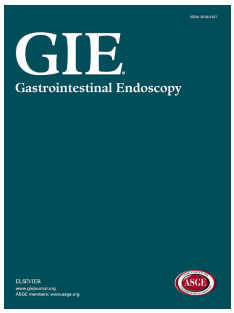

Technical feasibility, clinical effectiveness, and safety of esophageal stricture dilation using a novel endoscopic attachment cap in adults with eosinophilic esophagitis

Alain M. Schoepfer, MD, Sarah Henchoz, MD, Luc Biedermann, MD, Philipp Schreiner, MD, Thomas Greuter, MD, Antoine Reinhard, MD, Jonduri Senn, MD, Annett Franke, MD, Emanuel Burri, MD, Pascal Juillerat, MD, MPH, Hans-Uwe Simon, MD PhD, Alex Straumann, MD, Ekaterina Safroneeva, PhD, Sébastien Godat, MD

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Technical feasibility, clinical effectiveness, and safety of esophageal stricture dilation using a novel endoscopic attachment cap in adults with eosinophilic esophagitis

Short title: Esophageal dilation using a novel attachment cap in EoE

Alain M. Schoepfer, MD[1*], Sarah Henchoz, MD[1*], Luc Biedermann, MD[2], Philipp Schreiner, MD[2], Thomas Greuter, MD[1,2], Antoine Reinhard, MD[3], Jonduri Senn, MD[4], Annett Franke, MD[5], Emanuel Burri, MD[6], Pascal Juillerat, MD, MPH[7], Hans-Uwe Simon, MD PhD[8,9], Alex Straumann, MD[2], Ekaterina Safroneeva, PhD[10*], Sébastien Godat MD[1*]

*equal contribution of first two and last two authors

Affiliations:

1 Division of Gastroenterology and Hepatology, Centre Hospitalier Universitaire Vaudois (CHUV) and University of Lausanne, Lausanne, Switzerland

2 Division of Gastroenterology and Hepatology, University Hospital Zurich, Zurich, Switzerland

3 Division of Otorhinolaryngology, Centre Hospitalier Universitaire Vaudois (CHUV) and University of Lausanne, Lausanne, Switzerland

4 Division of Gastroenterology and Hepatology, Kantonsspital Lucerne, Lucerne, Switzerland

5 Division of Gastroenterology and Hepatology, Kantonsspital St Gallen, Switzerland

6 Gastroenterology and Hepatology, University Medical Clinic, Kantonsspital Baselland, Liestal, Switzerland

7 Division of Gastroenterology and Hepatology, Inselspital Bern and University of Bern, Bern, Switzerland

8 Institute of Pharmacology, University of Bern, Bern, Switzerland

9 Department of Clinical Immunology and Allergology, Sechenov University, Moscow, Russia

10 Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland

Correspondence address:

Professor Alain Schoepfer, MD

Division of Gastroenterology and Hepatology, Centre Hospitalier Universitaire Vaudois (CHUV), Rue du Bugnon 44/07/2425

CH-1011, Lausanne, Switzerland

Tel: +41 (0) 21 314 71 58

Email: alain.schoepfer@chuv.ch

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Conflict of interest: The authors do not have links with Ovesco Endoscopy AG, the company selling BougieCaps, neither to BSN medical producing the Strappal® tape.

The paper is submitted on behalf of all authors who had access to the full dataset and substantially participated in the work.

Word count: 2450 (text) + 391 (tables and figure legend) + 489 (references)

Technical feasibility, clinical effectiveness, and safety of esophageal stricture dilation using a novel endoscopic attachment cap in adults with eosinophilic esophagitis

Short title: Esophageal dilation using a novel attachment cap in EoE

Alain M. Schoepfer, MD[1*], Sarah Henchoz, MD[1*], Luc Biedermann, MD[2], Philipp Schreiner, MD[2], Thomas Greuter, MD[1,2], Antoine Reinhard, MD[3], Jonduri Senn, MD[4], Annett Franke, MD[5], Emanuel Burri, MD[6], Pascal Juillerat, MD, MPH[7], Hans-Uwe Simon, MD PhD[8,9], Alex Straumann, MD[2], Ekaterina Safroneeva, PhD[10*], Sébastien Godat MD[1*]

*equal contribution of first 2 and last 2 authors

Affiliations:

1 Division of Gastroenterology and Hepatology, Centre Hospitalier Universitaire Vaudois (CHUV) and University of Lausanne, Lausanne, Switzerland

2 Division of Gastroenterology and Hepatology, University Hospital Zurich, Zurich, Switzerland

3 Division of Otorhinolaryngology, Centre Hospitalier Universitaire Vaudois (CHUV) and University of Lausanne, Lausanne, Switzerland

4 Division of Gastroenterology and Hepatology, Kantonsspital Lucerne, Lucerne, Switzerland

5 Division of Gastroenterology and Hepatology, Kantonsspital St Gallen, Switzerland

6 Gastroenterology and Hepatology, University Medical Clinic, Kantonsspital Baselland, Liestal, Switzerland

7 Division of Gastroenterology and Hepatology, Inselspital Bern and University of Bern, Bern, Switzerland

8 Institute of Pharmacology, University of Bern, Bern, Switzerland

9 Department of Clinical Immunology and Allergology, Sechenov University, Moscow, Russia

10 Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland

Correspondence address:
Professor Alain Schoepfer, MD
Division of Gastroenterology and Hepatology, Centre Hospitalier Universitaire Vaudois (CHUV), Rue du Bugnon 44/07/2425
CH-1011, Lausanne, Switzerland
Tel: +41 (0) 21 314 71 58
Email: alain.schoepfer@chuv.ch

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ABSTRACT

Background and aims: BougieCap (Ovesco Endoscopy AG, Tübingen, Germany) is a new device that allows optical and tactile feedback during stricture dilation of the upper gastrointestinal tract. We evaluated the technical feasibility, clinical efficacy, and safety of a one-time esophageal stricture dilation using BougieCap in adults with eosinophilic esophagitis (EoE).

Methods: EoE patients prospectively included in the Swiss EoE Cohort were dilated with BougieCap in case of the presence of esophageal strictures (esophageal diameter ≤14 mm) and stricture-related symptoms. Symptoms were assessed before and 2 weeks after a single dilation session using the validated Eosinophilic Esophagitis Activity Index Patient Reported Outcomes (EEsAI PRO)instrument (score ranges from 0-100 points).

Results: Fifty patients (70% male, median age 41 years, median disease duration of 4 years, 50% treated with swallowed topical corticosteroids, 10% with proton pump inhibitors, 14% with combined swallowed topical corticosteroids plus proton pump inhibitors, 14% with elimination diet, 12% without anti-eosinophil therapy) were evaluated. Endoscopic bougienage was technically successful in 100%. Median esophageal diameter increased from 12 mm (IQR 12-13) to 16 mm (IQR 16-16, p<0.001)). Median symptom severity dropped from 32 points (IQR 27-41) to 0 (IQR 0-10, p<0.001) at 2 weeks post dilation. In one patient the BougieCap was temporarily lost after stricture dilation in the hypopharynx but could be retrieved. No severe adverse events were reported.

Conclusions: In adults with EoE, endoscopic treatment of esophageal strictures using BougieCap is technically feasible, safe and offers significant symptomatic improvement in the short term.

241 words

Keywords

Eosinophilic esophagitis, dilation, bougienage, stricture, fibrostenosis, BougieCap

INTRODUCTION

Eosinophilic esophagitis (EoE) is a chronic, local immune-mediated esophageal disease, characterized clinically by symptoms related to esophageal dysfunction and histologically by an eosinophil-predominant inflammation.[1] Adult EoE patients typically present with solid food dysphagia and food bolus impactions.[2] Meanwhile, there is robust evidence to show that in EoE patients uncontrolled eosinophil-predominant inflammation leads to subepithelial fibrosis with consecutive esophageal stricture formation.[3,4,5,6,7] Esophageal strictures represent a risk factor for food bolus impactions.[2,5] Therapeutic options include drugs (swallowed topical corticosteroids, proton-pump inhibitors), elimination diets, and esophageal dilation in case of stricturing disease.[8] Traditionally either bougies (wire-guided Savary bougies or less frequently Maloney & Hurst bougies) or through-the-scope (TTS) balloons have been used for dilation of esophageal strictures in EoE patients. In a recently published systematic review and meta-analysis, Dougherty et al[9] found in a sample of 2034 esophageal dilations in 977 EoE patients that the procedure was safe with a post-procedure hospitalization rate of 0.689%, clinically significant GI hemorrhages in 0.028%, clinically significant chest pain in 3.64%, and esophageal perforations in 0.033% per procedure.[9] Of note, none of the 9 reported esophageal perforations resulted in surgical intervention or mortality. The estimated esophageal perforation rate for bougies was 0.022% whereas it was 0.059% for balloons.[9] On the other hand, untreated EoE patients are also at risk for non-procedural related perforation, either spontaneously, or during food bolus impactions.[10] Despite the lack of evidence, the use of bougies has been banned by hospital hygienists in some institutions due to the fear of potentially transmitting infections from one patient to

another. The use of TTS balloons for esophageal dilation is characterized by considerable costs (roughly 300 Euros in Switzerland).

BougieCap (OVESCO Endoscopy AG, Tübingen, Germany) has recently been marketed in Europe for esophageal bougienage of strictures of the upper gastrointestinal tract under direct visual and tactile control. The single-use dome-shaped transparent hard plastic cap is attached to the endoscope tip using a circular tape (**Figure 1**). BougieCap is available in diameters of 7, 8, 9, 10, 12, 14, and 16 mm. BougieCaps from 7 to 10 mm diameter can be attached to endoscopes with an outer diameter between 5.5 to 6 mm whereas BougieCaps from 12 to 16 mm diameter can be mounted on endoscopes with an outer diameter between 9.8 to 10.3 mm. A 1.1 mm diameter orifice at the tip of the BougieCap allows passing a guidewire if needed whereas 2 lateral holes permit insufflation of air or CO_2 respectively as well as water flushing/aspiration. Data on the first 50 patients with benign esophageal strictures (one of them with EoE) dilated by BougieCap were recently published by Walter et al.[11] Endoscopic bougienage was successful in 96% and failed in 2 cases because of high resistance. A second case of an EoE patient dilated with the BougieCap was recently published by Zimmer.[12]

Given the limited evidence, we evaluated the first 50 patients of the Swiss EoE Cohort dilated with BougieCap in order to answer the following questions: First, is BougieCap dilation technically feasible in adults with EoE? Second, is BougieCap dilation in adults with EoE associated with symptom improvement? And third, are there safety issues when using BougieCap in EoE patients?

METHODS

Patients and methods

Adult patients with established EoE diagnosis were prospectively recruited into the Swiss Eosinophilic Esophagitis Cohort Study (SEECS).[13] This national cohort was

established in 2016 and is supported by the Swiss National Science Foundation. The SEECS currently follows 518 adult EoE patients. For inclusion, EoE patients must fulfill the following criteria according to the diagnostic guidelines: (1) symptoms of esophageal dysfunction; (2) peak eosinophil count ≥15 per high power field (orig. mag. x400), and (3) exclusion of other conditions associated with esophageal eosinophilia such as esophageal Crohn's disease.[1] Patients are excluded in case of a permanent address outside of Switzerland, refusal to sign the informed consent, and/or other conditions than EoE associated with esophageal eosinophilia.[1]

Patients are typically included into SEECS during a scheduled follow-up esophagogastroduodenoscopy. Patients complete the PRO questionnaire regarding symptoms and EoE-specific quality of life before the upper endoscopy. Symptoms are assessed using the validated Eosinophilic Esophagitis Activity Index Patient Reported Outcomes (EEsAI PRO) questionnaire with a 7-day symptom recall period.[14] The EEsAI PRO questionnaire was developed and validated according to guidelines from the United States Food and Drug Administration and has shown content validity, construct validity, criterion validity, interobserver reliability, feasibility, and responsiveness in several randomized clinical trials.[14,15,16,17]

The EEsAI PRO score ranges from 0 to 100 points with higher values indicating more severe clinical activity. Endoscopic activity was assessed using an endoscopy score based on the EREFS grading system which has been recently validated (**Supplementary Table 1**).[18,19] This endoscopic score ranges from 0 to 8 points (0 indicates no endoscopic activity, and 8 indicates most severe endoscopic activity). Length of stricture was assessed as length of superficial laceration post dilation. For assessment of histologic activity at least 3 biopsy specimens were taken from each the proximal and distal esophagus.[13] The study was approved by the 6 ethical committees covering the German and French speaking part of Switzerland (CER-VD 148/15). To be

eligible for BougieCap dilation, EoE patients included into SEECS had to fulfill the following criteria: (1) clinically active EoE, defined as EEsAI PRO ≥20 points; (2) esophageal diameter ≤14 mm (esophageal caliber was measured using BougieCap). Patients were not dilated if they were in clinical remission (defined as EEsAI PRO <20 points) or if the esophageal caliber was >14 mm.

The choice of BougieCap model to start with was at the discretion of the participating gastroenterologist who estimated the minimal esophageal caliber after careful inspection. The definition of "clinical remission" based on an EEsAI value of <20 points was validated in the framework of 2 randomized controlled trial using orodispersible budesonide tablets.[16,17] All procedures were performed with the patient under sedation using propofol.

Examinations were performed using either Pentax EG-2990I high-definition video gastroscopes (outer diameter 9.8 mm) or Olympus GIF-HQ190 high-definition video gastroscopes (outer diameter 9.9 mm). Use of BougieCap was demonstrated to participating gastroenterologists by the principal investigator during a zoom meeting. Participating endoscopists followed the recently published U.K. guidelines for esophageal dilation.[20] Technical feasibility, clinical efficacy, and safety were assessed after one dilation session. One week after esophageal stricture dilation patients were contacted by phone to inquire about the presence of postprocedural pain.

Patients completed the EEsAI PRO questionnaire again (7-day recall period) 14 days after BougieCap dilation. The principal investigator reminded patients by phone or email to return the completed questionnaire by mail. Antieosinophil treatment was not changed until patients had returned back their 2-week EEsAI PRO questionnaires. None of the patients received topical triamcinolone injection after dilation. Patients were recruited by participating gastroenterologists in 5 tertiary referral centers. BougieCap

was ordered by each center representative from Ovesco Endoscopy AG, Tübingen, Germany. The price for one BougieCap in Switzerland is 65 Euros.

Statistical analysis

Data were entered into an excel sheet (Microsoft excel 2010; Microsoft Corporation, Redmond, Wash, USA). The statistical analyses were performed using Stata (version 16 IC, College Station, Tex, USA). QQ-plots were used to analyze data distribution. Results of numerical data are presented either as mean ± standard deviation (SD) (for normally distributed data) or else as median, interquartile range (IQR), range (for nonparametric data). The Chi squared test was used to explore associations of categorical data between 2 groups. The Wilcoxon rank sum test was used to explore associations of nonparametric numerical data between 2 groups. For the purposes of this study, a p-value <0.05 was considered to be statistically significant.

RESULTS

Baseline characteristics

A total of 58 patients were included. Of these, 8 patients did not return the EEsAI PRO questionnaire 2 weeks after dilation and were therefore excluded. We analyzed the first 50 adult EoE patients of the SEECS that were dilated using BougieCap having a complete dataset. The baseline characteristics are shown in **Table 1**. Median age at inclusion was 41 years and median duration of EoE since diagnosis was 4 years. Twenty-five patients (50%) were under treatment with swallowed topical corticosteroids alone whereas 12% of patients had no treatment at all, the remaining 38% were treated with either proton pump inhibitors (10%), elimination diet (14%), or a combination of swallowed topical corticosteroids plus proton pump inhibitors (14%). Median symptom

severity, as assessed by the EEsAI PRO instrument, was 32 points before undergoing dilation. Esophageal strictures that could not be passed with the standard gastroscope were found in 20% of patients. Esophageal strictures were distributed equally between the proximal and distal esophagus.

Technical feasibility, clinical efficacy, and safety of esophageal stricture dilation using BougieCap

Esophageal stricture dilation was feasible in all patients (**Figure 2**). All procedures were performed without introduction of a guidewire and without fluoroscopic guidance. Median esophageal diameter before dilation was 12 mm and increased to a median of 16 mm after dilation (**Table 2, Figure 3**). Stricture length was in 74% of patients 1 or 2 cm and in 26% 3 or 4 cm. Superficial lacerations were documented in all patients. There were no adverse events observed with respect to bleeding, need for hospitalization, or esophageal perforation. During the telephone interview at 1 week after the esophageal stricture dilation, 26% of patients reported to have self-limiting postdilational thoracic pain.

During the endoscopy of the sixth patient (female, 38 years) we experienced a slipping of the BougieCap (caliber 16 mm) from the tip of the endoscope during the passage of the upper esophageal sphincter while pulling back the endoscope. The slipping of the BougieCap might have been related to improper attachement of the BougieCap or inadequate propofol sedation at the end of the examination with a consecutive spasm of the upper esophageal sphincter resisting the passage of the 16 mm diameter BougieCap. As a consequence, we found the BougieCap in the hypopharynx in proximity to the vocal cords (**Supplementary Figure 1**). The slipped BougieCap could be retrieved with a standard biopsy forceps. From this moment on we exchanged, on a off-label basis, the tape provided by OVESCO Endoscopy AG by a

strongly adherent tape used by the anaesthesiologists to fix the respiration tube (Strappal BSN Médical, adhesive tape, 2.5 cm x 10 m, **Supplementary Figure 2**). While using the Strappal tape for the fixations of the BougieCap, we no longer encountered any BougieCap slipping.

EoE-related symptoms had significantly improved 2 weeks after esophageal dilation (median of 32 points (IQR 27-41) on EEsAI PRO score before dilation compared with 0 (IQR 0-10) at 2 weeks after dilation, $p < 0.001$, **Figure 4**).

Logistic aspects

In half of the cases a combination of BougieCap 14 mm plus 16 mm was used (**Supplementary Table 2**). In the vast majority of patients 2 BougieCaps were used per EGD. Taking into account that the price for 1 BougieCap is 65 Euros, the costs for dilation material per EGD were on average 130 Euros.

DISCUSSION

This is the first study to evaluate the technical feasibility, clinical efficacy and safety of a one-time esophageal stricture dilation using BougieCap in a cohort of adults with EoE. We found that BougieCap dilation is feasible, clinically effective, and safe. Furthermore, we propose a solution for the problem of the “slipped BougieCap” by replacing the circular tape provided in the BougieCap kit by the highly adhesive Strappal tape.

The first study demonstrating feasibility, clinical efficacy, and safety of benign esophageal stricture dilation using BougieCap was recently published by Walter and coworkers.[11] Our findings regarding the feasibility, efficacy, and safety of BougieCap dilation in a population of adult EoE patients are in accordance with the data from this group. However, several important differences exist between our data and the cohort of Walter et al. First, our focus lies entirely on adults with EoE whereas Walter et al

evaluated a cohort of adults with various origins of esophageal stenosis, whereof peptic strictures (46%), radiation-induced strictures (26%), and anastomotic strictures (12%) were most frequently encountered. There was one patient with EoE-related esophageal stricture. Second, the mean (SD) esophageal diameter before dilation was 7.5 mm (standard deviation 2.4 mm) in the cohort of Walter et al, whereas the median esophageal diameter was 12 mm (IQR 12-13 mm) in our cohort. Third, very probably related to the smaller esophageal caliber before dilation in the study by Walter et al, their patients were more symptomatic before undergoing dilation when compared with our cohort (mean of 59 points in the Dysphagia Handicap Index (DHI) as compared with a median of 32 points in the EEsAI PRO instrument). The Dysphagia Handicap Index (DHI) questionnaire is a 25-item patient-reported outcome instrument that assesses the handicapping effect of dysphagia and covers physical, functional, and emotional aspects.[21] Every item of the DHI is rated from zero to 4 points and the score ranges, similar to the EEsAI PRO instrument, from 0 to 100 points with a higher number of points indicating more severe dysphagia. It should be noted that that DSI has not yet been evaluated in adult patients with EoE and that therefore comparisons with the values of the EEsAI PRO score should be made with caution.

Walter et al[11] were also the first to describe the problem of losing the BougieCap in 2 patients (4%) during the intervention. In their study the BougieCap was lost in the stomach and passed spontaneously with a bowel movement. We experienced a slipping of the BougieCap in one patient (2%). In contrast to the first report, we lost the device not in the stomach but while passing the upper esophageal sphincter. The BougieCap of 16 mm diameter got detached from the tip of the endoscope and was found subsequently in the hypopharynx in the proximity of the vocal cords. This event could have led to potentially worrisome outcomes such as desaturation or laryngospasm and motivated us to exchange, on an off-label basis, the circular tape provided in the

BougieCap kit by the highly adherent Strappal tape (2.5 cm width and 10 m length which costs roughly 5 Euros). Another option to reduce the risk of BougieCap slipping is to fix the first circular tape of the BougieCap set around the tip of the endoscope to tighten the fit of the BougieCap, afterwards the second circular tape is used to fix the BougieCap to the tip of the endoscope.

Our study has several strengths and also some limitations. We present the first study to systematically assess the technical feasibility, clinical efficacy, and safety of esophageal stricture dilation using BougieCap in adults with EoE. The cohort sample is sufficiently large to support conclusions regarding feasibility and efficacy. Assessment of clinical, endoscopic and histologic activity was performed in the framework of the SEECS using validated instruments specifically developed for EoE patients. Endoscopic procedures were performed by endoscopists familiar with EoE and the principles of esophageal stricture dilation. Furthermore, we propose a simple but effective solution for the problem of the “slipped BougieCap.” The issue with slipping of the BougieCap needs further evaluation in large patient series. As a first limitation, our study design does not allow a comparison of BougieCap with conventional techniques of esophageal bougienage (Savary bougies or TTS balloons). Second, the clinical efficacy was assessed only 2 weeks after the BougieCap dilation. It has yet to be determined whether clinical improvement can be maintained in the long-term. Third, three-quarters of patients had stricture length of maximum 2 cm, as such further data on the utility of BougieCap to treat narrow-caliber esophagus is needed.

In summary, we conclude that esophageal stricture dilation using BougieCap is technically feasible, clinically effective, and safe in adults with EoE. We recommend to replace the circular tape provided in the BougieCap set by a highly adhesive circular tape in order to prevent slipping of the BougieCap.

TABLES

Table 1: Demographic and disease-specific characteristics at baseline

Item	Frequency
Gender - Male - Female	 35 (70%) 15 (30%)
Age at BougieCap dilation (years) (median, IQR, range)	41, 31-49, 21-60
EoE disease duration since diagnosis (years) (median, IQR, range)	4, 2-6, 1-16
EoE disease duration since symptom onset (years) (median, IQR, range)	9, 7-11, 3-40
Diagnostic delay (years) (median, IQR, range)	4, 3-6, 0-25
Gastroesophageal reflux disease (ever diagnosed)	10 (20%)
Endoscopically active gastroesophageal reflux disease at the time of BougieCap dilation	0
Treatments - None - Swallowed topical corticosteroids (STC) - Proton pump inhibitors (PPI) - STP + PPI - Elimination diet	 6 (12%) 25 (50%) 5 (10%) 7 (14%) 7 (14%)
Dosage of STC (in mg) (median, IQR, range)	1, 1-2, 0.2-2
Baseline symptom severity (EEsAI PRO score) (median, IQR, range)	32, 27-41, 20-72
Peak eosinophil count per high-power field (median, IQR, range)	12, 5-36, 0-126
Endoscopic activity (EREFS range 0-8) (median, IQR, range)	4, 3-5, 1-8
Previous esophageal dilation	26 (54%)
Esophageal stricture ≤11 mm	10 (20%)
Location of esophageal stricture - Proximal - Distal	 22 (44%) 26 (52%)

- Proximal and distal	2 (4%)

Table 2: Esophageal diameter before and after dilation, clinical efficacy, and safety aspects

Item	**Frequency**
Minimal esophageal diameter before dilation (in mm) (median, IQR, range)	12, 12-13, 6-14
Minimal esophageal diameter after dilation (in mm) (median, IQR, range)	16, 16-16, 14-16
Increase in diameter per session (in mm) (median, IQR, range)	3, 3-4, 2-8
Stricture length (measured by length of superficial laceration after dilation) 1 cm 2 cm 3 cm 4 cm	 9 (18%) 28 (56%) 10 (20%) 3 (6%)
Superficial laceration after dilation	50 (100%)
Esophageal perforation	0
Bleeding necessitating endoscopic hemostasis	0
Bleeding necessitating blood transfusion	0
Bleeding necessitating hospitalization	0
Post-dilational pain	13 (26%)
Slipped BougieCap	1 (2%)
Symptom severity 2 weeks after dilation (EEsAI PRO score) (median, IQR, range)	0, 0-10, 0-28

Figure 1: BougieCaps of 12, 14, and 16 mm diameter and the 2 circular tapes provided for each BougieCap to fix it at the tip of the endoscope.

Figure 2: Esophageal stricture dilation using BougieCap. A, Stenosis (10 mm diameter). B, Dilation with BougieCap (12 mm). C, Superficial laceration.

Figure 3: Esophageal diameter (in mm) before and after esophageal dilation using horizontal box-plots. The box contains 50% of all values (percentile 25 to 75), the horizontal line in the box denotes the median (percentile 50). The median esophageal diameter post dilation is 16 mm (IQR 16-16 mm), as such the box-plot (which contains the values from the 25^{th} to the 75^{th} percentile) is collapsed to the median and visible only as a line.

Figure 4: EEsAI PRO score (range 0-100) before and 2 weeks after esophageal dilation using horizontal box-plots. The box contains 50% of all values (percentile 25 to 75), the horizontal line in the box denotes the median (percentile 50).

SUPPLEMENTARY FIGURES

Supplementary Figure 1: Slipped BougieCap (16 mm diameter) in the hypopharynx, adjancent to the vocal cords, after passage of the upper esophageal sphincter during the retraction of the endoscope.

Supplementary Figure 2: BougieCap secured with Strappal tape (high adhesive power) to avoid slipping of the cap.

SUPPLEMENTARY TABLES

Supplementary Table 1: The score to assess the overall endoscopic activity based on the EREFS grading system.[18,19] The overall score ranges from 0 to 8 points (0 indicates no endoscopic activity, 8 points indicates most severe endoscopic activity).

Endoscopic features	Points	Remarks
White exudates		
- Absent	0	
- Mild	1	Covering <10% of esophageal surface
- Severe	2	Covering >10% of esophageal surface
Rings		
- Absent	0	
- Mild	1	Subtle circumferential ridges
- Moderate	2	passage of 8-9.5 mm outer diameter endoscope possible
- Severe	3	passage of endoscope no longer possible
Edema		
- Absent	0	
- Present	1	Loss of vascular markings
Furrows		
- Absent	0	
- Present	1	
Strictures		
- Absent	0	
- Present	1	

Supplementary Table 2: Number and diameters of Bougie-caps used per session

Item	Frequency
Caliber of BougieCaps used	
- 10 mm + 12 mm	5 (10%)
- 12 mm + 1 4 mm	8 (16%)
- 12 mm + 14 mm + 16 mm	2 (4%)
- 14 mm	2 (4%)
- 14 mm + 16 mm	25 (50%)
- 16 mm	8 (16%)
Number of BougieCaps used per EGD	
- 1	11 (22%)
- 2	37 (74%)
- 3	2 (4%)
Number of BougieCaps used per EGD (median, IQR, range)	2, 2-2, 1-3

REFERENCES

[1] Lucendo AJ, Molina-Infante J, Arias A et al. Guidelines on eosinophilic esophagitis: evidence-based statements and recommendations of diagnosis and management in children and adults. United European Gastroenterol J 2017;5:335-358.

[2] Straumann A, Bussmann C, Zuber M et al. Eosinophilic esophagitis: analysis of food impaction and perforation in 251 adolescent and adult patients. Clin Gastroenterol Hepatol 2008;6:598-600.

[3] Dellon ES, Hirano I. Epidemiology and natural history of eosinophilic esophagitis. Gastroenterology 2018;154:319-332.

[4] Aceves SS, Newbury RO, Dohil R et al. Esophageal remodeling in pediatric eosinophilic esophagitis. J Allergy Clin Immunol 2007;119:206-212.

[5] Schoepfer AM, Safroneeva E, Bussmann C et al. Delay in diagnosis of eosinophilic esophagitis increases risk for stricture formation, in a time-dependent manner. Gastroenterology 2013;145:1230-1236.

[6] Kagalwalla AF, Akhtar N, Woodruff SA et al. Eosinophilic esophagitis: epithelial mesenchymal transition contributes to esophageal remodeling and reverses with treatment. J Allergy Clin Immunol 2012;129:1387-1396.

[7] Safroneeva E, Straumann A, Coslovsky M et al. Symptoms have modest accuracy in detecting endoscopic and histologic remission in adults with eosinophilic esophagitis. Gastroenterology 2016;150:581-590.

[8] Straumann A, Katzka DA. Diagnosis and Treatment of Eosinophilic Esophagitis. Gastroenterology 2018;154:346-335.

[9] Dougherty M, Runge TM, Eluri S et al. Esophageal dilation with either bougie or balloon technique as a treatment for eosinophilic esophagitis: a systematic review and meta-analysis. Gastrointest Endosc 2017;86:581-559.

[10] Arias-González L, Rey-Iborra E, Ruiz-Ponce M, et al. Esophageal perforation in eosinophilic esophagitis: A systematic review on clinical presentation, management and outcomes. Dig Liver Dis 2020;52:245–252.

[11] Walter B, Schmidbaur S, Rahman I et al. The BougieCap - a new method for endoscopic treatment of complex benign esophageal stenosis: results from a multicenter study. Endoscopy 2019;51:866-870.

[12] Zimmer V. Bougie cap esophageal passage: A novel potential tool for calibration of lumen diameter in eosinophilic esophagitis? Gastrointest Endosc 2018;88:568-569.

[13] Safroneeva E, Saner C, Rossel JB, et al. Cohort Profile: The Swiss Eosinophilic Esophagitis Cohort Study (SEECS). Inflamm Intest Dis. 2018;2:163-170.

[14] Schoepfer AM, Straumann A, Panczak R et al. Development and validation of a symptom-based activity index for adults with eosinophilic esophagitis. Gastroenterology 2014;147:1255-1266.

[15] Warners MJ, Hindryckx P, Levesque BG et al. Systematic Review: Disease Activity Indices in Eosinophilic Esophagitis. Am J Gastroenterol 2017;112:1658-1669.

[16] Lucendo AJ, Miehlke S, Schlag C et al. Efficacy of Budesonide Orodispersible Tablets as Induction Therapy for Eosinophilic Esophagitis in a Randomized Placebo-Controlled Trial. Gastroenterology 2019;157:74-86.

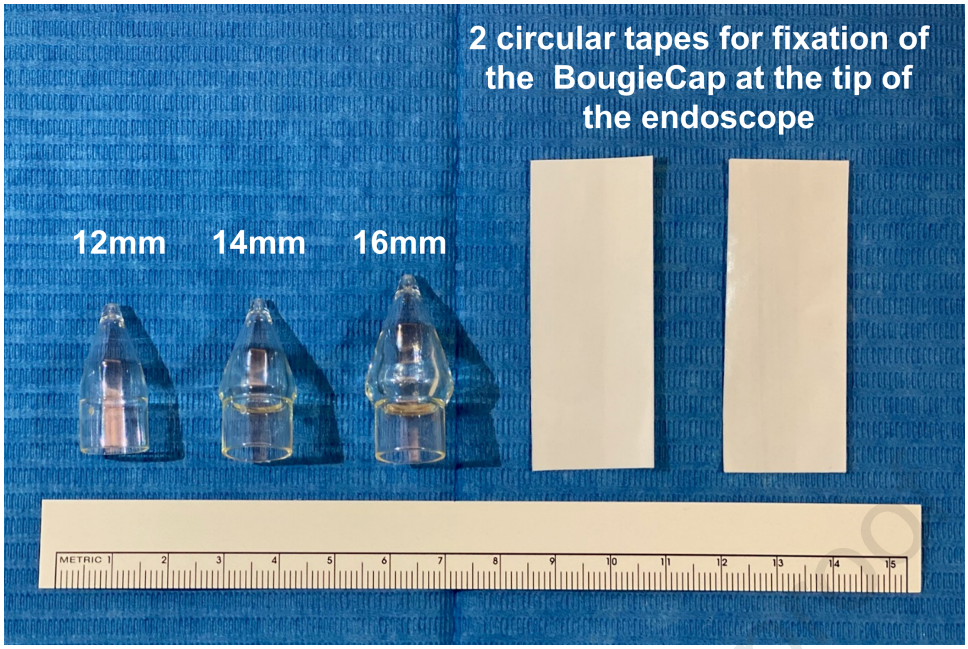
[17] Straumann A, Lucendo AJ, Miehlke S et al. Budesonide Orodispersible Tablets Maintain Remission in a Randomized, Placebo-Controlled Trial of Patients With Eosinophilic Esophagitis. Gastroenterology 2020;159:1672-1168.

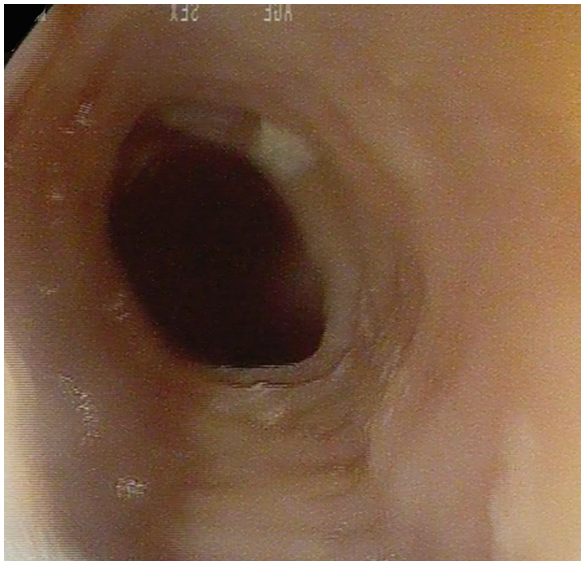
[18] Hirano I, Moy N, Heckman MG et al. Endoscopic assessment of the oesophageal features of eosinophilic esophagitis: validation of a novel classification and grading system. Gut 2013;62:489-495.

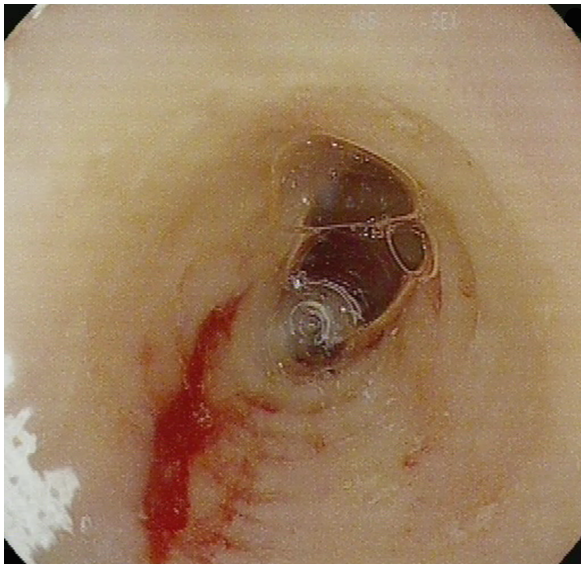
[19] Schoepfer AM, Hirano I, Coslovsky M et al. Variation in endoscopic activity assessment and endoscopy score validation in adults with eosinophilic esophagitis. Clin Gastroenterol Hepatol 2019;17:1477-1488.

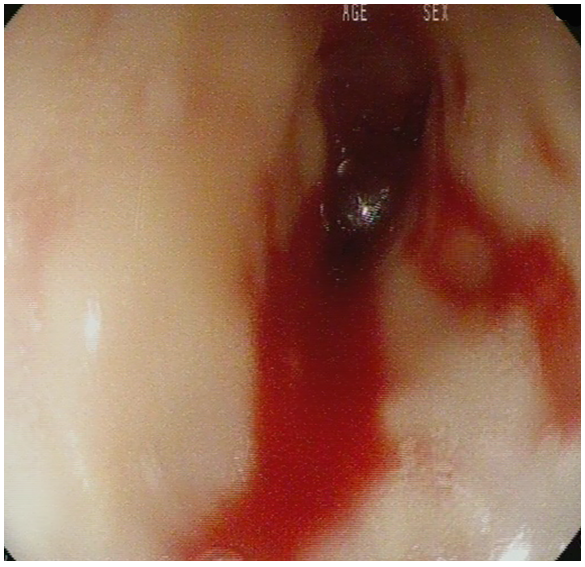
[20] Sami SS, Haboubi HN, Ang Y, et al. UK guidelines on oesophageal dilatation in clinical practice. Gut 2018 ;67 :1000-1023.

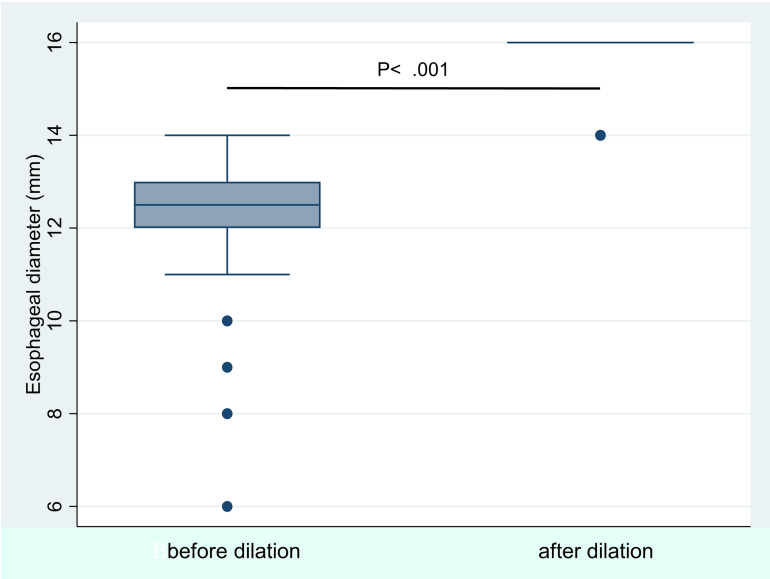
[21] Silbergleit A, Schultz L, Jacobson B et al. The Dysphagia Handicap Index: development and validation. Dysphagia 2012;27:46–52.

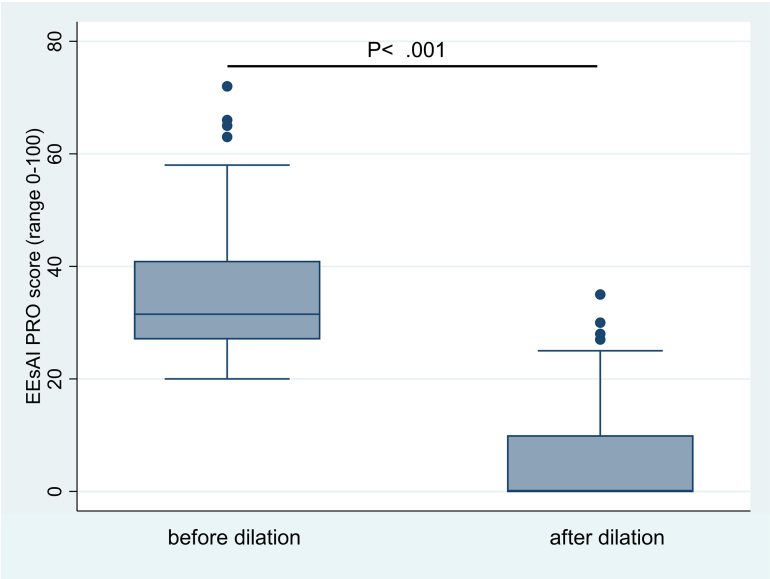


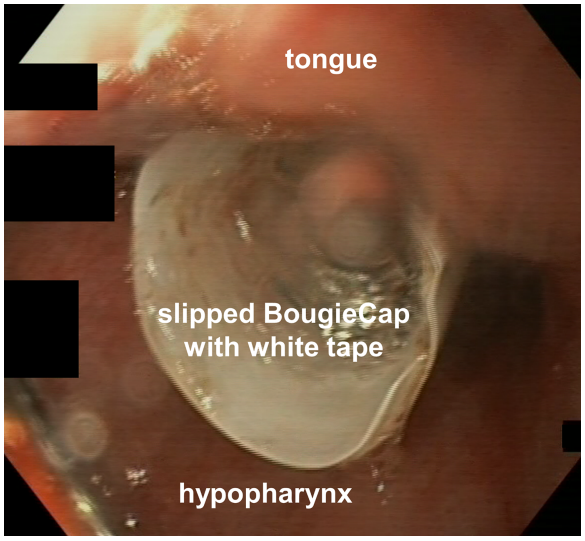












AUTHOR CONTRIBUTIONS

1 study concept

2 patient inclusion

3 statistical analyses

4 paper writing

5 relevant intellectual input

6 final approval of the manuscript

7 provided funding and technical support

8 study supervision

Alain M. Schoepfer 1,2,3,4,5,6,7,8; Sarah Henchoz 1,2,4,5,6,7; Luc Biedermann 2,4,5,6; Philipp Schreiner 2,4,5,6; Thomas Greuter 2,4,5,6; Antoine Reinhard 2,4,5,6; Jonduri Senn 2,4,5,6; Annett Franke 2,4,5,6; Emanuel Burri 2,4,5,6; Pascal Juillerat 2,4,5,6; Hans-Uwe Simon 1,4,5,6,7; Alex Straumann 2,4,5,6,7; Ekaterina Safroneeva 1,3,4,5,6,7; Sébastien Godat 1,2,4,5,6,7