



Same day barium esophagography and high-resolution manometry during the COVID-19 pandemic

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Abstract

Purpose Double contrast barium esophagography (BAS) and high-resolution manometry (HRM) are traditionally performed on separate days to allow for pre-procedural fasting. In an effort to minimize COVID-19 exposure and improve appointment efficiency with required pre-procedure testing, we permitted same day HRM prior to BAS. Our study aimed to evaluate the adequacy of barium mucosal coating with same day HRM prior to BAS compared to BAS alone.

Methods We performed a retrospective pilot cohort study including 14 patients undergoing same day HRM prior to BAS and 20 patients undergoing BAS alone over an 8-month interval during the COVID-19 pandemic. Three abdominal imaging subspecialty-trained radiologists blindly reviewed the images and graded adequacy of esophageal coating on a 4-point scale with a score of 1 representing inadequate coating and 4 representing optimal coating.

Results For the cohort studied thus far, the mean grade of the HRM and BAS group was 3.17 with a standard deviation of 0.66. The mean grade of the BAS alone group was 3.13 with a standard deviation of 0.79. There was no statistical difference in the adequacy of esophageal coating between the two groups (p -value 0.97).

Conclusion Same day HRM prior to BAS has no detrimental effect on barium mucosal coating compared to BAS alone. Though created to limit patient exposures during the COVID pandemic, same day BAS and HRM may prevent delays in care and improve convenience towards improved patient-centered care beyond the pandemic.

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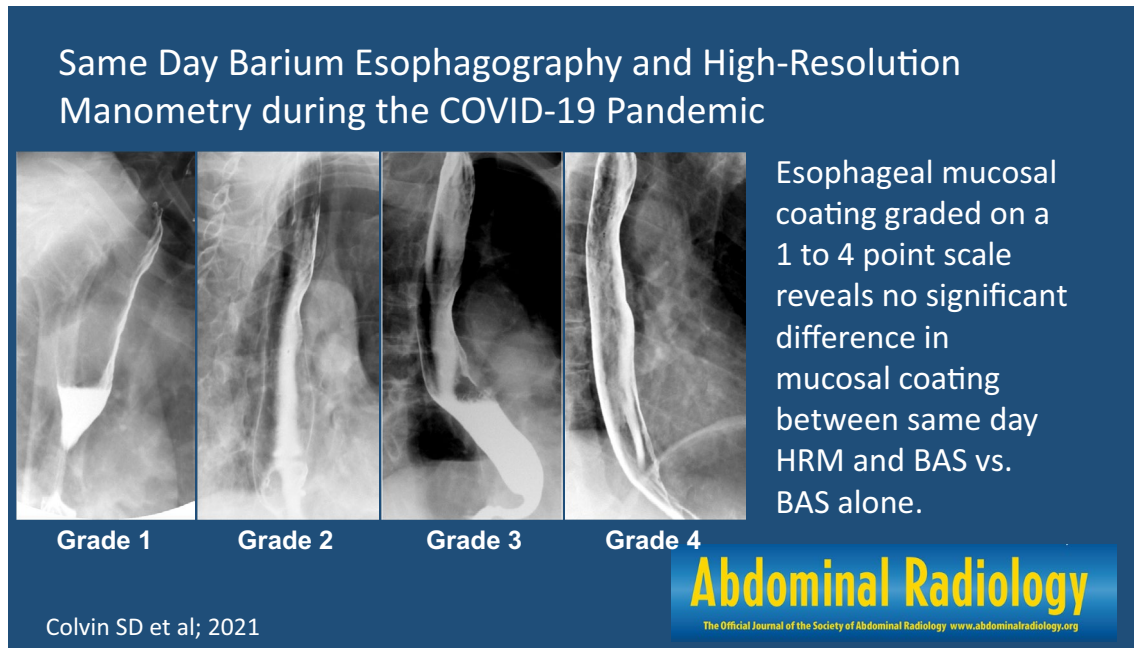
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Graphic abstract



Keywords Esophagus · Barium · COVID-19 · Pandemic · Manometry

Introduction

The COVID-19 pandemic presented unexpected challenges regarding patient care, with many institutions requiring mandatory screening to limit COVID-19 exposures and use of personal protective equipment (PPE) including gloves and surgical masks. Double contrast barium esophagography (BAS) and high-resolution manometry (HRM) are frequently used in conjunction to diagnose esophageal motility disorders and for pre-operative planning for many gastrointestinal operations including hiatal hernia repairs and myotomy for achalasia [1]. BAS indications are broad and include anatomical and functional evaluation of esophageal disorders including dysphagia, dysmotility, gastroesophageal reflux (GERD), malignancy, strictures, and hiatal hernias, among others [2]. HRM indications often overlap with BAS and include functional evaluation of dysphagia, GERD, and atypical chest pain [3]. Additionally, BAS and HRM are often used in conjunction for pre- and post-operative evaluation for various foregut operations. Our institution required COVID-19 screening prior to BAS and HRM as both procedures are considered aerosol-generating [4, 5]. Historically both studies require pre-procedural fasting to optimize HRM esophageal pressure results and BAS esophageal mucosal coating, and to reduce aspiration risks to the patient [2, 6]. When patients

are NPO, barium can adequately coat the esophageal mucosa for optimal visualization of mucosal pathology against an air-distended lumen. Same day performance of HRM and BAS prevents pre-procedure fasting for the second study, as liquids are consumed during each procedure. We aimed to minimize COVID-19 testing, conserve PPE, and increase efficiency at our institution by allowing same day HRM prior to BAS.

Methods

This retrospective observational study was submitted to the Institutional Review Board (IRB) prior to data collection. The IRB confirmed that no ethical approval was required for this study. Our retrospective cohort study included patients undergoing same day HRM prior to BAS and patients undergoing BAS alone from June 2020 to February 2021. We evaluated 34 patients total, including 14 patients with same day HRM prior to BAS and 20 patients with BAS alone. Only double contrast BAS exams were included in the study. BAS was performed by a board-certified, subspecialty radiologist in all patients, 18 without resident participation (6 HRM + BAS, 12 BAS alone) and 16 with resident participation (8 HRM + BAS, 8 BAS alone). Resident participation involved the exam being primarily performed by a resident with an abdominal subspecialist attending directly

supervising. Six of the exams were performed by one of the three blinded readers. Exams in both cohorts were controlled for the presence or absence of resident participation and radiologist performing the exam.

HRM protocol

After the patient had been fasting for at least six hours, the HRM catheter was inserted through the nare while the patient was in the upright posture. As the catheter was being inserted, the patient swallowed saline until the catheter was positioned in the stomach. The patient was then placed in the supine position for the duration of the study. Ten wet swallows of 5 mL of saline were used to initiate esophageal peristalsis and individual swallows were timed 30 s or more apart. After the study was complete, the manometry catheter was removed.

BAS protocol

Standing lateral and AP pharyngeal swallows were recorded using three approximately 5 to 10 mL swallows of thin barium in each position, as a screen for swallowing dysfunction and morphologic abnormalities. The patient was then placed in the standing left posterior oblique (LPO) position. Bicarbonate was administered in 10 mL water followed promptly by 60 mL thick barium, and 3 air contrast digital views of the esophagus were obtained. The patient was placed in the standing AP and lateral positions and air contrast views of the pharynx were obtained. Next, the patient was placed in

the right anterior oblique (RAO) position. Peristalsis was evaluated and recorded using 3 single swallows of approximately 10 mL each thin barium. Esophageal distensibility was evaluated using fluoroscopy while the patient drank 3 consecutive swallows (approximately 10 mL each) of thin barium to optimize detection of esophageal strictures. During multiple consecutive swallows of the remaining thin barium, spot images were obtained of the distended esophagus. The patient was then rotated into the supine and right posterior oblique (RPO) position to evaluate for reflux. If no spontaneous reflux occurred, provocative maneuvers were utilized including Valsalva maneuver, water siphon, and right lateral positioning. Coughing was not assessed as a provocative maneuver due to the COVID-19 pandemic. The table was then turned upright and a 12.5 mm barium tablet was administered with water in the standing LPO position.

Grading system

BAS images were retrospectively and independently reviewed by three blinded radiologists (SG, JZ, DM) with subspecialty training in abdominal imaging and fluoroscopy and 4, 7, and 18 years of experience, respectively. Each radiologist used a 4-point grading scale to grade the adequacy of esophageal coating. Grade 1 was defined as inadequate coating (difficulty seeing wall in continuity outlined by barium), grade 2 as suboptimal coating (wall seen in continuity but poor surface details), grade 3 as adequate coating (wall seen in continuity and adequate surface details), and grade 4 as optimal coating (wall seen very well, cannot imagine a better)

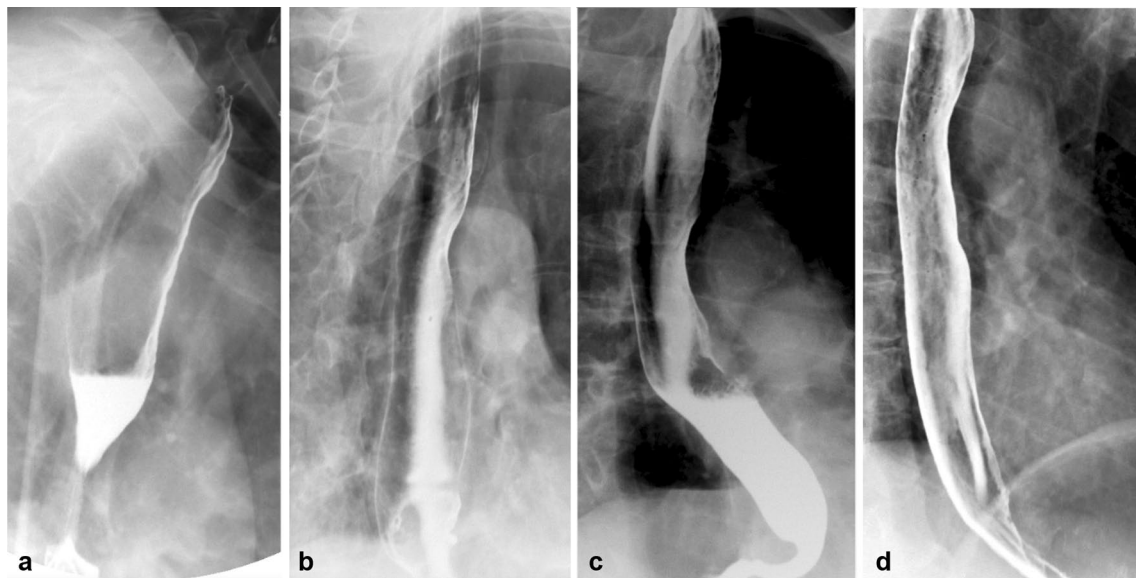


Fig. 1 Examples of esophageal mucosal coating grading system. **a** Grade 1 inadequate coating, difficulty seeing wall in continuity outlined by barium; **b** grade 2 suboptimal coating, wall seen in conti-

nity but poor surface details; **c** grade 3 adequate coating, wall seen in continuity and adequate surface details; **d** grade 4 optimal coating, wall seen very well and cannot imagine a better coating

coating) (Fig. 1). The overall mean, median, and standard deviation of the assigned grades were calculated for each of the groups. An unpaired t-test was used for statistical comparison of both groups.

Results

Demographics of each cohort are compared in Table 1. There is no significant difference between the mean age in both groups (53.3 years in BAS alone vs. 57.2 years in same day HRM and BAS, $p=0.49$). There is comparable distribution of gender between the two groups with both groups consisting of more females than males (70% female in BAS alone vs. 71% female in same day HRM and BAS, $p=0.93$).

In the same day HRM group, the time from HRM to BAS ranged from 37 min to 4 h and 18 min. The mean time between HRM and BAS was 1 h and 21 min with median time of 57 min and standard deviation of 58 min.

The overall BAS grading results of both groups are provided in Table 2. The individual reader same day HRM and BAS group grades range from 2 to 4 with an overall mean of 3.17, median 3.00, and standard deviation of 0.66 (Figs. 2, 3). The individual reader BAS alone group grades range from 1 to 4 with an overall mean of 3.13, median of 3.00, and standard deviation of 0.79 (Figs. 4, 5). The calculated p-value between the two groups is 0.97.

Discussion

HRM and BAS are often performed to evaluate motility disorders and for pre-operative planning for various gastrointestinal operations including hiatal hernia repair and myotomy for achalasia. Both HRM and BAS are considered potential aerosol-generating procedures by the American Gastroenterology Association and Radiological Society of North America COVID-19 Task Force, respectively, and require COVID-19 screening at many institutions [4, 5]. The American College of Radiology recommends fasting for at least 2 h prior to a routine BAS [2]. HRM and BAS are traditionally

performed on separate days to allow appropriate preprocedural fasting, theoretically optimizing HRM esophageal pressure measurements and BAS esophageal mucosal coating [2, 6]. We hypothesized that there was no loss in study quality utilizing same day HRM and BAS, while increasing efficiency, conserving resources, reducing patient expenses and time off work/traveling, and limiting patient exposures during the COVID pandemic.

BAS indications are highly variable and include functional and anatomic indications such as dysphagia, GERD, esophagitis, strictures, esophageal obstruction, suspected malignancy, as well as pre- and post-operative evaluation [2]. Current indications for HRM include functional evaluation (not anatomic) including dysphagia, GERD, atypical chest pain, and pre- and post-operative planning [3]. HRM and BAS are both essential for pre-operative planning for anti-reflux surgery to evaluate esophageal motility, exclude achalasia, and to determine baseline anatomy (i.e. presence/absence of hiatal hernia) [7–9]. The Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) also recommends BAS in the pre-operative workup for hiatal hernia repair with selective use of HRM [10]. Further, HRM and BAS play major roles in the diagnosis and evaluation of achalasia based on pressurization measurements, contraction patterns, characterization of the lower esophageal sphincter, and characteristic BAS appearance with delayed emptying on timed BAS [11].

BAS provides unique evaluation of mucosal pathology which HRM does not provide. BAS optimizes mucosal evaluation by distending the esophagus with air using an effervescent agent, followed by consumption of thick barium to coat the mucosa. The radiopaque barium outlines fine mucosal abnormalities against the radiolucent distended air-filled lumen. Pharyngeal and esophageal mucosal pathology are thus readily visible. These include esophagitis, ulceration, Barrett's esophagus, strictures, and malignancy, all of which are incompletely evaluated with HRM. [12–14]

Inexpensive, non-invasive, and readily available, BAS is often the first exam performed for patients presenting with esophageal symptoms [15]. Compared to the gold standard endoscopy, BAS has shown comparable sensitivity and specificity for detecting reflux esophagitis [16]. Additionally, BAS demonstrates comparable sensitivity to endoscopy for detection of esophageal carcinoma, measuring greater than 95% [17–21]. BAS is similarly excellent for detection of esophageal strictures, with a reported sensitivity of 95% [22]. Gupta et. al compared radiographically benign and malignant strictures with endoscopy and pathologic findings. 100% of radiographically benign strictures were endoscopically benign, 100% of radiographically malignant strictures were endoscopically malignant, and 93% of radiographically equivocal strictures were endoscopically benign, demonstrating high BAS and endoscopy correlation [23].

Table 1 Demographics of both cohorts

	BAS alone	Same day HRM and bas
Age		
Mean	53.3	57.2
Median	56.0	61.5
SD	16.6	15.4
Gender		
Male	30.0% (6/20)	28.6% (4/14)
Female	70.0% (14/20)	71.4% (10/14)

Table 2 Results of quality of esophageal coating in both cohorts

Attending	Same day HRM and BAS			Mean	Median
	Esophageal coating	Esophageal coating	Esophageal coating		
A	3	3	3	3.00	3
B	4	4	3	3.67	4
C	4	3	3	3.33	3
A	3	3	2	2.67	3
D	3	3	4	3.33	3
E	3	3	2	2.67	3
A	3	3	3	3.00	3
F	4	4	4	4.00	4
G	3	2	2	2.33	2
A	3	4	3	3.33	3
A	3	3	3	3.00	3
A	4	4	4	4.00	4
A	2	3	2	2.33	2
C	3	4	4	3.67	4
Overall mean					3.17
Overall median					3.00
Overall SD					0.66
Attending	BAS alone			Mean	Median
	Esophageal coating	Esophageal coating	Esophageal coating		
A	4	4	4	4.00	4
A	4	4	4	4.00	4
A	3	3	3	3.00	3
A	4	4	4	4.00	4
B	4	2	3	3.00	3
B	3	3	3	3.00	3
B	3	2	3	2.67	3
B	4	4	4	4.00	4
C	3	2	3	2.67	3
C	3	3	3	3.00	3
C	4	4	3	3.67	4
C	4	4	3	3.67	4
A	4	4	3	3.67	4
A	3	4	3	3.33	3
A	2	1	2	1.67	2
A	3	4	3	3.33	3
D	3	2	2	2.33	2
D	2	2	3	2.33	2
D	3	2	2	2.33	2
D	4	3	2	3.00	3
Overall mean					3.13
Overall median					3
Overall SD					0.79

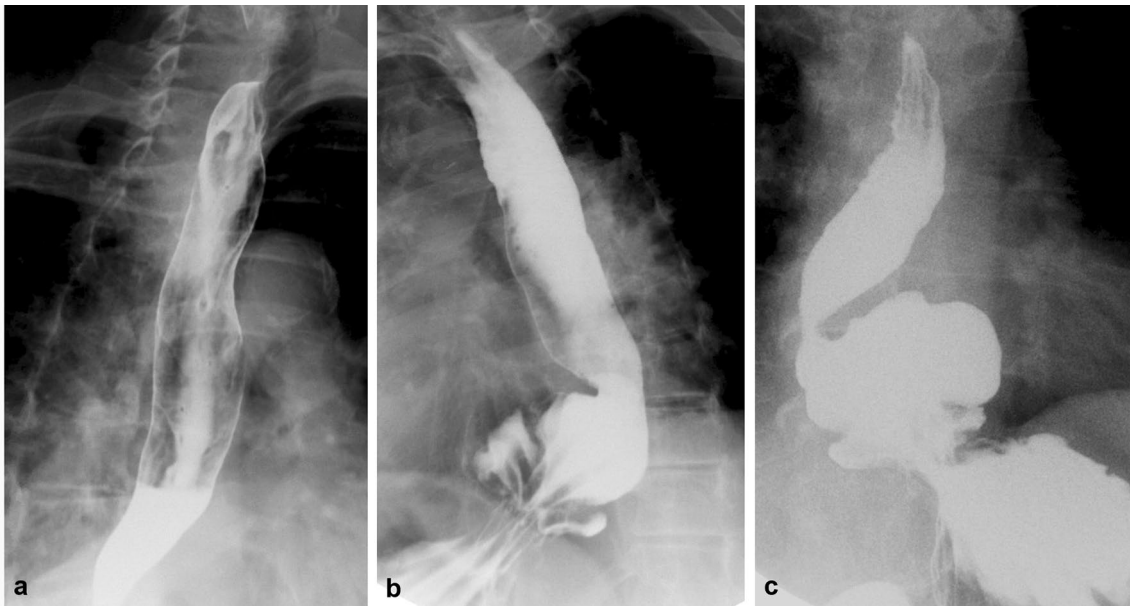


Fig. 2 68-year-old female with history of Nissen fundoplication presents with worsening reflux and dysphagia, undergoing evaluation for redo of paraesophageal hernia repair. Patient underwent same day HRM prior to BAS. HRM revealed hiatal hernia, normal lower

esophageal sphincter pressure, and intact primary peristalsis wave. BAS (a, b, and c) demonstrated partial dehiscence of the fundoplication with recurrent hiatal hernia and transthoracic migration. Barium esophageal coating was graded adequate to optimal (grade 3.67)

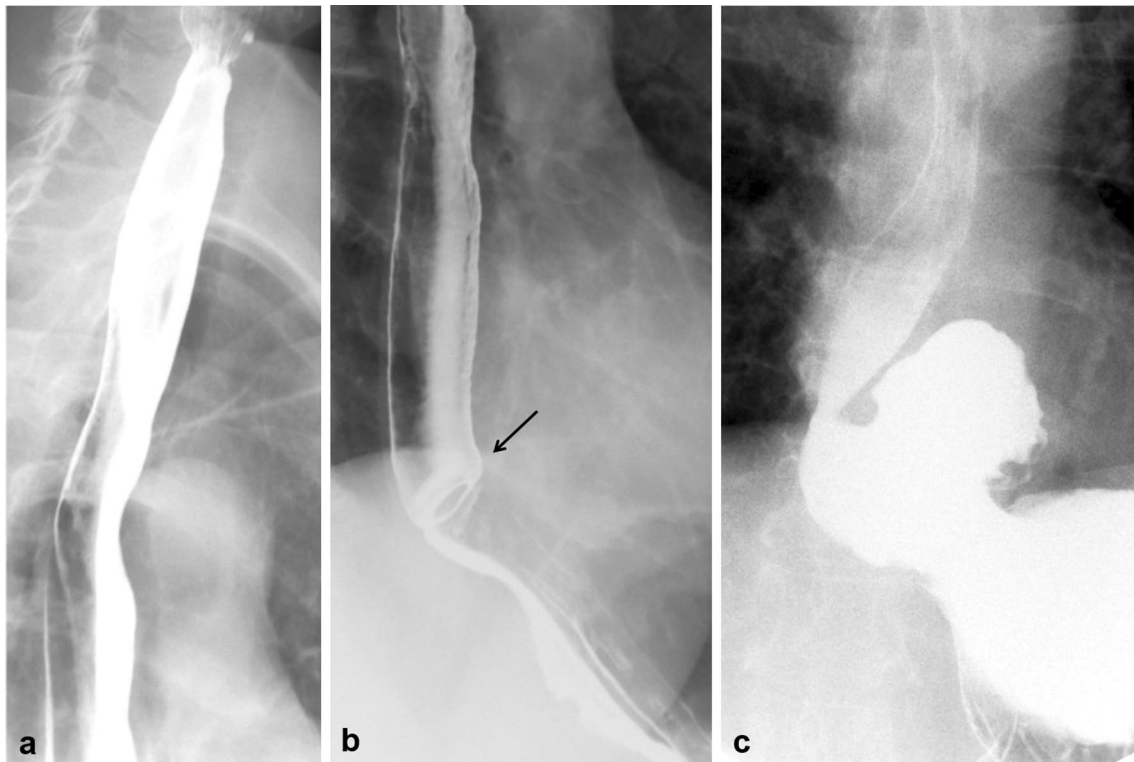


Fig. 3 70-year-old female with history of hiatal hernia and chronic gastroesophageal reflux disease (GERD), referred for pre-operative evaluation of hernia. Patient underwent same day HRM prior to BAS. HRM revealed hiatal hernia, low basal lower esophageal sphincter pressure, and fragmented peristalsis. **a** BAS demonstrated no abnormality of the upper 2/3 esophagus. **b** A Schatzki ring (arrow) was

present in the lower esophagus on standing air contrast LPO views. **c** During supine RPO reflux maneuvers, a type III paraesophageal hernia was noted involving the gastric cardia and fundus with superior displacement of the gastroesophageal junction. Barium esophageal coating was graded adequate to optimal (grade 3.33)

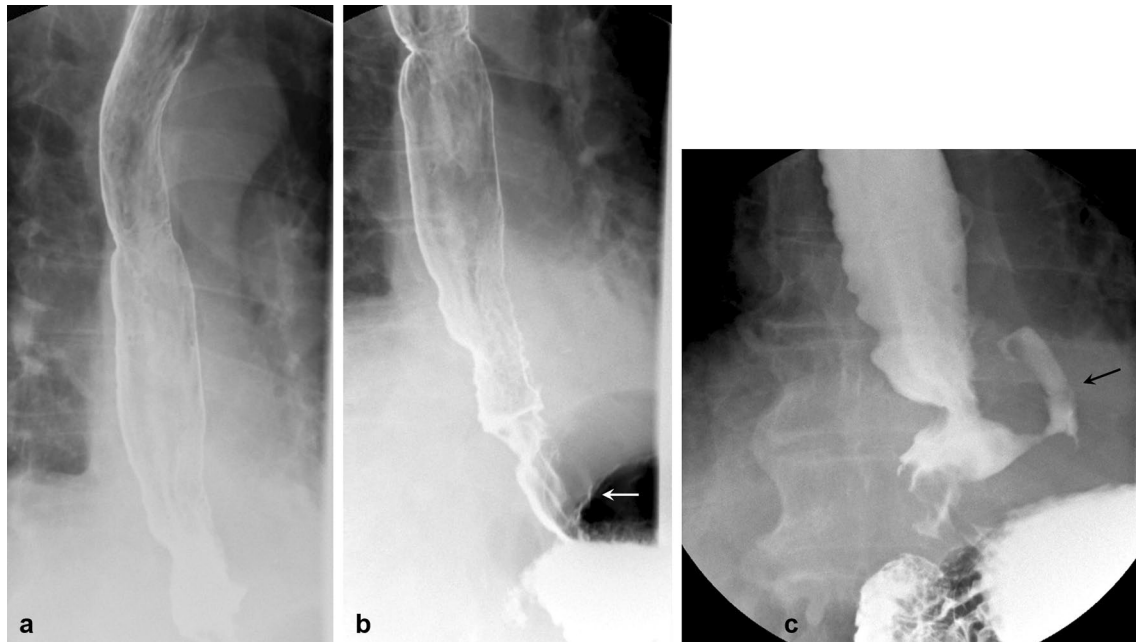


Fig. 4 59-year-old male with history of esophageal perforation secondary to suspected Boerhaave's syndrome undergoing follow-up after esophageal stent removal. Patient underwent BAS alone. **a** and **b** BAS demonstrated normal esophageal mucosa with subtle possible extraluminal contrast at the level of the distal esophagus (white

arrow). **c** Delayed magnified images of the distal esophagus demonstrate contained extraluminal contrast from the distal esophagus (black arrow). A wide stricture was also incidentally noted in the upper-to-mid thoracic esophagus. Barium esophageal coating was graded optimal (grade 4.00)

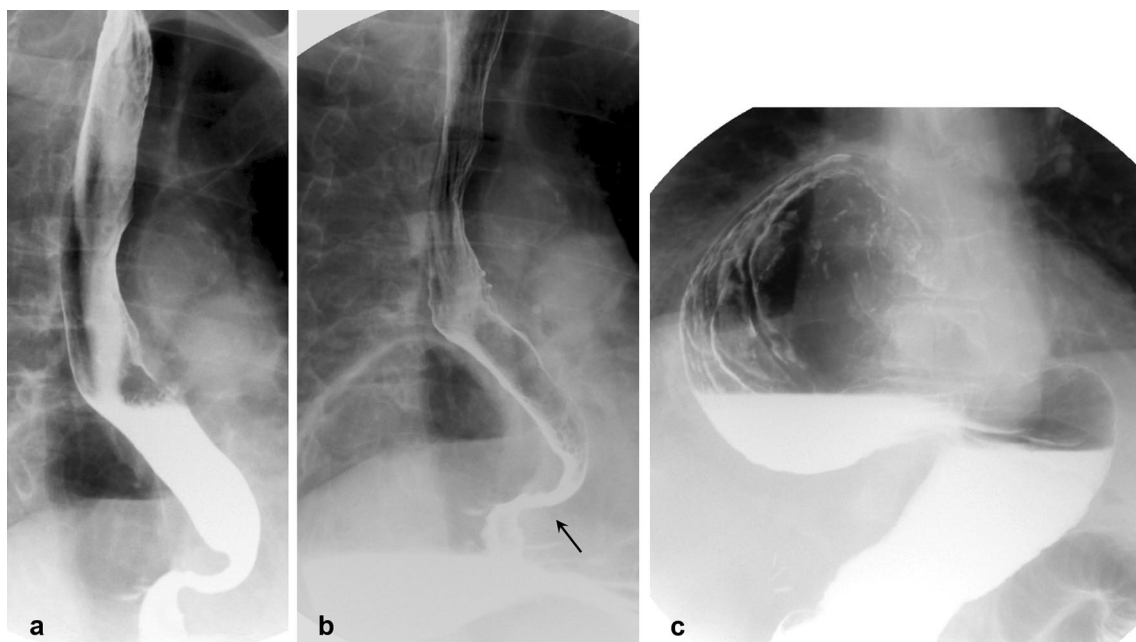


Fig. 5 61-year-old male with history of hiatal hernia undergoing pre-operative evaluation. Patient underwent BAS alone. **a** and **b** BAS demonstrated normal esophageal mucosa with narrowing of the distal esophagus due to extrinsic compression from a large type II parae-

sophageal hernia (arrow). **c** Erect AP view demonstrates the type II paraesophageal hernia with air-fluid levels. Barium esophageal coating was graded adequate (grade 3.00)

Poor esophageal coating and artifacts can reduce sensitivity for detection of mucosal abnormalities. Additionally, suboptimal coating may be a function of a patient's disease state. For example, a dilated, a motile esophagus in achalasia may have poorer esophageal coating compared to a normal peristaltic esophagus. Our retrospective study demonstrates no difference in quality of BAS mucosal coating in patients receiving same day HRM versus those receiving BAS alone. Additionally, each group has similar grading scale means (3.17 HRM + BAS vs. 3.13 BAS alone). Our mean time between HRM and BAS was 1 h and 21 min, less than the 2 h minimum fasting time recommended by the ACR. [2] These findings suggest that same day HRM and BAS may be performed with no significant effect on esophageal mucosal coating.

Same day HRM and BAS may prevent delays in care, limits COVID-19 exposures, minimizes COVID-19 preprocedural testing, and conserves PPE. The American Neurogastroenterology and Motility Society Task Force recommends sequential scheduling of procedures when possible to minimize the need for repeat COVID-19 testing [24]. As Lee et. al discusses, expediting care during the pandemic is particularly important for patients with obstructive motor disease, severe reflux, or those at risk of aspiration [25]. Beyond the pandemic, scheduling same day HRM and BAS may allow more convenient and efficient medical evaluation.

There are important considerations given the findings of this study. A main limitation of the study is that it is of low power, which limits extrapolation of results to a larger scale. Further evaluation with a larger patient population would provide insight into same day HRM and BAS quality across multiple institutions. Further, suboptimal coating may be a function of a patient's disease state rather than a non-fasting state, which may also explain why there was no significant difference between the groups. Additionally, many patients undergoing HRM and BAS also have endoscopy performed. Thus, suboptimal coating may be acceptable as EGD may be used for mucosal evaluation in these patients and HRM and BAS more for functional/anatomic evaluation (i.e. a timed achalasia study). Dedicated institutional protocols for same day HRM and BAS (i.e. minimum 2 h delay) should be considered and will be considered at our own institution following the pandemic.

In conclusion, this retrospective cohort study demonstrates no reduced quality in esophageal coating with same day BAS and HRM versus BAS alone. Same day BAS and HRM may prevent delays in care, improve efficiency, reduce patient expenses and travel time, and limit patient exposures both during and after the COVID-19 pandemic.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were

performed by Drs. SJG, DEM, and JGZ. The first draft of the manuscript was written by Dr. SDC and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability Excel spreadsheet used for data input and calculations is available upon request.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Consent to participate Not required.

Consent for publication Not required.

Ethical approval This is an observational study. The University of Alabama at Birmingham Institutional Review Board for Human Use has confirmed that no ethical approval is required. (IRB-30005990–004).

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