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Systematic Review

Effect of Body Position on High-resolution Esophageal Manometry Variables and Final Manometric Diagnosis

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Background/Aims

According to the Chicago classification version 3.0, high-resolution manometry (HRM) should be performed in the supine position. However, with the patient in the upright/sitting position, the test could more closely simulate real-life behavior and may be better tolerated. We performed a systematic review of the literature to search whether the manometric variables and the final diagnosis are affected by positional changes.

Methods

A literature search was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. Studies published in English that compared HRM results in different body positions were included. Moreover, the change in diagnosis of esophageal motility disorders according to the shift of body position was investigated.

Results

Seventeen studies including 1714 patients and healthy volunteers met the inclusion criteria. Six studies showed a significant increase in lower esophageal sphincter basal pressure in the supine position. Integrated relaxation pressure was significantly higher in the supine position in 10 of 13 studies. Distal contractile index was higher in the supine position in 9 out of 10 studies. One hundred and fifty-one patients (16.4%) out of 922 with normal HRM in the supine position were diagnosed with ineffective esophageal motility (IEM) when the test was performed in the upright position ($P < 0.001$).

Conclusions

Performing HRM in the upright position affects some variables and may change the final manometric diagnosis. Further studies to determine the normal values in the sitting position are needed.
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Key Words

Chicago; Esophageal motility disorders; Manometry; Reference values; Sitting position

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Introduction

High-resolution manometry (HRM) is considered the test of choice to evaluate esophageal motility disorders. The first sets of normal values were established in 2006.[1-3] The normative values (5th and 95th percentiles) were obtained in 75 healthy volunteers studied in the supine position with a solid-state manometric assembly with 36 circumferential sensors spaced at 1-cm intervals and ten 5-mL water swallows in each subject. A subsequent study performed on 400 patients[4] allowed a classification of esophageal motility disorders, namely the Chicago classification, that has been updated and has now reached the third version.[5] Normative thresholds can vary according to the HRM software system, catheter outer-diameter, bolus consistency and volume, age, obesity, ethnicity, and body position.[6] Cutoffs for abnormality established in the supine position may not be valid in the upright/sitting position. Historically also, the conventional water-perfused esophageal manometry was performed with the patient lying in the supine position, which allowed to test the peristaltic function without interference of gravity on bolus transit.[7] However, swallowing in the upright position is more similar to real-life behavior, may be more tolerable for patients with swallowing difficulties, and may reduce cardiovascular artifacts on the HRM tracing.[8] The aim of this study is to perform a systematic review on comparative studies testing the results obtained during HRM in supine and upright/sitting positions and to search whether HRM variables are influenced by body location and may change the final diagnosis.

Methods

We conducted a systematic review according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. An extensive literature search was conducted by 5 independent authors (C.G.R., D.F., M.C., M.S., and S.S.) to identify all clinical reports dealing with results of HRM comparing the supine and upright positions. PubMed, Cochrane, Embase, and Scopus databases were queried using the following terms: "body position", "esophageal manometry", "high resolution manometry", "HRM", and every possible combination with AND/OR. The search was restricted to studies published in English and was completed by consulting the listed references of each article. Studies with conventional esophageal manometry, and those assessing solid swallows, or which focused on upper esophageal sphincter parameters, or performed during general anesthesia, were excluded. Disagreements among authors were resolved by consensus; if no agreement could be reached, the senior author (L.B.) made the decision. For each selected study, data extracted included first author name, year of publication, nation where the study was performed, number of subjects involved, and whether they were healthy volunteers or symptomatic gastroesophageal reflux disease patients. The following parameters were recorded: protocol characteristics (angle of supine and upright position, number of swallows per set, water amount per swallow expressed in mL, catheter outer-diameter expressed in mm, and software used for data elaboration); upper esophageal sphincter characteristics, including basal pressure and residual pressure; lower esophageal sphincter (LES) characteristics, including basal pressure, integrated relaxation pressure (IRP), total and intra-abdominal length; and esophageal body characteristics, including distal contractile integral (DCI), intrabolus pressure (IBP), distal latency, mean peristaltic pressure, contractile pattern with percentage of failed, weak and rapid swallows, large and small breaks, and double-peak swallow. Lastly we reported the percentage of effective swallows and the change in diagnosis of esophageal motility disorders according to the shift of body position.

The methodological quality of the studies was assessed based on the most critical factors that increase the risk of bias in this specific context.[9] Statistical analysis was performed using the SPSS software version 23 (IBM, Armonk, NY, USA). The rate of patients with ineffective esophageal motility (IEM) in the supine versus upright position was compared using Chi-Square Test, and the statistical significance was established at less than the 0.05 level.

Results

Ninety publications were found applying the search criteria. Twenty-seven publications were duplicated and were removed. Sixty-three studies were examined and further screening revealed that only 17 articles met the inclusion criteria (Figure). All included studies were designed as case-series and had a low to moderate risk for bias based on a global assessment of methodological quality.[9]

High-resolution Manometry Protocols

One thousand seven hundred fourteen patients were included,[10-26] of whom 1284 were symptomatic and 430 asymptomatic individuals. The sequence of the position assumed during HRM was described in almost all studies. Some authors referred that the exam was started in the supine position and the subsequent series of swallows was performed in the sitting/upright position;[12,14,15,18,19,24] other referred the opposite.[16,20,22,23] Patients were randomly assigned

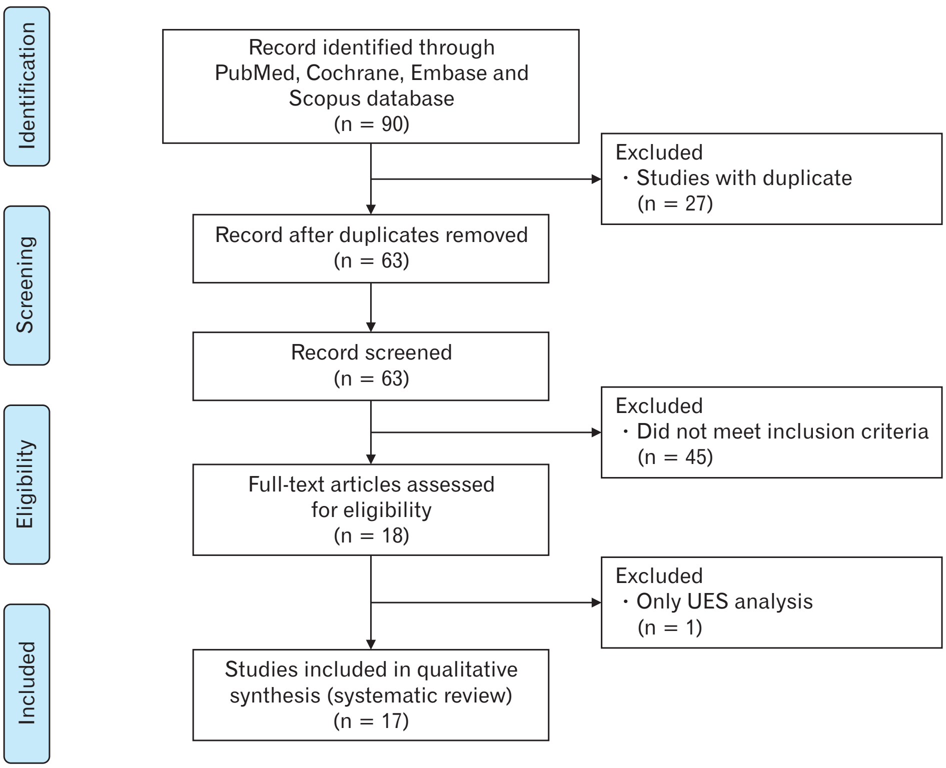

Figure. The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) diagram. UES, upper esophageal sphincter.

both to the upright or supine position in the studies by Zhang et al[17,21] and Misselwitz et al.[26] Only 5 studies[14,16,17,19,24] reported the inclination assumed by the patient during the exam: between 0° and 20° for the supine position and between 75° and 90° for the upright/sitting position. Every study included at least 5 water bolus swallows per set for each position. Data were analyzed using various manometric softwares: 12 studies[11-14,16,17,19-21,24-26] used Manoscan (of whom 3 and 9 from Medtronic [Minneapolis, MN, USA]), 3 studies[15,22,23] used Bioview by Sandhill Scientific Inc (Ranch, CO, USA), and 2 studies[10,18] used Trace! V1.2 videomanometry system (Hebbard System, Melbourne, Australia) (Table 1).

High-resolution Manometry Variables

In regard to LES parameters, LES length was analyzed in 5 studies,[11,15,19,21,23] 3 of which[15,21,23] found a greater LES length in the supine position. Six[15,20,21,23,24,26] of 8 studies[11,12,15,20,21,23,24,26] showed a significant increase in LES basal pressure in the supine position, 3 studies[11-13] did not find differences, and one[19] found a significantly higher pressure in the upright position. IRP was significantly higher in the supine position in 10 of 13 studies,[14-17,20-24,26] while in 2 studies[13,18] it was significantly increased in the upright position.

In regard to esophageal body parameters, DCI was higher in the supine position in 9 of 10 studies.[12,13,16-18,20,22-24,26] In the study by Besanko et al,[18] DCI value was significantly higher in the upright position in the subgroup of older healthy patients. Six studies[11-13,15,18,20] investigated mean peristaltic wave pressure: it was significantly higher in the supine position in 2 studies,[12,20] comparable in 3 studies,[11,13,15] and significantly higher in the upright position in 1 study.[18] IBP was significantly higher in the supine position in 3 studies,[20,23,24] whilst it was comparable in the 2 positions in 1 study.[13] Lastly, distal latency was investigated in 7 studies[16,17,20-24,26] and was significantly higher in the supine position in 4 studies.[16,17,20,24] The HRM values recorded in healthy subjects are summarized in Table 2.

Concordance of Final Manometric Diagnosis

Only 6 studies[10,12,14,20,24,26] for a total of 922 patients reported the difference in terms of final diagnosis in the 2 positions. One hundred and fifty-one patients (16.4%) with normal HRM in the supine position were diagnosed with IEM when the test was performed in the upright position ($P < 0.05$). Variations in final diagnosis including normal motility, IEM, absent peristalsis, distal esophageal spasm, hypercontractile motility, esophagogastric junction (EGJ) outflow obstruction, and achalasia are reported in Table 3.

Table 1. Patients Characteristics and High-resolution Manometry Protocol Features

Author	Subgroup	Body position	No. of patients	Type of patients	Patients position	Manometric software
Bernhard et al[10]		Supine	96	Symptomatic	Left lateral decubitus	Trace! V1.2 videomanometry system; Hebbard System
		Upright			NR	
Buduhan et al[11]		Supine	10	Healthy	NR	ManoView; Sierra Scientific Instruments
		Upright			NR	
Roman et al[12]		Supine	100	Symptomatic	NR	ManoView; Sierra Scientific Instruments
		Upright			NR	
Sweis et al[13]		Supine	21	Healthy	NR	ManoView; Sierra Scientific Instruments
		Upright	23		NR	
Xiao et al[14]		Supine	148	Symptomatic	0-10°	ManoView; Sierra Scientific Instruments
		Upright			70-90°	
Hoppo et al[15]	Isolated upright reflux	Supine	35	Symptomatic	NR	Bioview; Sandhill
		Upright			NR	
	Predominant upright bipositional reflux	Supine	53		NR	
		Upright			NR	
	Predominant supine bipositional reflux	Supine	27		NR	
		Upright			NR	
Xiao et al[16]	Healthy	Supine	75	Healthy	0-10°	ManoView; Given Imaging
		Upright			70-90°	
	No hiatal hernia	Supine	80	Symptomatic	0-10°	
		Upright			70-90°	
	Hiatal hernia	Supine	40	Symptomatic	0-10°	
		Upright			70-90°	
Zhang et al[17]	Volunteers	Supine	21	Healthy	0-20°	ManoView; Sierra Scientific Instruments
		Upright			70-90°	
	Patients	Supine	25	Symptomatic	0-20°	
		Upright			70-90°	
Besanko et al[18]	Younger	Supine	10	Healthy	Right lateral decubitus	Trace! V1.2 videomanometry system; Hebbard System
		Upright			NR	
	Older	Supine	10	Healthy	Right lateral decubitus	
		Upright			NR	
Hashmi et al[19]		Supine	50	Symptomatic	20°	ManoView; Sierra Scientific Instruments
		Upright			NR	
Ciriza-de-Los-Ríos et al[20]	Dysphagia group	Supine	49	Symptomatic	NR	ManoView; Given Imaging
		Upright			NR	
	GERD group	Supine	50		NR	
		Upright			NR	

Table 1. Continued

Author	Subgroup	Body position	No. of patients	Type of patients	Patients position	Manometric software
Zhang et al[21]		Supine	50	Healthy and symptomatic patients	NR	ManoView; Sierra Scientific Instruments
		Upright			NR	
Jung et al[22]		Supine	54	Healthy	NR	Bioview; Sandhill
		Upright			NR	
Do Carmo et al[23]		Supine	69	Healthy	NR	Bioview; Sandhill
		Upright			NR	
Hiranyatheb et al[24]		Supine	41	Healthy	10°	ManoView; Sierra Scientific Instruments
		Upright			80-90°	
Pu et al[25]		Supine	139	Symptomatic	NR	ManoView; Given Imaging
		Upright			NR	
Misselwitz et al[26]		Supine	72	Healthy	NR	ManoView; Sierra Scientific Instruments
		Upright			NR	
		Supine	366	Symptomatic	NR	
		Upright			NR	

NR, not reported.

Discussion

Even if different systems and catheters have been developed, current guidelines[5] suggest performing HRM with the patient lying supine as it was done during the conventional manometry era.[7] The supine position allows testing the peristaltic function without interference of gravity, but some authors argue that a seated position is more physiological and more similar to daily habits, thus increasing the diagnostic sensitivity. The present systematic review shows that a number of authors have analyzed and compared HRM patterns in the supine and upright/sitting positions, but the results have been inconclusive. Of the 10 studies[11,13,16-18,21-24,26] conducted on healthy subjects, only 2 studies[12,23] did not find significant differences concerning EGJ morphology. On the other hand, Buduhan et al[11] and Hoppo et al[15] found that the LES length was significantly shorter when the patients moved to the upright position, indicating that the LES barrier may be more effective in the supine position. Generally, the LES basal pressure resulted to be higher in the supine position. Zhang et al[21] and Xiao et al[16] speculated that higher IBP pressure and the gravity effect in the upright position may reduce LES pressures. Ciriza-de-Los-Ríos et al[20] suggested that the increased LES basal pressure in the supine position is a protective mechanism against gastroesophageal reflux due to a concomitant increase of intragastric pressure. The decreased IRP value in the upright position may be due to the fact that gravity itself facilitates the esophageal emptying.[16] On the contrary, in 3 studies[13,18,22] higher IRP values have been found in the upright position. Sweis et al[13] speculated that increased hydrostatic forces in the distal esophagus in the upright setting or changes in EGJ anatomy alter the resistance to flow. Besanko et al[18] found a significantly higher IRP in the upright position in a cohort of healthy old adults, and hypothesized that impaired swallow-induced relaxation and/or loss of LES compliance secondary to age may explain this finding. Moreover, it has been reported that variables such as age and HRM software correlate with the IRP measure and could influence the final manometric diagnosis.[22,23] Only Hashmi et al[19] found that both LES length and pressures were significantly lower in the supine position, and hypothesized that the LES creates a stronger barrier to reflux and a greater resistance to bolus flow while in the sitting position. Moreover, dysphagia could be missed if patients are examined only when supine. All studies[12,13,16-18,20,22-24,26] that analyzed esophageal body contraction vigor agree that the DCI is significantly greater in the supine position due to a higher resistance to flow typical of this position. Only Besanko et al[18] found that older adults have significantly

Table 2. High-resolution Manometry Findings in Healthy Subjects

Author	Subgroup	No. of patients	Body position	LES				Esophageal body		
				Total length (cm)	Basal pressure (mmHg)	IRP (mmHg)	DCI (mmHg·sec·cm)	IBP (mmHg)	DL (sec)	Mean wave pressure (mmHg)
Buduhan et al[11]		10	Supine	3.1 ± 1.0	17.3 ± 8.9	NR	NR	NR	NR	78.2
			Upright	3.2 ± 0.7	16.1 ± 12.5	NR	NR	NR	NR	78.4
			P-value	0.730	0.800					0.970
Sweis et al[13]		46	Supine	NR	18.9 (13.6)	3.8 ± 0.6	1303.4 ± 341.1	8.4 ± 1.0	NR	79.8 ± 8.2
			Upright	NR	22.9 (13.3)	6.2 ± 0.9	1058.7 ± 198.0	9.8 ± 1.1	NR	75.0 ± 7.2
			P-value		0.516	0.004	0.287			NR
Xiao et al[16]		75	Supine	NR	NR	7.9 (4.7)	1612 (1062)	NR	5.8 (1.3)	NR
			Upright	NR	NR	2.8 (4.3)	698 (597)	NR	6.4 (1.5)	NR
			P-value			< 0.001	< 0.001		< 0.001	
Zhang et al[17]	Volunteers	21	Supine	NR	NR	7.6 ± 2.6	1596.9 ± 916.9	NR	6.4 ± 1.0	NR
			Upright	NR	NR	5.5 ± 3.5	1259.0 ± 996.8	NR	5.9 ± 1.3	NR
			P-value			0.017	0.008		0.023	
Besanko et al[18]	Younger	10	Supine	NR	NR	2.6 ± 0.5	946.7 ± 201	NR	NR	40.6 ± 7.5
			Upright	NR	NR	3.1 ± 0.4	852.8 ± 190	NR	NR	41.4 ± 6.2
			P-value			NR	NR			NR
	Older	10	Supine	NR	NR	3.5 ± 0.9	834.8 ± 260	NR	NR	37.6 ± 9.1
			Upright	NR	NR	6.9 ± 1.1	1223.5 ± 292	NR	NR	49.5 ± 8.7
			P-value			0.010	0.006			0.007
Zhang et al[21]		50	Supine	3.4 ± 0.6	18.1 ± 7.8	7.8 ± 3.2	NR	NR	NR	NR
			Upright	3.3 ± 0.6	13.8 ± 5.9	5.6 ± 3.3	NR	NR	NR	NR
			P-value	0.192	< 0.001	< 0.001				
Jung et al[22]		54	Supine	NR	NR	7.8 (11.8)	1372.9 (1347)	NR	6.1 (1.2)	NR
			Upright	NR	NR	8.2 (5.1)	708.3 (864)	NR	6.9 (1.0)	NR
			P-value			0.860	< 0.01		< 0.01	
Do Carmo et al[23]		69	Supine	2.9 (1.1)	36.2 (21.7)	13.5 (8.2)	1785 (2018)	12.9 (5.7)	6.5 (1.5)	NR
			Upright	2.3 (0.7)	18.2 (12.6)	6.4 (6.3)	1176 (1361)	6.9 (6.2)	6.5 (1.7)	NR
			P-value	0.006	< 0.001	< 0.001	0.003	< 0.001	0.902	
Hiranyatheb et al[24]		41	Supine	NR	25.1 ± 10.3	7.5 ± 3.2	1274.6 ± 841.9	12.2 ± 3.6	6.3 ± 0.9	NR
			Upright	NR	20.4 ± 11.4	4.7 ± 3.4	1046.4 ± 754.4	9.8 ± 4.7	6.1 ± 1.0	NR
			P-value		< 0.001	< 0.001	0.003	< 0.001	0.087	

LES, lower esophageal sphincter; IRP, integrated relaxation pressure; DCI, distal contractile integral; IBP, intrabolus pressure; CFV, contraction front velocity; DL, distal latency; NR, not reported.
Values are expressed as mean ± standard deviation or mean (interquartile range).

Table 3. Variation in High-resolution Manometry Final Diagnosis According to Body Position

Author	Indications	Body position	Normal motility	Ineffective motility	Absent peristalsis	DES	Hypercontractile motility	EGJ-OO	Achalasia	Non specific
Bernard et al[10]	GERD	Supine	71	19	NR	6	NR	NR	NR	NR
		Upright	58	32	NR	6	NR	NR	NR	NR
Roman et al[12]	GERD, dysphagia, systemic sclerosis, post-fundoplication,	Supine	36	35	4	10	2	9	4	NR
		Upright	25	47	7	8	2	7	4	NR
Xiao et al[14]	NR	Supine	39	NR	NR	NR	NR	12	8	NR
		Upright	22	NR	NR	NR	NR	16	7	NR
Ciriza-de-Los-Ríos et al[20]	Dysphagia	Supine	25	7	2	6	1	NR	2	3
		Upright	17	10	2	12	0	NR	2	2
	GERD	Supine	29	9	0	9	0	NR	0	3
		Upright	21	16	0	10	0	NR	0	2
Hiranyatheb et al[24]	Healthy subjects	Supine	NR	5	NR	NR	NR	NR	NR	NR
		Upright	NR	10	NR	NR	NR	NR	NR	NR
Misselwitz et al[26]	Healthy subjects, foregut symptoms	Supine	278	89	29	8	4	20	10	NR
		Upright	197	172	41	9	4	4	11	NR

DES, distal esophageal spasm; EGJ-OO, esophagogastric junction outflow obstruction; NR, not reported; GERD, gastroesophageal reflux disease.

higher DCI in the sitting/upright position.

Overall, the diagnostic agreement in the final manometric diagnosis between the 2 positions varied from 67.6% to 90.0%.[10,14,26] It should be noted that other factors could influence a change in diagnosis in patients undergoing HRM. In fact, reproducibility of HRM may represent the Achille's heel of this technology, and when the test is repeated over time the diagnosis may change. Triadafilopoulos[27] reported a 41.0% change in diagnosis in patients who had an initial normal study after a mean interval between studies of 15 months. In contrast, in the only patient with achalasia the diagnosis remained stable over time. This suggests that change in the final diagnosis may not be clinically relevant, and precautions must be taken in the interpretation of HRM findings.

There are some limitations in this study. First, the heterogeneity of subjects included into the analysis: some studies involved both healthy and symptomatic adults. This may introduce a significant bias due to the multiple factors that can affect the HRM results.[6] Second, the studies considered in this review do not assume the same HRM classification or protocol in the assessment of results. Third, no studies considered the most recent HRM tools, such as multiple rapid swallows-DCI ratio and EGJ-contractile integral.[28,29]

Although the results of comparative studies analyzed in the present systematic review are still discordant, the upright/sitting position has more recently emerged as an alternative to the supine position, which appears to be uncomfortable for the patient and probably non-physiological.[6] However, normal values are needed to establish the most adequate body position for HRM in order to increase the reproducibility of the test. Interestingly, at least 1 clinical study in gastroesophageal reflux disease patients[30] and one non-comparative study[31] in normal volunteers considered the semi-recumbent position with 30° sit-back inclination which may be as much as comfortable both for the patient and the physician. Additionally, in this pilot study, the results obtained were similar to those previously described by Pandolfino et al[1] and Ghosh et al[2,3] in the supine position. More trials should be performed to evaluate if the semi-recumbent or upright position could become the reference standard in the future.

In conclusion, performing HRM in the upright position affect some manometric variables that may change the final manometric diagnosis. Further studies to determine the normal manometric values and evaluate patient reported outcomes and compliance in the sitting and semi-recumbent positions are needed.

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