FREMTIDEN FOR KUNSTIG INTELLIGENS I GI ENDOSKOPI -

VEN ELLER FJENDE?

MENNESKET VERSUS MASKINEN?

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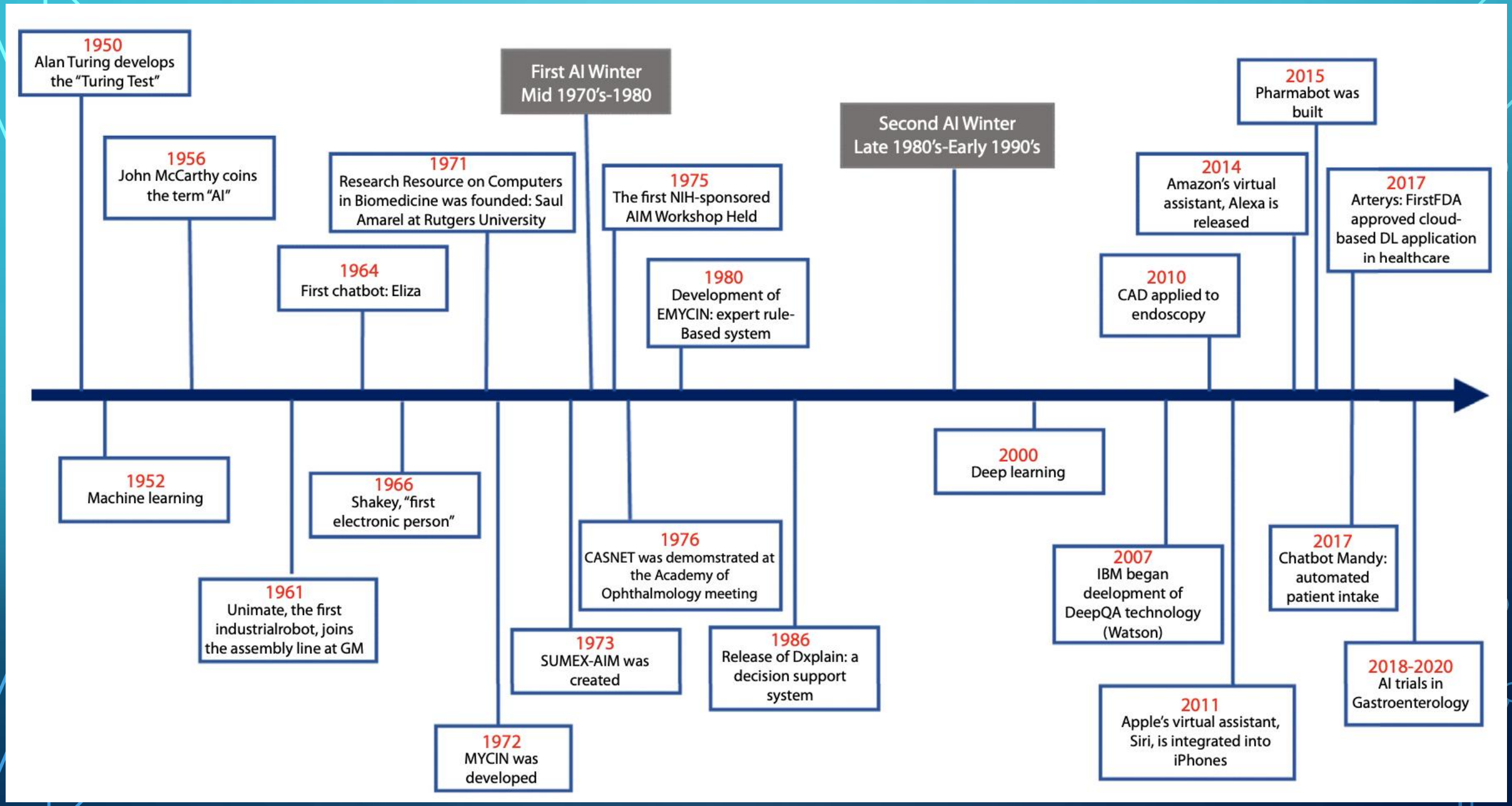
September 2022

ARTIFICIAL INTELLIGENCE

- The term artificial intelligence (AI) was first introduced in the 1950s and refers to the application of computers to perform complex tasks, such as solving problems and making nuanced decisions, that have traditionally been associated with human intelligence.

MACHINE LEARNING

- Machine learning (ML) lies at the crux of the most modern AI and encompasses algorithms on a wide spectrum from “supervised” to “unsupervised” learning.


1950
Alan Turing develops the "Turing Test"
1956
John McCarthy coins the term "AI"
1971
Research Resource on Computers in Biomedicine was founded: Saul Amarel at Rutgers University
First AI Winter
Mid 1970's-1980
1975
The first NIH-sponsored AIM Workshop Held
1964
First chatbot: Eliza
1980
Development of EMYCIN: expert rule-Based system
Second AI Winter
Late 1980's-Early 1990's
2015
Pharmabot was built
2014
Amazon's virtual assistant, Alexa is released
2017
Arterys: FirstFDA approved cloud-based DL application in healthcare
2010
CAD applied to endoscopy
1952
Machine learning
1966
Shakey, "first electronic person"
1961
Unimate, the first industrialrobot, joins the assembly line at GM
1976
CASNET was demomstrated at the Academy of Ophthalmology meeting
1973
SUMEX-AIM was created
1986
Release of Dxplain: a decision support system
1972
MYCIN was developed
2000
Deep learning
2007
IBM began deelopment of DeepQA technology (Watson)
2017
Chatbot Mandy: automated patient intake
2011
Apple's virtual assistant, Siri, is integrated into iPhones
2018-2020
AI trials in Gastroenterology

UPPER ENDOSCOPY

- Barrett's Esophagus
  - Identification of early neoplasia
  - Identify optimal biopsy site
  - Live endoscopic assistance
- Esophageal Cancer
  - Identify esophageal SCC
- H. Pylori Infection
  - Differentiate gastric atrophy and intestinal metaplasia
  - Identify H. Pylori related inflammation
- Gastric Cancer
  - Differentiate cancerous and non-cancerous gastric tissue
  - Determine gastric cancer invasion depth

COLONOSCOPY

- Colorectal Cancer
  - Bowel Preparation Assessment
  - Adenoma Detection
- Live Endoscopy Assistance
- Ulcerative Colitis
  - Determine severity of disease
  - Identify disease ares

CAPSULE ENDOSCOPY

- Obscure GI Bleeding
  - Identify source of small bowel bleeding
  - Identify mucosal erosions, ulcers, small bowel angioectasia
  - Reduction in time to interpret WCE reports
- Celiac Disease
  - Detection of villous atrophy

UPPER ENDOSCOPY

BARRETT'S ESOPHAGUS (BE)

- BE is the primary risk factor in the development of esophageal adenocarcinoma, which is associated especially with poor survival.
- Screening for BE and early esophageal adenocarcinoma is challenging, as evidenced by the fact that only 1 in 10 cases of esophageal adenocarcinoma are diagnosed within a screening program.
- An AI-enabled aid that can assist in the detection of neoplastic changes in BE has been a focus of AI research and has the potential to improve clinical outcomes.

BARRETT'S ESOPHAGUS (BE)

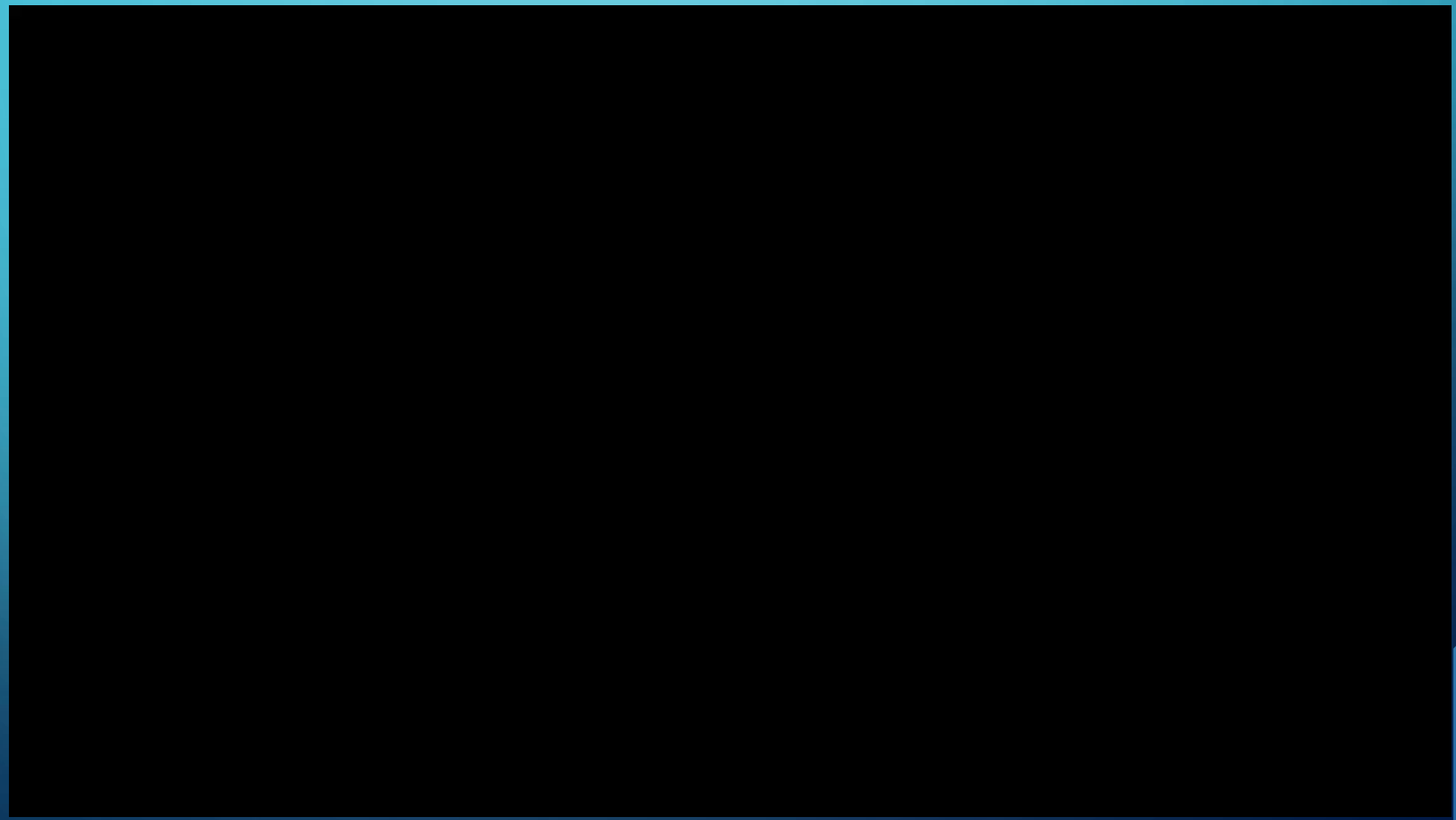
- The first true real-time application of a deep learning model to identify early neoplastic BE was published by Ebigbo et al in 2020 and deployed their previously developed CNN during live endoscopy to accurately identify cases of neoplastic BE with an accuracy of 89.9%, similar to that of expert endoscopists.

CNN convolutional neural network

Real-time use of artificial intelligence in the evaluation of cancer in Barrett's oesophagus

Ebigbo A, *et al*. *Gut* 2020;**69**:615–616. doi:10.1136/gutjnl-2019-319460

Alanna Ebigbo ,[1] Robert Mendel,[2,3] Andreas Probst,[1] Johannes Manzeneder,[1] Friederike Prinz,[1] Luis A de Souza Jr.,[4] Joao Papa,[5] Christoph Palm,[2,3] Helmut Messmann[1]



ESOPHAGEAL SQUAMOUS CELL CARCINOMA (SCC)

Real-time automated diagnosis of precancerous lesions and early esophageal squamous cell carcinoma using a deep learning model (with videos)

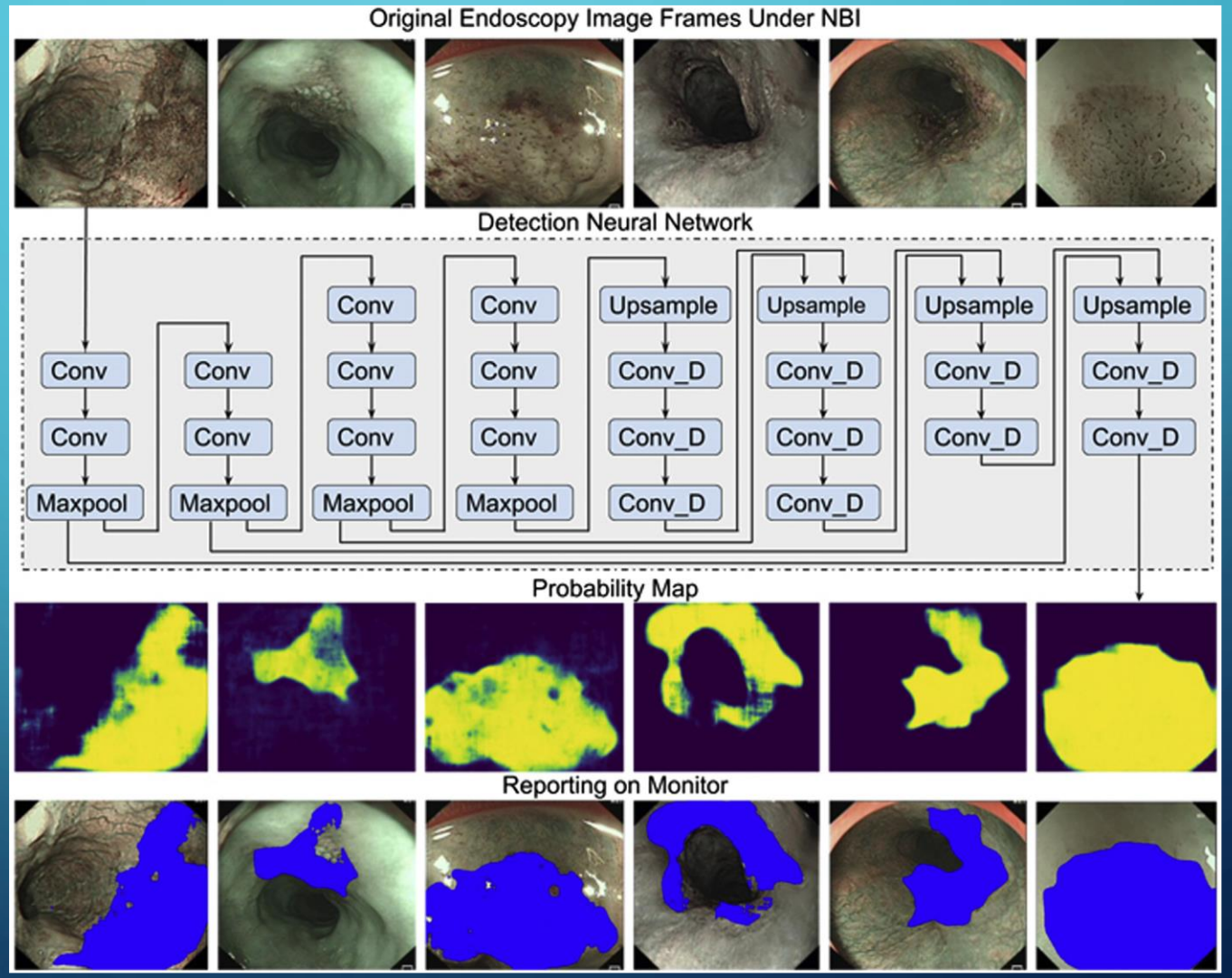
LinJie Guo, MD,[1] Xiao Xiao, PhD,[2] ChunCheng Wu, MD,[1] Xianhui Zeng, MD,[1] Yuhang Zhang, MD,[1] Jiang Du, NP,[1] Shuai Bai, NP,[1] Jia Xie, NP,[1] Zhiwei Zhang, MS,[2] Yuhong Li, BS,[2] Xuedan Wang, BS,[2] Onpan Cheung, MD,[3] Malay Sharma, MD,[4] Jingjia Liu, BS,[2] Bing Hu, MD[1]

Conclusions: A deep learning model demonstrated high sensitivity and specificity for both endoscopic images and video datasets. The real-time CAD system has a promising potential in the near future to assist endoscopists in diagnosing precancerous lesions and ESCCs. (Gastrointest Endosc 2020;91:41-51.)

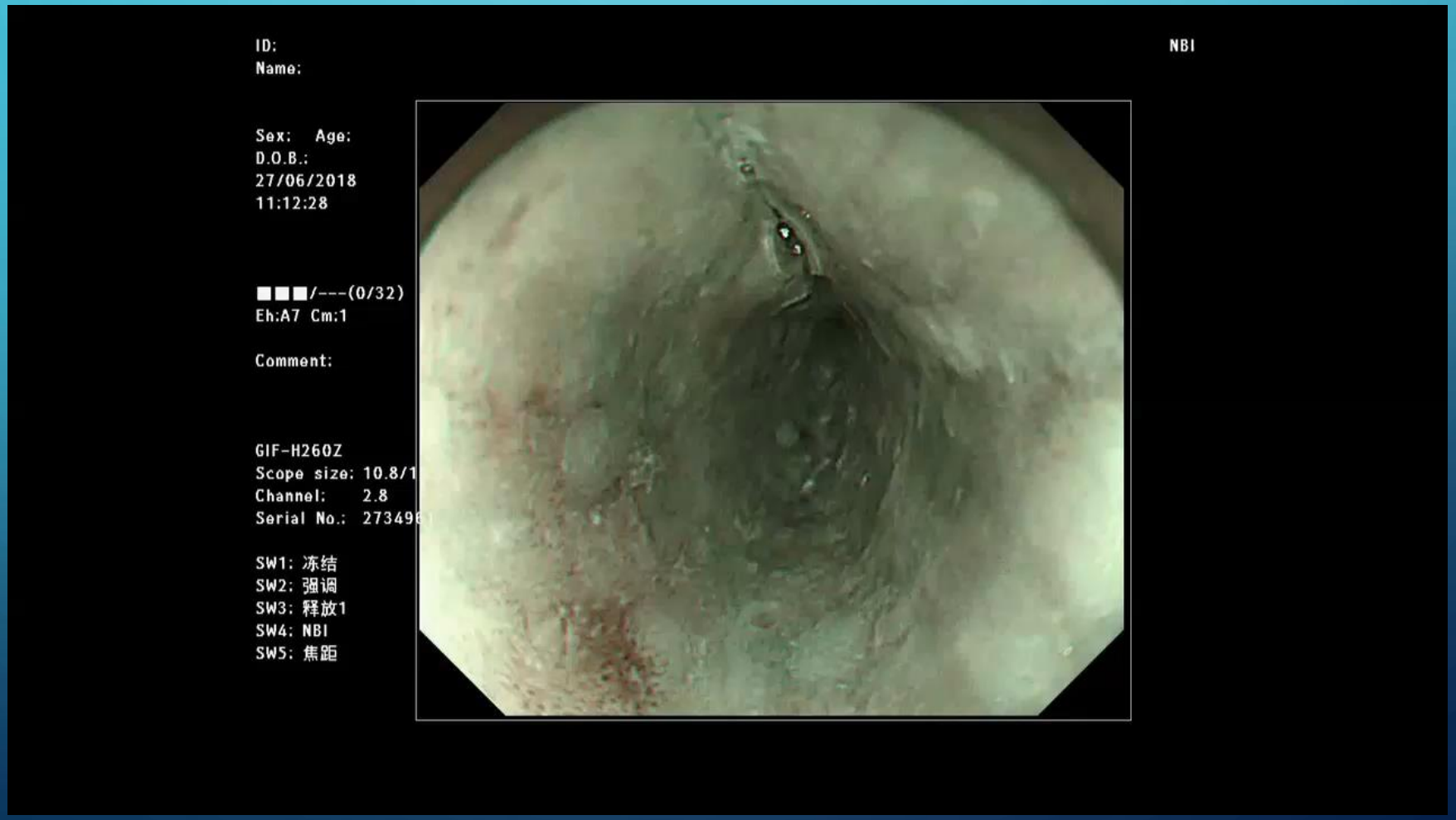
ESOPHAGEAL SQUAMOUS CELL CARCINOMA (SCC)

The yellow color indicates high possibility of a cancerous lesion, and the blue color indicates a noncancerous lesion.

When CAD detects any pre- cancerous lesion or early ESCC, the lesion of interest is covered with color



ESOPHAGEAL SQUAMOUS CELL CARCINOMA (SCC)



ESOPHAGEAL SQUAMOUS CELL CARCINOMA (SCC)

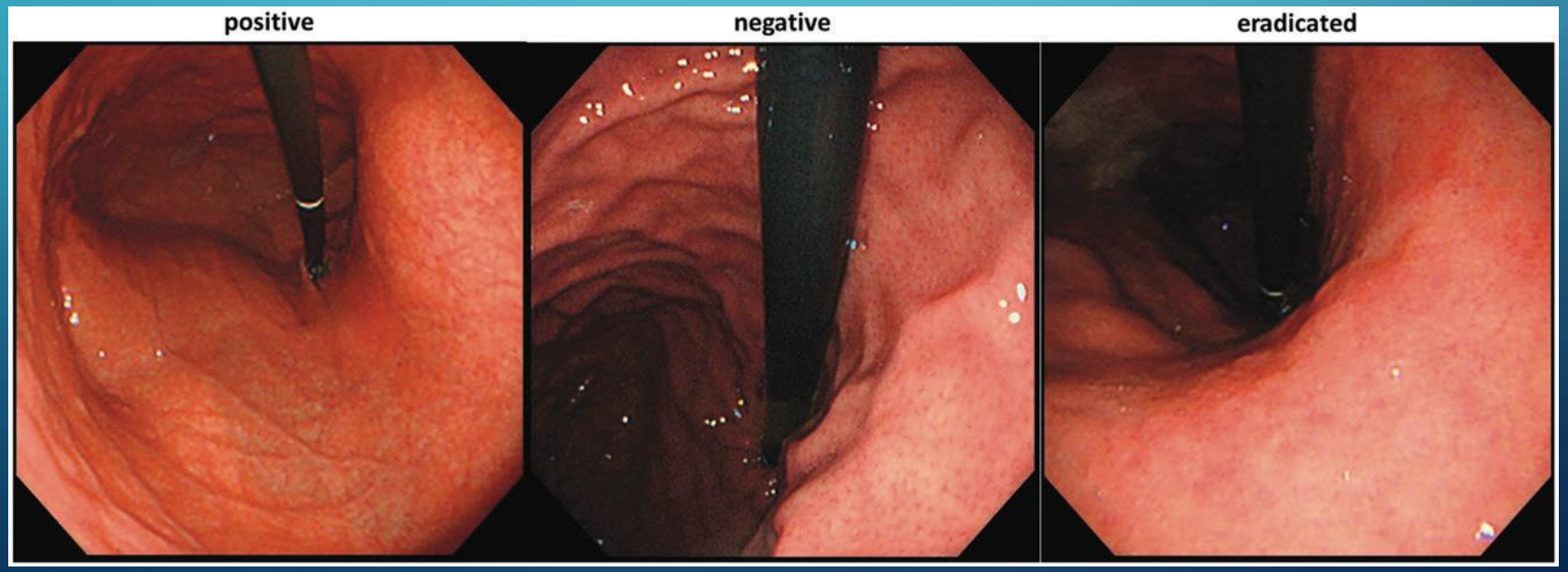
H. PYLORI INFECTION

- H. pylori infection plays a central role in the pathobiology of gastric cancer; it induces atrophic gastritis and intestinal metaplasia, eventually resulting in development of gastric cancer.

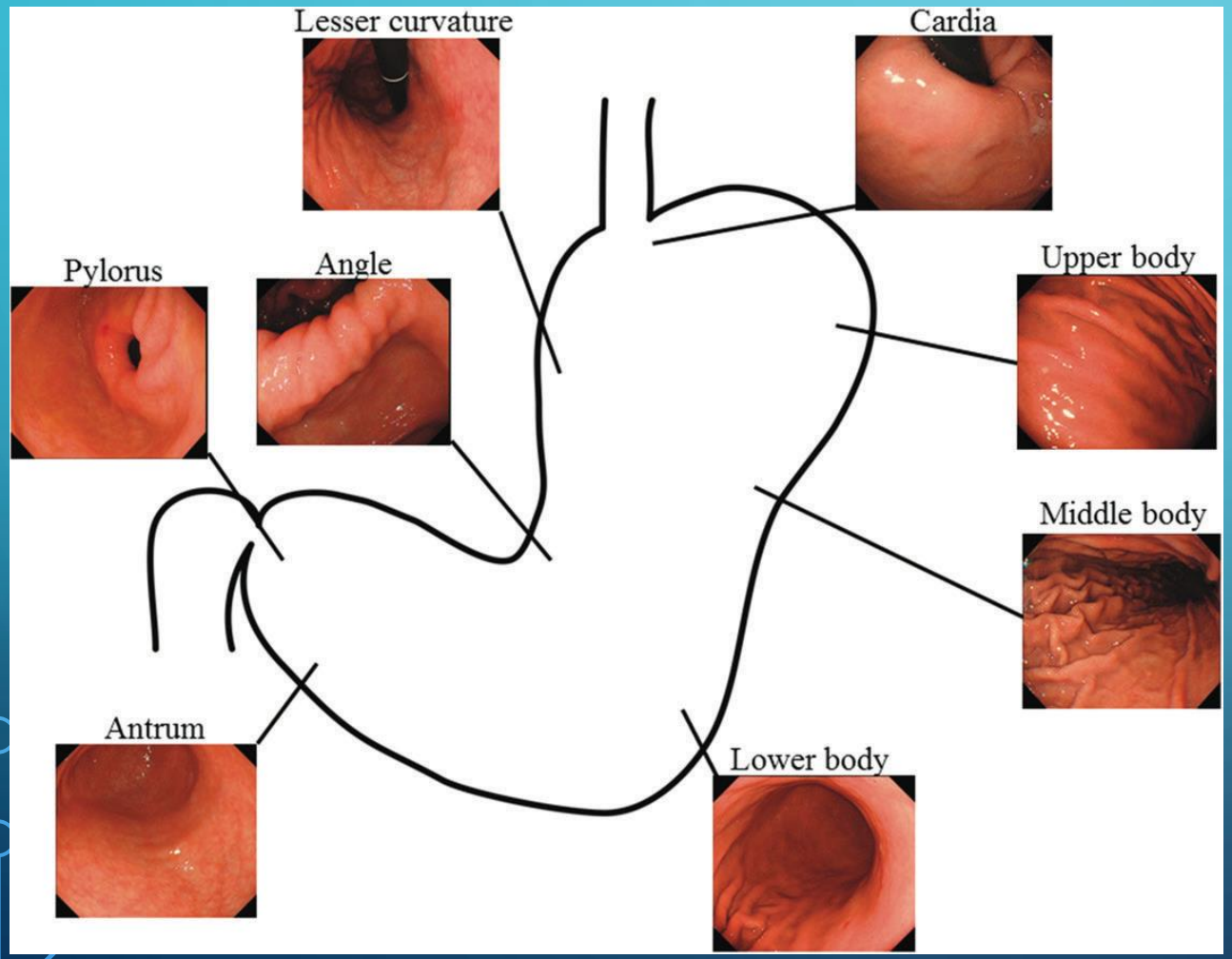
H. PYLORI INFECTION

Table 1. Baseline characteristics according to data set.

Characteristics	Development data set	Test data set
No. of images	98,564	23,699
No. of endoscopists	33	13
No. of patients	5236	847
H. pylori status, No. (%)		
positive	742 (14)	70 (8)
negative	3649 (70)	493 (58)
eradicated	845 (16)	284 (34)



H. PYLORI INFECTION



Study Highlights

WHAT IS KNOWN

- ✓ Endoscopy is frequently performed for evaluation of *H. pylori*-associated diseases.
- ✓ Evaluation of *H. pylori* at the time of endoscopy requires gastric biopsies as endoscopic impression alone is inaccurate.

WHAT IS NEW HERE

- ✓ The Computer-Aided Decision Support System was developed to evaluate for *H. pylori* infection based on endoscopic images.

TRANSLATIONAL IMPACT

- ✓ CNN may potentially replace gastric biopsies in patients undergoing evaluation for *H. pylori*-associated diseases.

Wu Lianlian et al. Deep neural network for endoscopic early gastric cancer detection … Endoscopy 2019; 51: 522–531

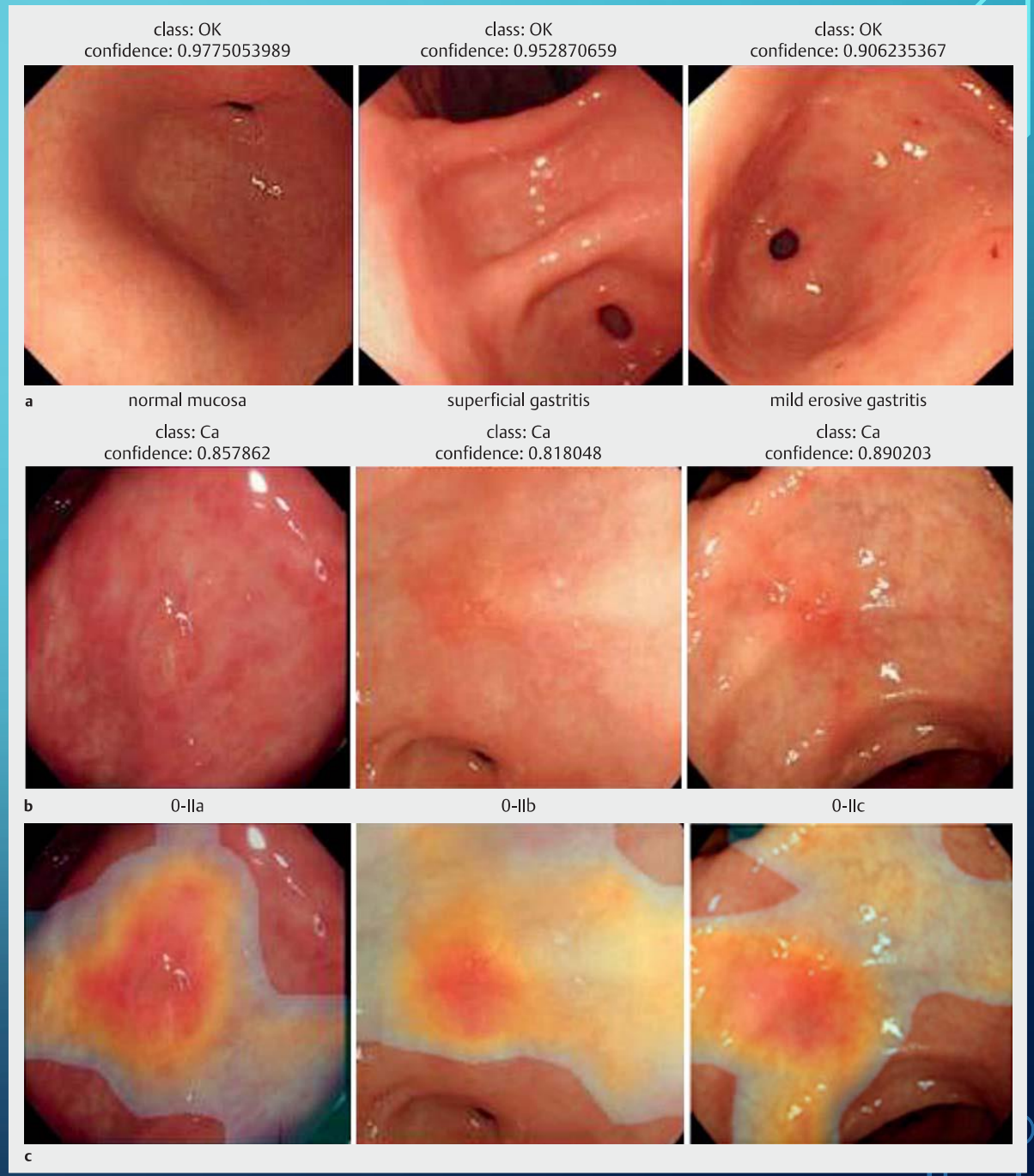
EARLY GASTRIC CANCER (EGC)

- 3170 gastric cancer and 5981 benign images were collected to train the DCNN to detect EGC. A total of 24549 images from different parts of stomach were collected to train the DCNN to monitor blind spots.
- The DCNN identified EGC from non-malignancy with an accuracy of 92.5 %, a sensitivity of 94.0 %, a specificity of 91.0%, a positive predictive value of 91.3%, and a negative predictive value of 93.8 %, outperforming all levels of endoscopists.

deep convolution neural network (DCNN)

EARLY GASTRIC CANCER (EGC)

- A: The displayed normal mucosa, superficial gastritis, and mild erosive gastritis were predicted to be non-malignant by the DCNN with confidence levels of 0.98, 0.95, and 0.91, respectively.
- B: The mucosal images from EGC type 0-IIa, 0-IIb, and 0-IIc were predicted to be malig- nant by the DCNN with confidence of 0.86, 0.82, and 0.89, respectively.
- C: Cancerous regions were indicated in the images from b after estab- lishing class activation maps (CAMs). The color depth of the CAMs was positively correlated with the prediction confidence.

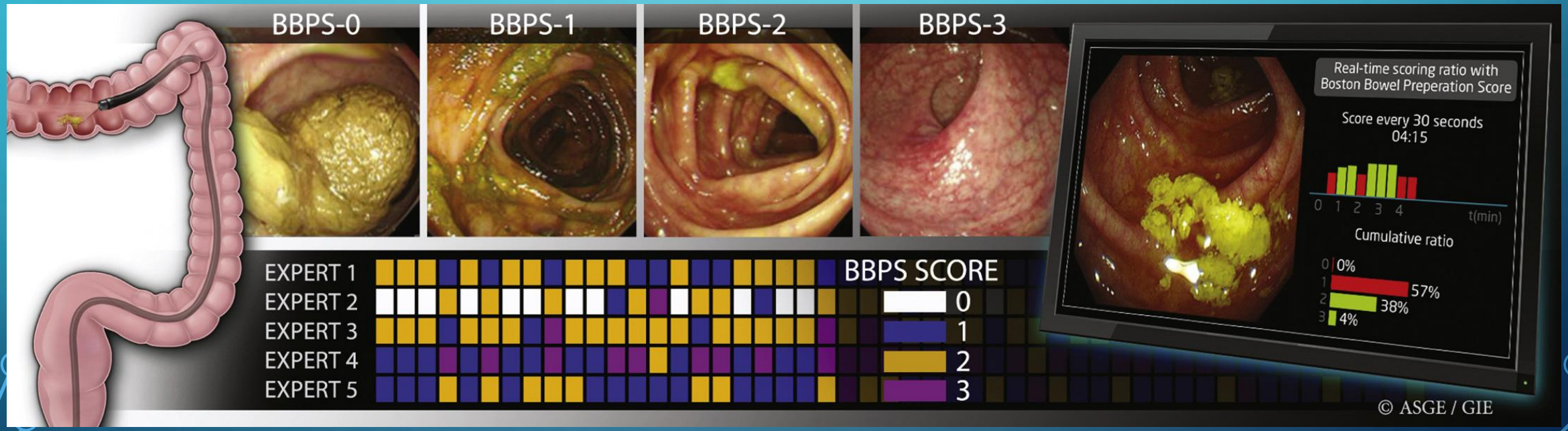


COLONOSCOPY

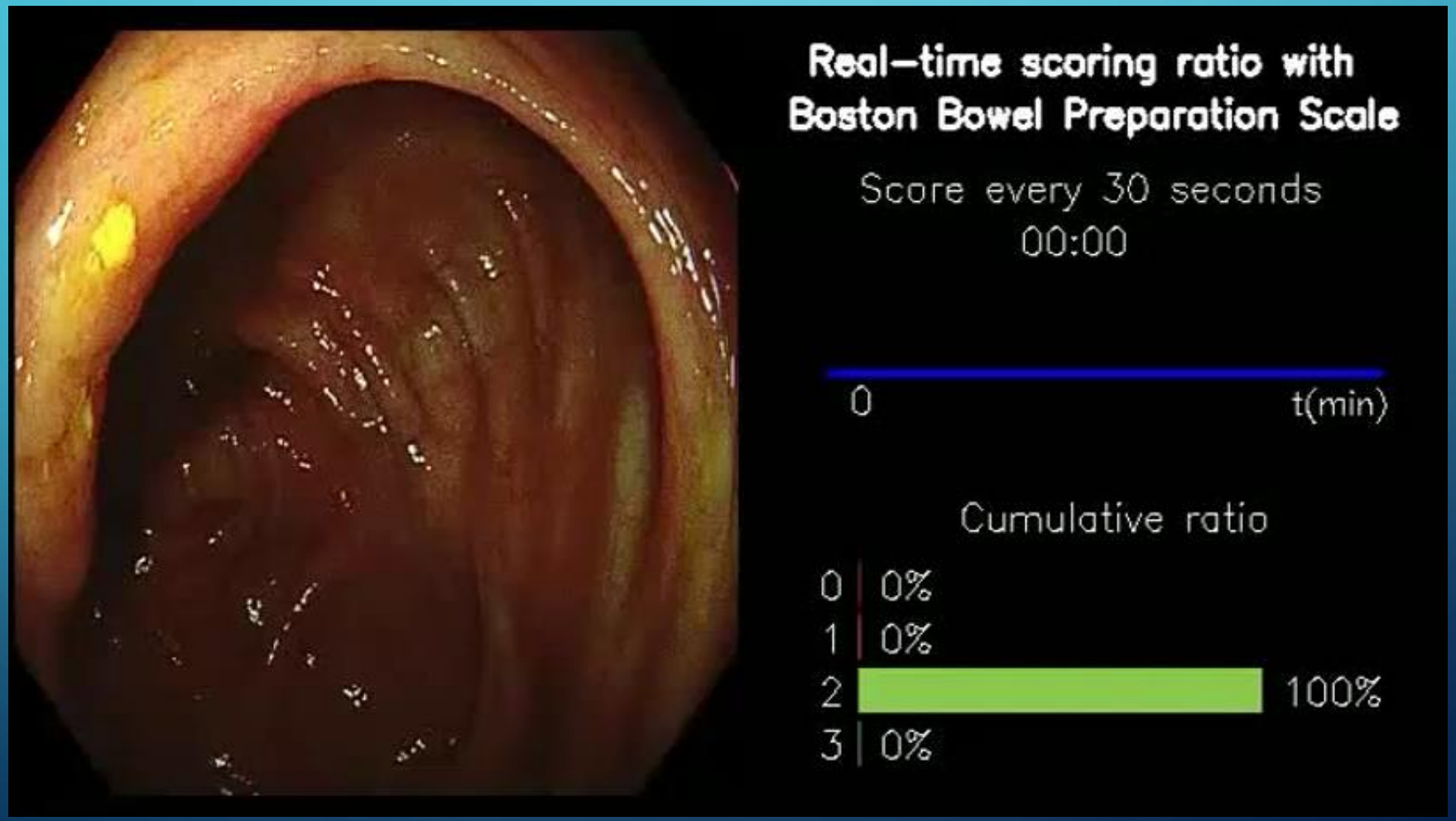
COLONOSCOPY - BOWEL PREPARATION ASSESSMENT

- A novel artificial intelligence system for the assessment of bowel preparation
- Results: ENDOANGEL achieved 93.33% accuracy in the human–machine contest with 120 images, which was bet- ter than that of all endoscopists. Moreover, ENDOANGEL achieved 80.00% accuracy among 100 images with bub- bles. In 20 colonoscopy videos, accuracy was 89.04%, and ENDOANGEL continuously showed the accumulated percentage of the images for different BBPS scores during the withdrawal phase and prompted us for bowel prep- aration scores every 30 seconds.
- Conclusions: We provided a novel and more accurate evaluation method for bowel preparation and developed an objective and stable systemdENDOANGELdthat could be applied reliably and steadily in clinical settings.
- (Gastrointest Endosc 2020;91:428-35.)

COLONOSCOPY
- BOWEL PREPARATION ASSESSMENT



COLONOSCOPY
- BOWEL PREPARATION ASSESSMENT



COLONOSCOPY - ADENOMA DETECTION

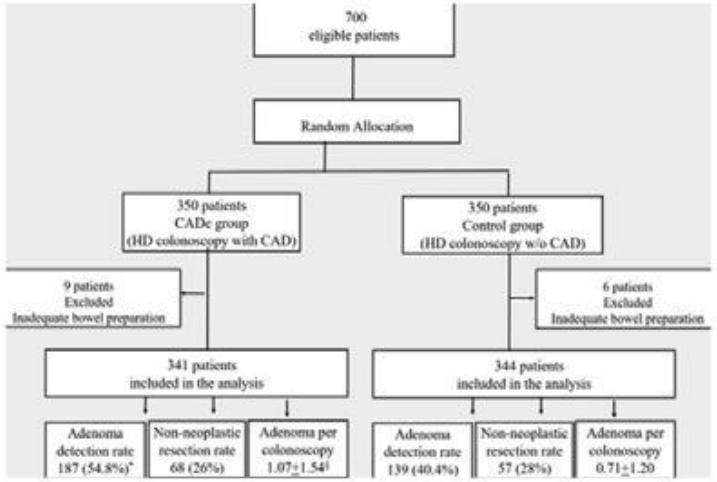
Efficacy of Real-Time Computer-Aided Detection of Colorectal Neoplasia in a Randomized Trial

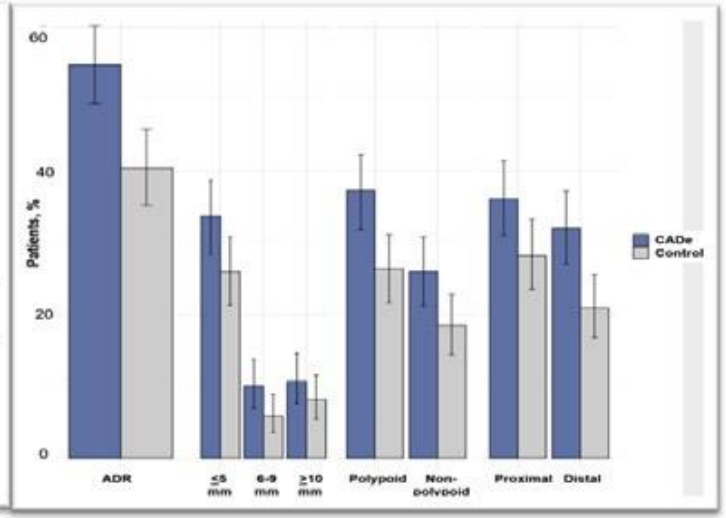
Alessandro Repici,[1] Matteo Badalamenti,[1] Roberta Maselli,[1] Loredana Correale,[1] Franco Radaelli,[2] Emanuele Rondonotti,[2] Elisa Ferrara,[1] Marco Spadaccini,[1] Asma Alkandari,[3] Alessandro Fugazza,[1] Andrea Anderloni,[1] Piera Alessia Galtieri,[1] Gaia Pellegatta,[1] Silvia Carrara,[1] Milena Di Leo,[1] Vincenzo Craviotto,[1] Laura Lamonaca,[1] Roberto Lorenzetti,[4] Alida Andrealli,[2] Giulio Antonelli,[4] Michael Wallace,[5] Prateek Sharma,[6] Thomas Rosch,[7] and Cesare Hassan[4]

[1]Department of Gastroenterology, Humanitas Research Hospital, Milano, Italy; [2]Gastroenterology Department, Valduce Hospital, Como, Italy; [3]Thanyan Alghanim Center for Gastroenterology and Hepatology, Alamiri Hospital, Kuwait, Kuwait; [4]Digestive Endoscopy, Nuovo Regina Margherita Hospital, Rome, Italy; [5]Mayo Clinic, Jacksonville, Florida; [6]Kansas City Veterans Affairs Hospital, Kansas City, Missouri; and [7]Department of Interdisciplinary Endoscopy, University Hospital Hamburg-Eppendorf, Hamburg, Germany

Gastroenterology 2020;159:512–520

Efficacy of Real-Time Computer-Aided Detection of Colorectal Neoplasia in a Randomized Trial





The use of a Real-time Computer-Aided Detection for detection of colorectal polyps resulted in a 30% increase of the Adenoma Detection Rate -ADR-

Gastroenterology

COLONOSCOPY - ADENOMA DETECTION

- In conclusion, we showed the safety and efficacy of integrating CADe in real-time colonoscopy. The substantial improvement of ADR and APC without increasing the removal of non-neoplastic lesions is likely to improve the quality of colonoscopy without affecting its efficiency.

WHAT YOU NEED TO KNOW

BACKGROUND AND CONTEXT

Deep learning systems allow for real-time computer-aided detection (CADe) of polyps with high-accuracy, but these systems have not been tested in randomized trials.

NEW FINDINGS

In randomized trial, inclusion of CADe in colonoscopy significantly increased adenoma detection rates and adenomas detected per colonoscopy, without increasing withdrawal time. Higher proportions of adenomas smaller than 5 mm and 6–9 mm were detected with CADe, regardless of morphology or location.

LIMITATIONS

This study was performed in an expert setting; studies are needed for inexperienced endoscopists.

IMPACT

Including CADe in colonoscopy examinations increases detection of adenomas without affecting safety.

COLONOSCOPY – ULCERATIVE COLITIS

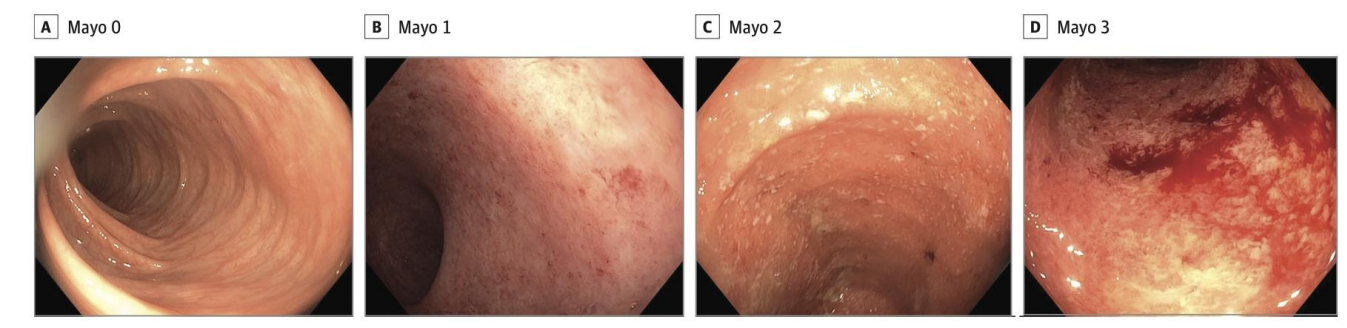
JAMA Network Open™

Original Investigation | Gastroenterology and Hepatology

Performance of a Deep Learning Model vs Human Reviewers in Grading Endoscopic Disease Severity of Patients With Ulcerative Colitis

Ryan W. Stidham, MD, MS; Wenshuo Liu, PhD; Shrinivas Bishu, MD; Michael D. Rice, MD; Peter D. R. Higgins, MD, PhD; Ji Zhu, PhD, MSc; Brahmajee K. Nallamothu, MD, MPH; Akbar K. Waljee, MD, MSc

JAMA Network Open. 2019;2(5):e193963.



Key Points

Question What is the agreement of automatically determined endoscopic severity of ulcerative colitis using deep learning models compared with expert human reviewers?

Findings In this diagnostic study including colonoscopy data from 3082 adults, performance of a deep learning model for distinguishing moderate to severe disease from remission compared with multiple expert reviewers was excellent, with an area under the receiver operating curve of 0.97 using still images and full-motion video.

Meaning Deep learning offers a practical and scalable method to provide objective and reproducible assessments of endoscopic disease severity for patients with ulcerative colitis.

COLONOSCOPY – ULCERATIVE COLITIS

Automatic, computer-aided determination of endoscopic and histological inflammation in patients with mild to moderate ulcerative colitis based on red density

Peter Bossuyt [1,2] Hiroshi Nakase,[3] Séverine Vermeire,[1] Gert de Hertogh,[4] Tom Eelbode,[5] Marc Ferrante,[1] Tadashi Hasegawa,[6] Hilde Willekens,[1] Yousuke Ikemoto,[7] Takao Makino,[7] Raf Bisschops[1]

Bossuyt P, *et al*. *Gut* 2020;**69**:1778–1786. doi:10.1136/gutjnl-2019-320056

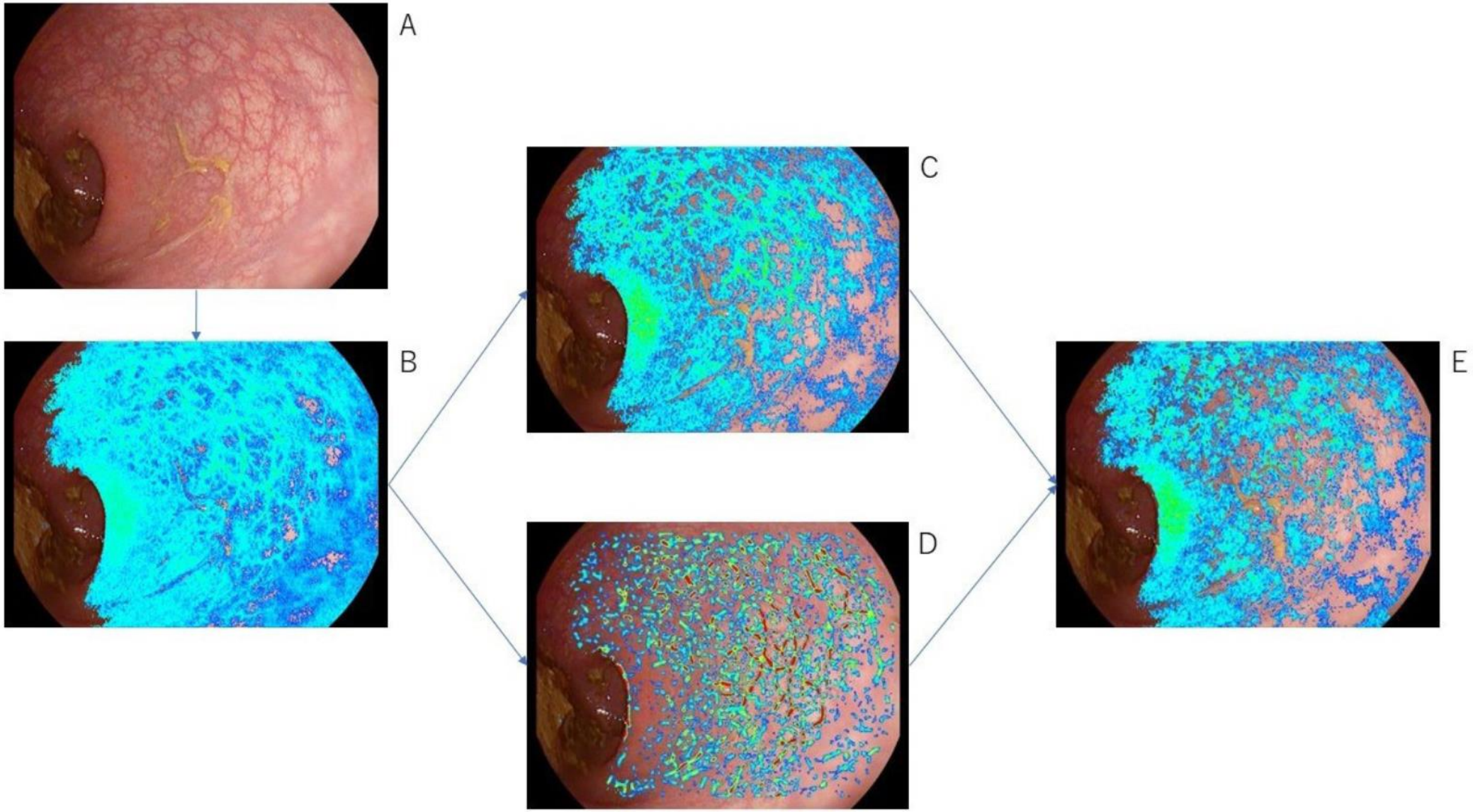


Figure 2 Visual representation of the different modifications in a sample endoscopic image: (A) standard white light high definition endoscopic image; (B) original colour map of the red density image; (C) colour map of the red density image after adapted range setting; (D) image with vascular pattern detection; (E) colour map of the red density after vascular pattern extraction.

Significance of this study

What is already known on this subject?

- Assessment of disease activity is subjective and leads to interobserver variability.
- Endoscopic scores are useful as treatment target if they are objective and predictive for further disease course.
- Regulatory authorities request a combined endpoint of endoscopic and histological remission for the claim of mucosal healing

What are the new findings?

- Red density (RD) is an operator-independent computer-based tool to determine disease activity in patients with UC.
- RD assesses disease activity based on evaluation of the redness map and vascular pattern recognition.
- RD scores correlated with endoscopic and histological features of UC activity.

How might it impact on clinical practice in the foreseeable future?

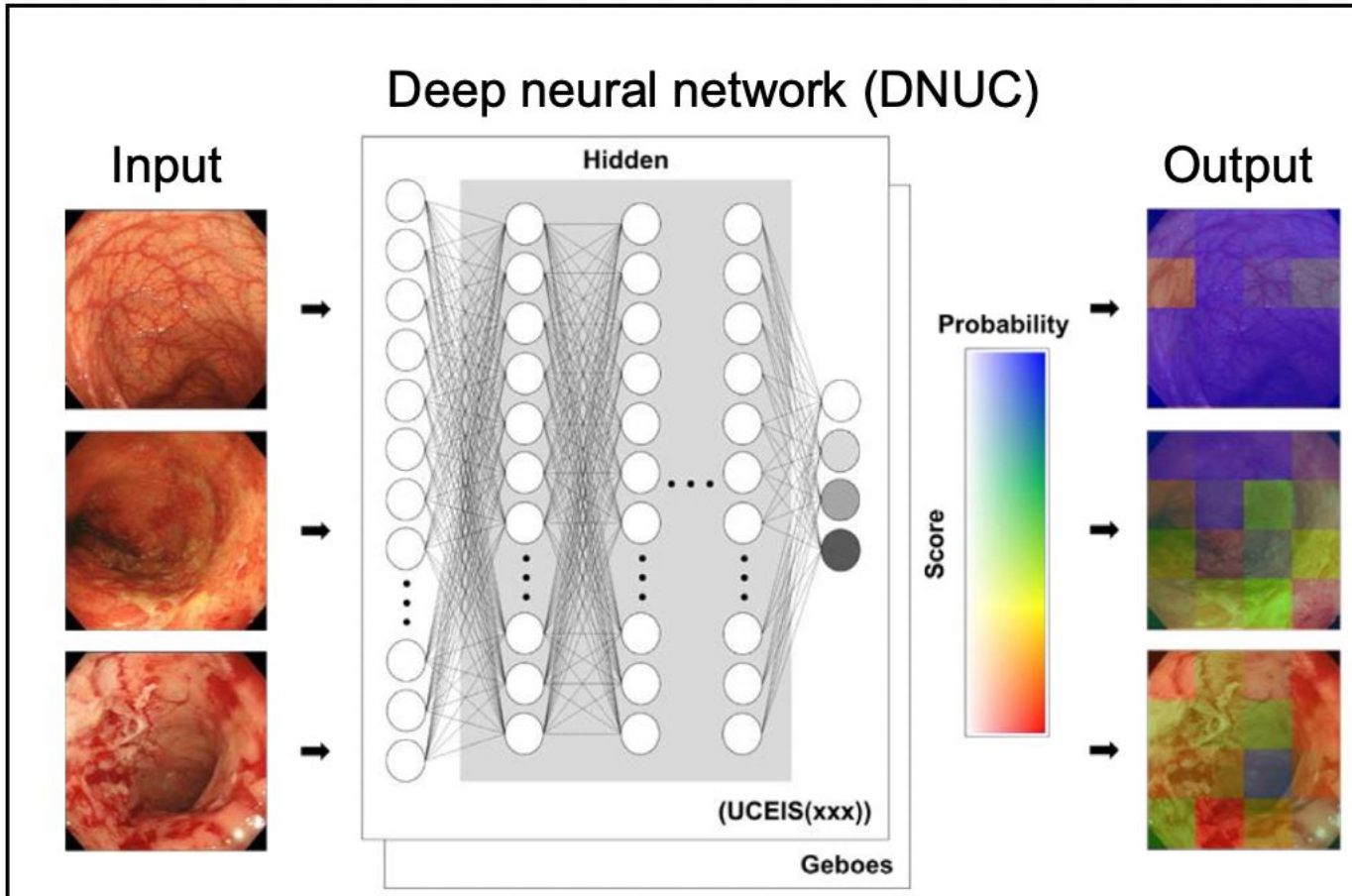
- This algorithm might be used for computer analysis of digital endoscopic images from patients with UC and evaluate healing or disease progression in an objective way.
- Larger, prospective studies are ongoing to confirm its accuracy and predictive value.

COLONOSCOPY – ULCERATIVE COLITIS

Development and Validation of a Deep Neural Network for Accurate Evaluation of Endoscopic Images From Patients With Ulcerative Colitis

Kento Takenaka,[1] Kazuo Ohtsuka,[1] Toshimitsu Fujii,[1] Mariko Negi,[2] Kohei Suzuki,[1] Hiromichi Shimizu,[1] Shiori Oshima,[3] Shintaro Akiyama,[1] Maiko Motobayashi,[1] Masakazu Nagahori,[1] Eiko Saito,[1] Katsuyoshi Matsuoka,[1] and Mamoru Watanabe[1]

Gastroenterology 2020;158:2150–2157



UCEIS (xxx)
Endoscopic remission : yes/no
Histologic remission : yes/no

90.1% accuracy
for determining endoscopic remission
in comparison with experts

92.9% accuracy
for predicting histologic remission
without need of mucosal biopsy

Gastroenterology

COLONOSCOPY – ULCERATIVE COLITIS

WHAT YOU NEED TO KNOW

BACKGROUND AND CONTEXT

Endoscopic assessment of ulcerative colitis (UC) is hindered by intra- and interobserver variability, and histologic evaluation requires biopsy collection, which is invasive.

NEW FINDINGS

The authors developed a deep neural network for evaluation of endoscopic images from patients with UC (DNUC). It identified patients in endoscopic and histologic remission without the need for biopsy analysis.

LIMITATIONS

This system requires testing in a larger population.

IMPACT

The DUNC might identify patients with UC in remission without the need for biopsy collection and analysis, saving time and costs.

CAPSULE ENDOSCOPY

Digestive Endoscopy 2020; **32**: 585–591 doi: 10.1111/den.13517

Original Article

Clinical usefulness of a deep learning-based system as the first screening on small-bowel capsule endoscopy reading

Tomonori Aoki,[1] Atsuo Yamada,[1] Kazuharu Aoyama,[3] Hiroaki Saito,[4] Gota Fujisawa,[1] Nariaki Odawara,[1] Ryo Kondo,[1] Akiyoshi Tsuboi,[5] Rei Ishibashi,[1] Ayako Nakada,[1] Ryota Niikura,[1] Mitsuhiro Fujishiro,[6] Shiro Oka,[5] Soichiro Ishihara,[2,7] Tomoki Matsuda,[4] Masato Nakahori,[4] Shinji Tanaka,[5] Kazuhiko Koike[1] and Tomohiro Tada[2,3,7]

Background and Aim: To examine whether our convolutional neural network (CNN) system based on deep learning can reduce the reading time of endoscopists without oversight of abnormalities in the capsule-endoscopy reading process.

Conclusions: Our CNN-based system for capsule endoscopy videos reduced the reading time of endoscopists without decreasing the detection rate of mucosal breaks. However, the reading level of endoscopists should be considered when using the system.

Ulcer severity grading in video capsule images of patients with Crohn's disease: an ordinal neural network solution

Yiftach Barash, MD, MSc,[1,2,3] Liran Azaria, MSc,[3] Shelly Soffer, MD,[3] Reuma Margalit Yehuda, MD,[2,4] Oranit Shlomi, MD,[2,4] Shomron Ben-Horin, MD,[2,4] Rami Eliakim, MD,[2,4] Eyal Klang, MD,[1,2,3] Uri Kopylov, MD[2,4]

Ramat Gan, Tel Hashomer, Israel

The aim of our study was to develop a deep learning algorithm for auto- mated grading of CD ulcers on CE.

Conclusions: CNN achieved high accuracy in detecting severe CD ulcerations. CNN-assisted CE readings in pa- tients with CD can potentially facilitate and improve diagnosis and monitoring in these patients.

(Gastrointest En- dosc 2021;93:187-92.)

Celiac disease diagnosis from videocapsule endoscopy images with residual learning and deep feature extraction

Xinle Wang[a], Haiyang Qian[a], Edward J. Ciaccio[b], Suzanne K. Lewis[b], Govind Bhagat[b,d], Peter H. Green[b], Shenghao Xu[c], Liang Huang[a], Rongke Gao[a,*], Yu Liu[a,*]

Computer Methods and Programs in Biomedicine 187 (2020) 105236

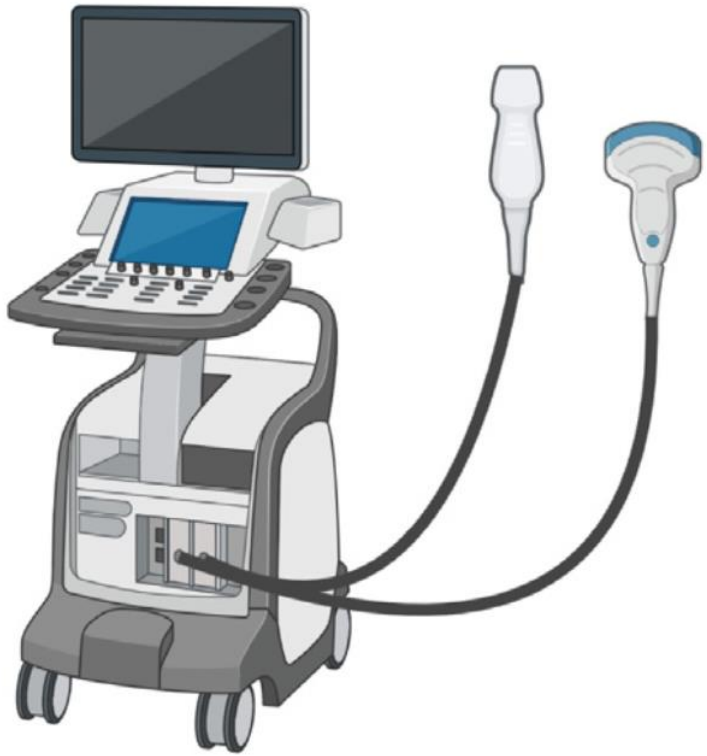
Conclusions: A novel deep learning recalibration module, with global response and local salient factors is proposed, and it has a high potential for utilizing deep learning networks to diagnose celiac disease using VCE images.

ARTIFICIAL INTELLIGENCE
- GASTROENTEROLOGY AND HEPATOLOGY

Machine Learning in GI Radiology

Hepatology

- Identification of liver disease
- Determine fibrosis stage
- Identify Liver Lesions
- Differentiate benign vs malignant lesions



Pancreatology

- Identification of intraductal papillary mucinous neoplasms
- Identification and staging of pancreatic cancer
- Diagnosis of pancreatic ductal adenocarcinoma
- Quantify degree of intrapancreatic fat

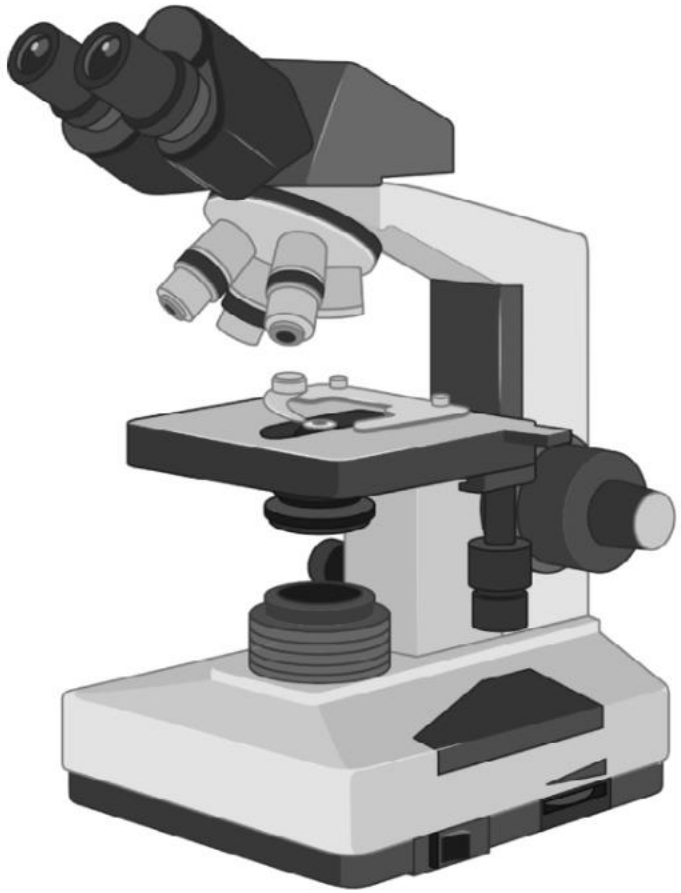
Machine Learning in GI Pathology

Luminal GI

- Diagosis of Celiac Disease
- Classify Colorectal Polyps
- Diagnosis of Barrett's Esophagus

Hepatology

- Diagnosis of NAFLD and NASH
- Identification of NAFLD
- Identification of specific histologic features such as macrosteatosis
- Determine degree of fibrosis
- Predict treatment response in NASH



GI Malignancy

- Survival prediction in colorectal cancer
- Identification of microsatellite instability
- Identification of Esophageal Adenocarcinoma
- Differentiation between HCC and Cholangiocarcinoma
- Predict prognosis and survival in HCC

Machine Learning in GI Electronic Health Record Data

Diagnosis

Celiac Disease
Colorectal Cancer
Esophageal Varices
Non-alcoholic Fatty Liver Disease

Outcome Prediction

Acetaminophen Overdose
Esophageal Cancer
Hepatocellular Carcinoma
Inflammatory Bowel Disease
Liver Transplant Survival
Lower GI Bleeding
Pancreatitis
Peptic Ulcer Bleeding
Primary Sclerosing Cholangitis

The GI Practice of the Future

Post- Hospital Care

- Post-hospital dicharge vital sign monitoring
- Remote monitoring of labs, such as hemoglobin after endoscopy
- Monitor voice patterns for signs of hepatic encephalopathy

Virtual GI Clinic

- Virtual clinic visits
- Home based diagnostic testing (ascites measurements, virtual capsule endoscopy)
- Virtual Reality therapies for functional disorders

FREMTIDEN….?

- Er AI-drevne algoritmer "medicinsk udstyr”?
- Skal brugen af AI reguleres af Sundhedsstyrelsen?
- Hvem er ansvarlig for nøjagtigheden af AI-baserede algoritmer
- Hvem holdes ansvarlig, når fejl uundgåeligt opstår som følge af disse modeller.

FREMTIDEN….?

- Der er et presserende behov for randomiserede forsøg og omfattende ekstern validering af udviklede algoritmer i forskellige populationer for at afbøde iboende skævheder
- Selvom mange af de ovenfor beskrevne AI algoritmer ser ud til at være enestående, må man forvente, at det ikke er tilfældet i den virkelige verden.