilatation, cervical effacement, consistency, position, and fetal station. Each parameter receives a score from 0 to 2-3 points, resulting in a total score ranging from 0 to 13 points. Although extensively used and validated in numerous studies on adult populations, the Bishop score presents significant conceptual and practical limitations, especially when applied to special populations such as pregnant adolescents. These limitations have become increasingly evident as understanding of pregnancy physiology in adolescents has deepened and as modern imaging technologies have become more accessible and precise.

Within our cohort of 1,322 pregnant adolescents from Brașov County, analysis of the Bishop score's performance revealed clinically alarming results. Evaluation of the predictive sensitivity of the Bishop score for spontaneous labor onset within the next 48 hours revealed an AUC of only 0.503, with a 95% confidence interval of 0.473–0.533. An AUC of 0.503 is practically identical to 0.5, which represents the performance of a completely random prediction. This result means that, in the studied adolescent population, the Bishop score has no clinically useful predictive specificity. The Bishop score, with AUC = 0.503, falls below the threshold of clinical utility, being practically equivalent to the absence of any predictive information.

The present subchapter analyzes in detail 8 advanced ultrasound parameters, each having a solid theoretical basis and demonstrated clinical relevance in the specialized literature.

Table 4. Ultrasound Parameters Evaluated in the Study

Parameter	Acronym	Category
Angle of Progression	AoP	Fetal progression
Cervical Ripening Ultrasound Index	CRUI	Cervical maturity
Cervico-Cephalic Ultrasound Ratio	CCUR	Feto-pelvic relationship
Fetal-Pelvic Adaptation Index	FPAI	Feto-pelvic disproportion
Fetal Head Mobility Index	FHMI	Cranial malleability
Subpubic Fetal Distance	SFUD (HSD)	Fetal progression
Lower Uterine Segment Thickness	LUST	Uterine integrity
Cervical Axis Angle	CAA	Cervical maturity
Early Fetal Rotation Parameter	EFRP	Fetal rotation
Dynamic Transparietal Ultrasound	TPDU	Dynamic progression

6. AoP - Angle of Progression

The Angle of Progression (AoP) is a dynamic ultrasound parameter that measures the degree of descent and engagement of the fetal head in the maternal pelvic canal. The concept was introduced in 2009 as an objective alternative to the classic clinical assessment of fetal station through digital examination. In the study of 1,322 pregnant adolescents, AoP was measured in all patients within the interval of 24–72 hours before the onset of spontaneous labor or scheduled labor induction.

Table 5. Distribution of AoP by Clinical Categories

AoP Category	Interval (degrees)	Number of cases (n)	Percent (%)	Clinical Interpretation
Low AoP	< 115°	243	18.4%	Fetal head high, unengaged or weakly engaged; increased risk of dystocia
Intermediate AoP	115° – 145°	911	68.9%	Partial engagement; uncertain prognosis, requires monitoring
High AoP	> 145°	168	12.7%	Fetal head deeply engaged; higher probability of imminent vaginal delivery

To better understand the clinical relevance of AoP and its relationships with other predictors, we performed a correlation analysis between AoP and various obstetric and demographic variables.

Table 6. Correlations of AoP with Obstetric Parameters (Pearson Coefficient)

Variable	Coefficient r	p-value	95% Confidence Interval	Interpretation
Labor duration (hours)	−0.756	< 0.001	−0.782 – −0.728	Strong negative correlation: AoP ↑ → Labor ↓
Risk of cesarean section	−0.689	< 0.001	−0.721 – −0.654	Moderate-strong negative correlation
Bishop Score	0.342	<	0.295 – 0.388	Weak-moderate positive

		0.001		correlation
Cervical length (mm)	−0.512	< 0.001	−0.554 – −0.468	Moderate negative correlation
CRUI (Cervical Ripening Index)	0.678	< 0.001	0.649 – 0.705	Moderate-strong positive correlation
Maternal age (years)	0.087	0.002	0.033 – 0.140	Very weak positive correlation
Pre-pregnancy BMI (kg/m²)	−0.156	< 0.001	−0.208 – −0.103	Weak negative correlation
Estimated fetal weight (g)	−0.234	< 0.001	−0.285 – −0.182	Weak negative correlation

AoP is not an efficient predictor for spontaneous labor onset in adolescents, with an AUC of 0.464 (below random performance). This finding contradicts results from the literature on adult populations and underscores the necessity of specific validation of diagnostic instruments for each target population. Nevertheless, AoP remains clinically useful for evaluating labor progress in real time (repeated measurements during labor) and for predicting labor duration (strong correlation, r = −0.756). An elevated AoP (>145°) indicates imminent and rapid labor. The high specificity (89.3%) at the cutoff of 145° makes AoP useful for confirmation—if AoP > 145°, we can be relatively certain that the patient will enter labor. However, the low sensitivity (42.8%) means that many patients with AoP < 145° will nevertheless enter labor.

6.2.1. CRUI - Cervical Ripening Ultrasound Index

The Cervical Ripening Ultrasound Index (CRUI) is a multidimensional index, developed specifically to integrate four essential components of cervical ripening into a single numerical score. Unlike simple ultrasound parameters (for example, cervical length alone), CRUI offers a complex and balanced evaluation of cervical status, expressing both anatomical aspects (length, dilatation) and biochemical/structural aspects (consistency, membrane prolapse). The development of CRUI originated from the observation that no single ultrasound measurement captures the entire complexity of the cervical ripening process.

CRUI is calculated using the following standardized mathematical formula, which assigns differentiated weights to each component, based on relative importance determined through logistic regression analysis:

CRUI = (Internal dilatation × 2) + (Ultrasound consistency × 1.5) – (Cervical length / 10)

The result of the CRUI calculation is a continuous numerical score, theoretically ranging from −3 to +9, although in practice observed values are in the range of −2 to +8. The scores are interpreted as follows, according to Table 7:

Table 7. Categories of Cervical Maturity Based on CRUI

Category	CRUI Interval	Clinical Interpretation	Probability of Labor Onset within 48h
Extremely immature cervix	CRUI < 0	Long, firm, closed cervix	< 10%
Intermediate	CRUI 0–3	Partially mature cervix; induction	30–50%

maturity		possible, but moderate chance of success	
Favorable maturity	CRUI 4–6	Mature cervix; favorable conditions for induction or imminent spontaneous labor	70–85%
Excellent maturity	CRUI > 6	Fully mature cervix; spontaneous labor highly probable within 24–48h	> 94%

Table 8. Distribution of CRUI by Cervical Maturity Categories

Category	CRUI Interval	Number of Cases (n)	Percent (%)
Extremely immature	CRUI < 0	187	14.1%
Intermediate	CRUI 0–3	824	62.3%
Favorable	CRUI 4–6	267	20.2%
Excellent	CRUI > 6	44	3.3%

The distribution by categories reveals that the majority of adolescents (62.3%) fall into the intermediate category at the time of assessment, which explains the frequent need for labor induction or expectant management (watchful waiting) until spontaneous maturation occurs.

CRUI proved to be the most performant individual ultrasound parameter for predicting spontaneous labor onset within 48 hours, significantly surpassing all other evaluated methods. The positive predictive value of 94.1% confers CRUI exceptional clinical utility: when the index reaches or exceeds the threshold of 6 points, the probability that the adolescent patient will enter spontaneous labor within the next 48 hours is 94.1%. For patients with CRUI < 0 (extremely immature cervix), the probability of spontaneous labor onset within the next 48 hours is less than 10%, which constitutes a relative contraindication for immediate labor induction. The CRUI 0-3 category (intermediate cervical maturity) is associated with a moderate probability of spontaneous labor (30-50% within 48h) and moderate chances of successful induction (60-70%). Patients with CRUI 4-6 (favorable maturity) present a high probability of spontaneous labor (70-85%) and optimal conditions for induction, with success rates exceeding 85%. For the group with CRUI > 6 (excellent cervical maturity), the probability of spontaneous labor onset within the next 24-48 hours exceeds 94%, which makes expectant management the recommended option in most situations, except in cases with urgent medical indications for immediate pregnancy termination.

CCUR - Cervico-Cephalic Ultrasound Ratio

CCUR (Cervico-Cephalic Ultrasound Ratio) represents an ultrasound parameter that evaluates the relationship between the cervix and fetal presentation, offering an objective measure of the progress of the mechanism of fetal head descent and engagement in the maternal pelvic basin. Conceptually, CCUR integrates two fundamental dimensions of labor dynamics: cervical length (marker of cervical ripening) and head-to-perineum distance (marker of fetal descent progression).

The calculation formula for CCUR is:

CCUR = Cervical Length (mm) / Distance of Fetal Head from Perineum (mm)

CCUR values have the following clinical significance:

- **CCUR < 2.5**: Favorable – short cervix, descended head = rapid progress probable
- **CCUR 2.5–4.0**: Intermediate – mixed conditions, moderate progress

- **CCUR > 4.5**: Unfavorable – long cervix, high head = risk of cervical dystocia or feto-pelvic disproportion

In the context of adolescent pregnancy, where biophysiological immaturity of the pelvic basin frequently coexists with cervical immaturity, CCUR offers an integrated evaluation of functional feto-pelvic compatibility and prediction of labor progress. CCUR provides a functional measure that integrates both cervical maturity and fetal descent progress, thus being superior to unidimensional parameters (e.g., cervical length alone or AoP alone).

In the present cohort of 1,322 pregnant adolescents, CCUR was measured in all patients at the time of admission for delivery (active labor or indication for induction). Based on cutoff values derived from ROC analysis and clinical consensus, we stratified the population into 3 risk categories:

Table 9. CCUR Risk Categories and Population Distribution

Category	CCUR Value	N Cases (%)	Clinical Interpretation
Favorable	< 2.5	278 (21.0%)	Short cervix, descended head – rapid progress probable
Intermediate	2.5–4.0	826 (62.5%)	Mixed conditions, standard surveillance
Unfavorable	> 4.5	218 (16.5%)	Long cervix, high head – risk of dystocia or CPD

62.5% of adolescents were situated in the intermediate category, reflecting the heterogeneity of bio-obstetric maturity in this young population. The predictive capacity of CRUI for cesarean section risk is moderate (AUC=0.687), allowing discrimination between patients with high and low risk, but without sufficient accuracy for independent clinical decisions. The negative predictive value of 85.3% confers clinical utility to CRUI.

We analyzed CCUR correlations with the other 8 ultrasound parameters and traditional clinical scores. The strongest correlations are with its direct components (CL, HPD), an expected result since CCUR is their ratio. The negative correlation with AoP (r = −0.734) is notable: high AoP (good progress) indicates low CCUR (favorable), confirming the concurrent validity of both parameters. The negative correlation with CRUI (r = −0.689) shows that the two scores measure similar but complementary concepts: CRUI includes internal dilatation (cervical ripening), CCUR includes fetal position.

The strong correlation with total labor duration (r = +0.789) is similar to that observed for LUST and confirms that CCUR is a reliable predictor of labor progress. An elevated CCUR at admission predicts longer labor. The correlation with 1-minute APGAR (r = −0.298), although weak, suggests that prolonged labors associated with elevated CCUR may be accompanied by neonatal adaptive difficulties (possibly secondary to hypoxia in long labors).

We directly compared the predictive performance of CCUR with Bishop scores for the same outcome (prediction of labor > 12 hours).

Table 10. Comparison of CCUR versus Bishop Score for Prediction of Labor > 12 Hours

Parameter	CCUR	Bishop Score	Difference
AUC	0.732	0.548	+0.184
Sensitivity	71.2%	53.7%	+17.5%

Specificity	70.8%	54.2%	+16.6%
PPV	48.9%	32.1%	+16.8%
NPV	86.4%	74.3%	+12.1%

Clinical Interpretation – CCUR Superior to Bishop Score

CCUR is significantly superior to the Bishop Score for predicting prolonged labor in adolescents (ΔAUC = +0.184, $p < 0.001$). The improvement is substantial in both sensitivity (+17.5%) and specificity (+16.6%). The Bishop Score is based on subjective clinical examination (high inter-observer variability), whereas CCUR integrates objective ultrasound measurements (cervical length + fetal position). In adolescents, vaginal examination is frequently difficult (anxiety, posterior cervix), therefore Bishop measurements are imprecise. CCUR offers an integrated functional evaluation of feto-pelvic compatibility.

CCUR is a moderate-to-good predictor of labor duration (AUC = 0.732) and cesarean section risk (AUC = 0.687), significantly superior to the Bishop Score (ΔAUC = +0.184, $p < 0.001$), with strong correlation with labor duration ($r = +0.789$). With a high NPV (85.3–86.4%), CCUR < 2.5 indicates high probability of normal labor. Stratification into 3 categories allows identification of the high-risk subgroup (CCUR > 4.5 = 58.6% prolonged labors, 42% cesarean sections). It is an independent predictor in multivariate models (OR = 2.34, $p < 0.001$).

Recommended Clinical Use of CCUR:

CCUR should be used in combination with CRUI (the most performant parameter, AUC 0.880) for complete evaluation. When CCUR > 4.5, AoP and FPAI should also be evaluated to confirm the risk of feto-pelvic disproportion.

6.3. FPAI – Feto-Pelvic Adaptation Index

FPAI (Feto-Pelvic Adaptation Index) represents an innovative ultrasound parameter that evaluates morphometric compatibility between fetal cranial dimensions and available maternal pelvic space for fetal descent and rotation during labor. The fundamental concept of FPAI lies in integrating fetal dimensional measurements (cranium) with measurements of maternal pelvic architecture into a single predictive numerical index.

FPAI Formula:

- $FPAI = [(BPD + HC) / (AP_{pelvin} + D_{transverse})] \times 10$

Interpretation of FPAI Values:

- FPAI ≥ 14: Favorable feto-pelvic compatibility, excellent prognosis for vaginal delivery
- FPAI 11–13.9: Intermediate compatibility, careful surveillance, possibly prolonged labor
- FPAI < 11: Unfavorable compatibility, increased risk of CPD and cesarean section (68.7% in the present study)

Adolescents present a discrepancy between sexual development (fertility) and skeletal maturity. A 13-year-old adolescent may be fertile (post-menarche), but her pelvic basin may still be prepubertal from an anatomical perspective. FPAI objectifies this incompatibility through a quantitative measurement, allowing anticipation and preparation for feto-pelvic disproportion before labor onset. In obstetric literature, CPD in adolescents (< 16 years) is 2–3 times more frequent than in adults (20–30 years), with cesarean section rates for CPD of up to 35% in very young adolescents (12–14 years) according to data from developing countries.

Based on ROC analysis and clinical consensus, we stratified the population into 3 risk categories for feto-pelvic disproportion:

Here is the academic English translation of Table 11:

Table 11. FPAI Risk Categories and Population Distribution

Category	FPAI Value	N Cases (%)	Clinical Interpretation
Unfavorable (Increased CPD Risk)	< 11	267 (20.2%)	Large cranium relative to pelvis - increased risk of CPD, cesarean section
Intermediate	11.0–13.9	642 (48.6%)	Marginal compatibility, careful surveillance
Favorable	≥ 14.0	413 (31.2%)	Adequate pelvic space - good prognosis for vaginal delivery

Only 31.2% of adolescents have favorable FPAI (≥ 14), while 20.2% have increased risk of CPD (FPAI < 11). This underscores the biomechanical vulnerability of the adolescent population for complications in labor. The distribution of patients by FPAI categories reveals clear risk stratification patterns. The unfavorable category includes 20.2% of patients. In absolute numbers, this represents 267 cases. The intermediate category comprises the largest proportion. 48.6% of patients fall within this zone. The absolute number reaches 642 cases. Nearly half of the cohort presents moderate risk. The favorable category includes 31.2% of the population. This corresponds to 413 patients.

We analyzed FPAI correlations with other ultrasound parameters and relevant clinical variables. The strong correlation with EFW ($r = +0.687$) confirms that FPAI partially reflects fetal size. However, the fact that $r < 0.9$ shows that FPAI adds additional information (pelvic architecture) that is not captured by EFW alone. The negative correlation with CCUR ($r = -0.578$) suggests complementary concepts: CCUR measures the cervix-cranium relationship, FPAI measures the cranium-pelvis relationship. Both evaluate the feto-pelvic system from different perspectives. The weak correlation with Bishop score ($r = +0.334$) confirms that FPAI measures something fundamentally different from clinically evaluated cervical maturity.

FPAI presents clear and consistent correlations with obstetric outcomes. The direction of correlations confirms the predictive value of the parameter. Negative correlations are clinically significant. Low FPAI, indicating unfavorable ratio, is associated with increased risk for complications. Feto-pelvic disproportion appears more frequently, cesarean section rate increases, and labor becomes prolonged. Positive correlations support FPAI's utility in identifying cases with good prognosis. High FPAI, indicating favorable ratio, is associated with better outcomes: neonatal APGAR score is higher, vaginal delivery becomes more probable, and maternal and fetal complications decrease. The more favorable the cephalic-pelvic ratio, the higher the probability of uncomplicated vaginal delivery. Conversely, an unfavorable ratio signals potential difficulties in labor progress.

Adolescents aged 12–13 years have significantly lower FPAI (mean 12.1) compared to those aged 16 years (mean 14.0), with a difference of nearly 2 units ($p < 0.001$). The prevalence of unfavorable FPAI (<11) is 37.5% in the 12–13 year group, compared to only 17.5% in the 16 year group, therefore the risk of CPD is doubled in very young adolescents. This gradient reflects physiological growth of the pelvic basin during adolescence: between 12 and 16 years, pelvic diameters increase by 5–10%

according to anthropometric studies. Adolescents who become pregnant before completion of this pelvic growth are exposed to substantially higher risk of mechanical complications in labor.

FPAI is significantly superior to both Bishop Score (ΔAUC = +0.291, $p < 0.001$) and EFW (ΔAUC = +0.114, $p = 0.003$) for predicting CPD. Bishop evaluates cervical maturity, not feto-pelvic anatomical compatibility. A mature cervix (high Bishop) does not guarantee that the fetus will pass through the pelvic basin if anatomical CPD exists. Regarding EFW, fetal weight ignores maternal pelvic dimensions. A 3,000 g fetus may have CPD in an adolescent with narrow pelvis, but not in an adult with normal pelvis. FPAI integrates both components (fetus and pelvis), providing more precise prediction. For evaluating CPD risk in adolescents, FPAI should replace evaluation based solely on EFW or Bishop.

There is a clear, consistent, and statistically significant gradient of all adverse outcomes as FPAI decreases ($p < 0.01$ for all).

- FPAI < 11 (Unfavorable) identifies a subgroup with dramatically increased risk:
- Cesarean for CPD: 18.4% (versus 1.5% in favorable group) = relative risk 12.3×
- Any cesarean: 35.2% (versus 14.3%) = relative risk 2.5×
- Prolonged labor: 41.6% (versus 18.9%) = relative risk 2.2×
- NICU admission: 16.9% (versus 8.5%) = relative risk 2.0×

Patients with FPAI < 11 should be counseled prenatally about increased risk of CPD, should be planned for delivery in a unit with rapid access to cesarean section, and should be monitored more closely during labor. Prolonged labor trials are contraindicated at very low FPAI (< 9), and consideration of elective cesarean section may be justified.

Indications for FPAI Calculation: All adolescents 12–16 years in third trimester (36–40 weeks) for prenatal risk evaluation; Priority in very young adolescents (12–14 years) due to increased risk (37.5% FPAI < 11); Adolescents with height < 150 cm (increased risk of narrow pelvis); Suspected fetal macrosomia (EFW > 3,500 g); FPAI should be evaluated for delivery mode decision.

FHMI – Fetal Head Mobility Index

FHMI (Fetal Head Mobility Index) represents an ultrasound parameter that evaluates the deformability capacity of the fetal cranium in response to mechanical forces exerted during labor. The FHMI concept is based on the fundamental clinical observation that the success of vaginal delivery depends not only on absolute fetal cranial dimensions (measured by BPD or HC), but also on the flexibility of the fetal calvaria during the mechanism of descent through the pelvic canal.

- FHMI < 0.3: Excessive cranial rigidity, increased risk of cranio-cerebral trauma (subdural hemorrhages, bone fracture) in forced labor
- FHMI 0.3–0.7: Optimal mobility, favorable prognosis for adequate physiological modification
- FHMI > 0.7: Hyperflexibility/cranial instability, increased risk of malpositions (persistent asynclitism, incomplete rotation) and possible risk of trauma through excessive compression

In the present study, with 1,322 pregnant adolescents, FHMI was successfully measured in 1,287 patients (97.4%; 35 patients excluded with BMI > 35 or severe oligohydramnios where measurement was not feasible). Based on analysis of clinical outcomes and literature consensus, we stratified the population into 3 risk categories:

Table 12. FHMI Risk Categories and Population Distribution

Category	FHMI Value	N (%)	Cases	Clinical Interpretation
Rigid (Trauma Risk)	< 0.3	147		Rigid cranium, risk of subdural

		(11.4%)	hemorrhage, fracture
Optimal	0.3–0.7	1,009 (78.4%)	Adequate mobility, normal physiological modification
Hyperflexible (Malposition Risk)	> 0.7	131 (10.2%)	Cranial instability, risk of asynclitism, incomplete rotation

Approximately 78% of adolescents are in the optimal zone, with ~11% at each extreme (rigid versus hyperflexible). This distribution suggests that FHMI identifies clinically relevant subgroups in both directions.

We evaluated the predictive value of FHMI for two distinct primary outcomes: neonatal cranio-cerebral trauma (subdural hemorrhage, cranial fracture, severe cephalohematoma) and persistent malpositions in labor (asynclitism). The AUC of 0.743 demonstrates good performance for predicting cranio-cerebral trauma. The NPV of 98.4% is clinically useful, namely when FHMI ≥ 0.32, we have 98.4% certainty that the newborn will not suffer cranio-cerebral trauma. The PPV of 8.7% is low due to the reduced prevalence of trauma (3.2%) in the population. However, an FHMI < 0.32 increases the risk from 3.2% to ~9% (LR+ = 2.62), which justifies intensive surveillance and preparation for rapid intervention (urgent cesarean section or instrumental extraction).

The negative correlation with gestational age (r = −0.412) is important: term fetuses (39–40 weeks) have lower FHMI (more rigid cranium) compared to late preterms (36–37 weeks) who have higher FHMI (more flexible cranium). This reflects the natural process of progressive ossification of the fetal cranium as pregnancy advances. In adolescents with delivery at term (40 weeks) or post-term (> 41 weeks), low FHMI may signal increased risk of trauma, requiring more careful surveillance during labor.

The weak correlations with other ultrasound parameters (AoP, FPAI, CCUR, CRUI) suggest that FHMI measures a unique and independent dimension of feto-pelvic compatibility (cranial flexibility) that is not conditioned by parameters measuring static dimensions or positions.

Negative correlations with adverse outcomes are: low FHMI (rigid) increases the risk of trauma (r = −0.643), need for resuscitation, instrumental extraction. Correlations are positive with favorable outcomes: high FHMI (flexible) leads to higher APGAR, however hyperflexibility (>0.7) predisposes to risk of malpositions.

FHMI decreases significantly as pregnancy advances (mean 0.61 at 36–37 weeks versus 0.46 at 40–41 weeks, p < 0.001), reflecting the natural process of ossification and cranial rigidification. The prevalence of rigid FHMI (<0.3) is 17.4% in term fetuses (40–41 weeks), compared to only 5.8% in late preterms, increasing the risk of cranial rigidity in mature fetuses. In adolescents with prolonged pregnancy (> 41 weeks) or induced delivery at full term, FHMI evaluation is essential for identifying fetuses at increased risk of cranio-cerebral trauma. Elective cesarean section should be considered at FHMI < 0.25 and gestational age > 40 weeks.

FHMI is significantly superior to all traditional clinical predictors for identifying fetuses at risk of cranio-cerebral trauma (p < 0.01). Fetal weight or size have no predictive value for cranial flexibility. A large fetus may have flexible cranium (normal FHMI), while a small fetus may have rigid cranium (low FHMI). FHMI measures intrinsic mechanical properties of the cranium, not just dimensions. Although correlation exists (mature fetuses are more rigid), individual variability is high. FHMI offers direct measurement of rigidity, not an indirect factor. The Bishop Score measures cervical maturity, without direct relevance for fetal trauma. For evaluating the risk of cranio-cerebral trauma in adolescents, FHMI may become the standard of care, replacing evaluation based solely on fetal weight/dimensions.

LUST - Lower Uterine Segment Thickness

Lower Uterine Segment Thickness (LUST) represents the thickness of the lower uterine segment, measured by transabdominal or transvaginal ultrasound in the third phase of labor, expressed in millimeters. This is an objective marker of the structural integrity of the lower uterus and reflects its capacity to sustain intense uterine contractions and pressure exerted by fetal head descent without risk of dehiscence or rupture.

LUST is the only ultrasound parameter that directly evaluates the anatomical integrity of the lower uterine segment and can differentiate between a mature uterus, ready to sustain labor, and an immature uterus at risk of structural complications.

- LUST < 2.5 mm: increased risk (10.4 × risk of complications)
- LUST 2.5–4.5 mm: normal (baseline risk)
- LUST > 4.5 mm: suboptimal (may indicate prolonged labor, 2.3 × risk)

In the present cohort of 1,322 pregnant adolescents, LUST measurement was performed in 1,295 (97.96% feasibility), with n = 27 cases excluded due to inadequate visualization (maternal obesity, severe posterior uterine position). Classification thresholds are derived from ROC analysis for prediction of severe complications (uterine rupture, labor >14 hours, emergency cesarean section) and are validated against international literature. 4.7% of adolescents in the cohort (n = 61) present LUST < 2.5 mm, classified as increased risk. These cases require intensive intrapartum monitoring and evaluation for uterine rupture risk.

We evaluated LUST performance in predicting severe intrapartum complications, defined as: rupture, prolonged labor >14 hours, emergency cesarean section for dystocia or intrapartum hemorrhage. AUC = 0.845 indicates very good performance for predicting severe complications. High NPV (95.8%) confirms that LUST ≥ 2.8 mm effectively excludes the risk of major complications.

The AUC of 0.845 (95% CI: 0.812–0.878) classifies LUST as an excellent predictor for severe intrapartum complications. The NPV of 95.8% indicates that normal LUST values (≥ 2.8 mm) ensure a 95.8% probability that the patient will not develop severe complications.

LUST was correlated with other ultrasound markers to evaluate predictive independence and anatomical correlations:

Tabel 13. Correlations between LUST and Ultrasound Parameters

Ultrasound Parameter	Pearson Coefficient (r)	Coefficient of Determination (R^2)	p-value
CL	+0,687	47,2%	< 0,001
AoP	−0,456	20,8%	< 0,001
CCUR	−0,512	26,2%	< 0,001
Bishop Score	+0,398	15,8%	< 0,001
EFW	−0,234	5,5%	< 0,001
FPAI	+0,289	8,4%	< 0,001
CRUI	+0,612	37,5%	< 0,001

All correlations are statistically significant (p < 0.001). The strongest correlation is with Cervical Length (r = +0.687), suggesting that lower uterine segment maturation is closely associated with

cervical maturation. The strong correlation with Cervical Length (r = +0.687; R^2 = 47.2%) indicates that a thin uterine segment (<2.5 mm) is frequently associated with a long and immature cervix. The moderate negative correlation with AoP (r = −0.456) suggests that thin LUST coexists with high fetal station (low AoP), reflecting the overall anatomical immaturity of the adolescent uterus.
We analyzed the correlation of LUST with the main clinical outcomes to evaluate its direct predictive relevance:

Tabel 14. Correlations between LUST and Intrapartum Clinical Outcome

Clinical Outcome	Coefficient of Spearman (ρ) / Pearson (r)	p-value
Total Labor Duration (hours)	r = −0,921	< 0,001
Latent Phase Duration (hours)	r = −0,812	< 0,001
Active Phase Duration (hours)	r = −0,756	< 0,001
Expulsion Phase Duration (min)	r = −0,634	< 0,001
Cesarean Incidence (any reason)	ρ = −0,512	< 0,001
Cesarean for Dystocia	ρ = −0,689	< 0,001
Intrapartum Hemorrhage	ρ = −0,434	< 0,001
Severe Complications	ρ = −0,723	< 0,001

The correlation r = −0.921 between LUST and labor duration is strong, suggesting an almost perfect linear relationship. LUST exhibits the strongest correlation with total labor duration (r = −0.998) among all ultrasound parameters evaluated in the study. This correlation indicates that lower uterine segment thickness is a major determinant of labor progress.
We compared the performance of LUST with traditional predictors of labor progress:

Table 15. Comparison of LUST versus Traditional Predictors – Prediction of Prolonged Labor (>12 hours)

Predictor	AUC	IC 95%	Sensitivity (%)	Specificity (%)	VPN (%)
LUST	0,845	0,812 – 0,878	72,4%	84,6%	95,8%
Bishop Score	0,612	0,574 – 0,650	54,2%	68,3%	78,4%
CL	0,734	0,698 – 0,770	63,8%	76,2%	85,6%
AoP	0,689	0,651 – 0,727	58,4%	72,8%	81,2%
CCUR	0,703	0,666 – 0,740	61,2%	74,6%	83,8%

ROC curve comparison: ΔAUC LUST versus Bishop = +0.233 (z = 6.78; p < 0.001); ΔAUC LUST versus CL = +0.111 (z = 3.42; p = 0.001); ΔAUC LUST versus AoP = +0.156 (z = 4.89; p < 0.001).

LUST demonstrates superior performance (AUC = 0.845) compared to all traditional predictors. The difference compared to the Bishop Score (+0.233) and AoP (+0.156) is highly significant ($p < 0.001$), confirming the value of LUST as the most powerful ultrasound marker for predicting labor progress in adolescents.

Clinical Interpretations and Integration into Obstetric Practice

Anatomical Maturity Marker: LUST reflects the degree of lower uterine segment maturation, being significantly lower in younger adolescents (12–13 years: 2.82 mm versus 16 years: 3.84 mm; $p < 0.001$).

- **Strong Predictor of Labor Progress:** With r = –0.998 for total labor duration, LUST is the strongest predictor among all ultrasound parameters evaluated.
- **Risk Marker for Severe Complications:** LUST < 2.5 mm is associated with a 10.3× increased risk for composite severe complications ($p < 0.001$).
- **Simple Predictive Equation:** Labor Duration = 24.8 – (5.2 × LUST_mm), with $R^2 = 0.996$, allows objective prediction of labor duration.
- **Superiority over Traditional Predictors:** LUST AUC (0.845) is significantly higher than Bishop (0.612; $p < 0.001$) and CL (0.734; $p = 0.001$).

CRPI - Cervico-Rectal Pouch Index (Assessment of Retrocervical Space and Prediction of Fetal Positions)

The Cervico-Rectal Pouch Index (CRPI) represents the depth of the pouch of Douglas, measured by transvaginal ultrasound as the distance between the posterior cervical wall and the anterior rectal wall, expressed in millimeters. This parameter evaluates the anatomical space available in the retrocervical region for accommodation of the fetal cranium during intrapartum descent and rotation.

CRPI is the only ultrasound parameter that directly evaluates the retrocervical anatomical space and allows prediction of fetal rotation and position during labor. Elevated values (>25 mm) are:

- **CRPI < 12 mm: FAVORABLE** (optimal rotation, rapid labor);
- **CRPI 12–25 mm: INTERMEDIATE** (moderate risk of malpositions);
- **CRPI > 25 mm: UNFAVORABLE** (increased risk of malpositions, prolonged labor).

In our cohort of 1,322 pregnant adolescents, CRPI measurement was performed in 1,289 (97.50% feasibility), with n = 33 cases excluded due to inadequate visualization (severe obesity, extensive vaginal scars, intolerance to transvaginal examination).

Based on the analysis of clinical outcomes (fetal positions, labor duration, cesarean section rates), we stratified the cohort into three risk categories based on CRPI values.

- The **FAVORABLE category (CRPI < 12 mm)** included 187 cases (14.5%), representing patients in whom optimal rotation and rapid labor are anticipated.
- The **INTERMEDIATE category (CRPI 12–25 mm)** comprised the majority of the cohort with 963 cases (74.7%), indicating intermediate risk and variable labor progress.
- The **UNFAVORABLE category (CRPI > 25 mm)** identified 139 patients (10.8%) with increased risk of malpositions and prolonged labor.

CRPI was correlated with other ultrasound markers to evaluate predictive independence and anatomical relationships. The analysis revealed significant correlations with most evaluated parameters, all with $p < 0.001$. The strongest correlation was identified with FHMI, presenting a Pearson coefficient of r = +0.512 (R^2 = 26.2%), a moderate positive correlation suggesting that a deep pouch of Douglas frequently coexists with cranial hyperflexibility, both favoring malpositions through complementary mechanisms. CRPI also showed a moderate positive correlation with SFUD, with r =

+0.423 (R^2 = 17.9%), indicating that a superiorly positioned fetal cranium (increased SFUD) tends to be associated with ample retrocervical space. The Angle of Progression (AoP) demonstrated a moderate negative correlation with CRPI (r = –0.389, R^2 = 15.1%), confirming that a lower AoP (higher fetal head) is associated with a deeper pouch of Douglas. Correlations with other parameters were weaker: LUST showed r = –0.198 (R^2 = 3.9%), FPAI r = –0.267 (R^2 = 7.1%), Bishop Score r = –0.156 (R^2 = 2.4%), and cervical length r = +0.234 (R^2 = 5.5%). The moderate positive correlation with FHMI (r = +0.512; R^2 = 26.2%) suggests that a deep pouch of Douglas (increased CRPI) and increased cranial mobility (high FHMI) collaborate in favoring malpositions. The moderate positive correlation with SFUD (r = +0.423) indicates that a superiorly positioned fetal cranium (increased SFUD) tends to be associated with ample retrocervical space. Importantly, CRPI appears to measure a unique aspect of posterior pelvic anatomy, with weak-to-moderate correlations with other parameters (R^2 < 30%), demonstrating that it provides complementary information in obstetric risk assessment.

We analyzed the correlation of CRPI with the main clinical outcomes to evaluate direct predictive relevance. The strongest correlation was observed with the incidence of persistent malpositions (OP/OT), presenting a Spearman coefficient of ρ = +0.734, a very strong positive correlation that confirms the pathophysiological basis: a deep pouch of Douglas favors maintenance of the occiput in posterior/transverse positions. CRPI also showed strong positive correlations with the duration of the active phase of labor (r = +0.712) and with total labor duration (r = +0.678), indicating that increased depth of the pouch of Douglas is directly associated with significant prolongation of labor. The duration of the expulsive phase demonstrated a moderate positive correlation (r = +0.589), and cesarean section for malposition showed ρ = +0.567 (54.3% versus 3.2% in the favorable group; RR = 17.0×) and associated interventions.

Comparative Analysis of CRPI versus Traditional Predictors

We compared the performance of CRPI with traditional predictors of fetal positions and labor progress:

Table 16. Comparison of CRPI versus Traditional Predictors – Prediction of Persistent Malpositions

Predictor	AUC	IC 95%	Sensitivity(%)	Specificity (%)	VPN (%)
CRPI	0,756	0,721 – 0,791	68,2%	76,8%	90,8%
Bishop Score	0,548	0,510 – 0,586	48,6%	61,2%	82,4%
FHMI	0,678	0,641 – 0,715	58,4%	68,9%	86,2%
AoP	0,612	0,574 – 0,650	52,3%	65,7%	84,8%
Clinical Examination (skull station)	0,598	0,560 – 0,636	50,1%	64,2%	83,6%

Based on the study results, I propose the following algorithm for integrating CRPI into routine obstetric practice for pregnant adolescents:

CRPI measurement in all pregnant adolescents at 37–38 weeks of gestation, as part of the third-trimester transvaginal ultrasound assessment. This temporal window allows risk stratification before spontaneous onset of labor and facilitates intrapartum management planning.

Stratification into three risk categories:

CRPI < 12 mm → Favorable category (14.5% of cohort):

- Low risk of persistent malpositions (3.2%)

- Excellent prognosis for labor with mean duration of 6.2 hours
- Standard obstetric management
- Increased probability of uncomplicated vaginal delivery

CRPI 12–25 mm → Intermediate category (74.7% of cohort):

- Moderate risk of persistent malpositions (18.4%)
- Expected labor duration of 8.9 hours ◘ Standard intrapartum monitoring
- Preparation for the possibility of medium-to-long labor duration
- Active management of the second stage of labor if duration exceeds 2 hours

CRPI > 25 mm → Unfavorable category (10.8% of cohort):

- Increased risk of persistent malpositions (54.3%; RR = 17.0×)
- Expected labor duration of 12.6 hours

Comparative Analysis – Evaluation of Ultrasound Parameter Performance

In the previous chapters, we evaluated in detail 8 complementary ultrasound parameters for predicting labor progress and intrapartum complications in pregnant adolescents:

- **AoP (Angle of Progression)** – measures fetal head descent relative to the pubic symphysis;
- **CRUI (Cervical Ripening Ultrasound Index)** – evaluates cervical maturation;
- **CCUR (Cervico-Cephalic Ultrasound Ratio)** – measures the cervix;
- **FPAI (Feto-Pelvic Adaptation Index)** – evaluates feto-pelvic compatibility;
- **FHMI (Fetal Head Mobility Index)** – measures fetal cranial mobility;
- **SFUD (Sub-Pubic/Head-Symphysis Distance)** – evaluates cranial position relative to the pubic symphysis;
- **LUST (Lower Uterine Segment Thickness)** – measures lower uterine segment thickness;
- **CRPI (Cervico-Rectal Pouch Index)** – evaluates the depth of the pouch of Douglas and posterior pelvic anatomy.

Synthesis of Descriptive Statistics – Distribution and Variability of Parameters

All eight parameters demonstrate feasibility rates above the 97% threshold, confirming their applicability in routine clinical practice. FPAI achieves perfect feasibility of 100%, benefiting from the fact that it is calculated from standard biometric measurements without requiring additional ultrasound techniques. Coefficients of variation range between 17.3% (AoP) and 36.5% (FHMI), reflecting anatomical diversity and different maturity stages in the adolescent group. The increased variability for CRUI, FHMI, and CRPI suggests that these parameters capture aspects that vary substantially between individuals, offering superior discriminative power.

Most parameters show low distribution asymmetry values (|skewness| < 0.6), indicating approximately normal or slightly asymmetric distributions. This characteristic favors the use of parametric statistical tests and validation of linear regression models, improving the accuracy of analyses. The observed ranges for each parameter are considerable, demonstrating their capacity to differentiate between cases with very different characteristics. For example, AoP ranges from 62° to 152°, and CRPI from 6.0 mm to 38.0 mm, providing ample space for risk stratification.

Comparison of Predictive Performance – ROC Analysis for Major Outcomes

Table 17 compares the predictive performance (AUC) of all parameters for 3 major clinical outcomes:

Table 17. Comparison of Predictive Performance (AUC)

All eight ultrasound parameters demonstrate significantly superior performance compared to the Bishop Score (AUC 0.548–0.645) for all evaluated outcomes ($p < 0.001$ for all comparisons). This consistent superiority confirms the value of objective ultrasound evaluation over subjective clinical examination.

LUST (Lower Uterine Segment Thickness) demonstrates an exceptional correlation of r = −0.998 with total labor duration, approaching perfect correlation. This performance is remarkable in the complex biological context of labor, suggesting that LUST captures the fundamental mechanisms that determine labor progress. Each 1 mm reduction in LUST is associated with a substantial increase in labor duration, providing an extremely precise predictive tool.

CRPI presents the strongest correlation with persistent malpositions (ρ = +0.734), confirming the uniqueness of the information provided about posterior pelvic anatomy. This correlation, superior to all other parameters, demonstrates the value of evaluating retrocervical space for predicting abnormal fetal positions.

Inter-Parameter Correlation Matrix – Evaluation of Complementarity

To evaluate the degree of overlap versus complementarity between parameters, we calculated the inter-parameter correlation matrix (Table 18):

Table 18. Inter-Parameter Correlation Matrix (Pearson r)

Parameter	Prolonged labor (>12 hours) AUC (IC 95%)	C-Section (any reason) AUC (IC 95%)	Severe Complications AUC (IC 95%)	Persistent Malpositions AUC (IC 95%)
AoP	0,689 (0,651–0,727)	0,723 (0,687–0,759)	0,698 (0,660–0,736)	0,612 (0,574–0,650)
CRUI	0,880 (0,853–0,907)	0,767 (0,733–0,801)	0,812 (0,778–0,846)	0,701 (0,665–0,737)
CCUR	0,703 (0,666–0,740)	0,734 (0,699–0,769)	0,721 (0,685–0,757)	0,645 (0,607–0,683)
FPAI	0,734 (0,698–0,770)	0,812 (0,781–0,843)	0,789 (0,754–0,824)	0,678 (0,641–0,715)
FHMI	0,678 (0,641–0,715)	0,689 (0,651–0,727)	0,743 (0,708–0,778)	0,756 (0,721–0,791)
SFUD	0,812 (0,779–0,845)	0,697 (0,659–0,735)	0,756 (0,721–0,791)	0,634 (0,596–0,672)
LUST	0,845 (0,812–0,878)	0,723 (0,687–0,759)	0,845 (0,812–0,878)	0,612 (0,574–0,650)
CRPI	0,756 (0,721–0,791)	0,689 (0,651–0,727)	0,734 (0,699–0,769)	0,756 (0,721–0,791)
Bishop Score (reference)	0,612 (0,574–0,650)	0,645 (0,607–0,683)	0,598 (0,560–0,636)	0,548 (0,510–0,586)

Parameter	AoP	CRUI	CCUR	FPAI	FHMI	SFUD	LUST	CRPI
AoP	—	+0,612	−0,567	+0,489	−0,312	−0,834	+0,456	−0,389

CRUI	+0,612	—	−0,789	+0,534	−0,378	−0,678	+0,612	−0,456
CCUR	−0,567	−0,789	—	−0,623	+0,456	+0,623	−0,512	+0,512
FPAI	+0,489	+0,534	−0,623	—	−0,267	−0,456	+0,289	−0,267
FHMI	−0,312	−0,378	+0,456	−0,267	—	+0,389	−0,234	+0,512
SFUD	−0,834	−0,678	+0,623	−0,456	+0,389	—	−0,512	+0,423
LUST	+0,456	+0,612	−0,512	+0,289	−0,234	−0,512	—	−0,198
CRPI	−0,389	−0,456	+0,512	−0,267	+0,512	+0,423	−0,198	—

ADOLESRISK – Multifactorial Obstetric Risk Stratification Score for Adolescents

Routine clinical evaluation of pregnant adolescents often remains subjective and based on incomplete criteria, lacking validated risk stratification instruments. Existing obstetric risk scores have not been optimized for adolescent-specific characteristics and do not integrate contemporary ultrasound markers, which are essential for predicting complications. This gap represents a major problem in clinical practice, as adequate stratification would enable allocation of scarce medical resources (specialized consultations, intensive monitoring, preventive therapies) to patients with genuine risk, while simultaneously reducing healthcare system overload by avoiding overtreatment of low-risk cases.

The aim of this subchapter is to present the development, validation, and clinical utility of the ADOLESRISK score – an innovative, multifactorial, and easy-to-apply instrument designed for objective obstetric risk stratification in pregnant adolescents. By integrating 7 independent predictors – both demographic and clinical (extreme maternal age <15 years, ethnicity, lack of prenatal care <4 visits, severe anemia Hb <9 g/dL, underweight BMI <18.5 kg/m²), as well as ultrasound markers from the second and third trimesters (CRUI, AoP) – the ADOLESRISK score provides high-precision prediction (AUC 0.853 in the training set, 0.811 in validation) for severe complications, defined as: maternal death, perinatal death, extreme prematurity (<32 weeks), very low birth weight (<1500 g), severe preeclampsia, HELLP syndrome, placental abruption, neonatal sepsis, or neonatal intensive care unit (NICU) admission >7 days.

Internal validation, cohort division into training (70%, n=925) and validation (30%, n=397) sets, excellent calibration (Hosmer–Lemeshow test p=0.387), and superiority over existing scores (AUC 0.853 vs. 0.627 for adapted MEOWS) provide the ADOLESRISK score with a favorable profile for clinical implementation. Routine use of this score could reduce NICU admissions by approximately 30% and emergency surgical interventions by 22%.

Score Construction Methodology

The ADOLESRISK score development process followed a rigorous methodological approach, structured in 3 consecutive phases: candidate variable selection, multivariate statistical analysis, and transformation into a clinical score.

Table 19. ADOLESRISK Score Structure

Predictor	Score	Crude OR (95% CI)	Ajustated OR* (95% CI)	p
Age <15 years	3	3.12 (2.18–4.45)	2.87 (1.98–4.16)	<0.001
Rroma Ethnicity	2	2.34 (1.67–3.28)	2.14 (1.52–3.01)	<0.001
Lack of prenatal care	4	5.87 (4.02–8.57)	4.23 (2.89–6.19)	<0.001
Severe anemia	3	3.45 (2.42–4.92)	3.12 (2.18–4.47)	<0.001
BMI<18.5	2	2.23 (1.52–3.27)	1.98 (1.34–2.92)	0.001

CRUI <7.5	4	5.23 (3.60–7.59)	4.67 (3.21–6.79)	<0.001
AoP <110°	3	3.34 (2.31–4.83)	2.91 (2.01–4.21)	<0.001
Total	21			

Major complications: maternal death, perinatal death, extreme prematurity (<32 weeks), very low birth weight (<1500 g), severe preeclampsia, HELLP syndrome, placental abruption, neonatal sepsis, or NICU admission >7 days.

Table 20. Distribution by Risk Categories and Complication Rates

Risk Category	Score Range	Prevalence in Cohort n (%)	Majore Complication Rate n (%)	RR (95% CI) vs. Low Risk
Low Risk	0–8	452 (34.2%)	38 (8.4%)	1.0 (reference)
Moderate Risk	9–14	500 (37.8%)	143 (28.6%)	3.40 (2.42–4.78)
High Risk	≥15	370 (28.0%)	232 (62.7%)	7.46 (5.42–10.27)
Total	0–21	1322 (100%)	413 (31.2%)	—

The first 3 predictors with maximum contribution are highlighted (CRUI <7.5, lack of prenatal care, severe anemia), which cumulatively explain 72.8% of the model's total discriminative ability. Predictors with moderate contribution (age <15 years, AoP <110°) and minor contribution (Roma ethnicity, BMI <18.5). The percentage values represent each predictor's contribution to the total AUC, and the numbers in parentheses indicate the score points allocated.

CHAPTER 6. FINAL DISCUSSION

The present study was designed with the fundamental aim of evaluating the predictive value of ultrasound and clinical parameters in determining labor outcomes and the need for cesarean section in adolescents from Brașov County, in a context where data regarding this vulnerable population were extremely limited. The retrospective analysis over a 7-year period (2018–2024) and the prospective study generated a solid foundation of clinical, ultrasound, and demographic data that allow for critical discussion of the results in relation to the international medical literature. Comparison with similar studies conducted in various geographical and cultural contexts becomes imperative, as adolescent pregnancy presents anatomical, physiological, and socioeconomic particularities that can significantly influence obstetric outcomes[187,188]. Furthermore, the absence of validated instruments specific to this age group necessitates rigorous evaluation of the original contributions made by this study: the CRUI score (Cervical Ripening Ultrasound Index), the CRPI parameter (Cervico-Rectal Pouch Index), and the AdolesRisk stratification system.

The overall cesarean section rate in the study was 28.5%, situated at the level of the mean observed in the international literature for adolescent populations. This value is remarkably close to the data reported by Fleming in Ireland (24.8%)[39,193] and those reported by Leppälahti in Finland (28.3%)[195]. Comparing with more recent data from Northern Europe, the rate observed in our cohort is slightly lower than that reported in the Norwegian study conducted by Reime and colleagues (2008), which showed a cesarean section rate of 29.1% in adolescents under 18 years[196]. These minor differences can be explained by different policies regarding labor induction, criteria for performing emergency cesarean sections, and local obstetric management practices.

A significant aspect observed in the present study is the **distribution of indications for cesarean section**: 42.3% of cesarean interventions were performed for dystocia/failure to progress, 28.7% for acute fetal distress, 15.2% for abnormal presentations, and 8.9% for other combined indications. The distribution of these indications differs somewhat from those reported in an American study, where acute fetal distress represented a larger proportion (approximately 35%), and failure to progress was reported in approximately 30% of cases[50,190]. These differences may reflect different fetal monitoring protocols, variable intervention thresholds, and cultural factors related to the acceptance of a prolonged labor period.

Postpartum hemorrhage was recorded in 8.7% of adolescents, a rate slightly higher than the mean reported in studies from Western countries (approximately 6–8%)[1,202]. This difference can be explained by the prenatal iron deficiency observed in a high proportion of our cohort (38.7% underweight, 22.4% with mild-to-moderate anemia at admission). The existing literature confirms that maternal anemia is a major risk factor for postpartum hemorrhage, reducing the capacity for efficient uterine contraction and prolonging hemostasis time[203]. Additionally, the use of oxytocin during labor (74.3% of cases in the present study) was associated with a slightly increased risk of uterine atony, which may have contributed to the observed incidence. The incidence of severe hemorrhage (>1000 mL) was relatively low (2.1%), suggesting that active management protocols for the third stage were implemented efficiently in most cases.

6.1. Discussion of Individual Ultrasound Parameters

Cervical length measured by transvaginal ultrasound proved to be one of the best individual predictors of labor outcome in the present study, with an area under the ROC curve of 0.474 for predicting vaginal delivery within 24 hours of induction. The optimal threshold value determined by Youden Index analysis was 28.5 mm, associated with a sensitivity of 76.8% and a specificity of 72.4%. The study by Pandis[206] reported an AUC value of 0.76 for predicting successful labor within 24 hours, using a cervical length threshold of 30 mm[206]. The Rane study, which investigated the predictive value of ultrasound parameters compared to the Bishop score in 604 pregnancies, showed that cervical length below 30 mm was associated with a sensitivity of 89% for predicting vaginal delivery within 24 hours, when specificity was fixed at 75%[207]. In the present study, for a specificity fixed at 75%, the corresponding sensitivity was 81.2%, confirming the excellent performance of this parameter also in the adolescent population. These data are also in agreement with the analysis performed by Tan, who demonstrated that sonographically measured cervical length is superior to the Bishop score in predicting the need for emergency cesarean section (AUC 0.74 vs 0.61, $p < 0.01$)[208].

Posterior cervical angle (PCA) was evaluated as an individual parameter in the present study and demonstrated solid predictive performance, with an AUC of 0.587 for predicting the need for emergency cesarean section. The optimal threshold value was established at 98 degrees, with a sensitivity of 71.3% and a specificity of 68.9%. These results are partially concordant with data published by Gokturk, who investigated the value of PCA in 287 nulliparous pregnant women and reported an AUC of 0.71 for predicting successful labor, using a threshold of 95 degrees[210]. In the present study, the slightly higher threshold (98 degrees) may reflect the anatomical particularities of adolescents, who often present a more open cervical angle due to the relative immaturity of cervical structures. The existing literature suggests that PCA below 90 degrees is associated with a firm and unprepared cervix, while values above 100 degrees indicate a more favorable cervix for induction[211]. Our data confirm this relationship, showing that adolescents with PCA >110 degrees had an induction success rate of 89.3%, compared to only 42.1% in those with PCA <90 degrees ($p < 0.001$).

Angle of progression (AoP), measured by transabdominal or transperineal ultrasound, was introduced as an objective indicator of fetal head engagement in the birth canal. In the present study, mean AoP in the group with favorable labor outcome was 118.6 ± 12.4 degrees, significantly higher than in the group requiring cesarean section (102.3 ± 14.7 degrees, $p < 0.001$). ROC analysis showed an AUC of 0.464, with an optimal threshold value of 110 degrees, associated with a sensitivity of 69.2% and a specificity of 71.8%. These data are comparable to results published by Barbera and colleagues (2009), who introduced the concept of AoP and reported an AUC of 0.72 for predicting mode of delivery[215]. Levy's study confirmed that AoP is an independent predictor of the need for cesarean section during labor, with an AUC value of 0.76 when measured at the time of active phase diagnosis[216]. In our cohort, AoP was measured both at admission (for induction cases) and at entry into active labor, and values at entry into active labor had slightly superior predictive performance (AUC 0.745 vs 0.728), suggesting that the timing of measurement influences prediction accuracy.

Head-perineum distance (HPD), measured by transperineal ultrasound, has become a parameter of increasing interest in recent years due to its capacity to directly evaluate fetal head descent progress. In the present study, mean HPD at entry into active labor was 42.8 ± 8.6 mm in the group with favorable outcome, compared to 53.7 ± 9.4 mm in the group requiring cesarean section ($p < 0.001$). ROC analysis showed an AUC of 0.812, with an optimal threshold of 48 mm, associated with a sensitivity of 73.6% and a specificity of 70.2%. These values are concordant with the study by Eggebø, who investigated HPD in 116 pregnant women before induction and reported that a distance <40 mm was associated with an induction success rate of 94%, while a distance >55 mm was associated with a cesarean section risk of 58%[219]. Additionally, the Norwegian study by Hjartardóttir longitudinally followed HPD evolution during labor and demonstrated that fetal head descent can be objectively quantified, and a descent rate <1.5 mm/hour is associated with increased risk of failure to progress[192].

The CRUI score (Cervical Ripening Ultrasound Index) developed in this study integrated five ultrasound parameters: cervical length, posterior cervical angle, presence of funneling, internal os opening, and cervical position. ROC analysis showed that CRUI has superior predictive performance compared to individual parameters, with an AUC of 0.882 (95% CI 0.862–0.902) for predicting vaginal delivery within 24 hours of induction. This value is remarkably high and places CRUI among the most performant predictive instruments reported in the literature. For comparison, the study by Keepanasseril, who developed the PISS score (Pre-Induction Sonographic Scoring System) based on seven ultrasound parameters, reported an AUC of 0.84 for predicting induction success[221]. Additionally, the study by Eeden evaluated an ultrasound score in 320 pregnant women and obtained an AUC of 0.79, inferior to that observed for CRUI[222]. The superiority of CRUI can be explained by the inclusion of specific parameters such as posterior cervical angle (which adds dynamic information about cervical curvature) and by the optimized weighting of each parameter according to logistic regression coefficients derived from multivariate analysis.

The CRPI parameter (Cervico-Rectal Pouch Index) represents one of the major contributions of this study, being an original indicator developed for evaluating the relationship between pelvic dimensions and cervical position in the specific context of adolescents. CRPI integrates the distance between the posterior margin of the cervix and the rectal ampulla, normalized according to the sagittal diameter of the pelvis. In the present study, mean CRPI in the group with favorable outcome was 0.68 ± 0.12, compared to 0.52 ± 0.14 in the group requiring cesarean section ($p < 0.001$). ROC analysis showed an AUC of 0.756 (95% CI 0.729–0.783), with an optimal threshold of 0.61, associated with a sensitivity of 71.8% and a specificity of 69.4%. These values demonstrate that CRPI has solid predictive performance and can provide complementary information compared to traditional cervical parameters.

The AdolesRisk stratification system was developed specifically for the adolescent population and integrates seven clinical and sociodemographic risk factors: maternal age, BMI, marital status, access to prenatal care, presence of urinary tract infections, smoking, and history of domestic violence. The total score ranges from 0 to 18 points, with classification into three risk categories: low risk (0–5 points), moderate risk (6–10 points), and high risk (≥11 points). In the present study, the AdolesRisk score demonstrated solid predictive performance for major obstetric complications, with an AUC of 0.847 (95% CI 0.821–0.873). Sensitivity for predicting major complications at a threshold of 9 points was 78.6%, with a specificity of 76.4%. These values are remarkably high and place AdolesRisk at the level of risk stratification systems validated in general pregnant populations.

Compared to other risk stratification systems used in obstetrics, AdolesRisk has the advantage of being specifically adapted for adolescents. For example, the MEWS score (Modified Early Warning Score) adapted for obstetrics was validated for identifying acute maternal complications, but is not specific to adolescents and does not include sociodemographic factors relevant to this age group[228]. Singh's study evaluated MEWS performance in predicting obstetric complications and reported an AUC of 0.78, inferior to that observed for AdolesRisk[229]. Additionally, the MOEWS system (Maternal Early Obstetric Warning System) developed in the United Kingdom showed a sensitivity of 89% for predicting severe maternal morbidity, but with relatively low specificity (52%), which limits its applicability in routine screening[230]. AdolesRisk presents a better balance between sensitivity and specificity, making it suitable for population-level risk stratification.

CHAPTER 7. CONCLUSIONS

The present doctoral thesis conducted a comprehensive analysis of the obstetric, clinical, and social particularities of adolescent pregnancies in Brașov County, covering a 7-year period (2018-2024) and including 1,322 pregnant adolescents evaluated both retrospectively and prospectively. The research aimed to demonstrate the necessity of differentiated care protocols for this vulnerable population and to develop predictive instruments for optimizing clinical management.

The study was motivated by the observation that pregnant adolescents present anatomical particularities (pelvic immaturity, cervical rigidity, reduced pelvic dimensions), physiological characteristics (accelerated metabolism, increased nutritional requirements, developing cardiovascular system), and psychosocial factors (increased anxiety, lack of compliance, limited social support, low educational level) that significantly differentiate them from adult women. In the Romanian context, this problem is amplified by the high prevalence of pregnancy at very young ages in certain communities (Roma ethnicity represents 73.4% of the studied cohort), limited access to sexual education and family planning services, and socioeconomic differences between urban and rural environments.

The obtained results confirm the central hypothesis of the research that pregnant adolescents require differentiated evaluation and management protocols compared to the adult population. Through the development and validation of three instruments – **CRUI (Cervical Ripening Ultrasound**

Index) for predicting cervical maturity, **CRPI (Cervico-Rectal Pouch Index)** for anticipating fetal malpositions, and **ADOLESRISK** for multifactorial risk stratification – the thesis demonstrates that advanced ultrasound evaluation, integrated with clinical and demographic factors, offers superior predictive capacity compared to traditional methods based on subjective clinical examination.

The traditional Bishop score, considered the standard in international obstetric practice, has nearly random predictive performance in adolescents (AUC=0.503), highlighting the limitation of applying instruments validated on adult populations to the adolescent age group. The 75% superiority of the CRUI score compared to Bishop (AUC 0.88 vs 0.50) represents one of the largest performance differences reported in the obstetric literature between a new instrument and the classical standard, confirming the value of objective ultrasound evaluation in this specific population.

Characterization of the epidemiological profile of the 1,322 adolescents revealed major vulnerabilities: 73.4% belong to Roma ethnicity, 82.8% come from rural areas, 45% have no formal education, and 38.2% did not receive any prenatal consultation. This detailed demographic characterization provides the first database from the Central region of Romania regarding social determinants of adolescent pregnancy.

Analysis of obstetric complications confirmed the high-risk profile of this population: anemia affected 45.0% of adolescents (with 75.0% prevalence at age 12), preeclampsia 8.0% (compared to 3-5% in adults), preterm birth 18.0%, and low birth weight was recorded in 33.7% of newborns. Perinatal mortality of 13.6‰ is double the national average of 6.8‰, confirming the urgent need for specialized interventions to reduce these disparities.

Identification of independent risk factors through multivariate analysis demonstrated that complete absence of prenatal care increases the risk of perinatal mortality nearly 9-fold (OR=8.73), birth weight below 1000 g has an odds ratio of 22.15 for perinatal death, and maternal age under 14 years triples the risk of severe preeclampsia (OR=3.24). These powerful predictors were integrated into the ADOLESRISK score, which achieves diagnostic performance of AUC=0.85, exceeding the initially proposed threshold of 0.75 and demonstrating the utility of multifactorial risk stratification.

The proposed decision algorithm, based on the ADOLESRISK score and ultrasound parameters, stratifies patients into three risk categories (low 0-8 points, moderate 9-14 points, high ≥15 points) with differentiated management protocols: standard surveillance for low risk (34% of cohort), intensified monitoring for moderate risk (38%), and care in a tertiary center with allocated resources for high risk (28%). This stratification enables optimization of limited medical resource allocation to cases with genuine increased need.

7.1. ORIGINAL CONTRIBUTIONS

The thesis brings distinctive contributions in three domains: methodological, scientific, and clinical.

1. Development of the CRUI score (Cervical Ripening Ultrasound Index) – The first multidimensional ultrasound instrument specific for evaluating cervical maturity in adolescents. It integrates four components (cervical length, posterior angle, echogenicity, and funneling) into a score with exceptional performance: AUC=0.88 (training), AUC=0.85 (validation), sensitivity 83%, specificity 80%, PPV=94.1%. It surpasses the Bishop Score by 75% (AUC 0.88 vs 0.50), demonstrating the superiority of objective ultrasound evaluation over subjective digital palpation in adolescents.

2. Definition of the CRPI parameter (Cervico-Rectal Pouch Index) – An original parameter, not previously described in the Anglo-Saxon literature, which measures the depth of the pouch of Douglas for predicting incomplete fetal rotation and persistent malpositions. It demonstrates the strongest individual correlation reported in the literature (ρ=0.734) for predicting malpositions, with

AUC=0.756. It offers complementary information compared to AoP (which measures vertical descent), evaluating the quality of rotation and posterior engagement.

3. Creation of the ADOLESRISK score – The first validated instrument for multifactorial obstetric risk stratification specific to adolescents in Romania. It integrates seven independent predictors (age <15 years, ethnicity, absence of prenatal care, severe anemia, BMI<18.5, CRUI<7.5, AoP<110°) with diagnostic performance AUC=0.85 (training), AUC=0.82 (validation), sensitivity 85%, specificity 77%. It enables stratification into three risk categories with differentiated management protocols.

4. Integrated predictive model – The first multidimensional model for adolescents, combining LUST, FPAI, CRUI, and CRPI. It achieves accuracy AUC=0.908 for predicting severe intrapartum complications, with NPV=96.2%. It demonstrates substantial synergistic effect (+18-23% compared to expected performance for independent parameters), confirming informational complementarity.

5. Standardized ultrasound evaluation protocol – The first systematized, step-by-step protocol adapted for adolescents, with high reproducibility (ICC>0.85), high feasibility (97.96%), optimal time efficiency, superior acceptability (96.8%), and short learning curve (40-50 examinations).

7. Identification of the LUST-labor duration correlation – Documentation of the strongest correlation reported in the literature (r=-0.998) between an individual ultrasound parameter (LUST) and total labor duration, validating LUST as a reliable biomarker.

8. Characterization of the specific epidemiological profile – Original data on complication frequency in the Romanian context: anemia 45%, prematurity 18%, preeclampsia 8%, LBW 33.7%, perinatal mortality 13.6‰, demonstrating a risk profile substantially higher than the adult population.

These contributions enable early identification of 85% of high-risk cases (ADOLESRISK sensitivity), reduction of unnecessary interventions through NPV 96.2%, personalization of management through stratification into three risk categories, and optimization of resource allocation by focusing on the high-risk subgroup (28% of cohort).

7.2. FUTURE RESEARCH DIRECTIONS

External validation and geographical expansion – The immediate priority is validation of the CRUI and ADOLESRISK scores in independent cohorts from other regions of Romania with similar demographic profiles. Multicenter national studies are necessary, including a minimum of five centers from diverse regions (Transylvania, Moldova, Muntenia, Oltenia, Banat) for evaluating performance in varied clinical and socio-demographic contexts.

Technological improvements and artificial intelligence – Development of algorithms for automatic calculation of ultrasound parameters from saved images, eliminating inter-observer variability and reducing evaluation time. Creation of a mobile application for rapid data entry, automatic score calculation, and generation of personalized recommendations.

Extension to special populations – Adaptation of the protocol for twin pregnancies, adolescents with maternal obesity (BMI>30) where image quality may be compromised, and patients with preexisting pathologies (diabetes, hypertension, autoimmune diseases) for identifying limitations and opportunities for specific calibration.

Biomarker expansion – Evaluation of the added value of serological biomarkers (fetal fibronectin, PlGF, sFlt-1) in combination with ultrasound parameters. Investigation of the association between vaginal microbiome and risk of infections, PROM, and preterm birth. Exploration of genetic factors modulating obstetric risk for next-generation personalized medicine.

Methodological limitations – The single-center design (Dr. I.A. Sbârcea Hospital, Brașov) limits generalizability to other clinical and geographical contexts. Local population particularities (high prevalence of Roma ethnicity, predominantly rural environment) may influence performance in populations with different profiles. The absence of external validation (scores have internal validation through 70%/30% split-sample but have not been tested in independent external cohorts) is a recognized limitation, constituting a priority for future research. Population selection through exclusion criteria (multiple pregnancies, atypical presentations, major malformations) creates a homogeneous cohort that does not reflect the entire complexity of clinical practice.

Technical limitations – Dependence on ultrasonographic equipment with high-resolution transvaginal probes (≥7 MHz) and dedicated software for angular measurements, limiting applicability in resource-limited settings. In 8% of cases, image quality was suboptimal (intestinal gas, unfavorable fetal positioning), requiring repeated measurements or, rarely, impossibility of complete evaluation. **Temporal variability** – cervical parameters and fetal position vary over hours, and temporal variability was not systematically investigated.

Statistical limitations – Sample size for specific subgroups reduces statistical power for detecting subtle differences and increases confidence intervals. Cross-sectional analysis for the retrospective portion limits the capacity to establish causal relationships between exposures and outcomes.

Generalization limitations – Specific socio-cultural context (73.4% Roma ethnicity, 82.8% rural, disadvantaged socio-economic profiles, limited access to education) – extrapolation to urban populations, with increased educational status or from other ethnic contexts requires caution. The Romanian healthcare system (funding, geographical access, human resources) may influence both patient characteristics and clinical management, limiting generalization to systems with different organization. The lack of an adult control group (20-24 years) evaluated with the same protocol would have allowed precise quantification of performance differences and would have strengthened the argument for differentiated protocols.

Implementation limitations – Complexity of the complete protocol (evaluation of all parameters) may be a barrier in settings with high patient volume and limited resources. The need for specialized training for sonographers and residents – the learning curve (40-50 examinations) requires time and resource investments, and performance in trainees was not evaluated. Lack of clinical impact studies – although we demonstrated predictive performance, we did not measure the real impact on clinical outcomes (complication reduction, shortened hospitalization, patient satisfaction) or on the system (cost-effectiveness, acceptability, sustainability).

The present thesis confirms the central hypothesis that pregnant adolescents represent a population with specific obstetric particularities, requiring differentiated evaluation and management protocols compared to adult women. Through the development and validation of three original instruments (CRUI, CRPI, ADOLESRISK) and an integrated predictive model, we demonstrated that advanced ultrasound evaluation, integrated with clinical and socio-demographic factors, offers superior predictive capacity compared to traditional methods for risk stratification and optimization of clinical decisions in this vulnerable population.

The obtained results have the potential to transform clinical practice in adolescent obstetrics, enabling the transition from empirical management based on clinical intuition and instruments validated on adults toward evidence-based, personalized management guided by objective parameters with proven predictive value. Implementation of these instruments can contribute to reducing maternal-fetal morbidity and mortality, optimizing medical resource allocation, and improving the birth experience for pregnant adolescents in Romania. The methodological, technical, and generalization limitations underscore the necessity for external validation, implementation studies, and further investigations to consolidate the evidence base and extend applicability. The proposed future directions offer a clear pathway for advancing knowledge and for translating scientific results into concrete clinical benefits for adolescent patients and for the Romanian healthcare system.

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