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Original Article

What is the source of pressure pain during abdominal examination in Korean medicine?

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ABSTRACT

Background: This study aimed to observe which anatomical structures change in the abdominal cavity and are involved in pressure pain during the pressurization of CV12 by using an ultrasonic diagnostic device in healthy subjects.
Methods: We recruited 52 healthy people and performed ultrasound imaging by gradually pressurizing the subject's CV12. We analyzed ultrasound images to observe the changes in abdominal anatomical structures during pressurization.
Results: A significant change in thickness appeared at the space above the peritoneum and stomach and at the space between the stomach and the abdominal aorta while pressing on CV12.

Pressure pain occurred in the following two cases. One was when from the posterior side of the stomach to the inner surface of the rectus abdominis became approximately 1.8 cm. The other was when the anterior side of the abdominal aorta approached the inner surface of the rectus abdominis by approximately 3 cm. Pressure pain occurred when CV12 was pressed to a depth of approximately 2.4 cm for females, 3.1 cm for males and 2.7 cm on average.
Conclusion: The stomach and tissues around the stomach undergo the greatest pressure change during the pressurization of CV12, and in particular, pressure pain occurs when the posterior wall of the stomach is under pressure. However, further study should be done for clinical application.

1. Introduction

Abdominal examination is a methodology of Korean medicine that is performed by doctors of Korean medicine by touching or pressing the patient's abdomen to check any abnormality. Abdominal examination includes checking the tension, induration, tenderness, distension, coldness or fever of the abdomen and provides the basis for understanding the pathological changes in the human body.[1–4]

The theoretical basis for abdominal examination was formed from the ancient medical texts 'Suwen', 'Lingshu' and 'Nanjing'. Abdominal examination was aggressively studied after the introduction of 'Shanghanzabinglun', which containing a systematic method of diagnosis in Japan and became an major part of the diagnosis in Kampo, but in Korea, it was insufficient compared to pulse diagnosis and tongue diagnosis. However, an international standard for abdominal physiological parametric detector was proposed by Japan and China at the ISO/TC249 in early 2015, and interest in abdominal examination is also growing in Korea.[4,5]

In Western medicine, abdominal examination is focused the strategy to materialize the target such as the size, shape, mobility, stiffness and tension of targets in the abdominal cavity.[6] Those difference seems to be based on a different epistemology about things between the West and the East. As medical engineering technology advances, medical diagnostic devices including ultrasound are actively utilized in Western medicine to observe anatomical changes in organs and tissues.[5,7]

In particular, diagnostic ultrasound, which obtain cross sectional images of the human body by calculating the reflection pattern of

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the ultrasound passing through different media, is widely using because it is relatively safe and are easy to manipulate. Abdominal ultrasonography is mainly used to diagnose conditions of the liver, gallbladder, biliary tract, kidney, spleen and pancreas.[8,9]

Various studies have been conducted in Korean medicine on abdominal examination, such as the stiffness, weakness, pain position and pain intensity of the abdomen.[5] However, a study observing the structural changes in the abdominal cavity during pressurization and when pressure pain occurs does not exist.

We aimed to identify the source of pressure pain in the abdominal cavity with ultrasound imaging while pressing CV12 in this study. We expected to obtain basic data for quantitative indicators of pressure pain in healthy subjects prior to a study of pressure pain in people with diseases.

2. Methods

2.1. Subject recruitment

The survey was conducted on a voluntary basis, and the participants agreed to the use of the collected data for scientific purposes. This study was performed under the consent of the Institutional Review Board (Consent No.: WKIRB-201906-BM-053).

2.1.1. Inclusion and exclusion criteria

The study was conducted on adults between the ages of 18 and 45 years old. The contents of this study were explained through prior interviews and then conducted to those who agreed in writing to participate in the study.

The following details are excluded from the study: a person with past history of liver, kidney, nervous system, immune system, respiratory system, endocrine system or blood tumor disease, cardiovascular disease and mental illness; a person who has skin infection or scar in the area of observation site (the abdomen).

2.1.2. Eligibility assessment and exclusion

Eligibility assessment has performed just before the test. The general characteristics of subjects, such as systolic and diastolic blood pressure, pulse rate, respiration rate, body temperature, height, weight, body mass index (BMI) and subcutaneous fat layer thickness at the eligibility assessment. The subcutaneous fat layer thickness was measured at 3 points: the midpoint of the triceps brachii (left); below the scapula (left); and the midpoint between the lower part of the rib and the upper part of the iliac crest (left).

After the eligibility assessment, 58 subjects were recruited in accordance with the criteria for selection, and 6 persons were excluded after the interview. Finally, 52 subjects were recruited. We explained the contents of this study through prior interviews and then conducted the interviews with those who agreed to participate in this study.

2.2. Abdominal examination

2.2.1. Preparation before the examination

The subjects were fasted for more than 2 h and drank at least 300 mL of water or tea (uncarbonated) immediately before the test for clear ultrasound imaging. The subjects then lay on a bed for ultrasound imaging and put a pillow under their knees to relax the abdominal muscles.

The researcher used a medical pen to mark the guidelines on the abdomen to specify the position of CV12. The researcher pressed the CV12 of the subjects with the hand before actual measurement so that the subject could recognize the pressure pain at a constant intensity. Then, if subjects felt a similar intensity of pain to the preceding one during the actual measurement, we asked that the subjects press the measurement stop button (Fig. 1).

The experimenter located the guide plate in accordance with the guidelines indicated on CV12 after applying an appropriate amount of gel to the probe for ultrasonic wave conduction.

2.2.2. Acupuncture point CV12

We selected CV12 among these acupoints because some of the acupoints were excluded from the experiment due to the difficulty of observation with the ultrasound device due to their location, for example, short distance from the bones or location in the lateral side of the abdomen. The other acupoints were excluded because

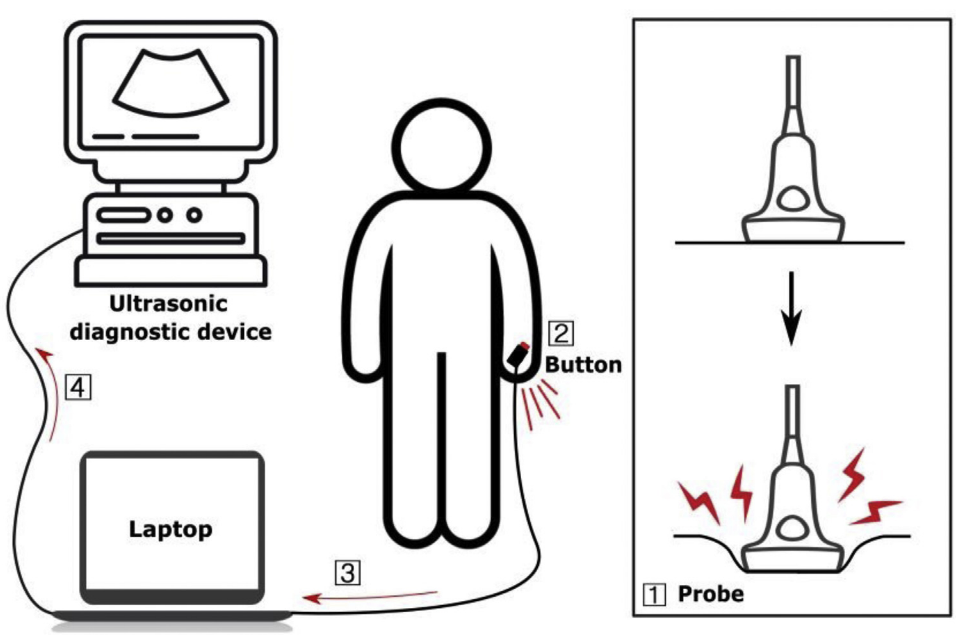

Fig. 1. Ultrasound imaging unit. The ultrasound imaging unit consisted of an ultrasonic diagnostic device, laptop and stop measuring button. The researcher pressed CV12 of the subject, and pressure pain occurred (1). If the button is pressed due to pressure pain (2), the button sends a stop signal to the laptop (3), the laptop sends the signal to the ultrasonic diagnostic device, and the ultrasonic diagnostic device stores the images taken so far (4).

they targeted the intestine, and it was difficult to clearly observe the intestines with the ultrasound device.

Acupuncture point CV12 (Jungwan) applies the WHO/WPRO standard meridian point location. CV12 is located 4 cun above the center of the umbilicus on the anterior median line. One cun was set as a ratio using the proportional methods. (The distance from the lower margin of the sternum body to the center of the umbilicus was set to 8 cun.)

Vertical and horizontal lines passing through CV12 were drawn using tapeline and a medical pen to clarify the reference point during the experiment (Supplement 1).

2.2.3. Ultrasound imaging

The experiment was divided into vertical and horizontal imaging of CV12. The researcher aligned the probes with the horizontal or vertical guidelines specifying CV12 at each experiment. Then, the subject was asked to stop breathing right before the measurement and the ultrasound image was taken.

The researcher took the vertical image of CV12 first. During the imaging, the researcher took care not to deviate from the guidelines and gradually pressed the probe harder. When the subject pressed the measurement stop button due to pressure pain, the researcher immediately stopped pressure on CV12.

The researcher checked the ultrasound image taken to ensure that the anatomical structures were properly captured and stored them based on the research number.

After vertical imaging, the researcher arranged the probe in the guidelines for horizontal imaging of CV12 and took them in the same process as for vertical imaging (Supplement 2).

Ultrasonic imaging was taken in video form. Still images were acquired at two times: before the applying pressure and when image taking ended due to pressure pain. Brightness, contrast and other features were adjusted using an image processing program (Photoshop CS6, Adobe, USA) to facilitate the analysis of the still image.

2.3. Outcome measurements

Observing the still images of ultrasound imaging from the experiment, we confirmed 5 different anatomical structures: the subcutaneous fat layer, rectus abdominis, area of the abdominal cavity, stomach and abdominal aorta. We analyzed the images based on these five structures because other structures were difficult to judge.

Three vertical lines penetrating the ultrasound image were drawn using the illustrator program (Illustrator CS6, Adobe, USA), and the depth of each structure was measured by drawing the lines at the point of passage through each structure. The median value was selected from the three measured depth data points, which were used to calculate the thickness change before and after pressure, cumulative thickness variation and so on.

2.4. Statistical analysis

The mean, ratio and standard deviation in the table were calculated with Microsoft Excel 365 (Microsoft, Inc.) The difference between males and females, or before and after pressurization, was statistically analyzed with Student's *t*-test methods in the SigmaPlot 14 program (Sigma Software, Inc.). The box plot (Fig. 2) was statistically analyzed with the SigmaPlot 14 program (Sigma Software, Inc.).

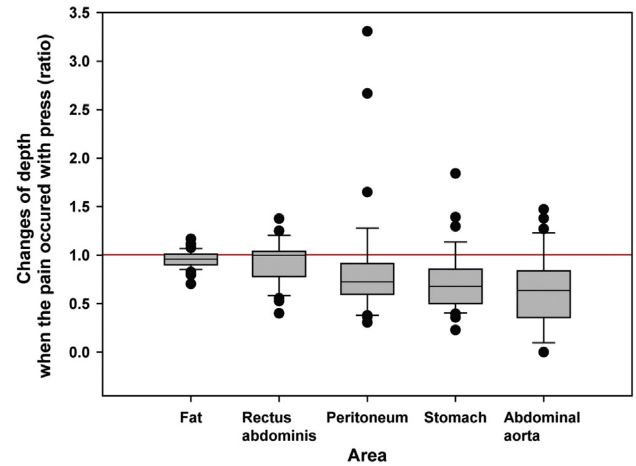

Fig. 2. Changes in each anatomical structure until pressure pain occurred. The data are expressed as the mean ratio ± the standard deviation. The box plot displays the overall changes in anatomical structures. There were few changes in the subcutaneous fat layer and rectus abdominis, while significant changes in thickness and similar deviations were shown in the space above the peritoneum, stomach and abdominal aorta.

3. Results

3.1. Demographic characteristics of the subjects

Fifty-eight subjects were recruited, but 6 persons were excluded after the interview. Twenty-seven women and 25 men were finally enrolled. The biological characteristics of the study subjects are listed in Table 1.

3.2. Structural changes in CV12 before and after pressure pain occurred

3.2.1. Vertical image

The subcutaneous fat layer and the rectus abdominis barely changed until the pressure pain occurs and as the pressure increases, the internal organs in the CV12 area are pushed to the periphery. It was easier to distinguish anatomical structures of post-pressurized images. Because as the pressure increases, the distance between organs in the abdominal cavity becomes closer and density of tissues are denser.

The anterior abdominal wall moved toward the posterior abdominal wall during the pressurization of CV12. Therefore, the location of the abdominal aorta appeared to be higher than before pressurization.

It was difficult to determine the depth of the abdominal aorta because it was irregularly distributed in the vertical image (Supplement 2).

3.2.2. Horizontal image

The subcutaneous fat layer and the rectus abdominis barely changed until pressure pain occurred, and as the pressure increased, the internal organs in the CV12 area were pushed to the periphery. It was also easier to distinguish the anatomical structures of post-pressurization images for the same reason as for vertical images.

The anterior abdominal wall moved toward the posterior abdominal wall during the pressurization of CV12. Thus, the location of the abdominal aorta also appeared to be higher than before pressurization.

The abdominal aorta was observed in a circle in horizontal images, and there were more clear locating criteria for the

Table 1
Biological Characteristics of Subjects

	All (N = 52)	Male (N = 25)	Female (N = 27)	p-value
Age	23.4 ± 3.8	22 ± 3.2	24.8 ± 3.9	0.007
BP (mmHg)	120.4 ± 12.2	114.3 ± 10.1	126.7 ± 10.9	0.000
	76.7 ± 7.8	75.8 ± 7.1	77.7 ± 8.5	0.385
PR (per min)	76.3 ± 11.6	77 ± 10.6	75.6 ± 12.7	0.667
RR (per min)	14.9 ± 1.5	15.1 ± 1.2	14.6 ± 1.7	0.223
BT (°C)	37.1 ± 0.3	37.2 ± 0.2	37 ± 0.3	0.006
Height (cm)	165.3 ± 8	158.8 ± 4.5	172 ± 4.5	0.000
Weight (kg)	63.2 ± 11.1	57 ± 8.4	69.7 ± 9.9	0.000
BMI (kg/m^2)	23.0 ± 2.9	22.6 ± 2.8	23.5 ± 3.0	0.268
SFT (mm)	19.6 ± 7	23.9 ± 6.2	17.8 ± 5.9	0.000

The data are expressed as the mean ± the standard deviation.
BP is blood pressure; PR is pulse rate; RR is respiration rate; BT is body temperature; BMI is body mass index; SFT is subcutaneous fat thickness.
p-value: male vs. female.

Table 2
Changes in Each Anatomical Structure Until Pressure Pain Occurred

	All (N = 52)	Male (N = 25)	Female (N = 27)	p-value
Subcutaneous fat layer	0.95 ± 0.09	0.93 ± 0.09	0.97 ± 0.09	0.119
Rectus abdominis	0.92 ± 0.20	0.97 ± 0.18	0.88 ± 0.20	0.097
Space above the peritoneum	0.9 ± 0.64	0.87 ± 0.61	0.92 ± 0.68	0.781
Stomach	0.68 ± 0.31	0.61 ± 0.180	0.72 ± 0.38	0.193
Abdominal aorta	0.61 ± 0.40	0.55 ± 0.40	0.65 ± 0.40	0.372

The data are expressed as the mean ratio ± the standard deviation.
There were no significance existed between male and female group.
p-value: male vs. female.

Table 3
Accumulative Thickness Changes in Each Anatomical Structure Until Pressure Pain Occurred (cm)

Sex	Female		Male		All	
Structure	Before	After	Before	After	Before	After
SF	1.88 ± 0.45	1.76 ± 0.37	1.54 ± 0.40	1.42 ± 0.31	1.71 ± 0.46	1.59 ± 0.38
RS	0.29 ± 0.10	0.24 ± 0.05	0.31 ± 0.32	0.27 ± 0.19	0.30 ± 0.23	0.25 ± 0.14
SP	−0.70 ± 0.27	−0.51 ± 0.18*	−0.70 ± 0.32	−0.57 ± 0.32	−0.70 ± 0.30	−0.54 ± 0.26*
St	−2.35 ± 0.57	−1.75 ± 0.54**	−2.78 ± 0.61	−1.81 ± 0.47**	−2.57 ± 0.62	−1.78 ± 0.50**
AA	−4.43 ± 0.61	−2.99 ± 1.09**	−5.08 ± 0.79	−3.28 ± 0.99**	−4.75 ± 0.77	−3.14 ± 1.04**

Values are express as mean ± standard deviation.
*$p < 0.005$.
**$p < 0.001$.
0 means the boundary between the subcutaneous fat layer and the rectus abdominis.
SF is subcutaneous fat; RS is rectus abdominis; SP is space above the peritoneum; St is stomach; AA is abdominal aorta.
A p-value below 0.001 is indicated as 0.000.

abdominal aorta in horizontal images than in vertical images (Supplement 2).

3.3. *Quantitative analysis of anatomical structures in the abdomen before and after pressure pain*

We used horizontal images with clear locating criteria for the abdominal aorta to observe changes in anatomical structure. The anatomical changes confirmed that most anatomical structures were reduced in thickness after pressurization due to the pressure.

The subcutaneous fat layer, rectus abdominis and space above the peritoneum and others were found to undergo relatively small changes in thickness. The rectus abdominis and subcutaneous fat layer showed significant inverse tendencies in men and women, apparently due to differences in muscle and subcutaneous fat development in males and females.

A significant reduction in thickness was observed in the stomach and in the space between the stomach and the abdominal aorta. The change was greater considering that the abdominal aorta had not been observed in most pre-pressurization images. There was no significant difference between males and females in any type of anatomical structure (Table 2). However, the distribution of change in each anatomical structure showed us a different result from the results in Table 2 (Fig. 2).

Aggregating the analysis results, we confirmed that a significant change in thickness appeared at the space above the peritoneum and the stomach and the space between the stomach and the abdominal aorta as the CV12 was pressurized.

Significant changes in thickness were observed in the rectus abdominis and in the space above the peritoneum, stomach and abdominal aorta in females through accumulative thickness changes in each anatomical structure until pressure pain occurred. However, significant changes in thickness were observed in the stomach and abdominal aorta in males.

When we aggregated the thickness changes of structures in females and males, we confirmed that significant changes in thickness appeared in the space above the peritoneum, stomach and abdominal aorta (Table 3).

Because the subcutaneous fat layer and rectus abdominis showed little change during the pressurization of CV12, we determined the boundary between these two structures as the baseline and determined the cumulative depth changes for the space above the peritoneum and the stomach and the space between the stomach and the abdominal aorta on the basis of the baseline (Supplement 3).

Pressure pain seemed to occur in two cases based on the cumulative data. One was when from the posterior side of the stomach to the inner surface of the rectus abdominis became approximately 1.8 cm. The other was when the anterior side of the abdominal aorta approached the inner surface of the rectus abdominis by approximately 3 cm. From the surface of the abdomen, pressure pain occurred when CV12 was pressed to a depth of approximately 2.4 cm for females, 3.1 cm for males and 2.7 cm on average.

4. Discussion

In this study, we observed the anatomical structures with ultrasonic diagnostic device during pressurization on CV12 and expected to visualize and strengthen the basis of quantifying the abdominal examination through this study, and the result has shown that the stomach and tissues around the stomach present the greatest pressure change during pressurizing on CV12, and in particular, the pressure pain occurred when the posterior wall of stomach is under pressure.

Previous studies on abdominal examination of patients with functional dyspepsia has reported that the pressure pain in the abdomen is quantitatively distinguishable threshold with a pressure algometer in the case of "*Simhabi*" and "*Simhabikyung*",[4,10] while the anatomical origin of the pain is not mentioned. However, in this study, we tried to observe which structures change and cause pressure pain during the pressurization of CV12 with an ultrasonic diagnostic device and we suppose it is the first study which tried to find the origin and mechanism of the abdominal examination.

We observed the subcutaneous fat layer, rectus abdominis, space of the abdominal cavity, stomach, visceral fat attached to the posterior abdominal wall, and so forth, with an ultrasonic diagnostic device. However, it was difficult to obtain clear images of other structures because of the gas in the gastrointestinal tract, including the stomach.[9] Thus, we classified and analyzed the ultrasound images of these five anatomical structures.

It is supposed that pressure pain occurs when the posterior wall of the stomach and its nearby tissues are under pressure. If we exclude the pressure pain due to the hypersensitivity of muscle and fascia through something like the abdominal-wall-tenderness test,[11] we can consider that the pressure pain reflects the changes in the stomach and nearby tissues. The changes include increased pressure due to food or gas inside the stomach, a tumor around the stomach, the inflammation of the stomach wall, the tension of the smooth muscle of stomach, and so forth. When the above changes occur in the posterior wall of the stomach, the increase in pressure pain will be remarkable compared to when the changes occur in the anterior wall of the stomach. However, it seems difficult to diagnose diseases such as gastric atony, gastroptosis, atrophic gastritis and functional dyspepsia that do not include food in the gastrointestinal tract because they have small anatomical or physical changes.

This study limited participants to healthy people, and patients with pathological conditions were not included because the evidence is not enough to test on the patients. However, the results can be helpful for further research on abdominal examination by providing basic data on pressure pain in healthy people. Furthermore, the participants were very healthy 20s and the muscle strength or elasticity of the fat tissues or intestine may very vary to the data of this study if experiment performed to the infants, children or seniors. Thus, we suggest the data in this study could be used as data from the idle condition and shall not be applied in broad generality.

We could observe the anatomical change in the abdomen during the pressurization on the CV12 and hypothesized the origin of the pressure pain, however, the quantitative data was collected from relatively small group of participants and is difficult to be used as an independent indicator as itself due to its deviation. We expect further study based on this study will performed in larger scale, then the data can be applied in the clinical area.

We used the method of pressing on the subject's abdomen with a linear probe in the course of the experiment, which is different from the situation in an actual abdominal examination. When we perform an abdominal examination, we approach the abdomen carefully with the wide part of the fingertips to reduce patient resistance; therefore, we assumed that the contact area of the fingertips of 4 fingers and the contact area of the linear probe are similar. In addition, the experimenter was instructed to make the force and velocity of pressurization as similar as possible between the pre-experimental simulation and the actual experiment.

Although details of contact area, pressure, and the patient's sensation will differ, of course, the pressure applied in the experiment was not thought to be significantly different between the experiment and the actual situation if we made the force and contact area as similar as possible through the preceding process.

Therefore, if medical technology develops an abdominal examination device that reflects the actual treatment environment of doctors of Korean medicine through continuous research in the future, it is expected that the accuracy of diagnosis can be ensured by observing anatomical structures together, not relying solely on the senses of oriental doctors and patients, and this development will also be helpful for the study of abdominal examination.

In conclusion, the stomach and tissues around the stomach present the greatest pressure change during pressurizing on CV12, and in particular, the pressure pain occurs when the posterior wall of stomach is under pressure. However, further study should be done for clinical application.

Author contributions

Conceptualization: OSK, H-JJ, J-HK and SL. Investigation: H-JJ, HIG, and EC. Formal analysis: OSK, J-HK, and SL. Writing - Original Draft: OSK, HIG, and EC. Writing - Review & Editing: OSK, H-JJ, J-HK, and SL.

Conflict of interest

The authors declare that there are no conflict of interest.

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Ethical statement

This study was performed under the consent of the Institutional Review Board (Consent No.: WKIRB-201906-BM-053). The survey was conducted on a voluntary basis, and the participants agreed to the use of the collected data for scientific purposes.

Data availability

Data will be made available upon request.

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