

• CLINICAL RESEARCH •

Miniature ultrasonic probes for diagnosis and treatment of digestive tract diseases

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Abstract

AIM: To investigate the clinical value of miniature ultrasonic probes (MUPs) for the diagnosis and treatment of digestive tract diseases.

METHODS: Endoscopic ultrasonography (EUS) was performed for patients with its indications with 7.5-20 MHz MUPs and double-cavity electronic endoscope. According to the diagnosis of MUPs, patients who had indications of treatment received endoscopic resection or surgical excision. Postoperative histological results were compared with the preoperative diagnosis of MUPs. A few patients without endoscopic resection or surgical excision were periodically followed up with MUPs.

RESULTS: A total of 537 patients were examined by MUPs, of them, 256 were diagnosed with gastrointestinal submucosal lesions, 146 with pseudo-submucosal lesions, 50 with digestive tract cancers, 17 with peptic ulcer, 11 with cholecystolithiasis, 8 with chronic pancreatitis, and 2 with achalasia and 47 were diagnosed as normal. After MUPs examinations, 220 patients received endoscopic resection or surgical excision, and the postoperative histological results of 211 patients were completely consistent with the preoperative diagnosis of MUPs. The diagnostic accuracy of MUPs was 95.9%. The result of follow-up with MUPs indicated that gastrointestinal leiomyoma, lipoma, phlebotangioma and cyst were unchanged within 1-2 years. The patients who received endoscopic resection or centesis did not have any complications.

CONCLUSION: MUPs are of value in diagnosing gastrointestinal submucosal lesions, staging of digestive tract cancers and biliary-pancreatic diseases. They play a very important role in making therapeutic plans.

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INTRODUCTION

With the development of endoscopic ultrasonography (EUS) in clinical application, great progress has been made in diagnostic specificity and sensitivity of digestive tract diseases. EUS has usually been performed with a standard ultrasonic endoscope since the introduction of EUS with miniature ultrasonic probes (MUPs) in clinical diagnosis in the 1990s^[1]. In August 2000, MUPs series were adopted in the First Affiliated Hospital of Zhejiang University and since then EUS with MUPs have been performed in 537 patients with digestive tract diseases. In the present article, the clinical values of MUPs in the diagnosis of gastrointestinal submucosal lesions, digestive tract cancers, and biliary-pancreatic diseases were analyzed and reported.

MATERIALS AND METHODS

Patients

A total of 537 patients presenting EUS indications were examined by MUPs. Their mean age was 54 years, ranging from 16 to 89 years. There were 280 men and 257 women.

Instruments

Instruments of EUS with MUPs included Fujino EG-410D double-cavity electronic gastroscope, Olympus-100 electronic colonoscope and Fujino SP-70 high-frequency echoprobe system. The frequency spectrum of the probes is between 7.5-20 MHz.

Methods

The preparation before MUPs examinations was the same as that before gastroscopy and colonoscopy examinations. Intramuscular injection of atropine or scopolamine could also be made. According to the information of the location and size of the lesion in gastrointestinal gained by conventional endoscope examinations, microprobes of different frequencies were used. Patients who presented the indications of treatment accepted endoscopic resection or surgical excision according to the diagnosis by MUPs. Postoperative histological examination results of resected lesions were checked with the preoperative diagnosis by MUPs, and for patients with biliary-pancreatic diseases, diagnosis by MUPs was checked with that by ERCP and spiral CT examination. A few patients who did not receive endoscopic resection or surgical excision were periodically followed up with MUPs. The tolerance to EUS with MUPs and complications related to the examination in all these patients were investigated as well.

RESULTS

The results of MUPs examinations of the 537 suspected patients and the histopathologic diagnoses of some cases are summarized in Table 1. After examinations by MUPs, 256 patients were diagnosed with gastrointestinal submucosal lesions, 146 with pseudo-submucosal lesions, 50 with digestive tract cancer, with peptic ulcer, 11 with cholecystolithiasis, 8 with chronic pancreatitis, and 2 with achalasia and 47 were

diagnosed as normal. Among the 256 patients with gastrointestinal submucosal lesions, 162 (64.3%) were diagnosed with leiomyoma. Among the 162 patients with leiomyoma, 96 had esophageal leiomyoma. Of the 96 esophageal leiomyoma cases, 62 had lesions originating from muscularis mucosae and 34 had lesions originating from muscularis propria. Of the 57 gastric leiomyoma cases, 5 had lesions originating from muscularis mucosae and 52 had lesions originating from muscularis propria. Of the 5 duodenal leiomyoma cases, 1 was derived from muscularis mucosae and 4 from muscularis propria. All the 4 cases of colonic leiomyomas were derived from muscularis propria. After MUPs examinations, 122 patients with gastrointestinal true submucosal lesions accepted further treatment of endoscopic resection, surgical excision or puncture. The postoperative pathological diagnosis agreed with the preoperative MUPs diagnosis in 113 cases, thus the accuracy rate of the diagnosis by MUPs was 92.6%. Of the 162 patients with leiomyoma, 86 received either endoscopic resection or surgical excision. In 80 cases, the preoperative MUPs examination results were identical to the postoperative pathological diagnosis. However, the histological results of only 6 patients suffering from leiomyosarcoma (2 cases), gastric neurofibroma, esophageal tuberculosis granuloma, esophageal cyst gland retention, and colonic carcinoid were not consistent with the preoperative diagnoses by MUPs. The accuracy rate of the diagnosis by MUPs was 93%. Among the 146 patients with pseudo-submucosal lesions, 56 were diagnosed with polypus, 37 with inflammatory protruding and thickening of gastrointestinal mucosae, and 53 with extrinsic compression. The polypus and inflammatory protruding were confirmed by pathological biopsy, and the organs of extrinsic compression included spleen (15 cases), gallbladder (9 cases), aorta (8 cases), liver (6 cases), pancreas (4 cases), splenic vein (2 cases), lymph node (3 cases), thoracic vertebrae (2 cases) and mass with unknown nature (4 cases). Of the 11 patients with cholelithiasis, 7 were diagnosed with cholecystolithiasis, and 4 with choledocholith, which was not detected by surface type-B ultrasonography but was confirmed by surgical operation or ERCP. Among the 8 patients with chronic pancreatitis, 4 were diagnosed with pseudocyst of

pancreas, 1 with abscess of pancreas, 1 with distension of main pancreatic duct and 2 with pancreatic echo enhancement. Of the 8 patients, 4 were further confirmed by surgical operation or ERCP. The depth and healing of ulcer were verified by examination of EUS in 17 patients with peptic ulcer. According to the MUPs examination, 47 patients had normal stratification and structure of digestive tract. Of them, 5 patients were diagnosed with duodenal accessory papilla. In addition, some patients with gastrointestinal leiomyoma, lipoma, phlebangioma, cyst, inflammatory protruding or thickening were periodically followed up by MUPs, and the results of examinations showed no changes of these lesions in 1-2 years, but some lesions occurred such as inflammatory protruding, thickening and cyst shrank. All the patients could well tolerate this examination without serious complications such as bleeding, perforation and cardiac or pulmonary accident. No complications occurred in patients who received endoscopic resection or puncture.

DISCUSSION

The diameter of MUPs is small, so it can pass through the biopsy tube of a conventional endoscope and be placed anywhere inside the digestive tract to perform EUS. MUPs can reach or pass any small tubule or narrow space where the standard ultrasonic endoscope can not reach. MUPs do not cause compression on organ structures such as esophagus. MUPs can be easily operated. The frequency range of the probes was broad^[1]. The significance and experiences in using EUS with MUPs for the diagnosis and treatment of digestive tract diseases are as the following.

Value of MUPs in diagnosing gastrointestinal submucosal lesions

Studies have shown that EUS is the best diagnostic method of gastrointestinal submucosal lesions. EUS could not only confirm if the lesion is a true submucosal lesion, but also ascertain accurately the size, location, origin and nature of the lesion^[2-6]. We performed EUS with MUPs, and found 7.5-20 MHz MUPs was very important for the diagnosis of gastrointestinal true submucosal lesions. By this examination, we could

Table 1 MUPs diagnosis of 537 patients and histopathological diagnosis of 211 cases

| Diseases | Esophagus | Stomach | Duodenum | Colon | Biliary tract | Pancreas | Total | Confirmation by pathological examination/operation |
|--|-----------|---------|----------|-------|---------------|----------|-------|--|
| Leiomyoma | 96 | 57 | 5 | 4 | | | 162 | 80/86 |
| Leiomyosarcoma | 3 | 4 | 1 | | | | 8 | 8/8 |
| Varicosis, Phlebangioma | 27 | 13 | 2 | | | | 42 | 3/3 |
| Lipoma | 1 | 4 | 1 | 2 | | | 8 | 3/3 |
| Cyst | 1 | 3 | 1 | 3 | | | 8 | 4/5 |
| Brunner adenoma | | | 5 | | | | 5 | 4/4 |
| Submucosal hematoma of esophagus | 2 | | | | | | 2 | 1/1 |
| Ectopic pancreas | | 18 | | | | | 18 | 7/9 |
| Lymphoma | | 3 | | | | | 3 | 3/3 |
| Polyp | 14 | 32 | 3 | 7 | | | 56 | 26/26 |
| Inflammatory protruding and thickening | 4 | 31 | 2 | | | | 37 | 37/37 |
| Pressure protruding lesions | 10 | 38 | 3 | 2 | | | 53 | 8/8 |
| Cancer | 13 | 23 | | 8 | | 6 | 50 | 42/42 |
| Cholecystolithiasis | | | | | 11 | | 11 | 11/11 |
| Chronic pancreatitis | | | | | | 8 | 8 | 4/4 |
| Peptic ulcer | | 16 | 1 | | | | 17 | |
| Achalasia | 2 | | | | | | 2 | |
| Normal | | | | | | | 47 | |
| Total | 173 | 242 | 24 | 26 | 11 | 14 | 537 | 211/220 |

determine the size, location, number and origin of the lesion. According to the ultrasonic characteristics of lesions, we could also distinguish the nature of different lesions^[7-11]. For example, scanned by MUPs, gastrointestinal leiomyoma presented homogeneous and hypoechoic lesions with a clear margin around the hyperechoic wrapping area, which was derived from muscularis mucosae or muscularis propria (Figure 1A). Gastrointestinal lipoma presented homogeneous and hyperechoic lesions with a distinct margin. The lesion often originated from submucosa (Figure 1B). Gastrointestinal cyst presented echoic lesions with a clear margin and enhancement behind. The lesion was often derived from submucosa (Figure 1C). Ectopic pancreas that often appeared in stomach or duodenum revealed non-homogeneous, middle-hyperechoic or patchy echoic lesions with a tubular structure and thickening of muscular layer. The lesions often originated from submucosa or muscularis propria (Figure 1D). Hemangioma and varicosis often appeared in gastric fundus and esophagus as echoic honeycomb-like lesions, and were easy to be deformed by compression. They mostly originated from mucosae or submucosae (Figure 1E). Our clinical research included not only these common submucosal lesions, but also leiomyosarcoma, lymphoma, carcinoid, neurofibroma, abscess, Brunner's adenoma and hematoma, etc. Leiomyoma was the most common benign tumor in gastrointestinal submucosal lesions, accounting for 64.3% of the total gastrointestinal submucosal lesions. According to our clinical and pathological study on gastrointestinal leiomyoma, leiomyoma mainly occurred in esophagus and stomach, and the incidence in small intestine and colon was much lower than that in esophagus and stomach. The size and layer of the origin of esophageal leiomyoma were obviously different from those of gastric leiomyoma. The majority of esophageal leiomyomas originated from muscularis mucosae, and the size was <1.0 cm. Whereas most of the gastric leiomyomas originated from muscularis propria, and the size was 1-2 cm. Almost all the patients with gastrointestinal leiomyoma only had a single lesion, which often progressed slowly or had no change^[12-14]. Among the 256 patients with gastrointestinal true submucosal lesions, 122 patients accepted further treatment of endoscopic resection, surgical excision, or puncture. The results showed that the size, layer, origin and number of the resected lesions were completely consistent with the diagnoses by MUPs. The nature of lesions was in agreement with preoperative diagnosis in 113 patients, and the diagnostic accuracy rate was 92.6%. Current studies with MUPs revealed its significant value in diagnosing gastrointestinal true submucosal lesions^[15-19]. In patients who were periodically followed, gastrointestinal leiomyoma, lipoma, ectopic pancreas, cyst and hemangioma remained unchanged within 1-2 years, and no obvious clinical symptoms were observed. This observation indicates that those who are old and can not or do not want to accept further treatment, with lesions located at unusual sites, should be regularly followed up.

Value of MUPs in diagnosing gastrointestinal pseudo-submucosal lesions

Scanning MUPs can display clearly the layer structure and adjacent organs of gastrointestinal tract, so that pseudo-submucosal or true submucosal protruding lesions could be accurately identified. According to our clinical experience, pseudo-submucosal lesions mainly included polypus, inflammatory protruding and pressure protruding lesions. Most gastrointestinal tract polypi and inflammatory protruding lesions could usually be diagnosed by conventional endoscopy. In a few patients, the color and structure of polypus or inflammatory prominence were similar to those of the surrounding normal mucosae, so we could not differentiate these lesions from submucosal lesions by conventional

endoscopy. By MUPs, according to the origin, layer structure, and changes of the lesion echoes, we could diagnose the lesions easily. As to some superficial and small lesions, we could not only locate them, but also show the layer structure and relationship of the lesions and gastrointestinal wall more clearly by changing probes with different frequencies. Gastrointestinal tract polypus and inflammatory prominences all originated from epithelia and mucosae. Polypus presented homogeneous or non-homogeneous, middle-hyperechoic lesions without envelope (Figure 1F). The latter manifested thickening or loss of epithelia and mucosae, but the layer, structure and echo of the lesions were all normal (Figure 1G). Our diagnostic accuracy rate of extrinsic compression by MUPs was 100%, the same as that reported by Cletti (1993) and Pfau (2002)^[20-21]. According to the complete layer and structure of gastrointestinal tract, the curved compression adventitia and the cross section images of surrounding tissues and structures, we could diagnose extrinsic compression easily by MUPs, just as by conventional ultrasonic endoscopy. At the same time, we could precisely distinguish most of the tissues and organs that caused the compression. Of the 537 patients, 53 were diagnosed with extrinsic compression, and the major organs that caused the compression were spleen (Figure 1H), gallbladder, aorta (Figure 1I), liver, pancreas, splenic vein, lymph node and thoracic vertebrae, etc. Furthermore, in most patients the compression was caused by the swelling and lesion of organs and tissues. So our clinical research confirmed the incomparable superiority of MUPs in diagnosing polypus, inflammatory protruding and extrinsic compression of gastrointestinal tract that are often difficult to be found out by conventional endoscopy.

Value of MUPs in diagnosing biliary-pancreatic diseases

When we performed EUS, we placed the ultrasonic probes in the gastrointestinal tract. Compared with surface ultrasonography, the probe closer to biliary tract and pancreas could avoid interference of duodenum and gas, so the images of biliary-pancreatic diseases (especially lesions of the lower middle part of common bile duct and ampulla) taken by EUS were clearer than those taken by surface ultrasonography. According to the literature, the diagnostic sensibility and specificity of EUS for choledocholith were 91% and 100% respectively, which were much higher than those of surface ultrasonography and common CT examination, and similar to those of ERCP, but the complications of EUS were much fewer than those of ERCP^[22,23]. In our study, 11 patients were diagnosed with cholelithiasis by a 7.5 MHz microprobe scan (Figure 1J, K). The calculi of the lower part of the common bile duct in 4 of the 11 patients were not detected by surface type B ultrasonography, but confirmed by ERCP or surgical operations. So MUPs are superior to surface ultrasonography and common CT for the diagnosis of calculus of the lower part of the common bile duct, and can greatly improve the diagnostic situations of common bile duct diseases. By MUPs, we could distinguish calculus from tumors in biliary tract by real-time observation and we could also observe the lesions of ampulla directly. Compared with surface ultrasonography, CT, and magnetic resonance cholangiopancreatography (MRCP), MUPs were much superior. Pancreas is deeply located, and its ultrasonic image may be influenced by abdominal gas, so ultrasonography has difficulty to examine it. By examinations with 7.5-12 MHz MUPs, 14 cases were diagnosed with pancreatic diseases. Of them, 8 cases had chronic pancreatitis, including 4 cases of pancreatic pseudocyst (Figure 1L), 1 case of abscess, 1 case of dilation of main pancreatic duct, and 2 cases of pancreatic echo enhancement. The results were consistent with those of spiral CT and ERCP. After examination by MUPs, 9 patients accepted surgical operations and the diagnoses were confirmed by pathologic examinations.

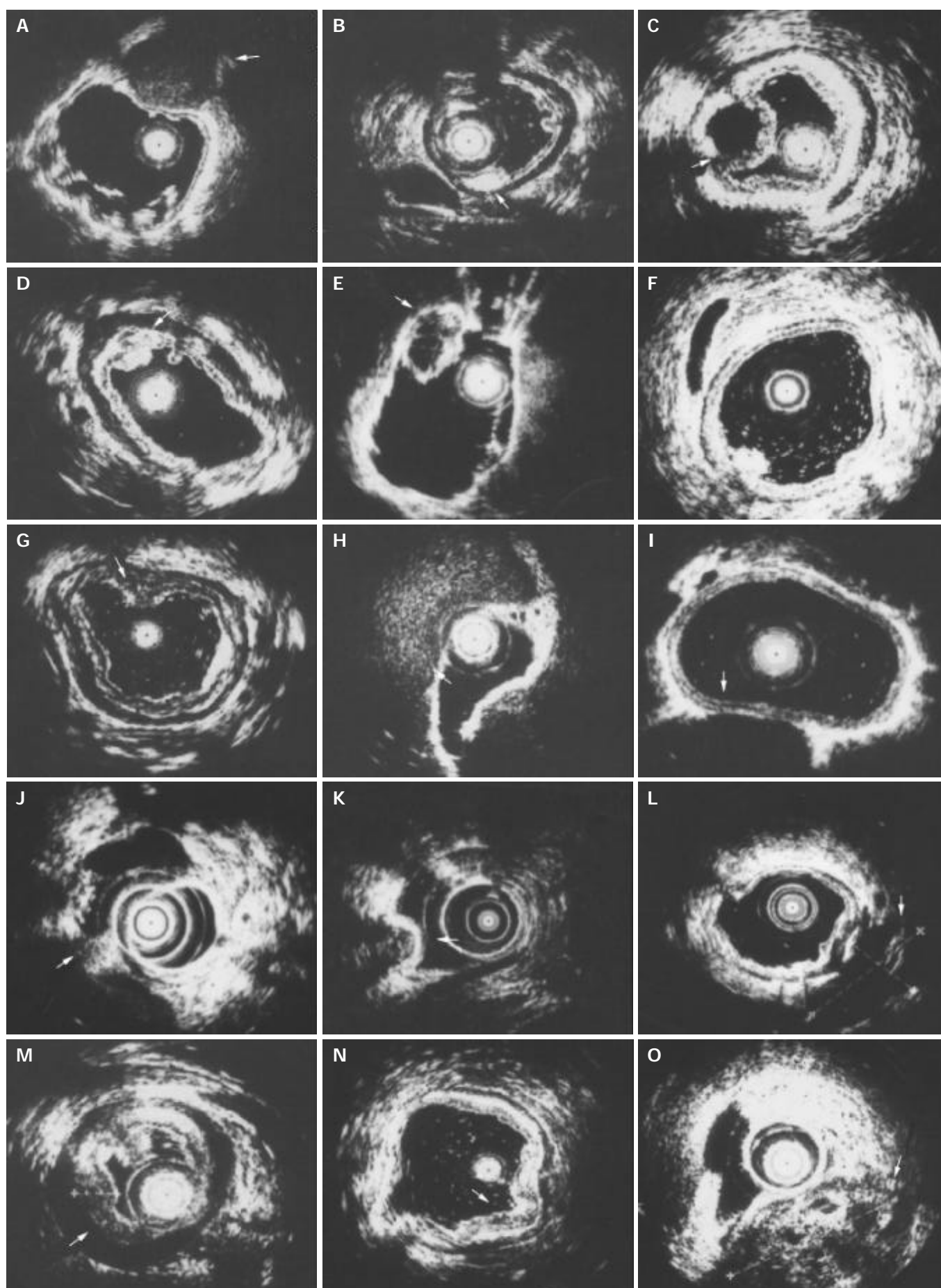


Figure 1 Lesions in digestive tract. A: Gastric leiomyoma, B: Gastric lipoma, C: Gastric cyst, D: Gastric ectopic pancreas, E: Gastric varicosis, F: Gastric polypi, G: Gastric inflammatory protruding, H: Gastric extrinsic compression (spleen), I: Esophageal extrinsic compression (aorta), J: Gallstone, K: Choledocholith, L: Pseudocyst of pancreas, M: Linitis plastica, N: Early gastric cancer, O: Pancreatic cancer.

On the basis of these results, we can make the conclusion that EUS with MUPs for pancreatic diseases is of diagnostic value. It can not only detect pancreatic duct, but also observe the changes of pancreatic parenchyma. Compared with ERCP, it was disadvantageous in displaying the full view of pancreatic duct, but it was advantageous in displaying the echo of pancreas, pancreatic calculus, and cyst. Furthermore, there were no ERCP-related complications in examinations by MUPs. So the diagnosis of pancreatic diseases by MUPs was effective, safe and convenient. Recently, there were reports about ultrasonography performed in biliary-pancreatic duct by MUPs^[1,24]. It can greatly improve the diagnostic situation of common bile duct and pancreatic parenchymal micro-lesions and has become the best diagnostic method for pancreatic endocrine tumors.

Value of MUPs in diagnosing and TNM staging of digestive tract cancer

TNM staging of digestive tract cancers by EUS is generally accepted. The sensitivity and specificity of EUS for TNM staging of digestive tract cancers were obviously higher than those of surface ultrasonography, conventional endoscopy, CT and MRI, etc, but EUS was inferior to CT and MRI in the diagnosis of stage M cancers^[25,26]. With 7.5-20 MHz microprobes, we researched the diagnosis, infiltrating depth and metastasis of surrounding lymph nodes in 50 patients with digestive tract cancers. The results showed the very important value of EUS with MUPs in diagnosing linitis plastica which could not be detected by conventional endoscopy. The growth pattern of this type of gastric cancer was unique. The cancer cells spread and infiltrated into submucosa. So it was hard to be detected by common biopsy. But it had special ultrasonic imaging changes which manifested obviously in diffuse thickening of gastric wall, loss of layer structure and hypoechoic lesion, etc. (Figure 1M). According to these ultrasonographic changes, 8 patients who were diagnosed with linitis plastica were confirmed by surgical operations. Investigations abroad have shown that the diagnostic accuracy rate of EUS for early stage gastrointestinal tract cancers was higher than that by any other examination^[24]. Our study also demonstrated that the depth of infiltration and surrounding lymph node metastasis in digestive tract cancers could be diagnosed by MUPs. 12-20 MHz microprobes could display the infiltrating depth of tumors in gastrointestinal wall clearly. A 7.5 MHz probe could show infiltrations in adjacent tissues, organs and lymph nodes, then we could judge whether the cancer lesion was in early stage (Figure 1N) or advanced stage (Figure 1O). The diagnoses by MUPs in 42 patients who received surgical operation or endoscopic resection were consistent with the pathological diagnoses. It is concluded that MUPs can be applied to TNM staging of digestive tract cancers. MUPs are superior to standard ultrasonic endoscopy because it can be inserted into the narrow gastrointestinal tract tumor infiltration or into other small tubules.

Value of MUPs in guiding treatment of digestive tract diseases

Our clinical research demonstrated that MUPs could not only diagnose digestive tract diseases, but also provide treatment plans for these diseases^[27-30]. MUPs had a very important diagnostic value in deciding the size, location, layer origin and nature of gastrointestinal submucosal lesions. By this examination, leiomyoma, lipoma and ectopic pancreas originating from above submucosae received endoscopic resection. Cysts derived from submucosa were treated by endoscopic puncture and aspiration. The procedure was effective, safe, economical and simple, and resulted in microtraumas only. Submucosal lesions originating from muscularis propria or adventitia were regarded as contraindications for endoscopic resection. The patients received

surgical operation or thoracoscopy or laparoscopy. Patients who did not undergo, or were unfavorable to undergo operations were followed up periodically; therefore, complications such as perforation were avoided. MUPs helped us in ascertaining the indications of endoscopic resection in patients with early stage gastrointestinal tract cancer. They also helped us in formulating scientific, reasonable treatment plans for patients with median or advanced stage of cancer. With the modality, hemangioma and varicosis in gastrointestinal tract were diagnosed, unnecessary biopsy and resection were avoided, and massive hemorrhage was prevented. The effective differentiation of inflammatory protruding from pressure protruding lesions helped formulate a correct treatment regimen and give up explorative operation. In addition, difficult biliary-pancreatic diseases could be diagnosed by MUPs; patients could be treated promptly and effectively. In conclusion, MUPs can greatly improve the accuracy rate of diagnosis and treatment of digestive tract diseases.

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