



A systematic review of capsule aspiration in capsule endoscopy

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Background: Capsule endoscopy (CE) is safe and widely accepted for small bowel (SB) investigation and an alternative to colonoscopy in specific clinical circumstances. As the capsule is orally ingested, the potential risk of aspiration is undoubtedly a constant concern among clinicians. However, it is a rare occurrence and often reported as isolated cases. Therefore, this review systematically compiles all the available data on capsule aspiration in the literature with an aim to provide an update on this complication of CE.

Methods: A systematic literature search was performed on PubMed with the search terms ‘capsule endoscopy’ AND ‘aspiration’, searched as keywords and MeSH. All observational cohort studies that reported aspiration among complications/outcomes, case reports and series on capsule aspiration were included. Manual citation search was performed. Two extractors reviewed abstract and full-text and performed data extraction.

Results: We found 95 relevant articles, and cross-checking references led to the inclusion of an additional 19 articles. We removed 57 and ended with 57 references—with 63 cases of aspirated capsules. One death was reported. The median age was 78, and there was male preponderance. The most common indication for CE was anaemia, and only aspiration of small bowel CE (SBCE) was reported. 61.9% of the aspirations were symptomatic; the most common symptom was coughing. 69.8% of capsules ended in the bronchus, but only 4 cases experienced desaturation. Thirty-two patients needed intervention for retrieval; the aspiration was self-resolved in the remaining. Only four patients had a history of dysphagia. Thirteen instances of aspiration were detected due to real-time viewing, and 24 cases from reviewing the capsule data afterwards.

Conclusions: With only 63 cases of aspirated capsules reported in the literature, this event remains rare, is safely managed, and should not discourage patients from the procedure. The importance of careful patient selection is crucial to minimize the likelihood of aspiration and capsule administration should be approached with precautions.

Keywords: Capsule endoscopy (CE); complications; aspiration; dysphagia; morbidity

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Introduction

Capsule endoscopy (CE) is considered a safe and widely accepted first-line method for investigating the small bowel (SB) due to its noninvasive and patient-friendly benefits (1). Recently, CE has been introduced for colon investigations and is considered an alternative to colonoscopy in specific clinical circumstances, with a high success rate, low complication rates and patient preference (2). The most common complication of small bowel capsule endoscopy (SBCE) is capsule retention which occurs in 1–2% of patients being evaluated for obscure gastrointestinal bleeding (OGIB) (3). Therefore, safety measures are established to exclude certain patients, minimizing retention risk. This includes patency capsules and cross-sectional imaging before investigation (4). Given that the capsule is ingested orally, possibility of aspiration should always be taken into consideration. Another study found capsule aspirations to be rare and often reported as isolated cases, mostly in elderly male patients with comorbidities (5). With the accumulating comorbidities, the increasingly prevalent ageing populations, the continuous advancement in CE technology and its increasing utilization as a diagnostic tool for both SB and colon, the number of complications may increase accordingly. Furthermore, it is crucial to identify and anticipate this complication in specific patient populations so that the required precautions can be taken. Therefore, necessary protocols should be established to carefully select the appropriate patients for the correct test. To offer an updated overview of the complication of capsule aspiration in CE, this systematic

review collated the existing data. We present this article in accordance with the PRISMA reporting checklist (available at <https://atm.amegroups.com/article/view/10.21037/atm-23-763/rc>).

Methods

A systematic literature search was performed using the database PubMed with search terms ‘capsule endoscopy’, and ‘aspiration’ searched as keywords and MeSH from January 1, 1996, through October 30, 2022. An additional search was performed in the PubMed database on November 12, 2022. To ensure thoroughness and consistency, the search strategy used in this additional search was borrowed from another article (3). The specific search string, which includes keywords related to CE detection, completion, and/or retention rates based on MeSH, can be found in [Appendix 1](#). By borrowing the search string from a previously published article, we aimed to benefit from an established and effective search strategy that had already been used successfully in the literature. This helps to ensure that the search is comprehensive, and no relevant articles are overlooked. All searches were performed without language restrictions. The initial screening process involved assessing titles and abstracts, followed by retrieving and independently reviewing the full texts of the shortlisted articles by two authors (Thorndal C and Selnes O). Relevant observational cohort studies that reported aspiration as one of the complications/outcomes were included, as well as case reports and case series on capsule aspiration. Manual citation search was also performed. Where appropriate, data extraction and statistical analyses were done using Microsoft Excel 2010 (Microsoft Corp., Redmond, WA, USA). Numerical results are reported as mean ± standard deviation (SD) and/or range.

Results

Using the above search strategy, 57 references were identified, presenting 63 cases of aspirated capsules. A total of 12 references were observational studies that reported information on capsule aspiration and the total number of CE performed in their patient groups; the remaining 45 were case reports or series. Detailed visualization of the search strategy and results are shown in *Figure 1*. Furthermore, *Table 1* presents a detailed summary of all 45 cases of capsule aspiration, along with six of the observational studies that provided comprehensive reporting

Highlight box

Key findings

- Aspiration of capsule endoscopy (CE) is a rare adverse event that can be safely managed.

What is known and what is new?

- CE is widely accepted for intestinal investigations, and extensive research has been conducted on complication rates.
- This review shows that only a small percentage of patients experience capsule aspiration.

What is the implication, and what should change now?

- Aspirations of CE should not discourage patients undergoing the procedure.
- However, in specific patient groups, the possibility of aspiration should be anticipated, and appropriate precautions should be taken beforehand.

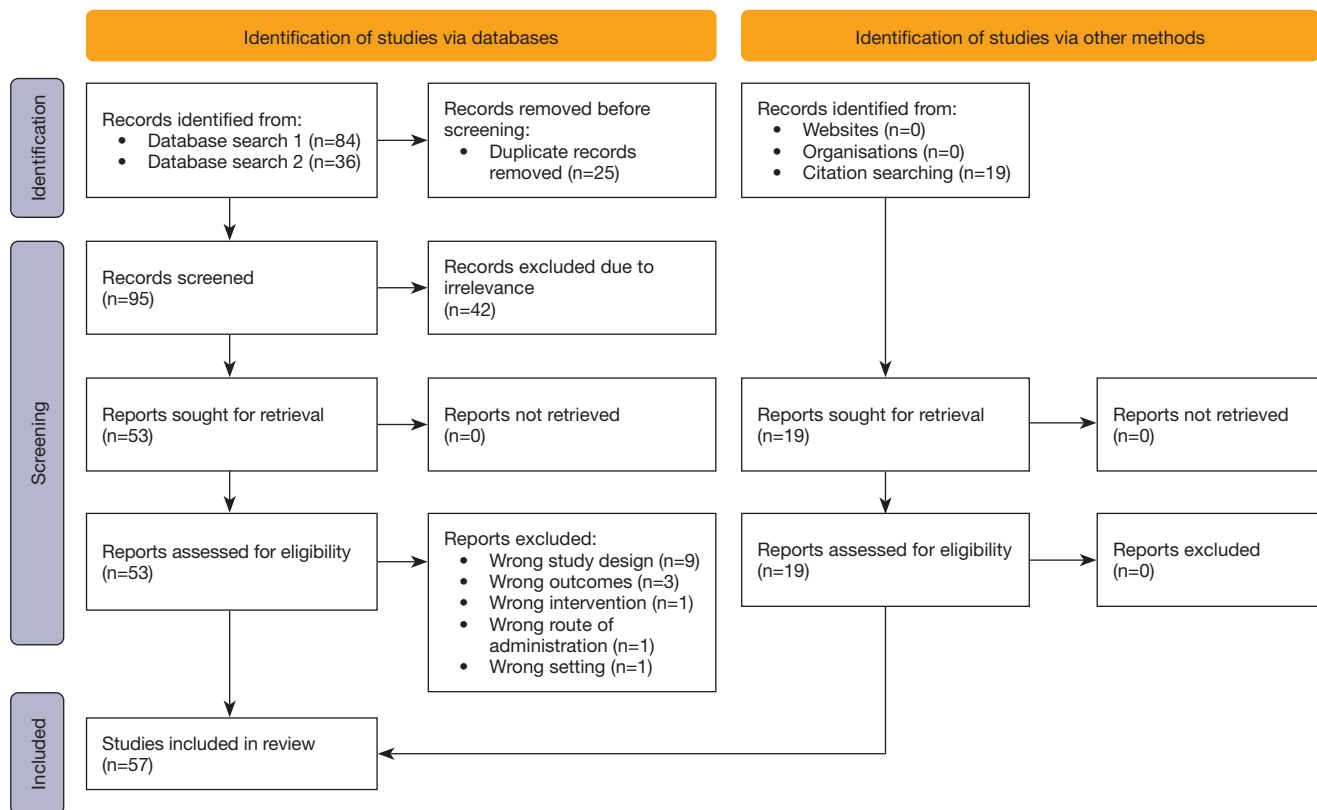


Figure 1 Flowchart illustrating the search strategy and study selection process.

on aspiration cases. In addition, the 12 observational studies are summarized in *Table 2*.

Patient and procedural information

Of the 63 cases of capsule aspiration, 52 (82.5%) occurred in male patients, with a mean age of 78.2 ± 8.4 years (range, 56–93). In 19 (30%) patients, comorbidities were not reported; of the remainder ($n=44$), 40 (63.5%) had comorbidities reported, and 4 (6.3%) had no specified comorbidities. Only 4 (6.3%) patients had a history of previous dysphagia; all were males above 65 years of age with severe preexisting comorbidities. Patient's physical condition was not well reported, but 6 (9.5%) patients were reported to be frail (6,10,18,24,30,38). Two patients reported physical conditions as good (14,25), and 1 reported intact function based on neurological examination (22). Twenty-four cases (38%) reported patients having difficulties swallowing the capsule, and 6 (9.5%) reported more than one attempt needed. Most reports did not specify the position in which the patient ingested the capsule. Still, 3 reported the patient

in an upright position (17,20,30), one standing (24) and one in a supine position with a pillow under the head (49). The most common indication for CE was iron deficiency anemia (IDA), with 39 (61.9%) cases reporting this; secondly was OGIB in 15 (23.8%) cases. In addition, 59 (93.6%) patients had SB investigations; the remaining 4 cases did not specify the modality of the CE.

Models of the CE

In 23 (36.5%) cases, the company and model of CE used were not specified. Thirty-two (50.8%) patients were examined using capsules from Given Imaging Ltd. (now Medtronic, Minneapolis, MN, USA): 7 used Mouth to Anus (M2A) capsules, 6 used PillCam SB, 6 used PillCam SB2, 2 used PillCam SB3, 1 used PillCam COLON1, 1 used PillCam patency capsule and the remainder were unspecified. In addition, there were 3 cases of aspiration of OMOM [Chongqing Jinshan Science and Technology (Group) Co., Ltd., Chongqing, China] and 1 case of aspiration of Ankon Technologies Co., (Shanghai, China).

Table 1 Overview of individual case reports on capsule aspiration

References	Age (years), Sex	Comorbidities	History of dysphagia	Indication for CE examination	Difficulty swallowing capsule	Capsule model	Ingestion symptoms	Symptoms during CE investigation	Symptoms after handling of aspiration	Time CE was aspirated	Anatomical location	Self-resolved or intervention	Identification of aspiration
Schneider <i>et al.</i> (6)	64, M	MVR (mechanical) underweight	No	IDA	Yes	M2A	Immediate cough	No	No	2 min	Right main bronchus	Yes	Symptoms
Tabib <i>et al.</i> (7)	87, M	Bladder cancer, CCF, AF, CAD, CKD	No	IDA, FOBT+	Yes	–	Immediate sensation in throat	Sensation in throat	–	–	Right main bronchus	No, rigid bronchoscopy, grasper forceps, FB basket	Symptoms, fluoroscopy
Sinn <i>et al.</i> (8)	69, F	–	No	IDA, OGIB	Yes	M2A	Immediate cough	No	No	50 sec	Bifurcation trachea	Yes	Reviewing data
Buchkremer <i>et al.</i> (9)	74, M	Ankylosing spondylitis	No	IDA, weight loss, chronic diarrhoea	No	M2A	Immediate dyspnea	Dyspnea	No	2 days	Right main bronchus	No, flexible bronchoscopy	Symptoms
Sepehr <i>et al.</i> (10)	67, M	HTN, DM, CVA	Yes	OGIB	Yes	M2A	Immediate cough, dyspnea, tachypneic, tachycardic	No	No	–	Left main bronchus	No, bronchoscopy, Roth net	Symptoms, real time viewing
Nathan and Biernat (11)	93, M	None	No	OGIB	Yes	–	Immediate cough	No	No	8 hours	Bronchus (NS)	Yes	Reviewing data
Shiff <i>et al.</i> (12)	75, M	None	No	IDA	Yes	PillCam	Immediate cough	–	–	Sec–min	Right main bronchus	Yes	Symptoms
Guy <i>et al.</i> (13)	90, M	CVA	No	IDA, melena	No	–	No	No	No	1–2 days	Bronchus (NS)	No, rigid bronchoscopy, FB basket	Reviewing data
Leeds <i>et al.</i> (14)	85, M	–	No	IDA	Yes	–	No	No	No	8 hours	Bronchus (NS)	Yes	Reviewing data
Koulaouzidis <i>et al.</i> (15)	76, M	–	–	IDA	No	PillCam SB	Immediate cough	No	No	15 sec	–	Yes	Reviewing data
Bredenoord <i>et al.</i> (16)	65, M	Resection of SC, diverticular disease, carcinoid tumor (ileum)	Yes	Carcinoma investigation	Yes	–	Immediate cough, dysphagia	No	No	–	Right main bronchus	Yes	Reviewing data
Jindal <i>et al.</i> (17)	68, M	–	No	IDA, OGIB	Yes	PillCam	Immediate cough	No	No	50 sec	Bronchus (NS)	Yes	Reviewing data
Fan <i>et al.</i> (18)	81, M	Emphysema, bronchitis, gastritis, ankylosing spondylitis	No	Weight loss, poor appetite, night sweat	Yes	OMOM	Immediate desaturation, tachypnoea	–	–	–	Right main bronchus	No, bronchoscopy, extraction basket	Real time viewing
Hill <i>et al.</i> (19)	89, M	Anticoagulation treatment	–	IDA, OGIB	Yes	–	No	No	No	8 hours	Right main bronchus	No, bronchoscopy	Reviewing data
Kurtz <i>et al.</i> (20)	73, M	RCC, MVR (tissue), hyperlipidemia	No	IDA, OGIB	No	–	Cough, sensation in throat after 2 min	No	No	–	Right main bronchus	No, bronchoscopy, FB basket	Real time viewing
Depriest <i>et al.</i> (21)	90, M	CAD, AF, PVD, CVA, COPD	No	IDA, OGIB	No	–	Immediate cough	No	No	–	Left main bronchus	No, bronchoscopy	Initial post procedure chest X-ray
Choi <i>et al.</i> (22)	75, M	CVA	No	OGIB	No	PillCam SB	Immediate cough	No	No	2 hours	Left main bronchus	No, bronchoscopy, Roth net, grasper forceps	Initial post procedure chest X-ray
Pezzoli <i>et al.</i> (23)	82, M	HTN	No	IDA	No	–	No	Cough	No	2 days	Left main bronchus	Yes	Reviewing data
Lucendo <i>et al.</i> (24)	80, M	PD, DM	No	IDA, FOBT+	Yes	PillCam SB	Immediate cough, dyspnea	No	No	20 sec	Trachea (carina)	Yes	Reviewing data
Shafi <i>et al.</i> (25)	67, M	HH, gastritis, diverticular disease, hemorrhoids	No	IDA, abdominal pain	No	–	No	Dyspnea after a few days	–	–	Right main bronchus	No, bronchoscopy	Symptoms
Lu <i>et al.</i> (26)	85, M	Gastritis and inflammation in descending and SC	No	IDA, melaena	Yes	OMOM	Immediate cough	No	No	–	NS	Yes, with cough encouragement	Real time viewing
Girdhar <i>et al.</i> (27)	83, M	COPD, GORD	No	IDA	–	PillCam SB2	Cough	Dyspnea after 1 hour	No	–	Left main bronchus	No, bronchoscopy, FB basket	Real time viewing
Parker <i>et al.</i> (28)	77, F	Hysterectomy, HH (oesophagus)	No	IDA, abdominal pain, weight loss	No	–	Immediate choking episode, cough	No	Massive intracranial haemorrhage hours later, deceased	–	NS	Yes	Symptoms

Table 1 (continued)

Table 1 (continued)

References	Age (years), Sex	Comorbidities	History of dysphagia	Indication for CE examination	Difficulty swallowing capsule	Capsule model	Ingestion symptoms	Symptoms during CE investigation	Symptoms after handling of aspiration	Time CE was aspirated	Anatomical location	Self-resolved or intervention	Identification of aspiration
Yarlagadda <i>et al.</i> (29)	80, M	AF, CVA	–	IDA, melena	No	M2A	No	No	–	–	Left main bronchus	No, bronchoscopy, FB basket	Reviewing data
Despott <i>et al.</i> (30)	65, M	ALD, chronic pancreatitis, COPD, gastric varices	No	IDA, OGIB	No	–	No	No	No	–	Right main bronchus	No, grasper forceps	Real time viewing
Despott <i>et al.</i> (30)	73, M	COPD	–	IDA	Yes	–	Immediate cough	No	No	–	Left main bronchus	No, Roth net	Real time viewing
Despott <i>et al.</i> (30)	81, M	None	–	IDA	Yes	–	Immediate choking sensation	No	No	–	Right main bronchus	No, rigid bronchoscopy, grasper forceps	Real time viewing
Singh <i>et al.</i> (31)	56, M	Mild COPD, HTN, Gout, CVA (left)	No	IDA	No	–	No	Progressive dyspnea over 2 weeks, cough	No	6 weeks	Right main bronchus	No, grasper forceps	Symptoms
Sánchez-Chávez and Martínez-García (32)	78, M	Gastric ulcer	No	OGIB, postprandial fullness, weight loss	Yes	PillCam COLON1	Immediate sensation in throat, cough	No	No	Few min	Bifurcation trachea	Yes	Reviewing data
Pereira <i>et al.</i> (33)	78, M	CKD on hemodialysis	–	OGIB	Yes	PillCam SB	Immediate cough	No	No	2 min 15 sec	Bronchus (NS)	Yes	Reviewing data
Hall <i>et al.</i> (34)	69, M	–	–	OGIB	–	PillCam	No	Cough 1 week after	No	7 days	Right main bronchus	No, flexible bronchoscopy, net	Symptoms
Ding <i>et al.</i> (35)	80, M	COPD, previous DU and angioectasia	–	IDA	No	–	Immediate cough	No	No	–	Right main bronchus	Yes, but Bronchoscopy, fell into Left main bronchus, then expectorated by patient	Symptoms
Ding <i>et al.</i> (35)	88, M	Previous gastric angiodysplasia	–	IDA	No	–	Immediate cough, dyspnea	No	No	2 hours 42 min	Trachea	Yes	Symptoms, reviewing data
Hussan <i>et al.</i> (36)	83, M	CKD, myelodysplasia	Yes	IDA	Yes	–	Immediately regurgitated, before manually pushing capsule down hypopharynx	No	No	30 hours	Right main bronchus	No, fiberoptic flexible bronchoscopy	Reviewing data
Elmunzer <i>et al.</i> (37)	83, M	Aspiration pneumonia, HH, CAD, AVR, PD, dementia	Yes	IDA, melena	Yes	–	Immediate cough	No	No	3 hours	Right main bronchus	No, fiberoptic bronchoscopy, endoscopic snare	Real time viewing
Mannami <i>et al.</i> (38)	85, M	DM, HTN, AF, distal gastrectomy	No	IDA, OGIB	Yes	PillCam SB2	Immediate sensation in throat	No	No	220 sec	Bronchus (NS)	Yes	Reviewing data
Magalhães-Costa <i>et al.</i> (39)	92, M	PD, DM	No	OGIB	No	PillCam SB2	No	Dyspnea, cough, capsule expelled	No	4 hours	Mouth and pharynx	Yes	Symptoms, reviewing data
Amarna <i>et al.</i> (40)	81, M	–	–	–	No	–	Immediate cough	No	No	110 days	Left main bronchus	No, flexible fiberoptic bronchoscopy, snare wire loop	Chest X-ray, reviewing data
Choi <i>et al.</i> (41)	82, M	–	No	Chronic diarrhoea, abdominal pain	No	OMOM	Immediate cough	No	No	–	Right main bronchus	No, FB basket	Real time viewing
Juanmartiñena Fernández <i>et al.</i> (42)	82, M	–	No	IDA	Yes	–	Cough	Cough, 12 hours later fever, leukocytosis, dyspnea	Fever, leukocytosis, dyspnea	25 min	Bronchus (NS)	Yes	Reviewing data
Juanmartiñena Fernández <i>et al.</i> (43)	81, M	Alzheimer, antiplatelet drug therapy	No	Melena	No	–	Immediate cough	No	No	17 sec	Tracheo-bronchial system	Yes	Reviewing data

Table 1 (continued)

Table 1 (continued)

References	Age (years), Sex	Comorbidities	History of dysphagia	Indication for CE examination	Difficulty swallowing capsule	Capsule model	Ingestion symptoms	Symptoms during CE investigation	Symptoms after handling of aspiration	Time CE was aspirated	Anatomical location	Self-resolved or intervention	Identification of aspiration
Buscot <i>et al.</i> (44)	74, M	CVA, COPD	No	IDA	No	PillCam SB2	Immediate choking episode, dyspnea, cough, desaturation	Dyspnea, coughing, desaturation	No	–	Left main bronchus	No, FB basket	Real time viewing
Ribaldone <i>et al.</i> (45)	75, M	–	No	IDA+ FOBT+	No	PillCam SB2	No	No	No	7 hours	Trachea	Yes	Reviewing data
Skouras <i>et al.</i> (46)	72, M	IBD, previous SB perforation, ileostomy, DM	No	High output stoma	No	PillCam SB2	No	No	No	30 min	Bifurcation trachea	No, retrieved with gastroscopie and put into duodenum	Real time viewing
Keil-Ríos <i>et al.</i> (47)	84, M	–	–	Fever, thickening of ileum	No	PillCam SB	No	Cough, capsule expelled	No	10 hours	Bronchus (NS)	Yes	Symptoms, reviewing data
Arroyo-Mercado and Martinez (48)	84, M	HTN, CAD, CCF, OA	No	IDA	No	–	No	No	No	9 min	Trachea (carina)	No, cough, hand thrust maneuver to midback, expelled capsule	Real time viewing
Dan <i>et al.</i> (49)	67, M	Emphysema and cardiomegaly	No	Nausea	No	Ankon	No	Cough, dyspnea	–	19 min	Bifurcation trachea; then bronchus (NS)	Yes	Real time viewing
Hilewitz <i>et al.</i> (50)	85, M	CAD	–	IDA	No	PillCam	Immediate cough	Cough	–	5 days	Right main bronchus	No, bronchoscopy, snare	Reviewing data
Rutazaana <i>et al.</i> (51)	67, M	Developmental delay	–	IDA	Yes	PillCam SB3	Immediate dyspnea	No	–	–	Right main bronchus	No, bronchoscopy	Symptoms
Takeda <i>et al.</i> (52)	77, M	SC and partial SB resection, gastrectomy, chronic right pneumothorax, CVA	–	IDA, OGIB	Yes	PillCam Patency capsule	Immediate dyspnea, desaturation	Dyspnea, desaturation	No	7 hours	Bronchus (NS)	No, flexible bronchoscopy, balloon catheter	Symptoms
Egger <i>et al.</i> (53)	69, M	Metastatic small cell lung cancer, DVT	No	IDA, melena	No	M2A	Sensation in throat	No	No	72 min	Pharynx	No, EGD with SDAC, advancing capsule to stomach	Real time viewing
Tamang and Mitnovetski (54)	87, M	–	–	IDA, FOBT+	No	PillCam SB3	Immediate cough, desaturation	Cough, desaturation	No	–	Right main bronchus	No, flexible bronchoscopy, endotracheal tube, fogarty catheters	Symptoms, real time viewing
Gaisinskaya <i>et al.</i> (55)	92, M	Gout, myelodysplastic syndrome, CKD	–	IDA, FOBT+	Yes	–	No	No	No	1 day	Bronchus (NS)	No, bronchoscopy	Reviewing data
Gomez <i>et al.</i> (56)	83, M	CAD, CVA	–	IDA	No	–	No	Yes	No	1 day	Right main bronchus	No, bronchoscopy, loop snare	Reviewing data

M, male; F, female; CE, capsule endoscopy; MVR, mitral valve replacement; IDA, iron deficiency anemia; CCF, congestive cardiac failure; AF, atrial fibrillation; CAD, coronary artery disease; CKD, chronic kidney disease; FOBT+, fecal occult blood test positive; FB, foreign body; OGIB, occult gastrointestinal bleeding; HTN, hypertension; DM, diabetes mellitus; CVA, cerebrovascular accident; NS, not specified; M2A, Mouth to Anus; SC, sigmoid colon; SB, small bowel; RCC, renal cell carcinoma; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; GORD, gastroesophageal reflux disease; PD, Parkinson disease; HH, hiatal hernia; ALD, alcohol induced liver disease; DU, duodenal ulcer; AVR, aortic valve repair; IBD, inflammatory bowel disease; OA, osteoarthritis; DVT, deep vein thrombosis; EGD, esophagogastroduodenoscopy; SDAC, Steris distal attachment cap.

Table 2 Overview of capsule aspirations in cohort observational studies

References	Number of centres	Total CE in cohort	Capsule modality	Number of aspirations	Comments
Tabib <i>et al.</i> (7)	1	600	SB	1	See <i>Table 1</i>
Rondonotti <i>et al.</i> (57)	4	733	NR	1	Capsule coughed up
Shiff <i>et al.</i> (12)	1	>1,000	SB	1	See <i>Table 1</i>
Bredenoord <i>et al.</i> (16)	1	>1,000	SB	1	See <i>Table 1</i>
Koulaouzidis <i>et al.</i> (15)	1	>2,000	SB	1	See <i>Table 1</i>
Girelli <i>et al.</i> (58)	2	267	SB	1	No symptoms before or after; remained in trachea for 18 hours, then expelled by cough
Li <i>et al.</i> (59)	1	427	SB	2	Retrieved via bronchoscopy; both patients were elderly, with a higher risk of laryngeal swallowing difficulty
Ding <i>et al.</i> (35)	1	About 300	SB	2	See <i>Table 1</i>
Sanchez-Chavez and Martinez-Garcia (32)	1	>200	SB	1	See <i>Table 1</i>
Soncini <i>et al.</i> (60)	30	1,667	SB	1	Transient, self-resolved
Pezzoli <i>et al.</i> (61)	1	900	SB	2	Tracheal aspiration; both over 80 years of age
Fernández-Urién <i>et al.</i> (62)	12	5,428	Oesophageal, SB & colon	2	Both no history of dysphagia

CE, capsule endoscopy; SB, small bowel; NR, not reported.

Presentation of capsule aspiration

Thirty-nine (61.9%) patients experienced symptoms of aspiration as they ingested the capsule. Among the patients, coughing was the most prevalent symptom, reported in 28 cases (71.8%), followed by dyspnea in 7 (17.9%) and 5 (12.8%) patients experiencing a foreign body sensation in the throat. Four patients desaturated, and 2 required supplemental oxygen. In 37 (94.8%) patients, the symptoms of aspiration occurred immediately or within a few minutes following ingestion; in the remaining, the symptoms manifested hours, days or, for some, even weeks later. Thirty-six (57%) patients were reported asymptomatic following the CE investigation, even though 27 (75%) had experienced ingestion symptoms. Fifteen (23.8%) cases were reported as having symptomatic CE investigations, with 6 (53.3%) developing dyspnea. The remaining cases had either a lack of information regarding the outcome of the investigations, or the capsule was removed due to immediate aspiration symptoms. Out of total capsules, 44 (69.8%) were found in the bronchial system, with the right main bronchus being the most common anatomical location in 21 (47.7%) cases. However, in 9 (20.4%) cases, the capsule was detected in the left main bronchus, while

10 (22.7%) capsules were lodged in the trachea, and two were found in the pharynx. The remainder did not specify the bronchial location. Among the patients, 16 (25.4%) experienced transient aspiration that lasted only second to minutes, and all cases resolved spontaneously. The duration of aspiration varied significantly between patients, with the longest recorded case lasting 110 days (40).

Handling of capsule aspiration and outcomes

Thirty-one (49.2%) patients needed intervention for retrieval of the capsule. Twenty-one (67.7%) of them were symptomatic at ingestion of the capsule. In 29 (93.5%) patients, bronchoscopy served as the primary approach for managing capsule aspiration. In 1 patient, the bronchoscopy was unsuccessful: the capsule fell into the left bronchus and was expectorated by the patient (35). In 1 patient, the capsule was retrieved with a bronchoscope and a foreign body basket, and then replaced in the gastrointestinal tract using the bronchoscope and forceps (44). Another patient had their capsule replaced by a gastroscope to the duodenum from the trachea (46). Of the 24 (38%) patients with self-resolved cases of aspiration, 15 (62.5%)

patients coughed up the capsule resulting in termination of the examination. Thirteen (86.6%) patients coughed up the capsule within minutes, and the remaining 2 (13.4%) coughed up the capsule hours after ingestion. Twenty-five (39.7%) cases detected aspiration from reviewing the capsule data afterwards, and 16 (25.4%) were detected due to real-time viewing. In 2 patients, initial post-procedure chest X-rays were done to locate the capsule, and in 16 (25.4%) cases, the patients were so symptomatic that aspiration was presumed clinically. Post-aspiration outcomes were reported in 47 (74.6%) cases, but only two patients had symptoms. One patient developed aspiration pneumonia 12 hours after the aspiration, which was only noted by reviewing the video. He was effectively treated with antibiotics (42). Another patient managed to cough up the capsule shortly after ingestion, but she died soon after the examination due to a massive intracranial hemorrhage (28). This case represents the sole recorded fatality. The remaining patients (95.7%) experienced recovery without any complications.

Aspiration rate

Twelve studies reported cases of capsule aspiration from a total of 56 centres, see *Table 2* for specifications. While the exact number of CE examinations conducted is unknown, there were approximately 14,522 CE examinations, among which only 16 cases of aspiration were reported. This indicates a remarkably low estimated rate of just 0.1%.

Discussion

The present review found that capsule aspiration is rare. It seems that aspiration primarily occurs among elderly male patients who have multiple comorbidities. In total, 39 cases were reported as symptomatic, with cough being the most frequent symptom and 94.8% having symptoms immediately. However, no significant respiratory compromise has ever been recorded. The most frequent indication was IDA, with the right main bronchus being the most common anatomical location involved. Among the patients who experienced capsule aspiration, slightly less than half required an intervention for capsule removal. In this series of capsule aspiration cases, bronchoscopy served as the primary approach for managing capsule aspiration, demonstrating a high success rate. 39.7% of capsules were discovered when reviewing data, and 25.9% with real-time viewing. A total of 95.7% of patients recovered uneventfully. This review outlines a particular patient group

where aspirations should be anticipated. Therefore, capsule administration, should be approached with precautions, and the need for stronger justification is indicated in this high-risk group. If specific precaution plans should be made for at-risk patients, the real time viewer would be a great attribute. It shows images during ongoing examination (63) and has been used more frequently in recent years. In this review, a total of 16 capsule aspirations was identified using the real time viewer, which allowed the clinicians to investigate whether the capsule was swallowed correctly. The real-time viewer has primarily been used to monitor the location of the capsule during the phases of the procedure, where delayed transit is common, and coupled it with early preventive interventions, which has significantly enhanced completion rate and positive finding rate (64,65). Real-time viewing could change the management of aspirations, where an immediate reading could save time before interventions and secure early detection, as the European Society of Gastrointestinal Endoscopy recommends (66). This review shows almost no patients experienced complications post-aspiration. However, 1 patient did noteworthy get aspiration pneumonia 12 hours after ingestion, and it was only noted due to reviewing the data. This rare case could potentially have been solved earlier, with the real-time viewer (42). It is noteworthy that the use of real time viewing may also increase the aspirations reporting, because less then would be self-resolved by patients. Another approach could be initial post procedure chest X-rays as 2 reports did (21,22), this is however a slightly more expensive procedure and would require the patients to be in the hospital, which limits the outpatient capsule delivery. Only 5 papers reported the position in which the patient swallowed the capsule. Attention should be drawn to positioning the patient correctly in an upright position when administering capsules to this particular group. To ensure early detection and appropriate management of potential aspirations, it is crucial for a clinician or other trained personnel to monitor the ingestion process closely.

This systematic review aims to provide an updated and comprehensive analysis of published evidence concerning capsule aspiration. Among the 63 cases included in this review, 45 originated from case reports or series. It is important to acknowledge that not all instances of capsule aspiration are reported or published, and our search may have missed some cases due to language and accessibility limitations, which could introduce a potential bias in the selection process and contribute to an underestimation of the true incidence. Additionally, only 12 observational

studies reported aspiration as one of their complications or outcomes, suggesting a possible underreporting and missing data on this event. However, despite the retrospective nature of case reports without statistical calculations, the included articles have been deemed suitable for the purpose of this review, indicating their adequacy in terms of quality. While the possibility of undetected or unreported cases is recognized, this systematic review represents the most up-to-date and comprehensive collection of relevant information, allowing for a more accurate estimation of capsule aspiration rates.

Aspiration of video capsules is an uncommon event that is scarcely reported on. One of the first reviews since the introduction of SBCE reported that in 22,840 procedures only 1.4% were retained, but no aspirated capsules were mentioned (67). A more recent review investigated the last two decades of distributed CE and reported that in 86,930 procedures only 2% experienced retention, but once again aspiration was not reported (3). However, another recent review does report on aspiration, with a pooled rate of aspiration as 0.00% (68). They found 5/23,449 aspiration cases, all occurring in SB investigations. They point out the risk of elderly age, but also that the rate of retention and SB incomplete examinations has declined over the years (68). In 2017, one review accumulated the data on aspiration of CE and found 37 individual cases (5). They conclude that aspiration is a rare event and safely managed, but the administration should be approached with precautions in certain patient groups. They find 94.6% male predominance and mean age of 78.9 ± 7.81 years (range, 64–93) (5), which correlates well with this review. The fact that with this comprehensive review, only additional 26 cases have been reported in the last 5 years, it is clearer that capsule aspiration is a very rare event.

Conclusions

This systematic review provides an updated and comprehensive analysis of published evidence on capsule aspiration, contributing to the current understanding of this complication. While acknowledging the potential for undetected or unreported cases, this review represents the most recent and extensive collection of relevant information, facilitating a more accurate estimation of capsule aspiration rates. In conclusion, based on the reported literature, capsule aspiration remains a rare adverse event that can be safely managed. It should not discourage patients from undergoing the procedure. However, it is

important to anticipate the possibility of aspiration in specific patient groups, and cautious measures should be taken when administering capsules.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Appendix 1

The specific search string

(capsule endoscopy OR capsule endoscopy OR capsule enteroscopy OR wireless capsule endoscopy OR wireless capsule enteroscopy OR capsule endoscope OR capsocam OR capsocam plus OR capsocam sv-1 OR capsocam sv1 OR endocapsule OR imaging m2a capsule OR m2a (capsule endoscope) OR mirocam OR mirocam green OR mirocam mc 1600 OR mirocam mc2000 OR mirocam navi OR mirocam system OR omom OR omom capsule endoscopy system OR pillcam OR pillcam colon OR pillcam colon 2 OR pillcam eso OR pillcam sb OR capsule endoscope OR capsule endoscopes OR video capsule endoscopy system OR video capsule endoscopy system capsule OR video capsule endoscopy system transmitter OR wireless capsule endoscope) AND (detection OR completion OR retention OR aspiration OR aspirate) NOT (review OR review OR meta-analysis OR analysis, meta OR meta-analysis OR meta-analysis OR meta-analysis). Filter applied: Humans (3).