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Impression And Functions Of Artificial Intelligence In General Surgery In India: A Comprehensive Review

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Abstract
Artificial Intelligence (AI) is transforming healthcare globally, and its impact is increasingly being felt in surgical domains, particularly general surgery. In India, where surgical resources are often stretched and disparities in healthcare access persist, AI offers a significant potential to enhance surgical precision, optimize workflow, and improve patient outcomes. This review paper presents an overview of the applications, benefits, limitations, and future prospects of AI in general surgery in India. It highlights how AI technologies such as computer vision, machine learning, robotic-assisted surgery, and predictive analytics are revolutionizing pre-operative planning, intra-operative assistance, and post-operative care. The paper also discusses challenges including infrastructure gaps, data privacy, regulatory frameworks, and surgeon adaptability. It is also play a vital role in improving diagnostic accuracy, surgical precision, patient safety, and operational efficiency. The capabilities of artificial intelligence (AI) have recently surged, largely due to advancements in deep learning inspired by the structure and function of the neural networks of the human brain. In the medical field, the impact of AI spans from diagnostics and treatment recommendations to patient engagement and monitoring, considerably improving efficiency and outcomes. The clinical integration of AI has also been examined in specialties, including pathology, radiology, and oncology. General surgery primarily involves manual manipulation and includes preoperative, intra-operative, and postoperative care, all of which are critical for saving lives. Other fields have strived to utilize and adopt AI; nonetheless, general surgery appears to have retrogressed. In this we analyzed the published research, to understand how the application of AI in general surgery differs from that in other medical fields. Based on previous research in other fields, the application of AI in the preoperative stage is nearing feasibility. Ongoing research efforts aim to utilize AI to improve and predict operative outcomes, enhance performance, and improve patient care. Finally, it provides recommendations for integrating AI in general surgery to improve healthcare delivery in India.

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I. Introduction

The integration of Artificial Intelligence into healthcare systems has progressed rapidly over the last decade. In general surgery, AI technologies enhance clinical decision-making, reduce human error, and support minimally invasive procedures. With the increasing availability of big data, AI algorithms are trained to identify patterns, predict outcomes, and recommend interventions, fundamentally reshaping surgical practice. It is also defined as the simulation of human intelligence by machines, is rapidly transforming many sectors, including healthcare. In the field of general surgery, AI is being deployed in preoperative diagnostics, surgical planning, intra-operative navigation, and postoperative care. With India's vast and diverse population, limited access to specialized surgical care in rural areas, and the increasing burden of complex diseases, AI has a vital role to play in modernizing surgical practice.

Artificial intelligence (AI) has emerged as a revolutionary force in modern medicine, significantly reshaping diagnostics and treatment planning across various specialties. In fields such as radiology and oncology, AI has had an unmistakable impact on improving diagnostic accuracy, enabling early disease detection, and optimizing treatment protocols. For instance, in radiology, AI algorithms have revolutionized image analysis, facilitating more accurate Interpretations and aiding in the early detection of illnesses. The scope of AI integration ranges from diagnostics to patient management and care. Predictive analytics utilizing sophisticated machine learning (ML) algorithms are increasingly being employed to identify high-risk patients, predict complications, and personalize care plans. This approach has ushered in a new era of proactive, patient-centric healthcare.

Moreover, AI is paving the way for precision medicine. By analyzing large datasets that include genetic profiles and patient histories, AI systems can provide treatments specifically tailored to the needs of individual patients. This approach significantly improves therapeutic effectiveness and minimizes side effects. Despite these advances, general surgery lags significantly behind other medical fields in both AI research and clinical applications. The volume of medical articles published on the use of AI is markedly lower in the field of surgery, especially in general surgery. While specialized fields such as neurosurgery and cardiology are increasingly incorporating AI to improve surgical planning and robotic assistance, general surgery has been notably slower in adopting these advanced technologies. The reasons for this delay are multi-factorial. One of these reasons relates to the diversity and spontaneity of surgical procedures. General surgery is a dynamic field where some operations are predictable and can be scheduled in advance, while others are unpredictable and often rely on real-time decision-making in the operating room. The variability in case types within general surgery complicates the collection of the extensive and consistent data necessary to train AI systems. This issue is further exacerbated by the relative scarcity of focused research efforts aimed at integrating AI into general surgical workflows.

Modern medicine scenario:

In modern medicine, the integration of AI has been particularly pronounced in specialties such as radiology, oncology, and cardiology. In radiology, AI algorithms have revolutionized diagnostic processes and enhanced the accuracy of image interpretation, which is crucial for early disease detection and treatment planning.

Recent studies on AI in radiology have produced important findings. *Lång et al*. compared the clinical safety of an AI-assisted screen reading protocol to that of the conventional double reading method used in mammography screening. The study involved 80,000 women and assessed early screening outcomes, including cancer detection rates, retest rates, false positive rates, positive predictive values of the retests, and the types of cancers detected. In the intervention group, 244 tumors were detected, comprising 184 invasive tumors and 60 in situ tumors. Meanwhile, in the control group, 203 tumors were identified, with 165 being invasive and38 in situ. A randomized controlled trial conducted by Nam et al. demonstrated that AI-based, compute raided design software enhances the detection rate of actionable lung nodules in chest radiographs of health-screening participants. The AI group exhibited a higher detection rate of actionable nodules compared to the non-AI group (0.59% vs. 0.25%). Additionally, the detection rate of malignant lung nodules was also higher in the AI group than in the non-AI group (0.15% vs. 0.0%). The rates of misdiagnosis and positive reporting were similar between the AI and non-AI groups. *Sachpekidis et al*. have demonstrated that a deep learning (DL)-based tool for automatically assessing bone marrow metabolism in patients with multiple myeloma is feasible and correlates with clinically relevant disease parameters. There is a significant positive correlation between the visual analysis of PET/CT scans and the metabolic tumor volume (MTV) and total lesion glycolysis (TLG) values, following the application of all six 18F-fluorodeoxyglucose (FDG) uptake thresholds. Additionally, significant differences in MTV and TLG values were observed between patient groups across all applied thresholds. The DL-based approach has demonstrated significant, moderate, positive correlations between bone marrow plasma cell infiltration and plasma β2-microglobulin levels, as well as with the automated quantitative PET/CT parameters, MTV and TLG.

Similarly, oncology has benefited from the use of AI, especially in the realm of personalized medicine. AI algorithms are employed to analyze patient data and predict responses to treatment, which allows oncologists to customize therapies based on the specific needs of individual patients. Clift et al. developed a clinically useful model that estimates the 10-year risk of breast cancer-related mortality for women at all stages of the disease. Additionally, they compared the outcomes of regression analyses with those of ML approaches. The final Cox model demonstrated good discriminatory power, evidenced by a Harrell's C-index of 0.858 (95% CI, 0.853–0.864), and showed moderate calibration. The model's performance varied across ethnic groups, exhibiting the highest discriminatory power in Chinese women (Harrell's C-index=0.931) and the lowest in Bangladeshi women (Harrell's C-index=0.794). Moreover, the model generally performed well across various cancer stages, though its discriminatory power decreased as the cancer stage advanced.

Alaimo et al. have developed and validated a ML model to predict the early recurrence of intrahepatic cholangiocarcinoma following hepatectomy. The model, trained using 14 clinicopathological characteristics, demonstrates promising accuracy in predicting recurrences occurring within 12 months after surgery. It identifies tumor burden score as the most significant predictor of early recurrence, followed by perineural involvement. Additionally, the model's predictions of early recurrence strongly correlate with 3-year overall survival rates. Patients predicted to experience early recurrence exhibit significantly lower 3-year overall survival rates compared to those without such predictions. A meta-analysis utilizing a substantial volume of recent data has been conducted to assess the effectiveness of AI in diagnosing lung cancer. The findings indicate that AI-assisted diagnostic systems achieve a sensitivity and specificity of 0.87, with a missed diagnosis rate and misdiagnosis rate each at 13%. The systems also show a positive likelihood ratio of 6.5, a negative likelihood ratio of 0.15, a diagnostic ratio of 43, and a Combined sum of areas under the target operating characteristic curve of 0.93.

Cardiology has kept pace with the AI revolution. AI systems in cardiology have been crucial in predicting cardiac events, thereby improving preventive cardiac care. A review has underscored the potential of AI for data interpretation and automated analysis in interventional cardiology procedures. ML techniques are employed in interventional cardiology for image reconstruction, interpretation, and analysis. ML models, including the lasso-penalized Cox proportional hazards regression model and the k-means clustering algorithm, have been utilized for predicting mortality and detecting the QRS complex, respectively. ML algorithms have been developed for angiographic recognition, coronary angiographic interpretation, and intravascular ultrasonographic image segmentation. These algorithms have demonstrated promising outcomes in terms of recall, precision, accuracy, and agreement with expert analysts.

Another review has found that wearable devices, such as smart watches and activity trackers, can collect and analyze long-term, continuous data on behavioral or physiological functions, providing healthcare providers with a more comprehensive picture of a patient's health compared to the traditional, sporadic measurements obtained through office consultations and hospitalizations. Wearable devices have numerous clinical applications, including screening for arrhythmias in high-risk populations and the remote management of chronic conditions like heart failure or peripheral artery disease. *Ishii et al*. have developed and validated an ML-based model to predict future adverse events in patients with atrial fibrillation and stable coronary artery disease. Using randomized survival forest and Cox regression models, they created an integer-based risk score for all-cause mortality, myocardial infarction, stroke, and major bleeding, collectively defined as net adverse clinical events. This scoring system categorizes patients into three risk groups: low-risk (0–4 points), intermediate (5–8 points), and high-risk (≥9 points). The integer-based risk score has demonstrated strong performance in both the development and validation cohorts, exhibiting good discriminatory and calibration power. Decision curve analysis has shown a significant net benefit associated with this score. The widespread adoption of AI in these specialties stands in stark contrast to its integration into general surgery, underscoring a significant gap in both research and clinical applications.

Advancing artificial intelligence in general surgery:

Research on AI in general surgery is expanding into numerous areas, reflecting the diverse applications of AI in this multifaceted field. The integration of AI into laparoscopic surgery enhances visualization, accuracy, and decision-making during procedures. *Wang D, et al*. In robotic surgery, AI has been leveraged to improve the precision and autonomy of robotic systems, marking a significant shift toward more advanced surgical techniques. *Endo et al.* discussed the impact of an AI system on identifying anatomical landmarks associated with reduced bile duct injury during laparoscopic cholecystectomy. After viewing a 20-second video where the AI highlighted landmarks, 26.9% of the images were annotated differently, primarily along the gallbladder line of the extrahepatic bile and cystic ducts. Of these changes, 70% were considered safe. The AI system assisted both novices and expertsin identifying landmarks such as the Rouviere sulcus and the inferior border of the liver, S4. It encouraged changing perspectives in 70% of cases, in a way that was considered safe.

Zhang et al. explored the feasibility of conditional autonomy in robotic surgery, specifically focusing on robotic appendectomy. This approach involved using demonstration data gathered from a human operator performing appendectomies in a simulated robotic environment to teach the system the movements and trajectories of the robotic instruments. Extensive validation in a simulated environment, utilizing the da Vinci research kit, demonstrated that the proposed method can perform appendectomies semi-automatically. A framework based on this method could decrease the total working path length, completion time, and appendix stump length, while preserving a high similarity to the demonstrated trajectories.

In addition, AI models for surgical risk assessment are currently being developed. These models use patient data and preoperative indicators to predict postoperative complications, aiming to tailor surgical approaches to the specific risks of individual patients. Additionally, AI plays a crucial role in surgical planning, especially in complex procedures. Here, AI-driven image interpretation aids surgeons in making informed decisions. El *Moheb et al*. demonstrated that the AI risk calculator, Predictive OpTimal Trees in Emergency Surgery Risk (POTTER), surpassed the surgeon's gestalt in predicting postoperative mortality and outcomes for patients undergoing emergency surgery, except in cases of septic shock. Risk prediction for mortality, bleeding, and pneumonia improved when surgeons used POTTER, although there was no significant improvement for septic shock or ventilator dependence. The AUC was calculated to evaluate the predictive performance of surgeons who used POTTER compared to those who did not.

The postoperative phase has also benefited from AI, particularly in the areas of wound analysis and care. AI applications here concentrate on analyzing images of wounds and predicting healing outcomes, potentially leading to more personalized and effective postoperative care strategies.

Tomé et al. highlighted the necessity of AI by demonstrating the challenges in predicting postoperative infections using only correlated data. According to their research, postoperative infections occurred in 24 out of 349 operations, which accounts for 6.89% of all surgeries in their database. Correlation tests employing Pearson and Spearman coefficients indicated a weak correlation between the risk factors and the incidence of infection. An artificial neural network designed for pattern recognition successfully predicted infections in 77.3% of cases, achieving an AUC of 0.9050. Among the misclassifications, seven cases were incorrectly identified as having an infection when none was present, representing 2.0% of the data. Conversely, five cases were incorrectly identified as not having an infection when one was present, representing 1.4% of the data.

Overall, these diverse areas of AI application in general surgery underscore the potential of AI to transform various aspects of surgical practice, from preoperative planning to postoperative care. As research progresses, the role of AI in general surgery is anticipated to grow, setting the stage for more innovative and effective surgical practices.

Bridging the artificial intelligence gap in general surgery:

The integration of AI into specialties like radiology and cardiology has significantly improved diagnostic accuracy and patient care. This stands in stark contrast to its use in general surgery. The disparity underscores the unique challenges faced in general surgery, which include the variability of surgical procedures and the difficulty in capturing comprehensive datasets for AI training. Understanding the challenges and successful strategies used in other specialties can provide valuable insights for adapting AI applications in general surgery, suggesting a more focused approach to research and development in this area. The primary issue is the relative scarcity of research directed toward implementing AI in general surgical environments. The inherent variability and complexity of general surgical procedures pose significant challenges in standardizing AI applications, which in turn complicates the integration of AI. Additionally, constructing comprehensive and uniform datasets, crucial for training AI, continues to be a major hurdle in this field. Despite these challenges, there are significant opportunities in general surgery where AI can make substantial contributions, such as in risk assessment and surgical planning. Success stories from other medical and surgical fields offer a blueprint and valuable insights for integrating AI into general surgery. By drawing on these experiences, general surgery can tailor AI tools to meet its unique needs, potentially transforming patient care and surgical outcome. Promoting research on AI and the application of AI in general surgery requires fostering interdisciplinary collaboration across various fields, establishing standardized data collection and sharing protocols, securing dedicated funding, and integrating AI education into medical training. It is necessary to address ethical considerations and provide regulatory support to build trust in AI applications. Pilot projects and clinical trials are essential to demonstrate the efficacy and safety of AI technologies in clinical settings, paving the way for their integration into general surgery to enhance outcomes and patient care.

Current Scenario in India

Leading tertiary care hospitals (e.g., AIIMS, Apollo, Fortis) are increasingly integrating AI-assisted systems. Government initiatives under the National Digital Health Mission (NDHM) aim to digitize patient data for better AI model training. Startups like Qure.ai, Niramai, and SigTuple are contributing to surgical diagnostics and preoperative AI. AI-related modules are being slowly introduced in surgical training curricula. Collaborative efforts between tech institutes (IITs, NITs) and medical colleges are ongoing.

II. Challenges And Limitations

Infrastructure Deficiency: Lack of high-speed internet, digital equipment, and trained staff in rural hospitals.
Data Privacy Concerns: Inadequate legal frameworks for protecting patient data used in AI training.
Bias and Reliability: AI tools trained on non-Indian datasets may not generalize well.
Resistance to Adoption: Surgeons may resist AI due to fear of deskilling or mistrust in machine recommendations.

Cost of Implementation:

- Initial capital investment in AI infrastructure is high.
- Data privacy and ethical concerns.
- Lack of large, annotated datasets for algorithm training.
- Integration issues with existing hospital information systems.
- Risk of over-reliance on AI and loss of clinical intuition.
- Legal and liability concerns in case of AI errors.

Ethical and Legal Considerations

AI use must comply with Indian Medical Council regulations, Personal Data Protection Bill, and ethical norms regarding patient consent. Liability in case of AI-led surgical error remains a gray area in Indian medico-legal systems.

Future Prospects

AI-Augmented Rural Surgery: Portable AI systems to aid general surgeries in rural India.
Federated Learning: Enabling hospitals to collaborate on AI training without sharing raw patient data.
Surgical Simulators: AI-based VR training for young surgeons.
Personalized Surgical Robotics: India-specific robotic platforms adapted for affordability and cultural context.

- Development of fully autonomous robotic systems.
- Integration of AI with genomic and biomarker data for personalized surgery.
- Real-time predictive analytics during surgery.
- Improved AI explain ability for better clinician trust.

III. Conclusion

AI holds immense promise in revolutionizing general surgery in India, from diagnosis to rehabilitation. While the technology is in its nascent stage of adoption, its potential to bridge the healthcare access gap, improve surgical outcomes, and enhance decision-making is significant. Addressing infrastructural, ethical, and regulatory challenges will be key to harnessing AI's full potential. Multi-stakeholder collaboration—between clinicians, engineers, policymakers, and patients—is essential for a sustainable AI-enabled surgical future in India. AI is reshaping the landscape of general surgery by augmenting the surgeon's capabilities at every stage of the surgical process. While it holds immense potential to improve precision, efficiency, and patient outcomes, careful attention must be paid to ethical considerations, validation, and integration.

The future of AI in general surgery is poised for transformative growth, driven by emerging technologies. Surgical robotics are increasing precision and safety, virtual reality simulations are providing unparalleled training experiences, and predictive analytics are improving postoperative care. Focusing research on these areas could significantly advance the field of general surgery, aligning it with the successes observed in other medical fields and opening new avenues for enhancing patient care. In radiology, oncology, and cardiology, AI has already begun to transform patient care by improving diagnostic accuracy, providing predictive analytics, and facilitating personalized treatment plans. However, the field of general surgery stands at the threshold of a significant technological evolution, facing unique challenges that hinder the integration of AI. To effectively incorporate AI into general surgery and address delays in current research and development, interdisciplinary collaboration is essential. This requires forming partnerships among medical practitioners, AI technologists, data scientists, and policymakers. These collaborative efforts are vital for managing the complexities of general surgical procedures, standardizing AI applications, and constructing the comprehensive datasets required for AI training. By leveraging diverse expertise, AI tools can be tailored to meet the unique requirements of general surgery, thereby improving surgical outcomes, procedural efficiency, and patient care.

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