Original Article

Blue Mode Imaging may Improve the Detection and Visualization of Small-Bowel Lesions: A Capsule Endoscopy Study

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ABSTRACT

Background/Aims: Diagnostic miss rate and time consumption are the two challenging limitations of small-bowel capsule endoscopy (SBCE). In this study, we aimed to know whether using of the blue mode (BM) combined with QuickView (QV) at a high reviewing speed could influence SBCE interpretation and accuracy. **Materials and Methods:** Seventy CE procedures were totally reviewed in four different ways; (1) using the conventional white light, (2) using the BM, [on a viewing speed at 10 frames per second (fps)], (3) using white light, and (4) using the BM (on a viewing speed at 20 fps). In study A, the results of (1) were compared with those of (2), and in study B, the results of (3) and (4) were separately compared with those of (1). **Results:** In study A, the total number of the vascular ($P < 0.001$) and the inflammatory lesions ($P = 0.005$) detected by BM was significantly higher than that detected by the white light. No lesion was found using the white light that was not detected by the BM. Moreover, the BM highly improved the image quality of all the vascular lesions and the erythematous ones from the nonvascular lesions. In study B, the total number of only the vascular lesions, detected by the BM on a rapid speed of viewing at 20 fps was significantly higher than that detected by the white light ($P = 0.035$). However, the true miss rate for the BM was 4%. **Conclusion:** BM imaging is a new method that improved the detection and visualization of the vascular and erythematous nonvascular lesions of SB as compared with the conventional white light imaging. Using of the BM at a slow viewing speed, markedly reduced the diagnostic miss rate of CE.

Key Words: Blue mode, capsule endoscopy, QuickView

Capsule endoscopy (CE) is undoubtedly the gold standard for the endoscopic examination of the entire small bowel (SB) as being a reliable, and noninvasive method.[1,2]

CE has proved to be a valuable tool in the evaluation of many diseases such as obscure gastrointestinal bleeding (OGIB),[3] suspected Crohn's disease (CD),[4] and NSAIDs-induced enteropathy.[5] It also has been shown to have a higher diagnostic yield for most of these indications compared with conventional diagnostic methods, for example, push enteroscopy, enteroclysis, small-bowel follow through, and computed tomography or angiography.[6-8]

However, one article has article that analyzed a master database, provided by Given® Imaging Ltd (Yoqneam, Israel), found that the global miss rate of CE is about 11% ranging between 0.5% for ulcerative diseases and 18.9% for neoplastic diseases.[9]

Over the past few years, several features have been updated in the CE software to facilitate and speed up the reading of CE recordings, and greatly improve the image quality.[1,10] These included the use of a Suspected Blood Indicator®,[11,12]

multi-viewing by simultaneous display of up to four images,[13] QuickView® (QV) system,[14,15] the Automatic viewing mode,[16] Blue mode (BM) imaging,[17,18] and lastly Fujinon intelligent color-enhancement (FICE™) system.[19,20]

Blue mode has been introduced by Given Imaging Ltd in May 2007 as a new technology of image enhancement to Rapid Reader 5.0 software. It is a color coefficient shift of light in the short wavelength range (490–430 nm) superimposed into a white light [red, blue, green (RGB)] image.[17] Although it is considered the first computed virtual chromoendoscopy technology that has been added to CE, its utility in the clinical practice is not fully studied.[17,18,20]

In this study, we aimed to know whether the use of BM combined with QV at a higher reviewing speed could influence CE interpretation and accuracy.

MATERIALS AND METHODS

During the period from October 2012 to June 2013, 70 patients (pts) underwent SBCE with PillCam® SB (Given Imaging Ltd, Yoqneam, Israel) in our hospital, the second department of internal medicine, Osaka Medical College. This study was approved by the ethics committee of Osaka Medical College.

The indications of CE examination were OGIB in 31 pts, a clinical trial that studied the portal hypertensive enteropathy in 30 pts with liver cirrhosis (Child score was A in 20 and B in 10 pts), and others such as suspected CD, anemia, and follow up after GI bleeding in the remaining 9 pts.

All CE procedures were reviewed in four different ways using two different imaging modes (white light and BM) and at two different viewing speeds (10 and 20 frames per second (fps) using QV) of SingleView. These ways were (1)– using the white light at 10 fps (Aw), (2)– using BM at 10 fps (Ab), (3) using white light at 20 fps (Bw), and (4) using BM at 20 fps (Bb).

In study A, the results of Aw were compared with those of Ab, whereas in study B, the results of Bw and Bb were separately compared with those of Aw. The Aw method was the reference for our study.

Four senior endoscopists (with experience in CE >300 SBCE reviews) participated, two of them for each study. Within each study, one endoscopist used the white light mode and the other used BM with fixing all the image resolution factors (such as brightness, sharpness, and color density) and they switched between the two different modes every 35 CE procedures, in a cross-over fashion.

The collected data for every CE procedure included the imaging method, SB passage time, the reading time, and the CE findings.

Methods
In study A, Aw and Ab were compared to elicit the differences between the two modes with regard to the detection and visualization of SB lesions.

Small-bowel lesions were classified into three categories; vascular, inflammatory, and other lesions. First, mean of the total number (sum) of lesions for each category was calculated, and compared within the two different modes. Next, the captured thumbnail images of Aw were meticulously matched with those of Ab (our reference) for assessment of the diagnostic missing rate.

The images of BM (Ab) were compared with those of white light mode (Aw) as regard getting the best image quality. A conclusion was reached by all the involved endoscopists for each image.

In study B, the two modes Bw and Bb at a reviewing speed of 20 fps (double that of study A) were separately compared with our reference Aw for assessment of the diagnostic miss rate.

CE procedure
Patients fasted for 12 h before the examination. They were administered 2 L polyethylene glycol–electrolyte solution in the evening of the day before the procedure. Each patient drank a solution that contained simethicone just before swallowing the capsule. Thereafter, they were not allowed to take anything by mouth for 4 h and they were observed for 8 h at the study site. After 8 h, the sensor array and the recording device were removed. RAPID reader 5 software was used (Given Imaging, Ltd, Yogneam, Israel).

Statistical analysis
The data were calculated as mean ± SD. The statistical comparisons were performed using one-way ANOVA (post hoc multiple comparisons; Dunnett test). Differences were considered statistically significant when the P value was ≤0.05. Statistical analysis was performed using the statistical software (SPSS, version 16.0; SPSS Inc, Chicago, IL).

RESULTS

In total, 70 CE procedures were analyzed. The mean SB passage time (h) was 4.9 ± 1.9. The mean SB reading times (min) were 29.5 ± 12.9 and 14.7 ± 6.5 in study A and B, respectively.

The vascular category of the SB lesions included red spots ± blood clots, angioectasia, varices, and submucosal vasculature, whereas the inflammatory category included erythema, erosions, and ulcers. The last category included other lesions such as xanthomata, submucosal tumors, and polyps.

In study A, total number of vascular ($P < 0.001$) and inflammatory lesions ($P = 0.005$) detected by the BM was significantly higher than that detected by the white light mode. However, we did not find any significant difference in the number of other lesions between the two modes ($P = 1.000$) [Table 1]. No lesion was found in the white light that had been missed by BM.

The BM imaging had a better visualization degree than white light for all the vascular lesions and only the erythematous lesions from the inflammatory ones [Figures 1 and 2]. However, the two modes were equal in performance with regard to visualization degree for nonerythematous inflammatory and noninflammatory lesions (including the other lesions' category) [Figure 3].

In study B, the total number of lesions detected by white light revealed no significant difference among the two speeds of viewing (10 and 20 fps) for all types of SB lesions [Table 2]. However, using BM viewing at a high speed of 20 fps (Bb) revealed a significant difference only for detection of vascular lesions among all the SB lesions compared with study Aw ($P = 0.035$), [Table 3]. On the other hand, the diagnostic miss rates for the white light and BM on a high speed of viewing (20 fps) were 17% and 4%, respectively in comparison to our reference; Aw.

DISCUSSION

Diagnostic miss rate and time consumption are the two most important limitations for reading SBCE, therefore BM and

Table 1: Comparison between the white light and blue mode on a speed of viewing at 10 fps

Lesions	n (mean±SD)		P
	White light (Aw)	Blue mode (Ab)	
Vascular	73 (1±1.17)	140 (2±1.5)	<0.001
Inflammatory	51 (0.7±1.0)	94 (1.3±1.1)	0.005
Others	26 (0.4±0.7)	28 (0.4±0.8)	1.000

fps: Frames per second

Table 2: White light imaging results on two different speeds of viewing (10 and 20 fps)

Lesions	n (mean±SD)		P
	10 fps (Aw)	20 fps (Bw)	
Vascular	73 (1±1.17)	46 (0.7±0.9)	0.175
Inflammatory	51 (0.7±1.0)	35 (0.5±0.7)	0.146
Others	26 (0.4±0.7)	22 (0.3±0.6)	0.107

fps: Frames per second

Table 3: Comparison between white light and blue mode on a speed of viewing at 10 and 20 fps, respectively

Lesions	n (mean±SD)		P
	White light 10 fps (Aw)	Blue mode 20 fps (Bw)	
Vascular	73 (1±1.17)	116 (1.7±1.4)	0.035
Inflammatory	51 (0.7±1.0)	75 (1.1±1.0)	0.217
Others	26 (0.4±0.7)	27 (0.4±0.8)	1.000

fps: Frames per second

Figure 1: Visualization degree of white light (upper row) for the vascular lesions compared with that of blue mode (lower row). (a) Red spot, (b) angioectasia, (c) serpiginous varix, and (d) blood vessels of the small bowel
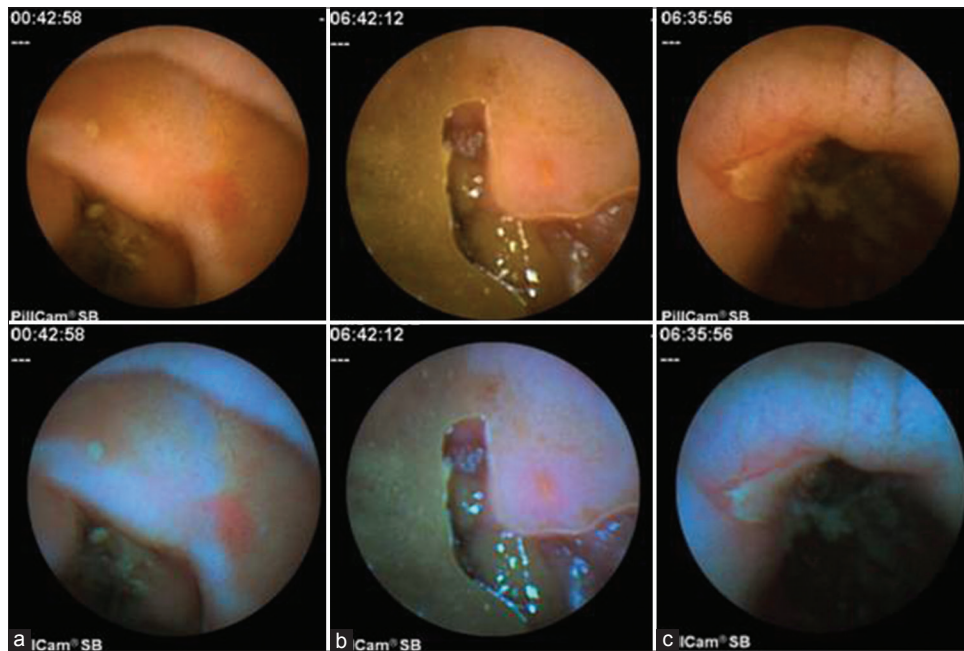
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Figure 2: Visualization degree of white light imaging for the erythematous nonvascular lesions (upper row) compared with that of blue mode (lower row). (a) Erythematous patch, (b) erosion with central erythema, and (c) ulcer with overlying cover with surrounding erythema
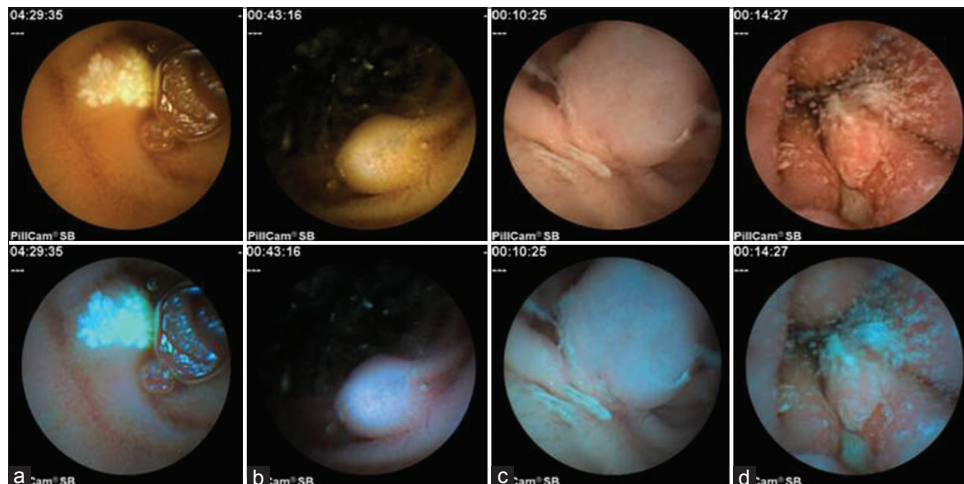

Figure 3: Comparison of the visualization degree between white light (upper row) and blue mode imaging (lower row) for the nonerythematous nonvascular lesions. (a) Xanthoma, (b) submucosal tumor, (c) duodenal polyp, and (d) duodenal ulcer (nonerythematous)

QV are invented as additional software approaches. However, there were very limited published data to assess the validity of combining BM with QV in clinical practice. In DDW2010, this idea was first presented by us in an abstract form.[21] In this study, we studied the validity of using BM on two different speeds of viewing (10 and 20 fps) through QV addition.

Compared with the white light, the BM imaging showed a better detection of the vascular and inflammatory lesions ($P < 0.001$ and $P = 0.005$, respectively) at a viewing speed of 10 fps, and only the vascular lesions at a viewing speed of 20 fps ($P = 0.035$). On the other hand, there was

no significant difference between the two modes regarding the detection of other lesions ($P = 1.00$). Moreover, there was no lesion detected by the white light mode that had been missed by the BM imaging.

Compared with the white light mode, BM had a better visualization degree for all kinds of vascular lesions, and only the erythematous kinds of inflammatory lesions.

In study B, the diagnostic miss rate of the white light imaging mode was 18%, which is greater than that estimated by a study by Weterhof et al.[10] this might be explained by the

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discrepancy in the viewing speed between that trial and our study. Surprisingly, we found that the BM imaging had a diagnostic miss rate of 4%, although it had a better detection of vascular lesions. The missed lesions were two nonbleeding red spots and one erosion. The discrepancy between the detection degree and the miss rate might emphasize that BM has false-positive or negative diagnostic values.

Although the previous studies that assessed the QV system concluded its unreliability mainly because of its unacceptable miss rate. Koulaouzidis *et al.*[17] stated that QV can be confidently in overt OGIB in an urgent inpatient setting and in outpatients with occult OGIB or suspected CD. Through the addition of BM to QV, we also supported the unreliability of QV because the possibility of missing a relevant pathology is still present.

The major limitations of our study were the small number of CE procedures and the lack of ideal solid diagnosis through the use of histopathology, push endoscopy, or double balloon endoscopy.

CONCLUSION

BM is considered a new method for better detection and visualization of the vascular and the erythematous nonvascular lesions. The global diagnostic miss rate of CE might be reduced to a reasonable degree, by using the BM imaging only on slow speeds of reviewing. Speeding up of CE reviewing will definitely cause missing of relevant lesions even if it is augmented by using of BM imaging.

In future, large scale studies comparing the results of BM with those of PE, DDE, or histopathology, are needed to precisely validate the utility of BM in clinical practice.

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