Artificial Intelligence in Clinical and Surgical Gynecology

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Abstract

Clinicians have increasingly been using artificial intelligence (AI) to make decisions and to increase their knowledge in various clinical and surgical gynecological areas. A vast amount of clinical, medical, and biological patient data is processed in fast computer networks using complex algorithms to create mathematical modeling. The development of these mathematical models gives hope of a promising future with their contribution to overcoming the difficulties encountered in the diagnosis, individualization of treatment plans and improving patient outcomes. Virtual AI in clinical gynecology uses pattern recognition to aid diagnosis, plan treatment, and predict outcomes in gynecological malignancies, assisted reproductive techniques, and urogynecology. In gynecological surgery, physical AI combines augmented reality in operations in the form of computer-aided or robotic platforms. However, AI is yet to be fully incorporated into modern medical practice to improve patient outcomes in clinical gynecology.

Keywords: Artificial intelligence, roboticsurgery, gynecology

Klinik ve Cerrahi Jinekolojide Yapay Zeka

Öz

Günümüzde klinisyenler, jinekolojinin çeşitli klinik ve cerrahi uygulamalarında karar vermede ve bilgilerinin arttırılmasında giderek artan oranlarda yapay zeka (AI) teknolojilerini kullanmaktadırlar. Hastalarla ilgili çok büyük miktarda klinik, tıbbi, biyolojik veri hızlı bilgisayar ağlarında karmaşık algoritmalar kullanarak işlenmekte ve matematiksel olarak modellemeler oluşturulmaktadır. Geliştirilen bu matematiksel modellemeler jinekolojik hastalıkların tanısında karşılaşılan zorlukların üstesinden gelme, tedavi yöntemlerinin kişisel değerlendirilmesi ve hasta sonuçlarının iyileştirilmesine olan katkılarıyla umut verici bir geleceğe sahip olduğumuzu göstermektedir. Klinik jinekoloji dalında sanal AI, jinekolojik malignitelerde, yardımlı üreme tekniklerinde, ürojinekolojide teşhis, tedavi algoritmaları ve sonuç tahminine yardımcı olmak için örüntü tanımayı kullanır. Jinekolojik cerrahi dalında fiziksel AI, operasyonlarda bilgisayar destekli veya robotik platformlar biçiminde arttırılmış gerçekliği birleştirerek kullanır. AI, klinik jinekolojide hasta sonuçlarını iyileştirmek için modern tıp uygulamalarına henüz tam dahil edilmemiştir.

Anahtar Sözcükler: Yapay zeka, robotikcerrahi, jinekoloji

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Artificial Intelligence in Gynecology

Artificial intelligence (AI) technology is used in gynecology for risk assessment in disease prevention, disease diagnosis, predicting treatment success, monitoring patients, and managing treatment complications[1]. AI software uses complex algorithms to analyze large amounts of data, enabling greater details to be reviewed as the information increases. It eases the workload of clinicians by assisting their interpretation and allowing them to make more confident decisions. AI is not meant to replace clinicians, but to serve them. It is important to keep in mind it is not a substitute for clinical experience[1].

AI has not yet been fully incorporated into modern medical practice to improve patient outcomes. Virtual AI in clinical gynecology uses pattern recognition to aid diagnosis, determine treatment plans, and predict outcomes in gynecological malignancies, assisted reproductive techniques, and urogynecology. Physical AI is used more than virtual AI in gynecological surgery. AI applications can assist the surgeon by providing better imaging before and during the operation. Physical AI combines augmented reality in operations in the form of computer-aided or robotic platforms. With the help of these platforms, risks can be reduced in invasive operations and the operation time can be shortened[2].

Artificial Intelligence in Gyneco-oncology Assisted Reproductive Technology

AI technology can be used for correct and efficient selection of high-quality sperm, oocyte, and embryo, and in recommending the most suitable Assisted Reproductive Technique (ART) suitable for the patient. Data collection is the first step in the workflow of AI technology in ART. For large-scale populations, a reproductive health database is created with electronic medical records, hospital data, and cloud data sharing, which includes digital recording of patient characteristics, treatment history, adverse events, physical examination findings, clinical laboratory findings, image analysis, and follow-up findings. In the second step, this data is analyzed using AI methods such as machine learning and natural language processing, and the appropriate model is selected. Afterwards, it aims to train, evaluate, and validate the model using a training dataset. The quantity and quality of the database affect the performance, applicability, and dissemination of the model. These practices help obtain successful results in reproductive medicine.

Various algorithms with AI applications using integrated image analysis for the automatic classification of oocytes, sperm, and embryos aim to increase efficiency, reduce errors, and reduce workload in ART. Currently, no method reliably recognizes oocyte quality and developmental competence. Lack of cytoplasmic maturation of oocytes and genetic factors are the main causes of fertilization failure. In a study that believes biomechanical characteristics to be equally important for cellular functions in addition to the structural features of cells, the maturation processes of mouse oocytes from the germinal vesicle to the metaphase II stage were visualized in vitro[3]. The Cytoplasmic Movement Velocities of each oocyte were evaluated with a mathematical classification tool and the probability of being developmentally sufficient or insufficient could be estimated with 91.03% accuracy. It was concluded that this protocol established for mice could be tested on oocytes of other species, including humans. Larger datasets created by adding new biomarkers and biomechanical properties to the data used in ideal oocyte selection can increase the success of quality oocyte recognition by AI applications. Today, it is important to evaluate the quality of cryopreserved oocytes in patients who want to preserve their fertility and to produce algorithms to create models that determine reproductive competence.

When evaluating the male factor in reproductive health, it is important to determine the morphology of sperm cells and to monitor changes in sperm motility. Today, computer-assisted sperm analysis (CASA) is used for routine examination. The system detects the position of the sperm heads in multiple microscopic fields. Algorithms are used to create a sperm movement pattern using kinematic parameters describing sperm velocities and proxy measurements for tail movement[4]. Sperm concentration and mobility can change according to individual health status, living habits, socio-demographic data, and environmental factors. There are studies developing an Artificial Neural Network (ANN) that can predict the results of semen analysis based on data collected through questionnaires[5]. This methodology can be a useful tool for predicting early diagnosis of patients with seminal disorders or for selecting candidates to be semen donors. One study retrospectively evaluated height, total testicular volume, follicle-stimulating hormone, luteinizing hormone, total testosterone, and ejaculate volume of azoospermic men. Both logistic regression analyses and neural networks were able to predict the presence or absence of chromosomal abnormalities with over 95% accuracy[6].

Evaluation of embryo morphology and development is important in obtaining better results in ART treatments[7]. Embryologists select embryos in the blastocyst stage with a non-invasive method based on observation. These evaluations, depending on a scoring system based on the morphology and dynamic development of the embryo, may differ depending on the experience and expertise of the embryologist[8,9]. In order to eliminate these subjective differences, computer-assisted grading based on semi-automatic morphological analysis of blastocysts was used. Embryo selection algorithms were used to characterize the main morphological features of the blastocyst[9]. It was concluded that blastocysts at the same developmental stage could be graded based on the measurement of inner cell mass (ICM) and trophectoderm (TE) thickness. The main limitation of these proposed algorithms is that it is a semi-automatic approach that requires user intervention depending on the image quality of the blastocyst. In later studies, a fully automated new algorithm was used to define the segmentation and measurement of TE and ICM in human blastocysts. The quality of blastocyst surface images were improved using Retinex theory[10]. The algorithm used for automatic segmentation of TE and ICM components enabled a more detailed evaluation of blastocysts[7]. In addition to automatic image identification studies, new technologies monitoring development with an automatic device have also been developed. Accelerated algorithms using dynamic tracking systems based on morphokinetic parameters did not provide sufficient benefit in embryo selection. Morphokinetic features can be used to exclude embryos with the lowest implantation potential[11].

AI technology was first used to create an ART outcome prediction model in 1997. In this model, an ANN was created with a 59% predictive power using only four inputs (age, number of eggs collected, number of embryos transferred, and whether there were frozen embryos)[12]. In 2011, a hybrid intelligence model with a genetic algorithm foundation was created using data mining to integrate decision tree learning techniques with information from IVF patient records[13]. This model was able not only to help predict outcomes but also to recommend modified IVF treatment based on individual patient characteristics. The disadvantage of the study was that the model was based on data from a single IVF center. Data collected from various centers can increase accuracy by representing a larger population. In 2015, AI methods with 84.4% predictive power were used[14]. Although the accuracy of the predictions is increasing, the model created is not well applied in clinical practice due to various problems. AI needs to be supported by more data to encourage its application in reproductive medicine.

Artificial Intelligence in Gyneco-oncology

Today, the prognosis of gynecological malignancies is based on the International Federation of Gynecology and Obstetrics (FIGO) classification[15]. Tailoring an individualized treatment plan for each patient is an important step in gynecooncology[16]. Personalized medicine is the prediction of disease susceptibility, prognosis, or response to treatment using personal information such as genetic makeup and medical history[17]. New radiological or molecular markers can guide patient management and help predict outcomes. AI technology helps clinicians make decisions and increase knowledge by allowing the identification of gray zones through a deeper understanding of complex molecular biology and pathophysiological concepts. Through the diversity in machine learning methods, high learning capacity and ability to perform complex mathematical modeling from different data types, AI is able to establish systems to diagnose and manage gynecological malignancies and prevent the development of complications.

In a radiological study, a diagnostic algorithm including diffusion-weighted magnetic resonance imaging (MRI) criteria was developed to distinguish malignant uterine sarcomas from benign atypical leiomyomas[18]. This study may change the treatment approach for atypical uterine masses in gynecology. KRAS mutations in endometrial cancer; WNT signal in ovarian, endometrial, and cervical cancer can predict cancer progression and prognosis on an individual basis[19,20]. In one study, a database constituted from 668 epithelial ovarian cancer cases over a 10-year period was created. An AI model that could compare various algorithms and classifications alongside traditional statistical approaches such as logistic regression was created. The model was used to predict the overall survival and outcome of surgery[21]. A clinical decision-scoring system using

ANN was developed for women with cervical intraepithelial neoplasia (CIN). In this system, colposcopic findings of 2267 women and data of Human Papillomavirus (HPV) biomarkers (E6 and E7 nRNA and p16INK4A) were used. The developed AI technology showed significant potential in patient follow-up with 93% sensitivity and 99.2% specificity for CIN2 prediction[22]. The proposed AI algorithm in gynecological malignancies has the potential to quickly compare current patient information with a huge database of previously treated patients. By using this technology, the best treatment method can be determined for the individual, and treatment results can be predicted. The performance of these systems will most likely increase with increasing dataset size and require further research in the area.

It is thought that the diagnostic performance and clinical use of colposcopy will become widespread with the development of digital colposcopy with high-resolution imaging capability and deep learning. The use of AI is practical and cost-effective when compared to the visual inspection of a Papanicolaou (PAP) smear and existing colposcopy methods based on observation after the application of acetic acid to the tissue. It would require minimal training and give immediate results, and patients would be treated at the same visit[23]. AI-guided digital colposcopy can help colposcopies improve their diagnostic performance, support busy workflow in the clinic, and provide effective training for new colposcopy training entrants. With the use of cloud data-based AI-guided digital colposcopy, people in different places can get equal access to the diagnosis of cervical cancer. Currently, no labeling, annotation, classification, and quality control of datasets is performed for AI-guided colposcopy training and validation. The lack of standardization of colposcopy equipment, terminology to collect data, and the use of static images instead of dynamic colposcopy images limit the use of AI-guided digital colposcopy[24]. Today, AI-guided digital colposcopy aims to assist colposcopists rather than replace them. AI deep learning algorithms can collect a large number of images related to cervical cancer screening and appropriately identify diseased tissue. Increased communication between colposcopists and AI engineers would provide resolution of technical, ethical, and legal issues and may stimulate the development of AI-guided digital colposcopy.

Artificial Intelligence in Gynecological Surgery

In gynecological surgery, the application of physical AI has found more uses than virtual AI[2]. AI applications were utilized in areas related to imaging and spatial awareness. AI can assist the surgeon by providing better preoperative and intraoperative imaging. The three-dimensional image (3DP) model revealed by preoperative MRI was compared retrospectively with the surgical findings. The 3DP was superior to its two-dimensional (2D) counterpart in demonstrating the depth, extent, and relationship of structures adjacent to the surgical field. It has also proven useful in a case report of deep infiltrating endometriosis[25]. These models can potentially be helpful in surgical planning, raising awareness, and protecting surrounding structures[25,26]. A study was conducted using an AI-based endoscopy system to estimate the depth and location of the ureters during gynecological surgery[27]. The algorithm used has proven to be able to alert surgeons and increase safety in cases where certain vessels or structures are difficult to visualize during surgical procedures.

Robotic surgery, a combination of both AI and minimally invasive surgery, used in various surgical fields has demonstrated superiority in complex gynecological diseases[28]. Uterine leiomyomas, adenomyosis, endometriosis, adnexal masses, tubal reanastomosis, and fertility preservation techniques can all benefit from robotic surgery[29]. Some robotics can even reduce vibrations to improve accuracy[2]. Additionally, the introduction of instruments which aid in-depth visibility, such as 3D laparoscopic surgery has the potential to provide better surgical outcomes[30].

Robotic myomectomy is a viable alternative to abdominal and laparoscopic myomectomy. Studies have shown various advantages of robotic myomectomy such as reduced blood loss, smaller scars, shorter hospital stay, and fewer postoperative complications in robotic myomectomy[31,32]. In contrast, other studies have shown that there is no significant difference in terms of duration of surgical operation, blood loss, complications, length of hospital stay, and readmission in robotic myomectomy when compared with standard laparoscopy[33]. In the case of deeply infiltrating endometriosis (DIE), better reproductive outcomes have been observed with robotic surgery when compared to laparoscopy[34,35]. Robotic surgery can distinguish boundaries between healthy myometrium and myometrial lesions in adenomyosis allowing the opportunity for suturing with 3DP[36]. Robotic assistance allows us to perform this procedure with a minimally invasive approach; however, adenomyosis resection is still a surgical procedure with uncertain clinical efficacy and reproductive outcomes. There is a lack of studies on subsequent pregnancy outcomes for robotic adenomyomectomy. New minimally invasive approaches such as laparoendoscopic single-site (LESS) surgery and natural-orifice transluminal endoscopic surgery (NOTES) can reduce surgical trauma, operative complications, and potentially improve outcomes. High expectations are placed on robotic surgery due to the poor ergonomics and long learning curve in conventional surgery. Although a few studies have shown that robotic surgery from one site is feasible and safe in patients with gynecological disease the number of studies is not sufficient to make a conclusion[37,38].

Artificial intelligence is promising in every step of gynecological surgery, from preoperative decision-making to targeting localization of surgical procedures. Minimally invasive surgical techniques are developing using the application of robotic surgery and image-guided surgical technologies. The aim is not to perform gynecological surgery autonomously with robots. Artificial intelligence applications are a tool that can increase the awareness of surgeon, supplement their skills, reduce their workload, and provide better surgical outcomes to patients.

Conclusion

AI applications enable personalized diagnostic and treatment algorithms in clinical gynecology. The performance and application of these models improve as the data base increases in quality and quantity. AI applications in gynecological surgery may aid the surgeon by providing better imaging before and during the operation. Computer-aided or robotic platforms are used in operations combining expeditions with augmented reality. By using these platforms, it is possible to decrease the risks of invasive operations and shorten the operation time. AI is not meant to replace the gynecologist, but to assist in decision-making. It is important to point out the value of the surgeon's clinical experience, as it is incomparable to any technological application.

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