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Review Article

Transforming Obstetrics and Gynecology With AI: A Mini Review On 5D Ultrasound Innovations

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Abstract

The integration of Artificial Intelligence (AI) in Ultrasound (US) imaging is revolutionizing diagnostic practices in Obstetrics and Gynecology (OB/GYN). This mini review examines the contemporary applications of AI in US imaging, emphasizing both its advantages and challenges. Analyzing 189 articles from 1994 to 2023, the review explores AI-driven advancements in areas such as fetal biometry, echocardiography, neurosonography, placental analysis, and the identification of fetal abnormalities. AI technologies have shown promise in automating measurements, enhancing image quality, and minimizing operator dependency, thus improving diagnostic accuracy and operational efficiency. Nevertheless, issues such as algorithm performance in low-quality images and the requirement for training with pathological data persist. The review highlights the necessity for continued research to optimize AI applications and facilitate their clinical adoption in OB/GYN.

Keywords: Artificial intelligence, Ultrasound imaging, Obstetrics, Gynecology, Fetal biometry, Echocardiography, Neurosonography, Placental analysis, Fetal abnormalities, 5D ultrasound

Introduction

Artificial Intelligence (AI) has made significant inroads into various fields of medicine, and its impact on Ultrasound (US) imaging in Obstetrics and Gynecology (OB/GYN) is particularly noteworthy. The application of AI in medical imaging aims to address the inherent challenges of traditional US, such as operator dependency, variability in image interpretation, and the need for extensive training [1]. AI technologies, including machine learning and deep learning, have the potential to enhance diagnostic accuracy, streamline workflows, and improve patient outcomes by automating processes and providing decision support [2]. In the field of OB/GYN, US imaging is indispensable due to its non-invasive nature, real-time imaging capabilities, and cost-effectiveness. However, the quality and reliability of US imaging are often influenced by the operator's expertise and the equipment used. AI integration seeks to mitigate these issues by offering automated solutions for image acquisition, analysis, and interpretation [3]. For instance, AI algorithms can assist in the detection and measurement of fetal biometry, the identification of congenital heart defects through fetal echocardiography, and the assessment of placental health and neurodevelopmental abnormalities [4]. Recent literature underscores the transformative potential of AI in US imaging. Studies have demonstrated that AI-assisted US can reduce examination time, decrease inter- and intra-operator variability, and enhance the accuracy of diagnostic procedures [5]. Despite these advancements, there are still challenges to be addressed, such as the algorithm's performance in suboptimal imaging conditions and the need for extensive training datasets that include pathological cases [6]. This mini review aims to provide a comprehensive overview of the current applications of AI in US imaging within OB/GYN, drawing from a systematic analysis of 189 articles published between 1994 and 2023. By highlighting both the benefits and limitations of AI technologies, this review seeks to inform future research directions and promote the effective clinical adoption of AI-assisted US in OB/GYN practices.

Materials and Methods

This systematic literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [7]. The aim was to provide a comprehensive overview of the applications of Artificial Intelligence (AI) in Ultrasound (US) imaging within the field of Obstetrics and Gynecology (OB/GYN). The review included studies published between 1994 and 2023.

Search Strategy

A systematic search was performed in the PubMed and Cochrane Library databases on May 14, 2023. The search terms used were a combination of keywords related to AI and US in OB/GYN, specifically: "artificial intelligence," "deep learning," "machine learning," "artificial neural networks," "ultrasound," "obstetrics," "gynecology," and "pregnancy." Filters for text availability (abstracts) were applied to ensure relevant studies were retrieved.

Inclusion and Exclusion Criteria

Studies were selected based on the following inclusion criteria:

I. Use of AI technologies in US imaging.

II. Focus on obstetrics or gynecology.

III. Published in English or German.

IV. Availability of full-text articles.

Exclusion criteria included:

a. Studies not involving AI or US.

b. Research focused on specialties other than OB/GYN.

c. Articles that did not provide sufficient data for analysis, such as protocols or reviews.

Screening and Data Extraction

The initial search yielded 737 records. After removing duplicates, 621 records were screened based on their titles and abstracts. Two independent reviewers assessed the eligibility of the articles. Discrepancies were resolved through discussion and consensus. Full-text copies of potentially relevant articles were obtained for further evaluation. Using the PICOS (Participants, Intervention, Comparison, Outcomes, Study design) framework, data were extracted and categorized. Participants included healthcare professionals in OB/GYN or radiology, AI specialists, and patients (pregnant or non-pregnant women). Interventions were defined as AI-assisted US applications. Comparisons were made between AI algorithms and human examiners or other AI algorithms. Outcomes focused on fields of AI applications, benefits and limitations of AI usage, and future research aspects.

Data Analysis

The included studies were categorized into two main sections: obstetrics and gynecology. Within each section, studies were further subdivided based on specific applications such as fetal biometry, echocardiography, neurosonography, placental assessment, and detection of fetal malformations. Quantitative and qualitative analyses were performed to summarize the findings. Figures and tables were used to illustrate the distribution of research topics and the performance of AI applications.

Ethical Considerations

As this study was a systematic review of existing literature, no ethical approval was required. However, all included studies were evaluated to ensure they adhered to ethical standards in their respective methodologies.

Results

Applications in Obstetrics

Fetal Biometry: Among the 148 obstetric studies, 27 focused on AI applications in fetal biometry. These studies demonstrated the use of AI algorithms in detecting and measuring standard planes in 2D and 3D US images. Automated measurements of Head Circumference (HC), Abdominal Circumference (AC), and femur length showed promise in reducing operator variability and enhancing measurement accuracy [8]. However, challenges such as algorithm performance in poor-quality images and high maternal BMI were noted [9-11].

Fetal Echocardiography: Twenty-three studies addressed AI applications in fetal echocardiography. AI-assisted US improved the detection of congenital heart diseases (CHD) by automating the acquisition of standard views such as the four-chamber view (4CV) and outflow tracts. Studies reported significant reductions in examination time and increased diagnostic accuracy. Nevertheless, limitations included the need for high-quality images and training with pathological cases to improve algorithm performance [12-14].

Fetal Neurosonography: Nineteen studies explored AI applications in fetal neurosonography, focusing on brain development and abnormality detection. AI models facilitated the acquisition of standard head planes and automated the detection of key anatomical structures. Benefits included reduced workload for sonographers and improved accuracy in measuring small structures. However, rapid anatomical development of the fetal brain posed challenges for AI algorithms, necessitating further refinement [15-17].

Placental and Umbilical Cord Assessment: Twenty articles investigated AI applications in assessing placental and umbilical cord characteristics. AI algorithms showed effectiveness in localizing and measuring placental volume, tissue texture, and vascularization. These advancements hold potential for early prediction of complications such as fetal growth restriction and hypertensive disorders. Yet, the difficulty in identifying the interface between the placenta and myometrium, particularly in early pregnancy, remained a limitation [18].

Detection of Fetal Malformations: Eleven studies focused on AI applications in detecting fetal malformations during the first and second trimester scans. Automated detection and measurement of

Nuchal Translucency (NT) and identification of structural anomalies were significantly enhanced by AI. These improvements promised reduced workload and higher diagnostic accuracy. However, challenges such as small data sets for rare anomalies and the need for real-time application persisted [19-23].

Prediction of Gestational Age: Ten studies addressed the use of AI in predicting Gestational Age (GA). AI algorithms utilizing measurements of fetal head, abdomen, and femur showed high accuracy in estimating GA. Particularly in low-resource settings, AI-assisted point-of-care US demonstrated potential in providing accurate GA estimates without the need for experienced sonographers. The primary limitation was the reduced accuracy in early and late stages of pregnancy [24-27].

Other Applications in Obstetrics: Additional studies explored AI applications in various obstetric fields, including fetal lung maturation, maternal factors, early pregnancy, intrapartum sonography, and workflow analysis. AI-assisted US improved diagnostic accuracy, reduced examination time, and enhanced workflow efficiency across these applications. However, challenges such as algorithm training with pathological cases and the need for quality control mechanisms were noted [28,29].

Applications in Gynecology

Adnexal Masses

Eleven studies investigated AI applications in the assessment of adnexal masses. AI algorithms demonstrated high accuracy in distinguishing between benign and malignant tumors using 2D and color Doppler US images. Despite the promising results, limitations included the need for larger, diverse data sets and consideration of clinical context in diagnostic decision-making [30,31].

Breast Masses

Eight studies focused on AI applications in breast US imaging. AI-assisted US showed potential in improving lesion detection and classification, particularly in dense breast tissues. The benefits included reduced unnecessary biopsies and shorter examination times. However, challenges such as the need for high-quality images and training with borderline cases persisted [32].

Endometrium

Five studies explored AI applications in evaluating endometrial characteristics. AI algorithms demonstrated high accuracy in assessing endometrial thickness and texture. The use of 3D US images provided improved identification of the endometrial-myometrial junction. Limitations included reduced accuracy in thin endometria and the need for manual selection of regions of interest [33,34].

Pelvic Floor

Six studies addressed AI applications in pelvic floor assessment. AI-assisted US enabled reliable detection of pelvic organ prolapse and measurement of pelvic anatomical landmarks. The significant reduction in examination time facilitated better patient care. Challenges included operator dependency and the need for manual selection of regions of interest before analysis [35].

Other Applications in Gynecology

Eleven studies explored various AI applications in gynecology, including endometriosis, premature ovarian failure, uterine fibroids, follicle tracking, and ectopic pregnancies. AI-assisted US improved diagnostic accuracy and reduced examination time across these applications. However, limitations such as the need for larger data sets and external validation were noted [36].

Discussion

The integration of Artificial Intelligence (AI) into Ultrasound (US) imaging within Obstetrics and Gynecology (OB/GYN) represents a significant advancement, promising improvements in diagnostic accuracy, workflow efficiency, and overall patient care. This review highlights the current applications, benefits, and challenges of AI-assisted US in OB/GYN, drawn from an analysis of 189 studies published between 1994 and 2023.

Benefits of AI in Ultrasound Imaging

AI has shown considerable potential in enhancing the diagnostic capabilities of US imaging. By automating measurements and standardizing image interpretation, AI can reduce inter- and intra-operator variability, which is a common challenge in traditional US imaging [1,24]. For instance, AI-assisted measurements of fetal biometry, such as head circumference, abdominal circumference, and femur length, have demonstrated improved accuracy and consistency compared to manual methods [12]. This consistency is crucial for monitoring fetal growth and development, which directly impacts clinical decision-making. In fetal echocardiography, AI has facilitated the automated acquisition of standard views, significantly reduced examination time and improving the detection rates of Congenital Heart Diseases (CHD) [30]. Similarly, AI applications in fetal neurosonography have enhanced the detection and measurement of key brain structures, contributing to early diagnosis and intervention for neurodevelopmental abnormalities [10,14,21]. These advancements underscore the role of AI in improving diagnostic accuracy and enabling timely medical interventions. AI has also been instrumental in assessing placental and umbilical cord characteristics, which are critical for predicting and managing complications such as fetal growth restriction and hypertensive disorders [17,25]. Automated analysis of placental volume, tissue texture, and vascularization can provide valuable insights that might be missed in manual assessments, thus enhancing prenatal care.

Challenges and Limitations

Despite its promise, AI-assisted US in OB/GYN is not without challenges. One of the primary limitations is the performance of AI algorithms in poor-quality images, which can be influenced by factors such as high maternal BMI, fetal position, and low contrast due to reduced amniotic fluid [6,9,17]. These conditions can impede the algorithm's ability to accurately detect and measure anatomical structures, necessitating further refinement and robust training with diverse datasets. Another significant challenge is the need for extensive training of AI models with pathological cases to improve their diagnostic capabilities. Many current AI applications have been trained predominantly on normal cases, which limits their effectiveness in identifying and diagnosing rare or complex abnormalities [30-36]. This gap highlights the necessity for large, annotated datasets that encompass a wide range of pathological conditions to enhance the generalizability and reliability of AI models. Ethical considerations and the "black box" nature of AI also pose challenges. The opacity of AI decision-making processes can hinder clinician trust and acceptance. Efforts to develop explainable AI (XAI) systems, which provide insights into how AI algorithms reach their conclusions, are crucial for fostering clinician confidence and promoting the integration of AI into clinical practice [1,4,31,36].

Future Directions

The future of AI in US imaging for OB/GYN holds great potential, with ongoing research aimed at addressing current limitations and expanding applications. Future studies should focus on improving algorithm robustness by incorporating diverse and extensive training datasets that include a broad spectrum of normal and pathological cases. Additionally, enhancing real-time application capabilities and developing quality control mechanisms will be essential for ensuring the clinical applicability and reliability of AI-assisted US. The development of XAI systems will be critical for addressing ethical concerns and increasing clinician trust in AI technologies. By making AI decision-making processes more transparent, clinicians can better understand and verify AI-generated diagnoses, thus facilitating more informed and confident clinical decisions. Moreover, expanding AI applications to include other aspects of maternal and fetal health, such as predicting adverse pregnancy outcomes and improving surgical planning, will further enhance the role of AI in OB/GYN. Collaborative efforts between AI developers, clinicians, and researchers will be vital for advancing these technologies and ensuring they meet the evolving needs of clinical practice.

Conclusion

AI-assisted US imaging represents a transformative advancement in OB/GYN, offering significant benefits in diagnostic accuracy, efficiency, and patient care. While challenges remain, ongoing research and development efforts are poised to address these issues and expand the clinical applications of AI in this field. By harnessing the potential of AI, the future of OB/GYN diagnostics and care promises to be more precise, efficient, and patient-centered.

Acknowledgement

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Conflicts of Interest

None

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