Determination of the Positional Relationship of the Second Houston Valve and Peritoneal Reflection Using Computed Tomographic Colonography and Magnetic Resonance Imaging

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Abstract

Purpose: The second Houston valve is used as a surrogate for estimating the position of the peritoneal reflection; however, the concordance between the positions of the valve and peritoneal reflection has not yet been investigated. This study aimed to clarify this positional relationship.

Methods: The positions of the second Houston valve and peritoneal reflection were assessed using tomographic colonography and magnetic resonance imaging. In total, 117 patients were enrolled in this study.

Results: The positions of the second Houston valve and peritoneal reflection were nearly concordant, although the space between them ranged from -20.7 to 33.9 mm. A peritoneal reflection located further from the anal verge than the second Houston valve was defined as a shallow peritoneal reflection. Male sex, high body weight, and high body mass index showed a significant correlation with a shallower peritoneal reflection as determined by univariate analysis (sex: P=0.0138, weight: P=0.0097, body mass index: P=0.0311). Multivariate analysis revealed significantly shallower peritoneal reflection in males (odds ratio: 2.75, 95% confidence interval: 1.15-6.56, P=0.023).

Conclusions: The second Houston valve is located near the peritoneal reflection and can be a useful surrogate marker for estimating its position. In heavier males, the peritoneal reflection tends to be located more cranially than the second Houston valve.

Introduction

Rectal cancer has a high local recurrence rate (22%) which can be reduced by preoperative radiation therapy [1, 2]. According to the European Society for Medical Oncology (ESMO) guidelines, preoperative chemoradiation (CRT) is indicated for lower rectal cancer but is not recommended for upper rectal cancer (occurring > 12 cm from the anal verge), which should be treated as colon cancer [3]. A meta-analysis by Cillian et al. reported a significantly lower local recurrence rate in the upper rectum than in the middle and lower rectum (odds ratio, 0.495) [4]. The ESMO guidelines define the lower rectum by using an endoscope to measure the distance from the anal verge [3]. However, the Japanese guidelines define the lower rectum by the peritoneal reflection and also recommend preoperative CRT for lower, but not upper, rectal cancer [5]. The reason for this is that if the lesion is located below the peritoneal reflection, it drains into the internal iliac system, which often leads to pelvic lymph node recurrence and metastasis to the lung, thus requiring treatment method different from that for other colorectal cancers. To the best of our knowledge, no report exists on whether the prognosis changes when lower rectal cancer is defined by anal verge or peritoneal reflection. However, it is necessary to accurately evaluate the position of the peritoneal reflection in relation to the cancerous lesion for treatment guidance.

A study reported difficulty in determining the position of the peritoneal reflection using endoscopic measurements, and observed significant individual variation in its position, ranging from 8.5 to 20 cm above the anal verge [6]. Another author reported the use of magnetic resonance imaging (MRI) to identify the peritoneal reflection based on recognition of its membrane structure [7]. It has been observed that in 14% of cases, peritoneal reflection was not visible on MRI, and that even when visible, the probability of diagnosing a localized lesion in the upper rectum was only 89% [8].

In Japan, the location of the second Houston valve is often considered to be concordant with that of the peritoneal reflection and it is widely used as a method for determining the location of the peritoneal reflection. The line connecting the superior border of the pubis and the inferior border of the fourth sacral vertebra is also used as a reference marker. However, in clinical practice, we occasionally find that a lesion that was preoperatively identified as being cranial to the second Houston valve is intraoperatively found to be positioned below the peritoneal reflection. To the best of our knowledge, no study has verified whether the location of the second Houston valve is concordant with that of the peritoneal reflection.

This study aimed to clarify the positional relationship between the second Houston valve and the peritoneal reflection; magnetic resonance imaging (MRI) would be used to identify the peritoneal reflection and computed tomographic colonography (CTC) for the identification of the second Houston valve. The study also aimed to develop an accurate method to determine the position of a lesion in relation to the peritoneal reflection in preoperative evaluation for rectal cancer.

Methods

Patients

A total of 117 patients with rectal cancer were enrolled in this study. Patients underwent CTC and MRI between January 2013 and March 2020 before treatment at the University of Tokyo Hospital. None of the patients ever underwent pelvic surgery. The study protocol was approved by the Ethics Committee of the University of Tokyo (No. 3252-(10)).

Procedures

CTC was performed after total colonoscopy with full bowel preparation using polyethylene glycol electrolyte lavage solution (Niflec®, Ajinomoto Pharma, Tokyo, Japan) using an auto-injector (PROTO CO2L, ACIST Medical Systems, Tokyo, Japan). An enema tube was inserted through the anus with the patient in the prone position, and CO_2 was automatically injected at a pressure of 20 mmHg. Three-dimensional computed tomography of the rectum was performed using an imaging workstation (Ziostation2®, Ziosoft Inc., Tokyo, Japan). MRI was performed on a 1.5T MRI scanner (MAGNETOM Avanto, Siemens Healthineers) with administration of an intramuscular spasmolytic. Sagittal T2-weighted images were obtained.

Evaluation of CTC and MRI

To fuse the information from CTC and MRI, a reference line was developed based on the bone information from both images. The reference line connected the superior border of the pubis and the inferior border of the fourth sacral vertebra. In CTC, the distance from the anterior wall of the second

Houston valve to the reference line and in MRI, the distance from the anterior wall of the peritoneal reflection to the reference line were measured on the lateral position (Fig. 1). For evaluating the positional relationship between the second Houston valve (HV) and the peritoneal reflection (PR), the distance between the second HV from PR was measured by subtracting the height of the PR from the height of the second HV. We defined a shallow PR as one in which the peritoneal reflection was more cranial than the second HV. A deep peritoneal reflection was defined as one in which the PR was more caudal than second HV.

Statistical analysis

Statistical analysis was performed using JMP (version 15.0; SAS Institute, Inc., Cary, NC, USA). The relationship between anatomical indices (sex, age, height, weight, and BMI) and second HV from PR was evaluated using Spearman's correlation coefficient. The heights of the second Houston valve, peritoneal reflection, and second HV from PR were analyzed by univariate logistic regression analysis using anatomical indices (sex, age, height, and weight) and multivariate analysis by logistic regression analysis using indices with P-values of < 0.10. Statistical significance was set at P-values of < 0.05.

Results

Depth of second Houston valve, peritoneal reflection, and distribution of the second HV from PR

Patient variables are shown in Table 1. We examined the positional relationship among the second HV, PR, and reference line. The second HV was cranial to the reference line in majority of cases (89%), as shown in Fig. 2A. The median value was 8.2 mm, and the measurement range was 15.9–24.6 mm. In contrast, the position of the peritoneal reflection was nearly concordant with that of the reference line, as shown in Fig. 2B. The median value was 2.4 mm, and the measurement range was 18.9–26.5 mm. The positional relationship between the second HV and PR was examined. The PR was slightly deeper than the second HV, as shown in Fig. 2C. The median value was 4.5 mm. We found significant variation in positional relationships. In some cases, the PR was located much deeper than the second HV (max: 33 mm), as shown in the 2D image in Fig. 2D. In other cases, the peritoneal reflection was concordant with the second HV, as shown in Fig. 2E, or it was located much shallower than the valve (minimum: -20 mm), as shown in the 2D image in Fig. 2F.

Table 1
Patient variables

Variable		No (%)
Number of patients		117
Sex	Male	74 (63.2%)
Age	Median(range), years	63 (32–86)
Height	Median(range), m	1.63 (1.42–18.4)
Weight	Median(range), kg	60(37–88)
BMI	Median(range)	22(14–30)
cTstage		
	cT1	34 (29.1%)
	cT2	36 (30.7%)
	cT3	39 (33.3%)
	cT4	8(6.8%)
Histologic type		
	Well, moderately	113 (96.6%)
	Poor, mucinous	4(3.4%)
Lymphatic invasion		
	Absent	97(82.9%)
	Present	20(17.1%)
Venous invasion		
	Absent	52 (44.4%)
	Present	65 (55.6%)

Correlation between second HV from PR and patient variables

The correlation of second HV from PR with patient variables is shown in Fig. 3. The peritoneal reflection was significantly shallower in males (0.0138). No correlation was found between age and height (age: 0.6787, r=-0.0387; height: 0.1231, r=-0.1433). Higher body weight and larger BMI values were correlated with a shallower peritoneal reflection (weight: 0.0097, r=-0.2382, BMI: 0.0311, r=-0.1994). We performed a logistic regression analysis to examine the relationship of the location of the second HV and the PR from the reference line, and the interrelationship between the location of the second HV and the PR with patient variables. The PR was located significantly more cranially than the reference line in patients with higher body weight and larger BMIs (OR: 0.96, 95% CI: 0.93–0.99, P = 0.0426). It was also significantly shallower in males (OR: 2.75, 95% CI: 1.15–6.56, 0.023).

Discussion

To the best of our knowledge, this is the first study to examine the positional relationship between the second HV and the PR using CTC and MRI.

The positions of the second HV and the PR were nearly concordant, with a displacement of up to 3 cm on the cephalocaudal side (Fig. 2C). Two earlier studies reported the distance from the anal verge to the peritoneal reflection. One measured the distance from the anal verge to the PR intraoperatively using an endoscope with a median of 13.2 cm and a range of 8.5–21.0 cm [6], and the other used an endoscope with a median of 8.8 cm and a range of 6.4–11.2 cm [9]. The distance from the anal verge to the second HV was also measured in 400 patients using a rigid endoscope, with a mean of 9.4 cm and a range of 7–12 cm [10]. Thus, from the anal verge, the measured distances between the valve and the PR were generally similar, with variations within a certain range, but there were large individual differences. We found no report that evaluated the positional relationship between the second Houston valve and the peritoneal reflection in the same patient. In this study, it was observed that the second HV tended to be located more cranially than the PR.

We examined the correlation between the position of the second HV and the PR, and patient variables. Univariate analysis revealed that the second Houston valve was caudal to the peritoneal reflection, and the peritoneal reflection was significantly shallower in males with high body weight and BMI (Fig. 3), whereas no correlation was observed with height or age. In the multivariate analysis, males were found to have a significantly shallower peritoneal reflection (Table 2). Previous studies examined the correlation between the position of the peritoneal reflection and patient variables. Wasserman et al. reported that the distance from the anal verge to the peritoneal reflection was greater in cases of high body weight and high BMI [6], and that the average distance tended to be greater in males than in females, as also reported by Memon et al. [11] and Najarian et al. [12]. These observations are in agreement with the results of the present study. We examined whether the shallower peritoneal reflection of the second Houston valve in males with a high BMI was due to a shallower PR or a deeper second HV. Using the reference line as the standard, we examined whether the positioning of the valve and the PR differed depending on patient variables. The PR was significantly more cranial than the reference line for heavier patients in the multivariate analysis. However, the position of the second HV was not affected by patient variables in the univariate analysis (Table 2). This suggests that the reason for the elevation of the second Houston valve in males with high body weight is due to a change in the height of the peritoneal reflection without a change in the position of the valve. The second HV is a structure in the intestinal tract with its position not dependent on patient variables. Higher peritoneal reflection in men with heavy body weight can possibly be attributed to a higher amount of retroperitoneal fat. This may result in a greater amount of fat below the peritoneal reflection, resulting in a higher position. In men, the seminal vesicles and prostate gland are located caudal to the PR, and thus the position of the PR is relatively higher in men than that in women.

Table 2
– Logistic regression analysis for the anatomical landmarks of the rectum

		Univariate analysis	**Multivariate analysis**		
		P-value	Odds Ratio	95% CI	P-value
Depth of the second Huston valve in CTC					
Sex	Male vs. female	0.4558			
Age (years)	< 63 vs. ≥63	0.3954			
Height (m)	< 1.63 vs. ≥1.63	0.2951			
Weight (kg)	continuous variable	0.5398			
Depth of peritoneal reflection in MRI					
Sex	Male vs. female	0.1311			
Age (years)	< 63 vs. ≥63	0.6809			
Height (m)	< 1.63 vs. ≥1.63	0.2491			
Weight (kg)	continuous variable	0.0968			
Positional relationship between the second Huston valve and peritoneal reflection					
Sex	Male vs. female	0.0047	2.75	1.15–6.56	0.023
Age (years)	< 63 vs. ≥63	0.3084			
Height (m)	< 1.63 vs. ≥1.63	0.1633			
Weight (kg)	continuous variable	0.0913	1.64	0.26–10.3	0.5973
* Stratified by median value					

In general, it is important to determine preoperatively whether a rectal cancer tumor is located cranial or caudal to the PR because cancers on the caudal side are associated with a higher local recurrence rate [13–15]. Preoperative CRT is recommended to reduce local recurrence for these cases [16–18]. The location of the PR is generally evaluated by MRI [19, 20], although a study reported that the PR was visible by MRI in only 74.4% cases [7]. Another study reported that the peritoneal reflection could be recognized with certainty in only 68.2% of cases, and could not be evaluated in approximately 30% of cases. The same study also revealed that when preoperative MRI was used to determine whether the lesion was located cranial or caudal to PR and results were compared with intraoperative findings, the assessment was incorrect in 10% of cases [16]. Therefore, MRI is not always reliable. The positional relationship between the second HV and the lesion can be easily observed during preoperative examination using endoscopy. Endoscopy of the rectums of 400 adults revealed that the second HV was visible in 92% of cases, while in 6.5% only one HV was visible, and in 1.5% no Houston valve was present [10]. The present study has revealed that second HV can be confirmed by endoscopy when it is difficult to evaluate the PR by MRI, and conversely, the second HV can be evaluated by MRI when it is difficult to evaluate endoscopically. It is important to make a comprehensive judgment based on multiple modalities, rather than a single modality, because the locations of the second HV and the PR may differ depending on patient background.

In Japan, upper and lower rectal cancers are customarily classified based on the location of the lesion in relation to the second HV, and the indication for CRT is determined. It is not clear whether dividing the upper and lower rectum based on the second HV or on the information obtained from MRIs reflect better prognosis. It was difficult to evaluate this in the present study because of the small number of cases and the single-center nature of the study. In future, it is necessary to examine which method reflects better prognosis, the method based on the second HV or the one based on MRI, and whether it should be included in CRT.

This study had several limitations. First, it was conducted at a single institution and only included Asians. Since the anatomical location of the second HV may differ based on race, further investigations are warranted in multi-center, multi-racial studies. Second, all patients had rectal cancer, which may have affected the original position of the second HV and the PR due to changes associated with tumor growth, such as invasion of the intestinal wall and intestinal dilatation. It would be desirable to conduct a similar study in patients without lesions. Third, CTC may cause the second HV to be pushed up cranially due to airflow, while with MRI, the position of the PR is stable due to the lack of air inflation. Thus, the second HV tends to be cranial to the PR. Intraoperative endoscopy or cadaveric studies might be used to examine the positional relationship between the second HV and the PR in real time and to evaluate the degree of displacement caused by air inflation.

Our study shows that the position of the second HV is concordant with that of the PR, although its position may differ depending on patient variables. We found that in males with a high BMI, the PR is located more cranially than the second HV. In conclusion, the location of the second HV is useful as a surrogate marker for estimating the positional relationship of the lesion and the PR at the time of preoperative endoscopic examination.

Declarations

Authors' contributions:

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Kazushige Kawai Kawai, Hiroaki Nozawa, Kazuhito Sasaki, Koji Murono, Shigenobu Emoto, Tsuyoshi Ozawa, Yuichiro Yokoyama, Shinya Abe, Yuzo Nagai, Hiroyuki Anzai, Hirofumi Sonoda and Soichiro Ishihara. The first draft of the manuscript was written by Shin Murai and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Competing interests:

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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Ethics approval:

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the ethics committee of the University of Tokyo (No. 3252-(10)).

Consent to participate:

Informed consent was obtained from all individual participants included in the study.

Consent for publication:

Patients signed informed consent regarding publishing their data and photographs.

Availability of data and material:

The data that support the findings of this study are available from the corresponding author, Shin Murai, upon reasonable request.

Code availability:

Not applicable

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Figures

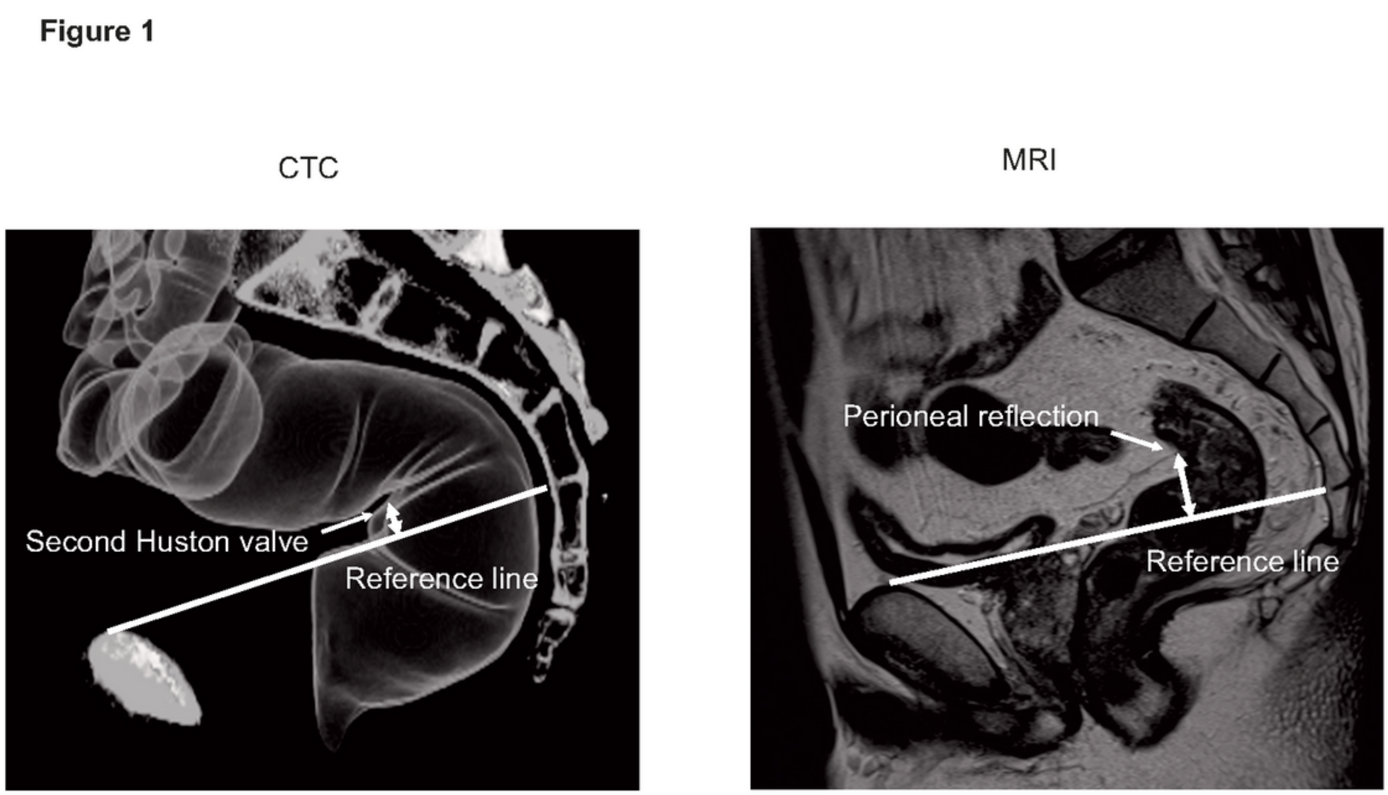

Figure 1

Positional relationship between the second Houston valve, peritoneal reflection, and reference line in the lateral position.

Reference line: the line connecting the superior border of the pubis and the inferior border of the fourth sacral vertebra.

Figure 2

Histogram plot showing the location of the second Houston valve from the reference line (A), the peritoneal reflection from the reference line (B), and the second Houston valve from the peritoneal reflection (C).

Representative images of the correlation between the second Houston valve and peritoneal reflection. Some cases showed the peritoneal reflection to be located deeper than the second Houston valve (D), at almost the same position (E), and shallower than the second Houston valve (F).

Second HV from PR: the value of subtracting the height of peritoneal reflection from the height of second Houston valve.

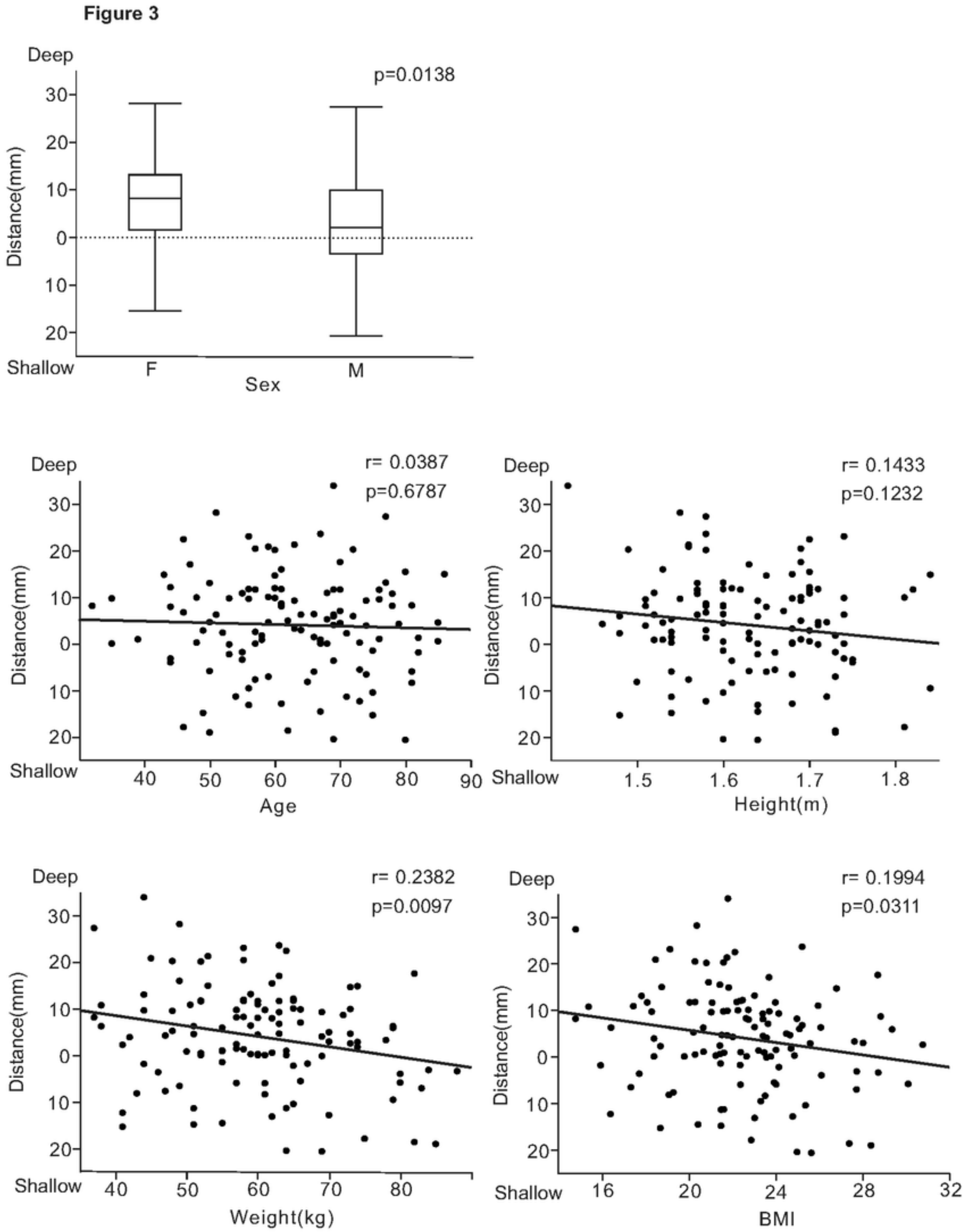

Figure 3

Correlation between the position of the second Houston valve and peritoneal reflection with patient variables. Box plot showing correlation by sex (A). Scatter plot and regression line showing the correlation by age (B), height (C), weight (D), and BMI (E)

The vertical axis is the distance of the second Houston valve from the peritoneal reflection to the cranial side. A distance > 0 means that the peritoneal reflection is located more cranially than the second Houston valve.

BMI: body mass index