



Changes in Esophageal Transit Scintigraphy After Peroral Endoscopic Myotomy in Patients With Achalasia

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Background/Aims: Esophageal transit scintigraphy is a non-invasive nuclear medicine imaging modality for people with esophageal transit problems. In particular, changes in esophageal motor function can be evaluated non-invasively before and after the treatment in patients undergoing peroral endoscopic myotomy (POEM) for achalasia. This study compared the changes in several parameters of esophageal transit and manometry in patients with achalasia who underwent POEM.

Methods: This study retrospectively analyzed prospectively collected data from POEM participants. We included 38 patients with achalasia who underwent high-resolution manometry and esophageal transit scintigraphy before POEM and after POEM from 2016 to 2023.

Results: All patients had clinical treatment successfully (Eckardt score < 3). Lower esophageal sphincter (LES) pressures were significantly reduced after POEM, including basal resting LES pressure and integrated relaxation pressure ($P < 0.001$). Esophageal emptying, as assessed by the residual fraction of retained radioactivity at 10 seconds after isotope ingestion, improved from 54.3% to 27.3% ($P < 0.001$). Analysis of the change in time-to-peak on the time-radioactivity curve showed that it shortened significantly in the upper and middle portions of the esophagus ($P < 0.05$) but not in the lower portion. The Eckardt symptom score significantly correlated with pre-POEM integrated relaxation pressure ($P < 0.05$). Post-POEM, the symptom score significantly correlated with time-to-peak of the upper portion of the esophagus ($P < 0.05$).

Conclusions: Patients with achalasia who received POEM showed improved not only manometric LES parameters but also esophageal transit. Analysis of the radiation curve's time-to-peak showed that improved retention in the upper portion is an indicator of symptoms improvement in patients who underwent POEM.

Keywords: Esophageal achalasia; Myotomy; Radionuclide imaging

INTRODUCTION

Achalasia is an esophageal motility disorder defined by impaired deglutitive relaxation of the lower esophageal sphincter (LES) and aperistalsis of the esophageal body.¹ Peroral endoscopic myotomy (POEM) is an emerging and minimally invasive endoscopic procedure for treating achalasia, showing excellent clinical outcomes and morpho-functional restoration of the esophagus.² In our previous studies, POEM has been shown to partially restore peristalsis and reduce the diameter of the esophageal body.³ In addition, POEM results in morphological

improvement in sigmoid-type achalasia.⁴ However, no studies have compared esophageal transit scintigraphy before and after POEM.

Esophageal transit scintigraphy (ETS) is recommended as a quantitative measure of the efficacy of achalasia treatment, and we have previously reported results that the usefulness of esophagography and ETS has been demonstrated.⁵⁻⁸ A region of interest in ETS is divided into upper, middle, and lower portions based on its anatomical structure, enabling ETS to quantify the total and regional transit of the esophagus. This study aims to investigate changes in esophageal transit and their pos-

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sible mechanisms by analyzing regional transit and its correlation with manometric parameters after POEM for treating achalasia.

MATERIALS AND METHODS

Study Participants

We studied a retrospective analysis of collected data from POEM participants prospectively. Thirty-eight patients with achalasia were included who underwent high-resolution manometry (HRM) and ETS before POEM and after POEM from 2016 to 2023. The diagnosis of achalasia was made on the basis of clinical symptoms, barium esophagography, and HRM according to the Chicago classification, version 3.0. The Eckardt symptom scoring system was used to evaluate patients' symptoms objectively. Follow-up measurements included the Eckardt symptom score, HRM, and ETS at 2 months after POEM. We were approved by the Institutional Review Board of Gangnam Severance Hospital (Approval No. 3-2024-0295).

High-resolution Manometry

The HRM was performed by the advancement of a 36-channel, solid-state probe system with high-fidelity circumferential sensors at 1 cm intervals through the nasal canal (Manoscan, Sierra Scientific Instruments Inc, Los Angeles, CA, USA). Measurements were performed with the patient in supine and sitting positions after fasting for at least 8 hours. Pressure data of 10 wet swallows were recorded and analyzed by the Manoscan 360. Chicago classification version 3.0 was used for all relevant measurements.⁹

Esophageal Transit Scintigraphy

ETS was performed with technetium-99m after overnight fasting using a gamma camera (Genesys Vertex; AdacLab, Milpitas, CA, USA) with a large field of view.⁶⁻⁸ Anterior scans were obtained in the upright position. At 0 second, 111 megabecquerel (3 millicurie) of technetium-99m pertechnetate suspended in 35 mL of water was administered orally while the patient was in the upright position; the patient was told not to swallow until directed. Half-life ($T_{1/2}$, min) was defined as the time required for the radioactivity to reach the half-maximal value in the esophagus. The residual fraction of retained radioactivity was determined at 10 seconds. R_{10} was the percentage of radioactivity remaining 10 seconds after swallowing the radioisotope compared to 0 second.

During ETS, regions of interest were set in the upper, middle, and lower portions of the esophagus; a time-radiation curve was obtained for each region by imaging with a gamma camera. The times at which the maximum amounts of radioactivity were measured in the upper, middle, and lower esophagus were compared in each patient.

Peroral Endoscopic Myotomy Procedure

POEM was performed in patients under general anesthesia and endoscopic CO₂ insufflation as described by Inoue et al.¹⁰ First, 10 mL saline supplemented with 0.3% indigo carmine was injected into the submucosal space 7 cm proximal to the esophagogastric junction. Subsequently, an electrosurgical knife with a triangular tip (KD-640L; Olympus, Tokyo, Japan) was used to make a 2-cm longitudinal mucosal incision to create a mucosal entry into the submucosal space. The submucosal layer was dissected to create a tunnel along the length of the esophagus and across the esophagogastric junction 3 cm into the proximal stomach. An endoscopic myotomy of the circular muscle was performed starting 2 cm below the entrance of the tunnel (median: 5 cm) and extending 2 cm to 3 cm into the proximal stomach. The mucosal entrance site was closed using endoscopic clips (EZ-CLIP; Olympus, Tokyo, Japan).

Statistical Methods

Comparisons of HRM and ETS data were performed using the paired *t* test. Kendall's correlation was used for correlation coefficient analysis. Results were considered statistically significant when *P* < 0.05. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 20.0 for Windows (SPSS, Chicago, IL, USA) and R version 4.3.0. The R stats package (version 4.3.0) correlation test function was used for correlation coefficient analysis. The R stats *t* test function

Table 1. Demographics of Patients

Characteristics	Data
Male	19 (50.0)
Age (yr)	40 (18-85)
Pre-POEM Eckardt score	5.81 ± 2.45
Achalasia type	
Type 1	8 (21.0)
Type 2	26 (68.5)
Unspecified	4 (10.5)

POEM, peroral endoscopic myotomy.

Data are presented as n (%), median (range), or mean ± SD.

was used to compare the data before and after POEM in paired *t* tests, using paired *t* tests assuming unequal variances.

RESULTS

Patient Characteristics

The demographics of the population studied are shown in Table 1. The study group comprised 19 males and 19 females, with a median age of 40.0 years (range: 18-85). The mean Eckardt symptom score before POEM was 5.81 (range 1-11). Based on the HRM results, 8 patients were classified as type I achalasia, and 26 were type II. We excluded patients with type III achalasia be-

cause they received a long myotomy. Eckardt symptom scores were significantly decreased after POEM ($P < 0.001$) within a mean follow-up time of 2 months.

Esophageal Manometric Outcomes

LES motility parameters were significantly reduced after POEM, including the basal LES pressure (pre: 36.3 ± 20.1 vs post: 14.1 ± 8.0 mmHg; $P < 0.001$) and integrated relaxation pressure (24.9 ± 13.4 vs 7.6 ± 4.7 mmHg; $P < 0.001$) (Table 2). POEM did not significantly affect the distal segment contraction integral of distal segment.

Changes in Esophageal Transit

The esophageal transit time ($T_{1/2}$ [min]) improved after POEM (46.0 ± 127.2 vs 5.1 ± 3.9) but did not reach statis-

Table 2. Comparison of Symptom Score, HRM, and Esophageal Transit After POEM

Variables	Pre-POEM	Post-POEM	P-value
Eckardt score	5.8 ± 2.5 (1.0-11.0)	0.5 ± 1.0 (0.0-3.0)	< 0.001
HRM parameters			
Basal LES pressure (mmHg)	36.3 ± 20.1 (3.6-88.3)	14.1 ± 8.0 (2.2-31.6)	< 0.001
IRP (mmHg)	24.9 ± 13.4 (0.1-47.2)	7.6 ± 4.7 (0.5-16.4)	< 0.001
DCI (mmHg-cm-s)	1965.5 ± 1822.3 (120.3-3847.6)	454.8 ± 354.4 (193.0-1055.9)	0.100
Esophageal transit parameters			
$T_{1/2}$ (min)	46.0 ± 127.2 (2.2-587.2)	5.1 ± 3.9 (2.1-16.4)	0.147
R_{10} (%)	54.3 ± 31.1 (2.5-90.9)	27.3 ± 22.8 (3.3-83.0)	< 0.001
Time to peak (sec)			
Upper	10.8 ± 8.1 (0.4-28.0)	6.4 ± 5.4 (2.0-25.0)	0.007
Middle	7.2 ± 6.1 (0.3-27.0)	4.6 ± 1.5 (2.0-9.0)	0.011
Lower	4.2 ± 4.1 (0.2-26.5)	3.2 ± 0.9 (1.5-5.5)	0.132

POEM, peroral endoscopic myotomy; HRM, high-resolution manometry; LES, lower esophageal sphincter; IRP, integrated relaxation pressure; DCI, distal contractile integral; $T_{1/2}$, half-life; R_{10} , the percentage of remaining radioactivity at 10 seconds.

Data are presented as mean \pm SD (range).

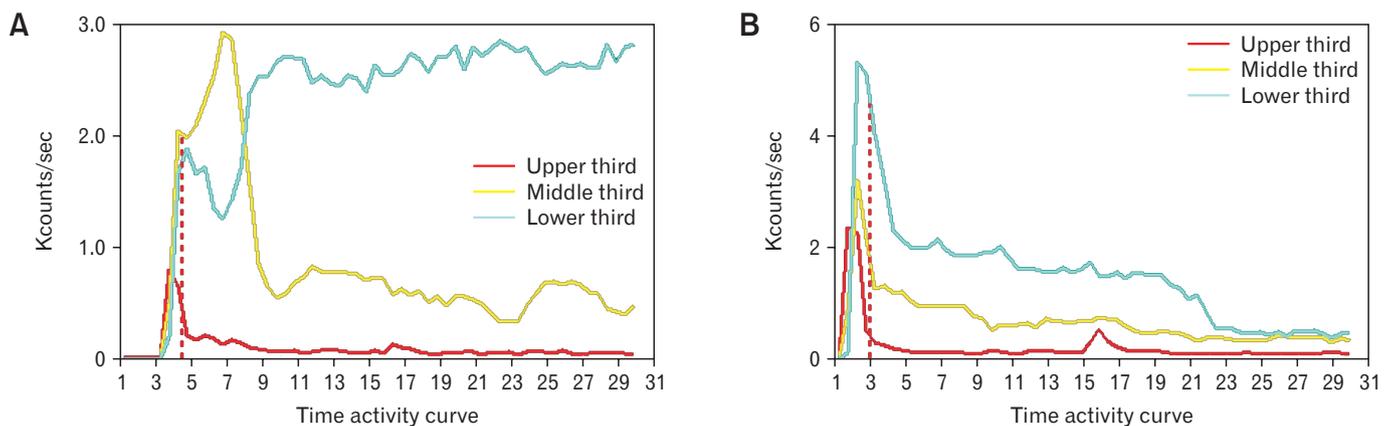


Figure 1. Esophageal transit scintigraphy (ETS) pre-peroral endoscopic myotomy (POEM) (A) and post-POEM (B). During ETS, each region of interest is set in the upper, middle, and lower portions of the esophagus. The time-radiation curve is obtained in each region by gamma camera imaging. The time at which the maximum amount of radioactivity is measured in the upper, middle, and lower esophagus is compared in each patient.

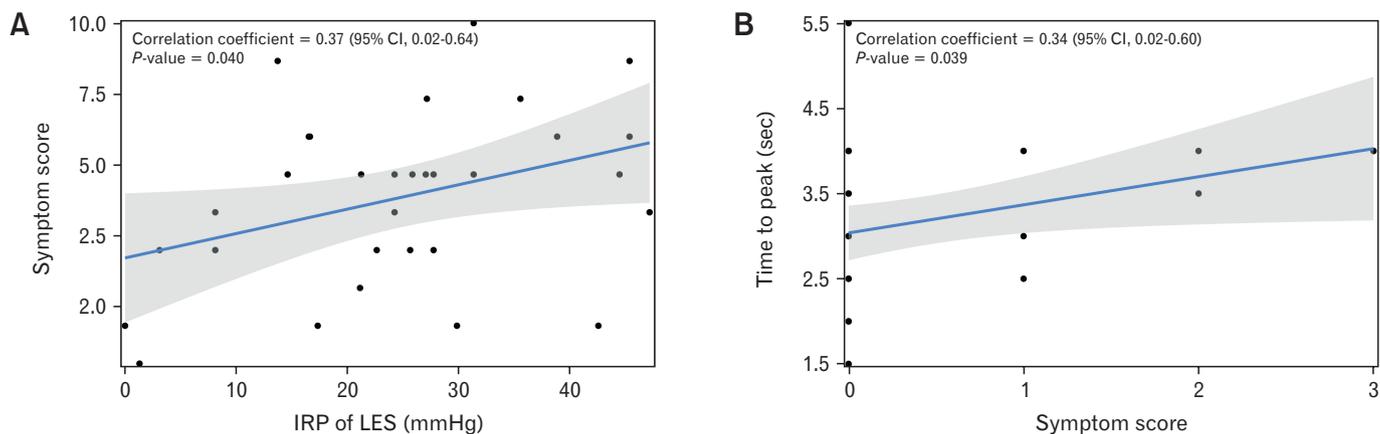


Figure 2. Scatterplot showing (A) the positive relationship between the symptom score and the pre-peroral endoscopic myotomy (POEM) integrated relaxation pressure (IRP) of the lower esophageal sphincter (LES) and (B) the positive correlation between the post-POEM symptom score and time-to-peak in the upper portion of the esophagus.

tical significance (Table 2). However, the esophageal emptying, assessed by the residual fraction of retained radioactivity at 10 seconds after isotope ingestion, significantly improved from 54.3% to 27.3% on average ($P < 0.001$). The time-to-peak on the time-radioactivity curve shortened significantly in the upper and middle portions of the esophagus ($P < 0.05$) but not in the lower portion (Fig. 1).

Correlation of Symptom Score, Manometric Parameters, and Esophageal Transit

Before POEM, the Eckardt symptom score significantly correlated with integrated relaxation pressure ($P < 0.05$). However, there was no significant correlation between symptom score and ETS parameters. After treatment, the symptom score significantly correlated with the radioactivity time-to-peak of the upper portion in post-POEM ($P < 0.05$) (Fig. 2). The symptom score did not correlate with HRM parameters.

DISCUSSION

The treatment response in achalasia has generally been evaluated by subjective symptom improvement. Symptoms of achalasia include dysphagia, regurgitation, chest pain, and weight loss. Dysphagia is subjective and related to esophageal dysmotility and/or transit. For a more objective assessment, esophageal manometry, and/or timed barium esophagogram have been used.⁸ Studies have shown that ETS enables physiological and quantitative evaluation of treatment response in achalasia patients who received pneumatic balloon dilatation.^{7,8}

In our previous studies,^{3,4} POEM has been shown to

restore peristalsis and to reduce the diameter of the body of the esophagus,^{3,4} resulting in favorable clinical outcomes. The angle of the tortuosity of the esophagus becomes more obtuse and the morphology improves in the sigmoid type of achalasia. Based on these 2 studies, we may speculate that POEM improves esophageal transit.

To our knowledge, this is one of the first studies to assess ETS after POEM. We found that transit parameters showed significant improvement following treatment. In addition, the Eckardt symptom score significantly correlated with the post-POEM time-to-peak in the upper portion of the esophagus. Therefore, the possible mechanism of improved transit post-POEM may include not only morphological improvement but also restoration of peristalsis. Another potential mechanism is that myotomy of the distal esophagus and LES reduces resistance from the esophagus to the stomach.

Simultaneous contraction or aperistalsis of the body impairs the passage of a food bolus and causes dysphagia. Ren et al¹¹ reported that POEM of the distal esophageal body decreases the proximal esophageal contraction pressure, suggesting that myotomy of the distal body inhibits the pressurization of the whole body and lessens resistance to the passage of a food bolus. Their findings that over half of the patients showed a recovery of some of the peristaltic contractions after POEM have been validated.³

The myotomy of the distal esophagus and LES may affect esophageal total and regional transit, as assessed by the radiation time-to-peak in the upper, middle, and lower esophagus. We found the time-to-peak was shortened in the middle and upper esophagus. Since myotomy itself is a destructive to the muscle and nerves of the

esophageal wall, it may weaken the contraction of the distal esophagus. Therefore, myotomy on the distal body of the esophagus and LES improved transit in the proximal but not the distal portion, accelerating esophageal transit and improving symptoms in patients who have undergone POEM.

Although timed barium esophagogram is a commonly used method to evaluate esophageal transit, we selected ETS for this study because of its unique advantage in enabling quantitative evaluation of regional transit in the upper, middle, and lower esophagus. Moreover, a previous study demonstrated a significant correlation between timed barium esophagogram and ETS results in patients with achalasia, validating the use of ETS for esophageal transit assessment.⁸ It is the ability to quantify segmental transit that offers valuable insight into post-treatment esophageal function. The observed improvement in upper esophageal transit following POEM, as reflected by shortened time-to-peak and its correlation with symptom relief, provides additional clinical insight. These findings suggest that changes in proximal esophageal transit may serve as a meaningful indicator of treatment response. To our knowledge, this is the first study to report such an association, suggesting a potentially relevant mechanism contributing to symptomatic improvement in patients undergoing POEM.

Our study has several limitations. First, the sample size was relatively small since achalasia is rare. Second, this study was retrospective and conducted in a single tertiary medical center, although we analyzed prospectively collected data.

In conclusion, patients with achalasia who received POEM showed improved esophageal transit and manometric parameters. Analysis of the post-POEM radiation curves' time-to-peak indicated improvement in the upper and middle portions of the esophagus and improved symptoms.

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REFERENCES

1. Vaezi MF, Pandolfino JE, Vela MF. ACG clinical guideline: diagnosis and management of achalasia. *Am J Gastroenterol* 2013;108:1238-1249.
2. Youn YH, Minami H, Chiu PW, Park H. Peroral endoscopic myotomy for treating achalasia and esophageal motility disorders. *J Neurogastroenterol Motil* 2016;22:14-24.
3. Huh CW, Youn YH, Chung H, Lee YC, Park H. Functional restoration of the esophagus after peroral endoscopic myotomy for achalasia. *PLoS One* 2017;12:e0178414.
4. Yoon HJ, Lee JE, Jung DH, Park JC, Youn YH, Park H. Morphologic restoration after peroral endoscopic myotomy in sigmoid-type achalasia. *J Neurogastroenterol Motil* 2020;26:67-73.
5. Chung JJ, Park HJ, Yu JS, et al. A comparison of esophagography and esophageal transit scintigraphy in the evaluation of usefulness of endoscopic pneumatic dilatation in achalasia. *Acta Radiol* 2008;49:498-505.
6. Moon JT, Jung IS, Kim YS, Cho SH, Park H, Lee SI. [Correlation between clinical symptoms and radiologic findings before and after pneumatic balloon dilatation for achalasia.] *Korean J Gastroenterol* 2008;52:16-20. [Korean]
7. Jeon HH, Youn YH, Rhee K, Kim JH, Park H, Conklin JL. For patients with primary achalasia the clinical success of pneumatic balloon dilatation can be predicted from the residual fraction of radionuclide during esophageal transit scintigraphy. *Dig Dis Sci* 2014;59:375-382.
8. Park YM, Jeon HH, Park JJ, Kim JH, Youn YH, Park H. Correlation between timed barium esophagogram and esophageal transit scintigraphy results in achalasia. *Dig Dis Sci* 2015;60:2390-2397.
9. Kahrilas PJ, Bredenoord AJ, Fox M, et al. The Chicago classification of esophageal motility disorders, v3.0. *Neurogastroenterol Motil* 2015;27:160-174.
10. Inoue H, Minami H, Kobayashi Y, et al. Peroral endoscopic myotomy (POEM) for esophageal achalasia. *Endoscopy* 2010;42:265-271.
11. Ren Y, Tang X, Chen F, et al. Myotomy of distal esophagus influences proximal esophageal contraction and upper esophageal sphincter relaxation in patients with achalasia after peroral endoscopic myotomy. *J Neurogastroenterol Motil* 2016;22:78-85.