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AI-Powered Innovations in Digestive Surgery: Current Evidence and Future Perspectives - A Systematic Literature

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ABSTRACT

Artificial Intelligence (AI) is transforming the field of digestive surgery, offering significant advancements in diagnostic accuracy, surgical precision, and perioperative management. Technologies such as machine learning (ML) and deep learning (DL) enhance surgical outcomes by identifying complex patterns in data, supporting real-time decision-making, and improving personalized patient care. This study aims to systematically evaluate the current applications, challenges, and future potential of AI-powered innovations in digestive surgery. A systematic literature review was conducted following PRISMA guidelines. The search utilized databases including Scopus, PubMed, Google Scholar, Crossref, and Web of Science. Keywords like "artificial intelligence," "machine learning," "digestive surgery," and "surgical AI" yielded 3,285 articles. After applying inclusion criteria, 23 studies published between 2020 and 2024 were selected for narrative synthesis. The review highlights AI's applications in endoscopic procedures, achieving diagnostic accuracy up to 98% for early-stage cancers. AI-driven systems enhance intraoperative precision, particularly in laparoscopic and robotic surgeries, reducing complication risks and improving outcomes. Moreover, AI-based predictive models support perioperative management by optimizing surgical planning and postoperative care, demonstrating improved efficiency and patient safety. AI is reshaping digestive surgery by enabling better diagnostics, personalized treatment, and improved surgical outcomes. Despite challenges like data quality and ethical concerns, the continued evolution of AI technologies holds promise for further advancements in surgical practices and education.

Keywords: artificial intelligence; digestive surgery; machine learning; perioperative management.

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INTRODUCTION

In recent years, the integration of Artificial Intelligence (AI) in medicine has emerged as a transformative force, reshaping various domains of healthcare. AI technologies, such as machine learning and predictive analytics, are increasingly utilized to analyze vast datasets, enabling healthcare professionals to identify patterns that may not be immediately apparent, thus facilitating timely interventions [8]. Digestive surgery, a highly specialized and complex field, stands to benefit significantly from AI-driven innovations.

The integration of Artificial Intelligence (AI) in digestive surgery is poised to significantly enhance surgical outcomes through improved diagnostic capabilities, intraoperative decision-making, and postoperative care. AI-driven innovations, such as machine learning algorithms, have demonstrated efficacy in predicting postoperative complications, thereby allowing for more tailored patient management strategies [47]. Furthermore, the combination of AI with surgical robotics is advancing the precision of procedures, facilitating better anatomical recognition and nerve preservation during

surgeries [50]. AI technologies are also being utilized in endoscopic procedures, improving the detection of colorectal lesions and aiding in the navigation of complex gastrointestinal anatomy [6], [10]. These advancements not only enhance surgical accuracy but also contribute to personalized treatment approaches, ultimately leading to improved patient outcomes and reduced recovery times [55]. However, the successful implementation of AI in digestive surgery requires addressing ethical considerations and ensuring transparency in AI decision-making processes [4], [49].

Digestive surgeries often involve intricate anatomical structures, necessitating meticulous attention to detail. The advent of robotic-assisted surgery has significantly enhanced the precision and dexterity required in these complex procedures. Robotic systems, such as the da Vinci Surgical System, provide surgeons with three-dimensional visualization and articulated instruments, which facilitate delicate dissection and suturing, essential for maintaining the integrity of surrounding tissues [16]. Studies have shown that robotic techniques can lead to improved surgical outcomes, including shorter hospital stays and lower complication rates compared to traditional methods [45], [56]. Furthermore, the use of robotic platforms allows for enhanced ergonomics and reduced surgeon fatigue, which can be particularly beneficial during lengthy operations [15]. However, the successful implementation of robotic surgery in digestive procedures requires thorough training and experience to navigate the challenges posed by the complex anatomy involved [38].

Traditional approaches, while effective, are not immune to challenges such as variability in surgical outcomes and human error. Surgical procedures often depend heavily on the surgeon's skill and experience, leading to inconsistencies in patient outcomes [52], [58]. For instance, studies have highlighted that human errors during surgery can result in complications that may adversely affect recovery times and overall patient health [32], [59]. The introduction of Artificial Intelligence (AI) in surgical settings aims to mitigate these issues by providing data-driven insights that enhance decision-making and reduce the likelihood of errors [24], [61]. AI systems can analyze vast amounts of patient data to identify patterns and predict complications, thereby supporting surgeons in making more informed choices [19], [48]. Furthermore, the automation of routine tasks through AI can allow surgeons to focus on more complex aspects of surgery, potentially improving precision and outcomes [24], [61].

Despite these advancements, the adoption of AI in digestive surgery faces several barriers, including technological limitations, cost considerations, and ethical concerns. Technological challenges, such as the reliability and accuracy of AI algorithms, are primary concerns among healthcare professionals, which can hinder the integration of AI into surgical practices [26], [42]. Additionally, the high costs associated with implementing AI technologies, including the need for specialized training and infrastructure, pose substantial financial barriers for many healthcare institutions [35], [11]. Ethical issues, particularly those related to data privacy, liability, and the need for human oversight, further complicate the acceptance of AI in surgical settings [9], [30]. The potential for AI to replace human judgment raises concerns about the erosion of the patient-provider relationship, emphasizing the importance of maintaining human interaction in healthcare [30]. Addressing these barriers is crucial for the successful integration of AI in digestive surgery, as it holds the potential to improve surgical outcomes and operational efficiency [35], [64].

The evidence supporting the widespread use of AI in this field remains scattered, necessitating a comprehensive evaluation of its current applications and future potential. This systematic literature review aims to consolidate the existing evidence on AI-powered innovations in digestive surgery, highlighting their impact on clinical practice and identifying gaps in knowledge. By examining the current landscape and exploring future perspectives, this review seeks to provide valuable insights into

how AI can revolutionize digestive surgical care and contribute to the broader advancement of surgical science.

METHOD

Review Protocol

The protocol was developed in accordance with the guidelines established by the Cochrane Collaboration for systematic reviews, and aligns with the recommendations set forth in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P) Statement [40].

Focus Question

The research question was formulated using the PICO framework, focusing on the following query: "What is the impact of AI-powered innovations on improving diagnostic accuracy, surgical precision, and perioperative management in digestive surgery?"

Population: Patients undergoing diagnostic, therapeutic, or surgical procedures for digestive conditions.

Intervention: Use of AI technologies, including machine learning, deep learning, and robotic-assisted systems in digestive surgery.

Comparison: Patients receiving traditional surgical care or procedures without AI integration.

Outcome: Enhanced diagnostic accuracy, improved surgical precision, reduced complication rates, and better perioperative outcomes.

Search Strategy

This research constituted a systematic literature review investigating the impact of AI-powered innovations on diagnostic accuracy, surgical precision, and perioperative management in digestive surgery. The literature search was conducted in January 2025, using articles from reputable international journals sourced from databases such as Google Scholar, PubMed, Crossref, Web of Science, and Scopus.

Keywords such as "artificial intelligence", "machine learning", "deep learning", "digestive surgery", "gastrointestinal procedures", and "surgical AI" yielded 3,285 documents. Only articles published in English between 2020 and 2024 were included in the analysis. Boolean operators (AND, OR) and wildcard characters (*) were strategically applied throughout the search process to refine results and capture variations of terms across the databases.

Study Selection and Eligibility Criteria

The systematic review process began with a comprehensive search of relevant articles on the use of AI-powered innovations in digestive surgery. To ensure accuracy and minimize potential bias, at least two researchers independently reviewed each article. The selection process involved an initial screening based on titles and abstracts to identify studies relevant to the research question. Articles deemed potentially relevant were then subjected to a full-text evaluation.

After applying the inclusion and exclusion criteria, a total of 23 articles were selected for inclusion in the review. Relevant data were extracted from these articles, including information such as the title, authors, publication year, study objectives, sample characteristics, research methods, AI technologies used, and key findings.

Subsequently, a narrative synthesis was conducted to summarize the results and identify recurring patterns, themes, and implications related to the impact of AI on diagnostic accuracy, surgical precision, and perioperative management in digestive surgery.

This systematic approach allowed for a rigorous synthesis of the evidence to address the research question comprehensively. The inclusion and exclusion criteria for this systematic review are outlined in Table 1.

Table 1. Inclusion and exclusion criteria

Inclusion	Exclusion
Article that discusses the AI-powered innovations in digestive surgery	Articles that are not related to the AI-powered innovations in digestive surgery
Research article	Non-research article
English documents	Non-English documents
Published year 2020-2024	Published outside 2020-2024
Available in full text	Not available full text
Open access	Non-open access
Research conducted in many countries	
Quantitative, qualitative, experimental research methods	Systematic review method, literature review, non-research

RESULTS AND DISCUSSION

Based on the search results using predetermined keywords and inclusion criteria, a total of 3,285 potential articles were initially retrieved from multiple databases: Scopus (n=452), PubMed (n=342), Crossref (n=1,113), Google Scholar (n=1,085), and Web of Science (n=293).

Following the title screening process, 2,015 articles with relevant titles were identified. At this stage, 1,851 articles were excluded for the following reasons: duplicate articles (n=1,230), articles not published between 2020 and 2024 (n=264), articles not available in open access (n=120), and non-original articles (n=237). Subsequent screening of abstracts resulted in the review of 164 papers, with 141 abstracts excluded for not matching the set criteria. A full-text assessment of 23 articles was then performed to determine eligibility, resulting in the inclusion of 23 studies in the systematic review (Figure 1).

These studies provide a comprehensive understanding of the impact of AI-powered innovations on digestive surgery, focusing on diagnostic accuracy, surgical precision, and perioperative management.

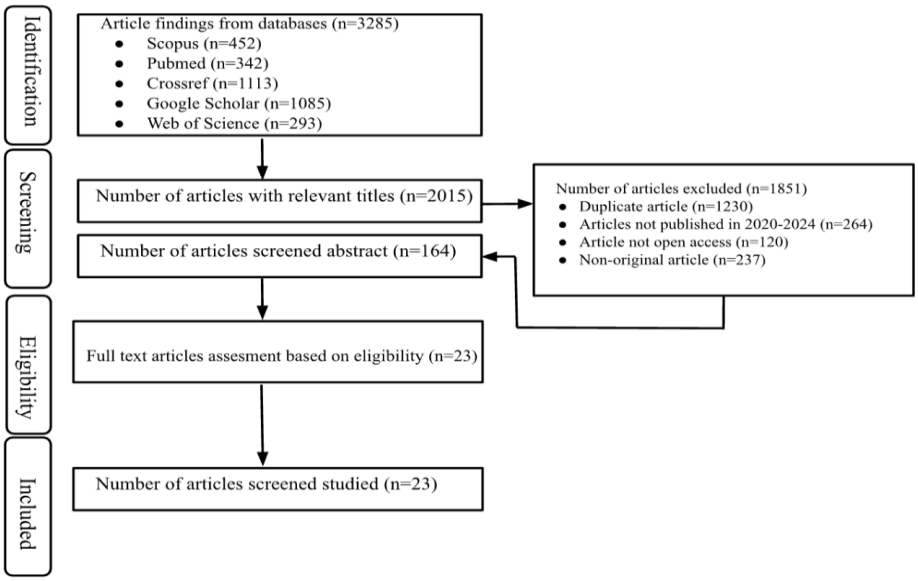

Figure 1. Article extraction process flowchart

Table 2. Data Extraction Result

Title, Authors, Year	Aims	Sample	Methods	Result
"Role of Artificial Intelligence in Hepatobiliary and Pancreatic Surgery" (Bari, Wadhwani and Dasari, 2021)	to evaluate AI's role in improving surgical outcomes and predicting complications in hepatobiliary and pancreatic surgery	15,657 patients	machine learning algorithms, deep learning for image analysis, and 3D imaging techniques	Results indicate improved surgical precision, reduced complications, and enhanced training outcomes with AI integration
"Artificial Intelligence-Assisted Surgery: Potential and Challenges" (Bodenstedt *et al.*, 2020)	to explore the potential of AI in surgery and identify the challenges for its effective implementation	Not available	machine learning, data annotation, and context-aware assistance systems for AI in surgery	potential improvements in surgical practice through AI, including enhanced decision support and workflow optimization
"Using Convolutional Neural Network to Predict Remission of Diabetes After Gastric Bypass Surgery: A Machine Learning Study from the Scandinavian Obesity Surgery Register" (Cao *et al.*, 2020)	To predict diabetes remission after gastric bypass surgery using convolutional neural networks.	8,057 patients with type 2 diabetes.	The study used data from the Scandinavian Obesity Surgery Register and applied convolutional neural networks for prediction analysis.	The CNN model outperformed traditional predictive indices, achieving an AUC of 0.83 for pharmacological remission and 0.82 for complete remission.
"Development and Validation of an Artificial Intelligence-Based Model to Predict Gastroesophageal Reflux Disease After Sleeve Gastrectomy" (Emile *et al.*, 2022)	To develop an AI model predicting GERD after sleeve gastrectomy	441 patients	Machine learning algorithms were used for model development, with data preprocessing and variable selection	The ensemble model achieved an AUC of 0.95, indicating high predictive performance for GERD
"Impact of AI System on Recognition for Anatomical Landmarks Related to Reducing Bile Duct Injury During Laparoscopic Cholecystectomy" (Endo, 2023)	To improve recognition of anatomical landmarks during laparoscopic cholecystectomy and reduce bile duct injury using an AI system	230 laparoscopic cholecystectomy videos, selecting 95 cases with mild inflammation for the deep learning model	developed a deep learning model for real-time identification of anatomical landmarks during laparoscopic cholecystectomy using video analysis	The AI system prompted annotation changes in 27% of cases, with 70% of changes considered safer
"Artificial Intelligence for Phase Recognition in Complex Laparoscopic Cholecystectomy" (Golany *et al.*, 2022)	To develop an AI system for recognizing surgical phases and improving patient safety in laparoscopic cholecystectomy	dataset of 371 laparoscopic cholecystectomy videos	two-stage AI model for feature extraction and temporal aggregation from surgical video frames	The AI model achieved 89% accuracy in recognizing surgical phases
"A Real-Time Spatiotemporal AI Model Analyzes Skill in Open Surgical Videos" (Goodman *et al.*, 2021)	To develop a real-time AI model for analyzing surgical skills in open surgery videos	1,997 annotated open surgical videos from YouTube	a multi-task neural network for action detection and tool recognition, utilizing the AVOS	The model achieved 0.71 mean precision and 0.73 mean recall for action recognition, with high performance on quality videos

Title, Authors, Year	Aims	Sample	Methods	Result
			dataset for training and evaluation	
"The Future of Artificial Intelligence in Surgery" (Hamilton, 2024)	The aims are to explore AI's transformative impact on surgery, enhance precision, and improve patient outcomes	100 videotaped segments for AI analysis and over 300,000 postoperative radiographs in a meta-review	data analysis from surgical videos, machine learning for predictive analytics, and gesture recognition technology	Results show improved accuracy in procedure segmentation, reduced instrument collisions, and enhanced cancer detection sensitivity
"A Surgeon's Guide to Artificial Intelligence-Driven Predictive Models" (Hassan *et al.*, 2022)	to educate surgeons on AI-driven predictive models to enhance surgical outcomes	Not available	machine learning algorithms for predicting surgical outcomes, including supervised learning and model evaluation techniques	AI-driven predictive models can significantly improve surgical outcomes and decision-making processes
"Application of Artificial Intelligence-Driven Endoscopic Screening and Diagnosis of Gastric Cancer" (Hsiao *et al.*, 2021)	To explore AI applications in endoscopic screening and diagnosis of gastric cancer.	2,570 images (1,492 cancerous and 1,078 noncancerous) and 30 patients' endoscopic images in different contexts	AI algorithms, including convolutional neural networks, to analyze endoscopic images and videos for gastric cancer detection.	AI systems achieved over 80% accuracy in diagnosing gastric cancer from endoscopic images and videos.
"Artificial Intelligence-based Computer Vision in Surgery: Recent Advances and Future Perspectives" (Kitaguchi *et al.*, 2021)	to summarize advances in AI and computer vision in surgery and discuss future integration into surgical practices	surgical video datasets, including Cholec120, Bypass170, and HeiCo	supervised learning, instance segmentation, and multi-institutional dataset construction for training AI in surgery	AI can achieve high accuracy in surgical step classification, but performance varies with dataset diversity
"Artificial Intelligence in Pancreatic Surgery: Current Applications" (Kuemmerli *et al.*, 2023)	To summarize the applications of AI in pancreatic surgery, focusing on preoperative evaluation, intraoperative support, surgical training, and postoperative risk management	38,209 patients undergoing pancreatectomy 5 and 34 preoperative patient	machine learning algorithms, radiomics for image analysis, and predictive modeling for surgical outcomes	improved predictive accuracy for complications using machine learning models compared to traditional methods, with AUC values reaching up to 86%
"Artificial Intelligence, Machine Learning, and Deep Learning in the Diagnosis and Management of Hepatocellular Carcinoma" (Larrain, 2024)	to explore AI techniques for detecting, diagnosing, and managing hepatocellular carcinoma (HCC) and to address implementation challenges	178 cirrhotic patients in one study and 360 patients with HCC in another	AI techniques such as ensemble learning, convolutional neural networks, and machine learning-based radiomic signatures for detecting and diagnosing HCC	Results show improved accuracy in predicting HCC prognosis and recurrence using AI models, with AUC values up to 0.92 and C-index up to 0.77

Title, Authors, Year	Aims	Sample	Methods	Result
"Patient Generated Health Data and Electronic Health Record Integration in Oncologic Surgery: A Call for Artificial Intelligence and Machine Learning" (Melstrom *et al.*, 2020)	to evaluate the integration of PGHD and PROs in surgical oncology and the role of AI and machine learning in enhancing patient care	one pilot involving 40 patients and another reporting on 132 patients	perioperative telemonitoring with wristband pedometers and electronic patient-reported outcomes (ePROs)	ePROs and PGHD improve patient engagement and recovery monitoring in surgical oncology
"Ensemble Deep Learning for the Prediction of Proficiency at a Virtual Simulator for Robot-Assisted Surgery" (Moglia *et al.*, 2022)	to predict proficiency acquisition in robot-assisted surgery using ensemble deep learning models	176 medical students without prior surgical simulator experience	deep neural networks to analyze training data from medical students performing tasks on a virtual reality simulator	Ensemble deep neural networks achieved higher accuracy in predicting proficiency acquisition compared to other machine learning models
"Surgical Instrument Detection and Tracking Technologies: Automating Dataset Labeling for Surgical Skill Assessment" (Nema and Vachhani, 2022)	To improve surgical instrument detection, automate dataset labeling, and enhance surgical skill assessment.	datasets from surgical videos, including the JHU-ISI Gesture and Skill Assessment Working Set (JIGSAWS).	deep learning algorithms, reinforcement learning frameworks, and convolutional neural networks for instrument detection and tracking.	improved accuracy and real-time performance in surgical instrument detection and tracking using deep learning models.
"A Novel High Accuracy Model for Automatic Surgical Workflow Recognition Using Artificial Intelligence in Laparoscopic Totally Extraperitoneal Inguinal Hernia Repair (TEP)" (Ortenzi, 2023)	To develop a high-accuracy AI model for automatic recognition of surgical steps in TEP inguinal hernia repair	619 TEP surgical videos	Videos were manually labeled, used to train an AI algorithm, and accuracy was assessed against manual annotations	The AI model achieved an overall accuracy of 88.8% in recognizing surgical steps
"Applications of Artificial Intelligence for the Diagnosis of Gastrointestinal Diseases" (Pecere *et al.*, 2021)	To explore AI applications in diagnosing gastrointestinal diseases and assess their clinical accuracy	100 patients for one AI system applied to ulcerative colitis and 3981 images from 114 patients	convolutional neural networks (CNNs) and image-based analysis for diagnosing gastrointestinal diseases	high diagnostic accuracy of AI systems, with sensitivity and specificity rates often exceeding 70%
"Towards Precision Medicine in Bariatric Surgery Prescription" (Pereira, Guimarães and Monteiro, 2023)	to explore precision medicine in bariatric surgery and identify factors influencing weight loss outcomes	cohort study with nearly 6000 patients and a meta-analysis involving 652 patients	analysis of existing literature and proposes machine learning models for predicting bariatric surgery outcomes	multiple patient-related factors influencing weight loss but emphasizes the need for better predictive models
"Artificial Intelligence in Colorectal Cancer Surgery: Present and Future Perspectives" (Quero *et al.*, 2022)	to explore current AI applications in colorectal cancer surgery and discuss future perspectives	4 videos from the Japan Society for Endoscopic Surgery dataset and 600	AI-based analysis of surgical videos and semantic segmentation of surgical instruments	AI models demonstrated reliable assessment of surgical skills and improved polyp detection rates in colonoscopy

Title, Authors, Year	Aims	Sample	Methods	Result
		intraoperative images for training AI models		
"Evaluating Surgical Expertise With AI-based Automated Instrument Recognition for Robotic Distal Gastrectomy" (Strong, 2024)	To evaluate surgical skill using AI-based instrument recognition in robotic distal gastrectomy.	55 patients	useing AI for automatic instrument recognition and analyzed instrument usage during surgeries	AI accurately identified surgical instruments and predicted skill levels, showing longer usage times for non-experienced surgeons
"The Challenges of Implementing Artificial Intelligence into Surgical Practice" (Tranter-Entwistle *et al.*, 2020)	to evaluate predictive models for common bile duct stones and identify challenges in data collection and implementation of artificial intelligence in surgical practice	1,315 patients	predictive modeling, data analysis, and manual review of coded data	The model achieved 87% NPV, 67% PPV, 37% sensitivity, and 96% specificity
"Augmenting Care in Hepatocellular Carcinoma with Artificial Intelligence" (Xu *et al.*, 2023)	to explore the role of artificial intelligence in improving the diagnosis and treatment of hepatocellular carcinoma (HCC)	Not available	various machine learning algorithms and predictive modeling techniques for diagnosing and treating hepatocellular carcinoma	AI models can effectively predict survival rates and identify microvascular invasion in hepatocellular carcinoma patients

DISCUSSION

Key Findings and Implications of AI for Digestive Surgery

Artificial Intelligence (AI) has emerged as a transformative force in the field of digestive surgery, enhancing various aspects from diagnosis to surgical execution. The integration of AI technologies, particularly machine learning (ML) and deep learning (DL), has shown significant promise in improving outcomes in gastrointestinal procedures.

One of the key findings is the application of AI in enhancing diagnostic accuracy during endoscopic procedures. AI algorithms, particularly convolutional neural networks (CNNs), have been developed to assist in the detection of early-stage cancers, such as esophageal and gastric cancers. For instance, studies have demonstrated that AI can achieve an accuracy of up to 98% in identifying esophageal cancer, significantly surpassing traditional methods that rely solely on human expertise [23], [28]. Furthermore, AI-driven systems have been employed to analyze endoscopic images, improving the sensitivity of preoperative assessments and potentially reducing the need for invasive procedures [43], [62].

AI has been instrumental in refining intraoperative techniques. For example, AI systems have been utilized to enhance the precision of laparoscopic surgeries by providing real-time feedback on anatomical structures, thereby reducing the risk of complications such as bile duct injuries during cholecystectomy [3], [13]. Additionally, AI technologies have been integrated

into robotic surgical systems, allowing for more precise movements and better visualization of complex anatomical regions [1], [14]. This integration not only improves surgical outcomes but also enhances the training of surgical residents by providing them with advanced simulation tools that utilize AI for skill assessment [27], [34].

Moreover, AI's role extends to perioperative management, where it aids in risk stratification and decision-making processes. Predictive models driven by AI have been developed to assess patient risks preoperatively, thereby optimizing surgical planning and resource allocation in operating rooms [22]. These models leverage vast datasets to identify patterns that may not be readily apparent to human clinicians, thus enhancing the overall efficiency of surgical care [29], [53].

In summary, the key findings regarding AI in digestive surgery highlight its significant impact on diagnostic accuracy, surgical precision, and perioperative management. The ongoing advancements in AI technologies promise to further transform the landscape of surgical practice, making it an essential component of modern healthcare.

Challenges in the Integration of AI in Digestive Surgical Practices

The integration of artificial intelligence (AI) into digestive surgical practices presents numerous challenges that must be addressed to fully realize its potential benefits. These challenges encompass technical, ethical, and operational dimensions, which can significantly impact the effectiveness and safety of AI applications in surgical settings.

One of the primary technical challenges is the need for high-quality data to train AI algorithms effectively. AI systems rely on vast amounts of data to learn and make accurate predictions. However, in the field of digestive surgery, data can be sparse, inconsistent, or biased, which can lead to suboptimal performance of AI models. For instance, studies have shown that classical algorithms for detecting conditions such as common bile duct stones have faced poor clinical uptake due to low accuracy, highlighting the necessity for robust data collection and algorithm training [60]. Furthermore, the complexity of surgical procedures and the variability in human anatomy add layers of difficulty in developing AI systems that can generalize well across different patient populations and surgical scenarios [53].

Ethical considerations also pose significant challenges in the integration of AI into surgical practices. Issues such as algorithmic bias, data privacy, and the transparency of AI decision-making processes are critical. For example, the deployment of AI in surgical settings must ensure that it does not inadvertently perpetuate existing biases in healthcare, which can lead to disparities in patient outcomes [3]. Additionally, the ethical implications of relying on AI for critical surgical decisions necessitate a careful examination of accountability and liability in the event of errors or adverse outcomes [3]. The integration of AI must be accompanied by clear guidelines and frameworks that address these ethical concerns to build trust among healthcare professionals and patients alike.

Operational challenges also arise when implementing AI technologies in surgical workflows. The integration of AI into existing surgical practices requires significant changes in training, protocols, and the overall surgical environment. Surgeons and surgical teams must be adequately trained to work alongside AI systems, which may involve a steep learning curve

[20], [21]. Moreover, the integration of AI tools into the surgical workflow must be seamless to avoid disruptions that could compromise patient safety. For instance, AI systems designed for intraoperative decision support need to be intuitive and provide real-time feedback without overwhelming the surgical team with information [4].

In summary, while AI holds great promise for enhancing digestive surgical practices through improved decision-making, predictive analytics, and operational efficiencies, several challenges must be addressed. These include ensuring high-quality data for training AI models, navigating ethical implications, and facilitating the operational integration of AI into surgical workflows. Addressing these challenges will be crucial for the successful adoption of AI technologies in digestive surgery and for maximizing their potential benefits for patient care.

Advancing AI in Digestive Surgery

Artificial Intelligence (AI) is increasingly transforming the field of digestive surgery, enhancing diagnostic accuracy, surgical precision, and patient outcomes. The integration of AI technologies into surgical practice is revolutionizing how surgeries are performed and improving preoperative assessments and postoperative care.

One significant application of AI in digestive surgery is in diagnostic imaging and decision-making. AI algorithms have demonstrated capabilities in analyzing imaging data, such as CT and MRI scans, to identify abnormalities and predict surgical outcomes. For instance, AI systems can assist in the early detection of conditions like hepatocellular carcinoma (HCC) by analyzing vast datasets and recognizing patterns that may be missed by human eyes [31], [65]. These systems utilize machine learning (ML) and deep learning (DL) techniques to enhance the accuracy of diagnoses, thus facilitating timely interventions [54].

Moreover, AI is being employed to optimize surgical workflows and improve intraoperative guidance. Technologies such as augmented reality (AR) and computer vision are being integrated into surgical procedures to provide real-time feedback and navigation assistance. For example, AI-driven systems can recognize surgical phases and actions, which is particularly beneficial in complex procedures like laparoscopic surgeries [17], [46]. This capability enhances the surgeon's precision and reduces the risk of complications by ensuring that critical anatomical structures are preserved during operations [57].

In the context of bariatric surgery, AI is paving the way for precision medicine by predicting patient responses to surgical interventions. Algorithms can analyze patient data to tailor surgical approaches based on individual characteristics, thereby improving outcomes and minimizing risks [44]. This personalized approach is crucial in managing obesity-related conditions and optimizing the effectiveness of metabolic surgeries [29].

Furthermore, AI's role extends to postoperative care, where it can assist in monitoring patient recovery and predicting complications. By analyzing electronic health records (EHRs) and patient-generated health data, AI systems can identify patients at risk of adverse events, enabling proactive management strategies [5], [33]. This predictive capability is vital in enhancing patient safety and improving overall surgical outcomes.

The educational aspect of AI in surgery cannot be overlooked. AI technologies are being utilized to enhance surgical training through simulation and skill assessment tools. These tools

provide objective evaluations of surgical techniques, helping to standardize training and improve the competency of surgical trainees [25], [37]. By integrating AI into educational frameworks, surgical programs can better prepare future surgeons for the complexities of modern surgical practice.

In summary, the advancement of AI in digestive surgery is multifaceted, encompassing diagnostic improvements, enhanced surgical precision, personalized patient care, and educational advancements. As these technologies continue to evolve, they hold the potential to significantly improve the quality of care in digestive surgery, ultimately leading to better patient outcomes and more efficient surgical practices.

Clinical Applications and Recommendations for AI in Digestive Surgery

The integration of artificial intelligence (AI) into digestive surgery presents a transformative opportunity to enhance surgical outcomes, improve patient safety, and optimize clinical workflows. This synthesis explores the clinical applications and recommendations for AI in digestive surgery, drawing on a variety of studies that highlight its current status and future potential.

AI has been effectively employed in various surgical contexts, particularly in bariatric surgery, where machine learning algorithms have been utilized to predict postoperative complications. For instance, study demonstrated the application of multiple machine learning techniques, such as decision trees and random forests, to detect severe complications within 30 days post-bariatric surgery, showcasing the potential of AI to enhance patient monitoring and risk stratification [2], [7]. Furthermore, Emile et al. developed an AI-based model to predict gastroesophageal reflux disease (GERD) following sleeve gastrectomy, indicating that AI can assist in preoperative planning by identifying patients at higher risk for adverse outcomes [12]. These applications underscore the utility of AI in refining surgical decision-making processes and tailoring patient care.

In the realm of minimally invasive surgery, AI technologies have been instrumental in enhancing surgical precision and efficiency. Sengun et al. highlighted the use of deep learning algorithms to identify critical anatomical structures, such as the left adrenal vein during adrenalectomy, which can significantly reduce intraoperative complications [31]. Additionally, the development of AI models for automatic surgical workflow recognition, as demonstrated by Ortenzi, can facilitate real-time monitoring of surgical procedures, thereby improving operational efficiency and safety [39]. Such advancements not only streamline surgical workflows but also provide valuable data for training and skill assessment of surgical teams.

The role of AI extends beyond intraoperative applications; it also encompasses perioperative management. Solanki et al. reviewed the potential of AI in managing major gastrointestinal surgeries, emphasizing its ability to analyze vast datasets for predictive analytics, which can inform anesthetic management and postoperative care [53]. Moreover, the integration of AI with electronic health records (EHRs) can enhance patient triage and postoperative follow-up, as highlighted by Melstrom et al., who called for the incorporation of patient-generated health data into surgical decision-making processes [33]. This holistic approach to patient management can lead to improved outcomes and reduced readmission rates.

AI's impact on surgical education and training is another critical aspect. The use of AI-driven tools for skill assessment, as explored by Igaki et al., can provide objective evaluations of surgical proficiency, thereby enhancing training programs and ensuring that surgeons are adequately prepared for complex procedures [25]. Furthermore, the application of AI in analyzing surgical videos can facilitate the identification of best practices and areas for improvement, contributing to the continuous development of surgical expertise [18].

In conclusion, the integration of AI into digestive surgery holds significant promise for enhancing surgical outcomes, optimizing patient management, and improving training methodologies. Continued research and collaboration among clinicians, data scientists, and regulatory bodies will be crucial in overcoming existing challenges and realizing the full potential of AI in this field.

CONCLUSION

Artificial Intelligence (AI) is revolutionizing digestive surgery by enhancing diagnostic accuracy, surgical precision, and perioperative management. Key advancements include AI's ability to detect gastrointestinal abnormalities with high accuracy, optimize intraoperative techniques, and improve patient outcomes. However, challenges such as data quality, ethical considerations, and operational integration must be addressed to fully realize its potential.

AI holds great promise for advancing personalized care, surgical education, and postoperative management. With continued research and collaboration, AI is set to become an integral component of modern digestive surgical practice, ensuring safer and more efficient outcomes for patients.

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