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**Colorectal cancer: Artificial intelligence and its role in surgical decision making**

Ghosh NK *et al*. AI in CRC surgery

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**Abstract**

Despite several advances in the oncological management of colorectal cancer (CRC), there still remains a lacuna in the treatment strategy, which differs from center to center and on the philosophy of the treating clinician that is not without bias. Personalized treatment is essential for the treatment of CRC to achieve better long-term outcomes and to reduce morbidity. Surgery has an important role to play in the treatment. Surgical treatment of CRC is decided based on clinical parameters and investigations and hence likely to have judgmental errors. Artificial intelligence has been reported to be useful in the surveillance, diagnosis, treatment, and follow-up with accuracy in several malignancies. However, it is still evolving and yet to be established in surgical decision making in CRC. It is not only useful preoperatively but also intraoperatively. Artificial intelligence helps to rectify the human surgical decision when clinical data and radiological and laboratory parameters are fed into the computer and may guide correct surgical treatment.

**Key Words:** Artificial Intelligence; Colorectal cancer; Clinical implications; Treatment strategy; Surgical treatment

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**Core Tip:** Treatment decision making in colorectal cancer significantly affects the outcome, which is a multidisciplinary team approach and is not without bias. Surgery plays a significant role in the treatment. Whether artificial intelligence may improve the outcome of surgery in colorectal cancer is not known. The present review focuses on its current role in surgical decision making and future impact.

**INTRODUCTION**

Mr. Alan Turing in 1950 hypothesized that a machine can also think like a human being in his book entitled “Computing Machinery and Intelligence”[1]. The term “artificial intelligence (AI)” was later coined by John McCarthy in a summer workshop[1,2]. AI has evolved from simple tasks to more complex tasks similar to a human brain[1].

AI has proven its worth in various day-to-day life and human requirements, including health care (health tracking devices)[3], automobiles (autopilot)[4], banking and finances (chatbots, robotraders)[5], surveillance (CCTV cameras), social media, entertainment, education, space exploration, industries (aluminum, dairy)[6-8], and disaster management[9,10]. One recent example is the efficient production of facemasks during the coronavirus disease 2019 pandemic[11] (Table 1). Its potential has been exploited in various fields of medicine, including online appointment scheduling, online check-in at hospitals, digitization of medical records, follow-up and immunization reminder, drug dosage algorithm, and adverse effect warnings during the prescription of multidrug combinations. Besides this, its application in the field of oncology is immense. AI is assisting in generating new approaches for cancer detection, screening of healthy subjects, diagnosis, classification of cancers using genomics, tumor microenvironment analysis, prognostication, follow-up, and new drug discovery[12-15].

Colorectal cancer (CRC) is one of the most common types of gastrointestinal (GI) tract malignancy and is the fourth most leading cause of cancer death globally[16,17]. AI has been used to facilitate screening, diagnosis (colonoscopy, advanced endoscopic modalities, imaging), genetic testing, and treatment (chemotherapy, radiotherapy, robotic assisted surgery)[18]. New research and developments are required for better patient management to improve the outcome.

In the past decade, several developments have taken place in the management of CRC, *e.g.*, revised anatomy of the rectum and concept of total mesorectal excision by Heald *et al*[19], concept of complete mesocolic excision and central vascular ligation by Hohenberger[20] for colon cancer, imaging and staging techniques, introduction of staplers[21], newer chemotherapeutic agents and biologicals, radiation therapy, and mode of surgery (laparoscopic and robotic surgery)[22,23] have significantly improved the outcome and sphincter preservation. However, there still remain numerous challenging issues like accurate preoperative diagnosis, staging, individualized and personalized treatment planning, and intraoperative challenges to minimize complications and improve the surgical outcome. Newer tools of AI have been used in various fields of medicine, including drug development, health monitoring, managing medical data, disease diagnostics, digital consultations, personalized treatment, analysis of health plans, and medical and surgical treatment[24] and is quickly finding a role in surgery and surgical decision making.

Two common fields of the AI used in medicine are: virtual and physical[25]. Virtual field is commonly used in medical imaging, clinical diagnosis, treatment, and drug research and development. Surgical and nursing robots are the part of physical fields. Because of ongoing innovations in AI, it is being used widely in medicine, both for diagnosis and management of tumors. AI has played a significant role in CRC at various stages and is reported to have improved the 5-year survival. The subsection of AI used in medicine is deep learning, which is responsible for widespread application of AI[26]. This method encompasses all the concepts of AI and is based on artificial neural networks (ANN), which is inspired by the neurons in a biological brain. Deep learning involves application of training a specific task on a larger data set, extracting information from them, and using them for future predictions about these tasks through flexible adaptation to the new data. Recently, deep learning has been used to predict cardiovascular risk based on retinal images[27], classification of skin lesions[28], mammogram-based breast cancer detection[29], and esophageal carcinoma[30]. However, application of AI in surgery is challenging, as unlike the use of static images, surgery includes dynamic procedural data like the patient clinical parameters, different devices used, and knowledge of clinical guidelines and from the experiences[31]. The uses and applications of various branches of AI in medicine as well as other fields are shown in Table 1.

In 2007, IBM began development of Deep QA technology (Watson). In 2017, Artery’s medical imaging platform was the first Food and Drug Administration approved cloud-based deep learning application in healthcare for cardiac disorders, which was faster in giving results as compared to the professionals(15 s *vs* 30 s)[32]. The Food and Drug Administration-approved “GI genius” in the year 2019 is the first device based on machine learning to aid clinicians in detecting polyps or tumors during colonoscopy.

This paper reviews the current status of AI in CRC surgical decision making and its future implications.

**USES OF AI IN GASTROINTESTINAL DISORDERS AND COLORECTAL CANCER**

AI is progressively being used in the understanding of GI diseases[33-35]. Imaging such as X-ray, computed tomography scanning, magnetic resonance imaging, or endoscopic imaging is being used for diagnosis[36-39]. The application of AI has led to early detection of intestinal malignancies or premalignant lesions, and inflammatory or other non-malignant diseases or lesions[40].

With IBM Watson for oncology (WFO), AI has found its increasing role in oncology therapy. It has been used in several malignancies like breast carcinoma, lung carcinoma, gastric cancer, colon and rectal cancer, *etc.* Initially, Memorial Sloan Kettering Cancer Center (New York, United States) started the use of WFO machine learning. WFO uses natural language processing and clinical data from multiple resources (treatment guidelines, expert opinions, literature, and medical records) to formulate treatment recommendations[41]. A recent meta-analysis[42] had shown the highest concordance between WFO and Mass Detection Tool in breast carcinoma and the lowest in stomach carcinoma. The Manipal Comprehensive Cancer Centre (Bangalore, India) has implemented WFO for treatment in 250 CRC patients[43]. There was a concordance in 92.7% of rectal and 81.0% of colon cancer patients between WFO and Mass Detection Tool recommendations[43].

**AI IN COLORECTAL CANCER**

AI is used in the diagnosis and treatment of colorectal polyps and cancer. In colorectal cancer, it helps in diagnosis, staging (lymph node or liver metastasis), preoperative treatment planning, response to treatment assessment, intraoperative assistance, postoperative prognostic information, *etc*[44-46].

***AI in preoperative surgical decision making: staging and planning***

After diagnosis of CRC is made, the most important consideration is staging to determine a further plan of management, whether upfront surgery, neoadjuvant treatment, or palliative treatment.

In locally advanced rectal cancer, preoperative chemoradiotherapy is known to reduce the local recurrence. However, selection of patients is essential to avoid unnecessary complications due to overtreatment. Therefore, there is a need for a system that can differentiate between T2 and T3 rectal cancers. Kim *et al*[47] used convolutional neural network models to distinguish T2 from T3 lesions from magnetic resonance imaging with an accuracy of 94%. Similarly, Wu *et al*[48] also used convolutional neural network to stage rectal cancers.

 In addition to its role in preoperative imaging, AI provides faster interpretation compared to radiologists (20 s *vs* 600 s) in the detection of lymph node metastasis in rectal cancer[49]. Preoperatively, positron emission tomography/computed tomography is commonly used in the case of indeterminate lesions on contrast-enhanced computed tomography to potentially find curable M1 disease (National Comprehensive Cancer Network guidelines version 3.2021). Recently, application of AI has improved the sensitivity and specificity of detection of pulmonary nodules[50]. AI can also be used to reconstruct the area of interest from two-dimensional data obtained from imaging and endoscopic findings to generate a three-dimensional structure for better delineation of the tumor in relation to the surrounding vital structures, which may be useful in preoperative surgical planning[51]. This is extremely useful in determining which patient will require a pelvic exenteration or which patient will require a lateral pelvic lymph node dissection. This is also useful to safeguard the important surrounding structures during surgery to reduce the postoperative morbidity and mortality related to it.

In colon cancer, clinical evidence of bulky nodal disease or T4b lesion entails neoadjuvant therapy (National Comprehensive Cancer Network guidelines version 3.2021). It is also recommended that the presence of nodal involvement in T1 cancer requires colectomy and lymphadenectomy. Kudo *et al*[52] applied machine learning ANN in 3134 patients with T1 CRC based on the patient’s data on age, gender, tumor size, location, morphology, lymphatic and vascular invasion, and histologic grade to predict nodal involvement. ANN model was significantly better in lymph node metastasis detection compared to guidelines (area under the curve: 0.83 *vs* area under the curve: 0.73, *P* value = 0.005). Therefore, these patients can be subjected to upfront surgery and lymphadenectomy instead of endoscopic treatment. A meta-analysis by Bedrikovetski *et al*[53] using 17 studies (12 used radiomics models and 5 used deep learning models) concluded that AI was more efficient than radiologists in predicting lymph node metastasis. Similarly, AI was found to be better in detecting metastatic nodes as compared to conventional positron emission tomography/computed tomography imaging[54].

***AI in intraoperative surgical decision making***

Execution of a surgery depends upon the operating skill and ability of decision making. In 1978, Dr. Spencer[55], a cardiovascular surgeon, mentioned that “a skilfully performed operation is about 75% decision making and 25% dexterity.” The decision making can be both technical or non-technical, which impacts patient outcome. Studies of surgical errors have shown that over half of the adverse events are due to cognitive errors[56]. But surgical training is more focused on skill training rather than decision making as it is a challenging task to train[57]. Decision-making skills may vary with experience of operating surgeons[58]. Thus, improving the quality of surgical decision making could help to improve the outcome of surgery.

Decision making is a three-step process, *i.e*. assessment of the situation, action-taking, and re-evaluation of the action’s consequences. AI has been used as a decision making aid in a variety of fields, both in medicine and in surgery[59,60]. AI can help surgeons to assess a given situation (*e.g*., retrieving better data about a clinical situation), the types of actions taken (*e.g*., through decision suggestion), and the process of re-evaluating the impact of the decision taken. Therefore, it can be achieved in three different ways: (1) Retrieving data and experience from similar clinical scenarios and to supplement sensory input during minimal access surgery, which are not available compared to open surgery; (2) Intraoperative pathology assessment, tumor margin mapping, tumor classification, and tissue identification; and (3) Suggestion of steps of surgery.

**Identification of surrounding structures:** Harangi *et al*[61] used an ANN model to distinguish ureter from uterine artery during laparoscopic hysterectomy with 94.2% accuracy. Similarly, Quellec *et al*[62] applied a system of retrieving related videos of retinal surgery, and subsequent steps were followed during surgery to minimize the risk of injury. AI made it possible to define dissection planes in the robotic gastrectomy and to identify the recurrent laryngeal nerve during thyroidectomy[63,64]. Various studies have shown improved detection of vital structures during laparoscopic cholecystectomy to prevent bile duct injury using AI (Madani *et al*[65], Mascagni *et al*[66], Tokuyasu *et al*[67]). Table 2 highlights the studies where AI was used for identification of vital structures.

In CRC surgery, AI can be used to detect nearby vital structures (nerve plexus, presacral venous plexus, ureter, bladder, urethra, prostate, seminal vesicles), lymph node metastasis (lateral pelvic nodes, nodes near the root of inferior mesenteric artery), determination of the margin of resection, vascularity, and adequacy of anastomosis.

Augmented reality augments surgeons’ intraoperative vision by providing a semi-transparent overlay of preoperative imaging on the area of interest[68]. It has been used in several GI surgical procedures like laparoscopic splenectomy[69] and pancreaticoduodenectomy[70]. Augmented reality can be applied to CRC surgeries to identify and preserve the nearby vital structures.

**Deciding the level of resection:** In CRC surgery, determination of margin status is important to decide the level of resection and consideration for the feasibility of an anastomosis or the creation of a stoma. Margin status can be obtained with “optical biopsy” (*in vivo* diagnostic imaging), which can avoid time-consuming resection and frozen section analysis. Fluorescence-guided surgery is evolving, and it has shown promising results in determination of liver or peritoneal metastasis, anastomotic perfusion, detection of sentinel nodes, ureter, and nerves, and intraoperative detection of primary and recurrent lesions during colorectal cancer surgery[71]. Such a concept can be extrapolated on to AI for more efficient performance. Modalities used for intraoperative optical biopsy are confocal laser endomicroscopy, hyperspectral imaging, optical coherence tomography, and contrast-enhanced ultrasonography. There are several studies where these modalities have been used to distinguish abnormal epithelium from normal with the help of AI (Table 3). Using hyperspectral imaging, Jansen-Winkeln *et al*[72] reported 94% accuracy in distinguishing carcinoma from adenoma and healthy mucosa using ANN on post-resection of colonic lesions during surgery. A couple of experimental studies have shown that laparoscopic hyperspectral imaging can be used to distinguish malignant tissue in CRC from normal tissue. These modalities can be used to help in surgical decision making in CRC as revisional surgery can be done intraoperatively rather than waiting for frozen sections or final histology avoiding another surgery[73,74]. AI has been effective in differentiating glioblastoma, parathyroid gland, and malignant lesions of the colon from adjacent normal tissues[75-77].

**Deciding the site of anastomosis:** Studies have shown the incidence of colocolic and colorectal anastomosis leak to be 3.3% and 8.6%, respectively[78] and has adverse clinical outcomes and economic burden[79]. It can lead to anastomotic site stricture, recurrence of malignancy, and poor evacuatory function. The literature has shown poor predictive value of surgeons’ perceptions of possible anastomotic site leaks that led to investigating other methods like the use of indocyanine green[80]. The robotic platform provides an inbuilt near infrared camera for assessment of vascularity at the resection margin and to reduce anastomotic site leakage[81]. A study by Mazaki *et al*[82], where auto-artificial intelligence was used to develop a predictive model for anastomotic leakage, showed that triple-row staplers can decrease the leak rate. There is an ongoing study by Taha *et al*[83] known as the PANIC study (The Prediction of Anastomotic Insufficiency risk after Colorectal surgery), which utilizes machine learning principles to formulate an algorithm for prediction of anastomotic leak following colonic (PANIC-C) or colorectal (PANIC-R) anastomosis. The results of the study are expected to be available by December 2022.

**Helping in operative step suggestion:** Operative step suggestion in CRC is at a developmental stage. In the literature, AI has been used in cataract surgery and spinal cord surgery with satisfactory results. Tian *et al*[84] developed VeBIRD (Video-Based Intelligent Recognition and Decision system) to track and classify the cataract grade on videos of phacoemulsification surgeries. It helped to decide the amount of ultrasonic energy needed to emulsify a cataract based on the grade. Therefore, a less experienced surgeon can perform the procedure with as much efficiency as that of an experienced surgeon. Somatosensory evoked potential is used during spinal cord surgeries to detect spinal cord injury. A decrease in somatosensory evoked potential value needs to be confirmed with awakening the patient and checking spinal cord function and this decrease in somatosensory evoked potential can be due to the effect of anesthesia. Fan *et al*[85] applied support vector regression and multi-support vector regression to distinguish spinal cord injury from anesthetic effect. Similarly, in CRC surgery such methods can help to find the area of interest to formulate standardized resection and differentiate intraoperative lymphorrhea from ureter or bladder injury using AI.

Colorectal cancer surgery requires accurate and judicious preoperative decisions to optimize the outcome of surgery (personalized treatment). The decision can be augmented by the use of AI, which is expected to be precise and without errors. It can assist in imaging, tissue diagnosis, and staging before surgery. It can be used preoperatively to choose patients for neoadjuvant therapy and those requiring upfront surgeries. Intraoperatively, it helps in the identification of tumor tissue (to determine the margin of resection), metastatic lymph nodes (for the extent of lymphadenectomy), and important surrounding structures. Its assistance is also useful in assessing the adequate vascularity at the anastomotic site that can decrease the postoperative anastomotic leak and thereby reduce the morbidity and mortality.

Like the application of AI in several domains of medicine and health, it may play a significant role in surgical decision making, enhancing the outcome, in addition to diagnosis (imaging, endoscopy, tissue diagnosis).

**FUTURE IMPLICATIONS**

The future is promising, where AI is likely to play a significant role in reducing the bias of the Mass Detection Tool in deciding the treatment strategy and reducing the diagnosis and planning time with uniformity and with no or minimum error. The day is not far when the surgical world may be able to find a personalized surgical treatment for each and every patient of CRC, with improved intraoperative technical execution and reduced complications. The overall time taken in the management of CRC will be reduced, the treatment will be standardized, and the outcome will be maximized.

**CONCLUSION**

The role of AI in CRC is currently limited to preoperative staging and assessment of surgical resection margins and anastomotic sites. Its application to surgical decision making is still evolving, and the literature is very limited. However, the future is promising.

**REFERENCES**

1 **Kaul V**, Enslin S, Gross SA. History of artificial intelligence in medicine. *Gastrointest Endosc* 2020; **92**: 807-812 [PMID: 32565184 DOI: 10.1016/j.gie.2020.06.040]

2 **Hamamoto R**, Suvarna K, Yamada M, Kobayashi K, Shinkai N, Miyake M, Takahashi M, Jinnai S, Shimoyama R, Sakai A, Takasawa K, Bolatkan A, Shozu K, Dozen A, Machino H, Takahashi S, Asada K, Komatsu M, Sese J, Kaneko S. Application of Artificial Intelligence Technology in Oncology: Towards the Establishment of Precision Medicine. *Cancers (Basel)* 2020; **12** [PMID: 33256107 DOI: 10.3390/cancers12123532]

3 **Meng Y**, Speier W, Shufelt C, Joung S, E Van Eyk J, Bairey Merz CN, Lopez M, Spiegel B, Arnold CW. A Machine Learning Approach to Classifying Self-Reported Health Status in a Cohort of Patients With Heart Disease Using Activity Tracker Data. *IEEE J Biomed Health Inform* 2020; **24**: 878-884 [PMID: 31199276 DOI: 10.1109/JBHI.2019.2922178]

4 **Kirsch D**. Autopilot and algorithms: accidents, errors, and the current need for human oversight. *J Clin Sleep Med* 2020; **16**: 1651-1652 [PMID: 32844741 DOI: 10.5664/jcsm.8762]

5 **Bredt S**. Artificial Intelligence (AI) in the Financial Sector-Potential and Public Strategies. *Front Artif Intell* 2019; **2**: 16 [PMID: 33733105 DOI: 10.3389/frai.2019.00016]

6 **Pahlevan SM**, Hosseini SMS, Goli A. Sustainable supply chain network design using products' life cycle in the aluminum industry. *Environ Sci Pollut Res Int* 2021 [PMID: 33474670 DOI: 10.1007/s11356-020-12150-8]

7 **Goli A**, Khademi-Zare H, Tavakkoli-Moghaddam R, Sadeghieh A, Sasanian M, Malekalipour Kordestanizadeh R. An integrated approach based on artificial intelligence and novel meta-heuristic algorithms to predict demand for dairy products: a case study. *Network* 2021; **32**: 1-35 [PMID: 33390063 DOI: 10.1080/0954898X.2020.1849841]

8 **Goli** A, Khademi Zare H, Tavakkoli-Moghaddam R, Sadeghieh A. (2019). Hybrid artificial intelligence and robust optimization for a multi-objective product portfolio problem. *Computers & Industrial Engineering* 2019; **137:** 106090 [DOI: 10.1016/j.cie.2019.106090]

9 **Goli** A, Malmir B. A Covering Tour Approach for Disaster Relief Locating and Routing with Fuzzy Demand. *International Journal of ITS Research* 2019; **18:** 140–152 [DOI: 10.1007/s13177-019-00185-2]

10 **Goli** A, Mohammadi H. Developing a sustainable operational management system using hybrid Shapley value and Multimoora method: case study petrochemical supply chain. *Environ Dev Sustain* 2021 [DOI: 10.1007/s10668-021-01844-9]

11 **Tirkolaee EB**, Goli A, Ghasemi P, Goodarzian F. Designing a sustainable closed-loop supply chain network of face masks during the COVID-19 pandemic: Pareto-based algorithms. *J Clean Prod* 2022; **333**: 130056 [PMID: 34924699 DOI: 10.1016/j.jclepro.2021.130056]

12 **Bhinder B**, Gilvary C, Madhukar NS, Elemento O. Artificial Intelligence in Cancer Research and Precision Medicine. *Cancer Discov* 2021; **11**: 900-915 [PMID: 33811123 DOI: 10.1158/2159-8290.CD-21-0090]

13 **Kann BH**, Hosny A, Aerts HJWL. Artificial intelligence for clinical oncology. *Cancer Cell* 2021; **39**: 916-927 [PMID: 33930310 DOI: 10.1016/j.ccell.2021.04.002]

14 **Huynh E**, Hosny A, Guthier C, Bitterman DS, Petit SF, Haas-Kogan DA, Kann B, Aerts HJWL, Mak RH. Artificial intelligence in radiation oncology. *Nat Rev Clin Oncol* 2020; **17**: 771-781 [PMID: 32843739 DOI: 10.1038/s41571-020-0417-8]

15 **Benzekry S**. Artificial Intelligence and Mechanistic Modeling for Clinical Decision Making in Oncology. *Clin Pharmacol Ther* 2020; **108**: 471-486 [PMID: 32557598 DOI: 10.1002/cpt.1951]

16 **Mármol I**, Sánchez-de-Diego C, Pradilla Dieste A, Cerrada E, Rodriguez Yoldi MJ. Colorectal Carcinoma: A General Overview and Future Perspectives in Colorectal Cancer. *Int J Mol Sci* 2017; **18** [PMID: 28106826 DOI: 10.3390/ijms18010197]

17 **Ou C**, Sun Z, Li X, Li X, Ren W, Qin Z, Zhang X, Yuan W, Wang J, Yu W, Zhang S, Peng Q, Yan Q, Xiong W, Li G, Ma J. MiR-590-5p, a density-sensitive microRNA, inhibits tumorigenesis by targeting YAP1 in colorectal cancer. *Cancer Lett* 2017; **399**: 53-63 [PMID: 28433598 DOI: 10.1016/j.canlet.2017.04.011]

18 **Mitsala A**, Tsalikidis C, Pitiakoudis M, Simopoulos C, Tsaroucha AK. Artificial Intelligence in Colorectal Cancer Screening, Diagnosis and Treatment. A New Era. *Curr Oncol* 2021; **28**: 1581-1607 [PMID: 33922402 DOI: 10.3390/curroncol28030149]

19 **Heald RJ**. The 'Holy Plane' of rectal surgery. *J R Soc Med* 1988; **81**: 503-508 [PMID: 3184105]

20 **Hohenberger W**, Weber K, Matzel K, Papadopoulos T, Merkel S. Standardized surgery for colonic cancer: complete mesocolic excision and central ligation--technical notes and outcome. *Colorectal Dis* 2009; **11**: 354-64; discussion 364-5 [PMID: 19016817 DOI: 10.1111/j.1463-1318.2008.01735.x]

21 **Moran BJ**. Stapling instruments for intestinal anastomosis in colorectal surgery. *Br J Surg* 1996; **83**: 902-909 [PMID: 8813772 DOI: 10.1002/bjs.1800830707]

22 **Jacobs M**, Verdeja JC, Goldstein HS. Minimally invasive colon resection (laparoscopic colectomy). *Surg Laparosc Endosc* 1991; **1**: 144-150 [PMID: 1688289]

23 **Weber PA**, Merola S, Wasielewski A, Ballantyne GH. Telerobotic-assisted laparoscopic right and sigmoid colectomies for benign disease. *Dis Colon Rectum* 2002; **45**: 1689-94; discussion 1695-6 [PMID: 12473897 DOI: 10.1007/s10350-004-7261-2]

24 **de Grey AD**. Artificial Intelligence and Medical Research: Time to Aim Higher? *Rejuvenation Res* 2016; **19**: 105-106 [PMID: 26993572 DOI: 10.1089/rej.2016.1827]

25 **Hamet P**, Tremblay J. Artificial intelligence in medicine. *Metabolism* 2017; **69S**: S36-S40 [PMID: 28126242 DOI: 10.1016/j.metabol.2017.01.011]

26 **LeCun Y**, Bengio Y, Hinton G. Deep learning. *Nature* 2015; **521**: 436-444 [PMID: 26017442 DOI: 10.1038/nature14539]

27 **Poplin R**, Varadarajan AV, Blumer K, Liu Y, McConnell MV, Corrado GS, Peng L, Webster DR. Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning. *Nat Biomed Eng* 2018; **2**: 158-164 [PMID: 31015713 DOI: 10.1038/s41551-018-0195-0]

28 **Esteva A**, Kuprel B, Novoa RA, Ko J, Swetter SM, Blau HM, Thrun S. Dermatologist-level classification of skin cancer with deep neural networks. *Nature* 2017; **542**: 115-118 [PMID: 28117445 DOI: 10.1038/nature21056]

29 **McKinney SM**, Sieniek M, Godbole V, Godwin J, Antropova N, Ashrafian H, Back T, Chesus M, Corrado GS, Darzi A, Etemadi M, Garcia-Vicente F, Gilbert FJ, Halling-Brown M, Hassabis D, Jansen S, Karthikesalingam A, Kelly CJ, King D, Ledsam JR, Melnick D, Mostofi H, Peng L, Reicher JJ, Romera-Paredes B, Sidebottom R, Suleyman M, Tse D, Young KC, De Fauw J, Shetty S. International evaluation of an AI system for breast cancer screening. *Nature* 2020; **577**: 89-94 [PMID: 31894144 DOI: 10.1038/s41586-019-1799-6]

30 **Horie Y**, Yoshio T, Aoyama K, Yoshimizu S, Horiuchi Y, Ishiyama A, Hirasawa T, Tsuchida T, Ozawa T, Ishihara S, Kumagai Y, Fujishiro M, Maetani I, Fujisaki J, Tada T. Diagnostic outcomes of esophageal cancer by artificial intelligence using convolutional neural networks. *Gastrointest Endosc* 2019; **89**: 25-32 [PMID: 30120958 DOI: 10.1016/j.gie.2018.07.037]

31 **Maier-Hein L**, Vedula SS, Speidel S, Navab N, Kikinis R, Park A, Eisenmann M, Feussner H, Forestier G, Giannarou S, Hashizume M, Katic D, Kenngott H, Kranzfelder M, Malpani A, März K, Neumuth T, Padoy N, Pugh C, Schoch N, Stoyanov D, Taylor R, Wagner M, Hager GD, Jannin P. Surgical data science for next-generation interventions. *Nat Biomed Eng* 2017; **1**: 691-696 [PMID: 31015666 DOI: 10.1038/s41551-017-0132-7]

32 . Marr B. First FDA approval for clinical Cloud-Based Deep Learning in Healthcare. 2017. (accessed 1 Jun 2017). Available from: https://www.forbes.com/sites/bernardmarr/2017/01/20/first-fda-approval-for-clinical-cloud-based-deep-learning-in-healthcare/#7a0ed8dc161c

33 **Reismann J**, Romualdi A, Kiss N, Minderjahn MI, Kallarackal J, Schad M, Reismann M. Diagnosis and classification of pediatric acute appendicitis by artificial intelligence methods: An investigator-independent approach. *PLoS One* 2019; **14**: e0222030 [PMID: 31553729 DOI: 10.1371/journal.pone.0222030]

34 **Reichling C**, Taieb J, Derangere V, Klopfenstein Q, Le Malicot K, Gornet JM, Becheur H, Fein F, Cojocarasu O, Kaminsky MC, Lagasse JP, Luet D, Nguyen S, Etienne PL, Gasmi M, Vanoli A, Perrier H, Puig PL, Emile JF, Lepage C, Ghiringhelli F. Artificial intelligence-guided tissue analysis combined with immune infiltrate assessment predicts stage III colon cancer outcomes in PETACC08 study. *Gut* 2020; **69**: 681-690 [PMID: 31780575 DOI: 10.1136/gutjnl-2019-319292]

35 **Maeda Y**, Kudo SE, Mori Y, Misawa M, Ogata N, Sasanuma S, Wakamura K, Oda M, Mori K, Ohtsuka K. Fully automated diagnostic system with artificial intelligence using endocytoscopy to identify the presence of histologic inflammation associated with ulcerative colitis (with video). *Gastrointest Endosc* 2019; **89**: 408-415 [PMID: 30268542 DOI: 10.1016/j.gie.2018.09.024]

36 **Ho TY**, Lin CW, Chang CC, Chen HT, Chen YJ, Lo YS, Hsiao PH, Chen PC, Lin CS, Tsou HK. Percutaneous endoscopic unilateral laminotomy and bilateral decompression under 3D real-time image-guided navigation for spinal stenosis in degenerative lumbar kyphoscoliosis patients: an innovative preliminary study. *BMC Musculoskelet Disord* 2020; **21**: 734 [PMID: 33172435 DOI: 10.1186/s12891-020-03745-w]

37 **Bhattacharya S**, Reddy Maddikunta PK, Pham QV, Gadekallu TR, Krishnan S SR, Chowdhary CL, Alazab M, Jalil Piran M. Deep learning and medical image processing for coronavirus (COVID-19) pandemic: A survey. *Sustain Cities Soc* 2021; **65**: 102589 [PMID: 33169099 DOI: 10.1016/j.scs.2020.102589]

38 **Karako K**, Song P, Chen Y, Tang W. Realizing 5G- and AI-based doctor-to-doctor remote diagnosis: opportunities, challenges, and prospects. *Biosci Trends* 2020; **14**: 314-317 [PMID: 33100291 DOI: 10.5582/bst.2020.03364]

39 **Shiyam Sundar LK**, Muzik O, Buvat I, Bidaut L, Beyer T. Potentials and caveats of AI in hybrid imaging. *Methods* 2021; **188**: 4-19 [PMID: 33068741 DOI: 10.1016/j.ymeth.2020.10.004]

40 **Le Berre C**, Sandborn WJ, Aridhi S, Devignes MD, Fournier L, Smaïl-Tabbone M, Danese S, Peyrin-Biroulet L. Application of Artificial Intelligence to Gastroenterology and Hepatology. *Gastroenterology* 2020; **158**: 76-94.e2 [PMID: 31593701 DOI: 10.1053/j.gastro.2019.08.058]

41 **Somashekhar SP,** Sepúlveda MJ, Norden AD, Rauthan A, Arun K, Patil P, Ethadka RY, Kumar RC. Early experience with IBM Watson for Oncology (WFO) cognitive computing system for lung and colorectal cancer treatment. [DOI: 10.1200/JCO.2017.35.15\_suppl.8527]

42 **Jie Z**, Zhiying Z, Li L. A meta-analysis of Watson for Oncology in clinical application. *Sci Rep* 2021; **11**: 5792 [PMID: 33707577 DOI: 10.1038/s41598-021-84973-5]

43 **Yang SY**, Roh KH, Kim YN, Cho M, Lim SH, Son T, Hyung WJ, Kim HI. Surgical Outcomes After Open, Laparoscopic, and Robotic Gastrectomy for Gastric Cancer. *Ann Surg Oncol* 2017; **24**: 1770-1777 [PMID: 28357674 DOI: 10.1245/s10434-017-5851-1]

44 **Zhang R**, Zheng Y, Poon CCY, Shen D, Lau JYW. Polyp detection during colonoscopy using a regression-based convolutional neural network with a tracker. *Pattern Recognit* 2018; **83**: 209-219 [PMID: 31105338 DOI: 10.1016/j.patcog.2018.05.026]

45 **Su JR**, Li Z, Shao XJ, Ji CR, Ji R, Zhou RC, Li GC, Liu GQ, He YS, Zuo XL, Li YQ. Impact of a real-time automatic quality control system on colorectal polyp and adenoma detection: a prospective randomized controlled study (with videos). *Gastrointest Endosc* 2020; **91**: 415-424.e4 [PMID: 31454493 DOI: 10.1016/j.gie.2019.08.026]

46 **Zhang S**, Han F, Liang Z, Tan J, Cao W, Gao Y, Pomeroy M, Ng K, Hou W. An investigation of CNN models for differentiating malignant from benign lesions using small pathologically proven datasets. *Comput Med Imaging Graph* 2019; **77**: 101645 [PMID: 31454710 DOI: 10.1016/j.compmedimag.2019.101645]

47 **Kim J,** Oh JE, Lee J, Kim MJ, Hur BY, Sohn DK, Lee B. Rectal cancer: Toward fully automatic discrimination of T2 and T3 rectal cancers using deep convolutional neural network. *Int J Imag Syst Tech* 2019; **29:** 247-259 [DOI: 10.1002/ima.22311]

48 **Wu QY**, Liu SL, Sun P, Li Y, Liu GW, Liu SS, Hu JL, Niu TY, Lu Y. Establishment and clinical application value of an automatic diagnosis platform for rectal cancer T-staging based on a deep neural network. *Chin Med J (Engl)* 2021; **134**: 821-828 [PMID: 33797468 DOI: 10.1097/CM9.0000000000001401]

49 **Ding L**, Liu GW, Zhao BC, Zhou YP, Li S, Zhang ZD, Guo YT, Li AQ, Lu Y, Yao HW, Yuan WT, Wang GY, Zhang DL, Wang L. Artificial intelligence system of faster region-based convolutional neural network surpassing senior radiologists in evaluation of metastatic lymph nodes of rectal cancer. *Chin Med J (Engl)* 2019; **132**: 379-387 [PMID: 30707177 DOI: 10.1097/CM9.0000000000000095]

50 **Schwyzer M**, Martini K, Benz DC, Burger IA, Ferraro DA, Kudura K, Treyer V, von Schulthess GK, Kaufmann PA, Huellner MW, Messerli M. Artificial intelligence for detecting small FDG-positive lung nodules in digital PET/CT: impact of image reconstructions on diagnostic performance. *Eur Radiol* 2020; **30**: 2031-2040 [PMID: 31822970 DOI: 10.1007/s00330-019-06498-w]

51 **Kim HJ**, Choi GS, Park JS, Park SY, Cho SH, Seo AN, Yoon GS. S122: impact of fluorescence and 3D images to completeness of lateral pelvic node dissection. *Surg Endosc* 2020; **34**: 469-476 [PMID: 31139999 DOI: 10.1007/s00464-019-06830-x]

52 **Kudo SE**, Ichimasa K, Villard B, Mori Y, Misawa M, Saito S, Hotta K, Saito Y, Matsuda T, Yamada K, Mitani T, Ohtsuka K, Chino A, Ide D, Imai K, Kishida Y, Nakamura K, Saiki Y, Tanaka M, Hoteya S, Yamashita S, Kinugasa Y, Fukuda M, Kudo T, Miyachi H, Ishida F, Itoh H, Oda M, Mori K. Artificial Intelligence System to Determine Risk of T1 Colorectal Cancer Metastasis to Lymph Node. *Gastroenterology* 2021; **160**: 1075-1084.e2 [PMID: 32979355 DOI: 10.1053/j.gastro.2020.09.027]

53 **Bedrikovetski S**, Dudi-Venkata NN, Kroon HM, Seow W, Vather R, Carneiro G, Moore JW, Sammour T. Artificial intelligence for pre-operative lymph node staging in colorectal cancer: a systematic review and meta-analysis. *BMC Cancer* 2021; **21**: 1058 [PMID: 34565338 DOI: 10.1186/s12885-021-08773-w]

54 **He J**, Wang Q, Zhang Y, Wu H, Zhou Y, Zhao S. Preoperative prediction of regional lymph node metastasis of colorectal cancer based on 18F-FDG PET/CT and machine learning. *Ann Nucl Med* 2021; **35**: 617-627 [PMID: 33738763 DOI: 10.1007/s12149-021-01605-8]

55 **Spencer F**. Teaching and measuring surgical techniques: the technical evaluation of competence. *Bull Am Coll Surg* 1978; **63:** 9-12

56 **Suliburk JW**, Buck QM, Pirko CJ, Massarweh NN, Barshes NR, Singh H, Rosengart TK. Analysis of Human Performance Deficiencies Associated With Surgical Adverse Events. *JAMA Netw Open* 2019; **2**: e198067 [PMID: 31365107 DOI: 10.1001/jamanetworkopen.2019.8067]

57 **Pugh CM**, Santacaterina S, DaRosa DA, Clark RE. Intra-operative decision making: more than meets the eye. *J Biomed Inform* 2011; **44**: 486-496 [PMID: 20096376 DOI: 10.1016/j.jbi.2010.01.001]

58 **Hashimoto DA**, Axelsson CG, Jones CB, Phitayakorn R, Petrusa E, McKinley SK, Gee D, Pugh C. Surgical procedural map scoring for decision-making in laparoscopic cholecystectomy. *Am J Surg* 2019; **217**: 356-361 [PMID: 30470551 DOI: 10.1016/j.amjsurg.2018.11.011]

59 **Hashimoto DA**, Rosman G, Witkowski ER, Stafford C, Navarette-Welton AJ, Rattner DW, Lillemoe KD, Rus DL, Meireles OR. Computer Vision Analysis of Intraoperative Video: Automated Recognition of Operative Steps in Laparoscopic Sleeve Gastrectomy. *Ann Surg* 2019; **270**: 414-421 [PMID: 31274652 DOI: 10.1097/SLA.0000000000003460]

60 **Hashimoto DA**, Rosman G, Rus D, Meireles OR. Artificial Intelligence in Surgery: Promises and Perils. *Ann Surg* 2018; **268**: 70-76 [PMID: 29389679 DOI: 10.1097/SLA.0000000000002693]

61 **Harangi B**, Hajdu A, Lampe R, Torok P. Recognizing ureter and uterine artery in endoscopic images using a convolutional neural network. In 2017 IEEE 30th International Symposium on Computer-Based Medical Systems (CBMS) 2017 Jun 22 (pp. 726-727). IEEE

62 **Quellec G,** Lamard M, Cazuguel G, Droueche Z, Roux C, Cochener B. Real-time retrieval of similar videos with application to computer-aided retinal surgery. In 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2011 Aug 30 (pp. 4465-4468). IEEE

63 **Kumazu Y**, Kobayashi N, Kitamura N, Rayan E, Neculoiu P, Misumi T, Hojo Y, Nakamura T, Kumamoto T, Kurahashi Y, Ishida Y, Masuda M, Shinohara H. Automated segmentation by deep learning of loose connective tissue fibers to define safe dissection planes in robot-assisted gastrectomy. *Sci Rep* 2021; **11**: 21198 [PMID: 34707141 DOI: 10.1038/s41598-021-00557-3]

64 **Gong J**, Holsinger FC, Noel JE, Mitani S, Jopling J, Bedi N, Koh YW, Orloff LA, Cernea CR, Yeung S. Using deep learning to identify the recurrent laryngeal nerve during thyroidectomy. *Sci Rep* 2021; **11**: 14306 [PMID: 34253767 DOI: 10.1038/s41598-021-93202-y]

65 **Madani A**, Namazi B, Altieri MS, Hashimoto DA, Rivera AM, Pucher PH, Navarrete-Welton A, Sankaranarayanan G, Brunt LM, Okrainec A, Alseidi A. Artificial Intelligence for Intraoperative Guidance: Using Semantic Segmentation to Identify Surgical Anatomy During Laparoscopic Cholecystectomy. *Ann Surg* 2020 [PMID: 33196488 DOI: 10.1097/SLA.0000000000004594]

66 **Mascagni P**, Vardazaryan A, Alapatt D, Urade T, Emre T, Fiorillo C, Pessaux P, Mutter D, Marescaux J, Costamagna G, Dallemagne B, Padoy N. Artificial Intelligence for Surgical Safety: Automatic Assessment of the Critical View of Safety in Laparoscopic Cholecystectomy Using Deep Learning. *Ann Surg* 2020 [PMID: 33201104 DOI: 10.1097/SLA.0000000000004351]

67 **Tokuyasu T**, Iwashita Y, Matsunobu Y, Kamiyama T, Ishikake M, Sakaguchi S, Ebe K, Tada K, Endo Y, Etoh T, Nakashima M, Inomata M. Development of an artificial intelligence system using deep learning to indicate anatomical landmarks during laparoscopic cholecystectomy. *Surg Endosc* 2021; **35**: 1651-1658 [PMID: 32306111 DOI: 10.1007/s00464-020-07548-x]

68 **Bernhardt S**, Nicolau SA, Soler L, Doignon C. The status of augmented reality in laparoscopic surgery as of 2016. *Med Image Anal* 2017; **37**: 66-90 [PMID: 28160692 DOI: 10.1016/j.media.2017.01.007]

69 **Ieiri S**, Uemura M, Konishi K, Souzaki R, Nagao Y, Tsutsumi N, Akahoshi T, Ohuchida K, Ohdaira T, Tomikawa M, Tanoue K, Hashizume M, Taguchi T. Augmented reality navigation system for laparoscopic splenectomy in children based on preoperative CT image using optical tracking device. *Pediatr Surg Int* 2012; **28**: 341-346 [PMID: 22130783 DOI: 10.1007/s00383-011-3034-x]

70 **Onda S**, Okamoto T, Kanehira M, Suzuki F, Ito R, Fujioka S, Suzuki N, Hattori A, Yanaga K. Identification of inferior pancreaticoduodenal artery during pancreaticoduodenectomy using augmented reality-based navigation system. *J Hepatobiliary Pancreat Sci* 2014; **21**: 281-287 [PMID: 23970384 DOI: 10.1002/jhbp.25]

71 **Galema HA**, Meijer RPJ, Lauwerends LJ, Verhoef C, Burggraaf J, Vahrmeijer AL, Hutteman M, Keereweer S, Hilling DE. Fluorescence-guided surgery in colorectal cancer; A review on clinical results and future perspectives. *Eur J Surg Oncol* 2021 [PMID: 34657780 DOI: 10.1016/j.ejso.2021.10.005]

72 **Jansen-Winkeln B**, Barberio M, Chalopin C, Schierle K, Diana M, Köhler H, Gockel I, Maktabi M. Feedforward Artificial Neural Network-Based Colorectal Cancer Detection Using Hyperspectral Imaging: A Step towards Automatic Optical Biopsy. *Cancers (Basel)* 2021; **13** [PMID: 33669082 DOI: 10.3390/cancers13050967]

73 **Köhler H**, Kulcke A, Maktabi M, Moulla Y, Jansen-Winkeln B, Barberio M, Diana M, Gockel I, Neumuth T, Chalopin C. Laparoscopic system for simultaneous high-resolution video and rapid hyperspectral imaging in the visible and near-infrared spectral range. *J Biomed Opt* 2020; **25** [PMID: 32860357 DOI: 10.1117/1.JBO.25.8.086004]

74 **Baltussen EJM**, Kok END, Brouwer de Koning SG, Sanders J, Aalbers AGJ, Kok NFM, Beets GL, Flohil CC, Bruin SC, Kuhlmann KFD, Sterenborg HJCM, Ruers TJM. Hyperspectral imaging for tissue classification, a way toward smart laparoscopic colorectal surgery. *J Biomed Opt* 2019; **24**: 1-9 [PMID: 30701726 DOI: 10.1117/1.JBO.24.1.016002]

75 **Ritschel K**, Pechlivanis I, Winter S. Brain tumor classification on intraoperative contrast-enhanced ultrasound. *Int J Comput Assist Radiol Surg* 2015; **10**: 531-540 [PMID: 24956998 DOI: 10.1007/s11548-014-1089-6]

76 **Hou F**, Yu Y, Liang Y. Automatic identification of parathyroid in optical coherence tomography images. *Lasers Surg Med* 2017; **49**: 305-311 [PMID: 28129441 DOI: 10.1002/lsm.22622]

77 **Ştefănescu D**, Streba C, Cârţână ET, Săftoiu A, Gruionu G, Gruionu LG. Computer Aided Diagnosis for Confocal Laser Endomicroscopy in Advanced Colorectal Adenocarcinoma. *PLoS One* 2016; **11**: e0154863 [PMID: 27144985 DOI: 10.1371/journal.pone.0154863]

78 **Krell RW**, Girotti ME, Fritze D, Campbell DA, Hendren S. Hospital readmissions after colectomy: a population-based study. *J Am Coll Surg* 2013; **217**: 1070-1079 [PMID: 24246621 DOI: 10.1016/j.jamcollsurg.2013.07.403]

79 **Lee SW**, Gregory D, Cool CL. Clinical and economic burden of colorectal and bariatric anastomotic leaks. *Surg Endosc* 2020; **34**: 4374-4381 [PMID: 31720809 DOI: 10.1007/s00464-019-07210-1]

80 **Karliczek A**, Harlaar NJ, Zeebregts CJ, Wiggers T, Baas PC, van Dam GM. Surgeons lack predictive accuracy for anastomotic leakage in gastrointestinal surgery. *Int J Colorectal Dis* 2009; **24**: 569-576 [PMID: 19221768 DOI: 10.1007/s00384-009-0658-6]

81 **Jafari MD**, Lee KH, Halabi WJ, Mills SD, Carmichael JC, Stamos MJ, Pigazzi A. The use of indocyanine green fluorescence to assess anastomotic perfusion during robotic assisted laparoscopic rectal surgery. *Surg Endosc* 2013; **27**: 3003-3008 [PMID: 23404152 DOI: 10.1007/s00464-013-2832-8]

82 **Mazaki J**, Katsumata K, Ohno Y, Udo R, Tago T, Kasahara K, Kuwabara H, Enomoto M, Ishizaki T, Nagakawa Y, Tsuchida A. A Novel Predictive Model for Anastomotic Leakage in Colorectal Cancer Using Auto-artificial Intelligence. *Anticancer Res* 2021; **41**: 5821-5825 [PMID: 34732457 DOI: 10.21873/anticanres.15400]

83 **Taha A,** Taha-Mehlitz S, Hendie A, Staudner T, Adamina M. Development and external validation of an international, multicenter machine learning algorithm for prediction of anastomotic insufficiency after colonic or colorectal anastomosis The Prediction of Anastomotic Insufficiency risk after Colorectal surgery (PANIC) study. Available from: https://clinicaltrials.gov/ct2/show/NCT04985981

84 **Tian S**, Yin XC, Wang ZB, Zhou F, Hao HW. A VidEo-Based Intelligent Recognition and Decision System for the Phacoemulsification Cataract Surgery. *Comput Math Methods Med* 2015; **2015**: 202934 [PMID: 26693249 DOI: 10.1155/2015/202934]

85 **Fan B**, Li HX, Hu Y. An Intelligent Decision System for Intraoperative Somatosensory Evoked Potential Monitoring. *IEEE Trans Neural Syst Rehabil Eng* 2016; **24**: 300-307 [PMID: 26415181 DOI: 10.1109/TNSRE.2015.2477557]

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**Table 1 Subfields of artificial intelligence and its application in day-to-day human life**

|  |  |  |
| --- | --- | --- |
| **S. No** | **Fields of AI** | **Description**  |
| 1 | Machine learning | Pattern identification and analysis where machine can help to improve based on past experiences provided from the given data set |
| 2 | Deep learning | Consists of multilayered neural networks called artificial neural network, which enables the computer to learn and make decisions on its own |
| 3 | Natural language processing | Ability of the computer to extract data from human language and make decisions |
| 4 | Computer vision | Potential to obtain information from a series of images or videos |
| 5 | Mixed-integer linear programming model[11] | It is helpful in finding the locational, supply, production, distribution, collection, quarantine, recycling, reuse, and disposal decisions within a multiperiod multiechelon multiproduct supply chain |
| 6 | Covering tour approach[9] | Optimizing the distribution and allocation of resources among individuals. It is useful at the time of crisis |
| 7 | Mixed-integer linear mathematical model[6] | This model optimizes economic, social, and environmental objectives simultaneously |
| 8 | Neural network with runner root algorithm[8] | Minimizing risk and maximizing return in industrial production |
| 9 | Meta-heuristic algorithms[7] | A comprehensive framework to predict the demand for dairy products |
| 10 | Hybrid shapley value and multimoora method[10] | An intelligent performance evaluation system for different supply chains in industries  |

AI: Artificial intelligence; S. No: Serial number.

**Table 2 Studies having found the role of artificial intelligence in identification of vital structures in surgery**

|  |  |  |  |
| --- | --- | --- | --- |
| **S. No** | **Primary aim** | **AI method used** | **Ref.** |
| 1 | Recognition of ureter and uterine artery | Convolutional neural network | Harangi *et al*[61], 2017  |
| 2 | Recognition of surgical steps of retinal surgery | Content-based video retrieval system | Quellec *et al*[62],2011 |
| 3 | To define safe dissection plane in robot assisted gastrectomy | Deep learning model based on U-net | Kumazu *et al*[63], 2021 |
| 4 | Recurrent laryngeal nerve detection during thyroidectomy | Deep learning computer vision algorithm | Gong *et al*[64], 2021 |

AI: Artificial intelligence; S. No: Serial number.

**Table 3 Studies of artificial intelligence differentiating normal epithelium from abnormal or malignant cells**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S. No** | **Modality used** | **Primary aim of study** | **AI method used** | **Ref.** |
| 1 | CEUS | To differentiate glioblastoma from normal tissue | Support vector machines | Ritschel *et al*[75], 2015 |
| 2 | OCT | To distinguish parathyroid tissue from thyroid, lymph node, and adipose tissue | Texture feature analysis and back propagation artificial neural network | Hou *et al*[76], 2017 |
| 3 | CLE | Normal colonic mucosa from malignant lesion | Fractal analysis and neural network modelling | Ştefănescu *et al*[77], 2016 |
| 4  | Hyperspectral imaging | Differentiation of colonic carcinoma from adenoma and healthy mucosa | Artificial neural network | Jansen-Winkeln *et al*[72], 2021 |

AI: Artificial intelligence; CEUS: Contrast-enhanced ultrasonography; OCT: Optical coherence tomography; CLE: Confocal laser endomicroscopy; S. No: Serial number.