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In Vivo Location of the Vermiform Appendix in Multidetector CT[1]
Multidetector CT에서 보인 우하복부에 위치한 충수의 생체 내 위치[1]

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Purpose: To provide a more detailed classification system regarding the position of the vermiform appendix within the right lower quadrant, as seen on multidetector computed tomography (MDCT) and to investigate the relative differences in frequency of appendiceal position according to patient gender and the pathologic state of appendix.

Materials and Methods: Between January 2008 and December 2010, 1157 patients were included in our final analysis: 542 patients with preoperative MDCT and subsequent appendectomy and 615 patients with visible appendix seen on MDCT performed as part of a health checkup. We classified the appendix according to its position relative to the cecum, the terminal ileum, and the external iliac vessels: type 1: antececal; type 2: preileal; type 3: postileal; type 4: subileal; type 5: subcecal; type 6: deep pelvic; type 7: retrocecal; and type 8: paracecal.

Results: The relative incidence of various positions of the appendix found in all of our study patients was: type 1: 3.5%; type 2: 1.7%; type 3: 9.0%; type 4: 12.9%; type 5: 42.3%; type 6: 16.2%; type 7: 10.9%; and type 8: 3.0%. According to patient gender, type 1 (male: 3.7% vs. female: 3.3%), type 3 (8.6% vs. 9.8%), type 4 (14.3% vs. 9.8%), type 5 (47.5% vs. 32.7%), type 7 (9.2% vs. 14.4%), and type 8 (3.4% vs. 2.2%) positions showed a statistically significant male predominance. In terms of the inflamed state, type 2 preileal (normal: 0.8% vs. inflamed: 2.8%), type 3 (10.2% vs. 7.6%), type 4 (14.0% vs. 11.6%), and type 5 (14.1% vs. 18.5%) positions showed a statistically significant difference.

Conclusion: Contrary to the common assumption that the retrocecal appendix is the most common position, the *in vivo* appendix is seen more often on MDCT in the subcecal and deep pelvic positions. The relative frequency of various positions of the appendix can also differ according to patient gender and the pathologic state.

Index terms
Anatomy
Appendix
Appendicitis
Multidetector Computed Tomography

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INTRODUCTION

Continuing advancements of multidetector computed tomography (MDCT) technology with improved resolution and the use of reformatted images have made it possible to delineate the entire length of the appendix, whether inflamed or normal, as well as to provide a clearer illustration of the relationship of the appendix to its adjacent intraperitoneal structures (1). During open appendectomy, informing the surgeon regarding the actual position of the appendix is important for determining the incision site, as a mismatched incision followed by an additional incision is related to an increased risk of postoperative pain, hematoma, nerve injury, and hernia formation (2). Information regarding the location of the appendix is less important in laparoscopic surgery than in open appendectomy. However, the median surgery time of laparoscopic appendectomy is also influenced by variability in the appendiceal position (3). Accurate delineation of the position of an inflamed appendix and surgeon notification would be helpful when performing laparoscopic surgery in which the surgeon only has a limited surgical view, as this will help prevent an aggressive and time-consuming search for the inflamed appendix.

The conventional, standard, surgical textbook has long maintained that the most common appendiceal position is retrocecal (4, 5). However, we have found that these conventional results did not correspond with our surgical and radiological experience in daily clinical practice. Previous reports based on the conventional CT and postmortem data revealed that the most common positions of the appendix were the retroileal and deep pelvic types (6, 7). The results of several recent studies regarding the position of the appendix using various medical imaging and laparoscopy, also provided data contradictory to the historical convention (7-10).

As the classification of each location type reported in the aforementioned studies do not exactly correlate with each other, it is difficult to directly compare their analyses of appendiceal locations within the right lower quadrant. Therefore, we attempted to develop a more detailed and modified classification system including all possible appendiceal positions within the right lower quadrant based on the literature reports and our clinical experience, and to investigate the *in vivo* frequency of each appendiceal position according to the patient gender and the pathologic state as seen on MDCT.

MATERIALS AND METHODS

This retrospective research protocol was approved by our institution's Ethics Committee, and informed consent was waived.

Patient Groups

Based on a review of our medical records from January 2008 to December 2010, 1157 patients (median age, 46 years; range, 20–89 years) were included in the final analysis. The total consisted of 542 patients who had undergone preoperative MDCT and subsequent appendectomy and who were included in the inflamed group, and 615 patients with visible appendix seen on MDCT done for their health checkup and who were included in the normal group in our final analysis. There were 790 male and 367 female patients, all of whom had inflamed or normal appendices identified on CT scanning performed in the right lower quadrant.

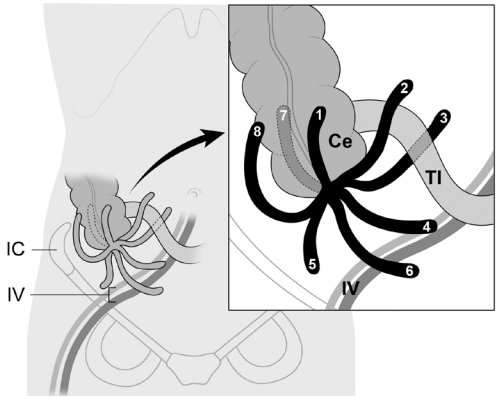

Fig. 1. Illustration of the appendiceal positions classified according to their relative location to the iliac crest (IC), terminal ileum (TI), cecum (Ce), and the iliac vessels (IV). 1, type 1 antececal; 2, type 2 preileal; 3, type 3 postileal; 4, type 4 subileal; 5, type 5 subcecal; 6, type 6 deep pelvic; 7, type 7 retrocecal; and 8, type 8 paracecal.

MDCT Technique

CT examinations were performed using a Definition AS+ 128-detector-row CT scanner (Siemens Medical Solutions, Forchheim, Germany) after injection of intravenous contrast medium (Iopromide, Ultravist 300; Bayer Healthcare, Berlin, Germany). The images were acquired during the portal venous phase (70-s delay after contrast injection; 100 kVp; 220 mAs; pitch, 1.25; and gantry speed, 0.5 s per rotation) and included the region from the dome of the diaphragm to the symphysis pubis. CareDose 4D tube current modulation software (Siemens Medical Solutions, Forchheim, Germany) was used. The technicians used a Syngo VB28B computer program (Siemens Medical Solutions, Forchheim, Germany) to reconstruct the axial and coronal images with a section thickness and interval of 4 mm. The reconstructions were performed on a Syngo Wizard commercially available console system (Siemens Medical Solutions, Forchheim, Germany). The entire process was performed by technicians at the operator console. The 4-mm-thick axial and 4-mm-thick coronal images were then transferred to a M-view picture archiving and communications system (Marotec Medical System, Seoul, Korea) as a separate series of images for subsequent interpretation.

Image Analysis

The positions of the appendix and the cecum were determined in consensus by two radiologists, each with more than 5 years of clinical experience in abdominal imaging, based on the axial and coronal reformatted images. The detailed positions of the appendix were defined and reclassified based on all possible positions described in the previously published literature and found by clinical experience not to be overlapping. The modified and detailed classification system consisted of eight possible appendiceal positions: type 1 (antececal position), in which the

tip of the appendix is located in front of the cecum (Figs. 1, 2A); type 2 (preileal position), in which the tip of the appendix is directed upward and above the horizontal line defined by the iliac crest and anterior to the terminal ileum (Figs. 1, 2B); type 3 (postileal position), in which the tip of the appendix is directed upward and is above the horizontal line defined by the iliac crest and posterior to the terminal ileum (Figs. 1, 2C); type 4 (subileal position), in which the tip of the appendix is in the peritoneal cavity caudal to the terminal ileum and toward the sacral promontory (Figs. 1, 2D); type 5 (subcecal position), in which the appendix is located beneath the caput ceci and in the iliac fossa and lateral umbilical fossa, but not below the right external iliac

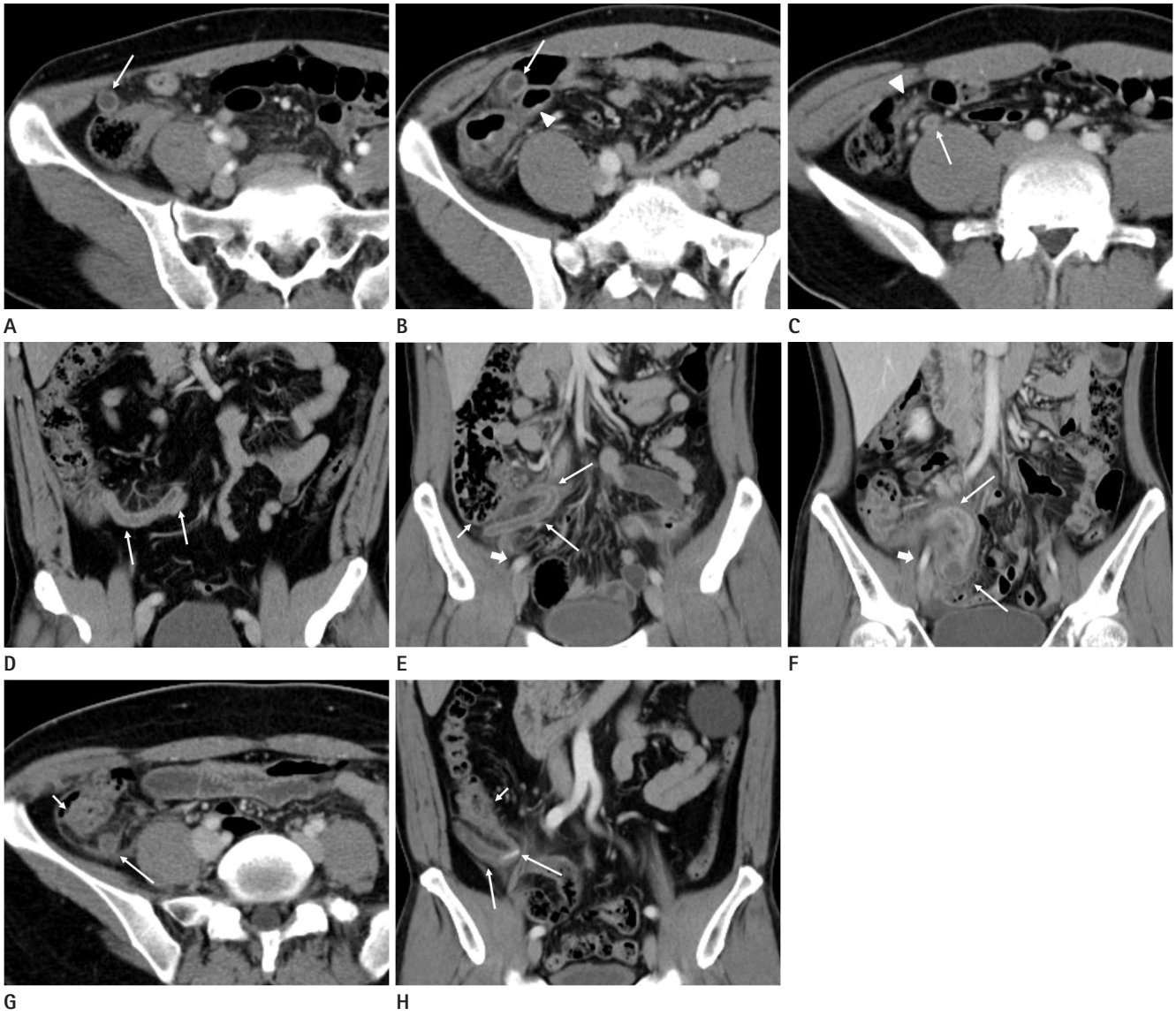

Fig. 2. Eight types of appendiceal positions seen on contrast-enhanced multidetector CT scans.
A. Axial image shows an inflamed appendix (arrow) located in front of the cecum (type 1).
B. Axial image reveals an inflamed appendix (arrow) directed upward and anterior to the terminal ileum (arrowhead) (type 2).
C. Axial image demonstrates an inflamed appendix (arrow) directed upward and posterior to the terminal ileum (arrowhead) (type 3).
D. Coronal reformatted image shows an inflamed appendix (arrows) directed toward the sacral promontory in the peritoneal cavity (type 4).
E. Coronal reformatted image reveals an inflamed appendix (long arrows) located beneath the cecum (short arrow) and in the iliac fossa and lateral umbilical fossa, although not beyond the external iliac vessels (thick arrow) (type 5).
F. Coronal reformatted image demonstrates an inflamed appendix (arrows) located in the true pelvic peritoneal cavity and with the tip located below the right external iliac vessels (thick arrow) (type 6).
G. Axial image demonstrates an inflamed appendix (long arrow) with the tip posterior to the cecum (short arrow) (type 7).
H. Coronal reformatted image shows an inflamed appendix (long arrows) with the tip posterolateral or lateral to the cecum (short arrow) (type 8).

vessels (Figs. 1, 2E); type 6 (deep pelvic position), in which the appendix is lying in the pelvic peritoneal cavity with the tip located below the right external iliac vessels (Figs. 1, 2F); type 7 (retrocecal position), in which the tip of the appendix is posterior to the cecum (Figs. 1, 2G); and type 8 (paracecal position), in which the tip of the appendix is posterolateral or lateral to the cecum (Figs. 1, 2H).

Statistical Analysis

We compared the frequencies of the appendiceal positions in relationship to the pathologic status and patient gender. Statistical analysis was performed using the chi-square test. A p value of < 0.05 was considered statistically significant.

RESULTS

In our study population, the subcecal position was most frequently encountered in 495 (42.8%) of the 1157 patients. The deep pelvic position and the subileal position were encountered in 187 (16.2%) and 149 (12.9%) patients, respectively. In the remaining patients, 126 (10.9%) patients had the appendix in the retrocecal, 104 (9.0%) in the postileal, 41 (3.5%) in the antececal, 35 (3.0%) in the paracecal, and 20 (1.7%) in the preileal position. The frequency analysis results showed different characteristics according to patient's gender and the inflamed state (Table 1). The gender differences seen in the relative frequency of the appendiceal positions were: type 1 antececal (male subgroup: 3.7% vs. female subgroup: 3.3%, $p = 0.004$); type 2 preileal (1.7% vs. 1.9%, $p = 0.113$); type 3 postileal (8.6% vs. 9.8%, $p < 0.001$); type 4 subileal (14.3% vs. 9.8%, $p < 0.001$); type 5 subcecal (47.5% vs. 32.7%, $p < 0.001$); type 6 deep pelvic (11.6% vs. 25.9%, $p = 0.836$); type 7 retrocecal (9.2% vs. 14.4%, $p = 0.017$); and type 8 paracecal (3.4% vs. 2.2%, $p < 0.001$). The differences between the relative frequency of the normal and inflamed subgroups are as follows: type 1 antececal (normal subgroup: 3.1% vs. inflamed subgroup: 4.1%, $p = 0.653$); type 2 preileal (0.8% vs. 2.8%, $p = 0.004$); type 3 postileal (10.2% vs. 7.6%, $p = 0.003$); type 4 subileal (14.0% vs. 11.6%, $p = 0.011$); type 5 subcecal (46.0% vs. 39.1%, $p < 0.001$); type 6 deep pelvic (14.2% vs. 18.4%, $p = 0.211$); type 7 retrocecal (9.1% vs. 12.9%, $p = 0.098$); and type 8 paracecal (2.6% vs. 3.5%, $p = 0.630$). According to patient gender, the antececal, postileal, subileal, subcecal, retrocecal, and paracecal positions showed a statistically significant male predominance. In terms of the pathologic state of the appendix, the preilieal, postileal, subileal, and subcecal positions showed a statistically significant lower incidence of inflamed appendix.

DISCUSSION

Previous studies have suggested that the tip of the vermiform appendix may be found in a variety of locations (4-10). From the standpoint of embryological theory, the position of the appendix could vary according to the degree of the counterclockwise rotation of the cecal base around the long axis from the right to the left during embryological development (4, 6). The standard surgical textbook and review articles describe the retrocecal position of the appendix as the most common site, based on Wakeley's results (5, 11-14). Wakeley (4) studied 10000 cadavers and reported retrocecal as the most common position of the appendix. However, several *in vivo* studies reported that the postileal, subcecal, and pelvic positions were seen more frequently than the retrocecal position. In a postmortem study, the position of the appendix would be mainly affected by gravity. In contrast, the *in vivo* location of the appendix would be determined by various factors such as the gravity, inflammation state, gender, internal bowel pressure, and movement of the cecum and adjacent bowels (7, 15). The exact comparison with results of previous *in vivo* studies is difficult because they used different classification systems (7-10). Our results are not in accord with that of previous *in vivo* CT studies (7, 10). These results are also different from a previous laparoscopic study that reported the pelvic position as the most common site of the appendix (8). Increased intraperitoneal pressure due to insufflations of carbon dioxide gas during laparoscopic surgery may be responsible for difference in the frequencies of appendiceal positions.

To date, no statistically significant results regarding gender differences in the appendiceal position have been reported (9, 16). However, we found a statistically significant gender difference in the appendiceal position, with a higher male prevalence in the antececal, postileal, subileal, and subcecal positions (Table 1). These findings could be explained by the gender differences in the development of the appendix, the cecum, as well as the pelvis. Assuming that there is no gender difference in the appendiceal length and the relative positions of the cecum and ap-

Table 1. Incidence of the Appendiceal Positions According to Patient Gender and Pathologic State

Positions	All Subjects	Male	Female	*p* Value	Normal	Inflamed	*p* Value
Antececal	41 (3.5)	29 (3.7)	12 (3.3)	0.004	19 (3.1)	22 (4.1)	0.653
Preileal	20 (1.7)	13 (1.7)	7 (1.9)	0.113	5 (0.8)	15 (2.8)	0.004
Postileal	104 (9.0)	68 (8.6)	36 (9.8)	< 0.001	63 (10.2)	41 (7.6)	0.003
Subileal	149 (12.9)	113 (14.3)	36 (9.8)	< 0.001	86 (14.0)	63 (11.6)	0.011
Subcecal	495 (42.8)	375 (47.5)	120 (32.7)	< 0.001	283 (46.0)	212 (39.1)	< 0.001
Deep pelvic	187 (16.2)	92 (11.6)	95 (25.9)	0.836	87 (14.2)	100 (18.4)	0.211
Retrocecal	126 (10.9)	73 (9.2)	53 (14.4)	0.017	56 (9.1)	70 (12.9)	0.098
Paracecal	35 (3.0)	27 (3.4)	8 (2.2)	< 0.001	16 (2.6)	19 (3.5)	0.630
Total	1157 (100)	790 (68.3)	367 (31.7)		615 (53.2)	542 (46.8)	

Note.—All figures are numbers (%).

pendix are fixed, the size of the false pelvis (pelvis major) could be an important factor in determining the location of the appendix. The pelvis is divided into the pelvis major (false pelvis), which is part of the abdominal cavity, and the pelvis minor (true pelvis), which contains the pelvic cavity. The female pelvis major is shallower than that of the male (17). Deeper pelvis major in males could be one explanation for the high frequency of the subcecal, postileal, and subileal positions in the male subgroup. The difference in the descent of the ovaries and testes as well as the peritoneal fixation could also cause differences in the location of the normal appendix in males and females (4, 16). In our male subgroup, the higher incidence of the antececal position may be related to the larger space and anterior-posterior diameter of the male pelvis major. According to one study examining fetuses, the location of the vermiform appendix was predominantly subcecal in the male fetuses while being postileal in the female fetuses (16). After birth, the location of the appendix shows many possible configurations due to asymmetric cecal enlargement, development of haustra, and morphological changes in the pelvic cavity (17, 18). The high incidence of the subcecal position at birth and the larger volume of the pelvis major may be reasons for the high incidence of the appendiceal positions near the cecum, including the retrocecal and paracecal positions, seen in the male patients.

Two studies reported the frequency of the appendiceal position in the normal and inflamed appendix groups, although it did not find a statistically significant difference between the two groups (9, 19). However, our results revealed a statistically significant difference between the normal and inflamed subgroups in the preileal, postileal, subileal, and subcecal positions (Table 1). Positional changes caused by intraluminal pressure and the larger space of the pelvis major rather than the pelvis minor, could explain the low frequency of the postileal, subileal, and subcecal postions in the inflamed subgroup. As with the penile erection mechanism, obstruction of the appendiceal orifice increases the intraluminal pressure and induces positional change. The larger space of the pelvis major makes this positional change more likely than in the pelvis minor. Interestingly, our study revealed that the preileal position was found more frequently in the inflamed subgroup. One previous study suggested that the non-retrocecal position, including the preileal position, was more prone to inflammation (20). Even with the increase of intraluminal pressure caused by luminal obstruction in the setting of appendicitis, the appendix seems to maintain its preileal position, probably due to fixation caused by adhesion to the adjacent mesentery and omentum as a result of periappendiceal inflammation.

The limitation of our study was inherent due to its retrospective nature as we did not randomly select and assign patients into the normal and inflamed groups. Limited selection of the two subgroups with different purposes of the MDCT examinations may have introduced a selection bias.

In conclusion, contrary to the common assumption that the position of the appendix is retrocecal, *in-vivo* appendices are found more often in the subcecal and deep pelvic positions on MDCT images. The relative frequency of various positions of the appendix could also differ according to the patient gender and the pathologic state of the appendix.

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Multidetector CT에서 보인 우하복부에 위치한 충수의 생체 내 위치[1]

이수림[1] · 구영미[1] · 최병길[2] · 변재영[2]

목적: 복부 multidetector CT (이하 MDCT)에서 보인 우하복부에 위치한 충수의 위치를 자세히 분류하고 환자의 성별과 병리학적 상태에 따른 위치의 차이를 알아보고자 하였다.

대상과 방법: 2008년 1월부터 2010년 12월까지 MDCT를 촬영하고 수술로 확인된 충수염 환자 542명과 건강검진 목적으로 시행한 MDCT에서 우하복부에 위치한 정상 충수가 보였던 615명을 포함한 1157명의 환자를 대상으로 하였다. 충수의 위치를 맹장, 회장, 외장골혈관을 고려하여 1형 맹장의 전방, 2형 말단회장의 전방, 3형 말단회장의 후방, 4형 회장의 하방, 5형 맹장의 하방, 6형 심부 골반강, 7형 맹장의 후방, 8형 맹장의 외측방으로 구분하였다.

결과: 분석한 환자의 복부 MDCT 소견에서 1형 3.5%, 2형 1.7%, 3형 9.0%, 4형 12.9%, 5형 42.3%, 6형 16.2%, 7형 10.9%, 8형 3.0%의 빈도를 보였다. 성별에 따라서 분석한 충수돌기의 상대적인 위치의 빈도는 1형(남성: 3.7% 대 여성: 3.3%), 3형(8.6% 대 9.8%), 4형(47.5% 대 32.7%), 5형(11.6% 대 25.9%), 7형(9.2% 대 14.4%), 8형(3.4% 대 2.2%)에서, 염증의 유무에 따른 분석에서는 2형(정상군: 0.8% 대 환자군: 2.8%), 3형(10.2% 대 7.6%), 4형(14.0% 대 11.6%)과 5형(46.0% 대 39.1%)에서 통계적으로 차이를 보였다.

결론: 일반적으로 알려진 가정과는 달리 복부 MDCT에서 보인 우하복부 충수의 위치는 맹장의 후방보다 맹장의 하방에서 더 자주 발견되며, 충수 위치의 상대빈도는 염증의 유무와 환자의 성별에 따라서 차이를 보였다.

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