ARTIFICIAL INTELLIGENCE

Machine Learning, Neural Networks and AI: The Role in BE Dysplasia Detection

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- Motus
- GI Supply
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Educational Grant:
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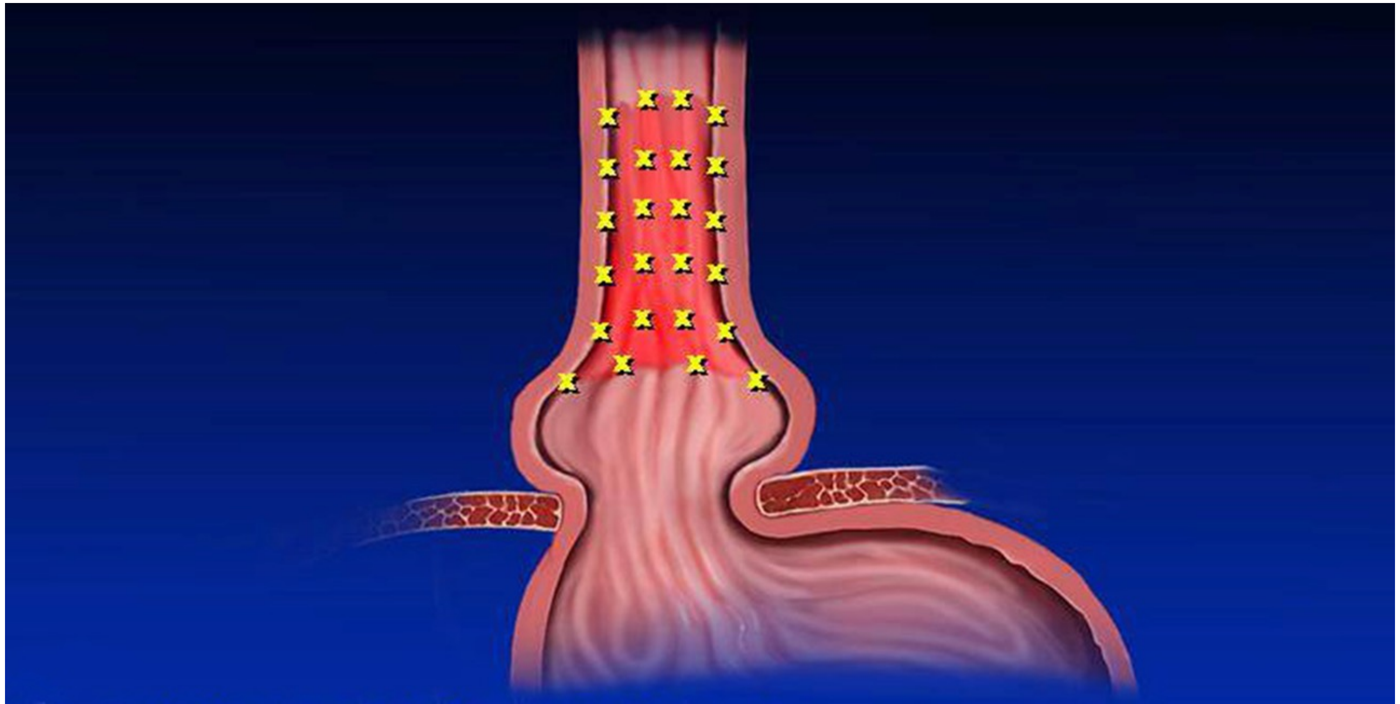
Surveillance of BE

- There are several guidelines for surveillance of Barrett's esophagus
- Surveillance aims to detect dysplasia and is currently only performed with endoscopy
- Seattle protocol is still recommended by U.S. guidelines for endoscopic surveillance



Surveillance of BE

- Non-adherence to Seattle protocol may lead to a significant decrease of dysplasia detection

CGH 2009; 7: 736-742

- Many studies show that the adherence to Seattle protocol is low

  - 16% (CGH 2018; 16;862-869)
  - 24% (EIO 2018; 6: E300-E307)

- A recent meta-analysis showed a modest benefit of surveillance

Gastro 2018; 154: 2068-2086

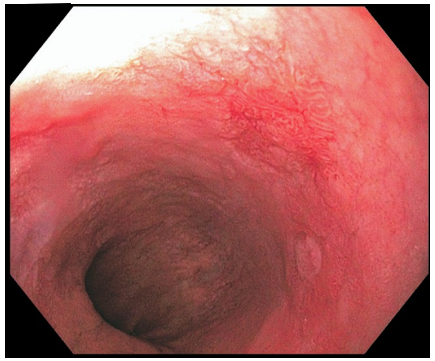
PIVI criteria for Neoplasia Detection

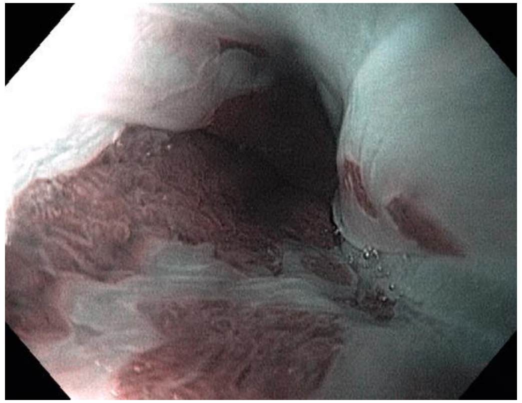
- The American Society of Gastrointestinal Endoscopy set the performance threshold for an optical technology
- Per-patient sensitivity of 90%, a negative predictive value (NPV) of 98% and a specificity of 80% for detecting early esophageal neoplasia

Gastrointest Endosc 2012; 76: 252–254

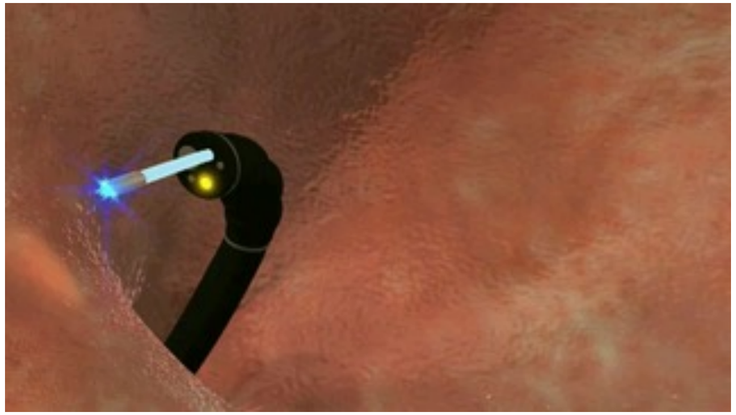
Endoscopy to detect dysplasia

- Chromoendoscopy
  - Acetic acid Spray
  - Virtual (NBI)





- Magnification
- Endocytoscopy



- Confocal laser Endomicroscopy
- Optical coherence tomography

ASGE Technology Committee systematic review and meta-analysis assessing the ASGE Preservation and Incorporation of Valuable Endoscopic Innovations thresholds for adopting real-time imaging–assisted endoscopic targeted biopsy during endoscopic surveillance of Barrett's esophagus

TABLE 2. Results of the meta-analysis

Technology	Total no. of studies	Sensitivity	95% CI	NPV	95% CI	Specificity	95% CI	Meets ASGE PIVI thresholds
Chromoendoscopy	7	91.9	89.4-93.8	95.5	90.8-97.9	89.9	80.1-95.2	No
Acetic acid	4	96.6	95.2-97.7	98.3	94.8-99.4	84.6	68.5-93.2	Yes
Methylene blue	2	64.2	36.2-84.7	69.8	30.6-92.3	95.9	76.5-99.4	No
NBI	9	94.2	82.6-98.2	97.5	95.1-98.7	94.4	80.5-98.6	Yes
NBI AFI	4	80.6	62.0-91.3	88.7	41.5-98.9	46	31.7-61.0	No
CLE	5	90.4	75.7-96.6	96.2	93.1-97.9	89.9	83.8-93.9	No
eCLE	2	90.4	71.9-97.2	98.3	94.2-99.5	92.7	87.0-96.0	Yes
pCLE	3	90.3	54.1-98.7	95.1	90.7-97.5	77.3	54.3-90.7	No

Communication from the ASGE Technology Committee

ASGE TECHNOLOGY COMMITTEE SYSTEMATIC REVIEW AND META-ANALYSIS

ASGE Technology Committee systematic review and meta-analysis assessing the ASGE Preservation and Incorporation of Valuable Endoscopic Innovations thresholds for adopting real-time imaging–assisted endoscopic targeted biopsy during endoscopic surveillance of Barrett's esophagus

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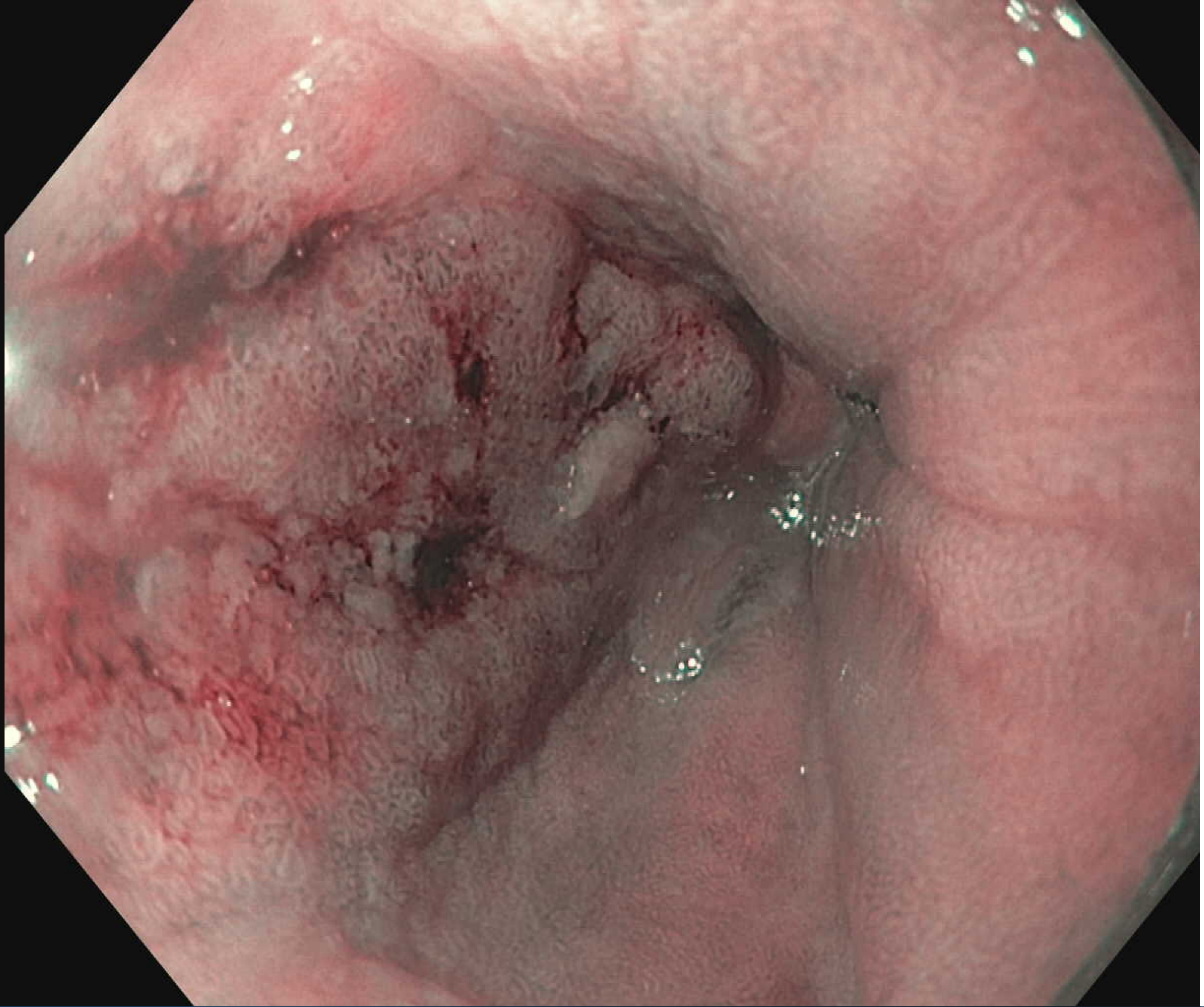
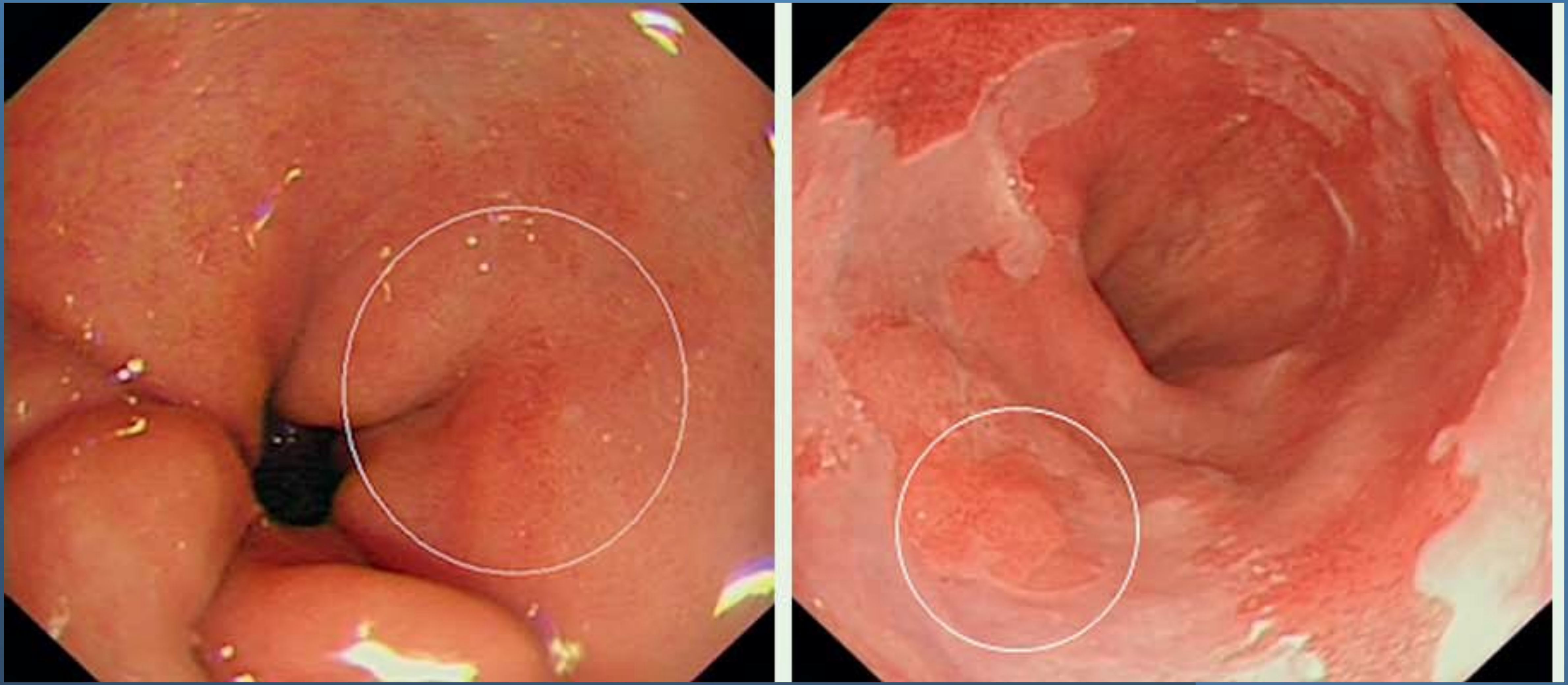
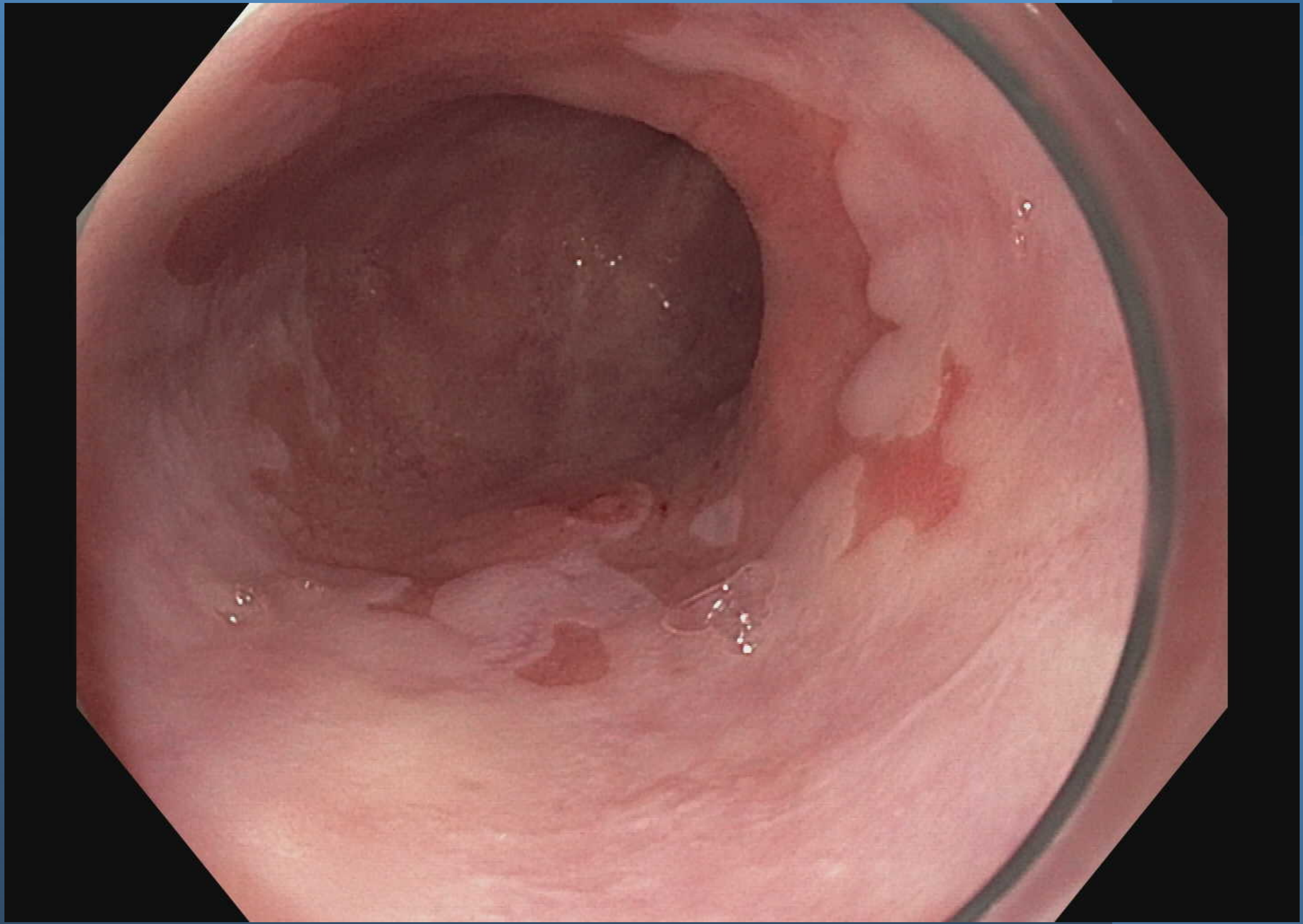
pCLE	3	90.3	54.1-98.7	95.1	90.7-97.5	77.3	54.3-90.7	No

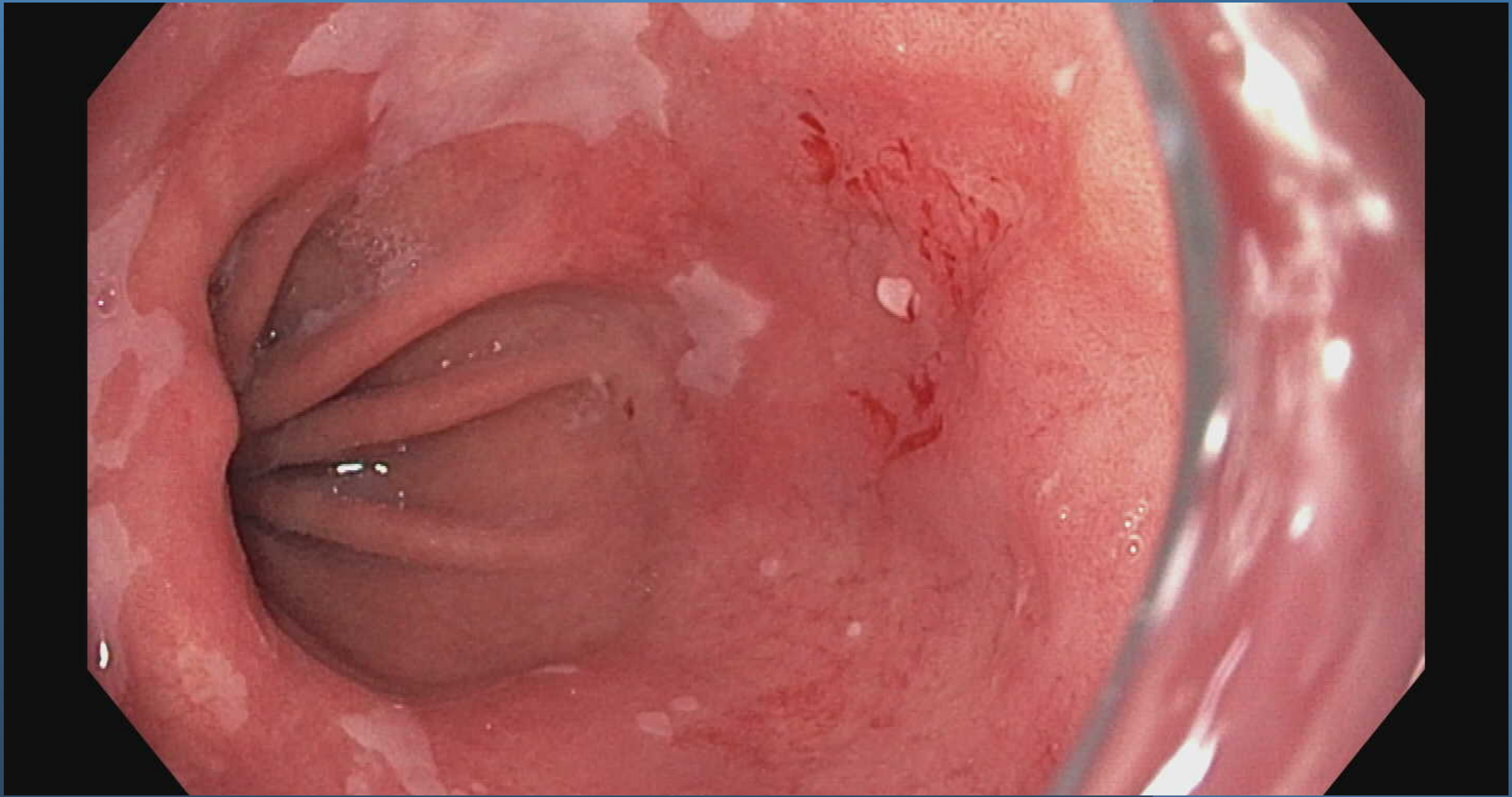
Pattern Recognition

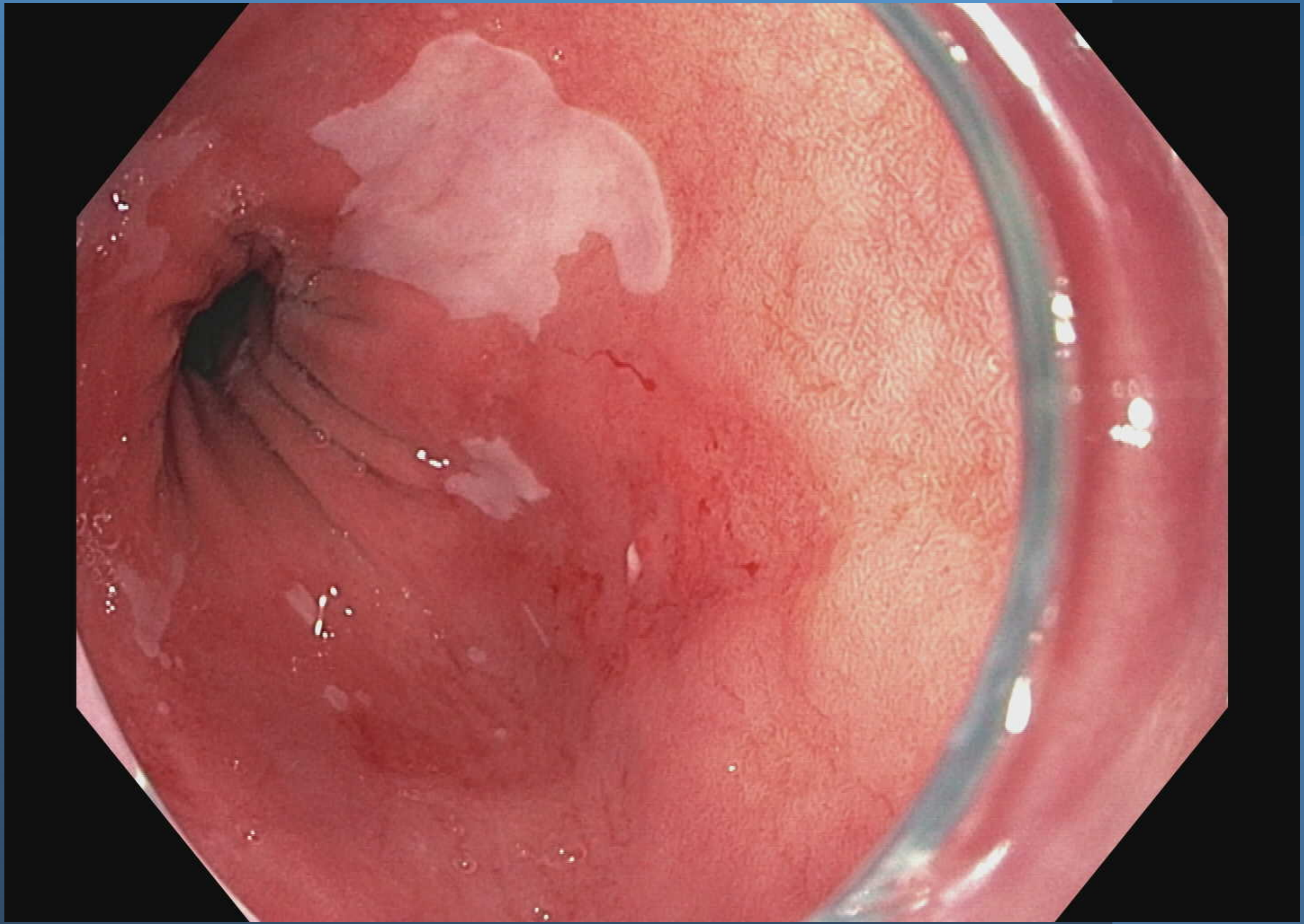


Suspicious Lesions









Human Dysplasia Detection

Two ”Modes”

Red Flag Detector Mode:

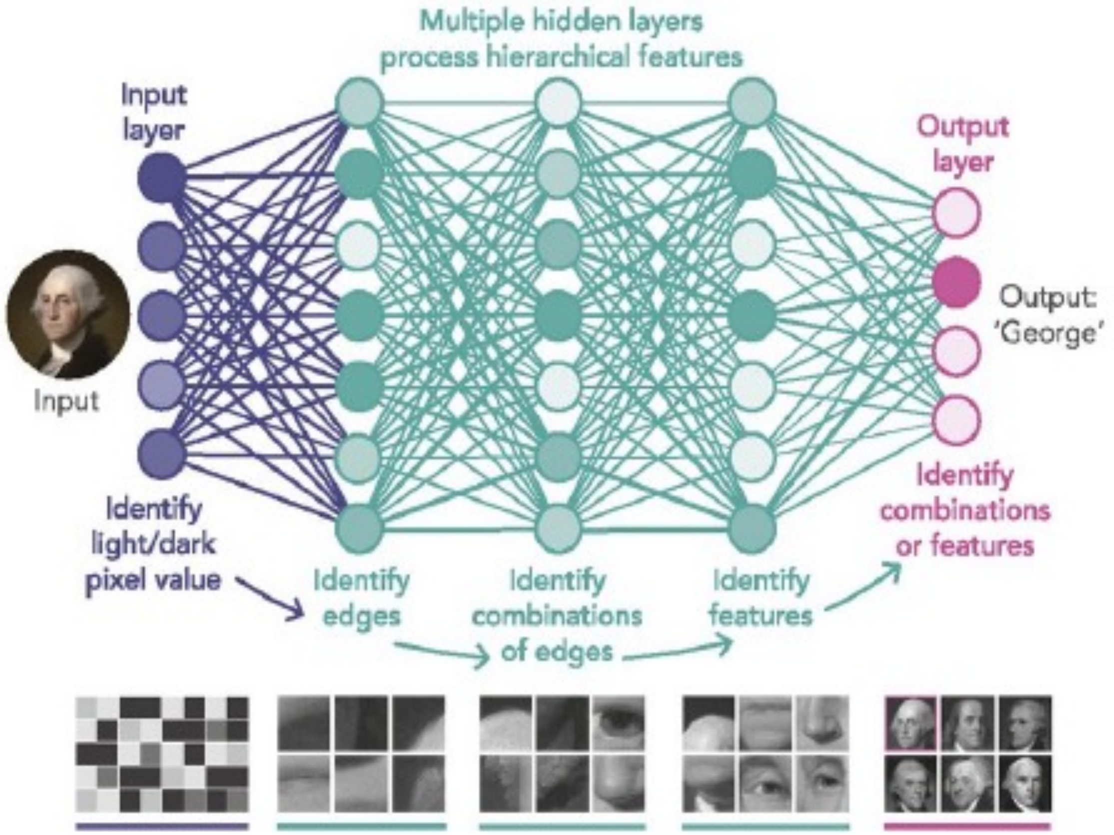
- Evaluate for Suspicious Lesions
- i.e. anything that is:
  - Raised
  - Depressed
  - Ulcerated
  - Bleeding
  - Discolored

In Vivo Optical Pathology Mode:

- Get close and interrogate
- If it looks dysplastic biopsy/resect it

Endoscopy to detect dysplasia

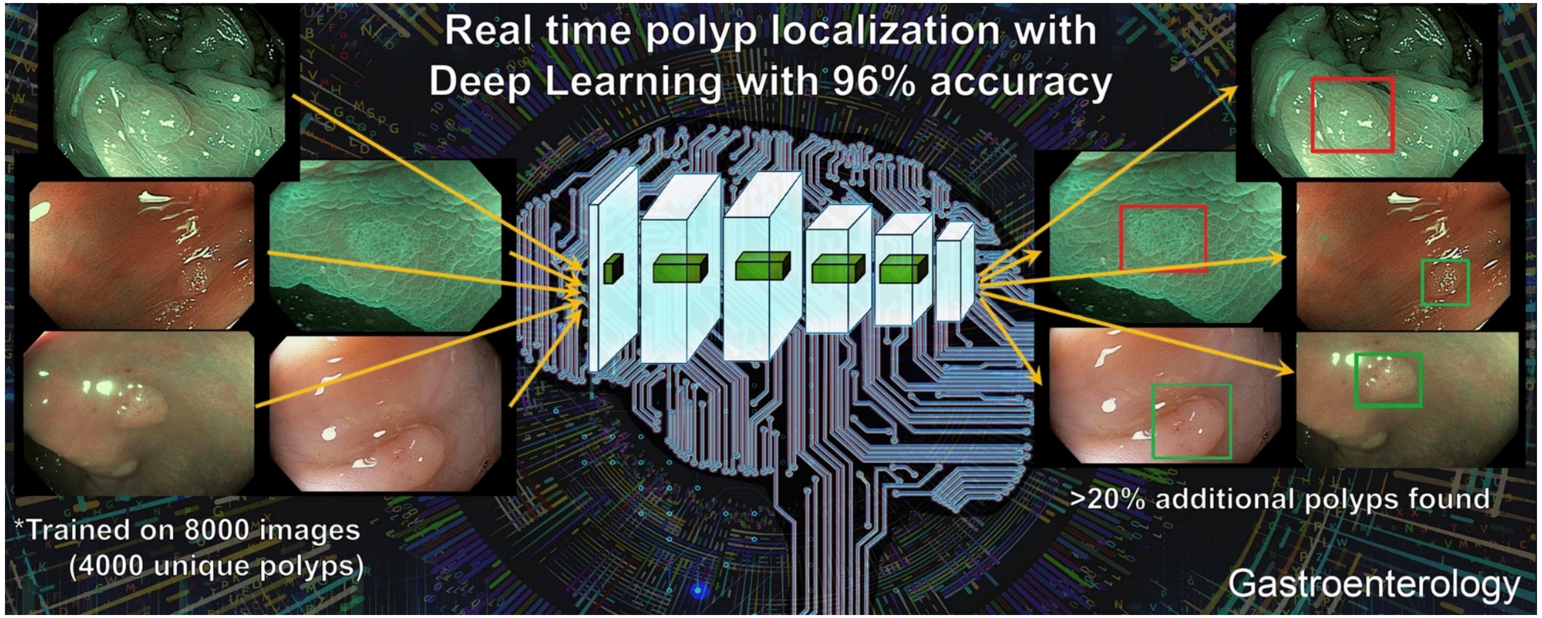
- Chromoendoscopy
  - Acetic acid
  - Virtual
- Magnification
- Endocytoscopy
- Confocal laser Endomicroscopy
- Optical Coherence Tomography
- Deep learning (Convolutional neural network)



GIE 2019; 89: 25–32

CNN system in colonoscopy

- We designed and trained deep CNNs to detect colon polyps
- The CNN identified polyps with an area under the receiver operating characteristic curve of 0.991 and an accuracy of 96.4%



Gastroenterology 2018; 155: 1069-1078

Artificial intelligence using convolutional neural networks for real-time detection of early esophageal neoplasia in Barrett's esophagus (with video)

Rintaro Hashimoto, MD, PhD,[1] James Requa,[2] Tyler Dao,[2] Andrew Ninh,[2] Elise Tran,[1] Daniel Mai,[1] Michael Lugo,[1] Nabil El-Hage Chehade, MD,[1] Kenneth J. Chang, MD,[1] Williams E. Karnes, MD,[1] Jason B. Samarasena, MD[1]

Orange, Irvine, California, USA

Background and Aims: The visual detection of early esophageal neoplasia (high-grade dysplasia and T1 cancer) in Barrett's esophagus (BE) with white-light and virtual chromoendoscopy still remains challenging. The aim of this study was to assess whether a convolutional neural artificial intelligence network can aid in the recognition of early esophageal neoplasia in BE.

Methods: Nine hundred sixteen images from 65 patients of histology-proven early esophageal neoplasia in BE containing high-grade dysplasia or T1 cancer were collected. The area of neoplasia was masked using image annotation software. Nine hundred nineteen control images were collected of BE without high-grade dysplasia. A convolutional neural network (CNN) algorithm was pretrained on ImageNet and then fine-tuned with the goal of providing the correct binary classification of "dysplastic" or "nondysplastic." We developed an object detection algorithm that drew localization boxes around regions classified as dysplasia.

Results: The CNN analyzed 458 test images (225 dysplasia and 233 nondysplasia) and correctly detected early neoplasia with sensitivity of 96.4%, specificity of 94.2%, and accuracy of 95.4%. With regard to the object detection algorithm for all images in the validation set, the system was able to achieve a mean average precision of .7533 at an intersection over union of .3

Conclusions: In this pilot study, our artificial intelligence model was able to detect early esophageal neoplasia in BE images with high accuracy. In addition, the object detection algorithm was able to draw a localization box

Gastrointestinal Endoscopy 2020

Aim

- To assess if a convolutional neural artificial intelligence network (CNN) can aid in the recognition of early esophageal neoplasia in BE

Strategy

<u>1st step</u>

Binary classification (dysplasia or non-dysplasia)

<u>2nd step</u>

Object detection(Localization)

Strategy

1st step

Binary classification (dysplasia or non-dysplasia)

- Xception architecture

2nd step

Object detection(Localization)

- YOLO v2

Methods

- 916 images in 70 patients were collected of histology-proven early esophageal neoplasia in BE

- Olympus 190 series

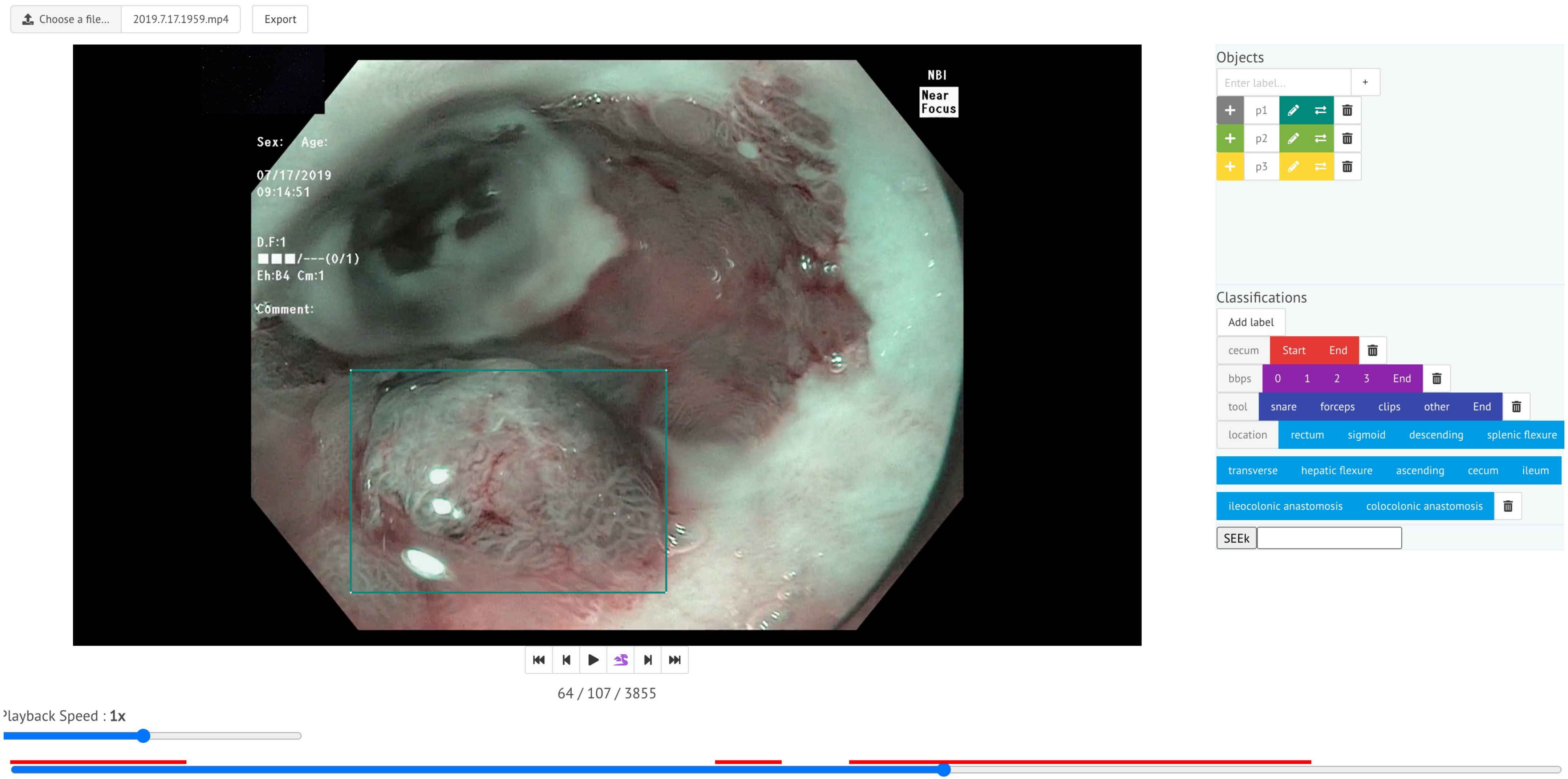
  WLI, NBI, Standard focus, Near focus,

- The area of neoplasia was masked using image annotation software

  by two endoscopists (R.H. and J.S.)

- 919 control images were collected of histology-proven or confocal laser endomicroscopy-proven BE without dysplasia

Annotation Software



Methods (binary classification)

- Convolutional Neural Network built on Tensorflow and pre-trained on ImageNet and our Colonoscopy database called CQD.

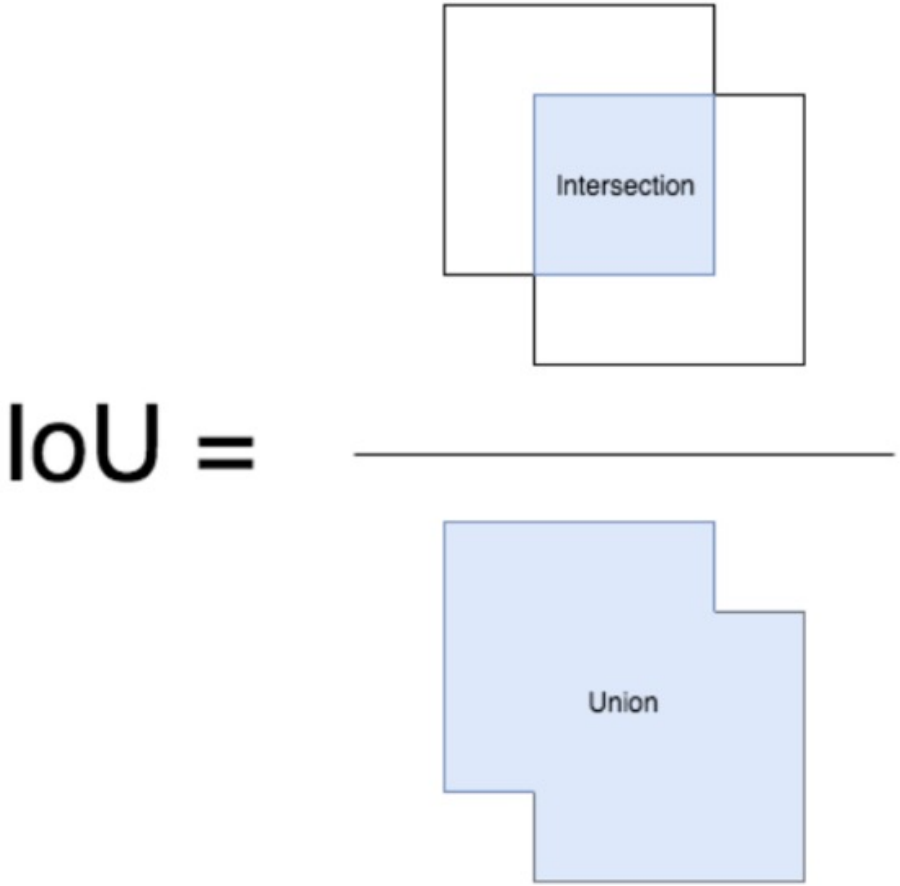
- CNN outputs a binary prediction for each input frame as a probability distribution between 0 – 0.5 (non-dysplastic) and 0.5 – 1 (dysplastic)

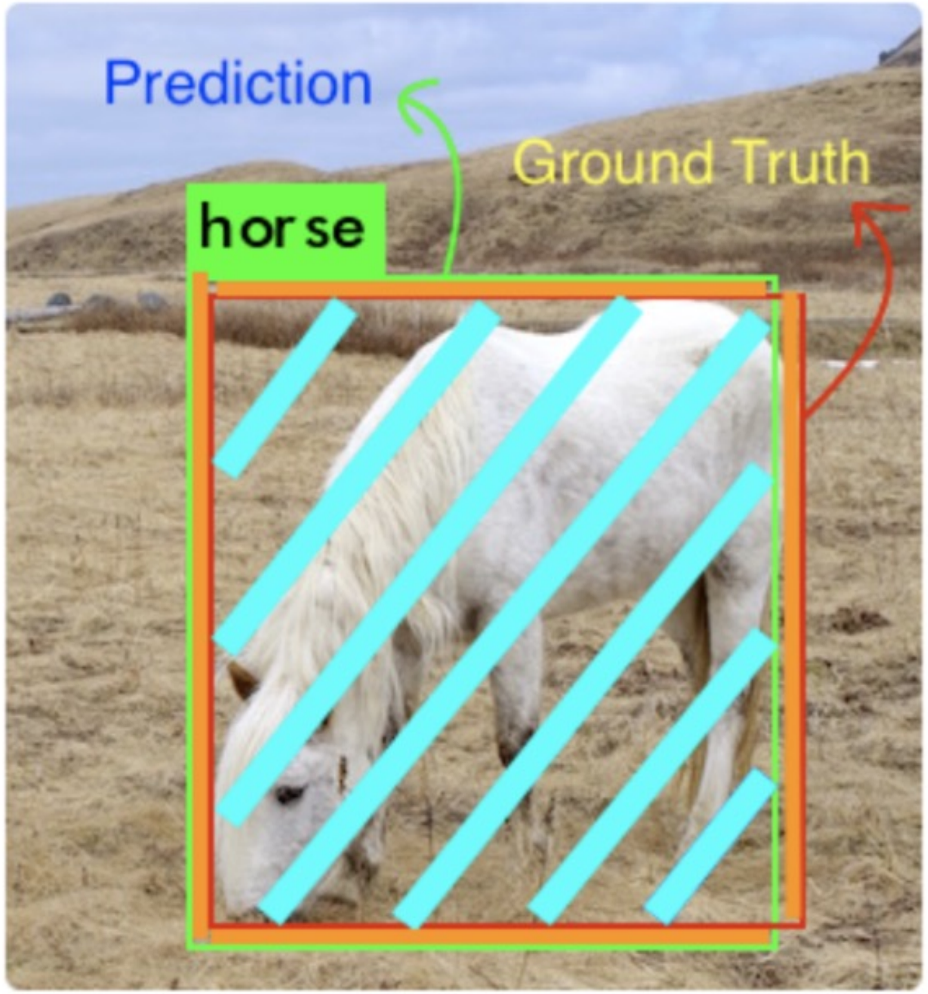
- Sensitivity, Specificity and Accuracy were calculated:
    - Per image
    - Per patient
    - Based on imaging techniques:
        - White Light Imaging (WLI)
        - Narrow Band Imaging (NBI)
        - Near focus
        - No Near focus

Methods (Localization)

- We additionally developed an object detection algorithm, which can localize the regions classified as dysplasia
- We predefine an IoU (Intersection over union) threshold at 0.3 to classify whether the prediction is a true positive or a false positive (IoU > 0.3=positive)

IoU (Intersection over union)

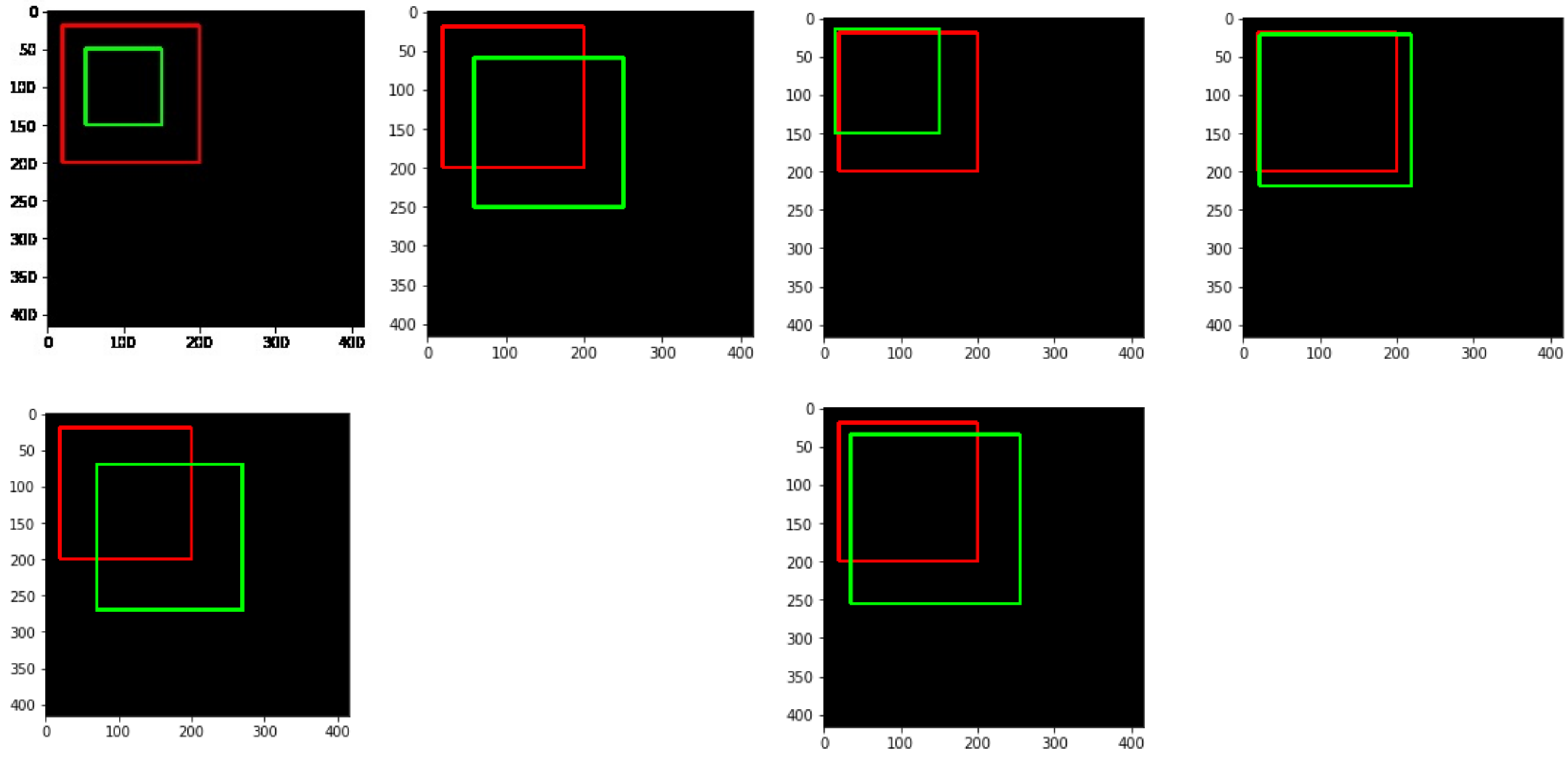




In this case the intersection is pretty large

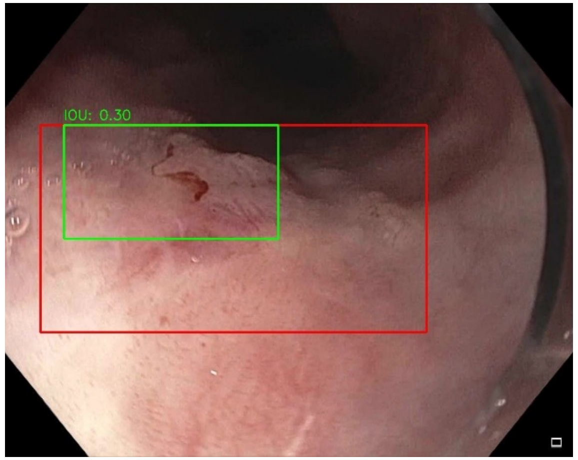
https://tarangshah.com/blog/2018-01-27/what-is-map-understanding-the-statistic-of-choice-for-comparing-object-detection-models/

IoU

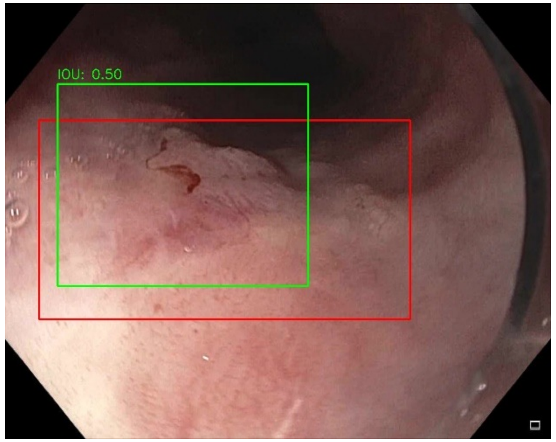


0.3 0.4 0.5 0.8

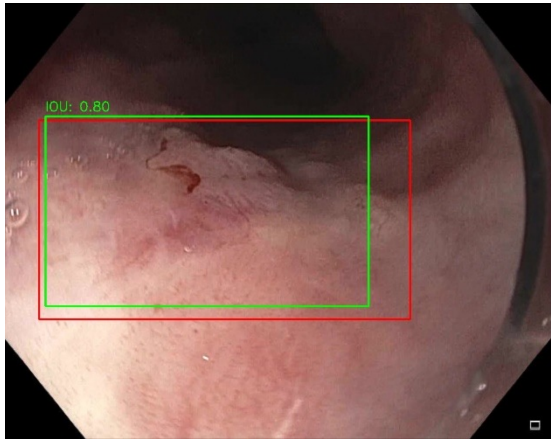
IoU



IoU 0.3



IoU 0.5



IoU 0.8

mAP (Mean Average Precision)

- TP (True Positive):Correct detect
- FP (False Positive): False detect
- FN (False Negative): Missed detect

		Actual	
		Positive	Negative
Predicted	Positive	True Positive	False Positive
	Negative	False Negative	True Negative

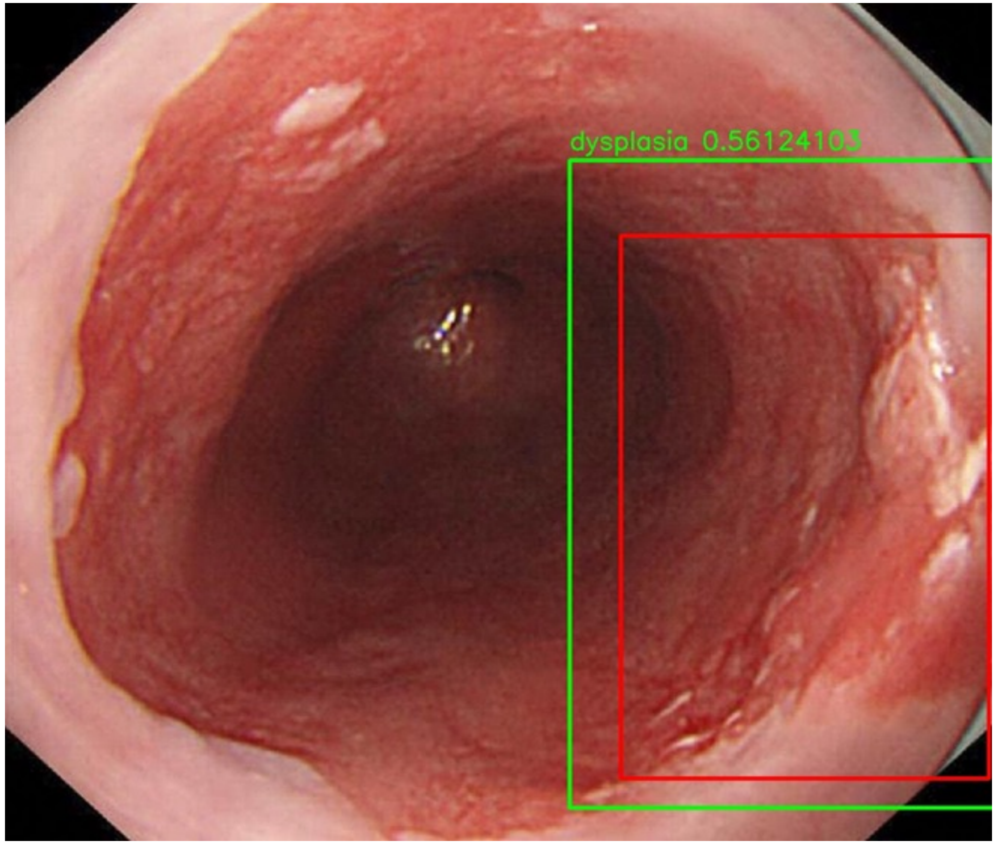
- Precision= TP (Correct detect)/TP+FP (Total positive results)
- Recall = TP (Correct detect) / TP + FN (Total dysplasia)

- AP = $\int_0^1 p(r)dr$ "The area under the precision-recall curve"

mAP was calculated based on an IoU 0.3

An example of detection

IoU > 0.3



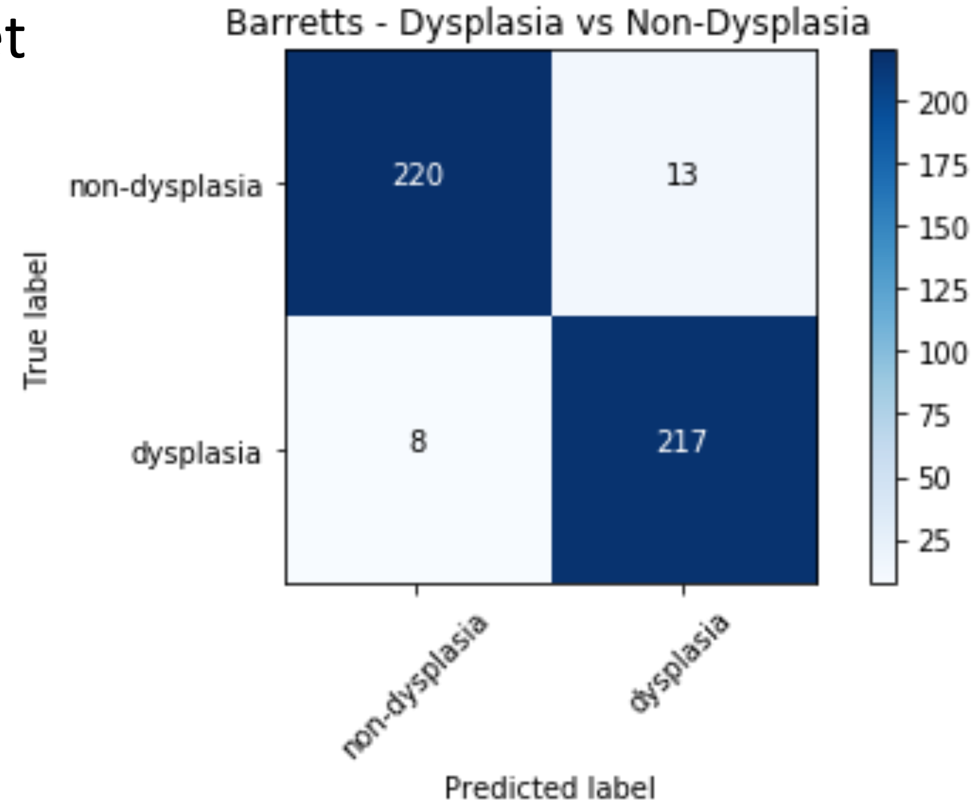
Results

Results: Binary Image Validation per image

A total of 458 images unique to the training set were used for validation

Multiclass CNN achieved:

- Sensitivity of 96.4%
- Specificity of 94.2%
- Accuracy of 95.4%



Results: Binary Image Validation per patient

- The CNN correctly diagnosed 24 of 26 (92.3%) cases of early esophageal dysplasia

- Sensitivity for each patient

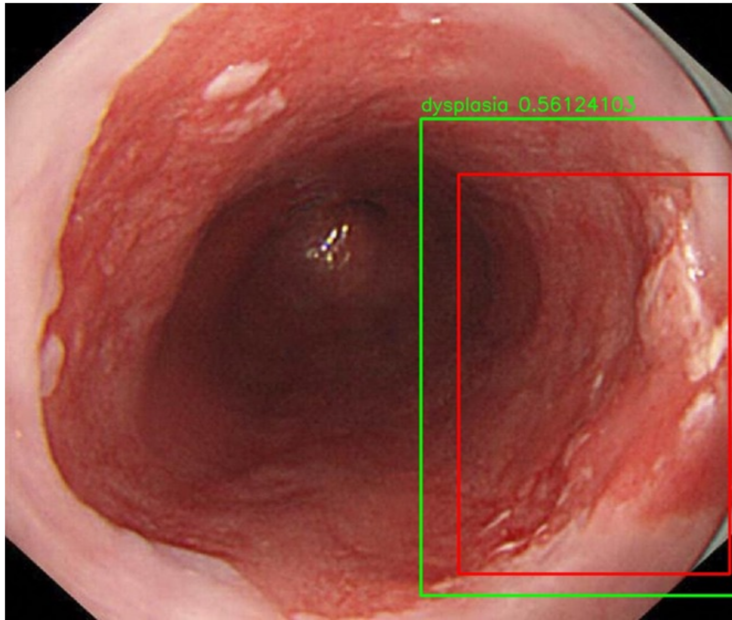
WLI only	18/19 (94.7%)	vs. NBI only	11/12(91.7%)	(N.S.)
Standard focus	20/21 (95.2%)	vs. Near focus	11/12(91.7%)	(N.S.)

Results: Object detection (Localization)

In validation set:

- mAP (mean average precision) with IoU 0.3 was 0.7533

- mAP for NBI images only= 0.802
- mAP For Near-focus images only = 0.819



Strengths - Speed

On GPU gtx1070,

The binary classifier runs at around 72 FPS

- 1 Prediction = 0.014sec

The localization algorithm YOLO v2 runs at around 45 FPS

- 1 Prediction = 0.022sec

Study Conclusion

- This early Artificial Intelligence algorithm using CNN was able to detect and localize early esophageal neoplasia in Barrett's Esophagus images with high accuracy

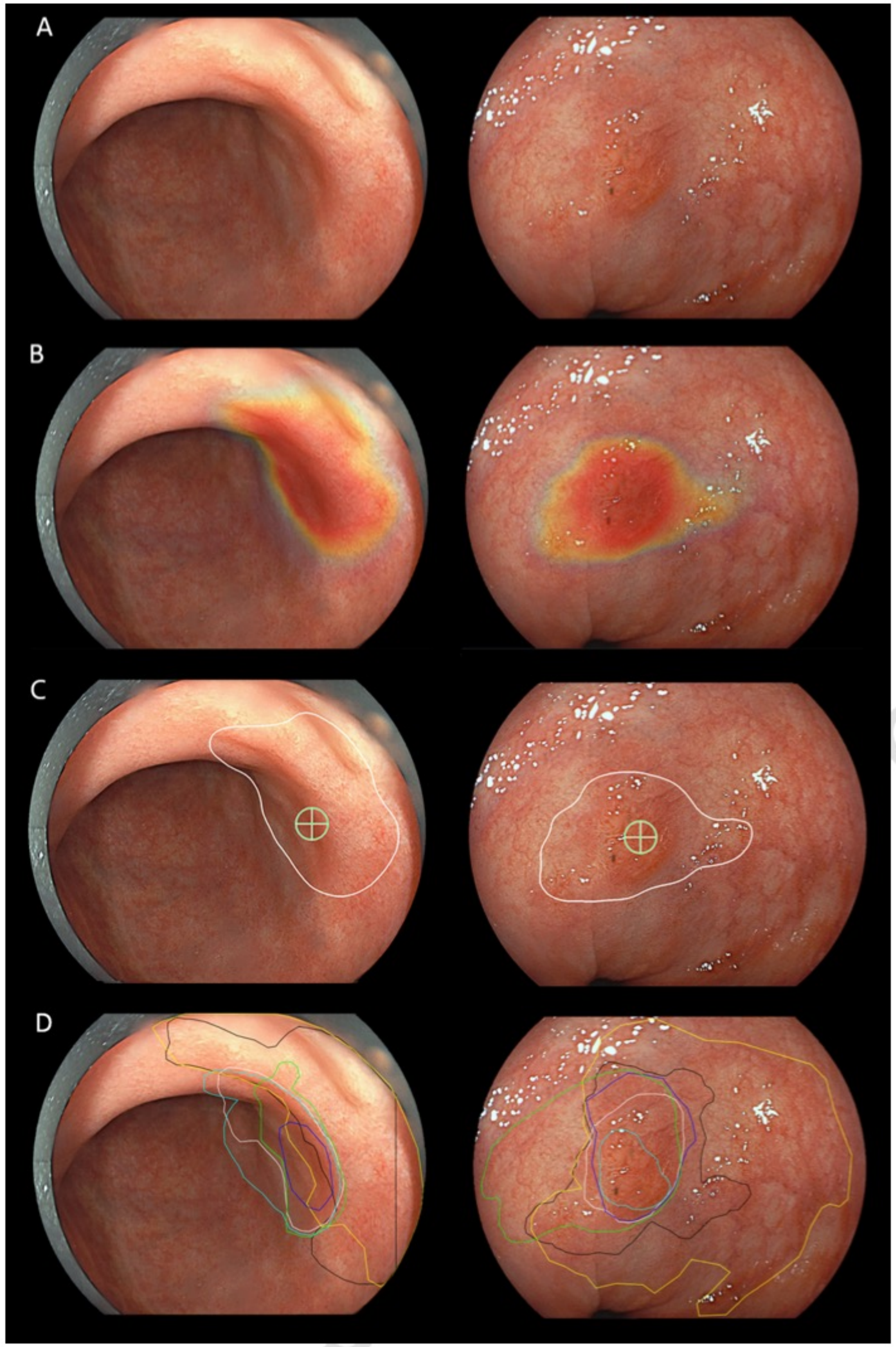
Deep-Learning System Detects Neoplasia in Patients With Barrett's Esophagus With Higher Accuracy Than Endoscopists in a Multistep Training and Validation Study With Benchmarking

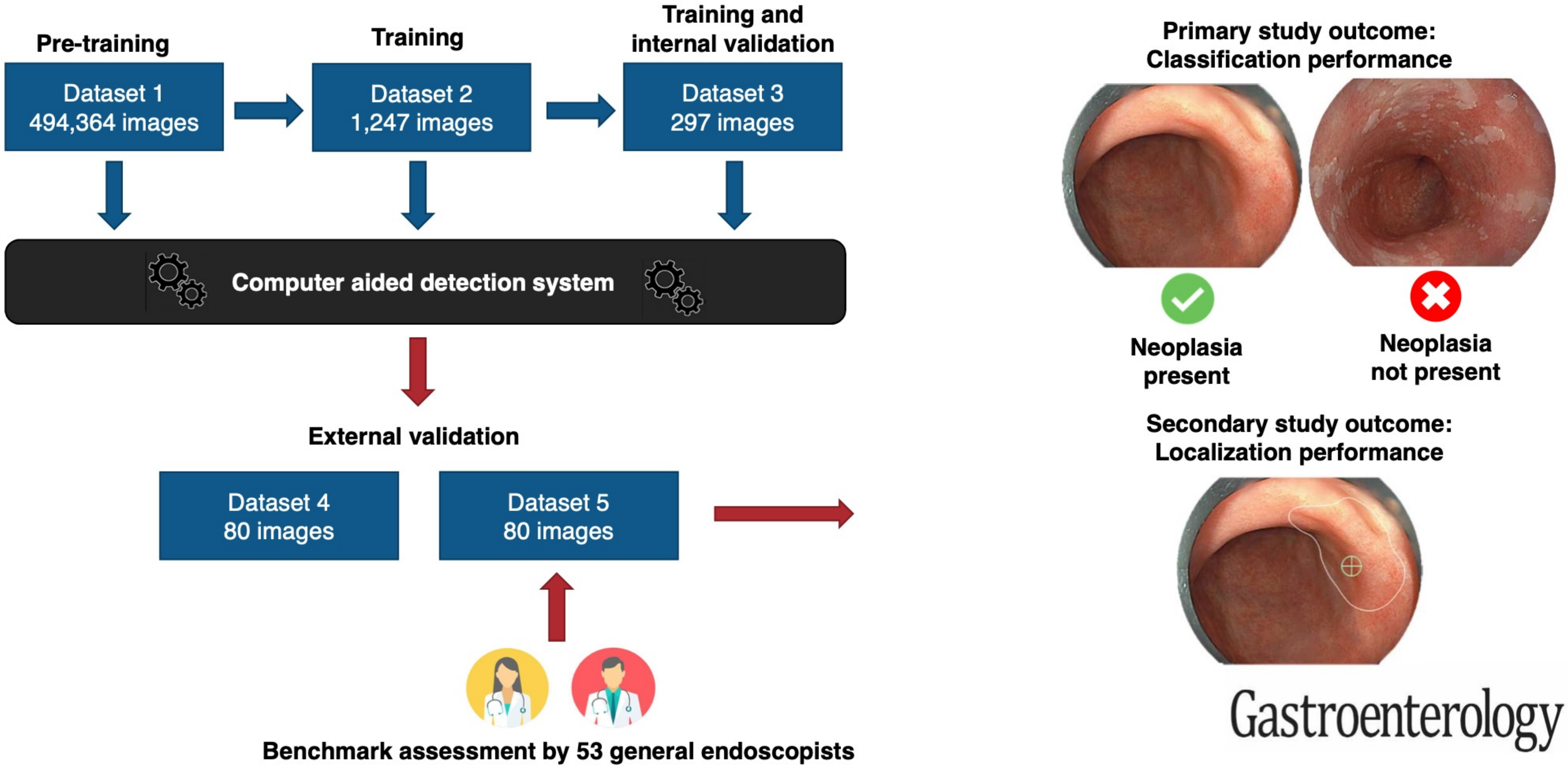
Albert J de Groof , Maarten R Struyvenberg , Joost van der Putten , Fons van der Sommen , Kiki N Fockens , Wouter L Curvers , Sveta Zinger , Roos E Pouw , Emmanuel Coron , Francisco Baldaque-Silva , Oliver Pech , Bas Weusten , Alexander Meining , Horst Neuhaus , Raf Bisschops , John Dent , Erik J Schoon , Peter H de With , Jacques J Bergman

Gastroenterology 2019

- Aim: develop a computer-aided detection (CAD) system to be used in real-time endoscopy procedures to improve detection of neoplasia in BE

- CAD system functions by:
    1. classifying an image as neoplastic or non-neoplastic
    2. producing a "heatmap"
    3. encircling the region suspicious for neoplasia
    4. marking the most abnormal part of the lesion → biopsy site




Pre-training
Training
Training and internal validation
Dataset 1
494,364 images
Dataset 2
1,247 images
Dataset 3
297 images
Computer aided detection system
External validation
Dataset 4
80 images
Dataset 5
80 images
Benchmark assessment by 53 general endoscopists
Primary study outcome:
Classification performance
Neoplasia present
Neoplasia not present
Secondary study outcome:
Localization performance
Gastroenterology

Results

- CAD system classified images as containing neoplasms or nondysplastic BE:
  - 89% accuracy
  - 90% sensitivity
  - 88% specificity
- CAD system vs general endoscopists
    - 88% vs 73% accuracy
    - 93% vs 72% sensitivity
    - 83% vs 74% specificity
- CAD system had higher accuracy than any of the individual 53 nonexpert endoscopists
- The CAD system identified the optimal site for biopsy of detected neoplasia in 92% of cases

Deep learning algorithm detection of Barrett's neoplasia with high accuracy during live endoscopic procedures: a pilot study (with video)

Albert J de Groof , Maarten R Struyvenberg , Kiki N Fockens , Joost van der Putten , Fons van der Sommen , Tim G Boers , Sveta Zinger , Raf Bisschops , Peter H de With , Roos E Pouw , Wouter L Curvers , Erik J Schoon , Jacques J G H M Bergman

Gastrointestinal Endoscopy 2020

Aims & Methods

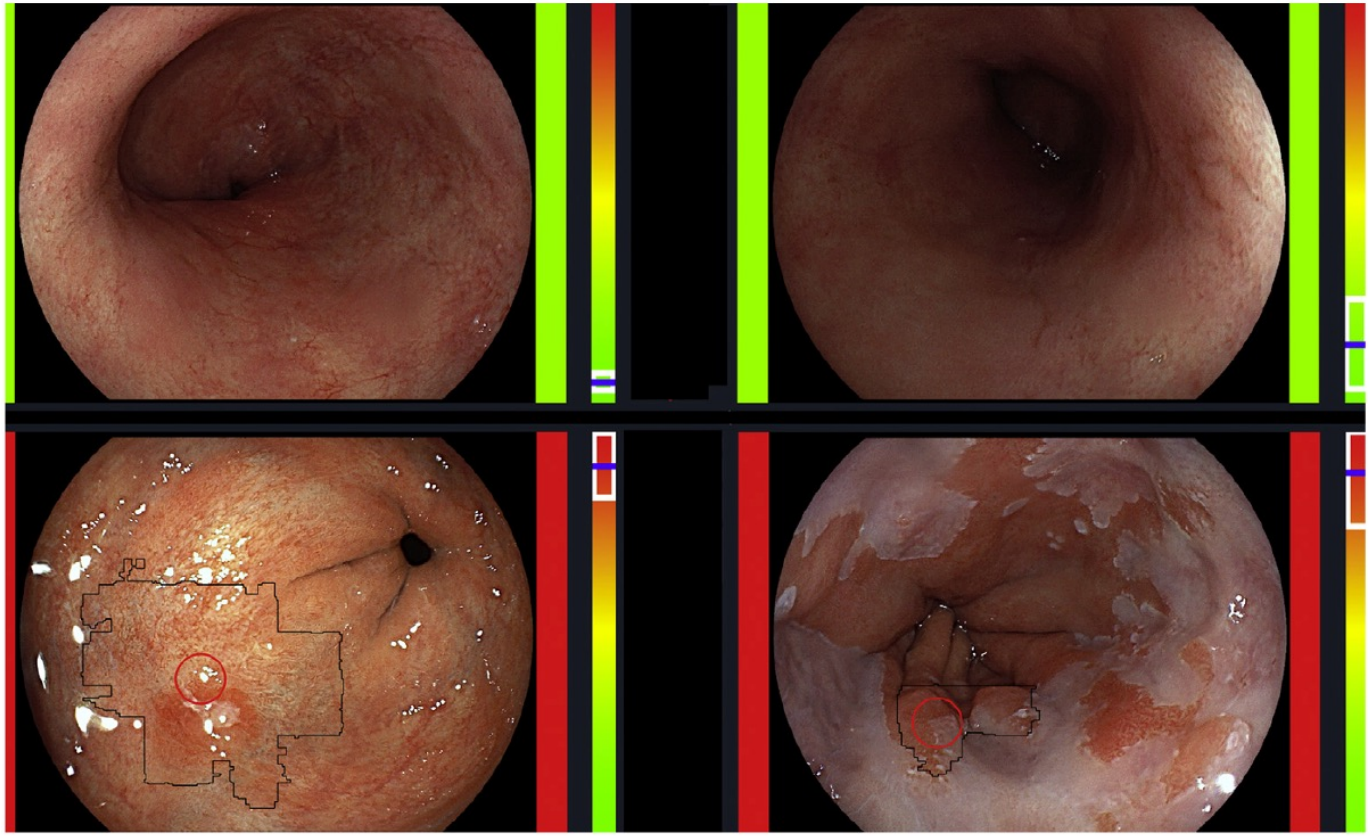
- To assess preliminary diagnostic accuracy of a recently developed CAD system for detection of BE during live endoscopic procedures

- CAD system tested during endoscopic procedures in :
  - 10 patients with NDBE
  - 10 patients with confirmed Barrett's neoplasia

- Three White-light endoscopy images were obtained at every 2-cm level of the Barrett's segment → analyzed by the CAD system → feedback to the endoscopist
- If 2/3 times the CAD system indicated there was a lesion, biopsy was performed of the lesion

- Outcome measures - diagnostic performance of the CAD system per level & per patient:
  - Accuracy, sensitivity, & specificity
  - Concordance of 3 sequential CAD predictions per level

Results

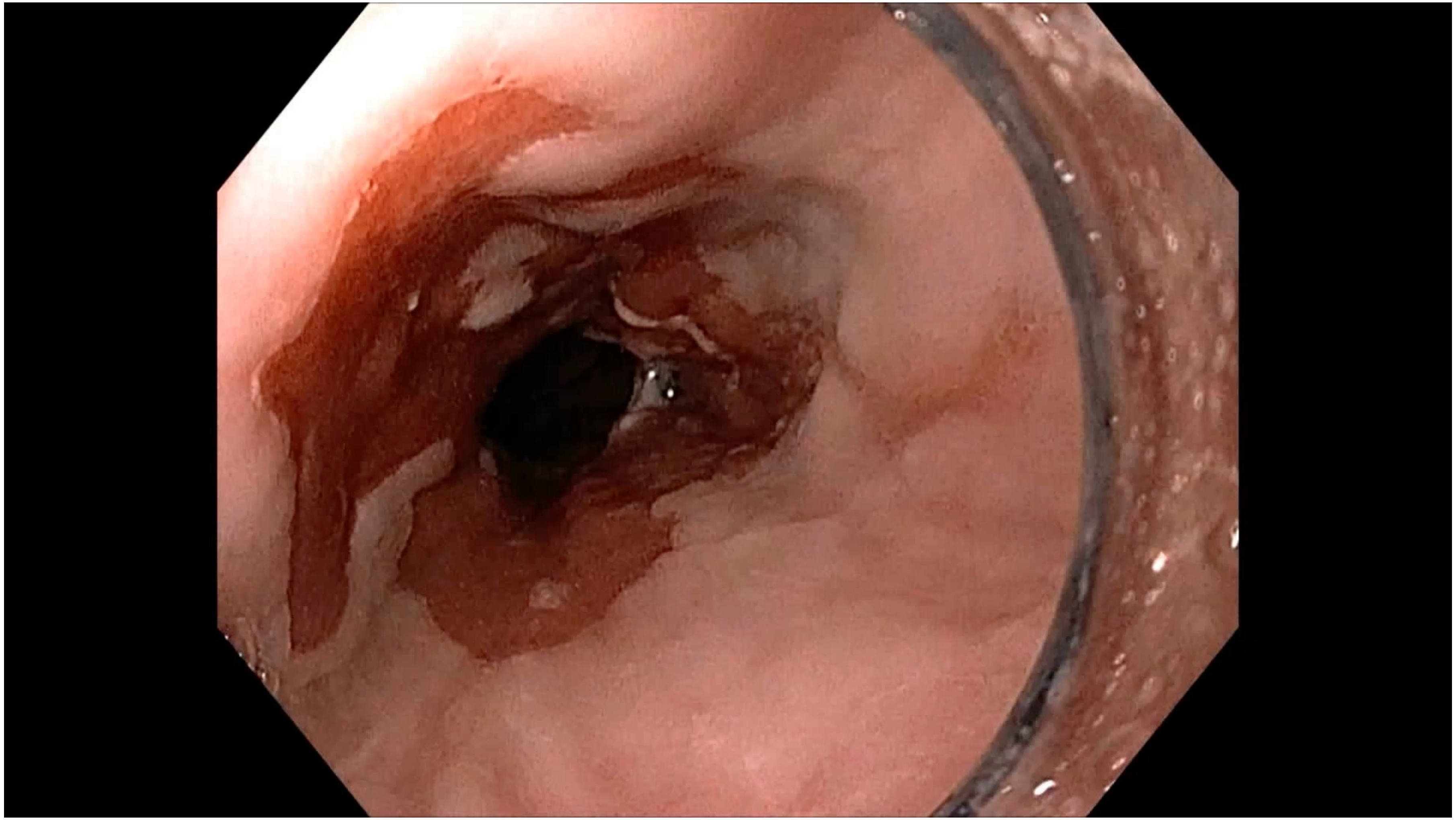


- Per-level analysis of CAD system:
  - Accuracy 90%,
  - Sensitivity 91%
  - Specificity 89 %

- 9/10 neoplastic patients were correctly diagnosed
  - The single lesion not detected by CAD showed NDBE in the endoscopic resection specimen

- CAD system produced false-positive predictions in only 1 NDBE patient
- CAD system produced 3 concordant predictions in 75% of all levels

<u>Continuous</u> Real Time AI Assisted Barrett's Surveillance Procedure



Hashimoto,. Samarasena Gastrointestinal Endoscopy 2020

Detection of Early Esophageal Neoplasia in Barrett's Esophagus Using Real Time Artificial Intelligence: A Multicenter External Video Validation Study

Jason Samarasena, Vani Konda, Arvind Trindade, Rintaro Hashimoto, Efren Rael, , Anastasia Chahine, Jennifer Kolb, Alyssa Choi, Andrew Ninh, Tyler Dao, James Requa, William Karnes

DDW 2021

Methods

- External Videos:
  - 40 video clips from 40 unique patients (white light and NBI, Length 1-6 mins)
    - From 2 outside institutions → unique to the algorithm's training database
    - 20 patients had at least 1 dysplastic lesion ; 20 patients had non-dysplastic BE
- Videos Reviewed :
  - Identified and time stamped by two expert endoscopists
  - Scored on a scale of subtlety from S1 (Most subtle) to S5 (Most visible)

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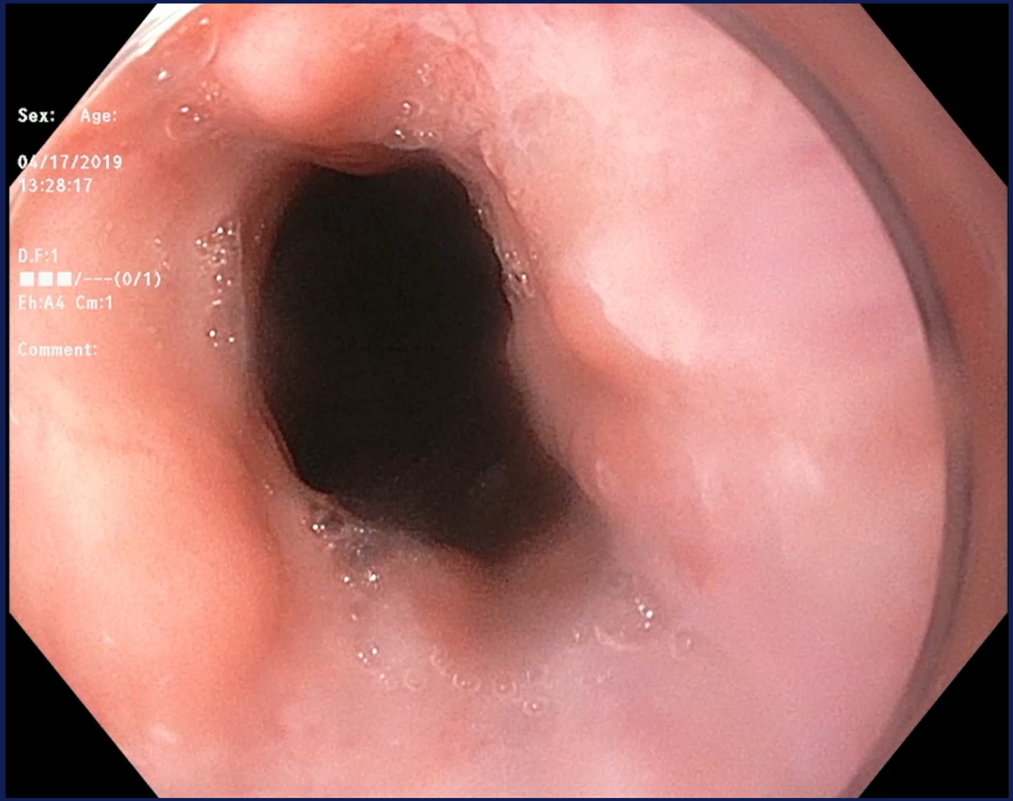
Results

- Dysplastic videos:
  - Algorithm detected 19/20 lesions
    - 95% per lesion sensitivity
- Non-dysplastic videos:
  - TN frames: 27559
  - FP frames: 1045

  } FP rate: 3.7%

  - False positive clinical predictions: Zero
  - Per patient negative predictive value: 100%



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Study Conclusion

- This external validation study shows promising results for a real-time AI algorithm
  - Demonstrates high sensitivity for dysplastic lesion detection while maintaining a low rate of false positive predictions
- Strengths of this system include a true real-time analysis that does not require freezing endoscopy to generate predictions
- The algorithm appears ready for prospective live real-time testing

Barrett’s AI Summary

- Barrett’s dysplasia detection during endoscopy is a skill set that is not easy to learn or teach
- A real time AI algorithm can potentially aid endoscopists detect neoplasia earlier so that appropriate preventative treatment is carried out
- If the algorithm is able to exceed PIVI thresholds, the number of random biopsies in the esophagus during surveillance endoscopy can be significantly reduced
- The use of AI in Barrett’s Esophagus is not limited to Dysplasia detection:
  - Quantitative measurement of Barrett’s Esophagus
  - Coaching endoscopists through a “high quality” examination
  - Training tool for Fellows and Endoscopists

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Thank You!

jsamaras@hs.uci.edu