

# Wireless Capsule Endoscopy in Correlation with Software Application in Gastrointestinal Diseases

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**ABSTRACT:** Wireless capsule endoscopy is one of the most recent investigation techniques of gastrointestinal pathology. Unlike conventional upper and lower endoscopy, it has the advantages of being a noninvasive and painless procedure. One of the capsule endoscopy disadvantages is represented by the necessary time to analyze the video frames obtained. Software applications proposed in this purpose could offer support in the images evaluation. Different algorithms have been described in the literature, but further research is needed to establish the practical value of computer vision tools in gastroenterology.

**KEYWORDS:** wireless capsule endoscopy, gastrointestinal pathology, software applications, esophagus, small bowel, colon

## Introduction

Wireless capsule endoscopy (WCE) represents a modern diagnostic technique of gastrointestinal pathologies.

Due to the fact that small bowel is difficult to examine by conventional endoscopy methods, capsule endoscopy is considered the gold standard in the diagnosis of small bowel lesions [1-5].

## Technical characteristics

The video capsule system includes a capsule designed for a single use, a recording system and a computer interface. The capsule, pill-size, contains a video camera and it is propelled through the gastrointestinal (GI) tract by peristalsis and naturally expelled by the body in 8 to 72 hours. The capsule's battery lasts around 8 hours, the average time of a full gastrointestinal transit. The video frames obtained, around 50.000, are wireless sent to the recording device attached to the abdomen of the patient, and downloaded after that on a computer for further analyses. [6, 7]

Since 2001, when the first commercial endoscopy capsule for the small bowel was developed, the system of WCE has been improved. Nowadays, endoscopy capsule is available also for esophagus and colon investigation. [8]

## Examination technique

According to the literature, currently it is not established a standard diet for the preparation of the bowel for the examination with capsule endoscopy. Although several studies have been performed in this regard, the results were not conclusive. However, it is well known that for a high diagnostic performance, for this examination is necessary the bowel cleanliness. From this point of view, it is recommended a clear liquid diet the day before the examination, and an overnight fast of 8-12 hours. Other recommendations are represented by avoiding smoking for 24 hours before the examination and not taking any medication in the last two hours prior the test time. It is also recommended to stop the administration of some drugs as iron preparations with 2-3 days before. [6, 9, 10]

## Clinical indications, risks and contraindications of WCE

Esophageal capsule endoscopy is used mainly for the screening of esophageal varices in patients with portal hypertension, but also for diagnosis and for the management of Barrett's esophagus. Several studies have been made for comparing the efficiency between capsule endoscopy and esophagogastroduodenoscopy (EGD) in the evaluation of the esophagus diseases. The results from these studies were not significantly to establish the role of capsule endoscopy in Barrett's esophagus. Until more

studies will be made in this purpose with a larger number of patients, EGD remains the gold standard investigation for patients with this pathology. One of the advantages of upper gastrointestinal endoscopy is the possibility to take biopsies and therefore detecting the dysplasia's degree associated with intestinal metaplasia. While the role of esophageal capsule endoscopy is controversial in the evaluation of Barrett oesophagus, in the screening and management of esophageal varices in patients with cirrhosis it is accepted. [6, 8, 11, 12]

The main clinical indications for the evaluation of small bowel's pathologies are represented by the obscure gastrointestinal bleeding, known and/or suspected Crohn's disease (CD), refractory or obscure celiac disease, polyposis syndromes and small-bowel tumors. [10, 13-14]

Obscure gastrointestinal bleedings (OGIB) represents the most frequent indication for the small bowel capsule endoscopy. The studies made in this purpose show a high diagnostic performance of the WCE in detecting occult gastrointestinal bleeding with negative upper and lower endoscopy. Several studies show that the accuracy of the capsule endoscopy is higher if it is performed in maximum two weeks from the bleeding episode. [2, 9, 15] The most common causes of OGIB are represented by angiodysplasias, ulcers and neoplasms. [9, 16]

Capsule endoscopy remains the gold standard examination for the diagnosis of small bowel's pathology, even though it has an estimated risk of 5% for retention in patients with known and/or suspected Crohn's disease. [2, 3] The most frequent clinical situations which require the use of WCE are represented by the negative upper and lower endoscopy in patients with suspected Crohn's disease and by the suggestive lesions for CD, but also for ulcerative colitis. The modifications found on small bowel capsule endoscopy, such as erythema, mucosal edema, ulcerations, etc., may appear in much other pathology. This is the reason why the diagnosis of CD should be established by the clinical data in correlation with relevant lesions found on capsule endoscopy.

Small bowel capsule endoscopy is a useful diagnostic tool also for the evaluation of refractory or obscure celiac disease. Video capsule endoscopy is an accurate alternative in patients with new and/or severe symptoms and in those which refuse to perform an upper gastrointestinal endoscopy, even though the

upper endoscopy with duodenal biopsies is the first choice diagnostic investigation. [17]

Other less frequent indications for wireless capsule endoscopy are represented by the polyposis syndromes, such as familial adenomatous polyposis and Peutz-Jeghers syndrome. [18, 19] WCE has also an important role in the detection of small bowel tumors. A significant number of tumors are discovered on the performed investigations for occult gastrointestinal bleedings. [20-22]

Colon capsule endoscopy is a minimally invasive alternative in patients with incomplete, contraindicated colonoscopy, or in those who refuse to perform this investigation. The most frequent clinical indications for colon capsule endoscopy are represented by the polyp detection, colorectal cancer screening, chronic inflammatory bowel disease, but also by the suspected or confirmed colonic diseases. Many studies have been performed to estimate the sensitivity and specificity of colon capsule endoscopy in comparison with conventional colonoscopy. [23-26]

A prospective study compared the results obtained by using the wireless capsule endoscopy with the ones from the colonoscopy. The study included 328 patients with known or suspected colon diseases, with the purpose of detecting the colorectal polyps or cancer. [8, 24] For the polyps detection of 6 mm in size or bigger, the sensitivity of colon capsule endoscopy was 64% and the specificity 84%. Also, from 19 cancers detected during the colonoscopy, 14 were detected also by capsule endoscopy. Another study performed by Spada et al [8, 27] has illustrated that the accuracy of colon capsule endoscopy increases and it is comparable with the one from colonoscopy when it is obtained an adequate bowel preparation. The most important risk of WCE is represented by the capsule retention, meaning the failed excretion of the capsule for 2 weeks or even more time. In this case, the capsule is extracted usually by surgery or endoscopic intervention. [9]

Wireless capsule endoscopy has the following contraindications: history of bowel obstruction, gastrointestinal fistulas, diverticula, impaired peristalsis, such as diabetic gastroparesis, and the suspicion of stenosis. Swallowing disorders, recent abdominal surgery, pacemakers and implanted electromagnetic devices are considered relative contraindications.

Due to the lack of the data regarding the safety, pregnancy is as well considered contraindication. [9, 20, 28, 29]

### **Advantages and disadvantages of capsule endoscopy**

Wireless capsule endoscopy is a modern, noninvasive and painless investigation, which does not require sedation. Another advantage of WCE is that during the examination the patient can also perform simple activities.

One of the main disadvantages of capsule endoscopy is represented by the high price of the single use capsule, but recent studies showed that the number of days of hospitalization has been reduced, as well as other necessary investigations. [30-32]

Another limitation of capsule endoscopy is the inability of taking biopsies, but it can be in this purpose associated with other endoscopy techniques. [30, 33]

The required time for the visual evaluation of a full capsule endoscopy video represents also a disadvantage, but software applications could make video analysis easier and shorter. [10]

### **Software application - purpose**

Currently, many applications are available for capsule endoscopy reading time reduction. Some of them were developed by the manufacturers, and some others were reported in the scientific literature. [34]

The main purpose of these applications is the reading time reduction of WCE videos without jeopardizing their accuracy. [10, 34]

Software applications are based mainly on topographic video segmentation, intestinal contraction detection, non-informative frame filtering, bleeding and abnormalities detection. [34]

### **Topographic video segmentation**

Berens et al [34] was first in 2004 who reported building a classifier for stomach/bowel that could predict the pylorus. One year later, Berens, Mackiewicz & Bell, proposed an improved classifier that could also indicate the Ileocecal Valve. In the same study, they compared k-nearest neighbor (kNN) with Support Vector Classifier (SVC) classifiers built for discriminating the gastrointestinal body parts. Later, they and Fisher have estimated the Gastric Transit Time and the Intestinal Transit Time by building a discriminator also for the mouth / esophagus and stomach regions. [34]

Another WCE video segmentation algorithm is based on a hidden Markov model (HMM). The comparison between the performance of different discriminators showed that, by adding texture and motion features in the building of the classifiers, the results have been improved. [35]

Coimbra et al [36] have performed a classification using a Bayesian classifier and have divided the video into four zones. First zone, Z1, represents the entrance and consists of image frames acquired before the capsule swallowing and images from the mouth and esophagus; second zone, Z2, from the oesogastric junction until the pylorus is represented by the stomach; third zone, Z3, is represented by the small bowel and it is delimited by the pylorus, and the last zone, Z4, represents the colon.

In 2007, Lee et al [34] used a new algorithm based on the different patterns of intestinal contractions for detecting digestive organs, dividing thus capsule endoscopy video into esophagus, stomach, duodenum and jejunum, ileum and colon.

An intelligent system capable of discriminating normal by abnormal tissue in WCE frames was described by Boulougoura et al. Even though the authors reported an accuracy of 100%, the results were not conclusive, considering that in the study have been used only 73 video images. [35, 37]

### **Non-informative frame filtering**

One of the advantages of using the software applications as support in the analyses of WCE video is represented by the ability to detect and remove non-informative frames, such as intestinal fluids, bubbles, debris, from the video sequence. Such an algorithm based on a bank of Gabor filters was proposed by Vilarino et al. in 2006. [34]

JungHwan Oh et al [38] proposed other two techniques to distinguish informative frames of non-informative frames, edge-based and clustering-based, in association with specular reflection detection technique. After associating the two methods with specular reflection detection, they obtained an accuracy of 95% for the edge-based technique, and an average of 97% in accuracy for the clustering-based technique.

### **Bleeding and abnormality detection**

A software tool for bleeding detection, called Suspected Blood Indicator (SBI), was proposed by Given Image Company but, due to its

accuracy, the human examination cannot be replaced. [39, 40]

Many methods have been used for bleeding detection. One of them, proposed by Sae Hwang et al [39], uses the Expectation Maximization (EM) clustering algorithm. Their results have achieved a sensitivity of 92% and 98% specificity.

Mackiewicz, Fisher and Jamieson [40] have created an algorithm based on adaptive color histogram model and Support Vector Classification. Another method proposed for the bleedings detection has used the improved Euler distance in CIELab colorimetric system. This study demonstrated a sensitivity of 92% and a specificity of 95%. [41]

Pan G et al [42] have detailed another bleeding detection method based on Probabilistic Neural Network. PNN classifier has the ability to recognize bleeding lesions in the WCE frames. This classifier has a sensitivity of 93.1% and a specificity of 85.6%.

Besides automatic image analysis tools proposed for the bleeding detection, systems capable to discriminate normal by abnormal tissue in WCE images have been also described.

Boulougoura et al [34] have described such a system based on 54 feature vector elements calculated from histograms of six channels. The images have been classified by an advanced neural network scheme. The reported accuracy of this intelligent system was 100%, but the small number of the capsule images evaluated was not enough for drawing conclusions.

More recently Li et al. (2011) [34, 43] have presented a new computer-aided detection scheme to diagnose small bowel tumors. The proposed scheme uses color texture features and multiple classifiers, such as k-nearest-neighbor, support vector machine and multilayer perceptron neural network. They have analyzed 1200 capsule endoscopy images, 600 normal and 600 abnormal images. The results from their study showed a promising performance for diagnosing the small bowel tumors. Intestinal polyps were also studied by several authors, their research papers focusing mostly on surface curvature detection [44] or contour detection [45].

## Conclusions

Wireless capsule endoscopy is a modern noninvasive investigation technique for the gastrointestinal pathology.

Due to the fact that WCE is a time-consuming procedure, the computer image

analysis algorithms could improve the performance of this examination.

Even though several studies have proposed different algorithms in this purpose, further research is needed to demonstrate the high accuracy obtained by correlating WCE with software applications.

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