Original Article
High value of high-resolution manometry applied in diagnosing hiatal hernia compared with barium esophagogram and endoscopy: a single-center retrospective study

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Abstract: Background: High-resolution manometry (HRM) is an unquestionable breakthrough for esophageal manometry, which has advantages of improved identification and easy interpretation compared with conventional methods. Hiatal hernia (HH) is mainly diagnosed with barium esophagogram or endoscopy. But recently, HRM is increasingly applied in the diagnosis of HH. Objectives: To study the value of HRM applied in diagnosing HH. Methods: Images of barium esophagogram, endoscopy and HRM for suspected HH patients were retrospectively analyzed, and diagnostic values were then evaluated and compared. The definite diagnosis of HH was made through surgery, and the golden standard was an increased ring-shaped defect at the esophageal hiatus (>2 cm). Results: Logistic regression analysis showed that the diagnoses of barium esophagogram, endoscopy and HRM were all not correlated with clinic features (Wald χ^2=1.089, 1.107, 0.984; P=0.205, 0.196, 0.231) after adjusting age, sex and body mass index (BMI). HRM and barium esophagogram had higher area under curve (AUC) compared with endoscopy ($Z_{HRM vs endoscopy}$ =3.277, P<0.05; $Z_{HRM vs endoscopy}$ =2.657, P<0.05), but the difference of AUC was not significant between HRM and barium esophagogram (Z=0.455, P>0.05). Both specificity and positive predictive value (PPV) were not statistically different between barium esophagogram, endoscopy and HRM (all P>0.05). Sensitivity, accuracy and negative predictive value (NPV) were higher for barium esophagogram and HRM than for endoscopy (all P<0.05), and not statistically different between barium esophagogram and HRM (all P>0.05). However, specificity and PPV of HRM were slightly elevated compared with barium esophagogram although the differences were not significant (all P>0.05). Conclusions: HRM had high value when applied in diagnosing HH and was therefore suitable for diagnosing HH.

Keywords: High-resolution manometry, barium esophagogram, endoscopy, receiver operating characteristic curve, diagnostic indexes

Introduction

High-resolution manometry (HRM) is an unquestionable breakthrough for esophageal manometry [1-6], which has advantages of improved identification and easy interpretation compared with conventional methods [7]. HRM records pressures using solid-state microtransducers at 12 points around the circumference at every centimeter of esophageal length and display the data in pseudo-three dimensional format using a topographic plot [8]. Therefore, HRM may offer a better evaluation of esophageal function [7]. Hiatal hernia (HH) is mainly diagnosed with barium esophagogram or endoscopy. But recently, HRM is increasingly applied in the diagnosis of HH [9, 10]. In this paper, the diagnostic values of barium esophagogram, endoscopy and HRM were evaluated and compared with the aim of determining an optimal imaging method.
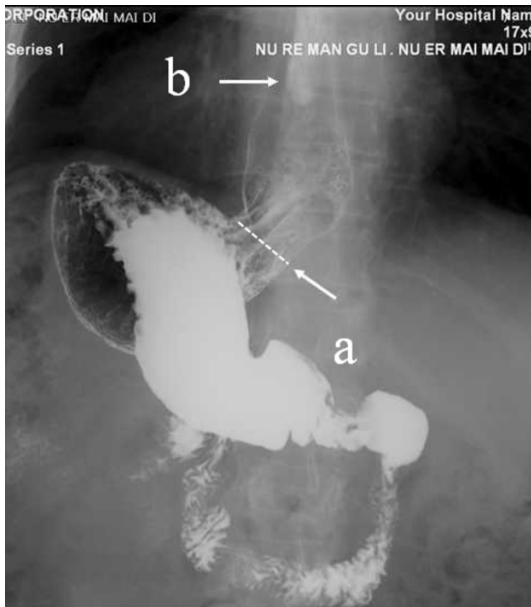
Materials and methods

Patients

A total of 130 suspected HH patients aged from 37 to 74 years, including 70 males and 60
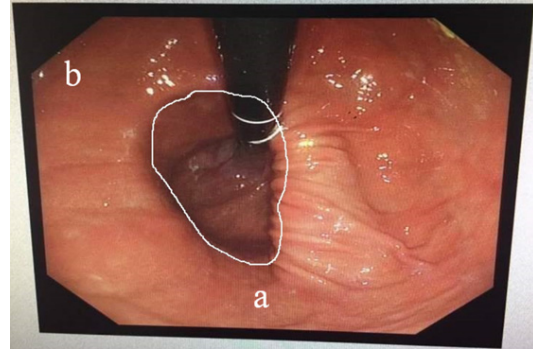
Figure 1. HH patient: "a" indicated a B ring, "b" indicated supradiaphragmatic gastric mucosa and "c" indicated a supradiaphragmatic hernia sac; HH: Hiatal hernia.
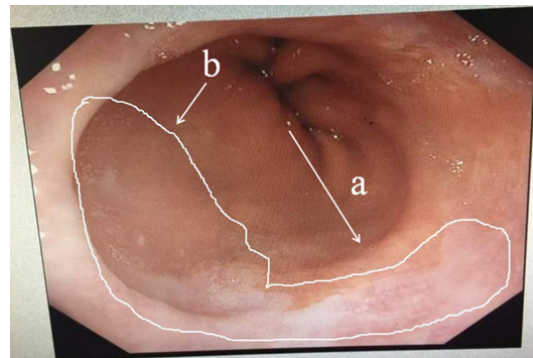

Figure 2. HH patient: "a" indicated a widened esophageal hiatus, "b" indicated the reflux of contrast agent in the stomach to the thoracic cavity; HH: Hiatal hernia.

Figure 3. HH patient: "a" indicated a widened or loose cardiac opening and "b" indicated a widened angle of His; HH: Hiatal hernia.

Figure 4. HH patient: "a" indicated the upward dentate line and "b" indicated the reflux of retention fluid in the stomach to the esophagus; HH: Hiatal hernia.

Figure 5. HH patient: "a" indicated gastric mucosa in the esophagus; HH: Hiatal hernia.
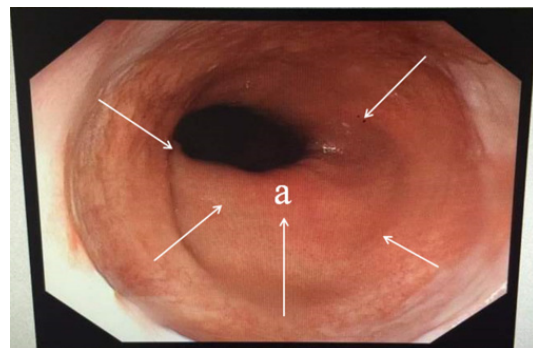
females, were included in this retrospective study. All patients were admitted to hospital because of digestive tract symptoms. Among them, 29 patients had retrosternal pain or discomfort, 26 patients had pain or discomfort below the xiphoid, 36 patients had burning or oppressing senseation in the local digestive tract, 34 patients had acid reflux, 26 patients had belching, and 33 patients had dysphagia. Barium esophagogram, endoscopy and HRM were performed in all patients, and the definite diagnosis of HH was made through surgery.
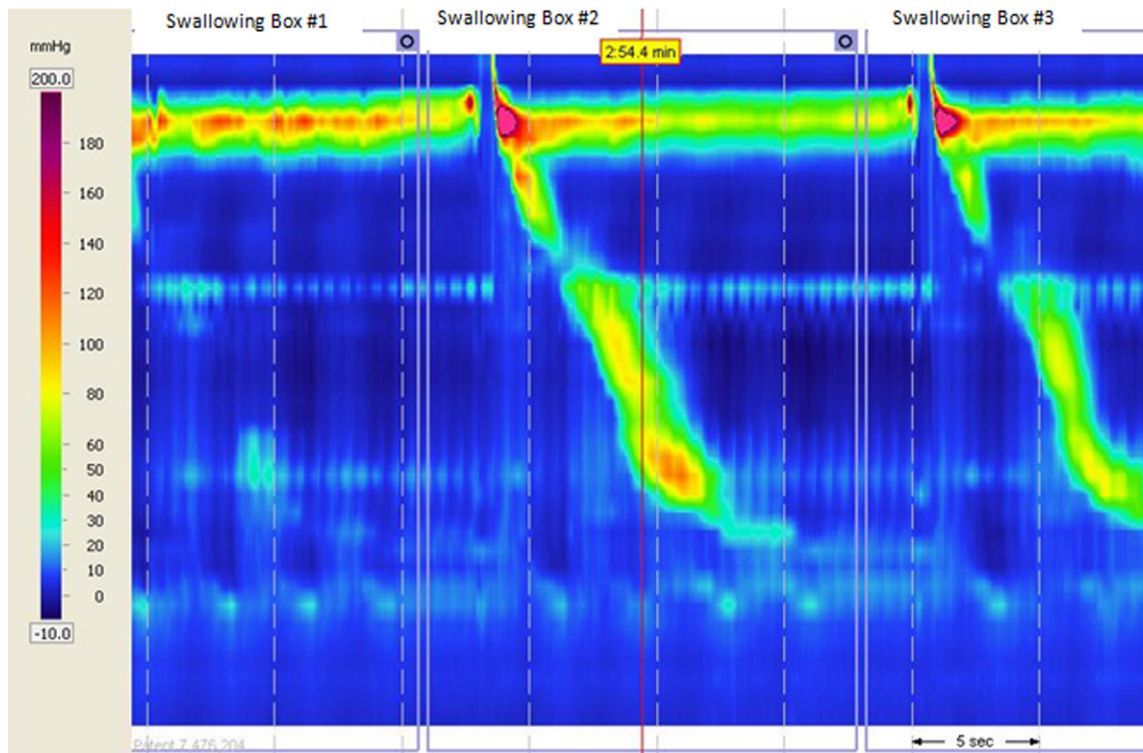
Figure 6. HH patient: it demonstrated a separation between the LES and CD. HH: Hiatal hernia, LES: Lower esophageal sphincter, CD: crural diaphragm.
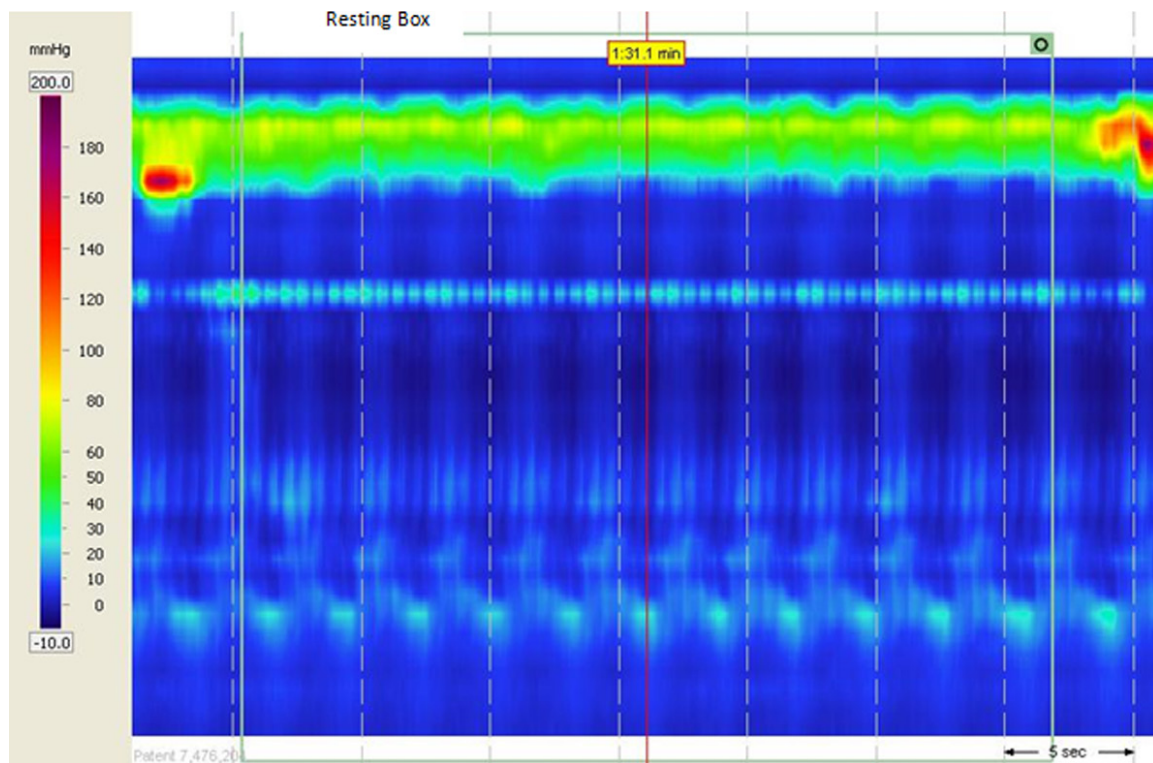
Figure 7. HH patient: it demonstrated a downward respiratory pressure inversion point. HH: Hiatal hernia.

Figure 8. HH patient: it demonstrated a LESP below the normal value. HH: Hiatal hernia, LESP: lower esophageal sphincter.

Table 1. Demographic information and basic clinic features of HH[*] patients and non-HH patients

		HH patients (n=100)	Non-HH patients (n=30)	X^2/t	P
Age (Years)		54.62±7.28	53.87±7.03	0.902	0.374
BMI[**]		22.65±4.41	22.39±4.36	0.51	0.618
Sex	Male (n=70)	52	18	0.594	0.441
	Female (n=60)	48	12		
Basic clinic features	Retrosternal pain or discomfort (n=29)	22	7	0.321	0.997
	Pain or discomfort below the xiphoid (n=26)	18	8		
	Burning or oppressing senseation in the local digestive tract (n=36)	26	10		
	Acid reflux (n=34)	25	9		
	Belching (n=26)	19	7		
	Dysphagia (n=33)	24	9		

[*]HH: Hiatal hernia, [**]BMI: Body mass index.

This study received the approval of the ethic committee of People's Hospital of Xinjiang Uygur Autonomous Region (2012168209).

Standard of diagnosis

The definite diagnosis of HH was made through surgery, and the golden standard was an increased ring-shaped defect at the esophageal hiatus (>2 cm). The diagnostic criteria of barium esophagogram consisted of direct signs including a supradiaphragmatic hernia sac, supradiaphragmatic gastric mucosa and a B ring at the squamocolumnar junction (SCJ) (**Figure 1**) and indirect signs including a widened esophageal hiatus, rebated angle between the cardia and fundus of the stomach and the reflux of stomach contents into the thoracic cavity (**Figure 2**).

Table 2. Results of barium esophagogram, endoscopy and HRM applied in diagnosing HH[*]

| | | Golden standard | | Total |
		Positive (n=100)	Negative (n=30)	
Barium esophagogram	Positive	85	8	93
	Negative	15	22	37
Endoscopy	Positive	34	5	39
	Negative	66	25	91
HRM[**]	Positive	78	4	82
	Negative	22	26	48

[*]HH: Hiatal hernia, [**]HRM: High-resolution manometry.

Figure 9. ROC curves of barium esophagogram, endoscopy and HRM applied in diagnosing HH. HH: Hiatal hernia, HRM: High-resolution manometry, ROC: Receiver operating characteristic.

The diagnostic criteria of endoscopy included a widened or loose cardiac opening (**Figure 3**), a separation <38 cm between the dentate line and the incisors (**Figure 4**), a widened angle of His (**Figure 3**) and gastric mucosa in the esophagus (**Figure 5**). The diagnostic criteria of HRM included a separation between the lower esophageal sphincter (LES) and crural diaphragm (CD) (**Figure 6**), a downward respiratory pressure inversion point (the reduced value =100) (**Figure 7**) and a lower esophageal sphincter pressure (LESP) below the normal value (13 mmHg) (**Figure 8**).

High-resolution esophageal manometry

HRM was carried out using a solid-state manometric system with an outer diameter of 4.2

mm Manoscan and 36 circumferential sensors spaced at 1-cm intervals (Given Scientific Instruments Inc, Los Angeles, CA, USA). Manometric data were analyzed with the most recent dedicated software (Mano-View Analysis, version 3.0; Given Imaging).

Assessment of the results of barium esophagogram, endoscopy and HRM

Two radiologists, two operating doctors of digestive endoscopy and two operating doctors of high-resolution esophageal manometry were respectively asked to make a diagnosis according to their own findings for these 130 patients. The two investigators employed in the same examination were blinded to the information from the other two examinations and made an independent diagnosis. Moreover, the two investigators should be in agreement after discussion if they had different opinions.
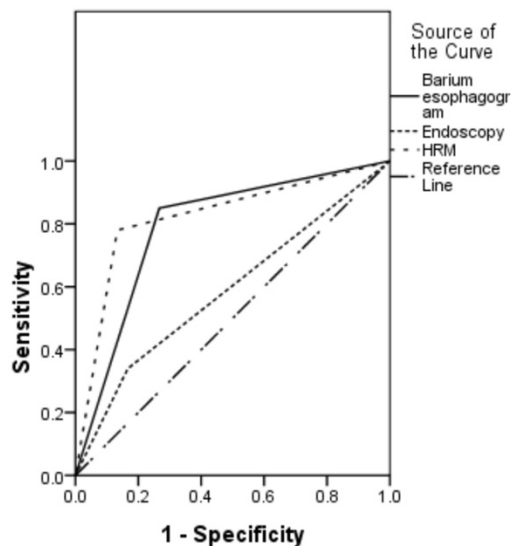
Statistical analysis

All data were analyzed with the SPSS version 19.0 (SPSS Inc., USA). Quantitative data were expressed as mean ± SD, and qualitative data were expressed as percentages. Qu-antitative data were analyzed with Student's t test. Qualitative data were analyzed with chi-square test or Fisher exact test. The correlation between the diagnoses and basic clinic features was analyzed with a backward stepwise logistic regression model. Receiver operating characteristic (ROC) curve was drawn and the area under curve (AUC) was calculated and compared with Z test. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy were determined with diagnostic test, and then compared with chi-square test. Significance was set at $P<0.05$.

Results

General data

Among these 130 suspected HH patients, 100 patients were definitely diagnosed with HH. The detailed results were shown in Supplementary Data. Demographic information and basic clinic features of HH patients and non-HH patients were shown in **Table 1**. Age, body mass index

Table 3. AUC of barium esophagogram, endoscopy and HRM applied in diagnosing HH[*]

	AUC	Standard error (SE)	P	95% Confidence Interval (CI)
Barium esophagogram	0.792	.052	<0.001	0.690-0.893
Endoscopy	0.587	.057	0.151	0.476-0.697
HRM[**]	0.823	.044	<0.001	0.738-0.909

[*]HH: Hiatal hernia, [**]HRM: High-resolution manometry.

Table 4. Diagnostic indexes of barium esophagogram, endoscopy and HRM applied in diagnosing HH[*]

	Sensitivity	Specificity	Accuracy	PPV	NPV
Barium esophagogram	85.00%	73.33%	82.31%	91.40%	59.46%
Endoscopy	34.00%	83.33%	45.38%	87.18%	27.47%
HRM[**]	78.00%	86.67%	80.00%	95.12%	54.17%

[*]HH: Hiatal hernia, [**]HRM: High-resolution manometry; The diagnostic criteria of barium esophagogram consisted of direct signs including a supradiaphragmatic hernia sac, supradiaphragmatic gastric mucosa and a B ring at the squamocolumnar junction (SCJ) and indirect signs including a widened esophageal hiatus, rebated angle between the cardia and fundus of the stomach and the reflux of stomach contents into the thoracic cavity. The diagnostic criteria of endoscopy included a widened or loose cardiac opening, a separation <38 cm between the dentate line and the incisors, a widened angle of His and gastric mucosa in the esophagus. The diagnostic criteria of HRM included a separation between the lower esophageal sphincter (LES) and crural diaphragm (CD), a downward respiratory pressure inversion point (the reduced value=100) and a lower esophageal sphincter pressure (LESP) below the normal value (13 mmHg).

Table 5. Comparison of diagnostic indexes between barium esophagogram, endoscopy and HRM[*]

	Total		Barium esophagogram vs Endoscopy		Barium esophagogram vs HRM		Endoscopy vs HRM	
	χ^2	P	χ^2	P	χ^2	P	χ^2	P
Sensitivity	68.803	0.000	53.968	<0.001	1.625	0.202	39.286	<0.001
Specificity	1.886	0.390						
Accuracy	52.217	0.000	38.390	<0.001	0.226	0.634	33.300	<0.001
PPV[**]	2.377	0.305						
NPV[***]	15.446	0.000	11.583	0.001	0.238	0.626	9.640	0.002

[*]HRM: High-resolution manometry, [**]PPV: Positive predictive value, [***]NPV: Negative predictive value.

(BMI), and distributions of sex and basic clinic features were not significantly different between HH patients and non-HH patients.

Correlation between the diagnoses and basic clinic features

According to the results of logistic regression analysis, the diagnoses of barium esophagogram, endoscopy and HRM were all not corre-

lated with clinic features (Wald χ^2=1.089, 1.107, 0.984; P=0.205, 0.196, 0.231) after adjusting age, sex and BMI.

Value of barium esophagogram, endoscopy and HRM applied in diagnosing HH

The results of barium esophagogram, endoscopy and HRM applied in diagnosing HH were shown in **Table 2**. According to ROC curve (**Figure 9**) and AUC (**Table 3**), HRM had high value (AUC>0.800) when applied in diagnosing HH, barium esophagogram had moderate value (AUC>0.700), and endoscopy had low value (AUC<0.800). According to the results of Z test, barium esophagogram and HRM had higher AUC compared with endoscopy ($Z_{HRM\ vs\ endoscopy}$=3.277, P<0.05; $Z_{HRM\ vs\ endoscopy}$=2.657, P<0.05), but the difference of AUC was not significant between barium esophagogram and HRM (Z=0.455, P>0.05).

Diagnostic indexes of barium esophagogram, endoscopy and HRM applied in diagnosing HH

Sensitivity, accuracy and NPV were very low for endoscopy applied in diagnosing HH, specificity and PPV were relatively high (**Table 4**). Sensitivity, specificity, accuracy and PPV were relatively high for barium esophagogram and HRM, especially for PPV and accuracy, NPV was relatively low (**Table 4**).

According to the results of chi-square test, both specificity and PPV were not statistically different between barium esophagogram, endoscopy and HRM (**Table 5**). Sensitivity, accuracy and NPV were higher for barium esophagogram and HRM than for endoscopy, and not statistically different between barium esophagogram and

HRM (**Table 5**). However, specificity and PPV of HRM were slightly elevated compared with barium esophagogram although the differences were not significant.

Discussion

The diagnosis of HH is frequently made on the basis of its presence during barium esophagogram or endoscopy [11, 12]. Barium esophagogram may demonstrate the location of hernia sac directly, and further determine the type and extent of the hernia and evaluate its size. However, the size of hernia cannot be accurately evaluated because esophageal peristalsis during barium esophagogram can induce shortening of the esophagus and resulting physiologic herniation, which is very difficult to distinguish from a small HH [13]. Moreover, many HH patients are absent of anatomical landmarks, for example, a B ring, which inevitably leads significant subjectivity into the evaluation process. Endoscopy has similar limitations in diagnosing HH. Moreover, in case of Barrett's metaplasia, it is more difficult for endoscopy to ascertain the location of the native SCJ, in addition, it is also more difficult for endoscopy to accurately localize the CD and precisely evaluate the size of the hernia because of excess air insufflation and presence of a wide hiatus [14].

As a more dynamic examination, HRM may provide more detailed and prolonged analysis for the pressure components of the esophagogastric junction (EGJ) [15]. It also, for the first time, provides a method to accomplish the continuum from normal to overt sliding hernia through determining intermediate grades of EGJ disruption. HRM has good demonstration for the separation between the LES and CD, and meanwhile does not induce physiologic herniation resulting from shortening of the esophagus during barium esophagogram and endoscopy. Therefore, its specificity is relatively high in diagnosing HH [4, 7, 10, 16].

In this paper, the diagnostic value was higher for HRM than for endoscopy when applied in diagnosing HH, however, the diagnostic value was not statistically different between HRM and barium esophagogram. Sensitivity, specificity, accuracy and PPV, especially accuracy and PPV, were relatively high for HRM and barium esophagogram. In addition, specificity and PPV of HRM were slightly elevated compared with barium esophagogram although the differ-

ences were not significant. Weijenborg PW et al [17] indicate that HRM has higher sensitivity and specificity for diagnosing HH compared with barium esophagogram, which is different from our finding. It may be explained by the fact that their reference standard for the diagnosis of HH was different from us. They employed the presence of a clear separation between the LES and CD during barium esophagogram or endoscopy as reference standard. In conclusion, HRM had high value when applied in diagnosing HH and was therefore suitable for diagnosing HH.

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Disclosure of conflict of interest

None.

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