Role of Endoscopic Ultrasound in Gastrointestinal Surgery

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Abstract Endoscopic Ultrasound is an emerging diagnostic tool in the field of Gastrointestinal Surgery. Our review article focuses on role of EUS in staging cancers (esophageal, gastric, biliary and rectal), detection of bilio-pancreatic calculi and diagnosis of chronic pancreatitis. Potential for performing EUS based therapeutic interventions are been explored and looks promising from the initial reports.

Keywords Endoscopy · Ultrasonography · Biliary disease · Pancreas

Background

In medicine, ultrasound was introduced for human brain and ventricle imaging by Dussik et al. [1]. Since then, there has been a steady progress of its usage in various branches of medical field over the past five decades. Ludwig pioneered the usage of ultrasonic technique to visualize the gallbladder and its pathology [2]. But its role was actually expanded by Wild who studied gastric cancers and researched intestinal

wall anatomy and introduced rectal scanner depicting the various layers of the bowel wall [3]. In Japan, Watanabe was looking at prostate cancer using “ultrasonic chairs” with a transrectal internal probe [4]. It was one of the earliest endoscopic ultrasonography reports, primarily for detection of prostate cancer. DiMagno was performing endoscopic ultrasound (EUS) in canines with an 8 cm long, rigid tip to obtain high-resolution images of various anatomic structures [5]. Strohm studied various hepatobiliary and pancreatic disorders with EUS in 18 subjects and was able to identify important anatomic structures of clinical significance, such as the common bile duct (CBD), superior mesenteric vein, inferior vena cava, pancreatic duct, and aorta [6]. Post-1990s, due to advancement in endoscopy and introduction of smaller transducers, flexible videoendoscope, higher-resolution images, and linear array technology, EUS is considered to be a safe and vital tool for performing fine needle aspiration (FNA). Ultrasound has vastly evolved from being noninvasive to invasive and able to perform tissue diagnosis. This review article focuses on different clinical situations in surgery where EUS has been validated to be an important tool not only for decision making but also for treatment plan.

Instrumentation

To perform EUS, an ultrasonic transducer is attached to the tip of the echoendoscope and the scopes are oblique viewing endoscopes with up to 360° of imaging. Two types of echoendoscopes are used to perform EUS, radial and linear. A new development is the forward-viewing EUS, which is useful in therapeutic cyst drainage [7]. The axis of radial endoscopes is perpendicular to the plane of scanning, and images are seen similar to those seen in computed tomography. It has a

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small accessory channel that allows for small mucosal biopsies, but only a portion of the needle is seen during the procedure; hence, it is used mostly for diagnostic indications. Whereas in linear endoscopes the entire length of the needle is visualized while performing biopsies and its scanning plane is parallel to the long axis of the endoscope, its role is more in EUS-guided FNA and therapeutic indication. The EUS is connected to a processor that enables to provide feedback in the form of images. Probes as thin as diameter of 2–2.6 mm, called “miniprobos” or “catheter probes” with radial echoendoscopes and higher resolution and frequency, ranging between 12 and 30 MHz are also in clinical use.

Anatomy of Bowel Wall with EUS

The gastrointestinal wall is seen as a five-layered structure with EUS—two layers of mucosa, one layer each of submucosa, muscularis, and subserosa/adventitia. Mucosa is divided into the first layer of superficial mucosa, which appears as a hyperechoic layer, and the second layer of deep mucosa, which is hypoechoic. The third layer is hyperechoic submucosa. The fourth layer is muscularis propria, which appears hypoechoic, and the fifth layer is adventitial connective tissue, which is hyperechoic. With miniprobos using 20 MHz, this five-layered structure is seen as nine-layered structure; mucosa is seen as four layers—one layer of submucosa, three layers of muscularis propria, and one layer of adventitia.

Indications for EUS

- Staging of cancers: esophageal, gastric, biliary, pancreatic, and rectal cancers
- Detection of calculi: the common bile duct and pancreatic duct
- Evaluation: submucosal and extramucosal lesions, thickened gastric folds, pancreatic lesions
- Diagnosis of chronic pancreatitis
- Therapeutic scope: EUS drainage of pancreatic pseudocysts, celiac plexus block for advanced pancreatic cancers, EUS-guided biliary drainage, drainage of intra-abdominal collections

Esophageal Cancer

Accurate staging of esophageal cancer predicts the treatment and prognosis in the current era. EUS helps to delineate the layers of the esophagus and thus it is a useful staging instrument for esophageal cancers in combination with CT

and PET scans (Fig. 1). The use of EUS-guided FNA has made it possible to achieve a tissue diagnosis with nodal staging, especially the celiac nodes. Only in 30% of patients with advanced esophageal cancers presenting with luminal obstruction, complete EUS staging is not possible [8].

Endoscopic mucosal resection or endoscopic submucosal dissection is performed on superficial esophageal tumors (seen confined to the mucosa and the lamina propria is not involved), which can be easily detected by EUS. The accuracy of EUS high-frequency probes in detecting mucosal cancers ranges from 81 to 100%, sensitivity is 100%, and low specificity of 81% for preoperative EUS detection of submucosal tumors [9].

Locoregional staging of esophageal cancer is best mapped using EUS as compared to CT as regard to tumor size and invasion (85% vs. 45%) and lymph node involvement (77% vs. 54%) [10]. van Westreenen et al. showed that the number of indicated cancer surgeries decreased from 44 to 21% for esophageal cancer when CT alone as compared to triple-array tests of CT, PET, and EUS for staging of the disease [11]. Post-chemoradiation, the accuracy of EUS is decreased and it cannot differentiate between fibrosis, inflammation, and recurrent disease.

Stomach Cancer

EUS is an established tool for the evaluation of gastric cancer, lymphoma, and prominent gastric folds. EUS can identify diffuse thickening of the gastric wall with hypoechoic or heterogeneous acoustic images or distortion of the normal layers of the wall in gastric cancer (Fig. 2). The accuracy of EUS in T staging is 80% compared to CT (15–43%) and similarly higher for EUS in N staging as 70% compared to CT (15–43%) [12].

Gastric lymphoma appears as an infiltrative lesion with hypoechoic infiltration of the deep mucosa and submucosa,

Fig. 1 EUS depicting esophageal lesion

Fig. 2 EUS showing a lesion in stomach extending up to the muscularis propria and the arrow pointing at the muscularis propria

and EUS facilitates imaging and performing FNA biopsy to make the diagnosis. Lipomas are seen arising from the submucosa with a homogenous hyperechoic pattern compared to gastrointestinal tumors (GIST) that are seen arising from muscularis propria with the hypoechoic pattern by EUS (Fig. 3).

Biliary Tree

Staging of pancreaticobiliary cancer, detection of the CBD or pancreatic calculi, or evaluation of biliary strictures has clearly paved the way for EUS. In biliary strictures, intraductal ultrasound (IDUS) combined with biopsy has shown increased accuracy of endoscopic retrograde cholangiopancreatography (ERCP). EUS is also helpful in detecting microlithiasis in subjects with pancreatitis of idiopathic etiology. For detection of CBD calculi, magnetic resonance cholangiopancreatogram (MRCP) is a noninvasive procedure and more accurate than CT, but cannot be performed in patients with the pacemaker, cerebral aneurysm clips, or those who are claustrophobic. In such patients, EUS is better

Fig. 3 EUS showing leiomyoma of stomach

than MRCP/ERCP with a specificity of detecting CBD calculi (Figs. 4 and 5) as high as 98% [13]. EUS is also better for stones <3 mm, and an EUS-based risk stratification strategy for CBD stones avoids unnecessary ERCPs.

Pancreatic Cancer

Pancreatic cancer has a high mortality rate and its presentation is usually in an advanced state of disease forming an unresectable tumor, hence the low median survival of approximately 4 months in untreated patients. The 5-year survival rate reaches 25% if surgery can achieve clear margins and negative lymph nodes [14]. Surgical treatment and diagnosis of pancreatic cancer is challenging due to its complex regional anatomy, and procuring a tissue diagnosis is not easy. Prior to EUS, definitive diagnosis of pancreatic masses is achieved by surgical or CT-guided FNA or endoscopic retrograde ERCP brush cytology. CT-guided biopsy has a risk of peritoneal dissemination of disease and a false-negative rate of 20% [15, 16] whereas ERCP brush cytology has a false-negative rate of nearly 30% [17]. The sensitivity to detect pancreatic tumors using EUS ranges from 85 to 100% in different studies [18–20].

EUS-FNA has revolutionized the tool of decision making in pancreatic cancer. In pancreatic cancer, EUS-FNA can be used to determine a diagnosis of malignancy in a patient with unresectable mass prior to adjuvant chemotherapy/radiotherapy or in a patient to achieve a definitive diagnosis prior to major surgical resection. It can also play a role to exclude other tumor types (lymphoma, small cell metastasis, or neuroendocrine tumor) or to document the absence of malignancy in difficult cases. The overall sensitivity and specificity of EUS-FNA for detecting pancreatic tumor is 85 and 98%, respectively, but a negative biopsy does not necessarily

Fig. 4 EUS findings seen in a case of carcinoma of gall bladder

Fig. 5 EUS showing the sludge in the common bile duct and the arrow pointing at the sludge

rule out the possibility of pancreatic cancer. Post-EUS-FNA complication is rare and includes pancreatitis, infection, and bleeding. EUS is best suited for locoregional staging and has a role in detection of small, occult liver metastases in patients with pancreatic tumors and an emerging role in locating occult pancreatic tumors in patients with liver metastases of unknown primary. Sensitivity of EUS has been on the higher side (93%) compared to CT (53%) and MRI (67%) for detecting tumors <3 cm, and for tumors <2 cm is 90, 40, and 33%, respectively [21].

To study tumor invasion of the portal vein, EUS is highly sensitive than CT or angiography. The specificity and accuracy of EUS to detect vascular invasion is 71 and 81% compared with 71 and 38% for angiography [21–23]. But CT scan is a better staging modality for celiac artery and mesenteric artery involvement compared to EUS. Hence, from the published data and clinical experience, EUS and CT are complementary for staging a patient with pancreatic cancer (Figs. 6 and 7). For CBD strictures and cholangiocarcinomas, ERCP is the ideal modality of investigation, but a definitive tissue diagnosis of a neoplastic stricture can be made by EUS-FNA. The sensitivity of EUS-FNA in biliary strictures ranges from 86 to 89% and specificity ranges from 89 to 100% [24].

Intraductal Ultrasound

IDUS is performed by insertion of an ultra-thin (2 mm) probe directly into the pancreatic duct during ERCP and is

Fig. 6 EUS depicting a lesion in the pancreatic head

Fig. 7 EUS depicting a lesion in the pancreatic ampulla

used to stage biliary strictures and neuroendocrine tumors. IDUS is very useful for preoperative localization of pancreatic endocrine tumors by tattooing with injecting India ink and helps to remove the tumor laparoscopically also. IDUS criteria suggesting malignancy include hypoechoic mass infiltrating surrounding tissue planes, heterogeneity of the internal echo pattern, notching or irregularity of outer border, a papillary surface, and disruption of the normal sonographic duct structure. In bile duct carcinomas, IDUS can improve the accuracy of local tumor staging, but its limitation is assessing the depth of tumor penetration outside the hepatoduodenal ligament, assessing distant metastasis, and inability to perform FNA.

Chronic Pancreatitis

Diagnosing chronic pancreatitis is a difficult task during the early phase of disease. Imaging modalities including CT, MRI, secretin simulation test, MRCP, and ERCP are useful to detect chronic pancreatitis based on pancreatic parenchymal and ductal changes. EUS has played an important role in detecting chronic pancreatitis with a much lower incidence of postprocedural pancreatitis as compared to ERCP. EUS can identify pancreatic parenchymal changes (hyperechoic foci with shadowing, lobularity with or without honeycombing, cysts, and stranding) and ductal changes (main pancreatic duct calculi, irregular ductal contour, dilated side branches, and hyperechoic main ductal margin) and help to diagnose chronic pancreatitis, based on the Rosemont classification [25].

Rectal Cancer

Endoluminal coils and MRI are routinely employed to determine depth of invasion and lymph node spread in rectal cancers. The accuracy of EUS is superior to CT and MRI and cost-effective for rectal cancers. In a study, abdominal CT plus EUS was the most cost-effective approach (US \$24,468/year) compared with CT with pelvic MRI (US

\$24,870) and CT alone (US\$26,076) for proximal rectal tumors [26].

The accuracy of CT for T staging in rectal cancer ranges from 65 to 75%, MRI from 75 to 85%, and highest for EUS ranging from 80 to 95%. Harewood et al. studied 80 prospective rectal cancer patients, with incorporation of EUS resulted in change of management in 31% of patients. T-staging accuracy was 71% for CT compared to 91% for EUS [27]. This accuracy declines after radiation because of peritumor edema and inflammatory and fibrotic changes in perirectal fat, but bowel staples do not interfere with EUS imaging.

Anal Sphincters, Fecal Incontinence, and Anal Abscesses

The detection of complex perianal abscesses and the mapping of complex fistulas have been fully achieved with anal ultrasound. EUS has revolutionized the imaging of the perianal area sphincter complex. Deen et al. performed endoanal ultrasound in 44 patients with fecal incontinence undergoing pelvic floor repair. All external sphincter defects seen by EUS were confirmed at operation, and in 21 of 22 patients, the internal sphincter defects were identified by EUS. The sensitivity was 100% for both sphincters, and specificity was 100 and 95.5% for the external and internal anal sphincters, respectively [28].

Meyenberger et al. performed EUS in 28 prospective patients with fecal incontinence undergoing surgical repair [29]. EUS identified all the external and internal anal sphincter defects and correctly excluded an external anal sphincter defect in 15 of 18 patients. Sultan et al. conducted a study on 12 consecutive patients with fecal incontinence who were undergoing sphincter repair surgery and performed clinical assessment, anal manometry, concentric needle EMG mapping, anal EUS, and histology of the excised defect [30]. Anal EUS aptly detected 9 cases of 12 patients who had defects of external anal sphincter at surgery. Thus, the accuracy was highest for EUS at 100% for detecting sphincter injury, compared with an accuracy of 75% each for manometry and electromyography, and lowest of 50% for clinical assessment.

Therapeutic Indication for EUS

EUS has played a major role in chronic pancreatitis and advanced pancreatic cancer patients with unbearable pain. EUS-guided celiac ganglion block or neurolysis for pain control is well documented [31]. Pancreatic pseudocysts can be drained using EUS with visualization of gastric, duodenal, and cyst wall vessels using the Doppler mode of sonography, without any risk of forming cutaneous fistulas

[32, 33]. Benefits of forward-viewing EUS scope in drainage of pseudocysts. In failed ERCP-bile duct/pancreatic duct cannulations, EUS has been successful in performing cholangiography or pancreatography. Maranki et al. have shown EUS having an overall success rate of 84% with 16% complication rate and no procedure-related mortality from a series of 49 patients with failed ERCP [34]. Clinical trials are being performed to study the role of various antitumor agents (being injected, EUS-guided) in unresectable pancreatic cancer [35–37]. Lah et al. have performed EUS-guided brachytherapy to malignant perigastric lymph node in a patient with recurrent esophageal cancer [38]. Similar case reports of performing EUS-guided ethanol injection into a gastrointestinal tumor or injecting paclitaxel post-ethanol lavage into pancreatic cystic tumors have been published [39, 40].

EUS, the combined device of endoscopy with ultrasound, has come a long way from being one more imaging tool for the gastroenterologist to a therapeutic tool with multiple indications, and its role is still developing.

References

1. Dussik KT, Dussik F, Wyt L (1947) Auf dem Weg zur Hyperphonographie des Gehirnes. *Wien Med Wochenschr* 97:425–429
2. Ludwig GD, Struthers FW (1949) Considerations underlying the use of ultrasound to detect gallstones and foreign bodies in tissue. Naval Medical Research Institute Reports, Project #004 001, Report No. 4, June
3. Wild JJ (1950) The use of ultrasonic pulses for the measurement of biological tissue changes. *Surgery* 27:183–187
4. Watanabe H, Kato H, Tanaka M et al (1968) Diagnostic application of ultrasonotomography for the prostate. *Jpn J Urol* 59:273–277
5. DiMagno EP, Buxton GL, Regan PT et al (1980) Ultrasonic endoscopy. *Lancet* 12:241–244
6. Strohm WD, Phillip J, Hagenmuller F et al (1980) Ultrasonic tomography by means of an ultrasonographic fiberendoscope. *Endoscopy* 12:241–244
7. Voermans R, Eisendrath P, Bruno M, Le Moine O, Devière J, Fockens P, the ARCADE group (2007) Initial evaluation of a novel prototype forward-viewing US endoscope in transmural drainage of pancreatic pseudocysts. *Gastrointest Endosc* 66:1013–1017
8. Van Dam J, Rice TW, Catalano MF, Kirby T, Sivak MV (1993) High grade malignant stricture is predictive of esophageal tumor stage. Risks of endosonographic evaluation. *Cancer* 71:2901–2917
9. Scotinotis IA, Kochman ML, Lewis JD et al (2001) Accuracy of EUS in the evaluation of Barrett's esophagus and high-grade dysplasia or intramucosal carcinoma. *Gastrointest Endosc* 54:689–696
10. Rosch T, Dittler HJ, Lorenz R et al (1992) The endosonographic staging of pancreatic cancer. *Dtsch Med Wochenschr* 117:563–569
11. van Westreenen HL, Heeren PA, van Dullermen HM et al (2005) Positron emission tomography with F-18-fluorodeoxyglucose in a combined staging strategy of esophageal cancer prevents unnecessary surgical explorations. *J Gastrointest Surg* 9:54–61
12. Botet JF, Lightdale CJ, Zuaber AG, Gerdes H, Winawer SJ, Urmacher C et al (1991) Preoperative staging of gastric cancer: comparison of EUS and dynamic CT. *Radiology* 181:426–432

13. Liu CL, Lo CM, Chan JK et al (2000) EUS for detection of occult cholelithiasis in patients with idiopathic pancreatitis. *Gastrointest Endosc* 51:28–32
14. Stephens J, Kuhn J, O'Brien J et al (1997) Surgical morbidity, mortality, and long-term survival in patients with peripancreatic cancer following pancreaticoduodenectomy. *Am J Surg* 174:600–604
15. Murr MM, Sarr MG, Oishi AJ, van Heerden JA (1997) Pancreatic cancer. *CA Cancer J Clin* 44:304–318
16. Bret PM, Nicolet V, Labadie M (1986) Percutaneous fine-needle aspiration biopsy of the pancreas. *Diagn Cytopathol* 2:221–227
17. Lee JG, Leung J (1998) Tissue sampling at ERCP in suspected pancreatic cancer. *Gastrointest Endosc Clin North Am* 8:221–235
18. Eloubeidi MA, Jhala D, Chhieng DC et al (2003) Yield of endoscopic ultrasound-guided fine-needle aspiration biopsy in patients with suspected pancreatic carcinoma. *Cancer* 99:285–292
19. Gress F, Gottlieb K, Sherman S et al (2001) Endoscopic ultrasonography-guided fine-needle aspiration biopsy of suspected pancreatic cancer. *Ann Intern Med* 134:459–464
20. Harewood GC, Wiersema MJ (2002) Endosonography-guided fine needle aspiration biopsy in the evaluation of pancreatic masses. *Am J Gastroenterol* 97:1386–1391
21. Ahmad NA, Lewis JD, Siegelman ES et al (2000) Role of endoscopic ultrasound and magnetic resonance imaging in the preoperative staging of pancreatic adenocarcinoma. *Am J Gastroenterol* 95:1926–1931
22. Rosch T, Dittler HJ, Strobel K et al (2000) Endoscopic ultrasound criteria for vascular invasion in the staging of cancer of the head of the pancreas: a blind reevaluation of videotapes. *Gastrointest Endosc* 52:469–477
23. Brugge WR, Lee MJ, Kelsey PB et al (1996) The use of EUS to diagnose malignant portal venous system invasion by pancreatic cancer. *Gastrointest Endosc* 43:561–567
24. Fritscher-Ravens A, Broering DC, Knoefel WT et al (2004) EUS-guided fine-needle aspiration of suspected hilar cholangiocarcinoma in potentially operable patients with negative brush cytology. *Am J Gastroenterol* 99:45–51
25. Catalano MF, Sahai A, Levy M et al (2009) EUS-based criteria for the diagnosis of chronic pancreatitis: the Rosemont classification. *Gastrointest Endosc* 69:1251–1261
26. Harewood GC, Wiersema MJ (2002) Cost-effectiveness of endoscopic ultrasonography in the evaluation of proximal rectal cancer. *Am J Gastroenterol* 97:874–882
27. Harewood GC, Wiersema MJ, Nelson H et al (2002) A prospective, blinded assessment of the impact of preoperative staging on the management of rectal cancer. *Gastroenterology* 123:24–32
28. Deen KI, Kumar D, Williams JG et al (1993) Anal sphincter defects: correlation between endoanal ultrasound and surgery. *Ann Surg* 218:201–205
29. Meyenberger C, Bertschinger P, Zala GF et al (1996) Anal sphincter defects in fecal incontinence: correlation between endosonography and surgery. *Endoscopy* 28:217–224
30. Sultan AH, Kamm MA, Talbot IC et al (1994) Anal endosonography for identifying external sphincter defects confirmed histologically. *Br J Surg* 81:463–465
31. Wiersema MJ, Wiersema LM (1996) Endosonography-guided celiac plexus neurolysis. *Gastrointest Endosc* 44:656–662
32. Francois E, Kahaleh M, Giovannini M et al (2002) EUS-guided pancreaticogastrostomy. *Gastrointest Endosc* 56:128–133
33. Kozarek RA, Brayko CM, Harlan J et al (1985) Endoscopic drainage of pancreatic pseudocysts. *Gastrointest Endosc* 31:322–327
34. Maranki J, Hernandez AJ, Arslan B et al (2009) Interventional endoscopic ultrasound-guided cholangiography: long-term experience of an emerging alternative to percutaneous transhepatic cholangiography. *Endoscopy* 41:532–538
35. Chang KJ, Nguyen PT, Thompson JA et al (2000) Phase I clinical trial of allogenic mixed lymphocyte culture (cytoimplant) delivered by endoscopic-ultrasound guided fine-needle injection in patients with advanced pancreatic carcinoma. *Cancer* 88:1325–1335
36. Hecht JR, Bedford R, Abbruzzese JL et al (2003) A phase I/II trial of intramural endoscopic ultrasound injection of ONYX-015 with intravenous gemcitabine in unresectable pancreatic carcinoma. *Clin Cancer Res* 9:555–561
37. Chang KJ, Senzer N, Chung T et al (2004) A novel gene transfer therapy against pancreatic cancer (TNFerade) delivered by endoscopic ultrasound (EUS) and percutaneously guided fine needle injection (FNI). *Digestive Disease Week*, oral presentation; 59:AB92
38. Lah JJ, Kuo JV, Chang KJ et al (2005) EUS-guided brachytherapy. *Gastrointest Endosc* 62:805–808
39. Gunter E, Lingenfelter T, Eitelbach F et al (2003) EUS-guided ethanol injection for treatment of a GI stromal tumor. *Gastrointest Endosc* 57:113–115
40. Oh H, Seo DW, Lee TY et al (2008) New treatment for cystic tumors of pancreas: EUS-guided ethanol lavage with paclitaxel injection. *Gastrointest Endosc* 67:636–642