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Development and Validation of an AI-Based Decision Support Tool (PROMETHEUS) for Predicting Methotrexate Success in Ectopic Pregnancy

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Abstract

Objective

*E*ctopic pregnancy (EP), a life-threatening condition in early pregnancy, requires accurate and timely management to reduce morbidity and mortality. While methotrexate therapy is a widely used non-invasive treatment, predicting its success remains challenging. This study introduces PROMETHEUS (Prediction of Methotrexate for Ectopic Pregnancy Treatment Success), an AI-driven decision support tool designed to assist clinicians in selecting optimal treatment strategies, aiming to minimize unnecessary surgeries and enhance patient outcomes.

Methods

A retrospective nested cohort study analyzed 602 cases of EP diagnosed at Tepecik Education and Research Hospital between 2013 and 2023. Patients were grouped based on treatment received: single-dose methotrexate, two-dose methotrexate, surgery, or surgery following failed methotrexate therapy. Twenty-four clinical parameters were recorded, with 22 included in the final analysis. PROMETHEUS was developed using 15 AI algorithms, including Bagging, J48, and Random Forest. The dataset was divided into training (80%) and validation (20%) cohorts.

Results

Key findings highlighted significant clinical differences between treatment groups, such as larger ectopic mass sizes and altered blood counts in patients requiring surgery after methotrexate failure. All algorithms used for modelling Prometheus achieved high accuracy ($p < 0.001$), of them Bagging algorithm demonstrated an optimal balance between sensitivity (92.7%) and specificity (94.8%), along with the highest AUC (93.8%) ($p < 0.001$).

Conclusion

PROMETHEUS represents an innovation in ectopic pregnancy management, offering a high-accuracy AI-based decision support tool to optimize methotrexate therapy selection. This innovation has the potential to reduce treatment-related morbidity, streamline clinical workflows, and enhance personalized care. Future multi-institutional studies are needed to validate PROMETHEUS or similar AI-based applications and expand their clinical applicability.

Synopsis; An AI-driven tool, PROMETHEUS, achieved 93.86% accuracy in predicting methotrexate success for ectopic pregnancy, optimizing treatment decisions and reducing unnecessary surgeries.

Introduction

Ectopic pregnancy (EP), a condition in which the embryo implants outside the uterine cavity, remains a significant cause of morbidity and mortality during the first trimester of pregnancy [1]. Despite

advancements in early diagnosis through transvaginal ultrasonography and beta-hCG monitoring, ectopic pregnancies continue to pose a life-threatening risk if not promptly treated [2]. Approximately 2% of all pregnancies are ectopic, making it a prevalent concern in obstetric care[3].

Management of ectopic pregnancy has evolved significantly, offering three primary treatment options: expectant management, medical therapy, and surgery [4]. Among these, medical treatment with methotrexate has gained prominence due to its non-invasive nature and high success rates, approaching 90% in well-selected cases[5]. Methotrexate, a folic acid antagonist, interferes with DNA synthesis, providing a viable alternative to surgical interventions, which remain the gold standard in certain clinical scenarios. However, a subset of patients may still require surgery following methotrexate therapy, either due to treatment failure or misclassification of the patient's condition. underscoring the need for accurate treatment selection.

The integration of artificial intelligence (AI) into clinical decision-making has recently sparked interest as a means to enhance diagnostic accuracy and optimize treatment strategies [6]. Despite this potential, the application of AI in predicting methotrexate success for ectopic pregnancies is still in its infancy. While a few studies have explored AI-based decision support systems for ectopic pregnancy, further research is essential to refine these models and improve their clinical utility [7, 8].

This study aims to develop and validate an AI-driven clinical decision support system, PROMETHEUS (Prediction of Methotrexate for Ectopic Pregnancy Treatment Success), to assist gynecologists in selecting the optimal treatment strategy for patients with ectopic pregnancy. Designed to function as an easily accessible mobile application, PROMETHEUS was developed to improve accuracy in predicting treatment success, with the goal of reducing unnecessary surgeries and enhancing patient outcomes.

Methods

This retrospective nested cohort study, as outlined in Fig. 1, was conducted using 1,003 electronic medical records of women diagnosed with ectopic pregnancy, with or without first trimester complications, at Tepecik Education and Research Hospital between January 2013 and January 2023. Ethics approval was obtained from the Non-Interventional Clinical Research Ethics Committee of the University of Health Sciences (S.B.Ü) Tepecik Education and Research Hospital (E.A.H.) on 06/06/2023, under approval number 2023/05–12, ensuring compliance with all relevant regulations.

Study population

To be eligible for inclusion, patients required a confirmed diagnosis of ectopic pregnancy and must have undergone at least one form of treatment—either medical (e.g., methotrexate administration) or surgical (e.g., salpingectomy or salpingostomy). Recognizing the limitations inherent in retrospective data collection, the study excluded patients with missing or incomplete data to reduce bias and maintain dataset integrity. Additionally, patients with incomplete demographic or clinical information, cases of

heterotopic pregnancy, suspected or confirmed ruptured ectopic pregnancy (EP), and clinically unstable patients were excluded, as these factors could introduce variability unrelated to treatment effects being analyzed. These complex clinical scenarios were intentionally excluded during the initial development phase to ensure the creation of a stable and generalizable model based on well-defined cases. Expectant management cases were excluded from the analysis due to both the low number of patients managed this way and the high rate of missing or incomplete documentation in their retrospective records. As a result, these cases could not provide reliable input for algorithm development and were not incorporated into the predictive modeling phase.

A total of 602 patients meeting the study criteria were included in the analysis. Of the 602 patients, 80% (n = 482) were randomly assigned to the training set and 20% (n = 120) to the validation set. For descriptive and demographic comparisons, patients were categorized into four groups based on the treatment they received: (1) single-dose methotrexate, (2) two-dose methotrexate, (3) primary surgery, and (4) surgery following failed methotrexate therapy. However, the primary goal of the model was to predict the success or failure of methotrexate treatment. Therefore, for algorithm development and performance evaluation, patients were ultimately regrouped into two main categories: those successfully treated with MTX and those who required surgical intervention. This binary classification allowed for more effective model training and reflects the tool's practical use in supporting treatment selection.

Parameters and Parameter Selection

For each eligible patient, 24 parameters were recorded, covering categories such as medical history, physical examination findings, ultrasound examination results, and laboratory tests conducted at the time of hospital admission. These parameters were selected to capture critical aspects of ectopic pregnancy presentation, diagnosis, and response to treatment, with priority given to those frequently reported in the literature as associated with ectopic pregnancy outcomes.

The medical histories of patients presenting to our clinic are routinely obtained by obstetrics and gynecology residents and documented on pre-prepared forms. Initial examinations are conducted either in the emergency department or outpatient clinics by resident physicians under the supervision of specialists, or directly by specialists, depending on the point of admission. All patients admitted with a diagnosis of ectopic pregnancy underwent ultrasonographic examination by experienced obstetrics and gynecology specialists using standardized devices, either the Voluson E6 or Samsung Sonoace R7. All blood analyses adhered to standardized laboratory protocols and were performed using automated biochemical and hematology analyzers (Olympus AU5400, Tokyo, Japan, and Beckman Coulter AU 5800).

On the other hand, certain parameters available in the administration system were not used in the analysis. As such, parameters recorded after the treatment decision, such as beta-hCG levels on days 4 and 7 or hCG ratios, were deliberately excluded. This approach was adopted to preserve the model's

applicability in real-time clinical decision-making, where only baseline values are available at the moment of treatment selection.

Testing and Evaluation

The 24 parameters identified for analysis were used to develop a deep learning-based decision support system, evaluated across 15 different artificial intelligence algorithms to achieve the highest possible accuracy. The algorithms included ClassificationViaRegression, J48, Bagging, DecisionTable, LogitBoost, RandomForest, Jrip, BayesNet, Logistic, MultiClassClassifier, NaiveBayes, MLPClassifier, RandomTree, SMO, and MultilayerPerceptron aiming to identify the most accurate model for decision support.

Of the 602 patients included in the study, 80% were used for training the decision support system, while the remaining 20% were reserved for validation/evaluation. During model development, some clinically significant variables were excluded, class attributes were adjusted, and data attributes were updated to introduce variations in the dataset. As a result of this evaluation, the top 5 most accurate algorithms were identified using 22 of the 24 parameters. History of previous ectopic pregnancy and vaginal bleeding were not included in the final predictive model due to their inconsistent behavior during feature selection. Although statistically significant in univariate analysis, these variables acted as potential sources of noise or outliers within the multivariate context, reducing overall model stability and predictive clarity. Therefore, they were excluded to preserve the robustness and accuracy of the algorithm. The parameters and how they were encoded in the algorithm are summarized in the Table 1.

Table 1
Database attributes

Attributes	Description
Patient History	
Age	Enter the patient's age in numeric format (e.g., 34)
Gestational age based on last menstrual period	Calculated in days rather than weeks for ease of use, enter in numeric form (e.g., 43)
Presence of intrauterine device (IUD)	Indicate whether the patient has an IUD by selecting "Yes" or "No"
IVF pregnancy	Indicates that the pregnancy was conceived through in vitro fertilization (IVF) by selecting "Yes" or "No"
Abdominal examination	
Pelvic Pain	Indicates the presence of pelvic pain at admission; select "Yes" or "No"
Guarding	Indicates the presence of guarding at admission; select "Yes" or "No"
Rebound tenderness	Indicates the presence of rebound at admission; select "Yes" or "No"
Tenderness	Indicates the presence of tenderness at admission; select "Yes" or "No"
Ultrasound findings	
Tubal hematoma	Indicate the presence of tubal hematoma on ultrasound at initial admission by selecting "Yes" or "No"
Size of EP	Multiply values measured in millimeters on the 2D ultrasound; enter the result in numeric form (e.g., 6577 mm^2)
GS	Indicate presence of Gestational Sac (GS) on ultrasound at initial admission by selecting "Yes" or "No"
YS	Indicate presence of Yolk Sac (YS) on ultrasound at initial admission; select "Yes" or "No"
CRL	Indicate presence of measurable Crown-rump length (CRL) at initial ultrasound; select "Yes" or "No"
FCA	Indicate presence of Fetal Cardiac Activity (FCA) on ultrasound at initial admission; select "Yes" or "No"
Presence of free fluid	Indicate presence of free fluid observed on ultrasound at the initial admission; select "Yes" or "No"
Laboratory findings	

Attributes	Description
HGB	Hemoglobin (Hb) level at initial presentation, enter in numeric form (e.g., 13.1 g/dL)
WBC	White blood cell (WBC) level at initial presentation, enter in numeric form e.g., 8.1 x 10^3/μL).
PDW	Platelet distribution width (PDW) level at initial presentation, enter in numeric form (e.g., 16.7%)
PLT	Platelet (PLT) level at initial presentation, enter in numeric form (e.g., 245 x 10^3/μL)
NEU	Neutrophil level at initial presentation, enter in numeric form (e.g., 4.9 x 10^3/μL)
LYM	Lymphocyte level at initial presentation, enter in numeric form (e.g., 2.2 x 10^3/μL)
Beta_W1	Beta-HCG level at initial presentation, enter in numeric form (e.g., 630 mıU/mL)

Results

Study population characteristic

The demographic data of the 602 pregnant women diagnosed with ectopic pregnancy (EP) are presented in Table 2. No statistically significant differences were observed between the ages of the patients and the gestational ages based on their last menstrual period. However, in patients with history of ectopic pregnancy was significantly lower (p = 0.001). Physical examination findings were more commonly observed in patients who required surgical intervention following initial medical treatment (p = 0.001).

Table 2
Demographic data of participants

Variable	First Dose MTX (225, 37.4%)	Second Dose MTX (52, 8.6%)	Surgery (259, 43%)	Surgery after MTX Therapy (66, 11%)	P-Value
Age	31.4 ± 5.5	30 ± 4.8	31.1 ± 5.7	32.1 ± 5	0.244
History of Previous Ectopic Pregnancy	21 (9.3%)	8 (15.3%)	17 (6.5%)	10 (15.2%)	0.001
Gestational Age by Last Menstrual Period (days)	37.7 ± 13.5	38.3 ± 14.8	35.1 ± 16.1	39.6 ± 14.1	0.064
Presence of Intrauterine Device	17 (7.5%)	3 (5.7%)	27 (10.4%)	2 (3%)	0.203
IVF Pregnancy	11 (4.8%)	1 (1.9%)	7 (2.7%)	2 (3%)	0.531
Presence of Pelvic Pain	144 (64%)	31 (59.6%)	235 (90.7%)	47 (71.2%)	< 0.001
Presence of Vaginal Bleeding	87 (38.6%)	28 (53.4%)	163 (62.9%)	37 (56%)	< 0.001
Presence of Guarding	9 (4.01%)	2 (3.8%)	145 (55.9%)	13 (19.6%)	< 0.001
Presence of Rebound Tenderness	5 (2.2%)	-	95 (36.6%)	5 (7.5%)	< 0.001
Presence of Tenderness	98 (43.5%)	26 (50%)	210 (81.8%)	38 (57.5%)	< 0.001
Tubal Hematoma Observed on Ultrasound	-	-	5 (1.9%)	-	0.049
Mass Size on Ultrasound (mm^2)	8140 ± 4350	6577 ± 3722	8957 ± 4090	9318 ± 4971	< 0.001
Presence of Gestational Sac on Ultrasound	18 (8%)	2 (3.8%)	90 (34.7%)	12 (18.1%)	< 0.001
Presence of Yolk Sac on Ultrasound	7 (3.1%)	-	61 (23.5%)	7 (10.6%)	< 0.001
Presence of Measurable CRL on Ultrasound	6 (2.6%)	-	49 (18.1%)	7 (10.6%)	< 0.001
Presence of FCA on Ultrasound	2 (0.89%)	-	29 (11.9%)	-	< 0.001

Variable	First Dose MTX (225, 37.4%)	Second Dose MTX (52, 8.6%)	Surgery (259, 43%)	Surgery after MTX Therapy (66, 11%)	P-Value
Presence of Free Fluid in Abdomen on Ultrasound	62 (27.5%)	18 (34.6%)	202 (77.9%)	27 (40.9%)	< 0.001
Hemoglobin (Hgb) Level at Admission	11.6 ± 1.3	12 ± 1.2	11.2 ± 1.5	11.9 ± 1.3	< 0.001
White Blood Cell (WBC) Level at Admission	8.1 ± 2.2	8.3 ± 2.5	10.2 ± 3.6	9.1 ± 2.8	< 0.001
PDW Level at Admission	16.7 ± 0.50	16.8 ± 0.32	16.7 ± 0.53	16.7 ± 0.53	0.428
Platelet (PLT) Level at Admission	245 ± 59.9	245 ± 49.2	251 ± 63.5	249 ± 71.3	0.638
Neutrophil (NEU) Level at Admission	4.9 ± 1.9	5.1 ± 2.3	7.4 ± 3.6	5.7 ± 2.5	< 0.001
Lymphocyte Level at Admission	2.33 ± 0.71	2.2 ± 0.614	2.03 ± 0.86	2.38 ± 0.69	< 0.001
Beta-hCG Level at Admission	630 (32–5199)	1235 (60–6742)	4294 (51–79945)	3818 (121–11042)	< 0.001

Tubal hematoma that was either symptomatic or prominently visualized on ultrasound was recorded in only 5 cases, all of which were in the surgical group. The ultrasound-measured size of the ectopic pregnancy was significantly larger in patients who underwent surgery after medical treatment failure (mass size 9318 ± 4971, $p < 0.001$). Additionally, all other ultrasound findings were more frequently observed in the surgical group compared to other groups ($p < 0.001$).

In the complete blood counts taken at admission, hemoglobin (Hgb) and lymphocyte levels were significantly lower in the surgical group, while white blood cell and neutrophil levels were significantly higher ($p < 0.001$).

Model performance, evaluation and prediction

For model development, the features selected for inclusion are shown in Table 1. Analyses were conducted across multiple algorithms to compare their performance metrics. The J48, Bagging, Decision Table, Random Forest, and Jrip algorithms demonstrated superior results across most feature sets (Fig. 2). Among these, the Bagging algorithm achieved the highest overall accuracy at 93.86%, making it the most effective model ($p < 0.001$).

A statistical comparison of predicted and actual treatment outcomes for each algorithm is presented in Table 3. All five algorithms yielded significant chi-square (χ^2) values ($p < 0.001$) that confirm a strong association between model predictions and clinical outcomes.

Table 3
Results of comparing predicted and actual treatment outcomes for the top five AI algorithms

Actual	**Successful MTX therapy**	**Surgery**	**p value**
Algorithm			
Bagging	269 (44.6%)	16 (2.7%)	< 0.001
Successful MTX therapy	21 (3.5%)	297 (49.3%)	
Surgery			
J48	266 (44.1%)	17 (2.8%)	< 0.001
Successful MTX therapy	24 (4%)	296 (49.1%)	
Surgery			
Decision Table	265 (44%)	18 (3%)	< 0.001
Successful MTX therapy	25 (4.1%)	295 (48.9%)	
Surgery			
Random Forest	264 (43.8%)	18 (3%)	< 0.001
Successful MTX therapy	26 (4.3%)	295 (48.9%)	
Surgery			
Jrip	264 (43.8%)	19 (3.1%)	< 0.001
Successful MTX therapy	26 (4.3%)	294 (48.8%)	
Surgery			

Further assessment of algorithmic performance, including confusion matrix distributions (true positives, false positives, false negatives, and true negatives) and their corresponding percentages, is summarized in Table 4. The Bagging algorithm demonstrated an optimal balance between sensitivity (92.7%) and specificity (94.8%), along with the highest AUC (93.8%), reflecting excellent discriminatory power. The remaining models also performed consistently well, with only minor variations across predictive values, underscoring the robustness and consistency of the multi-algorithm approach adopted in this study.

Table 4
Performance metrics of top five algorithms

Algorithm	Accuracy (%)	Sensitivity	Specificity	PPV	NPV	AUC (ROC)
Bagging	93.86%	92.7%	94.8%	94.4%	93.4%	93.8%
J48	93.84%	91.8%	94.6%	94.1%	93.0%	93.5%
Decision Table	93.81%	91.5%	94.4%	93.8%	92.8%	93.3%
Random Forest	93.69%	91.1%	94.2%	93.6%	92.5%	93.0%
Jrip	93.53%	90.9%	93.9%	93.3%	92.2%	92.8%

Additional file 1. Supplementary Video, Demonstration of the PROMETHEUS AI-based clinical decision support tool for predicting methotrexate treatment success in ectopic pregnancy. The video illustrates how the user enters clinical parameters and interprets the system's output in a simulated clinical case.

Using the Bagging algorithm, we developed a practical and user-friendly decision support tool (a fully compatible application with both desktop and mobile platforms) named PROMETHEUS (Prediction of Methotrexate for Ectopic Pregnancy Treatment Success), designed to predict methotrexate treatment outcomes in patients diagnosed with ectopic pregnancy.

PROMETHEUS enables clinicians to input essential patient data, including laboratory parameters, ultrasound findings, and clinical symptoms, via an intuitive interface. Upon data entry, the system instantly processes the information and provides a probability score indicating the likelihood of successful methotrexate treatment. This output is designed to complement clinical judgment, not replace it, serving as an additional layer of support in treatment planning. A demonstration of the PROMETHEUS interface and workflow is provided in Supplementary Video 1, showcasing how the system operates in a real-time clinical scenario.

Discussion

Ectopic pregnancy is one of the most life-threatening complications in early pregnancy, and the most effective approach to reducing morbidity is early and appropriate treatment selection. Although established guidelines exist, each patient's unique circumstances require individualized evaluation. Addressing this need, our study developed an AI-driven clinical decision support system, PROMETHEUS (Prediction of Methotrexate for Ectopic Pregnancy Treatment Success), achieving an accuracy of 93.86% in predicting the optimal treatment.

To our knowledge, PROMETHEUS is one of the first AI-based decision support system specifically designed for this purpose—a reliable, user-friendly tool intended to assist clinicians in selecting the most effective treatment for each patient with ectopic pregnancy.

Following the advent of AI in medical sciences, various algorithms for patient management have been evaluated across multiple medical fields. In a 2022 review by Fitzsimmons et al.[6], it was found that among the articles reviewed, 10 different systems and 6 multisystem diseases were evaluated in machine learning studies. In studies focused on ectopic pregnancy in the literature, it can be observed that research aimed at calculating clinical risks, such as diagnosis and treatment success, has been conducted since the early 2000s [9–12].

One of the first AI-based decision support system for ectopic pregnancy was developed by Kitporntheranunt et al. in 2010 [13], focusing solely on detecting and localizing ectopic pregnancies. However, due to the technological limitations of the time, its application is restricted by today's standards. In contrast, our study expands upon this foundation by not only addressing diagnosis but also integrating predictive modeling for treatment success, making it a more comprehensive tool for clinical decision-making. Similarly, in 2022, Rueangket et al. [7] aimed to develop a predictive model for the diagnosis of ectopic pregnancy by employing statistical calculations followed by AI algorithms, in a design similar to our study. They used four different AI algorithms—Logistic Regression, SVM, Decision Tree, and Neural Network—with Logistic Regression achieving the highest accuracy at 89%. In our study, a similar accuracy of 85% was achieved with the Logistic Regression model; however, higher accuracy rates were obtained using the Bagging algorithm. Unlike traditional statistical calculations, our study utilized AI modeling, aligning with findings from Ploywarong et al. [7], who reported that traditional statistical models were not as effective as AI networks. In developing PROMETHEUS, 15 different AI algorithms were employed, setting it apart from other studies in this field. This approach is one of the primary distinctions between our study and recent medical decision support or prediction studies in the literature, which typically utilize fewer algorithms[7, 8, 14, 15].

 In 2019, De Ramon Fernandez et al.[8] developed a decision support system to aid in treatment selection for patients presenting with ectopic pregnancy. While their study design shares similarities with ours, a key distinction lies in the AI algorithms used. Their analysis employed MLP, SVM, Deep Learning, and Naive Bayes algorithms, observing lower accuracy rates with single-stage classifiers but achieving higher accuracy with multi-class classifiers. Specifically, they reported approximately 96% accuracy with the MLP and SVM algorithms. In contrast, our study achieved similar accuracy rates, reaching up to 93%, by focusing on a single classifier to streamline the algorithm's complexity and usability. Unlike their approach, we obtained strong results using the Bagging and J48 algorithms, which proved effective within our model.

Furthermore, a distinguishing feature of our study compared not only to De Ramon Fernandez et al.[8] but also to other research in the literature was the testing of a broader range of algorithms. This comprehensive approach ultimately led to the development of PROMETHEUS, a user-friendly application intended for healthcare providers, including those without a background in computer or software engineering.

While this study offers a promising AI-driven approach, a few limitations provide areas for potential future enhancement. As with many retrospective studies, data completeness posed a challenge, with missing data necessitating the exclusion of certain patients. To address this issue, we opted to exclude patients with incomplete records, which, as a result, reduced the overall cohort size. Additionally, since the data were sourced from a single institution, the generalizability of the findings may be limited to similar clinical settings. As this was a retrospective evaluation, treatment success was defined based on the final clinical outcome rather than the initial clinician decision. We acknowledge that this approach may not fully capture the nuances of clinical judgment and represents another area for future refinement. Finally, although the study included robust internal validation, external validation with an independent dataset would be valuable to further confirm the model's effectiveness across diverse patient populations.

Despite these limitations, this study also presents several notable strengths, making PROMETHEUS an innovative clinical decision support tool for ectopic pregnancy treatment. A key advantage is the use of 15 different AI algorithms, which allowed for a comprehensive evaluation to identify the most accurate model, ultimately enhancing the tool's reliability. Among these, the Bagging algorithm demonstrated the highest accuracy at 93.86%, underscoring PROMETHEUS's strong predictive power for selecting effective treatment options. By focusing on ectopic pregnancy treatment success, PROMETHEUS supports individualized patient evaluation, enabling more personalized and effective treatment approaches.

Importantly, PROMETHEUS does not replace clinical judgment but serves as a supplementary decision support system to guide clinicians in assessing the appropriateness of methotrexate therapy. Its strength lies in the integration of multiple clinical parameters into a single predictive framework that delivers consistent, evidence-based suggestions. This approach may be especially beneficial in settings where access to senior decision-makers or real-time consultation is limited. While PROMETHEUS is not yet deployed in routine clinical practice, the results of this study lay the foundation for its prospective implementation and evaluation in real-world clinical workflows. In parallel, prospective validation studies have been initiated at our institution to assess the real-world performance of PROMETHEUS and support its integration into routine clinical workflows. Future multi-institutional studies are also needed to validate PROMETHEUS or similar AI-based applications and expand their clinical applicability.

In Conclusion

In summary, this study introduces PROMETHEUS, an AI-based decision support tool developed to assist in selecting appropriate treatment options for patients with ectopic pregnancy. By integrating a broad range of clinical variables and machine learning techniques, the model achieved high predictive accuracy, particularly with the Bagging algorithm. PROMETHEUS offers a practical, user-friendly platform that can support personalized treatment planning and may help clinicians avoid unnecessary surgical interventions by improving prediction accuracy for MTX eligibility. While further external validation

across diverse clinical settings is needed, the system represents a promising step toward enhancing clinical decision-making through artificial intelligence in early pregnancy complications.

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the Non-Interventional Clinical Research Ethics Committee of the University of Health Sciences, Tepecik Education and Research Hospital (approval number: 2023/05–12; date: 06 June 2023). The requirement for informed consent to participate was waived by the Ethics Committee due to the retrospective nature of the study and the absence of identifiable patient data. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Consent for publication

Not applicable.

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Author Contribution

OO, AKK, and AGK were responsible for the study's design and planning. OO, ET, AHİ, and YKA conducted the data collection, while AKK performed the data analysis, and AGK wrote the manuscript. All authors contributed to drafting the article or critically revising it for important intellectual content and approved the final version for submission.

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Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

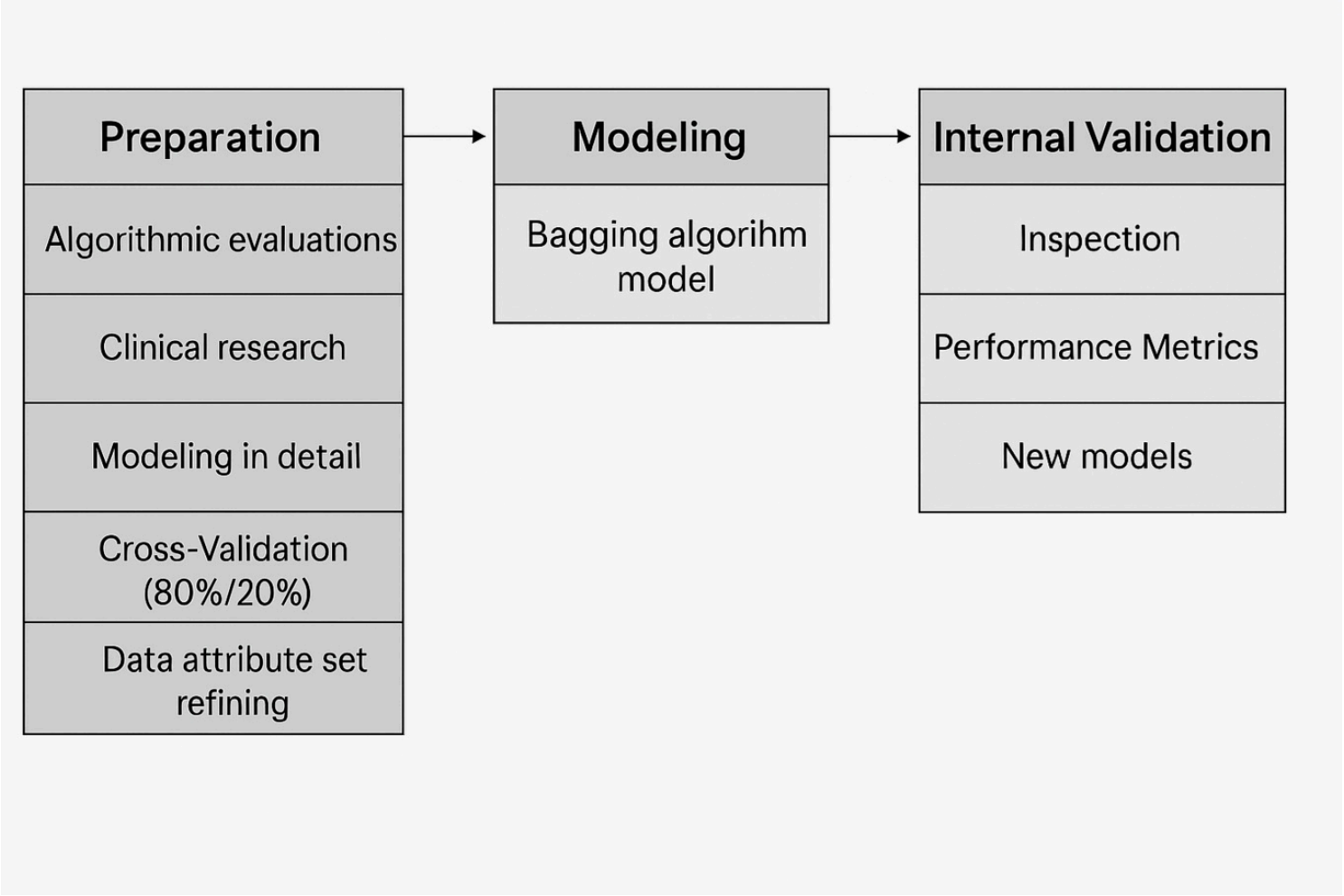


Figure 1

Flowchart of study

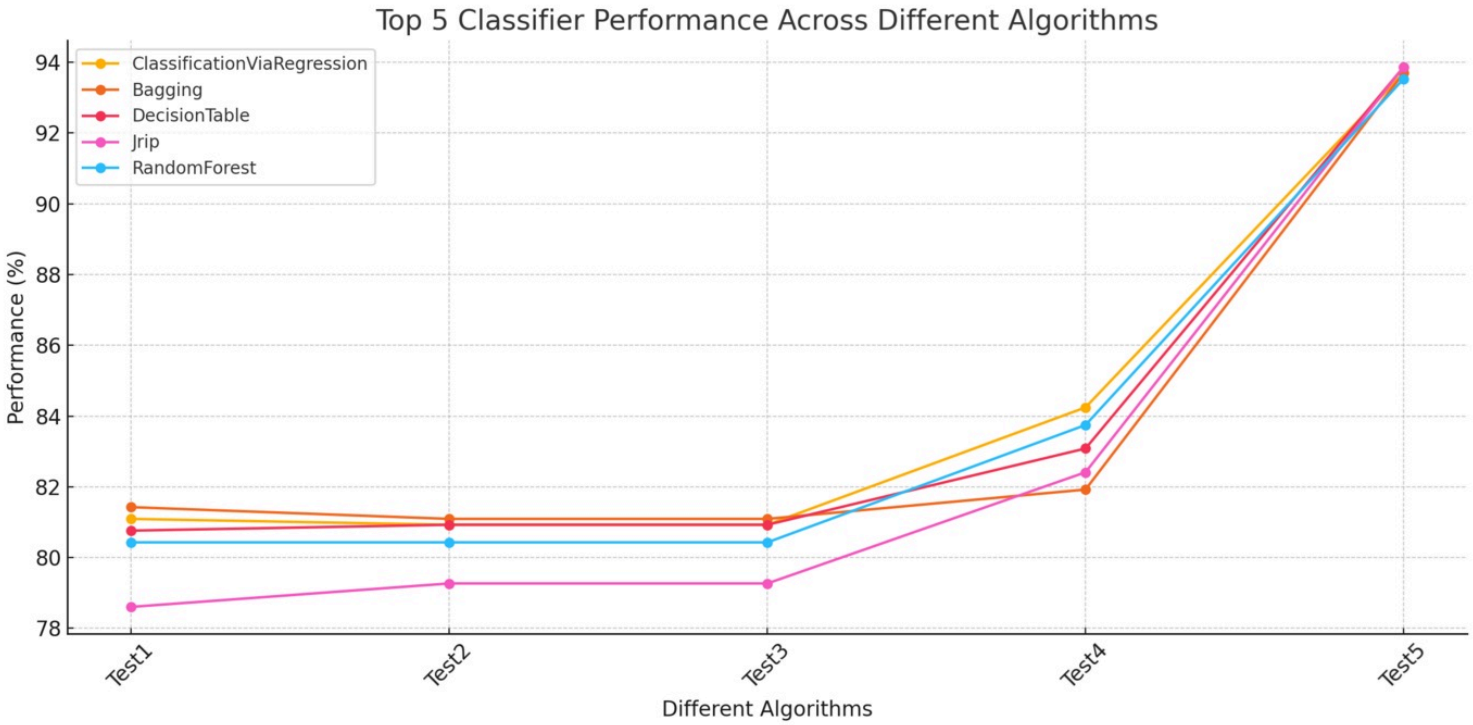


Figure 2

The variation in accuracy of the top 5 algorithms

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1.SupplementaryVideo.mp4