Chromoendoscopy with Automatic Lesion Enhancement in Magnetically Guided Capsule Endoscopy: a Feasibility Study

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DDW 2011 DIGESTIVE DISEASE WEEK® May 7-10, 2011 MCCORMICK PLACE: CHICAGO, IL

Background

Gastric cancer is the 2nd most lethal digestive neoplasm in the world. Intestinal metaplasia and dysplasia are precancerous signs which can grow to gastric cancers. The identification of these lesions and follow-up of afflicted patients could lead to early diagnosis. Diagnosis via conventional endoscopy is characterized by low interobserver agreement and poor correlation with histopathologic findings. Chromoendoscopy has been proven to significantly enhance the visibility of mucosa irregularities, like metaplasia and dysplasia mucosa. In 2010, magnetically guided capsule endoscopy (MGCE) was introduced. In MGCE a patient swallows an endoscopic capsule, which is navigated by an external magnetic field in a water-filled stomach. The procedure is virtually non-invasive, comfortable for the patient and requires no sedation [1]. Other approaches use a handheld external magnet, which is used in manipulating this capsule in the esophagus and stomach [2]. These approaches seem feasible and sufficiently accurate for gastric examination. Known difficulties in the diagnosis of metaplasia in conventional endoscopy transfer to MGCE. Therefore, MGCE may also require the use of stains, similar to chromoendoscopy. The goal of this work is to prove the feasibility of a staining procedure in an MGCE examination of the stomach.

Methods

Commercially available endoscopy capsules and pig-stomachs with lesion imitations and esophagus were used. First the stomach was filled with 2L of lukewarm water and capsule images were taken from all anatomical sections. The capsule was navigated inside the stomach using a plastic support to simulate magnetic steering. Second, the stomachs were stained through the esophagus to simulate the real-world procedure. 100 ml of methylene blue stain of 1.00g/L was introduced through the esophagus. After a time delay of 5 minutes, a 500mL lukewarm water was inserted via the esophagus three times and flushed out of the stomach. The stomach was then filled with 2L of water and the capsule was again introduced. Images were manually captured from all anatomical sections (See Figure 2 line 2). The images were post-processed to further enhance the visibility of mucosa and possible lesions (See Figure 2 line 3).

Contrast Enhancement Algorithm

We use an image processing algorithm called Contrast-limited adaptive histogram equalization (CLAHE [3]) to further enhance the contrast and the visibility of mucosa and lesions. Although the CLAHE algorithm takes into account different intensity-distributions in different image regions it does not specifically act on color characteristics. In this approach the algorithm is adapted in order to benefit from the knowledge about the chromaticity value of the applied stain and its deposition on lesions.

To that end, the color input Image $\mathcal{I}_i$ is converted into the L*A*B color space resulting in $\mathcal{I}_{LAB}$. Its intensity channel (L) is separately enhanced using the standard CLAHE algorithm resulting in a contrast enhanced image $\mathcal{I}_{enh}$.

The B-channel of the converted L*A*B image encodes the blue or yellow value of the image. This channel is subsequently searched for image regions over a threshold λ which was found characteristic for distinguishing between blue stained healthy mucosa and metaplasia lesions. When the threshold is applied, the intensity channel (L) in this particular region is further enhanced so that

$$\mathcal{I}_{enh} = \begin{cases} \mathcal{I}_{enh} & \text{where } \mathcal{I}_B < \lambda \\ \mathcal{I}_{enh} \times \zeta & \text{where } \mathcal{I}_B > \lambda \end{cases}$$

where ζ denotes an enhancement factor for the concerned regions. This adapted contrast enhancement algorithm takes into account the different degrees of staining between different mucosa types and potential lesions and therefore benefits from the a priori knowledge of the applied stain chromaticity. Examples are shown in Figure 1.
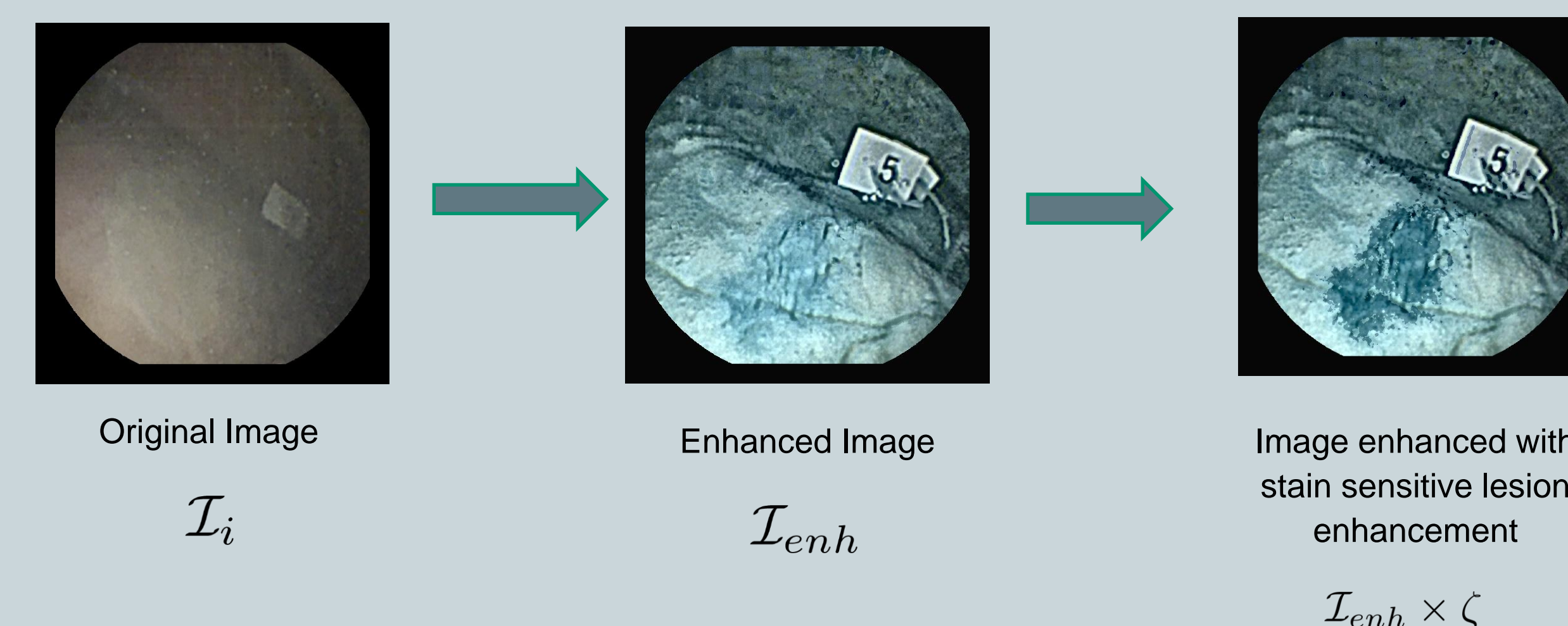

Original Image
$\mathcal{I}_i$

Enhanced Image
$\mathcal{I}_{enh}$

Image enhanced with stain sensitive lesion enhancement
$\mathcal{I}_{enh} \times \zeta$

Fig. 1. Comparison of different image enhancement methods for lesion imitations

Results

Similarly to the way that chromoendoscopy improves visibility over conventional endoscopy, MGCE with staining agents exhibits more prominent mucosa appearance. As in classic chromoendoscopy, we observed that stained mucosa appears more detailed than unstained mucosa. We also noted that the water is not dyed and hence does not impact the visibility. The applied staining procedure dyed the mucosa sufficiently. This observation holds for different camera poses, lighting conditions and scales.
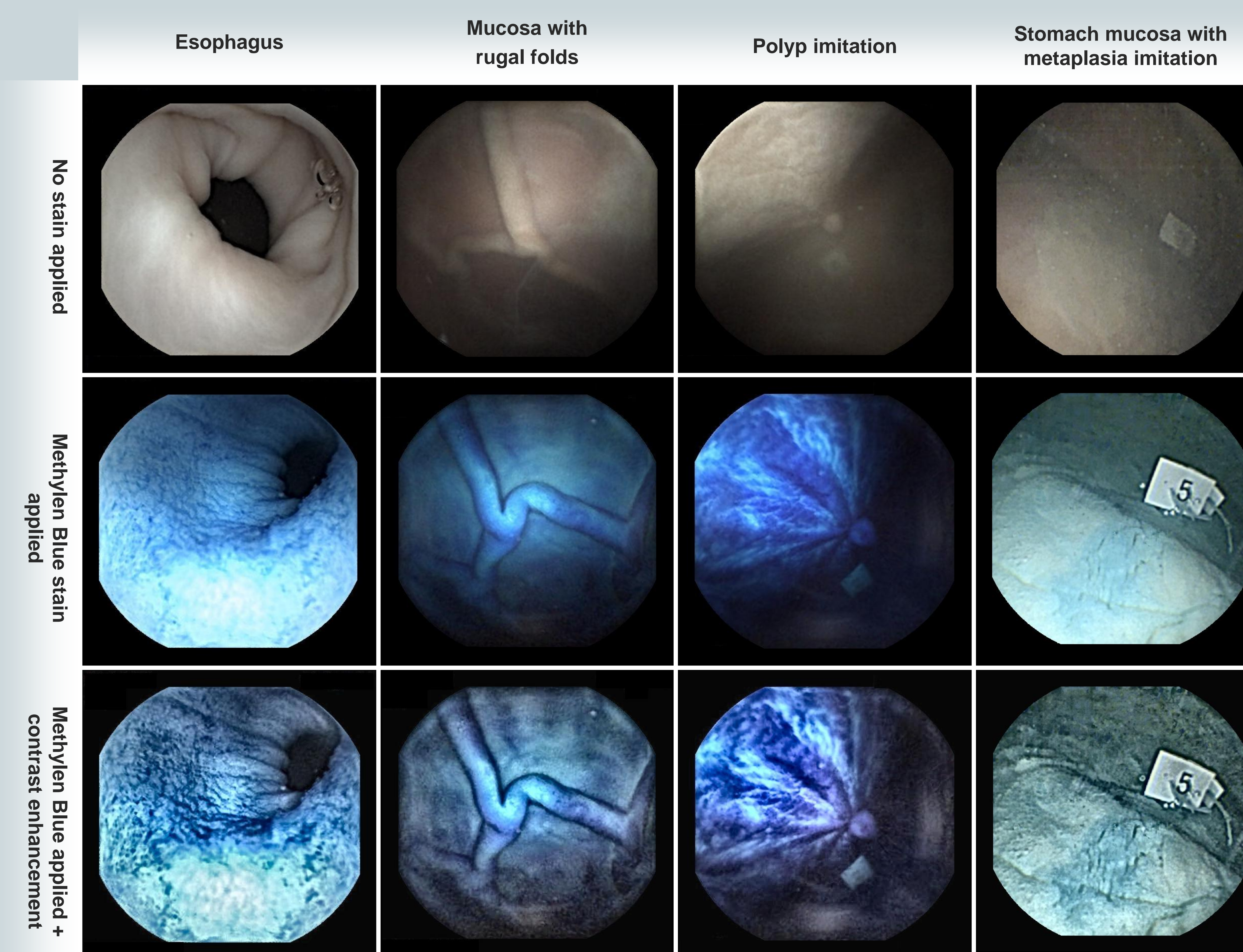
Refrences:
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	Esophagus	Mucosa with rugal folds	Polyp imitation	Stomach mucosa with metaplasia imitation
No stain applied				
Methylen Blue stain applied				
Methylen Blue applied + contrast enhancement				

Fig. 2: Overview over staining results at different anatomical regions

Conclusion

The results demonstrate that the proposed staining procedure can be applied to pig stomachs. Similar to the traditional chromoendoscopy the mucosa appears more detailed. Image processing algorithms can further improve the image quality and the visibility of metaplasia lesions. Though the visibility of polyps, metaplasia and dysplasia is enhanced, other pathologies may be masked. This, however, is acceptable for examinations focused on the detection of mucosa irregularities.