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Systematic Literature Review of Modern Techniques for Detecting the Onset of Endometriosis: Machine Learning and Artificial Intelligence Approach

A. O. Oluwakemi[1], R.S.Babatunde[2], J.F Ajao[3]
Department of Computer Science, Kwara State University, Malete.

ABSTRACT
Endometriosis is known as a chronic and severe health problem which affects reproductive age women between the age of 18-39 around the world. This illness is complicated to diagnosis using traditional techniques due to its nature. Endometriosis is detected medically using traditional techniques such as biomarkers, genetic analyses, laparoscopy, imaging modalities and while modern approaches includethe application of artificial intelligence. The major goal of this work is to conduct a systematic literature review (SLR) of traditional and modern techniques employed in detecting endometriosis covering publications from 2015 to 2024.The justification of this paper is to address the persistent challenges in diagnosing endometriosis by systematically reviewing both conventional and modern diagnostic approaches, thereby providing insights that can guide future research and improve early detection. The PRISMAmethodology widely acceptable for SLR was adopted in performing the review. We sourced for 503 publications from renown databases such as Google Scholars, ResearchGate, PubMed and Elsevier. Out of the 503 papers picked, we selected 85 publications for critical review.Only publications and articles in English language were considered.The outcome of this review shows that conventional diagnostic methods including laparoscopy, MRI, ultrasound and clinical evaluations are still employed in detecting endometriosis but they possess setbacks such as elevated prices, reliance on expertise skills and failure to spot this illness at early stage.However, this paper recommends the application of modern artificial intelligence-based techniques to enhance accuracy, reduce costs, and enable early detection of endometriosis.

Keywords: Artificial intelligence, Endometriosis, Laparoscopy, Machine Learning Ultrasound

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I. INTRODUCTION

Endometriosis is a health situation that is marked by the evidence of a fleshy growth outside the womb (Zondervan et al. 2020). This health condition peculiar to women is believed to affect 5-10% of women who are still in their reproductive years, totally over 2.8 million women in Europe and over 190 million women in the world (Parasar et al. 2017). A patient with endometriosis often experiences persistent pelvic discomfort, changes in menstrual cycles and among others dysmenorrhea. Likewise, endometriosis also causes infertility, affects sexual functions in women, and patients with this illness tends to have low self-esteem (Parasar et al. 2017). These factors according to (Tragantzopoulou, 2024) substantially increase the chances of the affected person having anxiety and depression in most cases. Women suffering from endometriosis are exposed to diminished health-related quality of life compared to unaffected women. Study presented by (Alonzo et al. 2024) suggest that there is a greater likelihood of depressive symptoms in women with this ailment, while other researchers such as (Piccolo et al. 2023; Shala & Darwish, 2022) recommend incidence of anxiety among affected women due to severity of pain.

Endometriosis is found in regions such as peritoneum of the uterus, around the egg sac or infiltrate pelvic region below the surface of the uterus. Medically, the symptoms of endometriosis are always coincided with the symptoms of other relative illness such as irritable bowel syndrome (IBS) or interstitial cystitis (IC) thereby making the detection of endometriosis complicated (Zondervan et al. 2020). When a patient is affected with endometriosis, most times, it can take up to 4 to 11 years before this illness can be spotted depending upon the intensity of the clinical actions taken (Scioscia et al.2020).

The golden method well known for diagnosis endometriosis is Laparoscopic technique. This method is acceptable internationally for detecting the presence of endometriosis in affected persons. Laparoscopy is minimally invasive surgical procedure used worldwide in detecting and diagnosing endometriosis. Non-invasive techniques applied in diagnosis this illness includes: ultrasonography, and Magnetic Resonance Imaging (MRI) (Zakhari et al.2021). Nonetheless, according to (Schwartz et al.2020), conducting accurate diagnosis using these

methods remains difficult due to deficiency of expertise and qualified physicians (Scioscia et al.2020). In recent time, a wide range of hormonal therapies have been utilized to inhibit endometrial proliferation with contraceptive tablets, GnRH agonist and GnRH antagonist. Before the affected patients undergo diagnosis, they invest lot of time and financial resources and also undergo needless clinical examinations (Zakhari et al.2021; Schwartz et al.2020).

Laparoscopy which is known as the gold standard in detecting endometriosis involves direct viewing of the affected region and biopsy of endometrial abnormalities. This method is invasive and also expensive. However, since the conventional methods are not providing total solutions to detecting endometriosis, scientist and clinical physicians are now adopting ML and AI in spotting this illness (Marinho et al.2020) with improve accuracy. This paper aim at reviewing relevant techniques that have applied in detecting endometriosis including the conventional approaches with the clear focus on ML and AI approaches.

II. RESEARCH OBJECTIVES

In this paper, we seek to investigate different techniques for detecting endometriosis by providing detailed literature review showing the advantages and limitations of these methods and comparing the outcomes of this study by pinpointing the setbacks in the current publications. The review conducted in this paper concentrates on conventional tools applied in diagnosing endometriosis including laparoscopy, ultrasound and MRI in conjunction with recent studies that applies Machine learning (ML) and Artificial Intelligence (AI). We aim to spot areas that need improvement in these studies and thereby propose our ways and techniques in filling the gaps. These comparative analysis of conventional and modern approaches of detecting endometriosis will provide insight to prevalent patterns, discrepancies and research gaps presents in current findings.

III. MATERIALS AND METHODS

3.1 Data Sources and Search Strategy

This paper adopts a comprehensive and well-structured methodology to spot relevant studies for the systematic literature review (SLR). The review covers publications that incorporates Laparoscopic, ultrasound, MRI, ML and AI approaches from 2015 to 2024. The search technique used in this experiment encompassed well-known academic databased and online platforms to ensure the inclusion of high-quality and relevant publications

3.1.1 Data Sources

The data sources for the investigation include well-known academic database such as Google scholar, ResearchGate, PubMed, IEEE, Elsevier (ScienceDirect) and ACM. Google Scholar serves as a search engine that helps researchers to search for scholarly articles across various fields of studies thereby enhancing access to recent publications. ResearchGate in the other hand is a social networking site for scholars and researchers. ResearchGate houses published articles and conference paper. We retrieved many endometriosis publications on this site. Similarly, PubMed (Publisher MEDLINE), a pubic database maintained by the US National Library of Medicine. This database was also used in obtaining peer-reviewed papers on endometriosis. The researchers also search for recent and relevant publications from these databases: IEEE and Elsevier. By exploring this well-known academic database, we were able to source for high quality publications, articles and conference papers that covers techniques applied in detecting endometriosis. These databases form the sources of data for this paper. Figure depicts the distributions of publications obtained from these databases for this experiment.

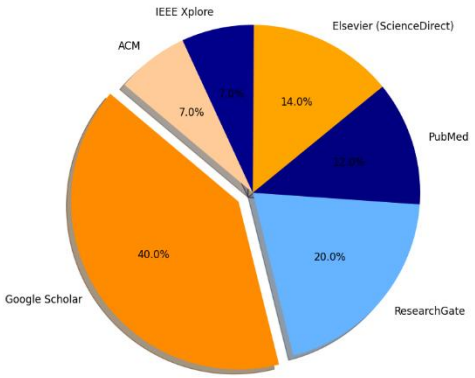


Figure 1: Graphical Representation of Percentages of Data from the Six Databases

3.1.2 ***Search Strategy***

The search strategy adopted in searching for the right publications that concentrated on diagnostic techniques for endometriosis were combinations of search terms and keywords. A combination of search terms we used to spot relevant publications. Common search terms used were words like "Endometriosis diagnosis", "Machine Learning in Endometriosis", "Artificial Intelligence in endometriosis detection", "Biomarkers and diagnostics techniques for endometriosis", "Laparoscopy for endometriosis diagnosis" etc. We narrowed down the search to specific year by specifying the year e.g. "endometriosis detection using machine learning 2023". These terms were utilized over 200 times. We present figure 2 which shows the frequencies of the search terms used during this experiment.

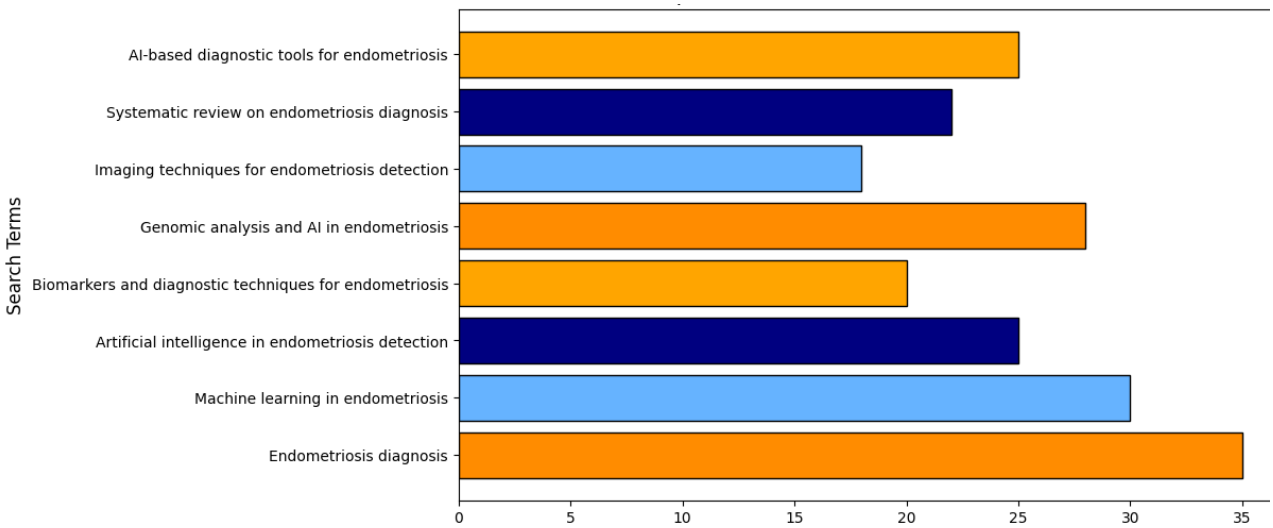


Figure 2: Frequency Of Search Terms Applied in Searching for Relevant Publication

3.2 Inclusion and Exclusion Criteria

We carefully selected publications to be included and excluded from the list of papers sourced in this study in order to guarantee the quality and usefulness of the literature review (Bhat et al. 2019). The inclusion criteria focused on articles, publications and journals published from 2015 to 2024 with emphasis on papers that investigated the use of AI and ML, laparoscopy, MRI and ultrasound in detecting endometriosis. We selected only the publications that were written in English language during this investigation (Chapron et al. 2019). Journals, articles and publications that offered emergent diagnostic methods we prioritized. We excluded published articles from 2014 and below and those written in other languages rather than English we also discarded (Laganà et al. 2017). In order to preserve the scope of our investigations, papers that did not explicitly address endometriosis were excluded automatically (Rush et al. 2019).

3.3Screening and Selection Process

A total of 403 publications were initially retrieved from the above-mentioned academic databases for consideration in the selection process. For an initial screening process, we read through the title and the abstract of each publication in order to determine their usefulness to endometriosis diagnosis and especially when referring to the usage of artificial intelligence (AI) and machine learning (ML). Efforts were made to eliminate duplicate records if identified in multiple sources to avoid redundancy. The rest of the studies were reviewed using the inclusion and exclusion criteria to see whether they met the purpose of the review. After this in-depth screening process, 85 studies were deemed as most relevant. Study selection is presented in Table 1.

Table 1: Article Selection Approach for this Study

S/ No.	Particular	Including	Excluding	Remarks
1.	Language	English	Other languages	The literature survey is based on only English papers. For investigating new advancements in the application of Machine Learning and Artificial Intelligence approaches in diagnosing endometriosis, a brief literature review is conducted on papers published from 2015 onwards. All the papers required for the literature survey are collected from Google Scholar, ResearchGate, PubMed, and Elsevier databases.
2.	Period	2015 to 2024	Before 2015	
3.	Databases	Google Scholar, Research Gate, PubMed and Elsevier, ACM, IEEE	Other sources	
4.	Keywords applied	"Endometriosis diagnosis", "Machine Learning	Unpublished papers, Master or Doctoral Thesis, White Papers,	

		in Endometriosis", "Artificial intelligence in endometriosis detection", "Biomarkers and diagnostic techniques for endometriosis",	Conferences Proceeding and Textbooks related to the topic Application of Machine Learning Approach in Inventory Management	

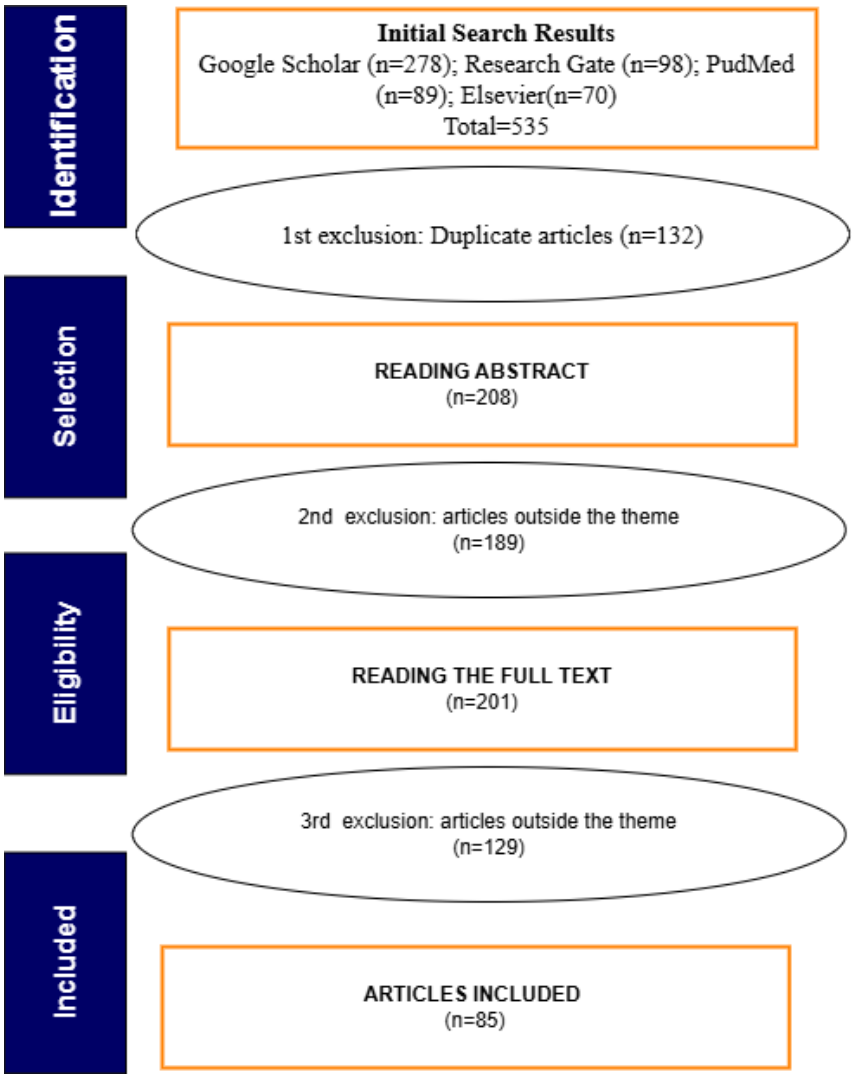


Figure 3 PRISMA Flow Diagram: Representation of Eligibility and Inclusion Articles

3.4 Quality Assessment

To ensure that the review conducted in this paper included only relevant, reliable and high-quality studies, a well-structure quality assessment was performed for each selected publication. We critically examined the study design for each selected publication as well as the sample size, strength of the method used and how closely the study matched the review focus of endometriosis detection using laparoscopy, MRI, Ultrasound, ML and AI. Studies with good and high-quality designs were rated higher. Studies with larger and more divers samples were also rated high due to better results. The clarity of the data collection techniques, proper use of AI frameworks and clear reporting and data preprocessing including evaluation metrics were also taking into consideration in order to access the quality of the selected articles. Irrelevant and poorly structured articles were discarded.

a. **Data Extraction and Analysis**

Important data points were obtained from the selected publications, covering the aim, methods, datasets, algorithms used and the results. The data obtained was analysed to compare different diagnostics methodologies, check their benefits and setbacks and ascertain the research gaps in the applications of ML and AI with other conventional techniques in detecting endometriosis. During the data extraction and analysis phase of this experiment, we employed tools to aid the process. These tools include: pandas, matplotlib, Jupyter notebook and PRIMA flow diagram generator. We used these tools several times during the investigation. Figure 4 depicts the frequency of data extraction tools utilized during the experiment.

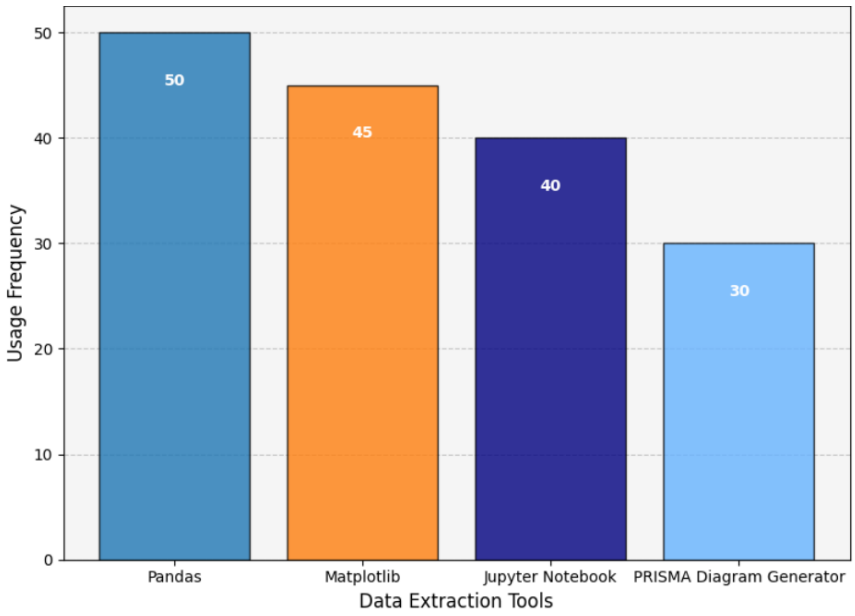


Figure 4: frequency of data extraction tools applied during the experiment

IV. RESULT AND DISCUSSION

4.1 Result

Following the removal of duplicates and the selection of publications, the articles were thoroughly reviewed, and the parameters outlined in the analytical matrix of this study were examined. This systematic literature review (SLR) examined 85 scientific studies that strictly adhered to the predetermined criteria for sample selection. The 85 selected papers were categorized into two groups. The initial category encompassed research centered on conventional methods for endometriosis diagnosis, whereas the subsequent category incorporated studies utilizing machine learning and artificial intelligence algorithms for diagnosing endometriosis. Below are some of the publications that applied conventional techniques in detecting endometriosis: [23] performed a retrospective analysis to evaluate its validity, demonstrating a high sensitivity of 90.1% and a positive predictive value of 81.0%, suggesting that laparoscopic diagnosis was frequently accurate. Nonetheless, its specificity was low (40.0%), resulting in a significant incidence of false positives, and the negative predictive value was 58.8%, indicating that several instances were overlooked [23]. The research, involving 96 women, underscored the inadequacies of exclusive reliance on visual inspection, stressing the necessity for histological validation to enhance diagnostic accuracy. The retrospective approach, limited sample size, and absence of interobserver variability analysis were significant shortcomings [23]. Notwithstanding these limitations, the results underscore the imperative of amalgamating laparoscopic visualization with histopathology and bolster the increasing interest in using machine learning and artificial intelligence for enhanced accuracy and objectivity in endometriosis diagnosis [23].

Lahdemaki et al. (2015) conducted a study to investigate laparoscopic findings in patients with probable endometriosis. The research was conducted at the Department of Obstetrics and Gynecology, University of Oulu, Finland, with 53 consecutive patients who underwent their initial laparoscopy from January 2006 to November 2011 [24]. The researchers employed laparoscopy as the principal diagnostic method to ascertain the existence and stage of endometriosis [24]. Forty percent of the patients were diagnosed with endometriosis. The predominant symptoms seen in identified individuals were dysmenorrhea (86%) and dyspareunia (81%), succeeded by vibration discomfort (71%), urine symptoms (29%), and reduced fertility (24%). Bowel symptoms were notably less prevalent in patients with endometriosis (5%) than in those without (28%) ($p = 0.034$). The median interval from symptom beginning to laparoscopic diagnosis was 1.9 years,

suggesting a relatively swift diagnostic procedure [24]. The study offers significant insights into symptom prevalence and diagnostic efficiency; nevertheless, it is constrained by its small sample size and retrospective design, potentially introducing selection bias and restricting the generalizability of the results. The study also lacked a control group and did not investigate long-term effects after diagnosis and therapy [24].

Pascoal et al. (2015) present an exhaustive assessment of the diagnostic techniques employed for the identification of endometriosis, a chronic condition associated with discomfort, infertility, and diminished quality of life [25]. The authors emphasize the difficulties in detecting endometriosis, chiefly attributable to diagnostic delays and verification bias, since not all patients receive conclusive diagnostic tests. The review assesses various diagnostic methods, including clinical evaluation (history and physical examination), biomarkers, diagnostic imaging (such as ultrasound and magnetic resonance imaging), surgical diagnosis, and histopathology [25]. The authors assert that although non-invasive techniques such as clinical evaluation, ultrasound, and MRI are not currently sufficient to supplant surgery in the diagnosis of all endometriosis subtypes, they can be important in identifying later stages of the condition [25]. The principal conclusion of the review is that no definitive gold-standard approach exists for diagnosing endometriosis. The authors advocate for employing a variety of diagnostic approaches customized to individual patient conditions. The analysis highlights that each method possesses distinct strengths and limits, necessitating a multi-modal approach for precise diagnosis [25].

Gichuhi et al. (2012) performed a study in Nairobi, Kenya, to evaluate the relationship between laparoscopic visualization and histopathology in the diagnosis of endometriosis [26]. The research encompassed 443 women having laparoscopy, with endometriosis identified both visually and via biopsy for histological validation. Results indicated that 77 women (17.4%) were identified using laparoscopic visualization, although only 30 (6.8%) exhibited positive histology for endometriosis [26]. The positive predictive value of laparoscopic visualization was low (39%), signifying a limited connection with histological diagnosis. The authors determined that histological confirmation is important, as laparoscopic visualization alone is an unreliable diagnostic approach for endometriosis [26].

Daniilidis et al. (2017) undertaken a study to assess the accuracy of laparoscopic diagnosis in identifying endometriosis and its association with infertility in 336 women aged 18–45, who experienced persistent pelvic pain and had no prior abdominal surgeries [27]. The study revealed that 56.8% of subjects exhibited no abnormal results, whereas 30% were identified with endometriosis at different stages [27]. Significantly, 26.4% of patients indicated either symptom amelioration or total resolution following the surgery. The research indicates that diagnostic laparoscopy is exceptionally precise in detecting pelvic diseases, with endometriosis as the predominant cause of chronic pelvic pain. Nonetheless, a considerable proportion of symptoms may be psychogenic [27].

Kido et al. (2022) present a comprehensive evaluation of the function of MRI in the diagnosis of endometriosis and associated disorders [28]. They emphasize the benefits of MRI, such as its superior contrast resolution and capability to identify ovarian endometriotic cysts and deeply infiltrating endometriosis without invasive techniques or radiation exposure [28]. The research highlights that fibrosis surrounding ectopic endometrial glands, manifesting as T2 hypointense lesions, facilitates the diagnosis of deeply infiltrating endometriosis and subsequent adhesions. The review succinctly encapsulates MRI data pertaining to ovarian endometriotic cysts and their pathogenic variants. Although MRI improves diagnostic precision, its availability and expense continue to pose challenges [28]. The study emphasizes the significance of MRI in the non-invasive diagnosis of endometriosis while advocating for extensive clinical validation [28].

Elsadawy and Ali (2023) examined the function of MRI in identifying endometriosis and its relationship with laparoscopic results utilizing the ENZIAN classification [29]. Their research revealed a significant agreement between MRI and laparoscopic ratings, especially in compartments A, B, O, and C. The MRI demonstrated high sensitivity in identifying deep infiltrated endometriosis (DIE), particularly in extensive lesions (100%). Nonetheless, the study exhibited drawbacks, such as a follow-up design, a single-institution setting, and interpretation of images by a sole radiologist [29]. Notwithstanding these limitations, the results underscore MRI's significance as a noninvasive diagnostic instrument for endometriosis, reinforcing its utility in preoperative planning and minimizing superfluous procedures. Additional multicentric investigations are advised for validation [29].

Alonzo et al. (2024) conduct a review of modern MRI techniques for the evaluation of endometriosis [30]. It emphasizes the efficacy of susceptibility-weighted imaging (SWI) and tractography in locating disease locations, indicating that both techniques provide enhanced sensitivity and specificity relative to conventional imaging [30]. The authors underscore the significance of standardized MRI protocols and the use of novel sequences to improve diagnostic precision. They also examine the possibility of diffusion-weighted imaging (DWI) and post-contrast sequences, but their functions are still being explored. The review highlights the changing dynamics of MRI applications in the diagnosis of endometriosis [30].

Sheha et al. (2022) assessed the diagnostic accuracy of Magnetic Resonance Imaging (MRI) for endometriosis by studying 40 premenopausal women with suspected endometriosis, determined through clinical

and/or sonographic evaluations [32]. MRI findings were juxtaposed with laparoscopic data, with histopathological confirmation serving as the gold standard [32]. The authors reported MRI sensitivity at 95.65%, specificity at 57.14%, positive predictive value (PPV) at 88%, negative predictive value (NPV) at 80%, and overall accuracy at 86.7%. The limitation of the study is its relatively small sample size of 40 patients, and the lower specificity (57.14%) of MRI may result in false positives [32].

Van den Bosch, T., & Van Schoubroeck, D. (2018) conducted a review of the diagnostic accuracy of transvaginal ultrasonography in pelvic endometriosis and adenomyosis, comparing it to magnetic resonance imaging (MRI) [33]. The study presented diagnostic criteria for endometriomas, guidelines for reporting the location of deep infiltrating endometriosis, and sonographic features of adenomyosis, including the differential diagnosis between focal adenomyosis and uterine fibroids [33]. Additionally, the study discussed the clinical relevance and limitations of ultrasound diagnosis for these conditions [33].

Dinh et al. (2020) conducted a study in 2020 to investigate the accuracy of ultrasound in the detection of endometriosis. They focused on instances in which endometriotic nodules were identified through ultrasound but were not evident during laparoscopy [34]. They employed preoperative ultrasound to detect a deep endometriosis lesion in the left uterosacral ligament, which was not detected during the subsequent laparoscopy [34]. The presence of profound endometriosis at the site was confirmed by histopathological examination. This case emphasizes the potential of ultrasound to assist surgeons in identifying specific lesions during surgery and to mitigate the risk of residual disease, thereby demonstrating the utility of ultrasound in preoperative mapping [34]. In the diagnosis and management of endometriosis, the study emphasizes the significance of ultrasound as a complementary instrument to laparoscopy [34].

In the other hand, we also reviewed publications that applied ML and AI in detecting endometriosis such as Zhang et al. (2023) investigated the incorporation of machine learning methodologies for the diagnosis of endometriosis through the combination of various indicators [35]. They employed 11 machine learning algorithms to develop 113 predictive models, detecting critical diagnostic genes such as FOS, EPHX1, DLGAP5, PCSK5, and ADAT1. The research demonstrates that these genes, particularly ADAT1, displayed robust predictive capabilities, with AUC values exceeding 0.78 across multiple datasets [35]. The authors emphasized the potential of these biomarkers to enhance diagnostic efficacy and elucidate the pathogenesis of endometriosis [35].

Bendifallah et al. (2022) investigated machine learning algorithms (MLA) for the diagnosis of endometriosis utilizing 16 clinical and symptomatological variables [36]. It was reported that LogitBoost, CART tree, Random Forest, and KNN attained sensitivity ranging from 0.82 to 1, specificity from 0 to 0.8, F1-scores from 0 to 0.88, and AUC from 0.5 to 0.89 in the training set, with AUCs between 0.91 and 0.95 in validation, indicating the potential of MLA to compete with diagnostic laparoscopy in clinical practice [36].

Cao et al. (2025) developed a machine learning-based nomogram to predict endometrial lesions in premenopausal breast cancer patients following tamoxifen therapy [37]. Using clinical data from 224 patients, three machine learning methods were evaluated, with LASSO regression integrated with logistic regression achieving the best performance (C-index of 0.874). The model demonstrated high accuracy (0.853) and precision (0.917), offering an effective tool for early detection and individualized treatment strategies, improving clinical decision-making in this patient group [37].

Sivajohan et al. (2022) performed a literature analysis to investigate the utilization of artificial intelligence (AI) in mitigating medicinal problems associated with endometriosis, a chronic ailment characterized by diagnostic delays that considerably impact patient care [38, 37]. The evaluation encompassed 36 papers derived from 1309 records, concentrating on AI models designed to enhance pathophysiology, diagnosis, prognosis, or management of endometriosis. The predominant machine learning approaches included logistic regression, decision trees, random forests, and support vector machines [38]. These studies employed a variety of data types, including biomarkers, clinical variables, genetic information, and imaging data. The AI models exhibited robust diagnostic and prognostic abilities, with sensitivities from 81.7% to 96.7% and specificities from 70.7% to 91.6%. The review emphasized the potential of AI to enhance endometriosis evaluation and advocated for additional research to improve reliability and model comparability for clinical applications [38].

Kitaya et al. (2024) created a convolutional neural network (CNN) model utilizing deep learning to identify endometrial micropolyps (EMiP) in patients with chronic endometritis (CE) [39]. The model, trained on fluid hysteroscopy pictures, exhibited exceptional diagnostic performance, achieving a sensitivity of 93.6% and an AUC of 0.930, equivalent to that of seasoned gynecologists [39]. This study underscores the promise of AI as a less invasive diagnostic alternative to conventional biopsy procedures, enhancing accuracy and efficiency in CE detection while alleviating patient discomfort and clinical stress [39].

Balica et al. (2023) considered deep learning for the early identification of endometriosis via ultrasound data. Five models namely: Xception, Inception-V4, ResNet50, DenseNet, and EfficientNetB2 were trained on retrospective data from 100 patients identified through laparoscopy or laparotomy [40]. A 5-fold cross-

validation method produced robust classification performance, achieving AUC scores of 0.85 and 0.90 in evaluation experiments [40]. Their findings underscore the potential of AI in minimizing diagnostic delays and enhancing early detection, presenting a promising instrument for non-invasive endometriosis diagnosis [40].

Tore et al. (2023) developed a machine learning-based diagnostic model for endometriosis using 627,566 clinical records [41]. They tested logistic regression, decision tree, random forest, AdaBoost, and XGBoost, with XGBoost achieving the highest AUC (0.725) [41]. The model had a sensitivity of 68.6% and a specificity of 62.9%. Feature importance analysis identified age, infertility, and uterine fibroids as key predictors. While the model aids diagnosis, its low predictive value highlights the need for more informative features to improve accuracy [41].

Visalaxia and Muthu (2021) investigated automatic identification of endometriosis through deep learning techniques. They utilized Minimal Invasive Surgery (MIS) laparoscopic imaging, augmenting picture quality for enhanced visual clarity [42]. The research utilized Convolutional Neural Networks (CNNs), particularly ResNet50, for classification purposes. Their model attained a training accuracy of 91%, a validation accuracy of 90%, a precision of 83%, a recall of 82%, and an AUC of 0.78. Notwithstanding its success, the study is constrained by the sample size, necessitating larger datasets for improved adaptation [42].

Akter et al. (2020) utilized an ensemble machine learning classifier called GenomeForest, which relies on chromosomal partitioning [43]. The approach entailed categorizing endometriosis patients in comparison to control patients utilizing 38 RNA-seq datasets and 80 enrichment-based DNA methylation (MBD-seq) datasets [43]. Performance evaluation was executed via six distinct experiments, attaining an F1 score of 0.968 for transcriptomics data and 0.918 for methylomics data. The method seeks to enhance endometriosis assessment using fewer surgical biopsy procedures [43].

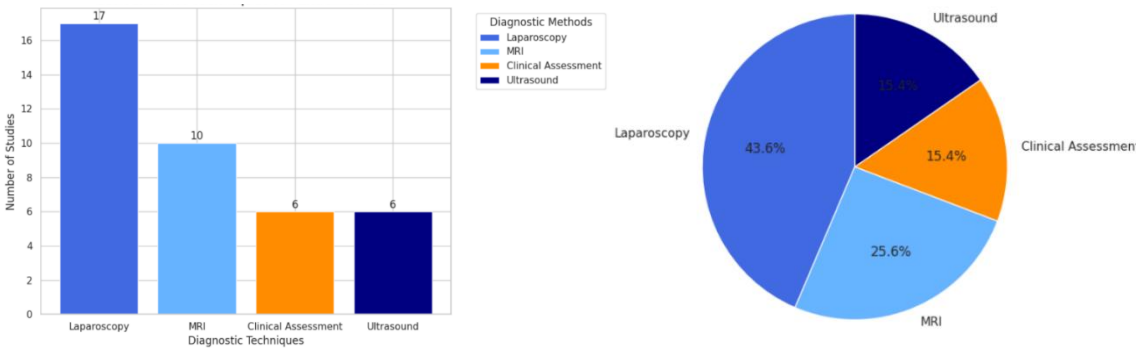
Yang et al. (2021) applied deep learning algorithms to classify and diagnose deep pelvic endometriosis (DPE) using vaginal ultrasound (VU) and magnetic resonance imaging (MRI). They utilized the visual geometry group with global average pooling (VGG-GAP) model for VU image recognition and improved the C3D model into the IC3D model for MRI image classification [44]. Their study analyzed VU and MRI images from 118 patients with DPE and 206 patients with other gynecological conditions. The results showed that the VGG-GAP model achieved a classification accuracy of 96.5% for VU images, while the IC3D model attained 99.2% accuracy for MRI images. Additionally, diagnostic accuracy using VU and MRI images was 90.68% and 92.37%, respectively. Their findings suggest that deep learning-based classification can enhance DPE diagnosis, with MRI proving more effective than VU [44].

Leibetseder et al. (2020) address the challenges of analyzing gynecologic laparoscopy videos, a key aspect of minimally invasive surgery (MIS). While video recordings aid treatment planning, documentation, and education, manual analysis remains time-consuming [45]. To advance computer vision and machine learning applications in this field, the authors introduce *GLENDA* (Gynecologic Laparoscopy Endometriosis Dataset), a dataset with region-based annotations of endometriosis. Created in collaboration with medical experts, GLENDA is the first of its kind. However, the paper lacks detailed dataset specifications and validation results, which would further strengthen its impact [45].

Podda et al. (2024) developed a multi-scale ensemble deep learning approach to automatically segment endometriotic lesions from transvaginal ultrasound images, improving diagnostic accuracy by combining multiple Convolutional Neural Networks (CNNs) trained at different granularities [46]. Their findings show that the ensemble method enhances segmentation performance compared to individual CNNs, even with a limited training dataset, and achieves a Dice coefficient of 82%, demonstrating strong detection accuracy in ultrasound-based endometriosis detection [46].

4.2 Analysis based on conventional techniques

Following a thorough examination of the 85 selected publications sourced from four databases, 39 studies presented findings on traditional methods for diagnosing endometriosis. 17 research utilized laparoscopy, which is regarded as the gold standard for diagnosis. 10 research employed Magnetic Resonance Imaging (MRI) for non-invasive detection, whereas 6 investigations concentrated on clinical assessment through symptom evaluation. Furthermore, 6 investigations utilized ultrasound as a diagnostic instrument. These findings underscore the many methodologies employed in traditional endometriosis diagnosis and their corresponding applications. Figure 5 (a) and (b) describe the frequency of journals that applied conventional techniques

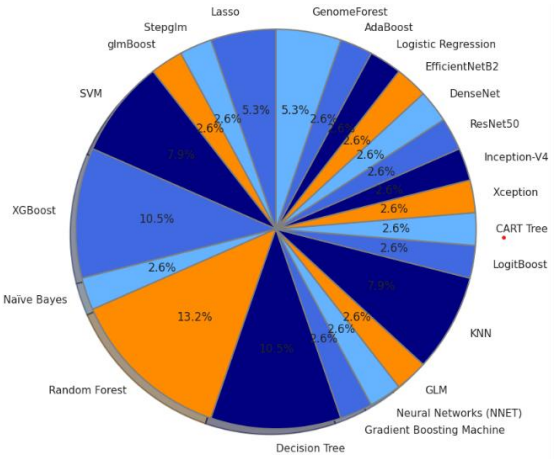


(a) (b)

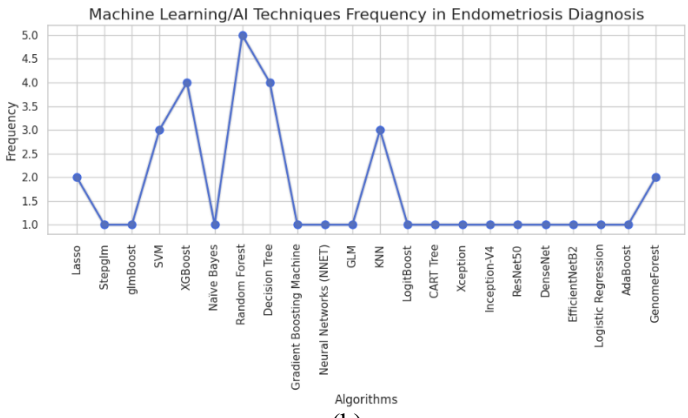
Figure 5 (a) and (b): Frequency of Papers by Conventional Techniques

4.3 Analysis based on Machine learning/AI Techniques

46 research employed machine learning (ML) and artificial intelligence (AI) methodologies for the detection of endometriosis, utilizing a variety of methods. Random Forest was utilized most frequently (5 times), followed by XGBoost and Decision Tree (4 times each), and Support Vector Machine (SVM) and K-Nearest Neighbors (KNN) (3 times each). Lasso was utilized on two occasions, whereas other models, such as Stepglm, glmBoost, Naïve Bayes, Gradient Boosting Machine, Neural Networks (NNET), Generalized Linear Model (GLM), LogitBoost, CART Tree, Xception, Inception-V4, ResNet50, DenseNet, EfficientNetB2, Logistic Regression, AdaBoost, and GenomeForest, were each employed once. This investigation underscores the extensive utilization of ensemble approaches like as Random Forest and XGBoost, demonstrating its efficacy in endometriosis diagnosis. Figure 6 (a) and (b) shows the count of each ML algorithms applied in the 46 selected papers.



(a)



(b)

Figure 6 (a), (b): Count of ML Algorithms Applied in the 46 Reviewed Papers

4.4 **Discussion**

This paper thoroughly examined 85 publications that employs both the conventional and modern method of detecting endometriosis. During the experiment, papers that applied conventional diagnostic procedures were reviewed with laparoscopy recognised as the gold standard in 17 studies. Furthermore, 10 studies employed Magnetic Resonance Imaging (MRI) for non-invasive detection, 6 studies concentrated on clinical assessment based on symptoms, and another 6 studies utilized ultrasound as a diagnostic instrument. These findings underscore the variety of traditional techniques employed in the diagnosis of endometriosis. Figures 5 (a) and (b) depict the prevalence of journals utilizing these traditional methodologies

In addition to conventional approaches, 46 studies investigated machine learning (ML) and artificial intelligence (AI) methodologies for the detection of endometriosis, utilizing diverse algorithms. The Random Forest model was utilized most frequently (5 instances), followed by XGBoost and Decision Tree (4 instances each), and Support Vector Machine (SVM) and K-Nearest Neighbors (KNN) (3 instances apiece). Additional models, such as Lasso (twice), Stepglm, glmBoost, Naïve Bayes, Gradient Boosting Machine, Neural Networks (NNET), Generalized Linear Model (GLM), LogitBoost, CART Tree, Xception, Inception-V4, ResNet50, DenseNet, EfficientNetB2, Logistic Regression, AdaBoost, and GenomeForest, were each utilized once. The inclination towards ensemble learning models such as Random Forest and XGBoost indicates their efficacy in improving diagnostic precision. Figures 6 (a) and (b) depict the prevalence of machine learning methods employed in the 46 chosen studies.

Notwithstanding progress in machine learning methodologies, numerous problems and research deficiencies remain. These encompass restricted sample sizes, overfitting, inadequate model accuracy, computational inefficiency, and the incapacity to generalize to novel data. Certain research encountered difficulties due to limited datasets (e.g., 224 cases, 118 instances), necessitating substantial processing resources like GPUs. Additional limitations encompassed selection bias, retrospective study designs, single-center data, and the lack of interobserver variability assessment. Moreover, conventional diagnostic methods encounter intrinsic limitations. Laparoscopic visualization possesses a low positive predictive value, does not identify all cases of endometriosis (particularly microscopic instances), and necessitates surgical proficiency. The MRI is constrained in identifying small cases and does not provide histological validation. Ultrasound and clinical diagnostic methods rely on operator proficiency, entail significant equipment costs, and frequently do not identify early-stage endometriosis. Moreover, limited patient sample sizes continue to pose a significant problem for both traditional and machine learning-based diagnostic methods, impacting model efficacy and clinical relevance. These findings underscore the necessity for expanded datasets, higher model generalizability, rigorous validation methods, and increased computational efficiency to maximize AI-driven endometriosis diagnosis and augment early detection capabilities.

V. CONCLUSION

This paper presents a systematic literature review to evaluate traditional and machine learning (ML)/AI-based methodologies for detecting endometriosis. Conventional techniques, including laparoscopy, MRI, ultrasound, and clinical evaluation, continue to be prevalent but encounter obstacles such as higher prices, reliance on operator skill, and restricted early detection efficacy. The review emphasized the increasing utilization of machine learning and artificial intelligence, with Random Forest, XGBoost, Decision Tree, and Support Vector Machine being the most commonly employed methods. Notwithstanding their capacity to enhance diagnostic precision, challenges including limited sample sizes, overfitting, computational inefficiencies, and constraints in generalization were noted. It is essential to tackle these difficulties by utilizing larger datasets, enhancing validation approaches, and optimizing model performance. Future research must concentrate on the integration of AI-driven models with clinical experience to augment the early and precise identification of endometriosis, hence enhancing patient outcomes.

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