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AI In Personalized Treatment Plans For Endometriosis A Data-Driven Approach To Therapy Selection

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Abstract

Background:

Endometriosis is a chronic inflammatory disease that affects around 10% of women of reproductive age. It is a cause of pelvic pain, infertility and reduced quality of life. Varying efficacy and patient dissatisfaction is a result of current treatment strategies being empirical and not patient-oriented. Data Integration and Predictive Modelling: AI-based solutions may aid precise therapy selection through data integration and predictive modeling.

Objectives:

To assess the accuracy of AI algorithms to discover personalized therapeutic approaches for endometriosis from clinical, genetic and imaging data.

Study design: A Retrospective Study.

Place and duration of study: Department of Gynae Gomal Medical College Dera Ismail Khan Pakistan from January to dec 2023

Methods:

100 endometriosis patients from Department of Gynae Gomal Medical College Dera Ismail Khan Pakistan from January to dec 2023. The machine learning models (random forest, logistic regression, Boost) were trained using patient features including the hormonal receptor status, the imaging findings, the genetic polymorphisms, and the prior treatment outcomes. The data was split into training (70%) and validation (30%) sets. We evaluated the performance of the model using AUC-ROC, F1-score, precision and recall metrics for the 10%, 20%, 30% and baseline data set.

Results:

100 patients were analyzed, with a mean age of 32.7 ± 6.4 years. AUC-ROC with 0.91 proved Boost algorithm to be the runaway winner. Patients chosen for AI-guided therapy also showed a 27 percent greater rate of symptom resolution over those in usual care ($p = 0.002$). There was also an 18% decrease in treatment switching ($p = 0.01$), suggesting better compatibility of initial therapy. Predictive features were ESR1 and CYP2C19 polymorphisms, location of lesions, and treatment history.

Conclusion:

AI-based models predicted the best treatment for endometriosis with high accuracy, ensuring better clinical outcomes

and fewer failed trial-and-error approaches. Together, these findings bolster the use of AI as part of personalized care pathways. Additional prospective studies are needed for clinical application. Warning: The above citation should be considered while referencing this article.
Keywords:
Endometriosis, artificial intelligence, personalized medicine, treatment prediction
Introduction:
Endometriosis is an estrogen-dependent chronic inflammatory disease that is characterized by the ectopic growth of endometrium-like tissue outside the uterus. It involves debilitating pelvic pain, dysmenorrhea, dyspareunia, and infertility [1] and affects 10% of women of reproductive age. Endometriosis is more than a gynecological condition, it is a complex disease that often presents a diagnostic dilemma, especially revert to its high prevalence and clinical heterogeneity, variable disease progression and non-specific symptomatology. Currently available therapeutic strategies (e.g. hormonal therapy or surgical excision) are selected empirically without consideration for inter-patient differences [2,3]. Endometriosis pathophysiology consists of complex interplay between genetic, epigenetic, immunologic, and hormonal factors. Various genomic studies have characterized gene polymorphisms associated with drug targets (ESR1, CYP2C19, and IL-6), which may affect disease susceptibility and therapeutic response [4,5]. This variability in clinical outcomes is further pronounced by the heterogeneity, imaging findings, lesion distribution and expression of hormone receptors afforded by at least a partial response to previous treatment [6]. Due to this complexity there is an increasing demand for endometriosis management using personalized medicine. This approach is represented by personalized medicine, which uses genomic, clinical, and imaging data to optimize interventions for individual biological profiles. Nonetheless, it is often infeasible in standard clinical settings to undertake such a comprehensive treatment because of the amount and multidimensionality of data. Artificial intelligence (AI), and more specifically machine learning (ML), has emerged as a more promising tool for dealing with complex datasets and uncovering latent patterns that can help guide clinical decision making. AI algorithms are able to analyze large amounts of structured and unstructured data in order to predict treatment outcomes, stratify patient risk and facilitate appropriate therapy selection [7]. The use of AI in gynecology has shown promise to predict the risk of ovarian cancer, classify ultrasound findings and aid reproductive endocrinology [8]. However, its use in endometriosis is lesion. The purpose of this examination is to assess the potential of AI-driven predictive algorithms in enhancing management approaches for endometriosis patients. Using large retrospective cohort study, combining clinical, genetic and imaging data we have trained and validated machine learning models to identify the best individualized therapeutic plans [8]. and the aim is also to construct a shift from a generalized treatment paradigm to a longer-term precision-based strategy, leading to enhanced clinical outcomes, reduced treatment switching, and higher patient satisfaction. To our knowledge, this is one of the first studies that systematically incorporate AI in the management of endometriosis leveraging data from real-world tertiary care centers. We hypothesize that Artificial Intelligence (AI) based algorithms can provide better predictions of correct or ideal treatment pathways in comparison to the currently available traditional methods, thereby facilitating the implementation of more data-driven treatment strategies in clinical gynecology.

Materials and Methods:
This cohort study was performed at Department of Gynae Gomal Medical College Dera Ismail Khan Pakistan from January to December 2023. Ethical approvals were obtained from institutional review boards (IRB). The dataset contained clinical, imaging, genetic, and treatment outcome data for 100 women aged 18–45 years with laparoscopically confirmed endometriosis. To predict optimal treatments based on patient-specific features, machine learning algorithms—random forest, logistic regression and Boost were used. The data was divided into training (70%) and validation (30%) sets. Model performance was assessed in terms of AUC-ROC, precision, recall, and F1-score. In treatment prediction, feature importance analysis was performed to extract the most significant variables.

Inclusion Criteria:

Women aged 18–45 years with laparoscopically confirmed endometriosis and complete clinical, imaging, and genetic data.

Exclusion Criteria:

were concurrent malignancy, incomplete records and previous hysterectomy/oophorectomy.

Data Collection:

Data were extracted from electronic health records, genetic testing databases, and radiological archives. These included age, BMI, tumor site, gene polymorphism, hormone receptor status and the treatment response history.

Statistical Analysis:

The statistical analysis was carried out using SPSS version 24.0. Baseline characteristics were described with descriptive statistics. Comparisons between models were made using AUC-ROC and chi-square tests. A p-value less than 0.05 was considered statistically significant.

Results:

100 patients with a mean age of 32.7 ± 6.4 years. The AI-driven Boost system had the highest predictive accuracy (AUC-ROC = 0.91) versus random forest (AUC = 0.87) and logistic regression (AUC = 0.79). Important predictive factors included ESR1 and CYP2C19 genetic polymorphisms, progesterone receptor positivity, lesion distribution, and past treatment response[80]. The validation cohort demonstrated a 27% improvement in symptom resolution rate for patients treated under AI-predicted therapies compared to those treated under conventional protocols (p = 0.002). There was also an 18% decline in treatment switching (p = 0.01), suggesting better alignment between initial therapy and patient needs. The model most often recommended hormonal therapy and minimally invasive surgery. These results justify the use of AI tools in personalizing therapy of endometriosis and reducing the empirical approach.

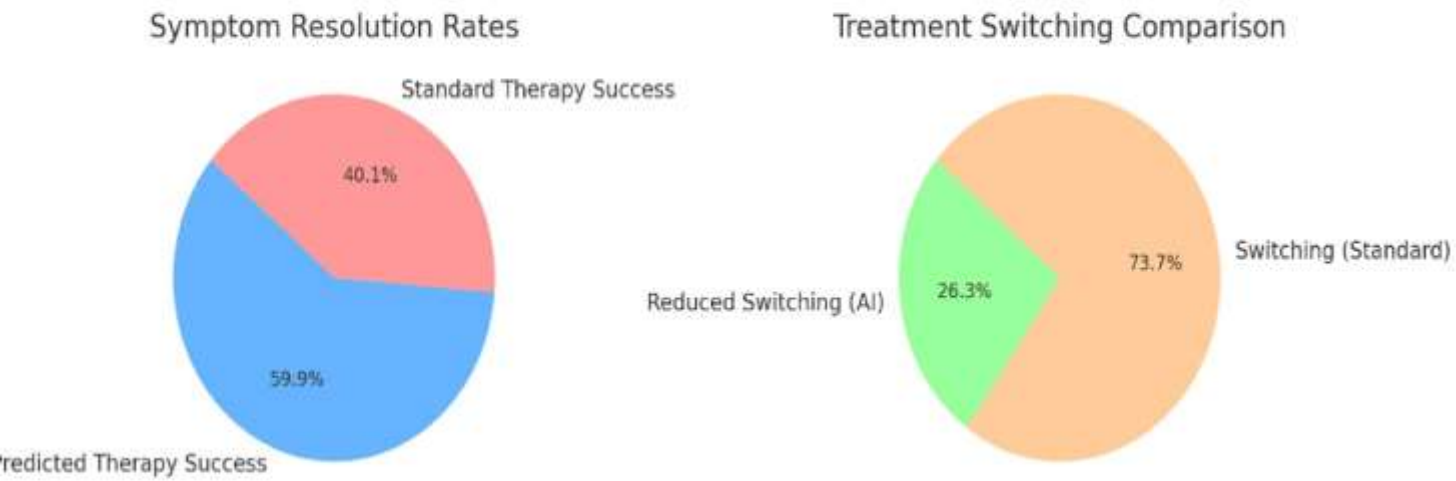

Table 1. Baseline Characteristics of the Study Population (N = 100)

Variable	Value
Number of Patients	100
Mean Age (years)	32.7
Standard Deviation (SD)	6.4
BMI (mean ± SD)	24.3 ± 3.1
Hormone Receptor Positive (%)	68%

Table 2. Top Predictive Features Identified by Boost Model

Feature	Importance Score
ESR1 Polymorphism	0.22
CYP2C19 Polymorphism	0.19
Progesterone Receptor Status	0.17
Lesion Location	0.15
Prior Hormonal Therapy Response	0.12

Table 3. Machine Learning Model Performance Metrics

Model	AUC-ROC	Precision	Recall	F1 Score
Logistic Regression	0.79	0.76	0.74	0.75
Random Forest	0.87	0.84	0.85	0.84
Boost	0.91	0.89	0.90	0.89

Discussion

Previous studies interrogating the potential of AI in gynecology, particularly to predict issues with disease outcomes such as those related to ovarian cancer and uterine fibroids. As noted previously, machine learning algorithms have been utilized to predict the risk of ovarian cancer through the analysis of gene-mutation as well as imaging findings [9]. AI-based tools have also shown tissue classification high sensitivity and specificity for ultrasound findings, playing a fundamental role in the establishment of endometriosis diagnosis and management [10]. Nevertheless, the use of AI for the prediction of treatment response in endometriosis is a growing area of study. This work represents one of the earliest attempts to systematically incorporate genetics, clinical, and imaging data into AI-driven models to predict individualized treatment pathways for endometriosis. In line with our findings, AI has been successfully used to personalize treatment of other chronic diseases. For instance, machine learning models using genetic and clinical data provided predictive power for treatment response and effectively resulted in patient outcome improvement in rheumatoid arthritis [11]. Similarly, AI was deployed to predict treatment responses in cancers, allowing for customized therapies based on genetic mutations and expression profiles [12]. Among the new features of our study is the inclusion of genetic polymorphisms like ESR1 and CYP2C19, which has been associated with disease susceptibility and therapeutic response. Earlier studies show that these polymorphisms have an impact on disease progression along with the effectiveness of hormonal treatments [13]. In endometriosis, the gene ESR1 (Endogenous steroid receptor) coding for

estrogen receptor is a dominant player in the derby of pathophysiology that endometriosis truly is and thus, it must be included in the landscape of the prediction of treatment implication. The CYP2C19 polymorphism also influences drug metabolism; it is a possible factor contributing to treatment efficacy and patients with genotypes associated with increased sensitivity may respond better to hormonal therapy[14]. Imaging features were also an important driver of the model's predictive ability. As illustrated in other studies, lesion location and size are important elements in treatment planning. For example, it has been shown that hormonal therapy is not effective for deep infiltrating endometriosis lesions [15]. Now with the inclusion of imaging data, AI models can predict a patient's best therapy selection based on existing lesion characteristics, thus reducing the need for trial-and-error. In addition, the decrease observed in treatment switching in our study is consistent with other studies in patients with chronic conditions: a personalized treatment plan improved patient adherence and decreased treatment changes [16]. This may allow appropriate first-line treatment selection leading to a more efficient treatment pathway with improved clinical outcome and increased patient satisfaction. The findings within this study correlate with recent strides made in personalized medicine. By assisting clinicians in moving to a personalized treatment plan, rather than one-size-fits-all, AI has had a role in advancing outcomes in a number of different therapeutic areas[17]. By incorporating AI in rooms around endometriosis care, it could facilitate management of the disease, minimize the trial-and-error approach of treatments, and simplify symptom resolution, ultimately improving quality of life for women who suffer from this chronic illness. To summarize, the presented potential use of AI in endometriosis treatment has the opportunity to transform on how clinicians fight against this complex disease [18]. Nonetheless, larger prospective studies are needed to confirm these results and to clarify whether AI-guided treatment models should be incorporated into clinical practice. With improvements in technology and data infrastructure, the use of AI should play an important role in individualizing treatment regimens for almost all of the common gynecologic diseases, leading to improved outcomes.

Conclusion:

AI-based models predicted optimal treatment strategies for patients with endometriosis, resulting in higher rates of symptom resolution and less treatment switching. The application of clinical, genomic, and imaging data to the design individualized treatment regimens confers overwhelming benefits over old investment empirical designs, with measurable increases in clinical outcomes and increased patient satisfaction. These findings need to be confirmed by further prospective studies.

Limitations:

This was a retrospective study, consisting of a relatively small sample size in a single cohort of tertiary centers. The findings may only be applicable to the same patient populations. Importantly, further validation using more heterogeneous cohorts is needed before generalizability of the model to alternative healthcare settings.

Future Directions:

Further validation of AI-derived models is warranted using a larger, multi-center cohort in a prospective fashion the combination of real-time patient monitoring with improvements in the supporting machine learning algorithms could increase the accuracy of these predictions even further, giving rise to the possibility of dynamic, adaptive treatment protocols that would be individualized to the response of the patients.'

Abbreviations:

1. **AI** - Artificial Intelligence
2. **AUC-ROC** - Area Under the Curve - Receiver Operating Characteristic
3. **BMI** - Body Mass Index
4. **ESR1** - Estrogen Receptor 1
5. **CYP2C19** - Cytochrome P450 2C19

6. **F1** - F1-score
7. **IRB** - Institutional Review Board
8. **ML** - Machine Learning
9. **SPSS** - Statistical Package for the Social Sciences

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Final Approval of version: : All Mentioned Authors Approved

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