ISSN: 0974-8369

Biology and Medicine

International, Open Access

Available online at: www.biolmedonline.com

Biology and Medicine

Pulatova and Isamukhamedova, Biol Med (Aligarh) 2015, 7:2
http://www.biolmedonline.com

Research Article Open Access

Modern Approach to the Comprehensive Ultrasonography of Gastric Cancer

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Abstract

Diagnosis and treatment of malignant tumors of the gastrointestinal tract is one of the most urgent problems of the modern medicine. This paper is based on the analysis of clinical, instrumental and morphological study of 55 patients with gastric cancer at the age of 36-82 yrs. Morphological verification of the diagnosis was obtained in all patients. Comprehensive ultrasound examination included two-dimensional transabdominal, contrast, duplex and triplex ultrasonography, as well as three-dimensional ultrasonography. The results of ultrasonography were compared with the results of radiologic, endoscopic methods, and with the data obtained during the surgery. The data obtained in the comprehensive ultrasound investigation of 30 almost healthy individuals served as the control (control group). In patients with gastric cancer we noted a considerable increase in the V_{max} value of the celiac trunk – 2.5 times, in the superior mesenteric artery – 2.0 times, in the left gastric artery – 1.7 times (when compared to the average values of patients of the main and the control group). In patients with gastric cancer in these arteries we revealed a significant increase in V_{min} and a significant decrease in RI as compared with the normal values. Blood flow velocity in the splenic vein in these groups did not differ significantly. Analysis of the results of three-dimensional reconstruction, duplex and triplex ultrasonography allowed to reveal additional sonographic signs except the traditional ones obtained with two-dimensional and contrast ultrasonography in patients with gastric cancer. So, we concluded that integrated ultrasound diagnosis should be widely used in the pathology of the stomach.

Keywords

Gastric cancer; Ultrasonography; Color dopplerpgraphy; Three-dimensional ultrasonography

Introduction

Diagnosis and treatment of malignant tumors of gastrointestinal tract is one of the most urgent problems of the modern medicine. Gastric cancer is one of the most common tumors in humans, and in the structure of oncological diseases it is on the second place in the world in men and on the third place in women [1,2]. Unsatisfactory results of the gastric cancer treatment are largely caused by the late diagnosis. Up to 80% of cases of gastric cancer are not diagnosed until stage III or IV when metastases to regional lymph nodes, liver, peritoneum, and ascites can be determined [3-5].

Surgery is the main method to treat gastric cancer, and its volume is determined by the localization of gastric tumors, its stage, growth form, and prevalence [6-8]. The 5 yrs survival rate after the surgery has been shown to vary from 5.5% to 25.0% in many countries with the average value not exceeding 17% [9,10].

Currently, the diagnosis of gastric cancer is performed by integration of endoscopic, radiographic, ultrasound methods of research. These methods allow to detect the presence of tumor, assess its localization, prevalence of the process, and obtain samples for morphological verification. However, preoperative diagnosis of tumors itself and vascular lesions caused by oncological process (signs that determine operability of gastric cancer) are the source of considerable difficulties. This requires development of new methodological approaches including the use of duplex and three-dimensional ultrasonography [11,12].

Ultrasound method of research has several advantages: noninvasive, highly informative, widespread in clinical practice. Until recent years, organs of the gastrointestinal tract have been studied very rarely. They are still not included in the mandatory list of organs subject to ultrasonography. This is partly caused by some objective reasons that hamper an ultrasound study of hollow organs of the gastrointestinal tract including stomach. These include: presence of a gas bubble dispersing ultrasound vibrations; changeable form of the body due to the change of tone, peristalsis, character and transfer of chimus, etc. [13-15].

In recent years, we can see an increased use of color-coded dopplerographic techniques that help to visualize most of the major vessels and blood flow in the wall of the gut tube and to assess the degree of ischemia [16-18]. However, Doppler characteristics and possibilities of three-dimensional technologies in the diagnosis of tumors of the gastrointestinal tract have not been studied in detail up to date.

The objective was improving the diagnosis of gastric cancer using the methods of ultrasonography (B-mode, duplex scanning, three-dimensional ultrasonography) to assess the extent of local and general prevalence of the cancer.

Materials and Methods

The study included 85 people who were divided into two groups.

The study group: 55 (64.7%) patients suffering from gastric cancer at the age from 36 to 82 yrs who were treated. There were 33 men (60.0%) and 22 (40.0%) women. Clinical, ultrasound, radiological, and morphological methods were conducted in all the patients in the preoperative period. Operative intervention in different volume was carried out in 44 (80.0%) cases; explorative laparotomy, which

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Received: February 27, 2015; **Accepted:** March 26, 2015; **Published:** May 16, 2015

Citation: Pulatova IZ, Isamukhamedova MA (2015) Modern Approach to the Comprehensive Ultrasonography of Gastric Cancer. Biol Med (Aligarh) 7(2): BM-084-15, 5 pages.

established an inoperable tumor process due to its invasion into surrounding organs and major blood vessels, was determined in 7 (12.7%) cases; symptomatic treatment of the disease in advanced cases, in the presence of metastasis, ascites – in 4 (7.3%) cases. All patients had histologically established adenocarcinoma.

The control group: 30 (35.3%) healthy individuals aged from 35 to 80 yrs. Among them there were 19 (63.3%) men and 11 (36.7%) women.

Ultrasound examination was performed on DC-7 (Mindray, China) and SonoAce X8 (Samsung Medison, Korea) devices equipped with convex multifrequency transducers (3.5-5.0 MHz). The program of comprehensive ultrasound techniques included the following methods: transabdominal gray-scale (B-mode) ultrasonography, contrast sonography using degassed liquid in the volume of 500-800 ml by the method of Worlicek *et al.* [19], and three-dimensional reconstruction. In order to assess blood flow in surgically significant vessels (celiac trunk, superior mesenteric artery, splenic vein, left gastric artery), as well as in the gastric wall, we used duplex scanning (pulsed wave dopplerography, color Doppler flow mapping, and energy Doppler).

Ultrasound examination was carried out in several stages, in fasting state.

First stage: general transabdominal sonography of the abdomen, retroperitoneum, and small pelvis.

Second stage: target sonography of the stomach in fasting state with the assessment of the organ's topography, condition of the walls, cavity of the stomach, median M-echo. Thereafter, we carried out contrast sonography of the stomach. We used degassed liquid as the contrast (boiling water, tea) in the volume of 500-800 ml.

Third stage: performing a three-dimensional ultrasonography of the contrasted stomach. This determined the location, extent, and contours of the surround mass formation and other characteristics.

Fourth stage: the study of major vessels (celiac trunk, left gastric and superior mesenteric artery, and splenic vein). Analysis of the blood flow was performed on receiving an optimum image of the vessel in B-mode and on assessing the state of the walls, echogenicity of the lumen, and length of the vessel. Then we differentiated vessels with arterial and venous spectra of the blood flow, performed a quantitative analysis of blood flow velocity curves, and assessed the direction and character of the flow. We have also studied basic quantitative parameters of the blood flow: peak systolic velocity (V_{max}), end-diastolic velocity (V_{min}), and angle-independent resistance index (RI). Thereafter, we detected and assessed the blood flow in the gastric mucosa.

The final step was to clarify localization of metastases in the liver, pancreas, ovaries, lymph nodes, determination of their number, size, and the presence of ascites.

A standard statistical processing of the results was performed. Normally distributed quantitative parameters presented as M ± s, the minimum and the maximum values. Differences were considered statistically significant at $p < 0.05$.

Results and Discussion

Analysis of the results of the comprehensive ultrasonography showed that acoustic shadow of the gas bubble in the projection of the body of the stomach was visualized on two-dimensional gray-scale ultrasonography in all patients of the control group. When contrasting the stomach with degassed liquid in the volume of 500-800 ml, gastric mucosal folds straightened and the gas bubble liquid was replaced, while the thickness of gastric walls did not exceed 6 mm all over its length. Gastric emptying was normal.

Three-dimensional reconstruction allowed to visualize the normal architecture of nonaffected gastric walls. Folding of mucous membrane was clearly marked, the lumen was free.

Single color loci were recorded in normal gastric walls during the study of blood flow in the modes of color Doppler flow mapping and energy of the reflected Doppler signal. Blood flow velocity in the major vessels was in the normal limits [20] (see Table 1).

Typical sonographic sign of gastric cancer was a badge-cockade symptom (affection of a hollow organ) which was observed in 48 (87.3%) patients. These patients had a thickening of gastric walls by more than 15 mm. In 7 (12.7%) patients, the thickness of gastric walls did not exceed 15 mm. Gastric walls has low echogenicity. Median M-echo was deformed (Figure 1).

In 31 (56.4%) patients, we determined an acoustic shadow of the gas bubble. Liquid and heterogeneous contents in the stomach were determined in 9 (16.4%) patients following fasting. There were no contents in the lumen of 15 (27.3%) patients.

At polyprojection scanning, after contrasting with degassed liquid, the cavity of the stomach and gastric wall were visualized throughout all the length (Figure 2).

In 19 (34.5%) patients due to the lesion of pyloro-antral portion of the stomach by tumor, there was significant narrowing of the lumen and delayed evacuation of the fluid, which was a sign of subcompensated stenosis.

All patients had thickening of the walls due to tumor infiltration, violation of a five-layer structure of the walls, and the presence of the tumor formation of different lengths.

In 52 (94.5%) patients, the use of three-dimensional reconstruction of the contrasted stomach allowed for clear visualization of three-dimensional processes in different parts of the body. Neoplastic lesions

Groups	Blood flow	Celiac trunk	Superior mesenteric artery	Left gastric artery	Splenic vein
Control ($n = 30$)	V_{max}, m/s	1.23 ± 0.15	1.41 ± 0.13	0.58 ± 0.11	0.23 ± 0.02
	V_{min}, m/s	0.53 ± 0.04	0.20 ± 0.02	0.16 ± 0.02	0.17 ± 0.02
	RI	0.69 ± 0.04	0.68 ± 0.06	0.72 ± 0.03	–
Main ($n = 55$)	V_{max}, m/s	3.15 ± 0.71*	2.81 ± 0.56*	0.98 ± 0.05**	0.31 ± 0.04
	V_{min}, m/s	0.79 ± 0.12*	1.09 ± 0.33*	0.29 ± 0.06*	0.23 ± 0.03
	RI	0.49 ± 0.19**	0.51 ± 0.11**	0.59 ± 0.06*	–

Note: *Significant difference from the control at $p < 0.05$; ** at $p < 0.01$.

Table 1: Parameters of blood flow in abdominal vessels of the studied patients

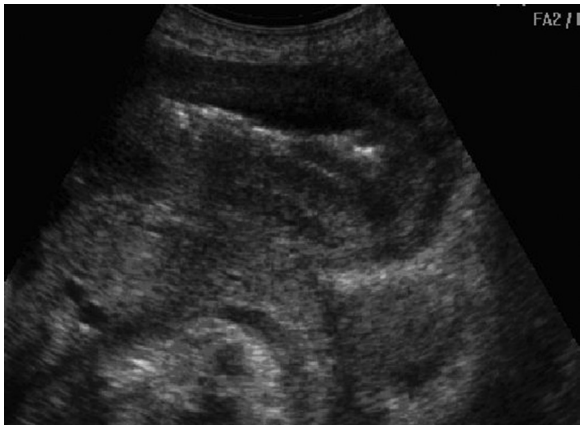


Figure 1: Ultrasound image of gastric cancer spreading to the body of pancreas in B-mode. The body of the stomach with thickened walls and deformation of the middle M-echo can be visualized

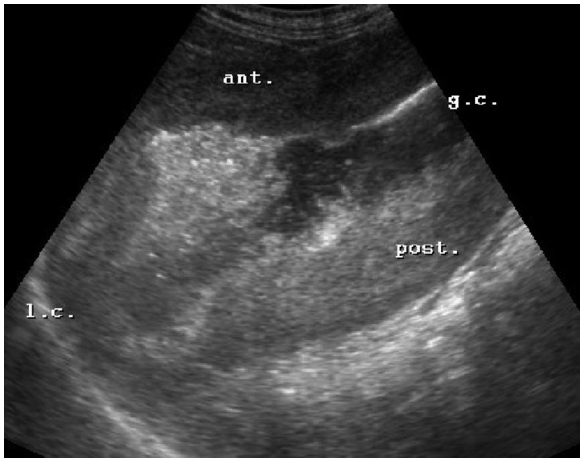


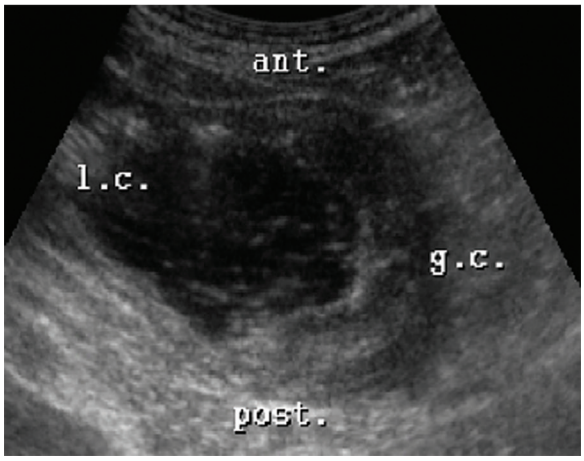
Figure 2: Ultrasound image of gastric cancer (ulcerative–infiltrative form) in B-mode. Thickening of gastric walls with the presence of ulcer on the anterior wall of the organ (contrast sonography) (ant. – anterior wall, post. – posterior wall, l.c. – lesser curvature, g.c. – greater curvature)

were visualized in the form of parietal formations with rough, unequal contours, penetration into the gastric lumen and deforming it. Normal architectonics was also affected. There was thickening of the gastric wall (Figure 3).

On three-dimensional reconstruction, the mass formation was situated in the whole cardiac portion of the stomach in 17 (30.9%) patients, in the body portion – in 17 (30.9%) patients, and in the pyloro-antral portion – in 15 (27.3%) patients. Subtotal lesion of the organ was observed in 3 (5.5%) patients. In 3 (5.5%) patients, three-dimensional ultrasonography was unable to visualize the tumor. In these patients, the tumor was located in the cardiac portion of the stomach, and its size did not exceed 1.5 cm.

Comprehensive ultrasound examination revealed regional lymph nodes affection in 32 (58.2%) patients, liver metastases – in 12 (21.8%) patients, ascites – in 11 (20.0%) patients, splenomegaly – in 6 (10.9%) patients, and metastases to the ovaries (Krukenberg metastasis) – 5 (9.1%) patients that were confirmed by CT and MRI scans and during the surgery.

(a)



(b)

Figure 3: Ultrasound images of gastric cancer (infiltrative form), the contrast study; a – two-dimensional ultrasonography. Wall thickening on the greater curvature of the stomach with thetransition to the anterior and posterior walls of the organ can be visualized (ant. – anterior wall, post. – posterior wall, l.c. – lesser curvature, g.c. – greater curvature); b – three-dimensional ultrasonography. Circularly thickened gastric walls are visualized. Subcompensated stenosis

Echographic signs of tumor vascular invasion in gastric cancer were the following: the presence of the mass lesion adjacent to the blood vessels that were detected in 9 (16.4%) patients; irregular thickening of the vessel wall – 8 (14.5%) patients; discontinuity and filling defects of the vessel in the affected area – in 6 (10.9%) patients; irregular narrowing of the vessel lumen – in 8 (14.5%) patients; irregularity of the vessel walls – 9 (16.4%) patients.

In patients with gastric cancer there was a significant increase in the V_{max} value of the celiac trunk – 2.5 times, in the superior mesenteric artery – 2.0 times, in the left gastric artery – 1.7 times (when compared to the average values of patients from the main and the control group). In patients with gastric cancer in these arteries, there was a significant

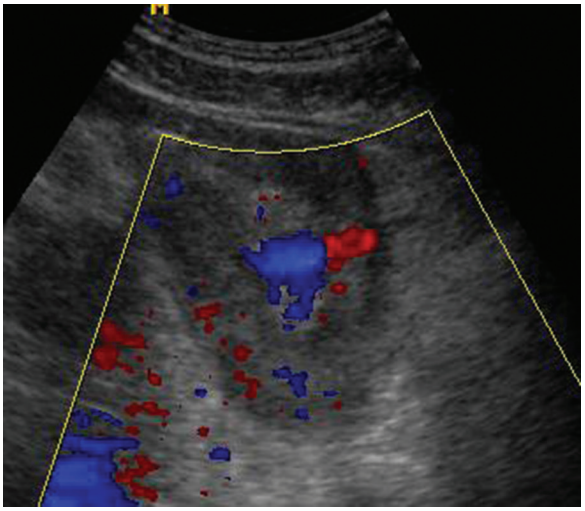


Figure 4: Ultrasound image of gastric cancer (infiltrative form) in the mode of color Doppler flow mapping. Atypical vascularization in the walls of the affected stomach

increase in V_{min} and a significant decrease in RI as compared with normal values. Blood flow velocity in the splenic vein did not differ considerably between groups (Table 1).

A distinctive sign of the gastric cancer was atypical vascularization of varying intensity in the walls of the stomach and tumor (Figure 4).

So, in 14 (25.5%) patients hypervascular lesions of the stomach wall were visualized with the involvement of all layers. Moderate vascularization of the stomach wall was observed in 30 (54.5%) patients, and single color loci were observed in 11 (20.0%) patients.

The invasion of tumor to the surrounding organs and structures (in 7 cases we carried out explorative laparotomy) was intraoperatively confirmed in 13 (23.6%) patients (out of 51 ones taken to the surgery).

For many years, specialists in ultrasound diagnosis have been studying the possibilities of ultrasonography of the stomach in healthy and sick people. Target pattern was first described in 1976 by Lutz and Petzold [21] in patients with gastric tumors. This pattern included an increased echogenicity in the central part of the organ and lowered echogenicity of the stomach wall. Lemeshko suggested the term called "symptom of affection of a hollow organ" (SAHO) in order to denote an ultrasound picture of changes in the gastrointestinal tract, particularly in the stomach lesions [22]. In her following work [23], the researcher studied the changes of the gastric walls in SAHO in more details. Our study showed that the symptom of affection of a hollow organ was detected in 87.3% of patients with gastric cancer.

According to Suk *et al.*, the thickness of the unaffected wall is in the range from 5 to 10 mm [24]. The studies of Liao *et al.* have found that in gastric cancer there is thickening of the stomach walls to over 10.3 mm [25]. In the studies that we reviewed, the wall thickness of unaffected stomach did not exceed 6 mm, while in gastric cancer there was a marked thickening of the wall up to 15 mm.

Woodcock *et al.* were the first who proposed the method of duplex scan. This method made it possible not only to visualize visceral arteries of the abdominal aorta but also to explore their hemodynamic characteristics [26]. Van Petersen *et al.* studied the effect of tumor of gastroduodenal zone on the presence of vascular stenosis of the celiac trunk and its hemodynamic changes [27]. According to Mikhailov and Tuhbatullin [28] and Yan *et al.* [29], malignant lesions of the stomach are characterized by mosaic and mixed types of abnormal blood flow in the blood vessels, reduced resistance index, the blood flow velocity curves have a relatively high diastolic component, while their indices of blood flow have lower values. In our studies, in patients with gastric cancer there was a significant increase in the V_{max} value of the celiac trunk – 2.5 times, in the superior mesenteric artery – 2.0 times, in the left gastric artery – 1.7 times, and a significant decrease in RI in these vessels with the presence of atypical vascularization in the walls of the affected stomach.

Mardanova *et al.* have found that comprehensive transabdominal ultrasonography (B-mode + duplex scanning mode) is highly efficient in determining of the presence of tumor in gastric cancer [30]. The sensitivity of this method according to the authors is 88%, specificity – 89%, and accuracy – 84%. In our studies, the sensitivity of ultrasonography in patients with gastric cancer was 91.5%, specificity – 90.0%, and accuracy – 89.9%. The number of the true-positive results was 52, true-negative – 27, false-positive – 3, and false-negative – 3.

Mitina [31] and Diomidova *et al.* [32] reported on the possibilities of three-dimensional ultrasonography of unaffected stomach. Using a three-dimensional scan, researchers were able to visualize layering of intact gastric wall more clearly. In the works of Tsutsui *et al.* [33] followed by Shi *et al.* [34], there are benefits of three-dimensional ultrasonography in visualization of anatomical and pathological structures of the gastrointestinal tract. Three-dimensional reconstruction of ultrasound imaging provides information that extends the capabilities of traditional two-dimensional ultrasonography, allowing to get an image in three dimensions, assess the condition of the local site and severity of the pathological process. It also allows to characterize shape and type of the tumor that is not always possible in the two-dimensional study with contrast. In our own studies in 94.0% of cases, we were able to visualize the tumor formation on three-dimensional reconstruction of the body.

Conclusion

Two-dimensional ultrasonography provides a measure of the overall prevalence of the tumor process, allows to identify metastases in the regional lymph nodes, liver and other organs, as well as ascites. This is essential when choosing tactics of treatment of patients suffering from gastric cancer. The comprehensive ultrasound study including duplex scanning (color Doppler flow mapping, the energy of the reflected Doppler signal and pulse Doppler) and three-dimensional reconstruction of ultrasound images with contrasting of the stomach allow to determine the location and extent of the malignant process, assess the extent of the tumor invasion into vessels and adjacent organs. This is an important addition to the results of two-dimensional gray-scale ultrasonography.

So, duplex scanning and three-dimensional ultrasonography, along with two-dimensional ultrasound study in B-mode, may be included into the comprehensive survey of patients suffering from gastric cancer, along with radiographic and endoscopic methods. This virtually would not increase the cost of the research due to its performance by one operator.

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Citation: Pulatova IZ, Isamukhamedova MA (2015) Modern Approach to the Comprehensive Ultrasonography of Gastric Cancer. Biol Med (Aligarh) 7(2): BM-084-15, 5 pages.