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Visualisation of the Ampulla of Vater on Small Bowel Capsule Endoscopy

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ABSTRACT

Background & Aims: Visualisation of lesions on small bowel capsule endoscopy (SBCE) depends on capsule motility. The aim of this study was to assess the delineation of the ampulla of Vater (AoV) across different levels of expertise and reading speeds.
Methods: This was a study whereby de-identified SBCE videos were reviewed by scrolling with mouse wheel and then at a speed of 10 frames per second (10 fps). Data regarding delineation of the AoV and bile was collected.
Results: Thirty patients (63.3% males, 63.5 years +/- SD 7.164) were included. The mean detection rate of AoV was higher when the mouse wheel was used than when compared to 10 fps for trainees (35% vs. 21.7%) and experts (33.8% vs 20.5%). The rate of concordance in the delineation of the AoV amongst experts declined with higher reviewing speeds (κ 0.493, p=0.98 mouse wheel vs κ 0.482, p=0.2 10 fps). Experts had a better agreement in detecting AoV than trainees (κ 0.493, p=0.98 vs 0.482, p=0.2 for mouse wheel and 10 fps respectively for experts: κ 0.135, p=0.75 for mouse wheel and 0.109, p=0.2 at 10 fps).
Conclusions: This study demonstrates that visualisation of the AoV is dependent on the level of expertise and capsule speed.

Key words: small bowel capsule endoscopy – ampulla of Vater – reading speed.

Abbreviations: AoV: ampulla of Vater; CE: capsule endoscopy; fps: frames per second; SB: small bowel; SBCE: small bowel capsule endoscopy; SD: standard deviation.

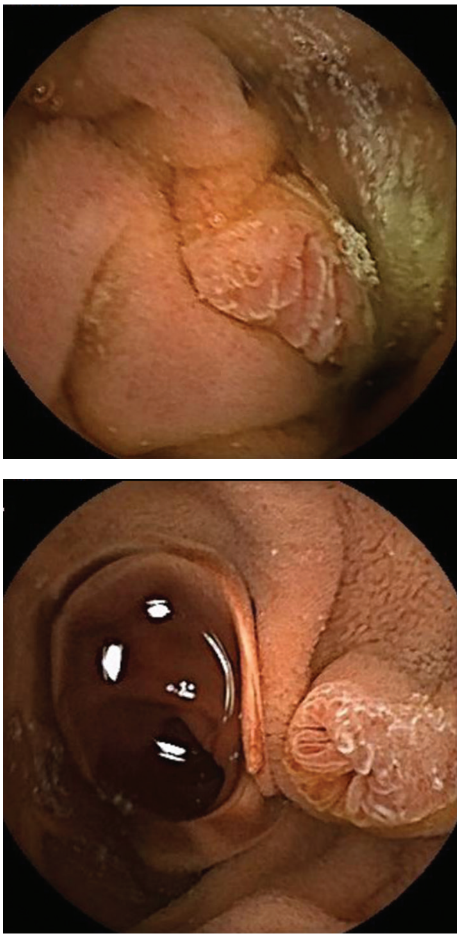
INTRODUCTION

The advent of capsule endoscopy (CE) in 2000 introduced novel means of assessment of the small bowel (SB) by allowing direct visualisation and evaluation of the enteric mucosa [1]. It is now recognised as a first-line, non-invasive diagnostic tool for SB pathology [2] and its role has also expanded to include assessment of colonic mucosa [3, 4]. Indications for small bowel capsule endoscopy (SBCE) include obscure gastrointestinal bleeding, Crohn's disease, non-responsive or refractory coeliac disease, iron deficiency anaemia, surveillance of inherited polyposis syndromes, and identification of SB tumours [5].

Diagnosis of SB tumours has increased over the years with the introduction of CE, reflecting a rise in their incidence (2-10%) [5, 6]. A 2015 retrospective study comparing clinical efficacy of different investigations for SB tumours demonstrated that SBCE had a diagnostic yield of 83.3%, higher than the diagnostic yield of computed tomography (CT) imaging (55.8%) and SB follow through (46.1%) [7, 8]. However, a proportion of tumours were noted to remain unidentified on SBCE, especially when located in the proximal jejunum [7, 9]. Several cases of missed SB lesion have been reported in the literature. These were diagnosed using alternative imaging modalities [9-11]. False negative results have also been noted for submucosal lesions with minimal mucosal and luminal involvement, including gastrointestinal stromal tumours [12] and neuroendocrine tumours [13].

There is limited literature on the ability of SBCE to delineate lesions in the SB and the anatomical AoV [14]. The AoV is not always visualised in the proximal small bowel as its view might be obscured by mucosal folds. Also, there is an inability to insufflate or wash with clear fluid to improve mucosal views, a technique that is utilised routinely during upper and lower gastrointestinal endoscopies. The reading speed of SBCE is a major impact factor in the delineation of pathology in the SB and AoV. There are studies that suggest using reading speeds slower than 15 frames per second (fps) at difficult sites, such as sharply angulated bowel loops. In a study by Kong et al. [15] the AoV was detected on SBCE in 43.6% of patients. The detection rates of abnormal findings in the SB on SBCE is significantly higher at lower reading speeds (15-20 fps vs 25 fps) [16]. The European Society of Gastrointestinal Endoscopy recommends a maximum reading speed of 10 fps in a single view mode [17]. The delineation of pathology is also dependent on previous reviewer experience. Literature available on this area is limited and contradictory. Several studies have demonstrated superiority in accuracy among expert readers compared to less experienced trainees and medical students [18-20]. Contrary to the above studies, other literature reported that reader experience was not associated with a difference in pathology detection rates [16]. Techniques that reduce the number of images examined on CE are time saving but are associated with considerable diagnostic miss rates [21]. AoV detection rate does not vary according to different CE reviewing platforms [22].

In this study we aimed to assess the delineation rates of AoV during SBCEs (Fig. 1, 2) and identify any significant variation in its detection by comparing different levels of expertise and different reading speeds. Bile detection was also identified using the same parameters and compared to AoV detection rates to further assess reliability of SBCE.



Figs. 1 & 2: Ampulla of Vater visible on small bowel capsule endoscopy.

METHODS

Study Design

Patients were randomly selected from the cohort of patients referred to Mater Dei Hospital Malta for SBCE between January 2021 and December 2022. Demographic data related to the patients undergoing SBCE including patient's age, gender and clinical indication was collected. Inclusion criteria were age over 18 years and a complete SBCE examination whereby the capsule entered the caecum. The exclusion criteria used were a history of previous surgery in view of the possibility of altered AoV anatomy resulting in poor visualisation, capsule retention within the stomach, incomplete SBCE and capsule endoscopies where the capsule remained in the duodenal bulb for a significant length of time (more than 15 minutes). Thirty capsules were then randomly selected. Clips of 15 minutes duration (from the 1st duodenal image) were prepared for each capsule by an expert SBCE reviewer (>5-year experience in reviewing SBCEs; clips were reviewed at 5 fps in single frames). The findings referred to as the standard in this study, (including delineation of the AoV) were determined and compared to the standard SBCE report. In case of disagreement, a second expert reviewer was involved to confirm the findings on SBCE. The de-identified video clips were uploaded on a secure virtual cloud and shared amongst the study participants.

The study participants included one expert (regarded as the standard), seven expert SBCE reviewers and six gastroenterology higher specialist trainees (doctors within the 4 year training period of gastroenterology) with limited experience in SBCE reading. All the study participants were blinded to each other's findings and analysed the video clips twice, first by scrolling through the video using the mouse-wheel, then by an automated speed at 10fps in single mode view, two weeks apart. The presence of both the AoV and bile were noted. The number of AoV delineated was also recorded.

Small Bowel Capsule Endoscopy

All patients had bowel preparation using a macrogol based osmotic laxative (Moviprep), taken as per local protocols one day prior to assessment. Patients were also instructed to follow a liquid diet for 3 days prior to SBCE. Prokinetics were not administered. SBCE was performed using PillCam SB3 for all patients (Medtronic, Minneapolis, USA) [23].

Ethical Approvals

All SBCE videos were deidentified and data collected in this study was anonymised. Written informed consent was collected from patients prior to the study. Ethical approval was sought and submitted to the records of the Faculty Research Ethics Committee, University of Malta. Data protection clearance was granted by the Data Protection Office, Mater Dei Hospital. Further ethical clearance was not required as all videos utilised were de-identified.

Statistical Analysis

Data was analysed using the IBM SPSS software platform, version 26. Cohen's Kappa co-efficient was used to assess the degree of agreement for AoV detection amongst the trainees,

Table I. Number of detected AoVs out of 30 capsule endoscopies

Standard		Trainee Cohort			Expert Cohort		
Mouse wheeln (%)	10 fps n (%)		Mouse wheel n (%)	10 fps n (%)		Mouse wheel n (%)	10 fps n (%)
8 (26.7)	8 (26.7)	Trainee 1	9 (30)	7 (23.3)	Expert 1	10 (33.3)	2 (6.7)
		Trainee 2	6 (20)	4 (13.3)	Expert 2	7 (23.3)	6 (20)
		Trainee 3	17 (56.7)	10 (33.3)	Expert 3	8 (26.7)	5 (16.7)
		Trainee 4	11 (36.7)	9 (30)	Expert 4	15 (50)	14 (46.7)
		Trainee 5	6 (20)	5 (16.7)	Expert 5	8 (26.7)	7 (23.3)
		Trainee 6	14 (46.7)	4 (13.3)	Expert 6	12 (40)	5 (16.7)
					Expert 7	11 (36.7)	4 (13.3)

fps: frames per second.

amongst experts, between trainee and expert cohorts and their collective comparison to the standard identified. The Kolmogorov Smirnov test was used as a non-parametric means of data comparison among the different study cohorts i.e. the standard, experts and trainees. Agreement was considered significant if the p value was less than 0.05. The following ranges of agreement for Cohen's Kappa co-efficient were considered: poor agreement if value was less than 0; slight agreement if value was between 0.00-0.20; fair agreement if Kappa co-efficient was between 0.21 – 0.40; moderate agreement if Kappa co-efficient was between 0.41 – 0.60; substantial agreement if value was between 0.61 – 0.80, and almost perfect agreement if Kappa co-efficient was 0.81 – 1.00 [24].

RESULTS

Data was collected from 30 patients (males (n=19, 63.3%; median age 63.5 years, SD +/-7.16). The indications for SBCE were iron deficiency anaemia (56.7%), SB Crohn's disease (16.7%) and overt gastrointestinal bleeding in 4 patients (13.3%). Other indications included investigation for malignancy (6.7%), eosinophilic gastroenteritis (3.3%) and assessment of familial adenomatous polyposis (3.3%).

Detection of ampulla of Vater

The AoV detection rate for the standard reviewer was 26.7% (n=8) for both speeds (Table I). The mean detection rates of AoV was higher when the mouse wheel was used (trainees n=10.5; 35%; experts n=10.1; 33.8%) when compared to video assessment at 10 fps (trainees: n=6.5; 21.7%; experts n=6.1; 20.5%) (p=0.2).

The rate of concordance of AoV detection between standard and experts declined with higher reviewing speeds for SBCE (Kappa co-efficient: 0.621; p=0.2 for mouse wheel; Kappa co-efficient: 0.513; p=0.2 for a speed of 10 fps (Table II).

The level of agreement in the detection of AoV between standard and experts, was higher (substantial agreement for mouse wheel: Kappa co-efficient: 0.621, p=0.2 and moderate agreement at 10fps Kappa co-efficient: 0.513, p=0.2) than that between the standard and trainees, the latter being fair for both when the mouse wheel was used (Kappa co-efficient: 0.347; p=0.2) and at 10 fps (Kappa co-efficient: 0.40; p=0.2).

Similarly stronger agreement was observed amongst the expert cohort compared to trainees. The interobserver agreement amongst the experts was moderate for both the mouse wheel (Kappa co-efficient at 0.493; p=0.98) and for speed of 10 fps (Kappa co-efficient: 0.482; p=0.2).

Table II. Comparison of AoV detection across experts, trainees and defined standard

	Mouse wheel		10 fps	
	Kappa co-efficient	p	Kappa co-efficient	p
Standard vs Trainees	0.347	0.2	0.400	0.2
Standard vs Experts	0.621	0.2	0.513	0.2
Trainees vs Experts	0.260	0.2	0.284	0.2
Trainee group	0.135	0.75	0.109	0.2
Expert group	0.493	0.98	0.482	0.2

For abbreviations see Table I.

There was slight agreement between trainees in AoV delineation, both when mouse wheel was used (Kappa co-efficient: 0.135; p=0.75) and at a speed of 10 fps (Kappa co-efficient: 0.109; p=0.2).

Comparison of AoV detection rate using mouse wheel vs a speed of 10 fps was better among experts (moderate Kappa co-efficient: 0.414; p=0.01) than among trainees (fair agreement - Kappa co-efficient: 0.323; p=0.018). These results are in keeping with a significantly higher agreement amongst the more experienced cohort.

There was no statistical difference in the data collected for the detection of the number of AoVs across reading speeds and reviewer experience (Table III). Agreement between standard and expert cohort was deemed fair both when mouse wheel was used (Kappa co-efficient 0.215, p=0.089) and at a speed

Table III. Comparison of number of AoV detected across experts, trainees and defined standard

	Mouse wheel		10 fps	
	Kappa co-efficient	p	Kappa co-efficient	p
Standard vs Trainees	0.394	0.200	0.41	0.2
Standard vs Experts	0.215	0.089	0.28	0.2
Trainees vs Experts	0.209	0.054	0.240	0.2
Trainee group	0.182	0.2	0.176	0.2
Expert group	0.345	0.079	0.347	0.138

For abbreviations see Table I.

Table IV. Number of instances of bile detection out of 30 capsule endoscopies

Standard		Trainee Cohort			Expert Cohort		
Mouse wheel (%)	10 fps n (%)		Mouse wheel n (%)	10 fps n (%)		Mouse wheel n (%)	10 fps n (%)
17 (56.6)	17 (56.6)	Trainee 1	23 (77)	25 (83.3)	Expert 1	24 (80)	26 (86.6)
		Trainee 2	13 (43)	17(56.6)	Expert 2	21(70)	25(83.3)
		Trainee 3	12 (40)	11 (36.6)	Expert 3	10 (33.3)	11(36.6)
		Trainee 4	11 (37)	20(66.6)	Expert 4	20(66.6)	20(66.6)
		Trainee 5	13 (43)	13 (43)	Expert 5	23(76.6)	23(76.6)
		Trainee 6	30 (100)	30(100)	Expert 6	26 (86.6)	27 (90)
					Expert 7	15(50)	15 (50)

For abbreviations see Table I.

of 10 fps (Kappa co-efficient: 0.28, p=0.2), whereas strength of agreement between standard and trainee cohort improved from fair when using mouse wheel (Kappa co-efficient 0.394, p=0.2) to moderate when using a speed of 10 fps (Kappa co-efficient: 0.41, p=0.2).

Delineation of Bile

There was a higher detection rate of bile by trainees than by experts (Table IV). Bile detection rate was 56.7% (n=17) by the standard both when using the mouse wheel and at a speed of 10fps. In the expert group, the mean bile detection rate was 66.2% (n=19.9) when using the mouse wheel and 70% (n=21) when viewed at 10 fps. Meanwhile, the mean bile detection rate for the trainees was 56.6% (n=17) when the capsule was viewed using mouse wheel and 64.4% (n=19.3) at 10 fps. The mean bile detection rate was higher at10fps as compared to scrolling using mouse wheel (p=0.001).

Statistical analysis comparing bile detection rate amongst the standard and trainees declined with higher reviewing speeds; fair agreement was noted (Kappa co-efficient: 0.253; p=0.2) when using mouse wheel, as compared to slight agreement (Kappa co-efficient: 0.112; p=0.054) when reviewing SBCE at a speed of 10 fps. Paradoxically, a weaker agreement was noted amongst standard and experts, for both mouse wheel and at a speed of 10 fps, with only slight agreement being observed for both mouse wheel (Kappa co-efficient 0.064; p=0.034) and at 10 fps (Kappa co-efficient: 0.085; p=0.2).

Table V shows the level of agreement for bile detection across different groups at different viewing speeds.

When comparing level of agreement for AoV delineation and bile detection (Table VI), a similar and in certain instances, stronger agreement for AoV detection was observed.

Table V. Comparison of bile detection across experts, trainees and defined standard

	Mouse wheel		10 fps	
	Kappa co-efficient	p	Kappa co-efficient	p
Standard vs Trainees	0.253	0.2	0.112	0.054
Standard vs Experts	0.064	0.034	0.085	0.2
Trainees vs Experts	0.073	0.193	0.133	0.2
Trainee group	0.247	0.04	0.128	0.2
Expert group	0.276	0.028	0.211	0.086

For abbreviations see Table I.

DISCUSSION

This study assessed rates of detection of AoV during SBCEs with the additional aims of identifying significant variation in AoV delineation upon using different reading speeds and according to different levels of expertise. Overall, mean AoV detection rates for both experts and trainees using different reading speeds were low, ranging from 20.5% to 35% with that for the standard being 26.7%. This is in keeping with the known difficulty of AoV identification encountered in the literature [14, 15, 25]. Lower mean AoV detection rates and poorer interobserver agreement of experts with standard were noted on using higher reviewing speeds of 10 fps compared to scrolling with the mouse wheel. Contrarily, comparison of agreement in delineation of the AoV of the trainee group with standard did not vary across reading speed. A possible reason for this could be due to false positive errors secondary to AoV misidentification. Interobserver agreement of experts with standard was found to be stronger than agreement of trainees with standard, for both different reading speeds. Similarly,

Table VI. Comparison of AoV and bile detection across experts, trainees and defined standard

	Mouse wheel				10 fps			
	AoV		Bile		AoV		Bile	
	Kappa co-efficient	P value	Kappa co-efficient	P value	Kappa co-efficient	P value	Kappa co-efficient	P value
Standard vs Trainees	0.347	0.2	0.253	0.2	0.400	0.2	0.112	0.054
Standard vs Experts	0.621	0.2	0.064	0.034	0.513	0.2	0.085	0.2

For abbreviations see Table I.

agreement of AoV detection using mouse wheel compared to a speed of 10 fps amongst experts was significantly higher than that amongst trainees (p=0.01), supporting our finding that correlation is stronger amongst the more experienced capsule readers.

The delineation of AoV as an anatomical landmark has been documented in numerous studies. AoV may be missed on SBCE in view of its medial location within sharply angulated bowel loops, therefore potentially being out of the capsule viewing range [15, 22, 26]. A SBCE does not allow for insufflation, thus limiting mucosal views at times. Additionally, SB transit consists of short bursts of fast movements, with slower velocities identified in the distal SB [27]. Being non-steerable, capsule propulsion is driven only by bowel movement. The high-speed proximal capsule passage [28] coincides with the area where the AoV and most neoplastic and vascular lesions are situated [29], therefore potentially making their identification more difficult. Similar to the possibility of missing AoV whilst reviewing a SBCE, other SB pathology might not be detected. This raises the issue of discussing with and consenting patients prior to colonoscopy procedures for the possibility of missed lesions.

Over time, considering the technological improvement, there has been no significant increase in AoV detection rates. In our study, the delineation of AoV by the standard in the videos chosen amounted to 26.7%. The reported detection rate varies from 10.4% to 43.6% (reading speed at 8-15fps) [14, 15, 25]. Other studies were not able to identify the AoV in any patients [30, 31] Studies assessing capsule light exposure, resolution and depth of view [22, 32-34], variable frame rate [35] did not show an improved delineation in AoV. Use of different capsule platforms did not show any significant variability in AoV detection rates [36]. The relatively low delineation rate of AoV on SBCE raises questions about potentially other missed pathology in the SB and highlights the importance of consenting patients for the possibility of missed pathology on SBCE.

There have been considerable advances in the field of deep learning applications to aid the detection of pathology on SBCE. However, there is lack of literature on the delineation of AoV in the small bowel by this method [37, 38]. There is also a lack of studies comparing the delineation of AoV and small bowel polyps by colon capsule endoscopy, Crohn's capsule endoscopy and standard SBCE. For future studies it would be interesting to assess whether double-headed capsules are superior in the delineation of AoV and small bowel polyps compared to single video recordings [39, 40].

In our study, substantial agreement was noted between standard and experts in AoV detection when using mouse wheel; correlation decreased to moderate agreement when higher speeds were used. The stronger concordance at lower reading speeds is in keeping with findings from other studies albeit SBCEs were viewed at higher speeds in these studies (15 fps, 20 fps and 25 fps) [16]. Our findings and available literature mirror ESGE recommendations to view video clips at a maximum speed of 10FPs (single view) and use slower reading speeds in the proximal SB [41].

In our study, a higher level of expertise correlated with the standard reviewer. This factor is not supported in all the previously published studies. Some of the studies corroborate our findings [18-20] whereas others did not observe such differences in the delineation of AoV on SBCE [16, 42].

The definition of the presence of bile is arbitrary. Studies in literature have identified varied rates of bile spout from the papilla, ranging from 18.8% to 81.4% [15, 22, 36]. Higher rates of AoV detection have been observed in conjunction with bile spout due to this occurrence acting as an indicator of an AoV in close vicinity and greater relaxation of the small bowel wall, with less mucosal folding [15,22]. Literature regarding the delineation of bile demonstrated paradoxical results compared to AoV detection where agreement of trainees with standard was stronger than agreement of experts with standard when using mouse wheel. This may be due to bile being mostly noticeable to the same degree to most capsule readers irrespective of their prior reading experience. Agreement in identification of bile did not vary across reading speed for experts, whereas there was poorer agreement in trainees vs standard cohorts on using the faster 10fps as compared to slower scrolling with mouse wheel.

Strengths of this study include the sizeable cohort of trainee and expert capsule reviewers, from across several European centres, all blinded to each other's findings. Capsule video clips were also reviewed 2 weeks apart using mouse wheel and at 10 fps, thus minimising bias from recollection of findings. Limitations of the study included the single platform utilised in this study and the small number of SBCEs that might have impacted on results. The quantity of bile noted during SBCE may be subjective. This might have affected the ability to delineate this finding on SBCE by the reviewers. One set of trainee results for bile detection had to be excluded from data analysis. This occurred as the findings were positive for bile detection in all capsule videos resulting in the answers being considered as a constant and hence rendering statistical analysis difficult. The use of only one experienced reader's set of results as a standard might have been a source of selection bias.

CONCLUSIONS

This study highlights the importance of using lower speeds whilst reviewing SBCEs, particularly in the proximal SB. The requirement of specific training and achieving competency in reviewing SBCE is also extremely important to ensure that reporting is up to standards. The introduction of artificial intelligence may aid in having less interobserver variation is such analysis. Furthermore, the outcome of this study underlines the importance of consenting patients for missed pathology during SBCE in addition to potential complications.

Conflicts of interest: None to declare.

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