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TA'LIMI & INNOVATSIYALARI

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- 14.00.02 - Morfologiya;
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- 14.00.04 - Otorinolaringologiya;
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- 14.00.06 - Kardiologiya;
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- 14.00.09 - Pediatriya;
- 14.00.10 - Yuqumli kasalliklar;
- 14.00.11 - Dermatologiya va venerologiya;
- 14.00.12 - Tibbiy reabilitologiya;
- 14.00.13 - Nevrologiya;
- 14.00.14 - Onkologiya;
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- 14.00.19 - Klinik radiologiya;
- 14.00.20 - Tibbiy genetika;
- 14.00.21 - Stomatologiya;
- 14.00.22 - Travmatologiya va ortopediya;
- 14.00.23 - Hamshiralik ishini tashkil etish;
- 14.00.24 - Sud tibbiyoti;
- 14.00.27 - Xirurgiya;
- 14.00.28 - Neyroxirurgiya;
- 14.00.41 - Xalq tabobati;
- 14.00.35 - Bolalar xirurgiyasi;
- 14.00.34 - Yurak-qon tomir xirurgiyasi

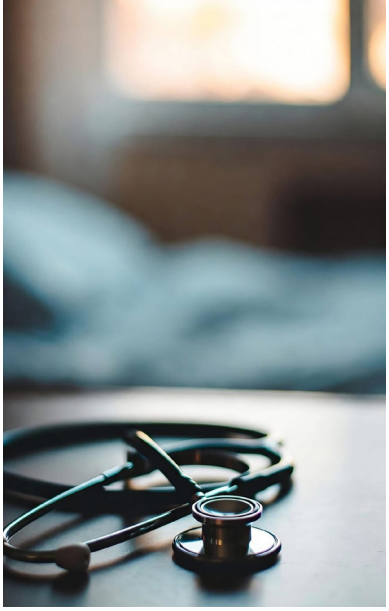
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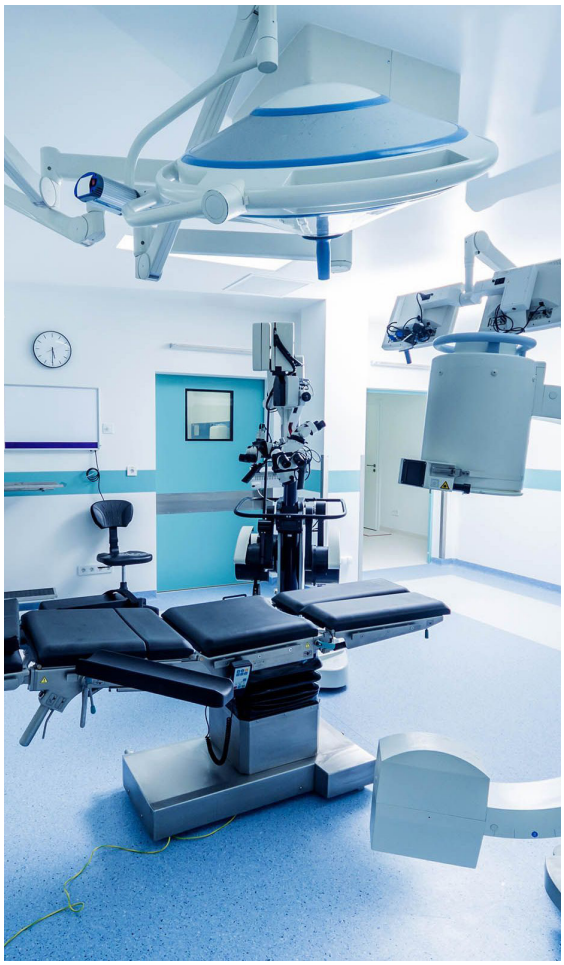
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MUNDARIJA

ОЦЕНКА РЕЗУЛЬТАТОВ КОМПЛЕКСНОГО ЛЕЧЕНИЯ ОСТЕОМИЕЛИТА ВЕРХНЕЙ ЧЕЛЮСТИ У БОЛЬНЫХ САХАРНЫМ ДИАБЕТОМ 2 ТИПА 22
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ARTIFICIAL INTELLIGENCE FOR ULTRASOUND ESTIMATION OF FETAL WEIGHT: OPPORTUNITIES, EVALUATION METRICS, AND COMPARISON WITH THE HADLOCK FORMULA

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Abstract: Background: Knowing the estimated fetal weight before delivery is important for assessing fetal growth and planning obstetric care. The Hadlock formula has remained the principal method for ultrasound-based fetal weight estimation for decades; however, its individual prediction errors remain real and measurable. Machine-learning methods, in turn, offer the possibility of identifying nonlinear relationships between fetal biometric measurements and clinical context that fixed equations cannot capture. Main body: This narrative review examines established ultrasound-based formulas, analyses the findings of recent machine-learning studies, and discusses how estimated fetal weight should be compared with actual birth weight. The most informative evaluation metrics include absolute error, mean absolute percentage error (MAPE), the proportion of predictions within ±10% of actual birth weight, systematic bias and Bland–Altman limits of agreement, as well as predictive accuracy across clinically relevant weight categories. Particular attention should be paid to the interval between ultrasound examination and delivery, as the fetus continues to grow after the measurements have been taken. Conclusion: Artificial intelligence represents a genuinely promising approach to improving the accuracy of fetal weight estimation. However, better statistical performance does not necessarily translate into better medical care. Before any model is introduced into clinical practice, it must undergo external validation, calibration assessment, and evaluation of its effectiveness across clinically relevant subgroups.

Key words: artificial intelligence; machine learning; estimated fetal weight; ultrasonography; fetal biometry; Hadlock formula; prediction error; pregnancy.

Annotatsiya: Dolzarblik: Tug‘ruqdan oldin homilaning taxminiy vaznini bilish uning o‘sishini baholash va akusherlik yordamini rejalashtirish uchun muhim ahamiyatga ega. Hadlock formulasi o‘nlab yillar davomida homila vaznini ultratovush tekshiruvi yordamida aniqlashning asosiy usuli bo‘lib kelgan, biroq ushbu usulning individual xatoliklari hanuzgacha mavjud va ularni o‘lchash mumkin. Mashinaviy o‘rganish usullari esa, o‘z navbatida, qat’iy tenglamalar orqali ifodalab bo‘lmaydigan homila biometrik ko‘rsatkichlari va klinik kontekst o‘rtasidagi chiziqli bo‘lmagan bog‘liqliklarni aniqlash imkonini beradi. Asosiy qism: Ushbu tavsifiy sharhda umumqabul qilingan ultratovush formulalari ko‘rib chiqiladi, mashinaviy o‘rganish sohasidagi so‘nggi tadqiqotlar natijalari tahlil qilinadi hamda homilaning hisoblangan vaznini tug‘ilishdagi haqiqiy vazni bilan qanday taqqoslash kerakligi muhokama qilinadi. Eng muhim baholash mezonlari — absolyut xato, o‘rtacha absolyut foizli xato (MAPE), bashoratlarning tug‘ilishdagi haqiqiy vazndan ±10% chegarada joylashgan ulushi, Bland–Altman usuli bo‘yicha tizimli siljish va kelishuv chegaralari, shuningdek, klinik jihatdan muhim vazn toifalari bo‘yicha bashorat aniqligidir. Ultratovush tekshiruvi o‘tkazilgan vaqt bilan tug‘ruq orasidagi interval alohida e’tiborga loyiq, chunki homila o‘lchov o‘tkazilgandan keyin ham o‘sishda davom etadi. Xulosa: Sun’iy intellekt homila vaznini baholash aniqligini oshirish uchun haqiqatan ham istiqbolli yo‘nalish hisoblanadi. Biroq statistik ko‘rsatkichlarning yaxshilanishi tibbiy yordam sifatining yaxshilanishini har doim ham anglatmaydi. Har qanday model klinik amaliyotga joriy etilishidan oldin tashqi validatsiyadan o‘tkazilishi, kalibrlash sifati tekshirilishi va klinik jihatdan muhim kichik guruhlarda samaradorligi ilmiy dalillar bilan tasdiqlanishi zarur.

Kalit so‘zlar: sun’iy intellekt; mashinaviy o‘rganish; homilaning taxminiy vazni; ultratovush tekshiruvi; homila biometriyasi; Hadlock formulasi; bashorat xatosi; homiladorlik.

Аннотация: Актуальность: Знание предполагаемой массы плода до родов важно для оценки его роста и планирования акушерской помощи. Формула Хадлока на протяжении десятилетий оставалась основным методом ультразвукового определения массы плода, однако индивидуальные погрешности этого метода остаются реальными и измеримыми. Методы машинного обучения, в свою очередь, позволяют выявлять нелинейные связи между фетометрическими показателями и клиническим контекстом, которые не могут быть отражены фиксированными уравнениями. Основная часть: В данном нарративном обзоре рассматриваются общепринятые ультразвуковые формулы, анализируются результаты недавних исследований в области машинного обучения и обсуждается, каким образом следует сопоставлять расчётную массу плода с массой тела при рождении. Наиболее информативными показателями являются абсолютная погрешность, средняя абсолютная процентная ошибка (MAPE), доля прогнозов, находящихся в пределах ±10% от фактической массы тела при рождении, систематическое смещение и границы согласия по Блэнду–Альтману, а также точность прогнозирования в клинически значимых категориях массы. Особого внимания заслуживает интервал между ультразвуковым исследованием и родами, поскольку плод продолжает расти и после проведения измерения. Заключение: Искусственный интеллект представляет собой действительно перспективное направление для повышения точности оценки массы плода. Однако более высокие статистические показатели не обязательно означают улучшение качества медицинской помощи. Прежде чем какая-либо модель будет внедрена в клиническую практику, необходимы внешняя валидация, проверка калибровки и подтверждение её эффективности в клинически значимых подгруппах.

Ключевые слова: искусственный интеллект; машинное обучение; расчётная масса плода; ультразвуковое исследование; фетометрия; формула Хадлока; ошибка прогноза; беременность.

INTRODUCTION

The paper explains the importance of estimated fetal weight (EFW) before delivery, as this enables clinicians to assess fetal growth, identify suspected fetal growth restriction or macrosomia, and plan delivery [2,12]. EFW is not measured directly; rather, it is calculated using ultrasound biometric measurements (biparietal diameter [BPD], head circumference [HC], abdominal circumference [AC], and femur length [FL]). Consequently, image quality, the selected estimation equation, fetal characteristics, and the clinical setting can all influence the result [6,9].

Well-documented limitations include substantial intraobserver and interobserver variability, as well as the fact that no single formula performs best in every clinical setting [6,9,12]. The Hadlock equations, published in the 1980s, remain the standard method [1,5]; however, individual prediction errors are real and measurable [2,3]. The stated aim of this paper is to provide a narrative methodological review of the potential contribution of artificial intelligence (AI) to ultrasound-based fetal weight estimation and to examine how machine-learning models can be fairly compared with the Hadlock formula. The paper does not propose a newly developed or validated model.

LITERATURE REVIEW

The review covers: (1) established ultrasound-based estimation equations, including Hadlock [1] (BPD, HC, AC, FL), Shepard [7] (BPD, AC), Campbell [8] (AC alone), Combs [10] (fetal volume-based), and the INTERGROWTH-21st gestational-age-specific estimated fetal weight standards [11]; (2) systematic reviews documenting measurement variability and persistent errors associated with existing estimation formulas [2,12,13]; and (3) recent machine-learning studies [14], including a study involving 3,525 pregnancies that compared machine-learning models, including TabPFN, with traditional estimation equations [4], and a larger multicentre study involving 9,674 singleton pregnancies that compared LightGBM and XGBoost with the Hadlock formula [5]. The latter demonstrated improved overall birth-weight prediction but only modest improvements in percentile classification. The review also highlights an important distinction that is frequently overlooked: predicting fetal weight as a continuous numerical variable is fundamentally different from classifying fetuses as small or large for gestational age.

Table 1. Examples of published approaches to ultrasound-based fetal-weight estimation. The original publications should be consulted to confirm equation coefficients, units, and implementation details

Method	Biometric inputs	Equation or principle	Role of gestational age (GA)
Hadlock IV	BPD, HC, AC, FL	log10(EFW) = 1.3596 + 0.0064·HC + 0.0424·AC + 0.174·FL + 0.00061·BPD·AC − 0.00386·AC·FL [1,3]	GA is generally used to interpret EFW by percentile; it is not directly in this equation.

Shepard	BPD, AC	log10(EFW) = −1.7492 + 0.166·BPD + 0.046·AC − 0.002646·AC·BPD [7]	GA is used when interpreting the estimate against growth references.
Campbell	AC	ln(EFW) = −4.564 + 0.282·AC − 0.00331·AC² [8,9]	GA supports assessment of growth appropriateness.
Combs	AC, FL, HC	EFW = 0.23718·AC²·FL + 0.03312·HC³ [10]	GA is needed to compare with gestational-age-specific norms.
INTERGROWTH-21st	AC, HC for EFW; GA for centiles	Published EFW model and gestational-age-specific standards [11]	Standards provide EFW percentiles across approximately 22–40 weeks.
Machine learning	May include BPD, HC, AC, FL, GA and selected clinical variables	No single universal equation; the model is trained on a dataset [4,5]	GA may be a predictor and/or used for percentile-based interpretation.

Note: EFW is expressed in grams (in kilograms for Shepard and Campbell) and biometric inputs in centimetres in the equations shown above; confirm the exact units and logarithm convention in each original source before implementation.

RESEARCH METHODOLOGY

This study is a narrative review based on selected cited publications rather than a systematic review. No reproducible systematic search strategy was employed, as no database list, search strings, or study selection protocol was documented. The methodological core of the study is a proposed framework for ensuring a fair comparison between Hadlock and machine learning (ML) models. Both approaches should be evaluated using the same eligible observations and identical outcome definitions. Data from a single pregnancy must never be divided between training and test sets. Separate training and validation datasets should be used, with final model performance assessed on an independent held-out test set. External validation in a different institution or population should also be required. Furthermore, the predictor set should be predefined based on clinical relevance rather than selected solely to improve model performance. The recommended evaluation metrics are presented in a structured format and include absolute error, mean absolute percentage error (MAPE), the percentage of predictions falling within ±10% of birth weight, systematic bias assessed using Bland–Altman limits of agreement, and model performance in clinically relevant low- and high-birth-weight categories. The risk of bias should be assessed in accordance with the PROBAST+AI framework [15].

Table 2. Recommended metrics for comparing Hadlock with candidate AI models

Metric	What it measures	Reporting note
Absolute error (AE), g	Magnitude of the difference for each case	Report the distribution and the mean/median.
Mean absolute percentage error (MAPE), %	Average relative magnitude of error	Define the calculation and report uncertainty where possible.
Predictions within ±10%, %	Proportion of estimates close to birth weight	Use alongside other metrics, not as the sole measure.
Bias and Bland–Altman limits	Average over/underestimation and range of agreement	Assess whether error varies with birth weight.
Low/high weight classification	Ability to identify clinically relevant categories	Specify the gestational-age reference standard and classification metrics.

ANALYSIS AND RESULTS

The analysis highlights several important methodological considerations. Mean error reflects the extent of systematic overestimation or underestimation of fetal weight, whereas percentage error is calculated as (EFW − birth weight)/birth weight × 100% and is commonly summarized using the mean absolute percentage error (MAPE). Although the ±10% accuracy threshold is widely used, it is insufficient as a standalone measure of model performance. Particular attention should be paid to the interval between ultrasound examination and delivery. When several weeks elapse between the scan and birth, the observed discrepancy between estimated fetal weight (EFW) and actual birth weight partly reflects normal fetal growth rather than measurement error

alone. Therefore, studies should define an acceptable scan-to-delivery interval a priori and conduct sensitivity analyses to assess the effect of variations in this interval. Gestational age is generally not incorporated directly into the fetal weight estimation equation itself. Instead, it is subsequently used to determine weight percentiles against established reference curves. Consequently, accuracy in estimating fetal weight in grams and accuracy in classifying fetal size relative to gestational age should be reported separately.

The available evidence also has several limitations. Differences in study populations, ultrasound protocols, predictor variables, and outcome definitions mean that favourable results obtained in development cohorts may not necessarily be generalizable to other clinical settings. Machine learning models introduce additional methodological risks, including overfitting, data leakage, missing data, and under-representation of clinically important subgroups [15]. Furthermore, superior average predictive performance alone does not establish clinical utility. Model calibration, subgroup-specific performance, and the clinical consequences of false-positive and false-negative predictions must also be considered. Ultimately, predictive models should support clinical decision-making rather than replace professional clinical judgement.

CONCLUSION

The Hadlock formula remains an established method for estimating fetal weight, despite the possibility of individual prediction errors. Artificial intelligence represents a promising approach to improving the accuracy of fetal weight estimation; however, its superiority must be demonstrated using real-world clinical data and independent validation cohorts rather than assumed. Before any predictive model is introduced into clinical practice, it should undergo external validation, calibration assessment, and evaluation of its effectiveness across clinically meaningful subgroups.

Future studies should prospectively specify the intended clinical application, clearly define inclusion criteria and the acceptable scan-to-delivery interval, and compare conventional equations with machine learning models using the same eligible observations and outcome definitions. External validation should be incorporated into the study design. Ultimately, clinical value should be determined by improvements in clinical decision-making and patient outcomes rather than statistical performance metrics alone.

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