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MINIREVIEWS

Review of small-bowel cleansing scales in capsule endoscopy: A panoply of choices

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Abstract

Evaluation of the quality of small-bowel cleansing is required to assess the reliability of findings in capsule endoscopy (CE). Moreover, consensus regarding the need of intestinal preparation for CE remains to be achieved. The presence of multiple grading scales for small-bowel preparation in CE, which are time-consuming and complicated, adds difficulty to the comparison of different small-bowel cleansing regimens and their application in clinical practice. Nowadays, a validated scale universally accepted for grading small-bowel cleansing is lacking. In fact, there are numerous grading systems with very different technical characteristics, namely, the parameters and the portion of the CE video that are analyzed, the objectivity of the analysis, the lesser or greater dependency on the operator, and the validation of the score. The authors performed a review which aims to systematize and summarize currently available small-bowel grading scales in CE.

Key words: Capsule endoscopy; Small-bowel; Small-bowel Cleansing Scales; Enteroscopy; Grading

Core tip: Evaluation of the quality of small-bowel cleansing is required to assess the reliability of findings in capsule endoscopy (CE). Moreover, consensus regarding the need of intestinal preparation for CE remains to be achieved. Currently, there are numerous grading systems with very different technical characteristics, namely, the parameters and the portion of the CE video that are analyzed, the objectivity of the analysis, the lesser or greater dependency on the operator, and the validation of the score. The main purpose of this review is to gather and concise all small-bowel cleansing scales in CE available, as this has not been previously performed.

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INTRODUCTION

Capsule endoscopy (CE) was introduced into clinical practice in 2001, and since then it has assumed an important role in the study of numerous small-bowel disorders, namely obscure gastrointestinal bleeding, Crohn's disease, small-bowel tumors, polyposis syndromes and celiac disease[1-4].

The diagnostic yield of CE and quality of mucosal visualization may be impaired by the presence of air bubbles, bile and intestinal debris. Moreover, evidence for the optimal approach for small-bowel preparation before CE is lacking. These research and clinical aspects emphasize the importance of a grading scale of small-bowel cleansing in CE, as the evaluation of the quality of small-bowel preparation is necessary to assess the accuracy of the findings in CE[5,6] and the presence of a universal grading score would contribute to standardize CE protocols and to compare the results of different methods of small-bowel preparation[6,7].

Nowadays, a validated scale universally accepted for grading small-bowel cleansing is lacking. In fact, there are numerous grading systems with very different technical characteristics, namely, the parameters and the portion of the CE video that are analysed, the objectivity of the analysis, the lesser or greater dependency on the operator, and the validation of the score.

This review aims to systematize and summarize available small-bowel grading scales in CE (Tables 1 and 2).

DISCUSSION

Computer dependent scales

In recent years, computer grading scales to evaluate small-bowel cleanliness have been developed and validated (Table 1)[6,8]. These computed scores are based on objective measurements and may potentially overcome the disadvantages of human dependent scoring systems, namely the subjectivity, complexity and lengthiness. Furthermore, the incorporation of these scores into the CE reading software would result in a fully automated score[6].

Van Weyenberg *et al*[6] developed a computed assessment of cleansing (CAC) score, based on objective measurements of colour intensities in red and green channels of the tissue colour bar of the Rapid Reader® in the PillCam CE® system. The authors assumed that if the tissue colour bar, which comprises the summary of all CE images, was converted to the red-green-blue mode (RGB), the relation between the mean intensity of the red and green channels could be used as a measure of small-bowel cleanliness. Therefore, areas of adequate mucosal visibility could be associated with high values of red intensity and low values of green intensity. Conversely, areas with high amount of intestinal debris could be associated with low values of red intensity and high values of green intensity. The mean intensity values of the green and red channels of the small-bowel segment of the tissue colour bar were determined using the histogram function of a photo-editing software. The final score was obtained by applying the formula [(Mean intensity of the red channel)/(Mean intensity of the green channel) - 1] × 10. The CAC score was further compared with three validated grading scales[5]. In this study, the authors concluded that the CAC score had a very good reproducibility and could be used to assess the overall and segmental quality of small-bowel cleanliness. Moreover, CAC score achieved a strong agreement with previously validated subjective scales[5].

Due to the potential advantage of a computed score of small-bowel cleansing in CE, other studies were developed to adapt the CAC score to the OMOM and MiroCam CE systems[9,10]. Ponte *et al*[10] aimed to adapt the CAC score to the MiroCam system and to evaluate its reliability with the MiroCam® CE system. The MiroCam reading software (Miroview Client®) has a function named "Map View" which displays a bar containing a representation of all images recorded by the CE. Although this bar can be zoomed, without zoom the bar is similar to the tissue colour bar of the Rapid Reader® in the PillCam® CE system. Applying the same methodology as used by Van Weyenberg *et al*[6], the mean intensities of the red and green channels of the small-bowel segment of the "Map View" bar of Miroview Client® were determined using the histogram option of two photo-editing softwares. The authors concluded that the reproducibility of the CAC score was excellent as the results of the two different photo-editing softwares were identical, resulting in an intra-test reliability of 1.0 ($P < 0.001$). CAC score achieved a moderate agreement with previously validated subjective scales[5]. The results were slightly inferior to those of Van Weyenberg *et al*[6] but still significant and reinforce the feasibility of the CAC score in the assessment of the intestinal preparation in CE systems other than the PillCam®.

More recently, Klein *et al*[8] designed and validated a computer algorithm based on the pixels in the tissue colour bar of the CE PillCam® system. To develop this algorithm, multiple points on the colour bar corresponding to a spectrum of inadequately or adequately segments were marked and defined as "adequate" or "inadequate" criteria. These criteria were defined based on the pixel color and hue derived from the pixel RGB values. A computer algorithm based on the pixels in each of the marked areas was then created, and applied to the entire tissue colour bar. Each pixel of the tissue colour bar was independently compared to the predefined criteria "adequate"/"inadequate". The computer algorithm then calculated and summarized the total number of "inadequate" pixels, their locations, the "adequate" to "inadequate" pixel ratio and the longest duration of consecutive "inadequate" pixels in the colour bar. Based on the image analysis results, the algorithm quantified

Table 1 Computer dependent scales

Ref.	Computer or human dependent	Capsule endoscopy system	Type of preparation	Qualitative/ quantitative scale	Reproducibility	Parameters evaluated	Entire video, segments of video or consecutive single frames	Time-consuming	Easy to perform[1]	Global assessment[2]
Van Weyenberg *et al*[6]	Computer dependent	PillCam	2 L of PEG	Quantitative	$r = 1.0$	Mean intensity values of the green and red channels of the small-bowel segment of the tissue colour bar	Tissue colour bar	No	ΔΔΔΔΔ	ΔΔΔΔ
Ponte *et al*[10]	Computer dependent	MiroCam	Clear liquid diet and overnight fast	Quantitative	$r = 1.0$	Mean intensity values of the green and red channels of the small-bowel segment of the tissue colour bar	Map view bar	No	ΔΔΔΔΔ	ΔΔΔΔ
Klein *et al*[8]	Computer dependent	PillCam	Clear liquid diet and overnight fast	Quantitative	Kappa = 0.9	Pixels of the small-bowel segment of the tissue colour bar	Tissue colour bar	No	ΔΔΔΔΔ	ΔΔΔΔ

[1]Graduation from Δ to ΔΔΔΔΔ, with higher classifications corresponding to easier scales; [2]Graduation from Δ to ΔΔΔΔΔ, with higher classifications corresponding to better scales. PEG: Polyethylene glycol.

the level of bowel preparation and a final result based on predetermined criteria was produced. Computer analysis restricted to adequate and inadequate cases yielded accurate classification of bowel preparation when compared to the subjective opinion of the authors with a sensitivity of 95%, specificity 82%, total accuracy 90%, and kappa 0.79.

OPERATOR DEPENDENT SCALES

The numerous operator dependent scales which have been developed are summarized in Table 2. Throughout this revision, the authors classified the scales taking into consideration the type of parameters that were used: Quantitative and/or qualitative.

Quantitative parameters

Park *et al*[11,12] developed and validated an operator dependent grading score which consists of the assessment of two parameters in the PillCam® CE, in patients who received 4 L of polyethylene glycol (PEG). The first parameter corresponds to the percentage of mucosa visualized which is classified from 0 to 3: Score 3, $\geqslant$ 75%; score 2, 50%-75%; score 1, 25%-50%; score 0, $\leqslant$ 25%. The second parameter refers to the degree of obscuration by bubbles, debris, and bile which is also classified from 0 to 3: score 3 (no obscuration), < 5%; score 2 (mild obscuration), 5%-25%; score 1 (moderate obscuration), 25%-50%; score 0 (severe obscuration), $\geqslant$ 50%. The two parameters of the Park's score were evaluated in images from the entire small bowel selected at 5-min intervals (1 frame/5 min). Mean scores of each parameter were obtained by summing the scores of all selected images and dividing them by the number of frames examined. The final score was then calculated by the overall average of the two mean scores. This scale showed an excellent inter-observer, intra-patient and intra-observer agreement. Moreover, the authors proposed a cut-off value of 2.25 for an adequate small-bowel preparation. The main limitation of this grading scale is the use of only 1 frame at 5 min intervals in the analysis of small bowel cleansing, which leaves the great majority of available frames unanalysed.

Brotz *et al*[5] developed and validated three grading systems in CE PillCam®, namely a quantitative index (QI), a qualitative evaluation (QE) and an overall adequacy assessment (OAA). As the QE and OAA are based on qualitative parameters, these scores are described in the corresponding section. In their study, patients received a clear liquid diet the day before the exam and an overnight fast. The QI was obtained by assessment of 5 elements [(1) Mucosal visualization; (2) Fluid and debris; (3) Bubbles; (4) Bile/chyme staining, and (5) Brightness], according to a 3-point scale (0 = severe impairment, 1 = moderate impairment, 2 = minimal impairment), leading to a total score ranging from 0 to 10, with higher scores corresponding to better cleansing. QI obtained a moderate interobserver agreement. As opposed to Park's score,

Table 2 Human dependent scales

Ref.	Computer or human dependent	Capsule endoscopy system	Type of preparation	Qualitative/ quantitative scale	Correlation coefficient	Parameters evaluated	Entire video, segments of video or consecutive single frames	Time-consuming	Easy to perform[1]	Global assessment[2]
Park *et al*[11]	Human dependent	PillCam	4 L of PEG	Quantitative	ICC = 0.80	Proportion of visualized mucosa and degree of obscuration by bubbles, debris, and bile	Consecutive single frames	Yes	ΔΔ	ΔΔΔ
QI - Brotz *et al*[5]	Human dependent	PillCam	Clear liquid diet and overnight fast	Quantitative	ICC = 0.47	QI based on percentage of mucosa visualized, fluid and debris, bubbles, bile/chyme staining, and brightness	Entire video	No	ΔΔΔΔ	ΔΔΔΔΔ
Spada *et al*[13]	Human dependent	PillCam	Clear liquid diet and overnight fast, or 2 L of PEG and simethicone	Quantitative	Kappa = 0.75-0.9	Proportion of mucosa visualized	Entire video	Yes	Δ	ΔΔΔ
Oliva *et al*[14]	Human dependent	PillCam	Clear liquid diet and overnight fast, or 25 or 50 mL/kg of PEG, and/or 20 mL of simethicone	Quantitative	Kappa = 0.89	Proportion of mucosa visualized	Consecutive single frames	Yes	ΔΔ	ΔΔΔ
van Tuyl *et al*[15]	Human dependent	PillCam	Clear liquid diet and overnight fast, or 1 L of PEG, or 2 L of PEG	Quantitative	Kappa = 0.78	Proportion of mucosa visualized	Segments of video	No	ΔΔ	ΔΔΔ
Caddy *et al*[16]	Human dependent	-	250 mL sodium picosulphate plus 500 mL PEG with or without erythromycin	Quantitative	Kappa = 0.3	Proportion of visualized mucosa	Entire video	No	ΔΔΔΔ	ΔΔ
Viazis *et al*[19]	Human dependent	PillCam	Clear liquid diet and overnight fast or 2 L PEG	Quantitative	-	Proportion of unclean mucosa due to intestinal debris	Entire video	Yes	ΔΔΔ	ΔΔ
Kantianis *et al*[22]	Human dependent	PillCam	2 and 4 L of PEG	Quantitative	-	Proportion of mucosa visualized	Consecutive single frames	Yes	Δ	Δ
Chen *et al*[23]	Human dependent	OMOM	Clear liquid diet and overnight fast, or 250 mL mannitol with or without simethicone	Quantitative	-	Proportion of mucosa visualized	Consecutive single frames	Yes	Δ	Δ
Rosa *et al*[25]	Human dependent	PillCam	Clear liquid diet and overnight fast, or 2 L of PEG with or without simethicone	Quantitative	-	Proportion of visualized mucosa	Entire video	Yes	ΔΔ	ΔΔ
Niv *et al*[26]	Human dependent	PillCam	Clear liquid diet and overnight fast, or NaP	Quantitative	-	Proportion of SBTT with invisible mucosa	Entire video	No	ΔΔΔ	ΔΔΔ
OAA - Brotz *et al*[5]	Human dependent	PillCam	Clear liquid diet and overnight fast	Qualitative	Kappa = 0.41	Overall assessment of small-bowel cleansing	Entire video	No	ΔΔΔΔΔ	ΔΔΔ
QE - Brotz *et al*[5]	Human dependent	PillCam	Clear liquid diet and overnight fast	Qualitative	Kappa = 0.20	QE based on percentage of mucosa visualized, fluid and debris, bubbles, bile/chyme staining, and brightness	Entire video	No	ΔΔΔΔ	ΔΔΔ
Albert *et al*[28]	Human dependent	PillCam	Overnight fast or simethicone	Qualitative	r = 0.89 (segment A)	Mucosal invisibility due to intraluminal bubbles	Segments of video	No	ΔΔΔ	ΔΔΔ

					and $r = 0.79$ (segment B)					
Pons Beltrán *et al*[29]	Human dependent	PillCam	Clear liquid diet, or 90 mL NaP, or 4 L of PEG	Qualitative	Kappa = 0.38	Amounts of enteric residues	Entire video	No	ΔΔΔΔ	ΔΔΔ
Ninomiya *et al*[30]	Human dependent	PillCam	Clear liquid diet and overnight fast, or citrate magnesium	Qualitative	-	Bubbles, food residues and intestinal juice color	Consecutive single frames	Yes	ΔΔ	ΔΔ
Esaki *et al*[31]	Human dependent	PillCam	Simethicone or magnesium citrate	Quantitative and Qualitative	r = 0.77-0.88	Fluid transparency and proportion of non-visualized mucosa	Entire video	Yes	ΔΔΔ	ΔΔΔΔ
Dai *et al*[32]	Human dependent	PillCam	4 L of PEG or overnight fast	Quantitative and qualitative	Kappa = 0.56	Proportion of visualized mucosa and overall visibility	Segments of video	Yes	ΔΔ	ΔΔΔ
Lapalus *et al*[33]	Human dependent	PillCam	Clear liquid diet and overnight fast, or NaP	Quantitative and qualitative	$r = 0.55$-0.8	Proportion of visualized mucosa and amounts of enteric liquid and bubbles	Segments of video	No	ΔΔΔ	ΔΔΔ
Hooks *et al*[34]	Human dependent	PillCam	Clear liquid diet and overnight fast, with or without lubiprostone	Quantitative and qualitative	-	Proportion of mucosa visualized and amounts of enteric debris	Entire video and segments of video	No	ΔΔΔ	ΔΔΔΔ

[1]Graduation from Δ to ΔΔΔΔΔ, with higher classifications corresponding to easier scales; [2]Graduation from Δ to ΔΔΔΔΔ, with higher classifications corresponding to better scales. PEG: Polyethylene glycol; QI: Quantitative index; QE: Qualitative evaluation; OAA: Overall adequacy assessment; ICC: Intraclass correlation coefficient.

the QI uses all available frames in the evaluation of small bowel cleansing.

Spada *et al*[13] developed an operator dependent small-bowel scale in PillCam® CE to evaluate different regimens of intestinal preparation. It consisted of a classification in "complete", "incomplete" and "insufficient" if visualization of the mucosa was equal to 100%, between 50%-100%, or less than 50%, respectively. This assessment was evaluated minute by minute and the overall small-bowel cleansing score was then calculated by determining the percentage of each classification. If different grades of cleansing level were present in each minute, the overall preparation level per minute was synthesized as follows: "complete", if the entire small-bowel wall was assessable for 35 s or more, with no more than 5 s of "insufficient" cleansing; "insufficient" if less than 50% of the small bowel wall was visible for 20 s or more; and "incomplete" in all the other cases. The authors achieved a good-to-excellent inter-observer agreement, with a kappa = 0.9 for completely clean and insufficiently clean small-bowel and a kappa = 0.75 for incompletely clean small bowel. The main limitation is that this scale is very cumbersome to perform and time-consuming.

In a study in paediatric patients using PillCam® CE, Oliva *et al*[14] applied a method of evaluation of small-bowel cleanliness similar to the score of Park *et al*[11]. The small-bowel transit time (SBTT) was divided into five equal segments and in each segment an image was picked at 5-min intervals. Every single image was evaluated according to the percentage of visualized mucosal surface area as follows: (1) < 25%; (2) 25%-49%; (3) 50%-74%; (4) 75%-89%; and (5) > 90%. Mean scores for each segment were obtained by summing the scores of all selected images and dividing the sum by the number of images. The total score for each patient was obtained by adding the five segmental scores. The authors achieved an excellent interobserver agreement (kappa 0.89) with this scale. This scale has, however, the same sampling limitations as the Park's scale.

In order to compare different small-bowel preparations for PillCam® CE, van Tuyl *et al*[15], developed a grading scale which analysed the amount of mucosa visualized. For each CE, the SBTT was divided in four quartiles and the first ten minutes of each quartile was classified according to the percentage of mucosa visualized. Moreover, the last ten minutes of the small intestine were also analysed. The visualization of the mucosa was graded into 6 categories: less than 5%, 5%-24%, 25%-49%, 50%-74%, 75%-95%, or more than 95%. Mucosal visibility was considered good if more than 75% of the mucosa was observed, otherwise it was graded as poor. Interobserver agreement for mucosal visualization was high with a kappa of 0.78. Although this scale is easier to perform than Park's and Oliva's scales, the level of cleanliness of significant portions of the CE video remain unexamined.

Caddy *et al*[16] developed a 4-graded scale which was further adopted in other studies[17,18], to analyse the effect of erythromycin in the completion rate of CE to the cecum. The scale consisted of the percentage of mucosa visualized which was graded as excellent, good, fair or poor if ⩾ 95%, 75%-94%, 50%-74%, and < 50% of the mucosa was visualized, respectively. The authors reported a poor inter-observer agreement with kappa 0.3. Nevertheless, if the parameters excellent and good were aggregated, a good level of agreement was achieved with a kappa of 0.7. Although this scale is easy and fast to implement, its low reproducibility limits its utilization.

In order to analyse the difference in small-bowel cleansing in patients receiving 2 L of a PEG and electrolyte lavage solution or ingesting a clear liquid diet during the entire day before PillCam® CE, Viazis *et al*[19] developed a classification which was subsequently adopted by other authors[20,21]. The enteric mucosa was classified as clean if less than 25% of it was covered by debris or intestinal contents. This small-bowel cleansing score consisted of recording the exact period of time during which the mucosa was considered unclean. If the total period was inferior to 10% of the SBTT the cleansing was classified was "adequate". Conversely, it was classified as "inadequate" if the period of time of unclean mucosa exceeded 10% of the SBTT. Despite the authors recognized the simplicity of use of this classification, this scale lacks validity and is cumbersome to implement.

In the study developed by Kantianis *et al*[22] to compare small-bowel cleansing using 2 L or 4 L of PEG, a 3-scale scoring system according to the visibility of the small-bowel mucosa in consecutive single frames captured every 3 min of the SBTT was adopted. Three points were given when 60%-100% of the mucosa was visible, 2 points when visibility of the mucosa ranged from 30% to 60% and 1 point if less than 30% of the mucosa was visible. The final score was obtained by dividing the sum of scores of each frame by (the total number of frames × 3), thus leading to a cleansing coefficient range between 0.33 (indicating the worst preparation) and 1.00 (indicating the ideal preparation). Although simple, the same limitations as other scales like Park's that use sampling frames remains.

In another study to evaluate different small-bowel regimens with mannitol and simethicone, Chen *et al*[23] created a method of evaluation of small-bowel cleansing using consecutive single frames of the small-bowel video selected at 3 min intervals. In each frame, the area of visible mucosa was outlined and calculated, as well as the area of the entire image. The ratio of both areas was graded as excellent (3 points), good (2 points), fair (1 point) and poor (0 point) if the ratio was 76%-100%, 51%-75%, 26%-50%, and 0%-25%, respectively. For overall assessment, small bowel cleansing for proximal and distal small bowel was separately graded, and considered adequate if the percentage of single frames assessed that was graded as good or excellent was ⩾ 85%, and inadequate otherwise. In a subsequent study[9], the same group of authors compared this scale, which they designated as assessment of cleansing score (AAC) with the CAC developed by Van Weyenberg *et al*[6]. The authors concluded that the assessment of interobserver reliability of these two scores showed a high intraclass correlation coefficient (ICC) and no significant difference between them was found using the kappa statistic. For AAC, the ICC was 0.791.

Similar to other studies[19,21,24], a 4-point scale based on the proportion of enteric mucosa visualized without any liquid, bubbles or debris was adopted by Rosa *et al*[25] in order to assess the difference in small-bowel cleansing using a liquid diet and an overnight fast or 2 L of PEG with or without simethicone. The authors recorded with the time counter of the Rapid Reader® software the exact time period during which the mucosa was not clean, due to contamination with fluid or debris. The presence of bubbles was evaluated separately. Small-bowel cleansing was graded in excellent in cases of perfect visualization in every small-bowel segments, in good where > 75% of the mucosa was in perfect conditions, with some fluid or debris remaining not interfering with the examination, in fair if 50%-75% of the mucosa was clean, with presence of enough fluid, bubbles or debris to prevent completely reliable examination and in poor if < 50% of the mucosa was clean with the presence of significant amounts of fluid or debris. The authors considered an adequate small-bowel preparation if > 75% of the mucosa was clean, corresponding to the "excellent" and "good" scores.

Niv *et al*[26] developed a cleansing scale taking into account the proportion of the SBTT which was filled with intraluminal fluid preventing visualization of the mucosa. The proportion of non-ideal visualization was determined, dividing the time duration of non-ideal visualization recorded with the time counter of the Rapid Reader® software by the SBTT. The degree of cleanliness was graded as good if this ratio is < 20%, moderate when between 21%-35% and poor if > 35%.

Qualitative parameters

As previously detailed, Brotz *et al*[5] developed and validated three grading systems in PillCam® CE system, namely a QI, a QE and an OAA. The QE was categorized in poor, fair, good and excellent according to the percentage of enteric mucosa visualized, the amounts of debris, bubbles, bile and level of brightness (Table 3). The OAA consisted of global assessment of small-bowel cleansing and rated as "adequate" or "inadequate". The authors concluded that the QI had the greatest reliability, the reliability for the OAA was in the moderate range, while the QE performed more poorly. Quantitative scales provide parameters more uniformly assessed thus reducing the subjective interpretation and providing a better evaluation of the small-bowel preparation level. These scales were adopted in other studies[27].

Albert *et al*[28] adopted a 4-grade system based on qualitative parameters do assess bowel preparation using the PillCam® CE system. Two segments of 1-h duration were selected, with the first segment (segment A) starting immediately after passage of CE through the

Table 3 Qualitative evaluation of small-bowel cleanliness developed by Brotz *et al*[5]

Qualitative evaluation
Excellent: Visualization of ⩾ 90% of mucosa; no or minimal, fluid and debris, bubbles, and bile/chyme staining; no or minimal, reduction of brightness
Good: Visualization of ⩾ 90% of mucosa; mild fluid and debris, bubbles, and bile/chyme staining; mildly reduced brightness
Fair: Visualization of < 90% of mucosa; moderate fluid and debris, bubbles, and bile/chyme staining; moderately reduced brightness
Poor: Visualization of < 80% of mucosa; excessive fluid and debris, bubbles, and bile/chyme staining; severely reduced brightness

Table 4 Grading scale of intestinal cleansing proposed by Ninomiya *et al*[30]

Residue elimination effect	
4 points	No food residue at all, clear views
3 points	Some food residue present, not interfering with observations
2 points	Quite a lot of food residue, slightly hindering observations
1 points	Large amount of food residue, hindering observations
Intestinal juice clarity	
4 points	Intestinal juice is clear, clear views
3 points	Intestinal juice is light colored and does not interfere with observations
2 points	Intestinal juice is light dark colored, slightly hindering observation
1 points	Intestinal juice is dark colored and interferes with observations
Froth reduction effect	
4 points	No froth, clear views
3 points	Froth present, not interfering with observations
2 points	Quite a lot of froth, slightly hindering observations
1 points	Large amount of froth, hindering observations

pylorus and the other segment (segment B) finishing before the passage through the ileocecal valve. In each segment, the impairment of visibility of the mucosa due to intraluminal gas bubbles was evaluated and graded as (0) if there was no intraluminal gas; (1) if only a few gas bubbles not limiting the interpretation were seen; (2) if there was an increased amount of intraluminal gas bubbles which moderately impaired visibility; and (3) if a large amount of gas bubbles which severely limited the interpretation of mucosal surface were found. Of note, the amount of food residue or small-bowel secretions was not analysed. This grading scale obtained a good interobserver agreement, with a Spearman correlation of $r = 0.89$ in segment A ($P < 0.001$) and $r = 0.79$ ($P < 0.001$) in segment B. This scale also suffers from sampling error limitations, as only two segments with 1-h duration from the entire CE video are analysed.

Pons Beltrán *et al*[29] proposed a 4-point subjective score of "poor", if there was intestinal content impending evaluation, "fair", if there was liquid or solid intestinal content allowing evaluation, "good", if there was no intestinal content or some content in the terminal ileum and/or cecum and "excellent", if there was no intestinal content in any part of the small-bowel or the cecum. Differently from QE, the enteric level of cleanliness in PillCam® CE was judged according to the amount of intestinal content throughout the small-bowel and cecum. Due to the subjectivity of the assessed parameter, the interobserver agreement was fair, with a kappa = 0.38.

In a study to assess the effect of magnesium citrate in small-bowel cleansing in PillCam® CE, Ninomiya *et al*[30] classified from 0 to 4, each of three parameters, namely food residue, intestinal juice clarity and bubbles (Table 4). After dividing the SBTT into three segments, images from each segment were recorded and classified according to the three parameters.

Quantitative and qualitative parameters

Esaki *et al*[31] developed a grading scale using the PillCam® CE system to assess the differences in small bowel preparation with magnesium citrate or simethicone. After determining the terciles of the SBTT, the authors evaluated the fluid transparency and mucosal invisibility in each segment, according to Table 5. The grade of fluid transparency was determined according to the predominant grade in each segment. The grade of mucosal invisibility was determined in each video segment by the proportion of duration in which air bubbles or food residues disturbed more than 50% of its visualization and interpretation. The overall score for each parameter corresponded to the sum of the grades obtained in each segment, ranging from 3 to 12. The authors achieved an excellent interobserver agreement in each segment analysed, with the results showing a strong correlation ($r = 0.88$, $P < 0.0001$ in the first tercile; $r = 0.77$, $P < 0.0001$ in the second tercile; $r = 0.81$, $P < 0.0001$ in the third tercile). Conversely, this grading system was applied by other authors who obtained a moderate intra-observer agreement (kappa = 0.52) and a poor interobserver agreement (kappa = 0.29 for fluid transparency and kappa = 0.42 for mucosal invisibility)[7].

Dai *et al*[32] studied the effect of bowel preparation with 4 L of PEG in small-bowel cleanliness. To assess the enteric cleanliness, the authors used an overall assessment of quality based on a 4-step scale: (1) large volume of residual ingested food or fecal material; (2) moderate volume of residual ingested food; (3) small volume of residual ingested food; and (4) clear or colored liquid. They also determined the proportion of the enteric wall visualized using 10-min video segments at 1-h intervals: (1) less than 25%; (2) 25% to 49%; (3) 50% to 75%; and (4) greater than 75%. The authors concluded that the score was subjective, as reflected by the fair interobserver agreement achieved with a kappa = 0.56.

Lapalus *et al*[33] created a small-bowel cleansing score in PillCam® to evaluate the effect of oral sodium phosphate in small-bowel preparation. The preparation was evaluated in five segments of 5 min, with the first segment starting at 5 min after passage of the CE

Table 5 Small-bowel cleansing scale of Esaki *et al*[31]

Fluid transparency	
Grade 1	Clear fluid without obscuring vision
Grade 2	Slightly dark fluid minimally obscuring vision
Grade 3	Opaque fluid partly obscuring vision
Grade 4	Turbid fluid severely obscuring vision
Mucosal invisibility[1]	
Grade 1	< 5% in duration of > 50% bubbles or residues
Grade 2	5%-15%
Grade 3	15%-25%
Grade 4	> 25%
Overall image quality[2]	
Grade A	3-5
Grade B	6-8
Grade C	9-12

[1]The percentage indicates the proportion of length of time of video image in which air bubbles or food residues disturbed more than 50% of visualization and interpretation; [2]The number indicates the sum of grades in each small intestinal segment.

through the pylorus, and the last segment corresponding to the 5 min before passage through the ileocecal valve. The remaining segments started at one fourth, one half, and three fourths of the SBTT. Each segment was graded in a 4-point scale according to the bowel cleanliness (1) no liquid and no bubbles (excellent); (2) clear liquid (good); (3) dark liquid and/or air bubbles (fair); and (4) food residue (poor) and the proportion of mucosa visualized [(1) $\geqslant$ to 75% of the mucosa visualized; (2) 50% to 74% of the mucosa visualized; (3) 25% to 49% of the mucosal visualized; and (4) $\leqslant$ to 24% of the mucosa visualized]. The interobserver agreement for the score of cleansing varied between 0.55 and 0.69 and for the score of visibility varied between 0.55 and 0.8.

Similarly to the previous grading scale, Hooks *et al*[34] developed a grading scale with quantitative and qualitative parameters using PillCam® CE to evaluate the effect of lubiprostone in the gastric and small-bowel transit time and in the enteric preparation. This last parameter was analysed with a 4-point scale considering the overall preparation in the proximal, middle and distal small bowel and the amount of mucosa visualized in 10-min segments at one-hour intervals, as described in Table 6.

In summary, various grading scales to assess the cleanliness of small-bowel in CE have been proposed, and a consensus regarding which scale is better remains to be achieved. Computer grading scales are based on objective measurements and may potentially overcome the disadvantages of human dependent scoring systems, namely the subjectivity, complexity and lengthiness. Current results of computer grading scales are encouraging and the future may encompass the incorporation of a fully automated cleansing score in the software of CE. Nevertheless, more research is warranted to ameliorate and achieve an optimal computed score completely independent of human action.

In human dependent grading scales, the authors consider that those which include the entire video have more advantages as the operator may score the small-bowel cleanliness during CE analysis, thus reducing the time of the procedure as the re-evaluation of single frames or segments of video is avoided. Moreover, sample bias is avoided as the overall video will be evaluated. The authors also conclude that operator dependent scales based on quantitative parameters may reduce subjective interpretation and provide a better evaluation of the small-bowel preparation level. Despite the heterogeneity of the methodology adopted by the developers of each small-bowel grading system in CE, which limit the comparison between the operator dependent grading scales, the authors suggest that the QI grading scale of Brotz *et al*[5] may aggregate the best characteristics for evaluation of small-bowel cleanliness in CE.

Table 6 Small-bowel cleansing scale of Hooks *et al*[34]

Overall preparation	
Excellent	Small bits of adherent solid material with clear or colored liquid
Good	Few liquids, small amounts of solid material, or dark fluid that did not interfere with the examination
Fair	Enough solid material or dark liquid to prevent a reliable examination
Poor	Large volume of residual food or fecal material precluding a complete examination
Proportion of mucosa visualized	
4 points	> 75%
3 points	50%-75%
2 points	25%-49%
1 point	< 25%

CONCLUSION

Numerous small-bowel grading scales to assess the cleanliness in CE have been developed, and a consensus regarding a universally accepted scale is lacking.

Computer grading scales are based on objective measurements and may potentially overcome the disadvantages of human dependent scoring systems, namely the subjectivity, complexity and lengthiness. Concerning human dependent grading scales, only few are validated and there is a huge heterogeneity regarding the methodology of each scale, namely the parameters and portion of the CE analysed and the objectivity of the analysis. Finally, human dependent scales which are based in quantitative assessments are more uniformly assessed thus reducing the subjective interpretation and providing a better evaluation of the small-bowel preparation.

REFERENCES

1 **Pennazio M**, Spada C, Eliakim R, Keuchel M, May A, Mulder CJ, Rondonotti E, Adler SN, Albert J, Baltes P, Barbaro F, Cellier C, Charton JP, Delvaux M, Despott EJ, Domagk D, Klein A, McAlindon M, Rosa B, Rowse G, Sanders DS, Saurin JC, Sidhu R, Dumonceau JM, Hassan C, Gralnek IM. Small-bowel capsule endoscopy and device-assisted enteroscopy for diagnosis and treatment of small-bowel disorders: European Society of Gastrointestinal Endoscopy

(ESGE) Clinical Guideline. *Endoscopy* 2015; **47**: 352-376 [PMID: 25826168 DOI: 10.1055/s-0034-1391855]
2 **Ladas SD**, Triantafyllou K, Spada C, Riccioni ME, Rey JF, Niv Y, Delvaux M, de Franchis R, Costamagna G. European Society of Gastrointestinal Endoscopy (ESGE): recommendations (2009) on clinical use of video capsule endoscopy to investigate small-bowel, esophageal and colonic diseases. *Endoscopy* 2010; **42**: 220-227 [PMID: 20195992 DOI: 10.1055/s-0029-1243968]
3 **Pinho R**, Mascarenhas-Saraiva M, Mão-de-Ferro S, Ferreira S, Almeida N, Figueiredo P, Rodrigues A, Cardoso H, Marques M, Rosa B, Cotter J, Vilas-Boas G, Cardoso C, Salgado M, Marcos-Pinto R. Multicenter survey on the use of device-assisted enteroscopy in Portugal. *United European Gastroenterol J* 2016; **4**: 264-274 [PMID: 27087956 DOI: 10.1177/2050640615604775]
4 **Pinho R**, Ponte A, Rodrigues A, Pinto-Pais T, Fernandes C, Ribeiro I, Silva J, Rodrigues J, Mascarenhas-Saraiva M, Carvalho J. Long-term rebleeding risk following endoscopic therapy of small-bowel vascular lesions with device-assisted enteroscopy. *Eur J Gastroenterol Hepatol* 2016; **28**: 479-485 [PMID: 26808473 DOI: 10.1097/MEG.0000000000000552]
5 **Brotz C**, Nandi N, Conn M, Daskalakis C, DiMarino M, Infantolino A, Katz LC, Schroeder T, Kastenberg D. A validation study of 3 grading systems to evaluate small-bowel cleansing for wireless capsule endoscopy: a quantitative index, a qualitative evaluation, and an overall adequacy assessment. *Gastrointest Endosc* 2009; **69**: 262-270, 270.e1 [PMID: 18851851 DOI: 10.1016/j.gie.2008.04.016]
6 **Van Weyenberg SJ**, De Leest HT, Mulder CJ. Description of a novel grading system to assess the quality of bowel preparation in video capsule endoscopy. *Endoscopy* 2011; **43**: 406-411 [PMID: 21425039 DOI: 10.1055/s-0030-1256228]
7 **Goyal J**, Goel A, McGwin G, Weber F. Analysis of a grading system to assess the quality of small-bowel preparation for capsule endoscopy: in search of the Holy Grail. *Endosc Int Open* 2014; **2**: E183-E186 [PMID: 26134966 DOI: 10.1055/s-0034-1377521]
8 **Klein A,** Gizbar M, Bourke M, Ahlenstiel G . A validated computerized cleansing score for Video Capsule Endoscopy. *Dig Endosc* 2015; **28**: 564-569 [PMID: 26716407 DOI: 10.1111/den.12599]
9 **Hong-Bin C**, Yue H, Su-Yu C, Chun H, Lan-Hua G, Dong-Ying D, Xiao-Juan L, Song H, Xiao-Lin L. Evaluation of visualized area percentage assessment of cleansing score and computed assessment of cleansing score for capsule endoscopy. *Saudi J Gastroenterol* 2013; **19**: 160-164 [PMID: 23828745 DOI: 10.4103/1319-3767.114512]
10 **Ponte A**, Pinho R, Rodrigues A, Silva S, Rodrigues J, Carvalho J. Validation of the Computed Assessment of Cleansing score with the Mirocam® system. *Rev Esp Enferm Dig* 2016; In press
11 **Park SC**, Keum B, Hyun JJ, Seo YS, Kim YS, Jeen YT, Chun HJ, Um SH, Kim CD, Ryu HS. A novel cleansing score system for capsule endoscopy. *World J Gastroenterol* 2010; **16**: 875-880 [PMID: 20143467]
12 **Park SC**, Keum B, Seo YS, Kim YS, Jeen YT, Chun HJ, Um SH, Kim CD, Ryu HS. Effect of bowel preparation with polyethylene glycol on quality of capsule endoscopy. *Dig Dis Sci* 2011; **56**: 1769-1775 [PMID: 21161380 DOI: 10.1007/s10620-010-1500-2]
13 **Spada C**, Riccioni ME, Familiari P, Spera G, Pirozzi GA, Marchese M, Bizzotto A, Ingrosso M, Costamagna G. Polyethylene glycol plus simethicone in small-bowel preparation for capsule endoscopy. *Dig Liver Dis* 2010; **42**: 365-370 [PMID: 19736051 DOI: 10.1016/j.dld.2009.07.017]
14 **Oliva S**, Cucchiara S, Spada C, Hassan C, Ferrari F, Civitelli F, Pagliaro G, Di Nardo G. Small bowel cleansing for capsule endoscopy in paediatric patients: a prospective randomized single-blind study. *Dig Liver Dis* 2014; **46**: 51-55 [PMID: 24041737 DOI: 10.1016/j.dld.2013.08.130]
15 **van Tuyl SA**, den Ouden H, Stolk MF, Kuipers EJ. Optimal preparation for video capsule endoscopy: a prospective, randomized, single-blind study. *Endoscopy* 2007; **39**: 1037-1040 [PMID: 18072052]
16 **Caddy GR**, Moran L, Chong AK, Miller AM, Taylor AC, Desmond PV. The effect of erythromycin on video capsule endoscopy intestinal-transit time. *Gastrointest Endosc* 2006; **63**: 262-266 [PMID: 16427932]
17 **Endo H**, Kondo Y, Inamori M, Ohya TR, Yanagawa T, Asayama M, Hisatomi K, Teratani T, Yoneda M, Nakajima A, Matsuhashi N. Ingesting 500 ml of polyethylene glycol solution during capsule endoscopy improves the image quality and completion rate to the cecum. *Dig Dis Sci* 2008; **53**: 3201-3205 [PMID: 18465241 DOI: 10.1007/s10620-008-0292-0]
18 **Ito T**, Ohata K, Ono A, Chiba H, Tsuji Y, Sato H, Matsuhashi N. Prospective controlled study on the effects of polyethylene glycol in capsule endoscopy. *World J Gastroenterol* 2012; **18**: 1789-1792 [PMID: 22553403 DOI: 10.3748/wjg.v18.i15.1789]
19 **Viazis N**, Sgouros S, Papaxoinis K, Vlachogiannakos J, Bergele C, Sklavos P, Panani A, Avgerinos A. Bowel preparation increases the diagnostic yield of capsule endoscopy: a prospective, randomized, controlled study. *Gastrointest Endosc* 2004; **60**: 534-538 [PMID: 15472674]
20 **Wei W**, Ge ZZ, Lu H, Gao YJ, Hu YB, Xiao SD. Purgative bowel cleansing combined with simethicone improves capsule endoscopy imaging. *Am J Gastroenterol* 2008; **103**: 77-82 [PMID: 18005366]
21 **Wi JH**, Moon JS, Choi MG, Kim JO, Do JH, Ryu JK, Shim KN, Lee KJ, Jang BI, Chun HJ. Bowel preparation for capsule endoscopy: a prospective randomized multicenter study. *Gut Liver* 2009; **3**: 180-185 [PMID: 20431743 DOI: 10.5009/gnl.2009.3.3.180]
22 **Kantianis A**, Karagiannis S, Liatsos C, Galanis P, Psilopoulos D, Tenta R, Kalantzis N, Mavrogiannis C. Comparison of two schemes of small bowel preparation for capsule endoscopy with polyethylene glycol: a prospective, randomized single-blind study. *Eur J Gastroenterol Hepatol* 2009; **21**: 1140-1144 [PMID: 19757514]
23 **Chen HB**, Huang Y, Chen SY, Song HW, Li XL, Dai DL, Xie JT, He S, Zhao YY, Huang C, Zhang SJ, Yang LN. Small bowel preparations for capsule endoscopy with mannitol and simethicone: a prospective, randomized, clinical trial. *J Clin Gastroenterol* 2011; **45**: 337-341 [PMID: 20871410 DOI: 10.1097/MCG.0b013e3181f0f3a3]
24 **Pons Beltrán V,** Carretero C, Gonzalez-Suárez B, Fernandez-Urien I, Muñoz-Navas M. Intestinal preparation prior to capsule endoscopy administration. *World J Gastroenterol* 2008; **14**: 5773-5775 [PMID: 18837100]
25 **Rosa BJ**, Barbosa M, Magalhães J, Rebelo A, Moreira MJ, Cotter J. Oral purgative and simethicone before small bowel capsule endoscopy. *World J Gastrointest Endosc* 2013; **5**: 67-73 [PMID: 23424190 DOI: 10.4253/wjge.v5.i2.67]
26 **Niv Y**, Niv G. Capsule endoscopy: role of bowel preparation in successful visualization. *Scand J Gastroenterol* 2004; **39**: 1005-1009 [PMID: 15513342]
27 **Magalhães-Costa P**, Carmo J, Bispo M, Santos S, Chagas C. Superiority of the Split-dose PEG Regimen for Small-Bowel Capsule Endoscopy: A Randomized Controlled Trial. *J Clin Gastroenterol* 2015; 50: e65-e70 [PMID: 26646803 DOI: 10.1097/MCG.0000000000000460]
28 **Albert J**, Göbel CM, Lesske J, Lotterer E, Nietsch H, Fleig WE. Simethicone for small bowel preparation for capsule endoscopy: a systematic, single-blinded, controlled study. *Gastrointest Endosc* 2004; **59**: 487-491 [PMID: 15044883]
29 **Pons Beltrán V**, González Suárez B, González Asanza C, Pérez-Cuadrado E, Fernández Diez S, Fernández-Urién I, Mata Bilbao A, Espinós Pérez JC, Pérez Grueso MJ, Argüello Viudez L, Valle Muñoz J, Carballo Alvarez F, Muñoz-Navas M, Llach Vila J, Ramírez Armengol JA, Balanzó Tintoré J, Sala Felis T, Menchen Fernández-Pacheco P. Evaluation of different bowel preparations for small bowel capsule endoscopy: a prospective, randomized, controlled study. *Dig Dis Sci* 2011; **56**: 2900-2905 [PMID: 21479818 DOI: 10.1007/s10620-011-1693-z]
30 **Ninomiya K**, Yao K, Matsui T, Sato Y, Kishi M, Karashima Y, Ishihara H, Hirai F. Effectiveness of magnesium citrate as preparation for capsule endoscopy: a randomized, prospective, open-label, intergroup trial. *Digestion* 2012; **86**: 27-33 [PMID: 22710397 DOI: 10.1159/000337937]

31 **Esaki M**, Matsumoto T, Kudo T, Yanaru-Fujisawa R, Nakamura S, Iida M. Bowel preparations for capsule endoscopy: a comparison between simethicone and magnesium citrate. *Gastrointest Endosc* 2009; **69**: 94-101 [PMID: 18710720 DOI: 10.1016/j.gie.2008.04.054]

32 **Dai N**, Gubler C, Hengstler P, Meyenberger C, Bauerfeind P. Improved capsule endoscopy after bowel preparation. *Gastrointest Endosc* 2005; **61**: 28-31 [PMID: 15672052]

33 **Lapalus MG**, Ben Soussan E, Saurin JC, Favre O, D'Halluin PN, Coumaros D, Gaudric M, Fumex F, Antonietti M, Gaudin JL, Jacob P, Heresbach D, Pilichos C, Fan R, Mozer M, Heyries L, Dumortier J, Ponchon T. Capsule endoscopy and bowel preparation with oral sodium phosphate: a prospective randomized controlled trial. *Gastrointest Endosc* 2008; **67**: 1091-1096 [PMID: 18513551 DOI: 10.1016/j.gie.2007.11.053]

34 **Hooks SB**, Rutland TJ, Di Palma JA. Lubiprostone neither decreases gastric and small-bowel transit time nor improves visualization of small bowel for capsule endoscopy: a double-blind, placebo-controlled study. *Gastrointest Endosc* 2009; **70**: 942-946 [PMID: 19577749 DOI: 10.1016/j.gie.2009.04.045]

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