Usefulness of Flexible Spectral Imaging Color Enhancement for the Detection and Diagnosis of Small Intestinal Lesions Found by Capsule Endoscopy

Usefulness of FICE-CE

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Abstract

Objective: Capsule endoscopy (CE) is an established technique for the detection and diagnosis of obscure gastrointestinal bleeding (OGIB). Flexible spectral imaging color enhancement (FICE) is a software feature of RAPID 6.5. This study assessed the value of FICE for accurate identification of red lesions during CE.

Methods: We randomly selected 10 patients who underwent CE for OGIB at Juntendo University. The CE images were read by 5 endoscopists. Small bowel videos, which were recorded by regular CE devices (PillCam SB2, Given Imaging), were evaluated on RAPID 6.5. We standardized the reading condition to dual view, at a speed of 20 frames per second in manual mode. This interpreted FICE-CE images obtained at settings 1-3. Both conventional images and FICE images were read at random. We defined a conventional image as standard and investigated the potential of FICE for detection of small intestinal lesions by the Steel-Dwass test.

Results: We considered that conventional images represented the baseline (100). On this basis, detection rates for FICE images were as follows: FICE1, 266.4 ± 33.1 ($P<0.0001$); FICE2, 255.4 ± 25.6 ($P<0.0001$); and FICE3, 117.0 ± 12.3 ($P=0.9447$). The detection rates using FICE1 and FICE2 images were significantly higher than conventional CE images. ~~There was no statistically significant difference between FICE1 and FICE2 (P=0.9863).~~

FICE1 and 2 were more useful for detecting erosions than conventional CE ($p<0.0001$) and FICE3 ($p<0.0001$).

Conclusions: FICE-CE has a high level of visibility by transparentizing bile or enhancing the color difference associated with reddish mucosa. We found that FICE-CE images were ~~appropriate for the initial detection and~~ useful for diagnosis of small intestinal lesions.

Key words: capsule endoscopy, Flexible Spectral Imaging Color Enhancement (FICE), small bowel

Introduction

Capsule endoscopy (CE) is an established technique for the detection and diagnosis of obscure gastrointestinal bleeding (OGIB) [1-8]. Several studies reported that CE is more effective in detecting small bowel lesions than other modalities, such as push enteroscopy [9, 10], small bowel radiography [11], and double balloon endoscopy [12]. When CE images are read, it is difficult to distinguish the thumbnail from zillions of images. The suspected blood indicator (SBI) software was expected to facilitate the detection of lesions, but it was found to be inadequate [13].

A function that could distinguish lesions from normal areas by enhancing the abnormal site was needed. For this purpose, flexible spectral imaging color enhancement (FICE) software creates a spectral image of a specific wavelength using an ordinary image and can obtain high-contrast images by selecting the wavelength suitable for a specific structure of tissues or vessels [14]. The advantage of this new digital processing system is enhanced detection and identification of pathologic changes and improved accuracy in diagnosis [15, 16]. Therefore, FICE makes it possible to obtain detailed enhanced images of mucosal structures. FICE-CE can enhance areas of bleeding or red-colored lesions and enables easy identification of lesions by processing the image under difficult conditions due to intestinal fluid [17]. In particular, vascular lesions have a tendency to occur at multiple sites in the small bowel, making it difficult to find the lesion responsible for small bowel bleeding, with the result of continued or repeated bleeding [18,19].

In this study, we aimed to evaluate the potential of FICE for accurate identification of the lesions seen during CE.

Materials and Methods

Methods

We randomly selected images from 10 patients who underwent CE for OGIB at Juntendo University. The CE images were read by 5 endoscopists who had experience in CE reading. Small bowel videos, which were recorded by regular CE devices (PillCam SB2, Given Imaging), were evaluated by RAPID 6.5. We standardized the reading condition in the manual mode, dual view, and reading speed of 20 frames per second. All endoscopists randomly read the 40 videos of all shot images showing 4 patterns for each of the 10 cases (10 cases; conventional, FICE1, FICE2, and FICE3). All images were read at random.

Data on our 10 cases provided interpretation of the CE-FICE images obtained at settings 1-3 (setting 1: red 595 nm, green 540 nm, blue 535 nm; setting 2: red 420 nm, green 520 nm, blue 530 nm; setting 3: red 595 nm, green 570 nm, blue 415 nm). FICE1 is to be used under relatively good conditions with little blood and turbidity from bile pigments, provides visualization through bile pigments and emphasizes lesions. FICE2 colors bile pigments with cyanogen, emphasizing differences between normal mucosa and lesions. FICE3 should be used under conditions of bile pigments blended with blood and colors blood with magenta and bile pigments with yellow. (Figure 1)

Analysis

Conventional images represented the baseline (100) to investigate the potential of FICE for detecting small intestinal lesions. Lesions were classified as a non-pathological red spot, angioectasia, erosion, ulcer, polyp, and others (e.g., submucosal tumor, lymphangiectasia). The number of lesions detected by conventional CE and FICE-CE were compared. Differences were analyzed by the Steel-Dwass test. All statistical tests were performed using a 5% significance level in JMP 9.0.2 (SAS Institute, Inc., Cary, NC, USA).

Results

Detection rates

The detection rates for FICE images using 100 as baseline were as follows: FICE1, 266.4± 33.1; FICE2, 255.4± 25.6, and FICE3, 117.0± 12.3. Therefore, the detection rates using FICE1 ($p<0.0001$) and FICE2 images ($p<0.0001$) were significantly better than with conventional CE images. There was no statistically significant difference between the conventional CE images and FICE3 (P=0.9447). Also, there was no statistically significant difference between FICE1 and FICE2 (P=0.9863).

Number of lesions

Using conventional CE, the number of non-pathological red spots was 3.84 ± 4.34, angioectasia 0.58 ± 0.15, erosions 3.3 ± 4.29, ulcers 1.66 ± 4.00, polyps 0.28 ± 0.67, and others 2.0 ± 2.87. With FICE1, the number of non-pathological red spots was 7.32 ± 7.97, angioectasia 0.92 ± 0.20, erosions 8.64 ± 8.55, ulcers 4.86 ± 12.86, polyps 0.14 ± 0.35, and others 0.84 ± 1.58. With FICE2, the number of non-pathological red spots was 6.86 ± 8.97, angioectasia 0.72 ± 0.18, erosions 11.94 ± 15.12, ulcers 5.6 ± 14.51, polyps 0.16 ± 0.42, and others 0.88 ±1.66. With FICE3, the number of non-pathological red spots was 4.36 ± 7.10, angioectasia 0.74 ± 0.20, erosions ~~8.64~~ 3.54 ± 4.03, ulcers 2.9 ± 8.50, polyps 0.16 ± 0.37, and others 0.88 ± 2.18. FICE1 and 2 were more useful for detecting erosions than conventional CE ($p<0.0001$) and were also more useful for detecting erosions than FICE3 ($p<0.0001$). On the other hand, conventional CE was more useful for other lesions than FICE-CE. In the number of angioectasias, ulcers, and polyps, the difference detected by between conventional CE and FICE-CE were not significant. FICE1 was superior to conventional CE in detecting non-pathological red spots ~~(false positives)~~.

Discussion

We investigated whether FICE-CE could improve detectability of lesions by standardizing the reading speed. This is the first report that showed the usefulness of FICE in CE by

standardizing reading speed. Reading speed is an important factor. If it is slowed down, the detection rate may be increased. In previous studies that showed the benefit of FICE-CE, endoscopists analyzed FICE-CE images with their favorite speed. Because they did not standardize the reading speed, results did not show the true benefit of FICE-CE. In our study, the 5 endoscopists analyzed the FICE-CE images with the same speed, which was 20 frames per second. In this study, the detection rates of FICE1 ($p<0.0001$) and FICE2 images ($p<0.0001$) were significantly better than that of conventional images (Table 2). On the other hand, there was no statistically significant difference between conventional CE images and FICE3 images ($P=0.9447$). Previous studies also reported that FICE1 and 2 improved detectability of small intestinal lesions, but that FICE3 did not [20, 21].

Furthermore, we investigated the efficacy of FICE according to various classifications of lesions and found that FICE1 and 2 were more useful for detecting erosions than conventional CE ($p<0.0001$). This is the same result as reported by Sakai et al. and Duque et al. [21, 22]. CE trainees are often likely to miss small erosions/ulcerations [23, 24]. Many erosions include few reddish lesions, and such lesions with poor color contrast are difficult to detect with the conventional images. Thus, because of enhancement of the inflammatory halo, FICE contributes to the diagnosis of erosions. On the other hand, the detection of angioectasia and ulcer did not differ significantly among the images. Angioectasia and ulcer can be rather easily detected by conventional CE because of their somewhat large size and reddish coloration. Nevertheless, some vascular lesions could be more accurately characterized with FICE-CE compared to conventional CE.

Several previous studies reported that FICE-CE improved the detectability of angioectasia, because it can emphasize the hypervascularity of the lesion and its vascular morphology. Gabriela et al. reported that FICE-CE appeared to have increased diagnostic accuracy by

highlighting small bowel angioectasias that were not identified by conventional CE [22]. Imagawa et al. reported that detectability of angioectasia was improved at wavelength FICE1 and 2, but detectability of erosion/ulceration or tumor was not improved [20]. Thus, they considered that FICE-CE might be particularly useful for detecting small-bowel angioectasias [20]. Nevertheless, our results showed that the number of detected angioectasias did not differ between FICE-CE and conventional CE. There are two main explanations for this. First, we assume that the conventional image is sufficient to detect angioectasias because angioectasias are very reddish lesions. Kobayashi et al. also reported with respect to angioectasias that sensitivity and specificity were very high with conventional CE as well as FICE-CE [25]. Second, in this study, there were very few angioectasias; therefore, to draw conclusions a larger number of cases with angioectasia are needed. FICE1 and 2 provide a high level of visibility of reddish mucosa. However, it is difficult to detect lesions having a color similar to the background. Polypoid lesions and lymphangiectasias that differ little from their surroundings are difficult to detect.

In actual clinical practice, it takes twice as long to read FICE-CE images in addition to conventional CE images, which is both a mental and physical strain. If more than one endoscopist reads CE images, one would do well to read the conventional image and another would rather read the FICE image, after which they would make a comprehensive diagnosis of the lesion together. With the further development of computer technology, we expect an abnormality will be automatically distinguished from zillions of images.

A limitation of our study was the relatively small number of patients. A longer prospective study with patient follow up may be required to confirm our findings.

In conclusion, ~~FICE-CE is valuable for the initial detection, while conventional CE is appropriate for the final diagnosis.~~ FICE-CE provides a high level of visibility by

transparentizing bile or enhancing the color difference associated with reddened mucosa. We found that FICE-CE were useful for ~~the initial detection and~~ diagnosis of small intestinal lesions. ~~CE-FICE may also be a good option for small bowel screening.~~

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Figure Legend

Figure1.

CE images of small intestinal lesions with conventional (top left), FICE1 (top right), FICE2 (bottom left), and FICE3 images (bottom right).

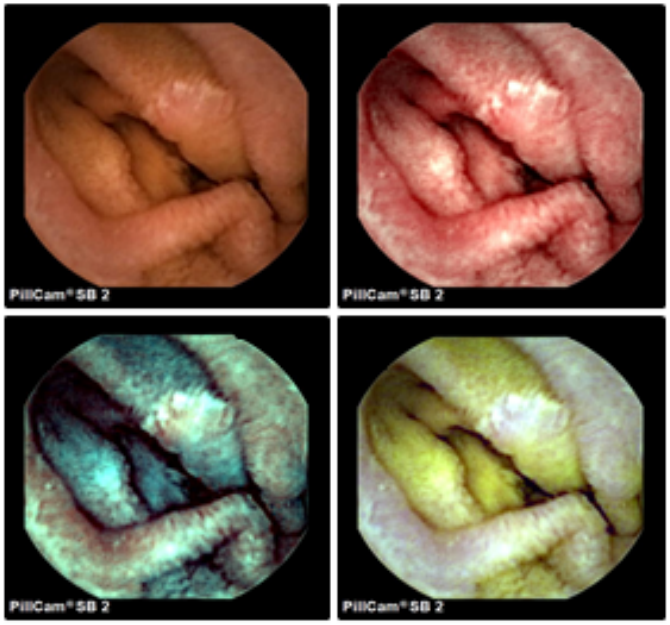
A: Polypoid lesions B: Erosions C: Angioectasia D: Ulcers E: Others (submucosal tumor)

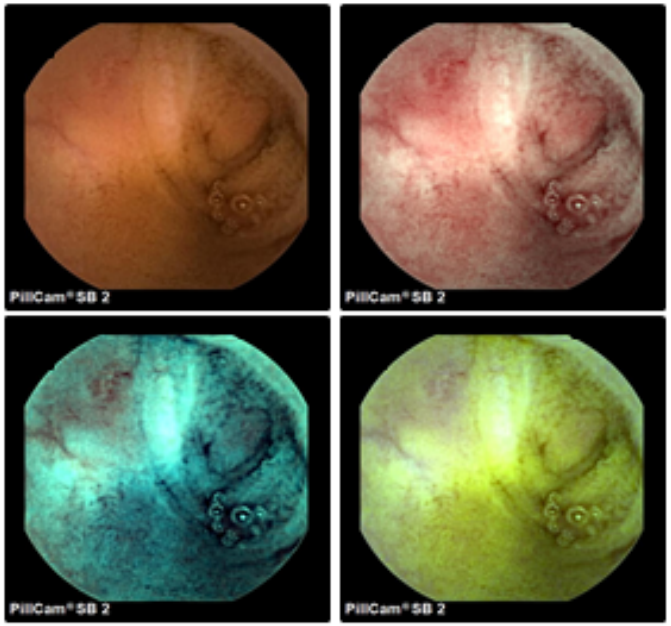
Figure2.

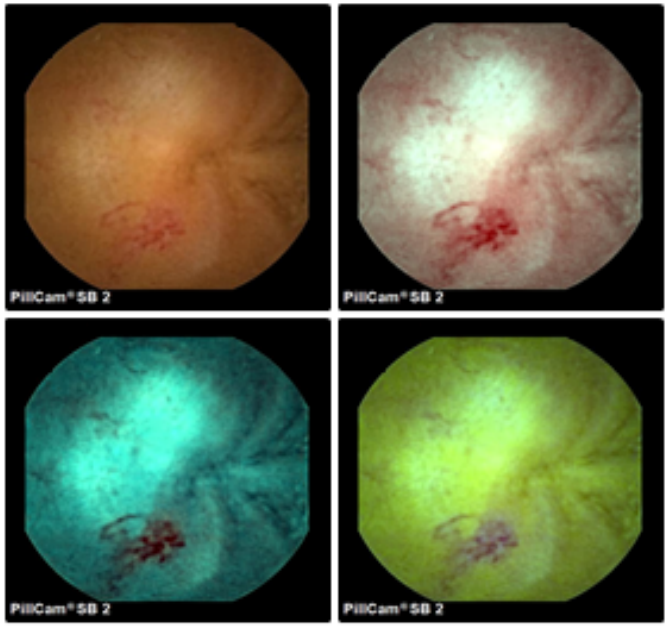
The mean number of small intestinal lesions detected by 5 endoscopists with conventional CE and FICE-CE. FICE1 ($p<0.0001$) and FICE2 ($p<0.0001$) were significantly better than with conventional CE. There was no statistically significant difference between the conventional CE and FICE3 ($P=0.9447$). There was no statistically significant difference between FICE1 and FICE2 ($P=0.9863$).

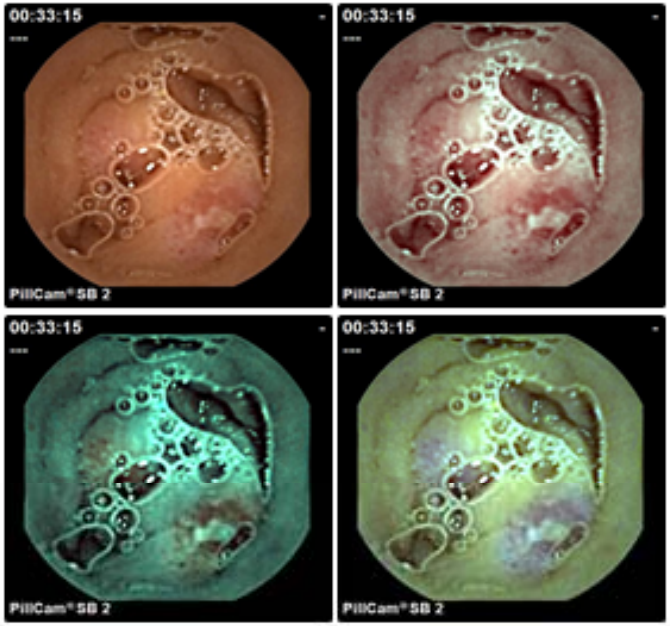
Figure3.

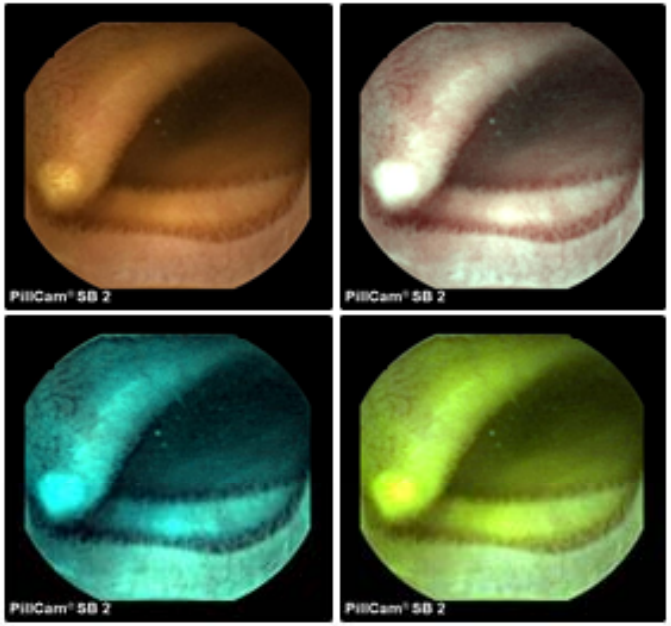
Comparison of mean number of small intestinal lesions detected with conventional CE and FICE-CE. FICE1 and 2 were more useful for detecting erosions than conventional CE ($p<0.0001$) and FICE3 ($p<0.0001$). For detecting other lesions, FICE-CE was not more useful than conventional CE.





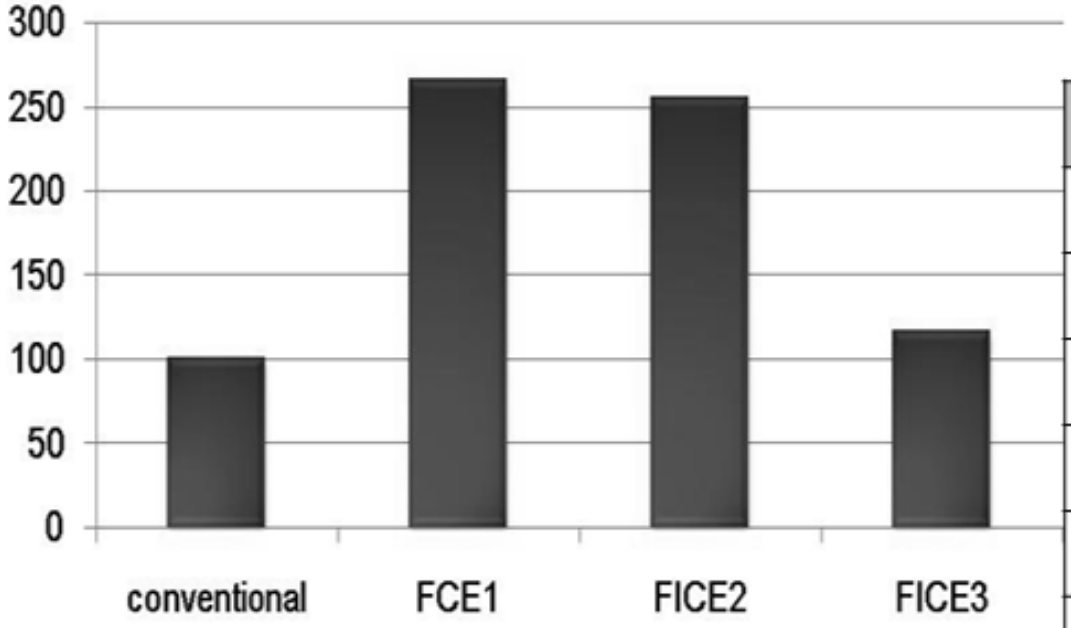






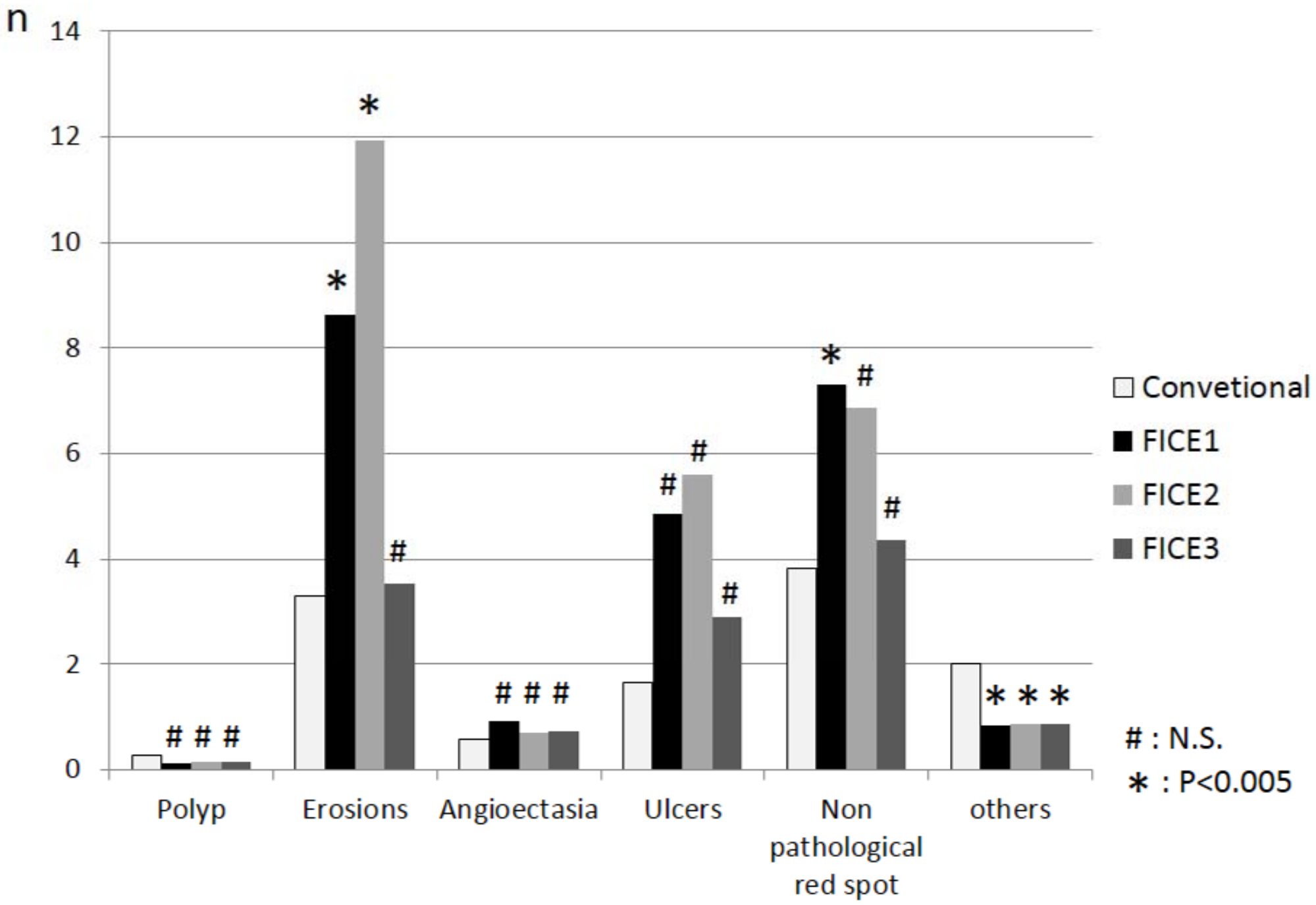
conventional	FICE1
FICE2	FICE3

A	B	C
D	E	



Mean ± S.E.	Baseline (100)	266.4 ± 33.1	255.4 ± 25.6	117.0 ± 12.3

	P-value
conventional vs. FICE1	P<0.0001
conventional vs. FICE2	P<0.0001
conventional vs. FICE3	0.9447
FICE1 vs. FICE2	0.9863
FICE1 vs. FICE3	P<0.0001
FICE2 vs. FICE3	P<0.0001


n
14
12
10
8
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4
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Polyp
Erosions
Angioectasia
Ulcers
Non pathological red spot
others
Convetional
FICE1
FICE2
FICE3
: N.S.
＊ : P<0.005