Clinical evaluation of the wireless JSPH-2 esophageal pH capsule: a single-center retrospective experience

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Background/aim
JSPH pH wireless capsule is a radio-telemetric capsule that attaches to the lower end of esophageal mucosa and measures pH and sends data to a wireless receiver. The aim of the study was to assess the clinical efficacy and safety of the JSPH pH wireless capsule in Kuwaiti patients with symptoms suggestive of gastroesophageal reflux disease (GERD).

Patients and methods
Patients with symptoms suggestive of GERD were included in the study. The JSPH-2 pH wireless capsule-recorded data were automatically analyzed by pH capsule data analyze software with pH tracings of day 1, day 2, and total 48-h test periods.

Results
A total of 63 patients from Jahra Hospital, Kuwait, were included in this study. A total of 43 (68.2%) patients had recorded parameters suggestive of GERD, whereas 20 (31.8%) patients were defined as non-GERD. On comparison of different recorded parameters suggestive of GERD between day 1 and day 2, the number of refluxes (P=0.048), total fraction time pH less than 4 (P=0.042), meal fraction time pH less than 4 (P=0.047), and DeMeester score (P=0.047) were statistically significant on day 1. On day 2, only five (11.6%) patients with GERD had been identified with abnormal pH data, whereas nine (20.9%) patients had been identified with an abnormal DeMeester score. A total of 14 (22.2%) patients reported mild to moderate disturbance of normal daily activities, diet, and sleeping during the monitoring period. A total of 32 (57.1%) patients experienced foreign body sensation, 15 (23.8%) showed chest discomfort, and seven (11.1%) had nausea.

Conclusion
The JSPH pH monitoring system is safe and well tolerated and can be used in clinical practice for diagnosis and monitoring of patients with GERD.

Keywords:
DeMeester, gastroesophageal reflux, JSPH pH wireless capsule

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Introduction

Gastroesophageal reflux disease (GERD) is a disease of reflux of the stomach content into the esophagus, leading to different symptoms and complications [1]. GERD prevalence is increasing in Asia, ranging from 5 to 18% [2]. GERD has an economic cost [3], affecting patient's quality of life while reducing 6–40% of workers' productivity, which has prompted several efforts to discover different modalities for its diagnosis [4].

GERD could be diagnosed by symptom questionnaire, diagnostic testing with proton pump inhibitor, endoscopy, and gastroesophageal reflux monitoring of esophageal pH, bilirubin reflux, impedance, pressure, and contractions. Regurgitation and heartburn are typical symptoms of GERD, but they cannot distinguish it from functional gastrointestinal diseases, especially among the Asian population [5]. Moreover, normal endoscopic findings could not exclude GERD in Asian patients, so high esophageal acid exposure is needed to be documented for its diagnosis.

Catheter-based 24-h ambulatory pH study has been considered the gold standard for diagnosis of GERD, correlating its symptoms with acid reflux [6]. However, several disadvantages have been reported for this procedure, including nasal and pharyngeal discomfort from the pH catheter, underestimation of reflux episodes owing to limitation of patient's daily physical activities and food habits, and

procedure mistakes such as catheter incorrect placement or migration [5,7].

Bravo pH wireless capsule, which is a pH radio-telemetric capsule, was invented in 2003 to overcome these limitations (Given Imaging; Medtronic Inc., Shoreview, Minnesota, USA) [8]. It attaches to the lower end of esophageal mucosa and measures pH and sends data to a wireless receiver [9].

Recently, a new pH wireless capsule (JSPH) was developed in China to improve the understanding of GERD among Asian patients.

The present study aims to assess the clinical efficacy and safety of the JSPH pH wireless capsule in Kuwaiti patients with symptoms suggestive of GERD.

Patients and methods

Study population

Patients with GERD symptoms and normal endoscopy finding were retrospectively enrolled between February 2017 and October 2020 from the outpatient and inpatient departments of Jahra Hospital, Kuwait, which is a huge tertiary medical hospital.

Ethical approval

The study was approved by Research Ethics Committee of Jahra Hospital of Kuwait in accordance with the Declaration of Helsinki principles with approval number "J1-17/3/2021". All studied patients signed an informed and written consent form before their inclusion in the study.

Inclusion criteria

Patients older than 18 years with typical symptoms of GERD such as regurgitation and heartburn or atypical symptoms of GERD such as belching, atypical chest pain, chronic unexplained pharyngeal pain, foreign body sensations, hoarseness of voice, bronchitis, and bronchial asthma were included in the study.

Exclusion criteria

Patients with severe esophageal erosions, severe esophageal motility disorder, esophageal varices, congenital esophageal malformation, esophageal stricture, obstruction, perforation, fistula, post-Nissen fundoplication, recent surgical history of the stomach within 6 months, history of bleeding tendency, gastrointestinal bleeding, severe ischemic cardiac disease, implanted electrical device, allergy to polymer materials, pregnancy, lactating, psychotic, or uncooperative were excluded from the study.

Pre-insertion action

Each included patient underwent coagulation profile test and ECG examination before enrollment in the current study. Patients were informed to stop taking proton pump inhibitor for 1 week, histamine 2 receptor antagonists for 5 days, and antacids for 1 day before the procedure.

Technique

Capsule description

The JSPH-2 pH capsule (Jinshan Science and Technology Co. Ltd, Chongqing, China) is composed of a capsule attached to a catheter, a portable receiver, and a computer workstation. The capsule size was 26.5 mm×5.5 mm×6 mm, and its weight was 1.4 g. The capsule consists of pH sensors of dry antimony electrode and reference electrode at its distal tip, a transmitter internal battery, and a clipping device. The battery life exceeded 96 h, transmitting pH data by radiofrequency telemetry every 15 s to the receiver with recording of data at 3 s sampling intervals and frequency of 0.33 Hz.

Buffer

The pH capsules were activated by removing the breaker. After waiting 15 s, a green blinking light every 3 s was observed indicative of capsule activation. Then, the activated pH capsule was calibrated by presoaking it under the surface of buffer solutions of pH 7.01, pH 4.00, and distilled water for 5 min.

Endoscopy

Patients were instructed to stop dining several hours before the procedure. Endoscopy was done after topical pharyngeal anesthesia with lidocaine hydrochloride spray. No sedation was given during the whole process. Endoscopy was withdrawn after measuring the distance between the incisors and the squamocolumnar junction (SCJ).

Capsule attachment technique

The length at the conveyer was marked using an adhesive tape. The delivery system was covered with a lubricant, and when the JSPH-2 capsule reached the posterior wall of oropharynx, patients were instructed to swallow to facilitate the entrance of the capsule to the esophagus with careful monitoring of the scales on the delivery, to place the pH capsule 5 cm above the SCJ, which could be confirmed by endoscopy. Thereafter, a vacuum pump was connected to the handle to apply suction pressure more than or equal to 0.08 MPa for 15–20 s to draw in the esophageal mucosa. Three buckles marked 1, 2, and 3 on the

handle of the delivery device were slid in turn: buckle 1 to close the clip, buckle 2 to release the clip from delivery device, and buckle 3 to release the whole capsule from the delivery device. Sliding the three buckles in turn was important for safe capsule placement without esophageal injury [10]. If resistance was encountered during removal of the conveyer even when all three buckles were slid to the end, it might indicate the wire on the capsule had not been completely released. In that case, unscrewing of the cap at the end of the capsule, opening of the handle, and sliding down of the buckles 2 and 3 down by 1 cm were performed to release the capsule from the conveyer. Finally, the vacuum pump was turned off and disconnected from the handle and then the delivery catheter was removed slowly. The endoscope was reintroduced to verify capsule attachment.

Postinsertion instructions

Patients were instructed to keep the wireless data receiver at a distance of less than or equal to 2 m during the recording period and to keep away from magnetic interferences. Patients were encouraged to keep normal daily activities and to avoid reflux-inducing drugs, carbonic acid beverage, and alcohol intake.

The patients were instructed to press the button when there was heartburn or after taking prescribed medication or before and after drinking or eating or before sleep and after waking up.

The patients were instructed to keep a detailed diary including daily activities, food intake, reflux symptoms, and other events for later interpretation with the pH data. Patients were instructed to notify the medical staff when the recorder was malfunctioning or patient experienced any severe adverse events. Patients were informed to return the receivers and diaries after 48 h. All recorded data were downloaded to a Jinshan pH-monitoring working station and automatically analyzed by pH capsule data analyze software with pH tracings of day 1, day 2, and the total 48-h test periods.

Follow-up of capsule

After several days, the capsule detached with natural sloughing of the esophageal mucosa passing out with stool. Patients were followed up with an radiograph image to make sure that the capsule went outside the body of patients.

Adverse events

All clinical and procedural adverse events were recorded. Clinical adverse events were assessed during or after capsule detachment, including heartburn, regurgitation, hoarseness of voice, throat discomfort, aspiration, nausea, vomiting, foreign body sensation, chest discomfort/pain, odynophagia, and dysphagia for solids or liquids. Procedural adverse events, such as esophageal mucosal trauma, bleeding, and perforation, were also assessed. Technical failure such as failure to calibrate before attachment, poor data transmission, attachment failure, premature detachment, and detachment failure was recorded.

Recording analysis

The pH data recording time was considered sufficient if it continued for at least 24 h. Abnormal esophageal acid exposure in wireless studies was diagnosed if the percentage of the total time with a pH less than 4.0 was 4.4% [11,12].

Statistics of pH trace of number of reflux episodes ($pH<4$), number of episodes more than 5 min, duration of longest reflux episode, the total time and its percentage (fraction time) when pH less than 4.0, and DeMeester score were recorded [13]. All these parameters were recorded in upright and supine positions, with meals and calculated as total duration. Moreover, the number of symptoms of chest pain and heartburn as related or not related to reflux episodes, besides symptoms index for reflux (SI), and symptom association probability (SAP) were determined.

Johnson-DeMeester score defined abnormal acid exposure positive (GERD) if the score more than 14.72 [14,15]. SI and SAP were considered as indicators of significant symptom-reflux associations if SI values more than 50% [16] and SAP value more than 95% [17].

The capsule was considered detached if the pH data suddenly dropped less than 2 for more than 2 h (in stomach) and then returned to 7.0 and never dropped again (in small bowel). Radiograph was done for confirmation so that the data during the detachment period was marked for exclusion during analysis.

Statistical analysis

Data were analyzed by Statistical Package for the Social Sciences (IBM, SSPS Inc., Chicago, IL, United States), version 23. Numbers and percentages represented the qualitative data. Mean, SDs, and ranges represented parametric quantitative data, whereas median with interquartile range represented quantitative nonparametric one. Qualitative data were compared between groups by χ^2 test. Quantitative data with parametric distribution were compared between groups by independent t test, whereas data with

nonparametric distribution was compared by Mann–Whitney test. The relationship of DeMeester score between total and individual recording days was assessed using the Spearman correlation coefficient. The confidence interval was set to 95%, and the margin of error accepted was set to 5%. So, the *P* value was considered significant if *P* value less than 0.05.

Results

Study population

A total of 71 patients were found to have symptoms suggestive of GERD for the current study. Overall, 63 patients were included in this study and eight patients were excluded. The mean age of the studied patients was 36.1±13.3 years. There were 24 (38%) female and 39 (62%) male patients.

Symptoms

The patients presented with regurgitation (*n*=39), heartburn (*n*=38), dyspepsia (*n*=26), abdominal pain (*n*=10), hoarseness of voice (*n*=4), chest pain (*n*=3), chronic cough (*n*=2), and dysphagia (*n*=1). GERD was statistically significant in the studied male patients. All patients in the current study with chest pain symptom were diagnosed as non-GERD (Table 1).

Capsule placement

The pH capsule was successfully placed at 5 cm above SCJ on the first attempt in all of the patients (Fig. 1).

Monitoring time

The 48-h recording time was found in 98.5% of the studied patients, whereas 38 of the 63 (60.3%) patients underwent an extended period (>48 h), with median extended recording time of 1.97 h (0.42–22.3) (Fig. 2).

Tolerability

A total of 14 (22.2%) patients reported mild to moderate disturbance of normal daily activities, diet, and sleeping during the monitoring period. Overall, 32 (57.1%) patients experienced foreign body sensation, chest discomfort was seen in 15 (23.8%), and nausea was seen in seven (11.1%).

Detachment

No technical failure occurred such as poor data transmission. No serious adverse events occurred. All patients were followed up during the study period. The capsule was detached spontaneously in all patients within 14 days as confirmed by radiograph. No patient required endoscopic capsule removal.

pH data analysis

The number of patients with recorded parameters suggestive of GERD was 43 (68.2%), whereas 20 (31.8%) patients were defined as non-GERD. All these recording parameters were significant in patients with GERD in comparison with non-GERD patients on day 1, day 2, and total except SI and SAP scores for chest pain, which were statistically insignificant (Table 2).

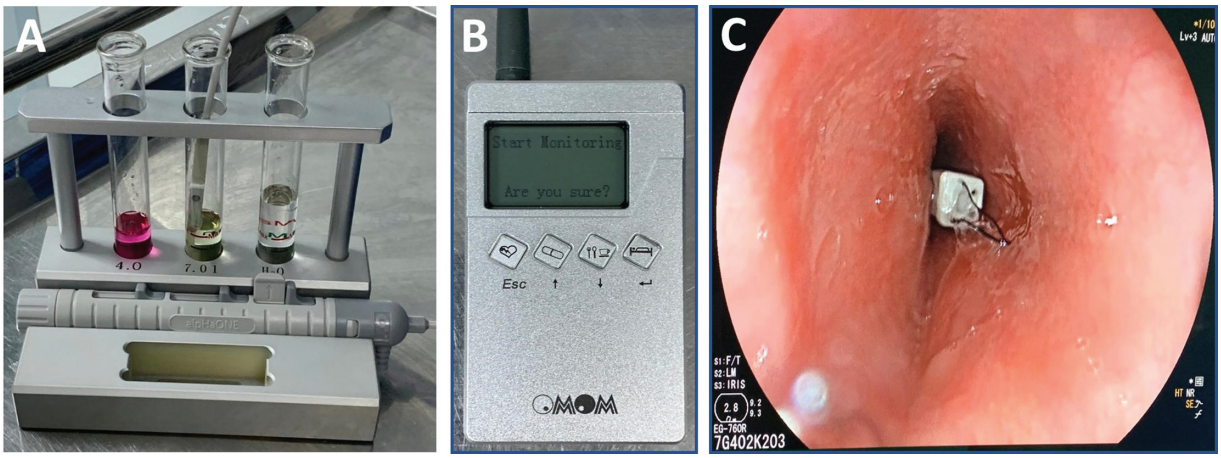
In the current study, the DeMeester score of day 1 was highly significantly correlated with DeMeester score of day 2 (r=0.520; P<0.0001). Moreover, the total DeMeester score was found to be highly

Table 1 Baseline characteristics of studied patients

Variables	GERD (*N*=43)	Non-GERD (*N*=20)	*P* value
Sex [*n* (%)]			
Females	10 (23.3)	14 (70)	0.0003
Males	33 (76.7)	6 (30)	
Age (years; mean±SD)	34.08±13.03	38.72±14	0.203
Indications [*n* (%)]			
Dyspepsia	19 (44.2)	7 (35)	0.490
Abdominal pain	7 (16.3)	3 (15)	0.897
Heartburn	27 (62.8)	11 (55)	0.556
Regurgitation	26 (60.5)	13 (65)	0.730
Hoarseness of voice	3 (7.0)	1 (4.0)	0.615
Chest pain	0	3 (12.0)	0.020
Chronic cough	1 (2.3)	1 (4.0)	0.694
Dysphagia	1 (2.3)	0	0.442
Presleeve	2 (4.7)	0	0.274
Postsleeve gastrectomy	1 (2.3)	1 (4.0)	0.694

GERD, gastroesophageal reflux disease.

Figure 1



JSPH-2 pH capsule measurement system: (a) pH capsule delivery system with pH capsule presoaked under the surface of buffer solution, (b) pH receiver device, and (c) pH capsule attached proximal to the squamocolumnar junction.

significantly correlated with DeMeester scores of day 1 and day 2 (r=0.890 and 0.721, respectively; P<0.0001) (Fig. 3).

On comparison of different recorded parameters suggestive of GERD between day 1 and day 2, the number of refluxes (P=0.048), total fraction time pH less than 4 (P=0.042), meal fraction time pH less than 4 (P=0.047), and DeMeester score (P=0.047) were statistically significant on day 1, whereas other parameters were statistically insignificant.

Five (11.6%) patients with GERD had been identified with abnormal pH data on day 2 only. Nine (20.9%) patients with GERD had been identified with abnormal DeMeester score on day 2 only.

One (2.3%) patient with GERD had been identified during 48-h with normal total fraction time pH less than 4 on day 1 and day 2, but positive SI was reported. Six (13.9%) patients with GERD had been identified during 48-h with normal total fraction time pH less than 4 on day 1 and day 2 but positive SAP was reported.

Change management of patients

The JSPH-2 pH capsule changed clinical management in 50% of the studied patients.

Discussion

The Bravo wireless esophageal pH monitoring system is a new, safe, well-tolerated diagnostic tool for diagnosis of GERD with prolonged pH monitoring in comparison with conventional catheter monitoring systems [18].

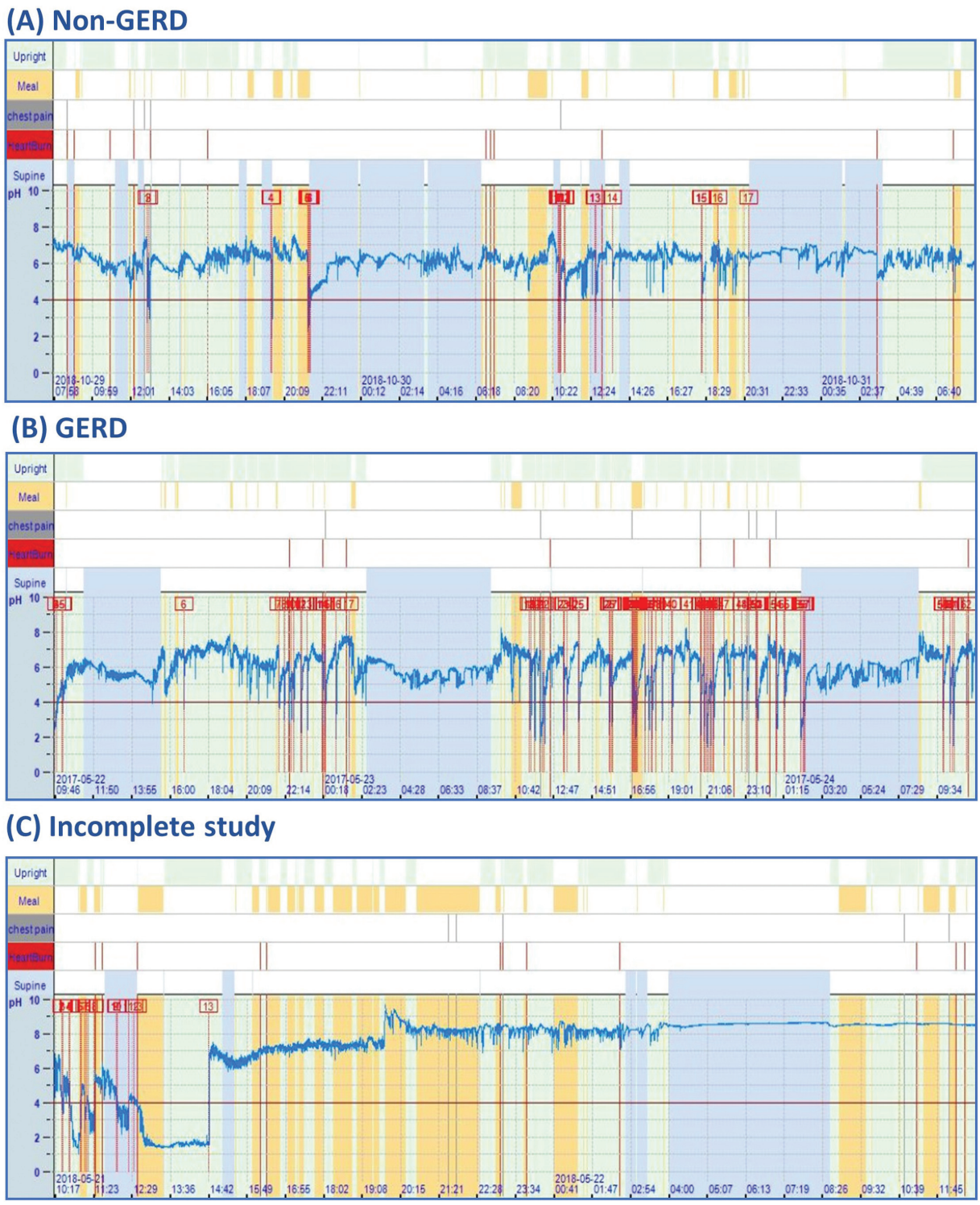
Recently, a new Chinese esophageal pH monitoring system was invented. The new JSPH-1 pH capsule showed similar results to those reported with conventional catheter pH measurement systems [19].

To our knowledge, this is the first clinical test for the Chinese JSPH-2 pH wireless pH monitoring system. The JSPH pH capsule system is rather smaller and lighter than the Bravo capsule. Importantly, the sampling frequency of the JSPH capsule was 1/3 s, which was faster than that of the Bravo capsule (1/6 s) [19].

pH monitoring of the current studied patients with GERD symptoms over 2 days instead of 1 day enabled recording of abnormal esophageal pH in an additional 20.9% of patients. This may have considerable clinical significance similar to another study, which showed that extended recording of wireless esophageal pH monitoring system more than 24 h could detect further day-to-day variability in acid exposure [18].

In the current study, 13.9% of the studied patients had positive DeMeester score, normal total fraction time pH less than 4 and positive SI/SAP, similar to a study which suggested that hypersensitive esophagus really belonged to the GERD spectrum as defined by Rome III criteria and cannot be displaced to the realm of functional gastrointestinal disorders [20].Subjective SI and SAP provided in the current study showed no

Figure 2



pH tracings using the Jinshan pH monitoring working station.

improvement in diagnosing GERD-related chest pain, as stated by a similar study [21].

Adverse events during the JSPH-2 pH capsule monitoring period showed similar adverse events to other study, including nausea, foreign body sensations, and chest pain. [19]. Foreign body sensation was a common symptom reported by patients in the current study, similar to other studies [10,22]. Like other studies, the studied patients reported chest discomfort owing to either mild injury during suction at the site of

Table 2 Comparison between different recorded scores between gastroesophageal reflux disease and non-gastroesophageal reflux disease groups

Variable	Day 1		Day 2		Total	
	GERD (*N*=43)	Non-GERD (*N*=20)	GERD (*N*=43)	Non-GERD (*N*=19)	GERD (*N*=43)	Non-GERD (*N*=20)
Number of refluxes						
Median (IQR)	38 (27–62)	9 (3–18)	28 (13–45)	6 (1.5–14.5)	69 (44–120)	17 (6–39)
P value	<0.0001		<0.0001		<0.0001	
Number of long refluxes >5 min						
Median (IQR)	5 (2–10)	0 (0–0)	3 (1–8)	0 (0–1)	8 (5–16)	0 (0–1)
P value	<0.0001		<0.0001		<0.0001	
Duration of longest reflux (h)						
Median (IQR)	0.37 (0.17–1.16)	0.05 (0.03–0.09)	0.26 (0.13–0.68)	0.06 (0.02–0.12)	0.73 (0.25–1.3)	0.08 (0.03–0.13)
P value	<0.0001		<0.0001		<0.0001	
Total fraction time pH<4 (%)						
Median (IQR)	7.9 (3.8–12.6)	0.6 (0.1–2)	5.6 (1.9–8.2)	0.4 (0.05–1.45)	6.6 (3.9–11.1)	0.5 (0.1–1.4)
P value	<0.0001		<0.0001		<0.0001	
Upright fraction time pH<4 (%)						
Median (IQR)	7.1 (4.5–12.4)	0.8 (0–2.2)	5.6 (1–11.7)	0.45 (0–2.65)	7.3 (3.4–10.5)	0.6 (0.1–1.8)
P value	<0.0001		<0.0001		<0.0001	
Supine fraction time pH<4 (%)						
Median (IQR)	4.1 (0.2–14.2)	0 (0–0.2)	2.3 (0–10.2)	0 (0–0.2)	4.6 (1.7–9.1)	0 (0–0.2)
P value	<0.0001		<0.0001		<0.0001	
Meal fraction time pH<4 (%)						
Median (IQR)	3.3 (1–13.5)	0.5 (0–1.8)	2.4 (0.2–8.2)	0.2 (0–1.45)	5.6 (1.5–11.2)	0.9 (0.1–2.4)
P value	0.002		0.002		<0.0001	
DeMeester score						
Median (IQR)	27.1 (15.1–41.1)	2.6 (0.8–7)	20.2 (6.3–36.6)	1.75 (0.45–5.2)	34.3 (21.5–47.6)	3 (1–8)
P value	<0.0001		<0.0001		<0.0001	
SI for chest pain						
Median (IQR)	0 (0–7.1)	0 (0–1.6)	0 (0–16.7)	0 (0–0)	0 (0–20)	0 (0–3.7)
P value	0.724		0.099		0.130	
SI for heartburn						
Median (IQR)	11.5 (0–33.3)	0 (0–1)	5.1 (0–30)	0 (0–1.9)	20 (0–33.3)	0 (0–5.5)
P value	0.002		0.006		0.001	
SAP for chest pain						
Median (IQR)	0 (0–63)	0 (0–0)	0 (0–75.1)	0 (0–0)	0 (0–90.4)	0 (0–75.3)
P value	0.718		0.078		0.355	
SAP for heartburn						
Median (IQR)	82.7 (0–99.4)	0 (0–0)	73.3 (0–93.4)	0 (0–83.6)	95.5 (0–100)	0 (0–83.1)
P value	0.004		0.033		0.004	

GERD, gastroesophageal reflux disease; IQR, interquartile range; SAP, symptom association probability; SI, symptom index.

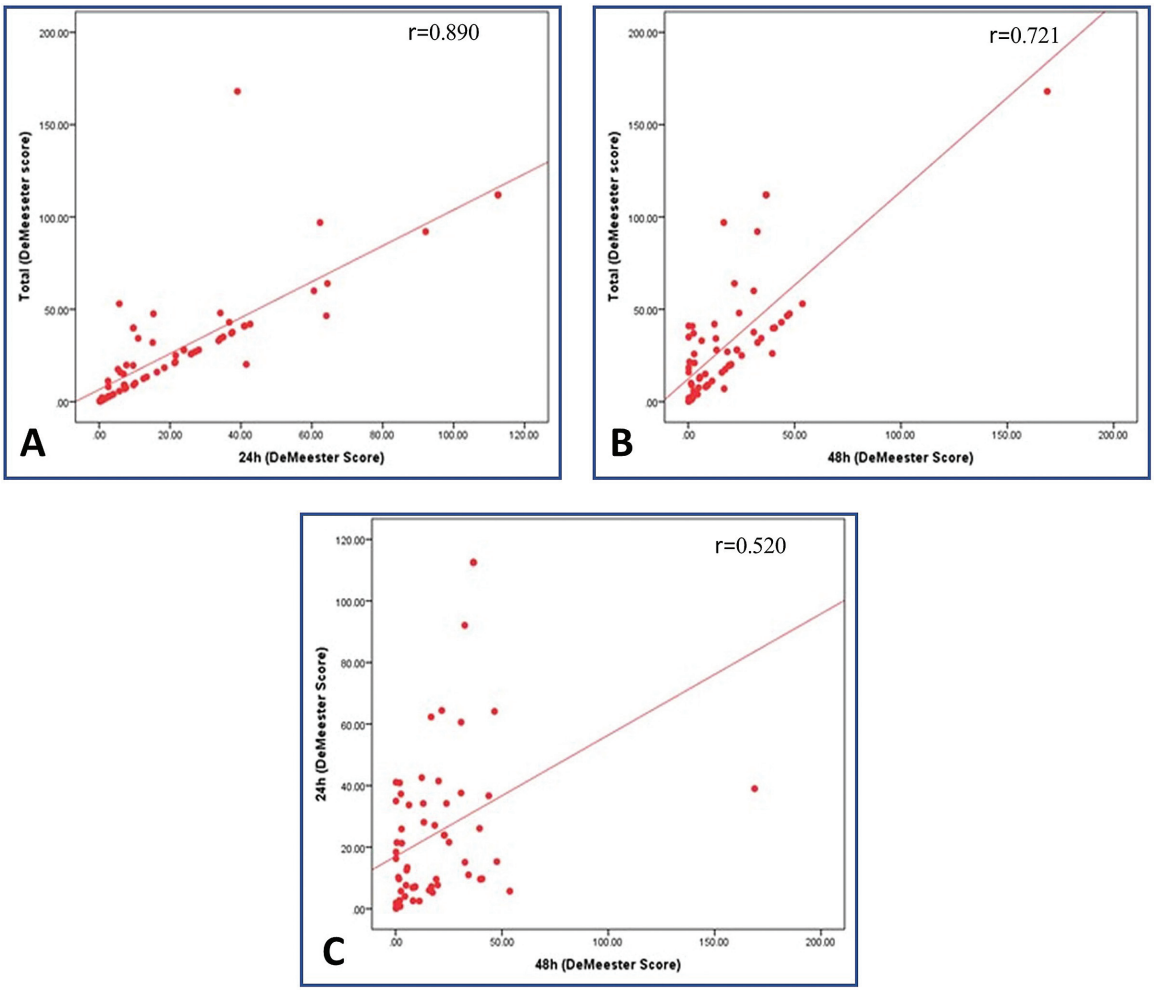
capsule attachment or hypercontractility of esophagus triggered by the attached capsule [10,19,23].

Most of the studied patients were satisfied with the JSPH-2 pH monitoring system as the device was well tolerated without serious adverse events or impairment to diet and daily activities with less nasopharyngeal discomfort than conventional catheter techniques [9,19].

Limitations of this study should be mentioned. This was a retrospective study carried out in a single center with a small sample size. Larger prospective studies on the JSPH pH capsule involving multiple centers, clinically comparing the JSPH pH capsule with other wireless systems, will be needed in the future.

Further studies are needed with extended esophageal pH monitoring up to 96 h by the JSPH capsule to increase the chance of identifying reflux events, establishing symptom association, and evaluating medication responses in patients with refractory symptoms. Moreover, further studies are needed for measuring intragastric pH by the JSPH capsule in the greater curvature of gastric body and acid pocket area, which is a proximal stomach area distal to the SCJ.

Figure 3



Correlations of the DeMeester score between total and individual recording days of the JSPH-2 pH capsule. (a) Positive correlation between total and day 1 (r=0.890, P<0.0001). (b) Positive correlation between total and day 2 (r=0.721, P<0.0001). (c) Positive correlation between day 1 and day 2 (r=0.520, P<0.0001).

Conclusion

The JSPH pH monitoring system is safe and well tolerated and can be used in clinical practice for diagnosis and monitoring of patients with GERD.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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