OBES SURG (2016) 26:2995–3000
DOI 10.1007/s11695-016-2221-1

ORIGINAL CONTRIBUTIONS

The Role of Conventional Ultrasonography in the Evaluation of Antrum Wall Thickness in Obese Patients

Fatih Mehmet Yazar[1] · **Murat Baykara**[1] · **Mustafa Karaağaç**[1] · **Ertan Bülbüloğlu**[1]

Published online: 22 June 2016

Abstract
Background The objective of this study is to evaluate the utility of conventional ultrasonography (USG) in the evaluation of the stomach antrum and distal corpus lesions.
Methods A prospective evaluation was made of 69 patients who underwent sleeve gastrectomy. Preoperative USG was applied to the patients and measurements were taken and recorded of the stomach antrum full layer wall thickness (USGFT) and of mucosal thickness (USGMT). Postoperatively, same parameters were again measured histopathologically and the pathological full thickness (PFT) and pathological mucosal thickness (PMT) values were compared.
Results When evaluation was made in respect of USG and pathological measurements, the USGFT was 8.51 ± 3.07 (range 4.5–15.8) and USGMT was 5.80 ± 2.15 (range 2.36–10.5). The PFT was determined as 8.13 ± 2.24 (range 4–14) and PMT as 5.53 ± 1.86 (range 2–10.5). In the histopathological examination, gastritis was seen in 53 (76.8 %) patients and *Helicobacter pylori* (HP) positivity was determined in 32 (46.4 %) patients. When the patients were grouped as obese (BMI ≤ 49.9 kg/m^2) (group 1, $n = 50$) and super obese (BMI ≥ 50 kg/m^2) (group 2, $n = 19$), no difference was determined between the groups ultrasonographically or histopathologically ($p > 0.05$). The antrum wall thickness was seen to be significantly greater in the patients with gastritis and HP positivity compared to the patients who were negative. In ROC analysis, cutoff values were calculated for USGFT (5.86 mm) and USGMT (4.49 mm). In gastritis diagnosis, the USGFT cutoff value was found to have 796 % sensitivity and 68.7 % specificity.
Conclusion USG was seen to be an extremely effective method in visualising the antrum wall and gastritis diagnosis can be made comfortably from the wall thickness measurement.

Keywords Ultrasound · BMI · Gastric wall thickness · Obesity

Introduction

The thickness of the stomach wall and especially of the antrum wall is affected by several malignant and benign diseases which originate in the stomach wall [1]. There are few and generally old studies in literature related to the use of imaging methods in the evaluation of the antrum wall [1–9]. The vast majority of those studies used computed tomography (CT) [1–3] and endosonographic (EUS) methods [4, 5]. Studies related to the use of conventional ultrasonography (USG) are very old [6–8] or were related to lumen evaluation rather than wall evaluation [9]. Before the development of advanced imaging methods, barium was used in studies for the evaluation of stomach lumen and ruga. However, these methods are of limited value to be able to evaluate the stomach wall [10]. As methods such as CT and EUS came into use with technological advances, this problem was eliminated [3]. However, CT cannot be used on pregnant patients because of radiation exposure or on super obese patients because of technical difficulties [11, 12], and although EUS is less invasive, it may not be able to be used as sedation is required and it may not be available in every centre [13]. Therefore, to be able to contribute new and current data to literature, this study was designed to compare the stomach wall thickness measured histopathologically in patients undergoing sleeve gastrectomy with the

✉ Fatih Mehmet Yazar
fmyazar@ksu.edu.tr

[1] Kahramanmaras Sutcu Imam University Faculty of Medicine, Kahramanmaras, Turkey

success of evaluation of the antrum, which is affected by many diseases involving the stomach wall, by conventional USG as a diagnostic modality which is simple, repeatable and universally available (Fig. 1).

The aim of this study was to verify with histopathological examination the efficacy of conventional USG in showing the antrum wall thickness in patients undergoing sleeve gastrectomy.

Materials and Methods

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. Informed consent was obtained from all individual participants included in the study. Sleeve gastrectomy surgery was applied to 69 consecutive patients because of morbid obesity, in a single centre between May 2015 and January 2016. The patients were aged over 18 years, with a body mass index (BMI) of $\geq$40 kg/m^2 or 35 $\geq$ kg/m^2 with concomitant diseases and were willing to participate in the study. Informed consent was obtained from all the patients. Exclusion criteria were a history of hiatus hernia, or any surgery such as plication gastric band which could affect the stomach wall thickness, or unwillingness to participate in the study.

All the surgical procedures were applied by two surgeons using the same surgical techniques and the ultrasonographic and pathological measurements were made by a single radiologist and pathologist. To avoid the radiologist and pathologist who took the measurements affecting each other's results, the results of the pathological and radiological examinations were collected by the surgical team and the data were coded under the headings of USGFT and USGMT and were sent for statistical analysis. Thus, it was aimed to avoid statistical errors.

Preoperative Ultrasonographic Measurements

US examination was applied to all patients preoperatively. All measurements of gastric wall thickness were taken using a high-resolution Doppler ultrasonography system (Aplio™ 400 Platinum, Toshiba Medical Systems Corporation, Tochigi, Japan) with a broadband convex probe. After 500 ml tap water intake, the probe was inserted to the hypochondrium of each individual and the hepatic left lobe was used as the acoustic window. Thickness was measured from the anterior wall of the gastric antrum in two ways, full thickness and only echogenic mucosal thickness. All data were recorded.

The USGMT measurement was taken as the measurement of the thickness of the echogenic area between the lumen and myoserosal hypoechogenicity, and the USGFT measurement was made by adding the myoserosal thickness to this area. All measurements were made three times and the average was taken for evaluation.

Surgical Procedure

The same surgical method was applied by the same surgical team to all the cases in the study. The procedure was applied with the five trocar method by laying the patient in the French position in the reverse Trendelenburg position. The abdomen was inflated with 14 mmHg carbon dioxide and starting at approximately 3 cm prepyloric, the stomach was mobilised by cutting the gastrocolic and gastrosplenic ligaments with a 5 mm Ligasure (Covidien, Dublin, Ireland). A 38 Fr orogastric tube was inserted as far as the prepyloric area. Then a laparoscopic 60-mm XL Endo-GIA stapler (Echelon Flex Endopath Stapler; Ethicon Endo-Surgery, Cincinnati, OH, USA) was used with the first two stapler cartridges as 4.2 mm green and the other cartridges as 3.5 mm blue. After resection was completed, the 12 mm trocar used for the trocar staples were removed from the area and the removed tissue was sent to the pathology laboratory in formaldehyde for pathological examination.

Postoperative Pathological Measurements

All the sleeve gastrectomies were sent to the pathology laboratory after surgery and after fixation in 10 % formaldehyde for 24 h. Four samples were taken from the antrum area, each approximately 1 × 0.5 × 0.5 cm in size and were embedded in paraffin blocks. Slices 4 μm in thickness were taken from the paraffin blocks and three samples were stained with haematoxylin and eosin (HE) for measurement of the wall thickness and the fourth sample was stained with M. Giemsa to determine the presence of HP. With an Olympus 13 × 53f model microscope (Olympus Corporation, Tokyo, Japan), the HE-stained preparations containing mucosa and serosa were evaluated for full layer wall thickness, mucosal thickness only and inflammation. The preparations stained with M. Giemsa were examined for the presence of HP. Full layer wall thickness and mucosal thickness were measured separately in the three samples and the average was calculated and recorded.

Histopathological full layer stomach wall thickness (PFT) was accepted as mucosa, submucosa muscularis propria and serosa and histopathological mucosa thickness (PMT) was accepted as mucosa, muscularis mucosa and submucosa.

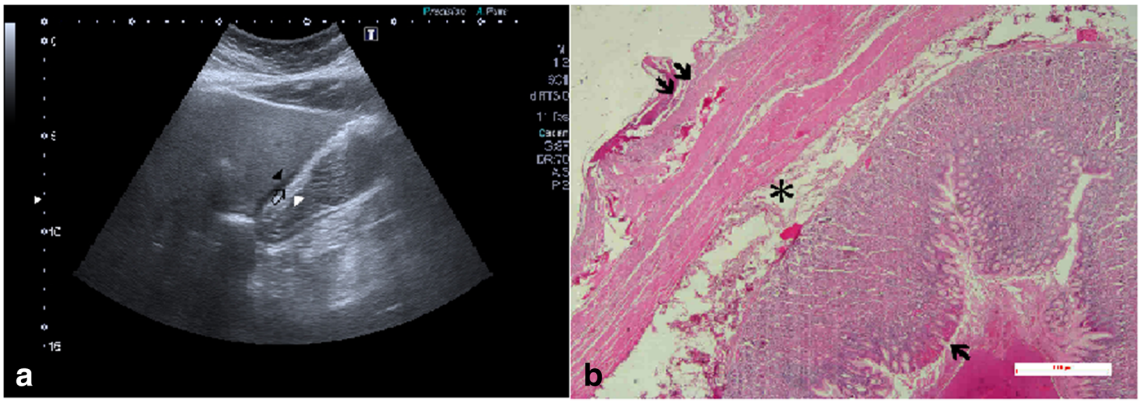

Fig. 1 **a** Axial abdominal US view for measurements, showing the border of serosa (*black arrow*) and the luminal border of mucosa (*white arrow*). **b** Pathology image from the same patient showing border of luminal mucosa (*arrow*), border of serosa (*double arrow*) and muscularis propria (*asterisk*) (H&E stain: original magnification ×20)

The patients were evaluated in respect of age, gender, comorbidities, BMI, USGFT, USGMT, PFT, PMT, gastritis and HP infection.

Statistics

In the analysis of the study data, SPSS 22.0 (SPSS, Chicago, IL, USA) software was used. Conformity of the data to normal distribution was tested with the Shapiro-Wilk test and variance homogeneity with the Levene test. In the comparison of two independent groups, the independent sample *t* tests together with the bootstrap results were used and the Mann-Whitney *U* test with the Monte Carlo simulation technique. Quantitative data were expressed in the tables as mean ± standard deviation (SD) and median and range (minimum-maximum) values. Categorical values were stated as number (n) and percentage (%). Data were examined in a 95 % confidence interval. A value of $p < 0.05$ was accepted as statistically significant.

Results

The patients included in the study were 50 (72.5 %) females and 19 (27.5 %) males with a mean age of 34.59 ± 9.44 years (range, 20–61 years) and mean BMI of 47.74 ± 7.09 (range, 35.66–78.72). In the evaluation in respect of the USG and pathological measurements, the mean USGFT was 8.51 ± 3.07 (range 4.5–15.8), USGMT 5.80 ± 2.15 (range 2.36–10.5), PFT 8.13 ± 2.24 (range 4–14) and PMT 5.53 ± 1.86 (range 2–10.5). In the histopathological examination, gastritis was determined in 53 (76.8 %) patients and HP positivity in 32 (46.4 %).

The patients were separated into two groups as obese (group 1, $n = 50$, BMI ≤ 49.9 kg/m^2) and super obese (group 2, $n = 19$, BMI ≥ 50 kg/m^2) and in the evaluation of the relationship between BMI values and wall thickness, the USGFT was determined as 8.83 ± 4.07 in group 1 and as 7.85 ± 2.97 in group 2. The USGMT was determined as 6.22 ± 2.81 in group 1 and as 5.28 ± 1.75 in group 2. No statistically significant difference was determined between the two groups in respect of either of these two parameters ($p = 0.34$, $p = 0.17$, respectively). In the histopathological evaluation, the PFT was 8.15 ± 2.29 in group 1 and 8.07 ± 2.17 in group 2. The PMT was measured as 5.59 ± 1.95 in group 1 and 5.39 ± 1.66 in group 2. No statistically significant difference was determined between the groups in respect of the histopathological results ($p = 0.90$, $p = 0.70$).

When wall thickness was evaluated according to gender, the USGFT was determined as 7.88 ± 2.53 in males and 8.76 ± 3.24 in females and USGMT as 5.67 ± 1.79 in males and 5.85 ± 2.29 in females. No statistically significant difference was determined between the genders in respect of the sonographic values ($p = 0.29$, $p = 0.74$, respectively). In the pathological evaluation of the wall thickness, the PFT was determined as 7.73 ± 1.78 in males and 8.28 ± 2.39 in females. The PMT values for males and females were 5.47 ± 1.51 and 5.56 ± 1.99, respectively. No statistically significant difference was determined between the genders in respect of the pathological values ($p = 0.37$, $p = 0.86$ respectively).

The patients were grouped as those positive for gastritis (group 1, $n = 53$) and negative (group 2, $n = 16$) and the relationship between wall thickness and gastritis was evaluated. The USGFT values were 9.26 ± 3.81 in group 1 and 6.23 ± 2.76 in group 2 and the USGMT values were 6.49 ± 2.53 and 4.21 ± 1.96, respectively. No statistically significant difference was determined between the patients with or without gastritis in respect of the ultrasonographic results of wall thickness and mucosa ($p = 0.004$, $p = 0.002$). In the pathological evaluation of both groups, the PFT values were determined as 8.57 ± 2.21 in group 1 and 6.65 ± 1.70 in group 2. The PMT values were determined as 5.83 ± 1.85 in group 1 and 4.56 ± 1.60 in group 2. A statistically significant difference was determined between the groups in respect of the pathological results ($p = 0.002$, $p = 0.016$, respectively).

The patients were grouped as those positive for HP (group 1, $n = 32$) and negative (group 2, $n = 37$) and the relationship between wall thickness and the presence of HP was evaluated. The USGFT values were 9.98 ± 4.45 in group 1 and 7.33 ± 2.64 in group 2 and the USGMT values were 6.98 ± 2.97 and 5.09 ± 1.82, respectively. A statistically significant difference was determined between the patients with or without HP in respect of the ultrasonographic results of wall thickness and mucosa ($p = 0.003$, $p = 0.002$). In the pathological evaluation of both groups, the PFT values were determined as 9.48 ± 2.14 in group 1 and 6.95 ± 1.59 in group 2. The PMT values were determined as 6.60 ± 1.58 in group 1 and 4.56 ± 1.60 in group 2. A statistically significant difference was determined between the groups in respect of the pathological results ($p = 0.001$, $p = 0.001$, respectively).

When the patients were grouped according to BMI values or the presence of gastritis, the ultrasonographic and pathological results were seen to be consistent with each other in both cases ($p > 0.05$).

In the ROC analyses, the cutoff values were calculated as USGFT (5.86 mm, $p < 0.001$) and USGMT (4.49 mm, $p < 0.001$). In gastritis diagnosis, the USGFT cutoff value was found to have 79.6 % sensitivity and 68.7 % specificity (AUC = 0.752 [95 % CI 0.606–0.899]) and the USGMT cut off value had 81.1 % sensitivity and 75 % specificity (AUC = 0.820 [95 % CI 0.694–0.954]).

Discussion

The aim of this study was not to question the place and importance of endoscopy, endosonography and CT in stomach lesions, but to evaluate the utility of conventional USG in patients with stomach antrum and relatively distal corpus lesions where these diagnostic modalities could not be used.

In brief, the results of the study showed that there was no relationship between the thickness of the stomach antrum wall and gender or BMI, but with gastritis or HP infection positivity, the thickness of the stomach wall increased and USG was seen to be an extremely reliable method in the determination of wall thickness. As USG was not considered a suitable method to demonstrate HP infection, ROC analysis was not applied for that but in the ROC analyses which were applied, it was seen that the 5.86-mm cutoff value could be used for the diagnosis of gastritis with high sensitivity and specificity. The USGMT cutoff values were seen to have higher sensitivity and specificity for gastritis diagnosis.

In studies in literature related to stomach wall thickness, various methods have been used [1–9]. Pickhardt and Asher evaluated the antrum wall thickness in 153 adult cadavers with tomographic examination. Before the procedure, standardisation was achieved by filling the stomachs with 1000 cc water and 150 cc contrast solution dissolved in water. Wall thickness was evaluated and antrum thickness was reported as 5–12 mm. However, the authors stated that endoscopic evaluation could only be made of ten subjects before the procedure. It can also be considered that as the study was post mortem, that could have affected the stomach wall thickness [3]. The current study differed in that evaluation was made of live, healthy individuals. The USG wall thickness measurements were seen to be mean USGFT 8.56 ± 3.80 (range 5.3–15.8) and USGMT 5.96 ± 2.58 (range 3.4–12.5). These results were seen to be similar to those reported in literature and sleeve gastrectomy was then applied to the same patients and the removed stomach tissue was processed with formaldehyde and examined pathologically. In evaluations in literature, although there has been no investigation of the effect of formaldehyde on stomach tissue, whether or not there is a change in the dimensions of the bone [14], palatal tonsils [15] and colorectal polyps [16] has been researched and while some studies have reported a statistically significant reduction in size of colorectal polyps, other studies have reported no effect. Therefore, it was not thought that formaldehyde fixation would affect the results and the ultrasonographic data were compared with the pathological data as a control group. The PFT values were determined as 8.13 ± 2.24 (range 4–14) and PMT as 5.53 ± 1.86 (range 2–10.5). When preoperative and postoperative full wall thickness and mucosa thickness values were compared, no statistically significant difference was seen between the groups ($p = 0.298$, $p = 0.292$, respectively).

In a recent study of six obese (BMI:54.7 ± 14.6 kg/m^2) and ten non-obese (BMI:23.8 ± 2.5 kg/m^2) patients, EUS was applied and evaluation was made of whether or not increased BMI had an effect on stomach wall thickness [4]. That study differed from the current study in that all parts of the stomach were evaluated in the anterior and posterior walls and no significant difference was seen between the results of the two groups. In that study, the antrum wall thickness was found to be 3.43 ± 0.72 in the obese patients and 3.42 ± 0.65 in the control group. In the current study, the full layer wall thickness was determined as 8.83 ± 4.07 in the obese patients and 7.85 ± 2.97 in the super obese patients. No statistically significant difference was seen between the groups. When verified pathologically, the results were seen to be similar (Tables 1 and 2). When the relationship between stomach wall thickness and gender was evaluated, although the stomach wall thickness in females was seen to be thicker than that of males, the difference was not significant. However, this result was thought to be associated not with gender but with the greater rate of gastritis and HP in the female patients compared to the males. As no study could be found in literature which evaluated the relationship between stomach wall thickness and gender, no comparison could be made with literature on this subject.

In the pathological examination of the current study, gastritis was determined in 76.8 % ($n = 53$) of the patients. In the

Table 1 Patient characteristics

Characteristics		Male ($n = 19$)	Female ($n = 50$)	P
Age		32.57 ± 8.34	35.36 ± 9.79	0.27
Body mass index (BMI) (kg/m^2)		49.01 ± 7.13	47.26 ± 7.09	0.36
USGFT		7.88 ± 2.53	8.76 ± 3.24	0.29
USGMT		5.67 ± 1.79	5.85 ± 2.29	0.74
Pat FT		7.73 ± 1.78	8.29 ± 2.29	0.37
Pat MT		5.47 ± 1.51	5.56 ± 1.99	0.86
Gastritis	Positive (n%)	11 (15.9)	42 (60.9)	
	Negative (n%)	8 (11.6)	8 (11.6)	
HP	Positive (n%)	7 (10.2)	25 (36.2)	
	Negative (n%)	12 (17.4)	25 (36.2)	

Data are expressed as the mean ± SD, unless otherwise noted

Independent t test (bootsrap)—Mann-Whitney U test (Monte Carlo)—Fisher exact test (Monte Carlo)—Pearson chi square test (Monte Carlo)

patients with gastritis, the antrum full layer thickness was determined ultrasonographically as 9.26 ± 3.81 and as 6.23 ± 2.76 in those who were negative. Increased mucosa thickness was seen ultrasonographically in the patients with gastritis. When the specimens were examined histopathologically, the results were seen to be similar to the ultrasonographic results. In the ROC analysis, USGFT values >5.86 mm were seen to have 79.6 % sensitivity and 68.7 % specificity in the diagnosis of gastritis. Moreover, an increase in mucosa thickness was seen to be more significant in the diagnosis of gastritis compared to the full thickness measurements (81.1 % sensitivity, 75 % specificity). In a study by Kul et al., the effects of HP infection on the gastric wall were evaluated and a relationship was reported between gastritis and gastric wall thickness >5 mm. In the same study, an increase in mucosa thickness was reported in patients with gastritis, which was similar to the findings of the current study [1].

HP infection of gastric mucosa is a chronic inflammatory process with eosinophil, macrophage and lymphocyte infiltration of the mucosal and submucosal tissue. As a result of HP mucosal infection, there is a change in the balance of cellular proliferation and apoptosis, and whereas chronic infection thickens the gastric wall in the early stage, the stomach wall thickness is reduced through apoptosis associated with mucosal atrophy [17–19]. In literature, HP infection has been reported to be seen in 80 % of atrophic gastritis cases and HP infection has not been observed in 10 % [20].

In a study by Avunduk et al. using EUS, infection was determined in 18 patients and the increased mucosal and submucosal wall thickness before treatment was reported to return to normal following treatment [5]. Kul et al. reported antrum wall thickness as 5.45 ± 2.09 (range 3.0–10.2) in HP negative patients and as 4.80 ± 1.81 (range 2.4–8.4) in a positive group [1]. In the current study, the stomach wall thickness was seen to have increased in the HP positive group and although there was an increase in mucosal thickness, it was not statistically significant.

There were some limitations to the current study. Sleeve gastrectomy was applied because of obesity to the patient group being evaluated and as stated in the "Introduction" section, while the formation of a patient group which would require high level technical devices in the use of CT would have

Table 2 Comparison of ultrasonographic and pathological data according to different parameters

Groups		USGFT	PFT	USGMT	PMT
Group 1[a] ($n = 50$)		8.83 ± 4.07	8.15 ± 2.29	6.22 ± 2.81	5.59 ± 1.95
Group 2[b] ($n = 19$)		7.85 ± 2.97	8.07 ± 2.17	5.28 ± 1.75	5.39 ± 1.66
P		0.34	0.90	0.17	0.70
Male ($n = 19$)		7.73 ± 2.52	7.73 ± 1.78	5.67 ± 1.79	5.47 ± 1.51
Female ($n = 50$)		8.87 ± 4.17	8.28 ± 2.39	6.08 ± 2.83	5.56 ± 1.99
P		0.27	0.37	0.56	0.86
Gastritis	Positive ($n = 53$)	9.26 ± 3.81	8.57 ± 2.21	6.49 ± 2.53	5.83 ± 1.85
	Negative ($n = 16$)	6.23 ± 2.76	6.65 ± 1.70	4.21 ± 1.96	4.56 ± 1.60
P		0.004	0.002	0.002	0.016
HP	Positive ($n = 32$)	9.98 ± 4.45	9.48 ± 2.14	6.98 ± 2.97	6.60 ± 1.58
	Negative ($n = 37$)	7.33 ± 2.64	6.95 ± 1.59	5.09 ± 1.82	4.60 ± 1.58
P		0.003	<0.001	0.002	<0.001

Data are expressed as the mean ± SD, unless otherwise noted

Independent t test (bootsrap)—Mann-Whitney U test (Monte Carlo)—Fisher exact test (Monte Carlo)—Pearson chi square test (Monte Carlo)

BMI body mass index, *HP Helicobacter pylori*

[a] BMI ≤ 49.9 kg/m^2

[b] BMI ≥ 50 kg/m^2

increased the positive aspects, the formation of such a group was not considered, as a study on pregnant patients would be unethical. A second group could have been formed of patients who were to undergo surgery because of stomach cancer and that such a group was not formed can be considered a limitation of the study. While evaluation of different anatomic localisations of the stomach wall has been made with tomography in previous studies, in the current study it was not possible to evaluate stomach areas such as the fundus with USG because of position and accessibility, which resulted in the evaluation of the antrum only. However, in patients where sufficient fullness could be achieved, it was observed that the corpus could be comfortably evaluated. Finally, because of the increased stomach capacity together with the increase in obesity, a change in the amount of fluid given could be seen. To be able to overcome this in the current study, the left border of the liver was determined as an anatomic landmark and it was aimed to provide standardisation by filling the stomach with water up to this point.

In conclusion, conventional USG applied by an experienced radiologist is an extremely effective method for the visualisation of the antrum wall, with which the diagnosis of gastritis can be comfortably made from the wall thickness measurement. Furthermore, to be able to make a definitive diagnosis with histopathological examination, conventional USG can be considered for use as the initial imaging method in the determination of these patients to be evaluated histopathologically.

Compliance with Ethical Standards This manuscript has not been published elsewhere and is not under consideration by another journal.

Conflict of Interest Drs. Author 1, Author 2, Author 3 and Author 4 have no conflicts of interest or financial ties to disclose.

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.

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

References

1. Kul S, Sert B, Sari A, et al. Effect of subclinical Helicobacter pylori infection on gastric wall thickness: multislice CT evaluation. Diagn Interv Radiol. 2008;14(3):138–42.
2. Insko EK, Levine MS, Birnbaum BA, et al. Benign and malignant lesions of the stomach: evaluation of CT criteria for differentiation. Radiology. 2003;228(1):166–71.
3. Pickhardt PJ, Asher DB. Wall thickening of the gastric antrum as a normal finding: multidetector CT with cadaveric comparison. AJR Am J Roentgenol. 2003;181(4):973–9.
4. Larsen MC, Yan BM, Morton J, et al. Determination of the relationship between gastric wall thickness and body mass index with endoscopicultrasound. Obes Surg. 2011;21(3):300–4.
5. Avunduk C, Navab F, Hampf F, et al. Prevalence of Helicobacter pylori infection in patients with large gastric folds: evaluation and follow-up with endoscopic ultrasound before and after antimicrobial therapy. Am J Gastroenterol. 1995;90(11):1969–73.
6. Lorentzen T, Nolsøe CP, Khattar SC, et al. Gastric and duodenal wall thickening on abdominal ultrasonography. Positive predictive value. J Ultrasound Med. 1993;12(11):633–7.
7. Stringer DA, Daneman A, Brunelle F, et al. Sonography of the normal and abnormal stomach (excluding hypertrophic pyloric stenosis in children. J Ultrasound Med. 1986;5(4):183–8.
8. Joharjy IA, Mustafa MA, Zaidi AJ. Fluid-aided sonography of the stomach and duodenum in the diagnosis of peptic ulcer disease in adult patients. J Ultrasound Med. 1990;9(2):77–84.
9. Van de Putte P, Perlas A. Gastric sonography in the severely obese surgical patient: a feasibility study. Anesth Analg. 2014;119(5):1105–10.
10. Dheer S, Levine MS, Redfern RO, et al. Radiographically diagnosed antral gastritis: findings in patients with and without Helicobacter pylori infection. Br J Radiol. 2002;75:805–11.
11. Franca Neto AH, Amorim MM, Nóbrega BM. Acute appendicitis in pregnancy: literature review. Rev Assoc Med Bras. 2015;61:170e7.
12. Long SS, Long C, Lai H, et al. Imaging strategies for right lower quadrant pain in pregnancy. AJR Am J Roentgenol. 2011;196:4e12.
13. Agostoni M, Fanti L, Arcidiacono PG, et al. Midazolam and pethidine versus propofol and fentanyl patient controlled sedation/analgesia for upper gastrointestinal tract ultrasound endoscopy: a prospective randomized controlled trial. Dig Liver Dis. 2007;39(11):1024–9.
14. Gedrange T, Mai R, Mack F, et al. Evaluation of shape and size changes of bone and remodelled bone substitute after different fixation methods. J Physiol Pharmacol. 2008;59 Suppl 5:87–94.
15. Vent J, Zimmermann C, Drebber U, et al. Influence of formalin fixation on tissue dimensions in palatal tonsils. Pathol Res Pract. 2014;210(1):59–61.
16. Turner JK, Wright M, Morgan M, et al. A prospective study of the accuracy and concordance between in-situ and postfixation measurements of colorectal polyp size and their potential impact upon surveillance. Eur J Gastroenterol Hepatol. 2013;25(5):562–7.
17. Toyoshima A, Ito M, Moriyama Y. Morphometrical analysis of the relationship between Helicobacter pylori infection and pathological changes of gastric mucosa using Sano's 4 point biopsy method. J Nippon Med Sch. 2000;67(4):250–60.
18. Piotrowski J, Skrodzka D, Slomiany A, et al. Helicobacter pylori lipopolysaccharide induces gastric epithelial cells apoptosis. Biochem Mol Biol Int. 1996;40(3):597–602.
19. Asaka M, Sugiyama T, Nobuta A, et al. Atrophic gastritis and intestinal metaplasia in Japan: results of a large multi center study. Helicobacter. 2001;6(4):294–29.