Normal Values for Water-Perfused Conventional Esophageal Manometry in a Healthy Thai Population

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Background: *Water-perfused conventional esophageal manometry has been the investigative tool of choice for evaluating esophageal motility disorders. Many studies demonstrated that many factors including difference in population group can affect the result of the manometric test.*
Objective: *To establish normal values of water-perfused conventional manometry for Thai people.*
Material and Method: *Thirty healthy volunteers (15 of each sex, aged 19 to 53 years) were recruited. Esophageal manometry using the water-perfused system was performed in each volunteer with ten 5-mL of water swallow and stationary pull-through technique in supine position. The values were calculated and demonstrated in mean, median, and 5th to 95th percentile. The effects of the gender on the measured parameters were analyzed.*
Results: *The mean value of peak contraction pressure and contraction time of the distal esophagus were 107.6 mmHg (5th to 95th percentile: 50.6 to 158.9 mmHg) and 3.3 s (2.63 to 4.59 s). The propagation velocity was 46.2 mm/s. The mean resting pressure of the lower esophageal sphincter was 6.12 mmHg. (5th to 95th percentile: 3.9 to 7.9 mmHg). These key parameters were not considerable different from those reported from the Western studies. The values were similar between genders except mean resting pressure and relaxation time of the LES, which were significantly higher in the female group.*
Conclusion: *A set of normal values for water-perfused esophageal manometry using stationary pull-through technique was established. Because the size of the population recruited was relatively small, further studies may be required to validate our results.*

Keywords: *Water-perfused, Esophageal manometry, Manometric test, Pull-through technique, Thai*

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Measurement of intraluminal pressure of the esophagus was first reported by Kronecker and Metzer in 1883[1]. The technique was not found clinically useful until in the 1950s with the initiation of the use of water-filled catheters and the development of the basic knowledge of esophageal manometry[2]. Since then, increasingly sophisticated equipment and techniques have been developed. The advent of the low compliance pneumohydraulic infusion pump[3], and long pressure sensors[4] allowed more accurate pressure measurements of the esophageal body as well as the lower esophageal sphincters. This manometric system which, at present, is known as "conventional (water-perfused) manometry" has been widely used for over the past decades for assessing the esophageal motility function.

Since many factors including differences in laboratory setting, and populations can influence the result of manometric study[5,6], it is important to define the range of normal values for esophageal pressures in the Thai population for more accurate evaluation of esophageal motility disorders. The objective of the present study is to determine such normal values.

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Material and Method

Thirty healthy asymptomatic volunteers comprising of 15 men and 15 women, ages 19 to 53

years (mean 30.1 years) were recruited. None had a history of dysphagia, regurgitation, heartburn, chest pain, esophageal surgery, diabetic mellitus, collagen connective tissue disease, or neurologic disorders. The volunteers were not allowed to take any drugs that were known to alter esophageal function for two weeks before the study. The study protocol was approved by the Ethics Committee of Ramathibodi Hospital, Mahidol University.

Esophageal manometry was performed using the stationary pull-through technique (SPT). All studies were done with the polygraph and 8-lumen polyvinyl Dent sleeve with a low compliance pneumohydraulic capillary-infusion system (Androfer pump), which was connected to a polygraph. The lower esophageal sphincter (LES) was measured by the sleeve which was positioned at the LES as identified by the stationary pull-through technique. The contraction of the esophageal body was measured with three openings positioned at 5, 10, and 15 cm above the upper border of the LES. The upper esophageal sphincter (UES) values were measured with the proximal opening, which were positioned at the UES as identified by SPT after measurements of the LES and the esophageal body were completed. Fifteen wet swallows of 10 mL of water were given, separated by 30 seconds intervals. The first five wet swallows were used as training exercises to adapt the volunteers to the technique; only the last 10 wet swallows were analyzed.

Criteria and definitions for manometric interpretation

Upper esophageal sphincter (UES)

Resting and closing pressure in the sphincter were measured with the atmospheric pressure as the reference point, standardized to zero. Relaxation was termed "complete" when the UES relaxation phase fell to within 5 mmHg of the cervical esophageal baseline pressure. The sphincter was defined as "coordinated" when the relaxation period of the UES entirely enclosed the pharyngeal contraction and the peak of pharyngeal contraction occurred at the nadir of UES relaxation.

Esophageal body

Measurements of the amplitude, duration and velocity of the peristaltic contraction were made following 10 mL of wet swallow at 5, 10, and 15 cm above the LES. Contraction amplitude was a measure of how tightly the muscles of the esophagus were squeezing during a contraction and was expressed in millimeters of mercury (mmHg). The peak contraction pressure (PCP) was measured from the baseline to the peak of the pressure wave. The baseline pressure (standardized as 0 mmHg.) was the pressure in the esophageal body between swallows. The average values were obtained from each channel at 5, 10, and 15 cm. and labeled as proximal, middle, and distal esophageal amplitude contractions, respectively.

The duration of contraction was a measurement of how long, in seconds, the muscles of the esophageal body were squeezing during contraction. The measurement was made from the point where the upstroke of the contraction left the baseline to the point where the downstroke of the contraction touched the baseline.

Propagation velocity (PV) was the measurement of how fast the contraction wave moved down the esophagus. It was expressed in centimeters per second (cm/s). The measurement was made by determining the time between the beginning of the upstroke of the contractions in the proximal port and the next adjacent port, and using this to divide 5, which is the number of centimeters between the ports.

Lower esophageal sphincter

Measurements of the LES pressure were made, using the intragastric baseline pressure as the reference point (0 mmHg). The sphincter pressure was measured from gastric baseline to the end expiratory pressure. The resting and relaxation pressures of the LES were measured by the SPT, in response to wet swallows where complete relaxation was defined as the LES pressure decreased to 0 mmHg after a wet swallow.

Statistical analysis

The data were analyzed using Stata Statistical Software: Release 14. StataCorp. 2015. (College Station, Texas: StataCorp LP). Normal values were reported in mean with standard deviation (SD), median, and 5th and 95th percentile. Comparisons of the normal values between genders were conducted using Wilcoxon matched-pairs signed-ranks test and paired t-test. All *p*-values were two-tailed and *p*-value of less than 0.05 was considered as significant.

Results

Esophageal manometry was successfully performed in all 30 volunteers. The anthropometric characteristics of the volunteers are shown in Table 1.

Upper esophageal sphincter

The results of the measurements for UES are given in Table 2, for men and women separately. The

Table 1. Anthropometric characteristics of volunteers

Characteristic	Overall (n = 30)	Male (n = 15)	Female (n = 15)
Age (years): mean (SD)	30.1 (7.7)	28.6 (6.3)	31.5 (8.9)
Weight (kg): mean (SD)	56.6 (9.8)	63.2 (7.7)	49.6 (6.1)
Height (cm): mean (SD)	162.0 (8.2)	168.8 (5.3)	155.2 (3.5)
BMI (cm/m^2): mean	21.6	22.4	20.6

BMI = body mass index

mean value of resting pressure in all volunteers was 73.3 mmHg (5^{th} to 95^{th} percentile: 41.8 to 121.4 mmHg). The mean closing pressure was 143.5 mmHg (5^{th} to 95^{th} percentile: 91.0 to 227.0 mmHg). The mean UES length was 1.9 cm. There was no statistically significant difference of these three parameters between both sexes. The UES relaxation in all swallows were completed and coordinated.

Esophageal body

The parameters of esophageal body are shown in Table 3. The mean resting pressure was 6.1 mmHg. When analyzed in terms of gender, the mean resting pressure in female was significantly higher than that in male group (6.7 vs. 5.5 mmHg; $p = 0.016$). More distal part of the esophageal body showed a trend towards higher and longer values of PCP and contraction time (CT). There was no statistically significant difference of the PCP and CT based on gender.

Lower esophageal sphincter

The LES measurements are summarized in Table 4. The mean resting pressure of the LES was 6.1 mmHg (5^{th} to 95^{th} percentile: 3.1 to 7.9 mmHg). The closing pressure was 83.3 mmHg (5^{th} to 95^{th}: 49.8 to 134.3 mmHg). The resting intragastric pressure was 21.4 mmHg (5^{th} to 95^{th} percentile: 15.7 to 28.3). The relaxation time was 9.5 seconds (5^{th} to 95^{th} percentile: 7.4 to 11.6 mmHg). Analyzing of these parameters per gender was performed. In men, the mean length of the LES and distance from nares to the respiratory inversion point (RIP) were significantly higher whereas the values of mean resting pressure and mean relaxation time were significantly lower than those in women. The relaxation and coordination of the LES were completed in all swallows.

Normal values of esophageal manometry: comparison with the western studies

Normal values of water-perfused manometry with SPT from our study was compared to the values derived from Western populations[5,7]. The values from our study are not considerably different from others except the mean value of the resting and closing pressure of the UES, the resting pressure of the esophageal body, and the closing pressure of the LES which were all higher than those from other studies Table 5.

Discussion

It is generally accepted that esophageal manometry is the gold standard for evaluating the motor function of the esophageal body and lower esophageal sphincter. In the present study, normal values of manometric measurements in a healthy Thai men and women were established. The results from our study were comparable to the data from the Western populations[5,7] and can be used as reference values for the esophageal manometry using low pressure water infusion pump system. The values of the manometric parameters were also taken separately in each gender group. Most of these values were equivalent between groups except the mean resting pressure and relaxation time of the LES which were higher in the female group, whereas the mean distance between RIP and nares and length of the LES were longer in the male group. Similar results regarding the differences in the manometric parameters between men and women were also reported in other studies[8,9]. However, the results of a manometric study may be affected by many other factors such as age, race, BMI, manometric system, and position during the test[9,10]. In our study, the mean BMI in male was higher than that in female group, whereas female appeared to be older than male subjects. Esophageal manometry can also be performed by using a solid-state transducer system instead of the water infusion system as in our study. Some advantages of the solid state over the water-perfused catheter have been noted. The solid catheters have much higher frequency-response characteristics resulting in a much quicker

Table 2. Measurement for the upper esophageal sphincter

Measure	Overall			Male			Female			*p*-value
	Mean (SD)	Median (range)	5th to 95th percentile	Mean (SD)	Median (range)	5th to 95th percentile	Mean (SD)	Median (range)	5th to 95th percentile	
Resting pressure (mmHg)	73.3 (22.8)	69.6 (40.1 to 130.3)	41.8 to 121.4	73.4 (26.6)	67.7 (40.1 to 130.3)	40.1 to 130.3	73.1 (19.2)	71.6 (44.8 to 121.4)	44.8 to 121.4	0.974
Closing pressure (mmHg)	143.5 (41.9)	139.8 (65.0 to 238.7)	91.0 to 227.0	143.7 (36.4)	143.7 (92.3 to 227.0)	92.3 to 227.0	143.3 (48.1)	130.0 (65.0 to 238.7)	65.0 to 238.7	0.979
UES length (cm)	1.9 (0.4)	2.0 (1.0 to 3.0)	1.0 to 2.0	2.0 (0.4)	2.0 (1.0 to 3.0)	1.0 to 3.0	1.9 (0.3)	2.0 (1.0 to 2.0)	1.0 to 2.0	0.325
Relaxation time (s)	1.1 (0.2)	1.0 (1.0 to 2.0)	1.0 to 1.5	1.1 (0.3)	1.0 (1.0 to 2.0)	1.0 to 2.0	1.1 (0.1)	1.0 (1.0 to 1.5)	1.0 to 1.5	0.749
Relaxation					All complete					
Coordination					All coordinated					

UES = upper esophageal sphincter

measurement of the abruptly changed pressure particularly at the pharynx and UES[11]. The solid-state devices may also require less effort to use and learn[11]. The major drawbacks are their much higher cost and more susceptible to damage.

Over the past 30 years, the advancement of computerized technology and the development of the assemblies with much more number of pressure sensors led to what is now known as high-resolution manometry (HRM)[12,13]. When compared to the conventional manometry, HRM can provide more comprehensive data measured from the sphincters and esophageal body with easier technique[14]. This allows HRM to become the predominant manometric system at present[15]. However, the cost of HRM system is also much higher than that of conventional manometry. The water-perfused conventional manometry is therefore more economical and still be a good investigative option for diagnosing esophageal motility disorders in a high patient-volume motility laboratory where HRM cannot be afforded.

The limitations of this study include the relatively low number of the volunteers, and the recruitment of the volunteers that was performed only at Ramathibodi hospital. These may not really reflect the data of entire Thai population. Further studies with a bigger sample size and more proper recruitment of the healthy volunteers are required to validate our findings.

Conclusion

The normal values of the water-perfused conventional manometry studied in 30 healthy Thai volunteers were established. The values of the key parameters as the peak contraction pressure, contraction time, propagation velocity, and the resting pressure of the LES were in line with other reports from the Western countries. The differences in the values of some parameters between genders were demonstrated. Further studies with a larger sample size and more proper subjects' recruitment is required to validate the findings of the present study.

What is already known on this topic?

Different manometric settings, study protocols and demographic factors of the subjects as age, race or BMI can influence the result of manometric measurement.

Normative values for water-perfused manometry already exist, but it based on the data from the Western population.

Table 3. Measurement of esophageal body

Measure	Overall			Male			Female			*p*-value
	Mean (SD)	Median (range)	5th to 95th percentile	Mean (SD)	Median (range)	5th to 95th percentile	Mean (SD)	Median (range)	5th to 95th percentile	
Resting pressure (mmHg)	6.1 (1.4)	6.3 (3.4 to 8.4)	3.9 to 7.9	5.5 (1.4)	5.6 (3.4 to 7.5)	3.4 to 7.5	6.7 (1.1)	6.7 (4.3 to 8.4)	4.3 to 8.3	0.016
PCP (mmHg) - Proximal	52.1 (22.5)	46.5 (19.1 to 97.4)	24.6 to 95.8	52.1 (24.2)	44.2 (19.1 to 97.4)	19.1 to 97.4	52.1 (21.6)	48.4 (24.7 to 95.8)	24.7 to 95.8	0.999
PCP (mmHg) - Middle	75.6 (27.8)	65.5 (36.3 to 150.6)	44.3 to 130.6	66.1 (24.5)	59.3 (36.3 to 130.6)	36.3 to 130.6	85.2 (28.4)	81.6 (54.7 to 150.6)	54.7 to 150.6	0.054
PCP (mmHg) - Distal	107.6 (31.4)	112.2 (46.3 to 166.2)	50.6 to 158.9	98.4 (34.5)	90.4 (46.3 to 158.9)	46.3 to 158.9	116.7 (26.0)	116.4 (74.6 to 166.2)	74.6 to 166.2	0.111
Contraction time(s) - Proximal	2.5 (1.0)	2.4 (0.6 to 1.5)	1.5 to 3.4	2.3 (0.6)	2.3 (1.5 to 3.1)	1.5 to 3.15	2.7 (1.3)	2.4 (1.1 to 6.6)	1.1 to 6.6	0.442
Contraction time(s) - Middle	2.75 (0.49)	2.8 (1.9 to 4.0)	2.1 to 3.6	2.7 (0.5)	2.7 (1.9 to 3.6)	1.5 to 3.6	2.8 (0.5)	2.8 (2.1 to 4.0)	2.1 to 4.0	0.357
Contraction time(s) - Distal	3.3 (0.5)	3.2 (2.4 to 5.0)	2.6 to 4.6	3.2 (0.4)	3.1 (2.4 to 4.2)	2.4 to 4.2	3.5 (0.7)	3.2 (2.6 to 5.0)	2.6 to 5.0	0.213
PV (mm/s)	46.2 (5.9)	-	-	48.9 (4.3)	-	-	43.5 (7.6)	-	-	-

PCP = peak contraction pressure; PV = peristaltic velocity

Table 4. Lower esophageal measurements

Measure	Overall			Male			Female			*p*-value
	Mean (SD)	Median (range)	5th to 95th percentile	Mean (SD)	Median (range)	5th to 95th percentile	Mean (SD)	Median (range)	5th-95th percentile	
Resting pressure (mmHg)	6.1 (1.4)	6.3 (3.5 to 8.4)	3.9 to 7.9	5.5 (1.4)	5.6 (3.4 to 7.5)	3.4 to 7.5	6.7 (1.1)	6.7 (4.3 to 8.4)	4.3 to 8.4	0.016
Closing pressure (mmHg)	83.3 (28.8)	81.1 (33.9 to 175.1)	49.8 to 134.3	83.6 (32.2)	73.7 (52.6 to 175.1)	52.6 to 175.1	82.9 (26.1)	83.2 (33.9 to 134.3)	33.9 to 134.3	0.709
Relaxation time UES	1.1 (0.2)	1.0 (1.0 to 2.0)	1.0 to 1.5	1.1 (0.3)	1.0 (1.0 to 2.0)	1.0 to 2.0	1.1 (0.1)	1.0 (1.0 to 1.5)	1.0 to 1.50	0.749
Upper border of LES (cm from nares)	42.9 (1.9)	-	-	44.6 (2.3)	-	-	41.3 (1.5)	-	-	-
LES length (cm)	1.9 (0.3)	2.0 (1.0 to 3.0)	1.5 to 2.0	2.1 (0.3)	2.0 (2.0 to 3.0)	2.0 to 3.0	1.8 (0.3)	2.0 (1.0 to 2.0)	1.0 to 2.0	0.023
RIP (cm from nares)	43.5 (2.6)	43.0 (40.0 to 49.0)	40.0 to 47.0	45.3 (2.2)	46.0 (41.0 to 49.0)	41.0 to 49.0	41.7 (1.3)	41.00 (40.0 to 44.0)	40.0 to 44.0	0.000
Length below diaphragm (cm)	1.4 (0.8)	-	-	1.3 (0.6)	-	-	1.4 (0.91)	-	-	-
Resting intragastric pressure (mmHg)	21.4 (4.01)	22.0 (13.5 to 30.1)	15.7 to 28.3	21.3 (4.0)	22.3 (13.5 to 26.2)	13.5 to 26.2	21.5 (4.2)	21.8 (15.9 to 30.1)	15.9 to 30.1	0.887
Relaxation time LES	9.5 (1.2)	9.4 (7.0 to 11.9)	7.4 to 11.6	8.9 (0.5)	8.8 (8.1 to 10.0)	8.1 to 10.0	10.0 (1.4)	10.3 (7.0 to 11.9)	7.0 to 11.9	0.0065
Coordination		All coordinated			All coordinated			All coordinated		-

LES = Lower esophageal sphincter; RIP = respiratory inversion point; UES = upper esophageal sphincter

Table 5. Comparison of measurements with western values

Measure	Our results	Duranceau et al[5]	Richter et al[7]
UES: mean (SD)			
Resting pressure (mmHg)	70.9 (22.8)	50.3 (17.5)	-
Closing pressure (mmHg)	138.9 (48.6)	96.2 (37.8)	-
UES length (cm)	2.00 (0.1)	-	-
Relaxation time (s)	1.08 (0.2)	1.30 (0.4)	-
Esophageal body: mean (SD)			
Resting pressure (mmHg)	6.12 (1.4)	2.3 (2.8)	-
Peak contraction pressure (mmHg)			
Proximal	52.2 (22.6)	55.8 (25.6)	62 (29)
Middle	75.6 (27.8)	74.7 (29.3)	70 (32)
Distal	104.1 (35.9)	60.3 (20.6)	90 (41)
Contraction time (s)			
Proximal	2.51 (1.0)	4.9 (1.4)	3.5 (0.7)
Middle	2.75 (0.5)	-	3.9 (0.9)
Distal	3.32 (0.5)	5.8 (1.9)	4.0 (1.1)
Propagation velocity (mm/s)	47.2 (6.3)	25.4 (6.4)	35 (0.9)
LES: mean (SD)			
Resting pressure (mid resp) (mmHg)	21.4 (4.0)	24.8 (6.8)	24.2 (10.1)
Closing pressure (mmHg)	83.3 (28.8)	48.2 (18.0)	-
Relaxation time (s)	9.48 (1.2)	9.8 (1.5)	-
Upper border of LES (cm from nares)	42.9 (2.6)	-	-
LES length (cm)	1.95 (0.3)	-	-
RIP (cm from nares)	43.50 (2.6)	-	-
Length below diaphragm (cm)	1.37 (0.8)	-	-
RIGP (mmHg)	7.76 (1.2)	7.3 (2.3)	-

LES = lower esophageal sphincter; RIGP = resting intragastric pressure; RIP = respiratory inversion point; UES = upper esophageal sphincter

What this study adds?

This study reveals the normal values for the water-perfused conventional manometry in a group of healthy Thai subjects and can be used as a set of reference values for diagnosing esophageal motility disorders at least in Thai population.

Potential conflicts of interest

None.

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การศึกษาค่ามาตรฐานของ water-perfused esophageal manometry ในประชากรชายและหญิงไทยที่มีสุขภาพดี

ปีติโชติ หิรัญเทพ, สุริยะ จักกะพาก, ไข่มุกด์ เพ็ชรศรีกุล, ภาณุวัฒน์ เลิศสิทธิชัย

ภูมิหลัง: *การตรวจหลอดอาหารด้วยเครื่อง water-perfused conventional manometry นั้นเป็นการตรวจมาตรฐานเพื่อช่วยในการวินิจฉัยความผิดปกติของการบีบตัวของหลอดอาหาร ค่ามาตรฐานที่นำมาใช้ในการวินิจฉัยโรคอ้างอิงจากผลการศึกษาในกลุ่มประชากรในประเทศตะวันตก อย่างไรก็ตามมีการศึกษาในอดีตบ่งชี้ว่า ความแตกต่างของกลุ่มประชากรอาจมีผลเปลี่ยนแปลงต่อค่าปกติที่วัดจากเครื่องมือชนิดนี้ ซึ่งอาจมีผลต่อการวินิจฉัยโรคของหลอดอาหารด้วย*

วัตถุประสงค์: *เพื่อศึกษาค่ามาตรฐานของการทำงานของหลอดอาหารในประชากรชายและหญิงไทยด้วยเครื่อง water-perfused esophageal manometry*

วัสดุและวิธีการ: *ทำการตรวจการทำงานของหลอดอาหารโดยใช้เครื่อง water-perfused esophageal manometry โดยทำในกลุ่มตัวอย่างทั้งสองเพศเท่าๆ กัน จำนวน 30 คน ที่เป็นคนไทยที่มีสุขภาพดี ข้อมูลที่ได้ในแต่ละตัวแปรจะถูกนำมาคำนวณเพื่อหาค่าเฉลี่ย (mean), ค่าเบี่ยงเบนมาตรฐาน (standard deviation), ค่ามัธยฐาน (median) และค่าเปอร์เซ็นต์ไทล์ที่ 5 และ 95*

ผลการศึกษา: *ค่าเฉลี่ยของ peak contraction pressure และ contraction time ที่หลอดอาหารส่วนปลายเท่ากับ 107.6 มิลลิเมตรปรอท และ 3.3 วินาที ตามลำดับ ค่าเฉลี่ยของ propagation velocity เท่ากับ 46.2 มิลลิเมตรต่อวินาที ค่าเฉลี่ยของ resting pressure ที่ lower esophageal sphincter (LES) เท่ากับ 6.12 มิลลิเมตรปรอท เมื่อนำตัวแปรมาวิเคราะห์เพื่อหาความแตกต่างระหว่างเพศ พบว่าค่าเฉลี่ยของ resting pressure และ relaxation time ของ LES ในกลุ่มตัวอย่างเพศหญิงมีค่ามากกว่าในเพศชายอย่างมีนัยสำคัญ*

สรุป: *ค่ามาตรฐานของการตรวจหลอดอาหารโดยใช้เครื่อง water-perfused esophageal manometry ในกลุ่มตัวอย่างคนไทยจากการศึกษานี้สามารถนำไปใช้ประกอบการวินิจฉัยความผิดปกติของการบีบตัวของหลอดอาหารได้ ตัวแปรที่มีความแตกต่างระหว่างเพศชายและหญิง ได้แก่ resting pressure และ relaxation time*