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Artificial Intelligence in Veterinary Surgical Research: Current Applications and Prospects

Turki K. Almalki[1], Mohamed A. Marzok[1*], Zakriya Al Mohamad[1], Abdelrahman Hereba[2], Mohamed W. El-Sherif[3*], Mahmoud A. Hassan[3] and Mahmoud S. Saber[3]

[1] *Department of Clinical Studies, College of Veterinary Medicine, King Faisal University, Al Ahsaa 31982, Saudi Arabia.*

[2] *Department of Microbiology, College of Veterinary Medicine, King Faisal University, Al Ahsaa 31982, Saudi Arabia.*

[3] *Department of Surgery, Faculty of Veterinary Medicine, New Valley University, Al Kharga, New Valley 27511, Egypt.*

Abstract

ARTIFICIAL intelligence (AI) has made great modification in human surgical research. Opportunities still exist for their application in veterinary surgical sciences with potentially transformative implications for animal health together with comparative medicine research. The objective of this review was to investigate what AI can currently do and what it might do in the future in terms of veterinary surgical research during the whole procedural process, which consists of pre, intra, and postoperative contributions, limitations, and future directions. Literature was searched to find out the use of AI in veterinary surgical sciences, a thorough literature search was conducted in the following databases (PubMed, Scopus, CAB Abstracts, Web of Science) and articles from the year 2018 to 2025 were evaluated. The studies were categorized based on pre, intra and postoperative application and a cross analysis of data management, ethics and translational applicability was carried out. The applications of AI in veterinary surgical research are advanced, with a focus mainly on preoperative diagnostic imaging and post operative histopathologic analysis. Machine learning models have the potential to accurately choose surgical cases, predict the results, and even assess the outcomes with a precision of more than 85.0% of the result. However, the intraoperative application of AI tools in veterinary practice is not as developed as in human surgery, mainly due to the scarcity of veterinary specialists' technological adaptation problems. AI is expected to revolutionize veterinary surgical research; however, it needs cooperations, uniform data gathering rules, and the creation of algorithms for different animal species.

Keywords: Artificial Intelligence, Machine Learning, Surgical Research, Veterinary Surgery.

Introduction

AI has come, in the last decade, to be the leading and supportive factor in revolution of the surgical sciences through the establishment of machine learning for preoperative planning, intraoperative navigation, and postoperative outcome prediction [1, 2]. However, the veterinary profession has lagged significantly behind in the use of AI technologies and, as a result, a major knowledge gap has been created which prohibits the progress of animal healthcare and the study of comparative medicine [3].

The incorporation of AI-supported diagnostic imaging and treatment planning has just begun in the clinical veterinary area, while the role of AI in surgical veterinary studies has not yet been revealed and poorly assessed [4]. This presents a significant challenge, as veterinary surgery operates at the forefront of animal health and welfare as well as the translational research for furthering human medicine [5].

*Corresponding authors: Mohammed Marzok, E-mail: mmarzok@kfu.edu.sa, Tel.: 009660549184646
& Mohamed El-Sherif, E-mail: mohamedelsherif@vet.nvu.edu.eg, Tel.: 01008467944

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The multifarious characteristics of veterinary surgical research that involves multispecies and anatomical and physiological components offers a challenge and opportunity for the development of AI [6]. In human surgery, development of AI models has been possible due to a standard protocol and large homogeneous datasets of different surgical procedures. In compiling veterinary surgical research, it is important to note that each species has its differences, lower sample sizes and [7].

Artificial intelligence has the potential to address numerous methodological issues in current veterinary surgery research, including variability in data collection methods as well as continuity in long-term outcome assessment. Some of the challenges include evaluating subjective outcomes, time consuming data analysis, surgical interventions being inconsistent among species, and tracking patients years later. The increasing need for evidence based veterinary care and strict research protocols correspond quite nicely to AI's ability to simply and reliably reproduce results [8].

The current study seeks to investigate the potential uses of artificial intelligence (AI) in veterinary surgical research, from surgical planning prior to surgical procedures to intraoperative navigation and tracking and monitoring recovery afterwards. The article aims to present the current applications, highlight alternative methods, recognize limitations, and discuss future possibilities while providing a roadmap to favorably integrate AI into veterinary surgical science, from initial diagnosis to healing.

Material and Methods

Literature Search Strategy

A systematic literature search was conducted across multiple databases including PubMed, Scopus, Web of Science, CAB Abstracts, and Google Scholar from January 2018 to December 2025. The search strategy employed combinations of keywords including "artificial intelligence," "machine learning," "deep learning," "neural networks," "veterinary surgery," "animal surgery," "surgical research," "comparative medicine," and species-specific terms.

Inclusion and Exclusion Criteria

Inclusion criteria encompassed peer-reviewed articles addressing AI applications in veterinary surgical sciences, including diagnostic imaging for surgical planning, intra-operative guidance systems, post-operative outcome assessment, surgical technique evaluation, and translational research studies. Conference proceedings and preprints from recognized veterinary and AI conferences were included when they contained substantial methodological or clinical contributions.

Exclusion criteria eliminated non-surgical AI applications such as herd health management, epidemiological modeling, and general clinical diagnostics not directly related to surgical intervention or research.

Framework for Analysis

Studies were categorized according to a comprehensive framework organizing AI applications into three primary phases:

Preoperative applications: Study design optimization, case selection algorithms, predictive modeling, and surgical planning

Intraoperative applications: Real-time navigation, image guidance, robotic assistance, and surgeon performance assessment

Postoperative applications: Automated histopathology analysis, prognosis prediction, rehabilitation monitoring, and outcome evaluation

Cross cutting themes included data management strategies, ethical considerations, translational research value, and species-specific adaptations.

Evaluation Metrics

Each identified application was evaluated for methodological contributions, clinical impact, evidence quality, limitations, and potential for broader implementation. Particular attention was given to comparative analysis with human surgical AI applications and identification of veterinary-specific innovation opportunities.

Results

AI preoperative surgical applications

The advancement and the use of AI in pre-operative veterinary surgical investigation have been the most advanced and implemented. Machine learning algorithms have been developed for the interpretation of medical imaging, with convolutional neural networks (CNNs) classified into applications that accurately detect surgical pathology across species [9, 10].

Predictive modeling represents another significant preoperative application, with studies demonstrating AI's capability to guess surgical outcomes, complications, and recovery patterns. The quality of evidence varies substantially across studies [11-14]. Cetintav and Yalcin (2025) investigated machine learning (ML) with a well-constructed retrospective cohort study for their ML models (80:20 train-test split) and external validation.

Conversely, other studies had limitations regarding their method [15].

Banzato et al. (2021) reported on only 120 thoracic radiographs from a single institution and did not include external validation. The experiment used to evaluate the use of AI to detect common technical errors in thoracic radiographs in canines. The experiment resulted in algorithm success rate 81.5% [4].

Another study was conducted to assess a decision support AI performance system against just three veterinary radiologists in canine and feline patients, limiting models' generalizability [10]. Studies varied in the methodological design (from proof-of-concept studies, <50 cases; to multi-institutional validation studies, >500 cases) making it difficult to complete a meta-analysis [15-17].

Utilizing AI enabled classification systems, researchers have improved case selection for research studies, although the quality of evidence varies [18]. A study demonstrated strong methodology with canine cutaneous tumors (n=350) determined by several pathologists, establishing strong ground truth labels [19]. The circumstances surrounding case selection relates to verification bias, where AI predictions impact histopathological interpretation. Additionally, 23% of reviewed papers (n = 7/31) provided a confidence interval for accuracy statistics while 15% (n =5/31) provided prospective validation, which diminishes the strength of conclusions made by the studies regarding clinical use [20].

AI intraoperative surgical applications

AI applications for intraoperative use still have not made their way into the foreground in veterinary surgeries. The reluctance to embrace them is due to some stringent technical and economic limitations. Our research could point out five major barriers: (1) absence of robots specifically made for veterinary surgeries, (2) nonexistence of intraoperative imaging protocols applicable to all species, (3) lack of clinical computational infrastructure in veterinary operating rooms, (4) lack of training datasets of intraoperative videos, and (5) veterinary medicine's regulatory ambiguity around AI-assisted surgical systems.

Although there are difficulties, the trial implementations are still showing good results. Alini et al. (2023) created a computer-assisted orthopedic surgery system for big animals with accuracy of 1.2mm in cutting guidance, but 45 minutes was needed for the system setup as opposed to 10 for the manual planning [17]. A review study was conducted to evaluate the annotation of open-source surgical videos and provide suggestions and opportunities for improvement in the field [21].

Current solutions being rolled out are: (1) implementation of smartphone based augmented reality systems for surgical assistance, (2) using cloud processing to get around the local computer power limitation, and (3) transfer learning from human surgical datasets with species-specific systems [17, 22, 23].

Postoperative surgical applications

Applications of AI in the postoperative period show big promise and their use is increasing in veterinary surgical research. One of the most successful applications is the automatic histopathology analysis. Here, deep learning algorithms have reached a level of accuracy comparable to the experts in classifying tissues and identifying pathological features among several species [24, 25].

Prognostic prediction models based on machine learning methods have shown promise in several surgical settings. Veterinary oncology studies have developed artificial intelligence systems that combine surgical records, histopathology, and clinical variables to predict long-term outcomes with higher accuracy than traditional staging models [26].

The monitoring of rehabilitation is a novel application in which AI algorithms quantify movement patterns, activity levels, and recovery metrics, creating an objective measure informed by wearable sensors and video analysis. These systems allow for an objective measurement and evaluation of post-operative rehabilitation recovery and function outcomes, type of patient species and surgical procedure notwithstanding [27].

The application of natural language processing algorithms has enabled automated data analysis for research studies through extraction of relevant information from clinical notes, surgical notes, and follow-up reports while greatly reducing the burden of manual data accumulation and facilitating consistency in multi-center research projects [28].

Key challenges

A range of key challenges arose in the literature analysis. The lack of data is the largest bottleneck, and datasets in veterinary medicine are markedly smaller than those available for human medicine. Data limitations are further compounded by species diversification; algorithms developed for one type of species may not necessarily be transferred to others without major modifications.

The issues of standardization underscore all phases of AI implementations, where variations in surgical processes and outcome metrics, as well as data collection methodologies, limit the capacity to develop AI systems broadly applicable to veterinary medicine. The lack of a standardized veterinary surgical database is evidence of professional registries in human medicine that support the development and, ultimately, validation of AI systems [29].

Ethical considerations that require further exploration that are unique to veterinary medicine include possibilities of AI-based treatment recommendations, data ownership and sharing of data across institutions, and potential biases produced from reported AI-based evidence on species. Further, understanding ethical considerations in informed consent is important when a pet owner makes decisions on behalf of the patient [30-32].

Veterinary specific opportunities

The surgical discipline of veterinary medicine poses specific opportunities for AI development that are underutilized. The normal anatomical and physiological variation among breeds within species allow for a unique test case of algorithm robustness variation compared to the lesion-based variations one may see in a human patient. Variations in breeds across species continue to develop generalized AI models for both feline, canine and human applications. In other words, many veterinary innovations will maintain translational ability to human institutions [33-35].

The veterinary medicine AI systems demonstrated successful transfer of learning from one species to another by taking advantage of comparative variability of anatomy. Human-trained computational pathology models of pan-species, for example, achieved 94% accuracy in dog transmissible venereal tumors and 88% in devils from Tasmania, with noticeable performance in 18 vertebrate species [36]. They also point to the potential for cross species generalizability in veterinary AI. An attribute plentiful in human exclusive datasets by default of diminished physiological heterogeneity. While prospects for the multi-species surgical atlas and zoo validation remain auspicious, no externally published data currently substantiates such specific applications [36].

Veterinary surgical practice constraints engendered a frugal innovative culture that generated affordable technologies with significant impacts. Definitive documentation of veterinary innovations being translated into human pilot studies is limited, but tools such as the Global IDEAL Sub framework show increasing recognition that rural human healthcare benefits from the translational potential of surgical technologies from resource constrained environments, including the veterinary environment [37].

Veterinary medicine presents specific lenient platform for accelerated AI prototyping and verification, with reduced regulatory controls and moral permissions for terminal investigations and tissue biopsies. This allows greater fidelity of verification of surgical or pathological AI instruments than in human cases. As an example, new veterinary pathology research utilized AI for precise measurement of cancer margins and cell distributions, permitting more rapid algorithm iteration [38]. Although absolute proof of decreased development cycles from 36 to 12 months is lacking, application of veterinary oncology artificial intelligence breakthroughs to human oncology is increasingly frequent in the literature [33, 39].

Discussion

Current State and Interpretation

The adoption of artificial intelligence in veterinary surgery remains in its early stages, with current implementations largely concentrated in diagnostic imaging and post-operative assessment, where tools can be readily adapted from human medicine. According to a 2025 scoping review, the field suffers from disorganized development efforts, largely due to the fragmented nature of veterinary clinical practices and limited inter-institutional collaboration [29]. These patterns mirror the early trajectory of AI in human surgery, where non-operative applications significantly outpaced intra-operative integration due to technical, ethical, and logistical barriers [34]. An observation during this review is that the gap is widening between veterinary surgery AI applications and human surgery AI applications, largely due to limitations of resources and limited market incentive for veterinary specific AI development [14].

Comparative Analysis with Human Surgical Research

Human surgical research has achieved substantial AI integration across all phases, with navigation systems, robotic assistance, and real-time decision support becoming increasingly routine [2]. There are some factors slowing down AI development for veterinary medicine. These range from reduced, divided datasets, limited budgets, and species complexities that prevent common model building. Also, commercial motivations remain low because of the rather modest size of the veterinary AI technologies' market base [29, 40].

Still, veterinary surgery is a specific site for artificial intelligence because it offers a space for experimental malleability and natural interspecies heterogeneity animals, including dogs and cats, that may be used for systematic research studies. These settings could allow for the verification and extrapolatable of AI in ways that would not be morally viable in human studies. However, the veterinary field has not yet been recognized or benefitted from these opportunities for AI development [41].

Veterinary AI Contributions to Human Surgery

Although knowledge in artificial intelligence of veterinary medicine has for some time been motivated by advances in human healthcare, there is increasing acknowledgment of two-way translation potential. Characteristically, the spectrum in patient mass and structural anatomy from 2 kg cats to 700 kg horses constitutes a significant background for training broadly transferrable surgical AI systems. That spectrum would expand effectiveness in applications such as pediatric compared to adult human surgery, in which such variability is of greatest importance [42].

Even in low resource environments, veterinary AI systems also influence human global health planning. The resultant veterinary clinic-based AI systems generally employ edge computing and model compression, producing outputs for implementing AI in low-resource human hospitals [33].

Comparative oncology demonstrates that spontaneous neoplasms of domesticated animals, such as canine osteosarcoma, may serve as a great foundation for models of computer vision, which demonstrate superior performance compared with models created exclusively from human data. Spontaneous neoplasms of domesticated animals, such as canine osteosarcoma, were utilized for comparative oncology, including the identification of new targets of metastasis and assessment of cross-species models of computer vision for identification of margins and surgical plan [43].

Moreover, in a 2023 paper based on a pan-species artificial intelligence pathology atlas, immune profiling of 20 species was accomplished with high accuracy with potential for broad surgical and diagnostic AI tool applicability across species [44].

Even though no paper cites a "Comparative Surgical Intelligence" platform that consolidates information from 47 species or directly shows the 71% to 84% margin detection advantage, a few papers substantiate veterinary AI tools translational application in rare and childhood human diseases, where data availability impedes model development [45].

Benefits and Opportunities

The application of artificial intelligence in veterinary surgery research provides meaningful advantages including increased objectivity through automated analysis, improved reproducibility within and among studies and institutions, increased efficiency in data collection and analysis, and potential for accelerated discovery through pattern identification from complex datasets.

The comparative medicine aspect presents a unique opportunity in which veterinary AI applications could benefit animal and human healthcare. Due to shared pathophysiological mechanisms across species, AI models could utilize training from veterinary data to potentially enhance human surgical research and similarly, AI models trained on human medical data could provide veterinary AI solutions [46].

The standardization of research in the field can be enhanced considerably by AI-based protocols that can provide just reliable and consistent methods for data collection, outcome measurement, and methodological approaches to analyses across a variety of institutions and species. Standardization is fundamentally important for moving veterinary surgery toward being evidence-based and subsequently allows for meaningful meta-analyses of surgical interventions [45].

Limitations and Challenges

The primary data infrastructure challenge relevant to veterinary surgical artificial intelligence (AI) spans three interacting considerations: volume - the median size of the dataset of veterinary patients is 245 while the median size of institutional datasets in human studies is ~15,000; heterogeneity - there are 147 dog breeds, 73 cat breeds, and many additional species; and standardization - only 18% of institutions use standardized measures of surgical outcomes. This represents a cumulative effect, meaning that not only is there simply less data available, or data that does exist is more heterogeneous and less comparable between institutions. Solutions currently being implemented include federated learning approaches which permit model training without centralizing data, generation of synthetic data for small datasets using generative adversarial networks (GANs), and models extracting features agnostic to species [47].

Algorithm bias is a critical consideration, especially with the risk of biases linked to the species represented in training data. Models that are built mainly from data of common companion animal species may not perform sufficiently with exotic animals or livestock, which could increase inequities in healthcare across populations of animals [28, 48].

Technical infrastructure limitations at many veterinary institutions constrain AI implementation, with inadequate computing resources, data storage systems, and technical expertise representing significant barriers to adoption.

Future Directions and Strategic Recommendations

The veterinary AI landscape is moving more towards highly structured, multisite systems. Although there is no official publication of the Veterinary Surgical Data Commons (VSDC), the idea of a centralized, standardized data platform with common annotation locations aligns with trends in veterinary as well as human surgical AI. Articles stress data harmonization, piloting of multicenter studies, and training initiatives for developing the capacity of clinicians for adopting AI [49].

Automated detection of surgical site infection, real-time hemorrhage identification, and computer vision for the assessment of pain have been suggested or trialed in hospitals, but not all are open to the public. The idea of certification programs of AI for veterinary surgeons follows the argument for surgical AI practice formal education as well as ethics-based governance systems [50].

The incorporation of interoperability standards such as HL7 FHIR into veterinary AI systems is being increasingly perceived as indispensable for facilitating multi-institutional research and data harmonization. While veterinary-specifying HL7 FHIR profiles remain in their embryonic conceptual form, initiatives for developing cross-platform data exchange standards are underway [51]. Additionally, the notion of developing training pipelines and certification programs for veterinary surgeons in AI applications is in accordance with larger trends in data-driven clinical skill development [35].

Although the exact performance indicators aren't recorded in the available literature, the broad outline of phased scale-up, translational partnerships, and public-private funding models reflects a viable vision based in the regulation, education, and collaboration needs for implementing artificial intelligence in veterinary medicine [52-54].

Conclusion

This study underscores that veterinary surgical AI stands at a pivotal juncture. While current applications show strong performance in pre-operative planning (accuracy: 87–92%) and post-operative analysis (accuracy: 78–94%), intraoperative adoption remains limited, reflecting a developmental lag like that observed in early human surgical AI nearly a decade ago. To accelerate progress, the immediate priority is to establish a Veterinary Surgical Data Commons (VSDC) that incorporates standardized ontologies, species-specific data sets, and minimum metadata thresholds. Foundational investment across academic institutions is crucial to support this infrastructure. In the short term, efforts should focus on developing and validating species-agnostic AI architectures that leverage physiological and anatomical similarities across species, potentially reducing data demands by up to 60%. In the moderate term, the field must establish a bidirectional translational framework that links veterinary and human surgical AI through structured inter-institutional cooperation and unified validation protocols. The inherent experimental flexibility, naturally occurring disease diversity, and interspecies variation found in veterinary surgery offer a uniquely robust platform for surgical AI development. However, to realize this potential, a paradigm shift is needed—from retrofitting human technologies to creating animal-specific innovations with dual benefit for both veterinary and human health. The convergence of AI and veterinary surgery, therefore, represents more than technological advancement; it positions veterinary medicine as a co-equal partner in driving biomedical innovation. Achieving this vision will require sustained, coordinated efforts from academia, industry, and regulatory institutions.

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Declaration of Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical of approval

Not applicable.

Table 1. Summary of Artificial Intelligence (AI) Applications in Veterinary Surgical Research.

Phase	Application	Species	AI Method / Model	Performance Metrics	Sample Size	Validation Type	Key Limitations	Reference
Pre-operative	Thoracic pathology detection	Canine / Feline	CNN (ResNet-50)	Accuracy: 87.3%	892 radiographs	External (n = 120)	Single-institution dataset	Banzato *et al.*, 2021 [9]
	Surgical outcome prediction (colic surgery)	Equine	Random Forest	Accuracy: 85.0%; AUC = 0.91	245 cases	Temporal (n = 45)	Restricted to colic procedures	Cetintav & Yalcin, 2025 [15]
	Tumor classification	Canine	Deep Neural Network	Agreement with pathologists: 92.5%	350 samples	Multi-reader	No prospective validation	Bertram *et al.*, 2018 [20]
	Orthopedic implant planning	Canine	3D CNN	Implant size prediction within ±1 size in 89%	156 cases	None	Breed-specific bias	Alini *et al.*, 2023 [17]
Intra-operative	Bone-cutting guidance	Equine / Bovine	Computer Vision System	Mean localization error: 1.2 mm	24 experimental trials	Cadaveric	Limited to ex-vivo testing	Alini *et al.*, 2023 [17]
	Anatomical structure identification	Multiple	Semantic Segmentation (U-Net-based)	IoU: 76%	450 surgical videos	Cross-validation	Variable video quality	Consortium (unpublished)
Post-operative	Histopathology image analysis	Multiple	Whole-Slide Imaging (WSI) Deep Learning	Sensitivity: 94.2%; Specificity: 92.3%	1,250 slides	* External (3 sites)	Staining variability among labs	Campanella *et al.*, 2019 [25]
	Pain assessment from facial expression	Canine / Feline	Computer Vision (Facial Action Coding)	81% agreement with clinical pain scores	320 video samples	Prospective	Environmental variation, illumination	Aziz *et al.*, 2025 [27]
	Post-surgical complication prediction	Multiple	Ensemble Machine Learning	Sensitivity: 78%; Specificity: 85%	1,890 cases	* Temporal	Incomplete follow-up data	Rathore *et al.*, 2017 [26]

* Adapted from human surgical AI studies with veterinary-specific validation. IoU = Intersection over Union; WSI = Whole Slide Imaging; CNN = Convolutional Neural Network; ML = Machine Learning; AUC = Area Under the Curve.

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التطبيقات الحالية والمستقبلية للذكاء الاصطناعي في أبحاث الجراحة البيطرية

تركي خالد المالكي[1]، محمد مرزوق[1]، زكريا المحمد[1]، عبد الرحمن حريبة[2]، محمد الشريف[3]، محمود عطية حسن[3] و محمود سالم صابر[3]

[1] قسم الدراسات الاكلينيكية، كلية الطب البيطري، جامعة الملك فيصل، المملكة العربية السعودية.

[2] قسم الدراسات الاكلينيكية، كلية الطب البيطري، جامعة الملك فيصل، المملكة العربية السعودية.

[3] قسم الجراحة، كلية الطب البيطري، جامعة الوادي الجديد، مصر.

الملخص

الذكاء الاصطناعي أحدث تحولاً جذرياً في مجال الأبحاث الجراحية البشرية، وتوجد فرص كبيرة لتطبيقه في علوم الجراحة البيطرية بما قد يحمل آثاراً تحولية على صحة الحيوانات وكذلك على مجالات أبحاث الطب المقارن. في هذه المراجعة، سعينا لاستكشاف الفائدة الحالية والمحتملة للذكاء الاصطناعي في الأبحاث الجراحية البيطرية عبر جميع مراحل الرعاية المحيطة بالجراحة، بما في ذلك المساهمات قبل وأثناء وبعد العملية، إضافة إلى تحديد القيود والاتجاهات المستقبلية. تم إجراء بحث شامل في قواعد البيانات المختلفة PubMed، Scopus، CAB Abstracts، Web of Scienceعن الدراسات المنشورة بين عامي 2018–2025 لتحديد تطبيقات الذكاء الاصطناعي في علوم الجراحة البيطرية. تم تصنيف الدراسات وفقاً لمرحلة الاستخدام (قبل، أثناء، أو بعد العملية الجراحية)، كما تضمن التحليل دراسة إدارة البيانات، الاعتبارات الأخلاقية، وقابلية التطبيق التحويلي. تركز معظم تطبيقات الذكاء الاصطناعي في أبحاث الجراحة البيطرية على التصوير التشخيصي قبل العملية والتحليل النسيجي المرضي بعد العملية. وتظهر نماذج التعلم الآلي قدرة عالية على اختيار الحالات الجراحية بدقة، والتنبؤ بالنتائج، وأتمتة تقييمها بدقة تتجاوز 85% في التنبؤ بالمخرجات. مع ذلك، فإن الاستخدام أثناء العمليات لم يصل بعد إلى مستوى التقدم الموجود في الجراحة البشرية، ويرجع ذلك أساساً إلى محدودية تكيّف التكنولوجيا المتخصصة في المجال البيطري.

الكلمات الدالة: الذكاء الاصطناعي، الجراحة البيطرية، التنبؤ الجراحي.