"Screening and Diagnosis of esophageal cancer from in-vivo microscopy images"

Challenge Data ENS
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I. Company overview

Mauna Kea Technologies is a global medical device company focused on eliminating uncertainties related to the diagnosis and treatment of cancer and other diseases thanks to real-time in vivo microscopic visualization. The Company's flagship product, Cellvizio®, has received clearance/approval in a wide range of applications in more than 40 countries, including the United States, Europe, Japan, China, Canada, Brazil, and Mexico.

Please feel free to contact Fanny Louvet-de Verchère (fanny@maunakeatech.com) should you have any questions related to this challenge.

II. Problem definition

a) Clinical context

Cellvizio® - Mauna Kea Technologies' flagship product - is routinely used for the screening of Barrett's Esophagus (BE), a predisposing condition to esophageal cancer.

BE is very often observed in patients suffering from Gastroesophageal Reflux Disease (or GERD), which means that the liquid inside their stomach often comes up in the esophagus (*see figure 1*). This liquid is very acidic (pH 1-4) and as a result damages the esophagus tissue when coming up. In reaction to this aggression, the healthy esophageal tissue sometimes evolves into intestinal tissue (intestinal metaplasia), which can cope with high acidic exposure. When such Intestinal Metaplasia can be observed, the condition is called Barrett's Esophagus (*see figure 2*).

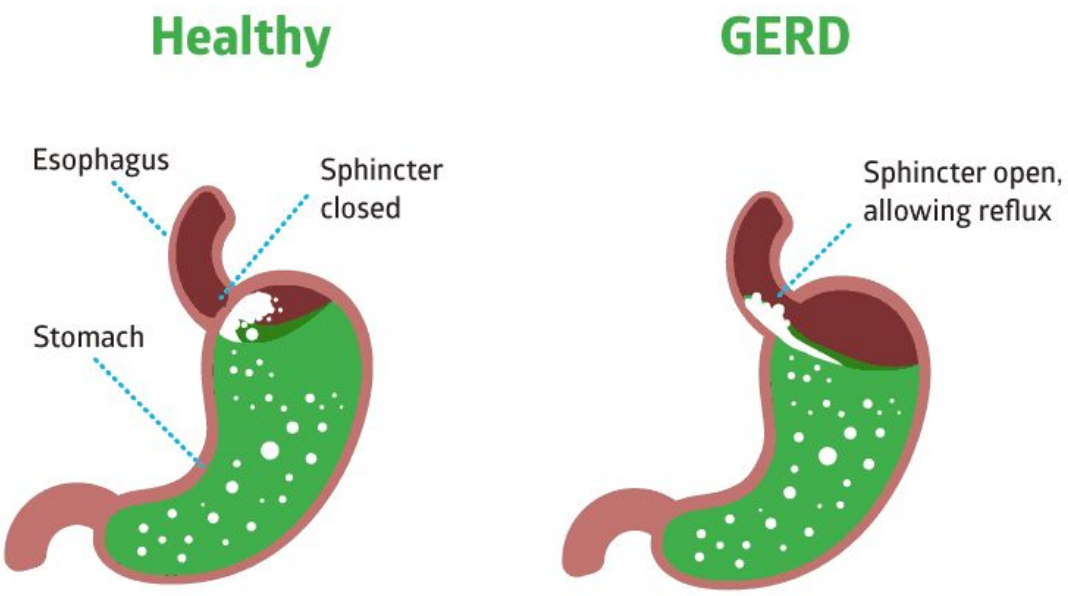

Figure 1. Healthy vs GERD.

GERD patients' lower esophageal sphincter (the muscle at the junction of the esophagus and the stomach) does not work well. As a result, food and gastric liquid is not kept securely in the stomach and can go back up in the esophagus. This causes heartburn and the risk of developing Barrett's Esophagus, which is a precancerous condition.
Source: https://www.algaecal.com/expert-insights/acid-reflux/

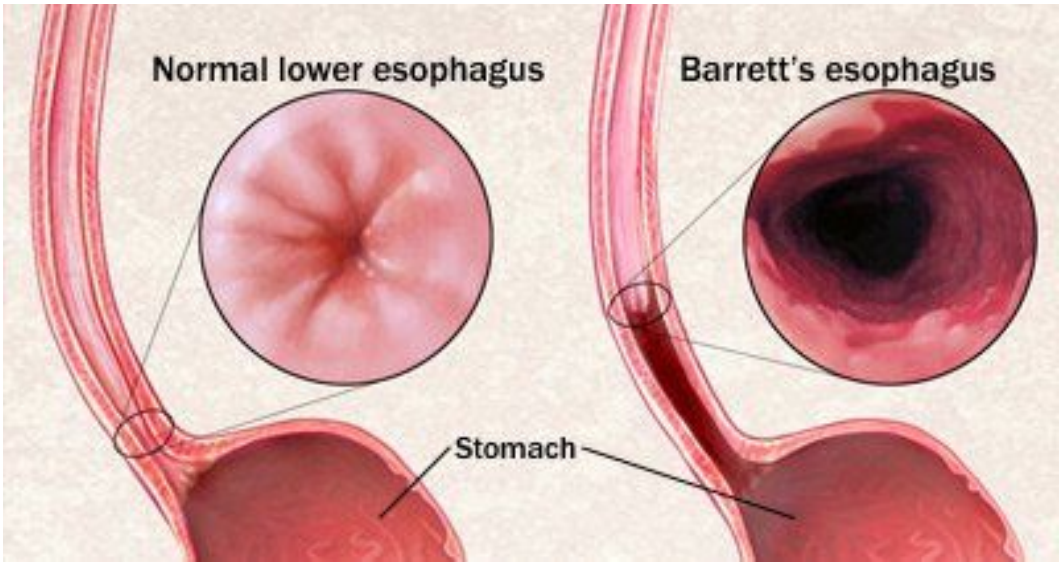

Figure 2. Healthy vs Barrett's Esophagus.

Left: healthy esophageal tissue. Right: when damaged by stomach liquid coming up, healthy tissue sometimes is transformed into intestinal tissue (Intestinal metaplasia), to cope with high acidic environment. This condition is called Barrett's Esophagus. Intestinal Metaplasia has a redden aspect and always begin at the junction between stomach and esophagus. It can be restricted to a small area, or spreaded over a few centimeters.
Source: https://www.homenaturalcures.com/barretts-esophagus-natural-cure-treatment-remedy/

Due to higher risk of developing cancer, patients suffering from GERD and Barrett's Esophagus undergo surveillance via endoscopy.

During an endoscopy procedure, a camera is inserted into patients' esophagus (*see Figure 3*). Images obtained are classic macroscopic images (classic video).

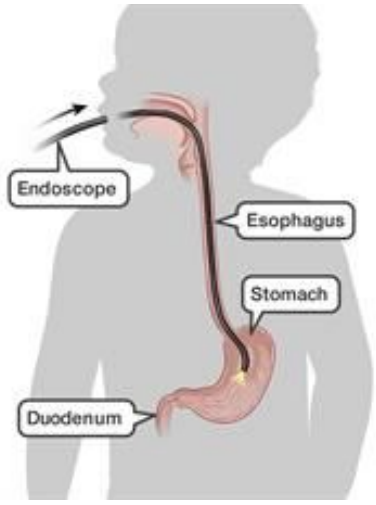

Figure 3. Scheme of an endoscopy procedure.
A camera with a light is inserted into the patient's esophagus and stomach by the oral route.
Source: https://www.aboutkidshealth.ca/Article?contentid=2472&language=English

Cellvizio® is then used to get a more accurate view, at a microscopic level.

Cellvizio® probe is inserted into the operating channel of the endoscope, and thus reaches the esophagus-stomach junction (*see Figure 4*). The images obtained are live *microscopic* images which help physicians make key treatment decisions (*see Figure 5*).

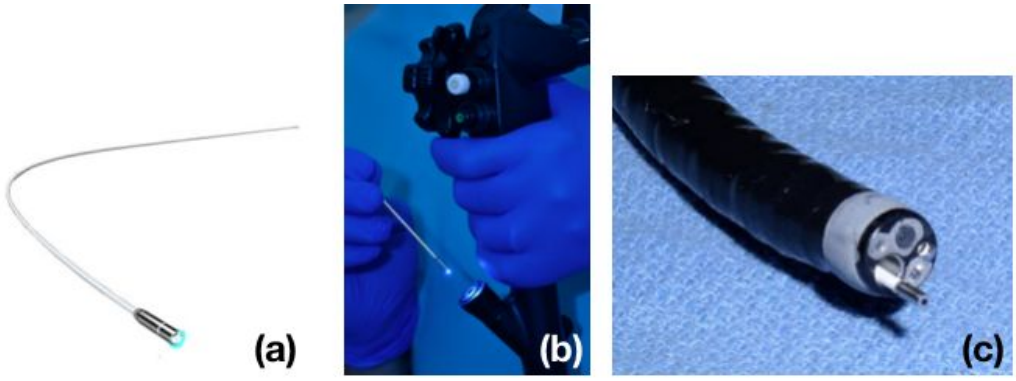

Figure 4. How Cellvizio® probe is used in combination with an endoscope.
(a) Cellvizio® probe. (b) The physician introduces Cellvizio® probe into the endoscope's operative channel.
(c) The probe appears on the other end of the scope, ready to image live tissue.

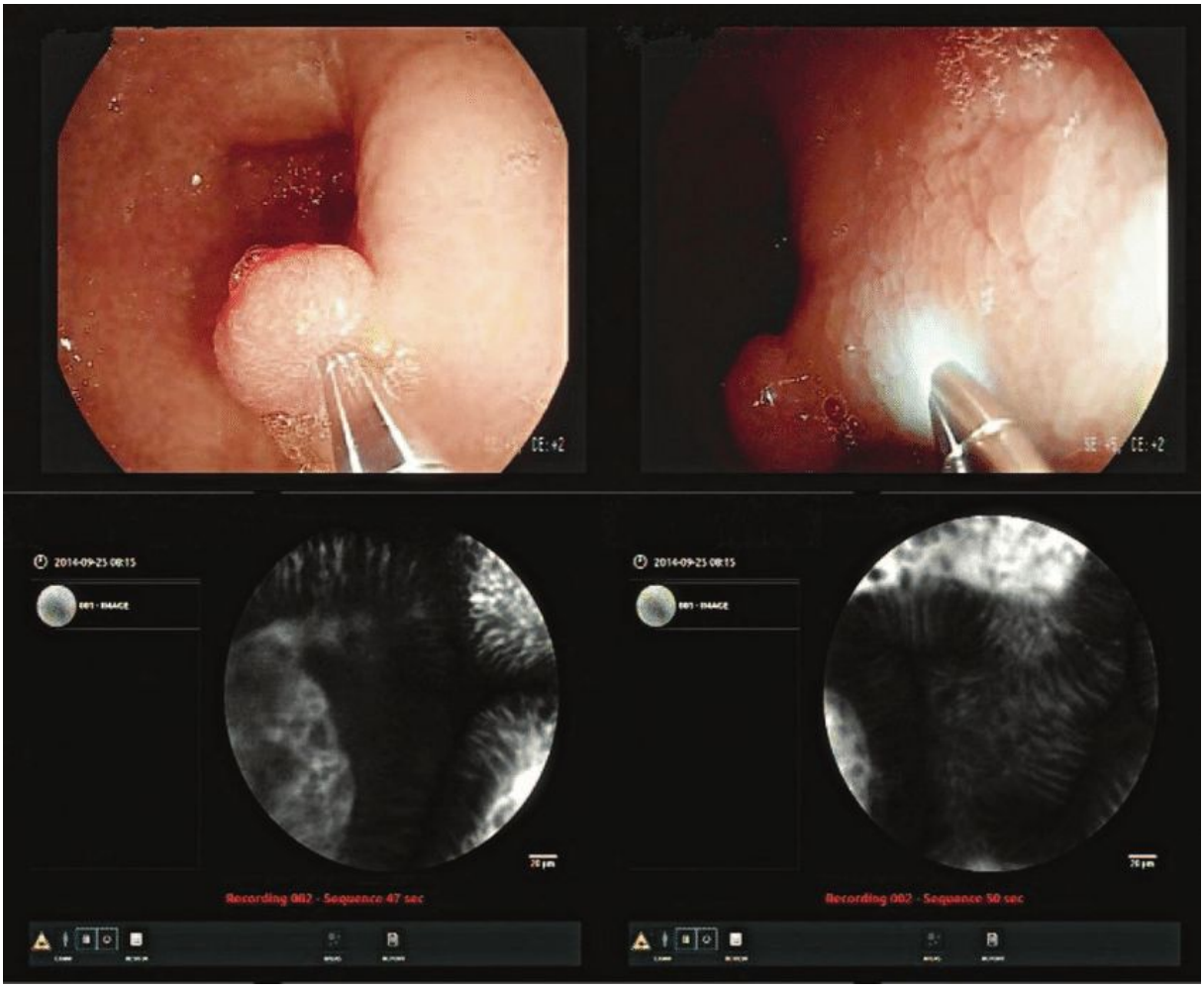

Figure 5. Once the Cellvizio® probe is in place, physicians can see both the macroscopic images (above), where the Cellvizio® probe appears, and the microscopic images (below).

The different grades of esophageal cancer development to be seen are:

a) **Squamous epithelium** (healthy tissue)
b) **Intestinal Metaplasia** (healthy esophageal tissue is transformed into intestinal tissue)
c) **Low-grade dysplasia** (the transformed intestinal tissue continues to evolve into pre-cancerous cells)
d) **High-grade dysplasia** (precancerous condition)
e) Cancer

If the physician goes a little bit too far and reaches the stomach, he could also spot some **Gastric Metaplasia** (healthy Gastric tissue, close to the esophageal junction).

b) Challenge definition

During a screening procedure, Cellvizio® images move fast and physicians are juggling with a lot of information at the same time, which makes it sometimes tricky to not miss any valuable clinical information.

The goal of this challenge is to build an image classifier to assist physicians in the screening and diagnosis of esophageal cancer. Such a tool would have a massive impact on patient management and patient lives.

The proposed classes to be recognized are:

- Squamous Epithelium
- Intestinal Metaplasia
- Gastric Metaplasia
- Dysplasia/Cancer

III) Input and output variables description

a) Inputs

Inputs are images acquired from 61 patients.

Each image is a 2D matrix **x_i_p** where **i** is an index ranging from 0 to the number of images acquired from patient **p**.

The rationale for including a patient index is that there might be some level of correlation between images acquired from one single patient which is larger than from two different patients.

b) Outputs

The output **y_i_p** is an index **c** corresponding to the class of image **x_i_p**

c is an integer ranging from 0 to 3:

- 0 is “Squamous_Epithelium”
- 1 is “Intestinal_metaplasia”
- 2 is “Gastric_metaplasia”
- 3 is “Dysplasia_and_Cancer”

c) Number of samples

There is a total of 11161 images acquired from 61 patients.

d) Split between training and test

The split between the training and the two test sets is 80%-10%-10%.

The training set is made of 9446 images, acquired from 44 patients:

Class	Number of Images
0	1469
1	3177
2	1206
3	3594

The two test sets, Test_1 and Test_2, are as follow:

1. 893 images acquired from 10 patients
2. 822 images acquired from 7 patients

The total is 1715 images acquired from 17 patients.

We guarantee that if an image acquired from a patient is in the training set, there is no image acquired from the same patient in any test sets.

IV) Metric

Non weighted Multiclass accuracy =

(Number of images in the test set automatically assigned to the correct class) /

(Number of images in the test set)

V) Benchmark

Results were obtained with a standard convolutional neural network (CNN, 3 convolutional layers, each convolutional layer followed by dropout and pooling).

The non-weighted accuracy was 75% on the test set.

Note that this result is without performing any:

- Images pre-processing
- Images augmentation (noise, linear transforms or local deformations)
- Features computation