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Cap-assisted endoscopic treatment of esophageal food bolus impaction and/or foreign body ingestion: a systematic review and meta-analysis

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Abstract

Background Esophageal food bolus and/or foreign body (FB) impaction is a common gastrointestinal emergency. This meta-analysis reports on the pooled outcomes of cap-assisted endoscopic removal of esophageal FB.

Methods We conducted a comprehensive search of several databases (inception to February 2022) to identify studies reporting on the use of a cap in the endoscopic treatment of esophageal FB ingestion. A random effects model was used to calculate the pooled odds ratio (OR) and mean difference (MD), and I^2 values were used to assess the heterogeneity.

Results Six studies were analyzed that included 677 patients treated with cap-assisted and 694 with conventional endoscopy. The cap-assisted method demonstrated statistically significant superiority regarding technical success (pooled OR 7.1, 95% confidence interval [CI] 1.9-26.9; P=0.004), *en bloc* removal (pooled OR 26.6, 95%CI 17.6-40.2; P<0.001), as well as a significantly shorter procedure time (4.6 min, 95%CI -6.5 to -2.8; P<0.001), compared to conventional methods. Better technical success was achieved with the cap-assisted method performed under anesthesia (OR 8.7, 95%CI 1.6-47.7; P=0.01); however, a shorter procedure time was noted for the cap-assisted method without anesthesia (MD -1.5, 95%CI -2.7 to -0.4; P=0.01). Pooled adverse events were comparable. Pooled OR for mucosal tear was significantly lower with cap in food bolus impaction (OR 0.07, 95%CI 0.01-0.38; P=0.02).

Conclusion Cap-assisted endoscopic removal of esophageal FB is associated with better technical success and *en bloc* removal, and a shorter procedure time compared to conventional methods, with comparable adverse events.

Keywords Cap-assisted endoscopy, food bolus, meta-analysis

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Introduction

Esophageal food bolus and/or foreign body (FB) impaction is one of the most common reasons for urgent gastroenterology consultation and endoscopy in the emergency room [1-3]. Esophageal FBs include sharp pointed objects (e.g., fish/chicken bones), short blunt objects and food boluses (e.g., boneless meat). Timely and safe endoscopic intervention to remove the impaction is paramount to improve patient outcomes and prevent complications, including aspiration, esophageal injury, and perforation. Studies have demonstrated that early and rapid removal of the FB and/or food bolus is associated with a better prognosis as compared to late intervention and/or prolonged procedure time [1,4].

*Authors contributed equally to the writing of the manuscript
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Different centers and endoscopists use different sedation protocols for the removal of esophageal FBs. Some perform these endoscopic procedures under moderate conscious sedation, reserving the use of general anesthesia for prolonged cases or when there is concern about very proximal impaction. However, other centers routinely perform such procedures under general anesthesia (GA) to maximize airway protection and aspiration prevention.

Different centers and endoscopists also use different endoscopic techniques for removal of esophageal impactions. The most commonly described method is the push technique, where an attempt is made to push the food impaction gently into the stomach. If this fails, the food bolus is then removed either *en bloc* or piecemeal, using a variety of endoscopic accessories to "pull out" the FB retrogradely, with or without the use of an overtube. In recent years, multiple studies have reported on the efficacy of the use of a transparent cap attached to the distal end of an upper endoscope to aid in the removal of esophageal food impaction *en bloc*, to provide improved visualization and to protect the esophageal wall for removal of FBs [5-10]. In this study, we performed a systematic review and meta-analysis of the use of cap assistance compared to other techniques for endoscopic treatment of esophageal food impaction bolus and/or FB retrieval, and the use of moderate sedation compared to GA for sedation during these procedures.

Materials and methods

Search strategy

We conducted a comprehensive search of several databases and conference proceedings, including Ovid MEDLINE, EMBASE, EBM Reviews, Scopus and Web of Science databases (earliest inception to February 2022). The key words used in the literature search and the results of the search are summarized in Appendix 1. We followed the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines [11] (Appendix 2), and the Preferred Reporting Methods in Systematic Review and Meta-analyses (PRISMA) [12] checklist (Appendix 3) to identify studies reporting on the use of cap assistance in esophageal food bolus and/or FB removal by upper endoscopy.

The search was restricted to studies in human subjects, with no restrictions on study language. Two authors (JB, HR) independently reviewed the titles and abstracts of studies identified in the primary search and excluded studies that did not address the research question, based on pre-specified exclusion and inclusion criteria. The full text of the remaining articles was reviewed to determine whether they contained relevant information. Any discrepancy in article selection was resolved by consensus, and in discussion with a coauthor (BPM). The bibliographic section of the selected articles, as well as the systematic and narrative articles on the topic, were manually searched for additional relevant articles.

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Study selection

In this meta-analysis, we included studies that evaluated the use of a transparent distal upper endoscopy cap in the treatment of esophageal food bolus and/or FB. Studies were included irrespectively of inpatient/outpatient setting and geography, as long as they provided the data needed for the analysis. Exclusion criteria included studies on FB removal from the stomach or duodenum, and studies involving a pediatric population. In cases of multiple publications from the same cohort and/or overlapping cohorts, data from the most recent and/or most appropriate comprehensive report were included.

Data abstraction and quality assessment

Data on study-related outcomes in the individual studies were abstracted onto a standardized form by at least 2 authors (JB, HR), and 2 authors (JB, HR) did the quality scoring independently. When necessary, primary study authors were contacted via email for additional data points not mentioned in their studies. The Jadad scale was used to assess the quality of randomized controlled studies and the Newcastle-Ottawa scale was used for the others [13,14]. The details of the quality scoring questions are provided in Supplementary Tables 1 and 2.

Outcomes assessed

The outcomes assessed in this study were as follows: pooled rates of technical success, pooled procedure times, and pooled adverse events. The assessment of adverse event severity was reported according to the American Society of Gastrointestinal Endoscopy (ASGE) Lexicon [15] when feasible. Otherwise, adverse events were reported as in the primary studies.

Statistical analysis

We used meta-analysis techniques to calculate the pooled estimates in each case, following the methods suggested by DerSimonian and Laird, and using a random-effects model [16]. When the incidence of an outcome was zero in a study, a continuity correction of 0.5 was added to the number of incident cases before statistical analysis. Pooled proportions with corresponding 95% confidence intervals (CI) were calculated for categorical outcomes and pooled mean differences (MD) were calculated for continuous outcomes. We assessed heterogeneity between study-specific

estimates using the Cochran Q statistical test for heterogeneity and the I^2 statistic [17,18]. In this, values of <30%, 30-60%, 61-75%, and >75% were suggestive of low, moderate, substantial, and considerable heterogeneity, respectively. Publication bias was ascertained qualitatively, by visual inspection of funnel plots, and quantitatively, by the Egger test [19,20]. All analyses were performed using Comprehensive Meta-Analysis (CMA) software, version 3 (BioStat, Englewood, NJ).

Results

Search results and population characteristics

From an initial total of 973 articles, 715 studies were retained after deduplication. After screening, 29 manuscripts were reviewed in full length. The final analysis included a total of 6 studies that compared the use of the cap-assisted endoscopic technique to conventional methods [5-10]. A total of 1371 patients were treated for esophageal food bolus and/or FB impaction: 677 with the cap-assisted endoscopic technique and 694 patients with conventional methods. Fig. 1 shows a schematic diagram of the study selection.

Males accounted for 59% of the total patients and the mean age of the study populations ranged from 47.6-62.8 years. Dysphagia and odynophagia were the most common presenting symptoms. Commonly encountered underlying esophageal abnormalities were peptic strictures (32%) and eosinophilic esophagitis (20%). Other less commonly reported abnormalities were Schatzki's ring (5%), anastomotic stricture (3%), tumor (2.4%), and post-corrosive esophagitis. Steak was the most common type of impacted food bolus in 47.8%. Fish bone (8.6%), chicken bone (6.9%), and seeds/pits (12%) were the other impacted FBs. The study and population demographics are summarized in Table 1, and additional data points of interest are summarized in Supplementary Table 1.

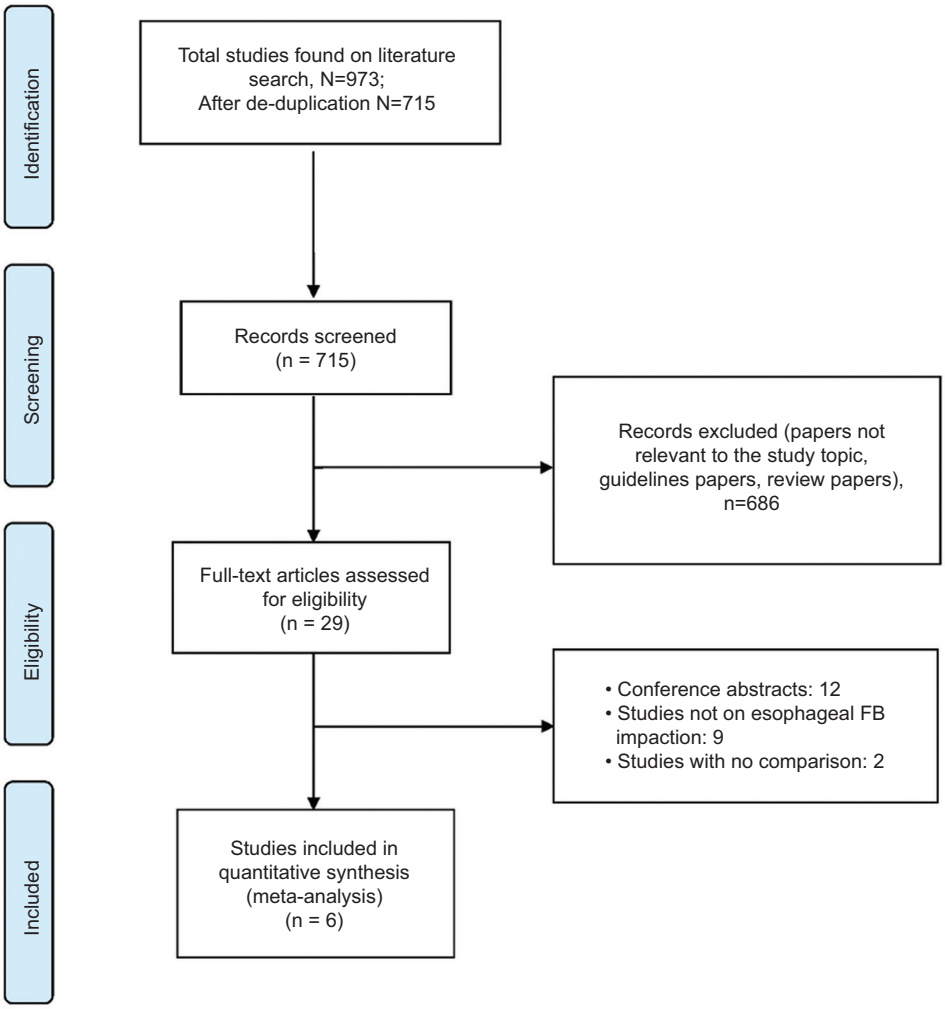

Figure 1 Study selection flowchart
FB, food bolus and/or foreign body

Table 1 Study and population characteristics

Author, [ref.] year	Study details	Cause of obstruction	Total (N)	Study cohorts	Patients per cohort	Male/ Female	Mean age, years (standard deviation)	Sedation	Technical success	*En bloc* removal	Procedure time (minutes)	Complication			
												Esophageal mucosal tear	Perforation	Locoregional bleeding	Other
Ooi, [6] 2021	Randomized controlled trial, 2017-2019, multicenter, Australia	Food bolus	342	Cap-assisted	171	119/52	54.7±15.2	GA	170	159	23.0±0.6	0	0	0	9 (sore throat)
				Conventional	171	122/49	53.6±14.7	GA	160	48	47.0±1.3	13	0	0	None
Ooi, [7] 2018	Prospective, non-randomized controlled trial, 2011-2016, single center, Australia	Food bolus	199	Cap-assisted	93	65/28	57.5±20.2	GA	93	82	34.3±8.0	0	0	0	None
				Conventional	106	74/32	60.8±19.8	GA	104	25	43.3±22.6	5	0	0	1 (aspiration pneumonia)
Wahba, [8] 2019	Prospective, non-randomized controlled trial, 2016-2018, multicenter, Egypt	Food bolus	216	Cap-assisted	106	44/62	51.7	Topical lidocaine	NR	85	6.9±3.5	0	0	0	none
				Conventional	110	48/62	52.9	Topical lidocaine	NR	17	15.7±4.1	5	0	4	none
Zhang, [9] 2013	Randomized controlled trial, single center, 2009-2010, China	Foreign bodies	70	Cap-assisted	35	12/23	47.6	Topical Pontocaine	NR	NR	2.6	33	0	17	11 (sick reaction)
				Conventional	35	17/18	48.9	Topical Pontocaine	NR	NR	4.1	31	0	18	7 (sick reaction)
Fang, [5] 2020	Retrospective cohort study, Propensity matched, single center, 2004-2018, China	Foreign bodies	448	Cap-assisted	224	121/103	62.8±16.7	Topical lidocaine	224	NR	4.1±3.3	3	9	5	none
				Conventional	224	127/97	62.4±18.2	Topical lidocaine	222	NR	8±12.6	2	8	7	none
Zhao, [10] 2017	Randomized controlled trial, China	Foreign bodies	96	Cap-assisted	48	NR	NR	Topical oropharyngeal anesthesia	48	NR	8.6±3.2	0	0	0	none
				Conventional	48	NR	NR		46	NR	10.6±5.5	0	0	0	none

GA, general anesthesia; NR, not reported

Characteristics and quality of included studies

Three studies [6,10,21] were randomized controlled trials (RCTs), 2 studies were non-randomized controlled trials [7,8], and 1 [5] was a retrospective propensity-matched study. Based on the Jadad scale of assessment for RCTs, the 3 studies were considered to be of moderate risk for bias, primarily due to the inability to blind. Based on the Newcastle-Ottawa scale for comparative cohort studies, the remaining 3 non-randomized studies were considered of high quality. Details of study quality assessments are summarized in Supplementary Table 2A,B.

Meta-analysis outcomes

Pooled rates, odds ratio (OR) for technical success

With the assistance of the cap, the pooled rate of technical success was 99.5% (95%CI 98.2-99.8) compared to 97.1% (95%CI 92.6-98.9) in the conventional methods group. The pooled OR of technical success with cap assistance compared to conventional methods was 7.1 (95%CI 1.9-26.9); P=0.004; I^2=0% (Fig. 2).

Pooled rates, OR for en bloc removal

The pooled rate of *en bloc* removal with cap assistance was 87.9% (95%CI 78.1-93.6) and with conventional methods it was 22.5% (95%CI 16-30.7). The pooled OR of *en bloc* removal with cap assistance compared to conventional methods was 26.6 (95%CI 17.6-40.2); P<0.001; I^2=0% (Fig. 3).

Pooled MD in procedure time

The pooled MD of procedure time with cap assistance compared to conventional methods was -4.6 min (95%CI -6.5 to -2.8); P<0.001; I^2=99% (Fig. 4). The actual pooled mean procedure time was 13.2 min (95%CI 2.7-23.8), standard error 5.4, with the cap and 21.4 min (95%CI 1-43.8), standard error 11.4, with the conventional method.

Subgroup analysis based on the use of GA

When GA was used, the pooled rate of technical success was 99.4% (95%CI 97.2-99.9) with cap assistance and 95.9% (95%CI 87.5-98.7) without cap. The pooled OR of technical success showed it was significantly better with cap assistance under GA, OR 8.7 (95%CI 1.6-47.7; P=0.01).

On the other hand, when GA was not used, the pooled rate of technical success in cap-assisted FB removal was 99.5% (95%CI 96.7-99.9) and in conventional FB removal it was 98.1% (95%CI 91.6-99.6). The pooled rate of technical success with cap assistance was comparable to conventional methods, pooled OR 5.1 (95%CI 0.6-44.4; P=0.1) (Supplementary Fig. 1).

The pooled MD in procedure time with cap assistance was comparable to conventional methods in studies that used GA, MD -12.1 (95%CI -34.8 to 10.6; P=0.3), whereas the pooled MD in procedure time with cap assistance was significantly faster as compared to conventional methods in studies

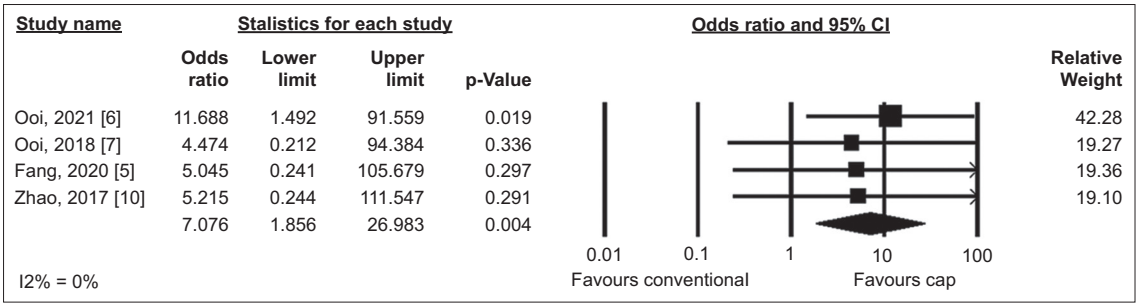

Figure 2 Forest plot, odds ratio – technical success
CI, confidence interval

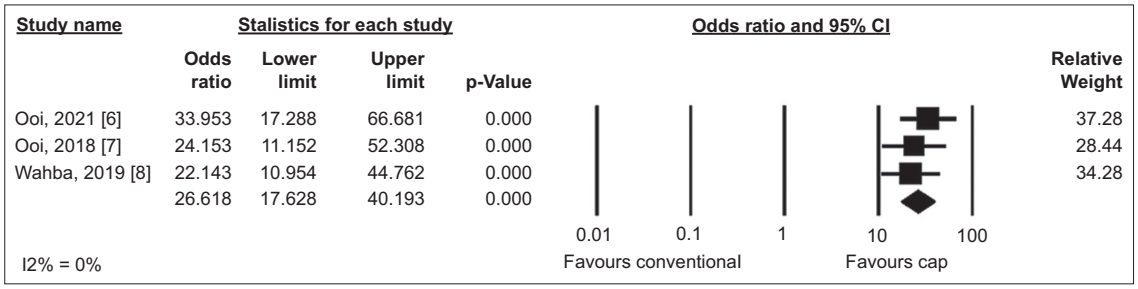

Figure 3 Forest plot, odds ratio – *en bloc* removal
CI, confidence interval

that did not use GA, MD -1.5 (95%CI -2.7 to -0.4; P=0.01) (Supplementary Fig. 2).

Pooled OR for adverse events

The pooled OR for adverse events with cap assistance compared to conventional methods was as follows: esophageal mucosal tear was 0.4 (95%CI 0.1-1.7; P=0.2), locoregional bleeding was 0.8 (95%CI 0.1-1.7; P=0.2), and perforation was 1.1 (95%CI 0.5-2.6; P=0.8). In studies that evaluated a food bolus, the pooled OR of mucosal tear was significantly lower with cap-assisted endoscopy compared to conventional methods, OR 0.07 (95%CI 0.01-0.38; P=0.02) (Supplementary Figs. 3-5). All pooled results are summarized in Table 2.

Validation of meta-analysis results

Sensitivity analysis

To assess whether any one study had a dominant effect on the meta-analysis, we excluded one study at a time and analyzed its effect on the main summary estimate. After excluding the study by Ooi *et al* [6], there was a loss of statistical significance in the cap-assisted group for technical success (pooled OR 4.72, 95%CI 0.80-27.90; P=0.09).

Heterogeneity

We assessed dispersion of the calculated rates using the I^2 percentage values. Overall low heterogeneity was noted among

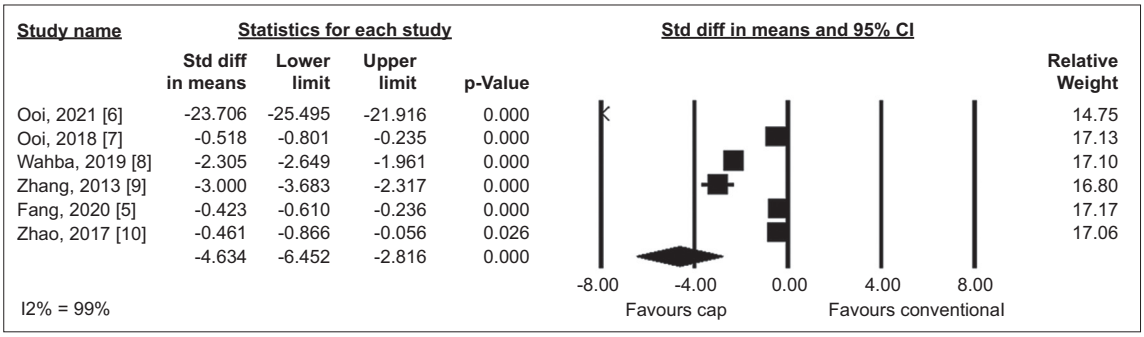

Figure 4 Forest plot, mean difference – procedure time
CI, confidence interval

Table 2 Summary of pooled rates

Outcome	Pooled OR (95% confidence interval); P-value	Heterogeneity: I^2 (%)
Technical success	7.1 (1.9-26.9); P=0.004 Cap: 99.5% (98.2-99.8) Conv: 97.1% (92.6-98.9); P=0.03	0
Anesthesia:		
yes (cap vs. conventional)	8.7 (1.6-47.7); P=0.01	
no (cap vs. conventional)	5.1 (0.6-44.4); P=0.1	
Cap with GA	99.4% (97.2-99.9)	
Conventional with GA	95.9% (87.5-98.7)	
Cap without GA	99.5% (96.7-99.9)	
Conventional without GA	98.1% (91.6-99.6)	
En bloc removal	26.6 (17.6-40.2); P<0.001 Cap: 87.9% (78.1-93.6) Conv: 22.5% (16-30.7); P<0.001	0
Procedure time (min)	MD -4.6 (-6.5 to -2.8); P<0.001	99
Cap	Pooled mean 13.2 (2.7-23.8) min, SE=5.4	
	Pooled mean 21.4 (1-43.8) min, SE=11.4	
Conventional		
Anesthesia:		
Yes	MD -12.1 (-34.8 to 10.6); P=0.3	
No	MD -1.5 (-2.7 to -0.4); P=0.01	
Adverse events		
Mucosal tear	OR 0.4 (0.1-1.7); P=0.2	48
– - food bolus	OR 0.07 (0.01-0.38); P=0.02	
Loco-regional bleeding	OR 0.8 (0.4-1.5); P=0.4	0
Perforation	OR 1.1 (0.5-2.6); P=0.8	0

OR, odds ratio, MD, mean difference (cap vs. conventional); GA, general anesthesia; SE, standard error

pooled OR for *en bloc* resection, esophageal mucosal tears, and technical success. However high heterogeneity was noted while calculating the MD in procedure times. This was probably due to differences in the definitions of procedure time used in the included studies.

Publication bias

A publication bias assessment was deferred as the total number of studies included in the final analysis was less than 10.

Discussion

In this meta-analysis of 6 studies, we demonstrated that the cap-assisted technique for endoscopic treatment of esophageal food bolus and/or FB impaction was associated with a significantly better technical success rate (P=0.004) and *en bloc* removal rate (P<0.001), with a shorter procedure time (P<0.001), compared to other conventional endoscopic methods. This is the first meta-analysis to address this topic and the results support the use of cap assistance in endoscopic removal of esophageal FB and/or food bolus impaction compared to standard techniques.

Esophageal impaction of an ingested FB is a common endoscopic emergency encountered in clinical practice and can result in serious adverse events, including aspiration pneumonia, bleeding, perforation and even death [1-4]. The global burden of FB impaction is increasing because of the increasing prevalence of strictures related to acid reflux disease and eosinophilic esophagitis [1-4,22]. Both the push and pull techniques have been described for retrieval of impacted FBs, as described earlier. The ASGE recommends caution with the push technique in certain clinical situations, given the associated risk of perforation [1]. If the push technique is unsuccessful or not used, the pull technique is implemented; this often leads to piecemeal extraction, which can be time consuming and can cause injury to the surrounding esophageal mucosa [2,4].

The cap-assisted technique involves the use of a transparent cap fitted onto the tip of the endoscope, similar to the caps used in esophageal variceal ligation. Current ASGE guidelines do not mention the cap-assisted technique for FB extraction [1]. European Society of Gastrointestinal Endoscopy (ESGE) guidelines recommend cap-assisted techniques if an overtube is not available, to reduce the risk of mucosal injury during removal of a sharp pointed object [4]. Both guidelines were published before most of the studies included in this meta-analysis were published. The cap-assisted technique has been studied more recently to explore its advantages over conventional methods for extraction of FBs. The cap enables the endoscopist to apply strong suction to the FB surface and dislodge it from the surrounding esophageal wall, which results in rapid *en bloc* removal of the food bolus. In addition, it provides improved visualization for access to the FB, especially for proximal impactions. This probably translates to significantly shorter procedure times, as we found in our analysis. The *en bloc* removal was calculated for food bolus impactions and not FB.

Another interesting finding of this study was on the use of GA. Sedation protocols differ based on different hospital policies. In some centers, the routine use of GA is part of the protocol for endoscopic esophageal FB removal. However, in many centers, including our own, GA is used at the endoscopist's discretion. The deciding factors are usually based on the risk of aspiration, proximal location, anticipation of a prolonged procedure time, and/or concern for intolerance of standard conscious sedation. Both the ASGE and ESGE guidelines consider its use in high-risk patients and the ASGE states that most cases may be managed with conscious sedation.

In this study the pooled rate of technical success in cap-assisted FB removal with the use of GA was 99.4%, compared to 95.9% for conventional FB removal, whereas the pooled technical successes were comparable between the cap-assisted technique and conventional methods when GA was not used (99.5% vs. 98.1%; P=0.1). Although the use of GA was associated with better technical success in the cap-assisted group compared to conventional methods (P=0.01), the pooled MD in procedure time was shorter with cap assistance in studies that did not employ GA (P=0.01). This finding might reflect differences in the calculation of procedure time, and more studies are needed to ascertain the clinical impact of this finding.

The pooled adverse events were comparable between cap-assisted endoscopy and conventional methods. The major reported events were esophageal mucosal tear, locoregional bleeding and perforation. However, in a subgroup analysis of food bolus impactions alone, the pooled OR of mucosal tear was significantly lower with the use of a cap as compared to the conventional methods (P=0.02). This may be due to protection of the esophageal wall afforded by the cap during faster and more atraumatic removal of the FB. The perforation rates were related to the endoscopy procedure itself; however, granular details about the underlying disease, such as malignancy, were not provided in the included studies.

Our analysis demonstrates several strengths, including the most up-to-date systematic literature search with well-defined inclusion criteria, careful exclusion of redundant studies, inclusion of high-quality studies with rigorous evaluation of study quality to establish or refute the validity of the results. Secondly, we only included studies that compared outcomes with cap-assisted versus conventional endoscopic techniques for FB removal and the majority of the included studies were prospective in nature. Thirdly, the included studies in our analysis span various geographical locations, thus making our results more generalizable to routine clinical practice. Finally, we encountered low amounts of heterogeneity for most of our reported outcomes.

There are limitations to this study, most of which are inherent to any meta-analysis. We could include only 6 studies, as only that many were available, which could have underpowered our outcomes. These studies included patients with food bolus impaction only, FB impaction only or both. However, all these studies compared the efficacy of cap vs. no cap use in esophageal impaction; therefore, we felt it was reasonable to combine the studies for our analysis. Data pertaining to food bolus alone or FB alone were not sufficient (only 2 studies in each group) to calculate pooled rates of technical success. The procedure times were calculated from beginning of sedation to extubation

in 2 studies and from beginning of esophageal examination to removal of FB in 3 studies, which could have led to heterogeneity for pooled MD in procedure time. Nevertheless, this meta-analysis is based on the best available global data on the endoscopic treatment of esophageal food bolus and/or FB.

In conclusion, this meta-analysis demonstrated significantly better pooled technical success and *en bloc* removal, and shorter procedure times with cap-assisted endoscopic removal of esophageal food bolus and/or FB impaction. The incidence of esophageal mucosal tear was significantly lower with the use of the cap for retrieval of esophageal food bolus impactions. Excellent clinical outcomes seem to be achievable, even without the use of GA. Additional research is warranted to further study the type and size of transparent cap that would provide the best clinical outcome.

Summary Box

What is already known:

- Endoscopic treatment of food bolus and/or foreign body (FB) impaction is a life-threatening emergency
- Gentle pushing of the food bolus into the stomach can be successful; however, it is up to the endoscopist's discretion to use endoscopic tools to retrieve the FB or remove the food bolus based on the clinical situation
- Use of general anesthesia in such cases is dependent on the institutional policy and endoscopist's comfort level, keeping in mind the safety of the patient's airway

What the new findings are:

- The use of a transparent cap was associated with a significantly better technical success rate and *en bloc* removal rate of food bolus and/or FB impaction in the esophagus
- It was associated with faster procedure times as compared to conventional techniques
- It was associated with fewer adverse events, especially esophageal mucosal tears in food bolus impactions
- It can be safely performed without general anesthesia and seems to demonstrate comparable clinical outcomes when general anesthesia is used

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Supplementary Table 1 Supplementary data

Author, [ref.] year	Study cohorts	(N) per cohort	Underlying disease							Location of Impaction		
			Peptic stricture	Eosinophilic esophagitis	Schatzki ring	Anastomotic stricture	Tumor	No pathology (normal esophagus)	Other	Distal	Middle	Proximal
Ooi 2021 [6]	Cap-assisted	171	69	48	8	6	0	40	NR	130	35	6
	Conventional	171	63	51	9	4	0	44	NR	132	37	2
Ooi 2018 [7]	Cap-assisted	93	26	18	5	4	1	39	NR	61	27	5
	Conventional	106	38	24	5	3	3	33	NR	71	31	4
Wahba 2019 [8]	Cap-assisted	106	21	4	5	1	4	37	post corrosive esophagitis-32; esophagitis-2	23	37	46
	Conventional	110	24	6	5	4	6	34	post corrosive esophagitis-30; esophagitis-1	27	34	49
Zhang 2013 [9]	Cap-assisted	35	0	0	0	0	0	0	1 (hiatal hernia), 2 (peptic ulcer); esophagitis-3	0	0	35
	Conventional	35	0	0	0	0	0	0	2 (hiatal hernia), 1 (peptic ulcer), 1 (achalasia); esophagitis-2	0	0	35
Fang 2020 [5]	Cap-assisted	224	0	0	0	0	2	209	4; benign stricture-9	24	67	133
	Conventional	224	0	0	0	0	13	164	11; benign stricture-36	26	69	129
Zhao 2017 [10]	Cap-assisted	48	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	Conventional	48	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

NR, not reported

Supplementary Table 2A Study quality assessment – Jadad scoring system

Author, [ref.] year	Randomization			Blinding			Account of all patients	Score (total=5)	Risk of bias
	Randomization mentioned: +1	Randomization appropriate: +1	Inappropriate method of randomization: -1	Blinding mentioned: +1	Method appropriate: +1	Method inappropriate: -1	All pts accounted for: +1		
Ooi 2021 [6]	1	1	0	0	0	-1	1	2	Moderate
Zhang 2013 [9]	1	1	0	0	0	-1	1	2	Moderate
Zhao 2017 [10]	1	1	0	0	0	-1	1	2	Moderate

Supplementary Table 2B Study quality assessment – Newcastle-Ottawa scoring system

Author, [ref.] year	Selection				Comparability	Outcome			Score	Quality
	Representativeness of the average adult in community	Cohort size	Information on outcomes	Outcome not present at start	Comparison group adequately controlled for	Adequate clinical assessment	Follow-up time	Adequacy of follow up	MAX=8, HIGH>6, MEDIUM 4-6, LOW<4	
	Population based: 1; Multi-center: 0.5; Single-center: 0	>40 patients: 1; 39-20: 0.5; <20: 0	Information with clarity: 1; information derived: 0.5	Not present: 1; present: 0	Yes: 1; no: 0	Yes: 1; no: 0	Yes: 1; not mentioned: 0	All patients followed up: 1; >50% followed up: 0.5; <50% followed up OR not mentioned: 0		
Ooi 2018 [7]	0	1	1	1	1	1	1	1	7	High
Wahba 2019 [8]	0.5	1	1	1	1	1	1	1	7.5	High
Fang 2020 [5]	0	1	1	1	1	1	1	1	7	High

Appendix

Searches ran on 02/02/2022

OVID

Database(s): Ovid MEDLINE® ALL (1946 to February 02, 2022), EBM Revie–s - Cochrane Central Register of Controlled Trials February 2022, EBM Revie–s - Cochrane Database of Systematic Reviews

Appendix 1 Literature search strategy

#	Searches	Results
1	*upper endoscopy/or *EGD/or esophagoscopy or *esophagogastroduodenoscopy	204
2	*food bolus/or *food impaction/or *foreign body/or food bolus.mp. or foreign body.mp. or food impaction.mp.	371
3	*clear cap/or *cap assisted endoscopy/or cap.mp. or clear cap.mp.	475
4	1 and 2 and 3	1050
5	remove duplicates from 4	704

PubMed, 1816 results (English only)

((endoscopy [majr] AND cap-assisted [majr]) “R “”GD”[majr] “R “clear ”ap”[majr] OR esophagogastroduodenoscopy [tiab]) AND“
(“food bo”us”[majr] “R “foreign b”dy”[majr] OR food impaction [tiab] OR foreign body impaction [tiab]) AND“
(“upper endosc”py”[majr] OR esophagogastroduodenoscopy [tiab])

Scopus

1	TITLE-ABS-KEY (“("endosc”py" O“ ""GD" OR esophagogastroduodenoscopy) AND “("Food bo”us" O“ "foreign b”dy" O“ "food impact”on" O“ "foreign body impact”on") AND “("clear ”ap" O“ "cap assis”ed" OR cap) AND (endoscopy))	105

Web of Science

“	("endosc”py" O“ ""GD" OR esophagogastroduodenoscopy) AND “("Food bo”us" O“ "foreign b”dy" O“ "food impact”on" O“ "foreign body impact”on") AND “("clear ”ap" O“ "cap assis”ed" OR cap) AND (endoscopy)	164

973 total article references
258 duplicates found in EndNote
715 total references in EndNote

Appendix 2 MOOSE checklist [11]

Item No	Recommendation	Reported on Page No
	Reporting of background should include	
1	Problem definition	5
2	Hypothesis statement	-na-
3	Description of study outcome (s)	5-6
4	Type of exposure or intervention used	5-6
5	Type of study designs used	-na-
6	Study population	5-6
	Reporting of search strategy should include	
7	Qualifications of searchers (e.g., librarians and investigators)	7, Appendix 1
8	Search strategy, including time period included in the synthesis and key words	7, Appendix 1
9	Effort to include all available studies, including contact with authors	8
10	Databases and registries searched	Appendix 1
11	Search software used, name and version, including special features used (e.g., explosion)	-na-
12	Use of hand searching (e.g., reference lists of obtained articles)	8
13	List of citations located and those excluded, including justification	Figure 1
14	Method of addressing articles published in languages other than English	8
15	Method of handling abstracts and unpublished studies	7, 8
16	Description of any contact with authors	8
	Reporting of methods should include	
17	Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	8
18	Rationale for the selection and coding of data (e.g., sound clinical principles or convenience)	8
19	Documentation of how data were classified and coded (e.g., multiple raters, blinding and interrater reliability)	-na-
20	Assessment of confounding (e.g., comparability of cases and controls in studies where appropriate)	-na-
21	Assessment of study quality, including blinding of quality assessors, stratification or regression on possible predictors of study results	8, Supplementary Table 2A, B
22	Assessment of heterogeneity	9
23	Description of statistical methods (e.g., complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	9
24	Provision of appropriate tables and graphics	provided
	Reporting of results should include	
25	Graphic summarizing individual study estimates and overall estimate	Forest plots, Table 2
26	Table giving descriptive information for each study included	Table 1
27	Results of sensitivity testing (e.g., subgroup analysis)	Table 2
28	Indication of statistical uncertainty of findings	13

Item No	Recommendation	Reported on page No
	Reporting of discussion should include	
29	Quantitative assessment of bias (e.g., publication bias)	13
30	Justification for exclusion (e.g., exclusion of non-English language citations)	-na-
31	Assessment of quality of included studies	Supplementary Table 2
	Reporting of conclusions should include	
32	Consideration of alternative explanations for observed results	14-16
33	Generalization of the conclusions (i.e., appropriate for the data presented and within the domain of the literature review)	14
34	Guidelines for future research	16
35	Disclosure of funding source	17

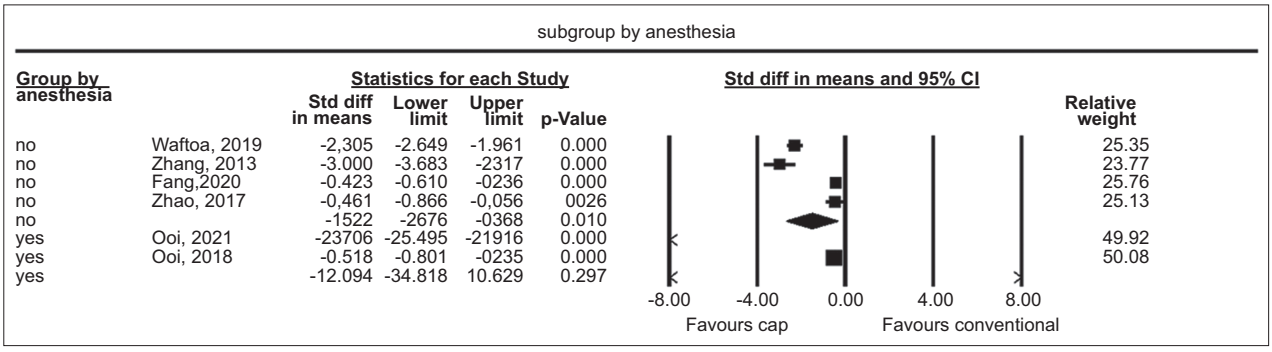
Appendix 3 PRISMA checklist

Section/topic	#	Checklist item	Reported on page #
		Title	
Title	1	Identify the report as a systematic review, meta-analysis, or both	1
		Abstract	
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number	4
		Introduction	
Rationale	3	Describe the rationale for the review in the context of what is already known	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS)	6
		Methods	
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number	-na-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched	Appendix-1
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated	8, appendix-1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis)	8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators	8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made	8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis	9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means)	9
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis	9
Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies)	11
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified	12
		Results	
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram	10, 11, 12
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations	10, Table 1
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12)	11, Supplementary Table 2
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot	11, 12

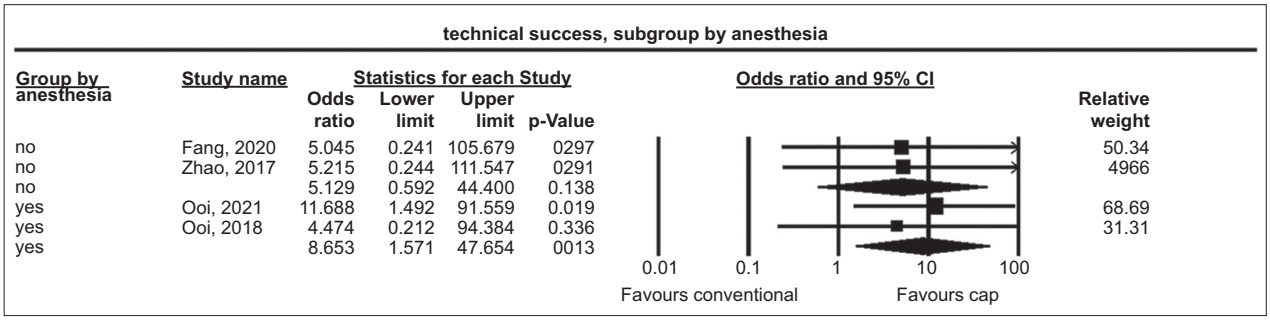
(Contd...)

Appendix 3 *(Continued)*

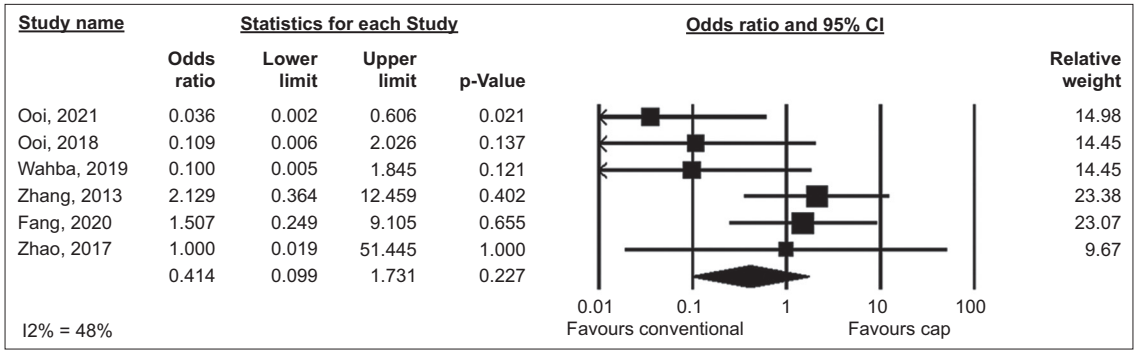
Section/topic	#	Checklist item	Reported on page #
Synthesis of results	21	Present the main results of the review. If meta-analyses are done, include for each, confidence intervals and measures of consistency	11, 12
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15)	Supplementary Table 2
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16])	13, Table 2
		Discussion	
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers)	14-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias)	16
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research	16
		Funding	
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review	17



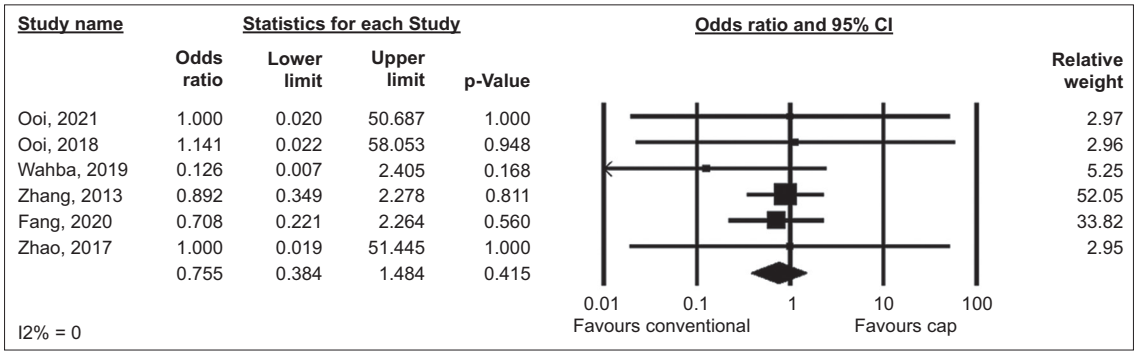
Supplementary Figure 1 Forest plot, subgroup analysis of technical success by anesthesia
CI, confidence interval



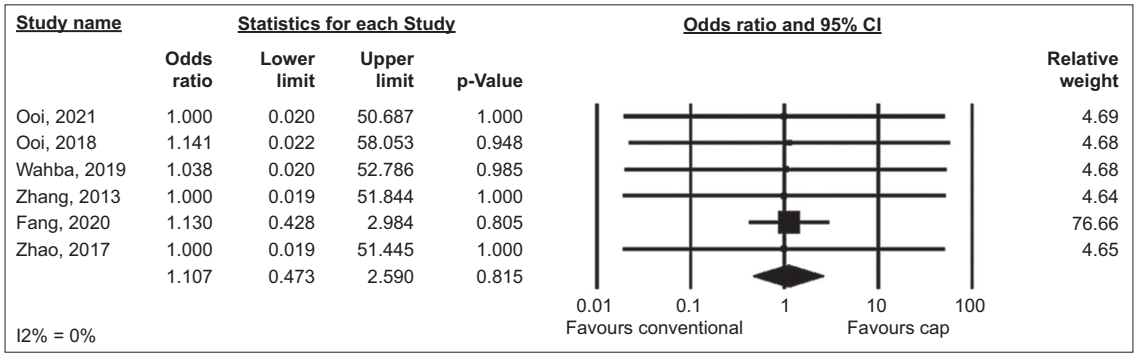
Supplementary Figure 2 Forest plot, subgroup analysis of procedure time by anesthesia
CI, confidence interval



Supplementary Figure 3 Forest plot, mucosal tear
CI, confidence interval



Supplementary Figure 4 Forest plot, locoregional bleeding
CI, confidence interval



Supplementary Figure 5 Forest plot, perforation
CI, confidence interval