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MINIREVIEWS

Review of current and evolving clinical indications for endoscopic ultrasound

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Abstract

For the first several years after its development, endoscopic ultrasound (EUS) was primarily limited to identification of pancreatic malignancies. Since this time, the field of EUS has advanced at a tremendous speed in terms of additional clinical diagnostic and therapeutic uses. The combination of ultrasound with endoscopy provides a unique interventional modality that is a minimally invasive alternative to various surgical interventions. Given the expanding recommended indications for EUS, this article will serve to review the most common uses with supporting evidence, while also exploring innovative endeavors that may soon become common clinical practice.

Key words: Endoscopic ultrasound; Pancreatic carcinoma; Celiac plexus neurolysis; Mediastinal lymphadenopathy; Pancreatic fluid collection

Core tip: Endoscopy has presented the opportunity to improve outcomes and lessen complications in a multitude of diseases and disorders. Endoscopic ultrasound (EUS) in particular has been at the forefront in the development of novel treatment and diagnostic methods. While there have been prior articles reviewing common indications for the clinical use of EUS, the sheer volume of recent studies centered on this modality denotes an opportunity to provide an update on that information. Additionally, recent reports of using EUS with innovative techniques, such as anal dyssynergia refractory to standard therapy, warrant discussion in this forum.

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INTRODUCTION

Advancement in the clinical application and use of endoscopic ultrasound (EUS) in recent years has transformed the field of gastroenterology, with the ability to identify and manage a wide variety of disorders, even extending beyond the gastrointestinal tract (GIT). EUS combines endoscopy with intraluminal ultrasonography using a high frequency transducer to produce high-resolution ultrasound (US) images. Prior to its development in the early 1980s, external US imaging was the primary means of diagnosing clinical problems related to the biliary system. However, trans-abdominal US was limited in providing a diagnosis in 30% of cases secondary to the presence of intestinal gas obstructing views[1].

SRI international (Menlo Park, California) produced a high-resolution ultrasonic probe used in conjunction with a side-viewing endoscope with which to evaluate the ability to identify important vasculature and organs within the upper abdomen. This prototype EUS was used in a canine as the 80-mm rigid end prevented safe use in humans; it demonstrated real-time images of the aorta, spleen, gallbladder, left kidney and gastric rugae, as well as the hepatic and portal venous systems[1].

The original EUS prototype to be used in humans was developed by Olympus Opt. Company (Tokyo, Japan) using a conventional gastroscope[2]. This instrument consisted of attaching an ultrasonic probe to the rigid end of a fiberscope which transmitted at a frequency of 5 MHz to a depth of 3 cm. Strohm *et al*[2] conducted a study in which this endoscope model was used to identify organs proximal to the stomach in 18 patients. Using the aorta and vena cava as landmarks, the pancreas was identified and measured in 9 of 18 patients. The gallbladder and distal bile duct were also found on imaging in some patients, but the scope's limited mobility prevented passage through the pylorus and, thus, visualization of the duodenum. They compared the quality of these images to those obtained with conventional US, and discovered that those obtained *via* EUS appeared equivocal. This new EUS, however, provided sharper visualization of the distal common bile duct (CBD) than transabdominal US[2].

Both studies demonstrated a new means of acquiring high-resolution views of various organs and vessels that with further development could prove to be superior to transcutaneous US[1,2]. With improvement in the echoendoscope, various groups began applying this technology to advance clinical diagnoses of upper abdominal pathology. Current guidelines for the diagnostic indication of EUS produced by the American Cancer Society and American Society for Gastrointestinal Endoscopy (ASGE) include evaluation of upper gastrointestinal malignancies, mediastinal adenopathy, pancreatic lesions and cancers, and submucosal tumors[3,4]. The use of EUS has expanded beyond purely investigative uses to also become a minimally invasive means of therapeutic intervention. This article will review the primary clinical uses for EUS along with fundamental supporting study data.

Diagnostic indications

Pancreatic cancer: EUS was first evaluated for its efficacy in confirming suspected pancreatic carcinoma in the mid-1980s. These early studies revealed EUS was superior to trans-abdominal US, including differentiating pancreatitis from a pancreatic tumor and identifying ampullary and papillary tumors[4]. After multiple studies throughout the 1990s, EUS sensitivity approached beyond 90% in detecting malignant pancreatic tumors[5]. One such study from Akahoshi *et al*[6] sought to analyze the precision of EUS in earlier diagnosis of pancreatic cancer with accurate tumor staging. In this era, pancreatic cancers were identified primarily by abnormal laboratory results or abdominal US and computed tomography (CT), and thus found at very advanced stages. In the study's evaluation of 96 patients suspected of having pancreatic carcinoma based on abnormal labs or imaging and their clinical presentation, diagnosis was confirmed by post-operative histology, autopsy, or surgical exploration in non-resectable cases. They found EUS had a sensitivity of 83% in diagnosing malignant pancreatic masses less than 3 cm in size, and a sensitivity of 92% for those beyond 3 cm, with an overall specificity of 97%[6]. This high sensitivity rate was not significantly decreased by location within the pancreas; although, masses in the pancreatic body or tail were identified with a sensitivity of 100% relative to 85% for the body of the pancreas. EUS in this study revealed 64% accuracy in pancreatic tumor staging T1-T3. The main etiology for incorrect staging was those patients with masses larger than 3 cm, which limited the tissue depth penetration of the 7.5 MHz transducer[6]. These were, and remain, profound findings, as earlier diagnosis and more accurate local staging could improve patient survival. Current studies have demonstrated diagnostic sensitivity of EUS approaches 99% for malignant pancreatic tumors of 2-3 cm size which is far superior to other imaging modalities, including CT, transabdominal US, and magnetic resonance imaging (MRI)[7-9]. This is likely due to the ability to have close proximity of the endoscope transducer to the lesion of interest. Of course, EUS is not without limitations in the accuracy of diagnosing pancreatic cancer. The presence of pancreatitis, which can result in significant heterogeneous appearance of pancreatic tissue, may result in highly trained endosonographers missing an underlying pancreatic neoplasm[4,10]. As MRI techniques and equipment become more high-tech, magnetic resonance cholangiopancreatography (MRCP) has been used with increasing frequency in patients suspected of having a pancreatic malignancy. MRI has superior soft-tissue contrast compared to CT imaging, resulting in the ability to differentiate pancreatic masses[4,11]. However, as EUS affords superb visualization of the

pancreas and remains one of the most accurate means for identifying pancreatic lesions, it is considered a first-line modality for diagnosing and staging of pancreatic adenocarcinoma.

EUS is not only accurate in detecting pancreatic malignancies, but is the primary tool to rule out pancreatic cancer[8]. A large single study completed at UC Irvine by Klapman *et al*[8] determined the negative predictive value (NPV) of EUS for patients with possible cancer of the pancreas. A total 693 patients were referred for EUS due to the potential of pancreatic cancer; focus was placed on the 155 with normal pancreatic imaging on EUS. Most of this group had been referred for EUS based on abnormal CT imaging. These patients were monitored for 24 mo, at the end of which none developed malignancy of the pancreas, resulting in a 100% NPV (95%CI: 98.2-100.0)[8].

Today, EUS imaging is combined with fine-needle aspiration (FNA) to improve diagnostic accuracy of pancreatic masses. Cytological or histological confirmation of the lesion is required to determine the appropriate treatment, especially if the mass is unresectable. Retrospective reviews of EUS database information shows EUS-FNA diagnostic precision of 89% for solid pancreatic masses[9,11,12,13]. The ability to obtain samples of pancreatic lesions concerning for malignancy during real-time imaging has a direct impact on the medical management of these patients. As only a minority of patients are candidates for curative surgery at time of presentation with pancreatic carcinoma, obtaining cytological or histological diagnostic confirmation is necessary to proceed with chemotherapy[9,12,13]. Touchefu *et al*[12] examined the influence of EUS-FNA on patient management in 100 patients; intention-to-diagnose analysis revealed the FNA results directly guided treatment plans in 62 patients.

It is additionally highly recommended, and in many healthcare settings standard of care, that a cytopathologist or cytology technician be onsite to guide FNA sampling. Various studies have demonstrated the likelihood of diagnosis obtained is much improved. A large prospective multicenter study conducted in the mid-1990s evaluated 474 EUS-guided FNA diagnoses of various sites and lesions. NPV was 72% without an on-site pathologist *vs* 100% in those centers with direct pathologist assistance[4,14]. Furthermore, a retrospective study evaluating academic centers with cytopathologists on site ruled in or out a malignant diagnosis twice as often and were less likely to have unacceptable samples[14-17].

Additional supportive data for on-site cytopathology with EUS-FNA of suspicious lesions was revealed in a recent large meta-analysis by Hébert-Magee *et al*[16] reviewing 34 studies with approximately 3600 patients with solid pancreatic masses. Of those patients, a total of 2285 were found to have pancreatic adenocarcinomas. Sensitivity of FNA ranged from 0.50-1.00, with sensitivity rates notably lower in those studies without on-site cytopathology, even when correcting for sources of heterogeneity of study size and diagnostic reference standard used[16,17]. Thus, given the continued dismal survival rates for pancreatic cancer (approximately 24% survival at 1 year and 5% at 2 years) and increased chance of unresectability with late presentation, EUS-FNA biopsy can provide an earlier diagnosis and potential alternative diagnosis to decrease patient mortality. It remains superior in accurately identifying and ruling out pancreatic malignancies compared to imaging *via* CT, conventional US, and MR[8].

Mediastinal adenopathy and non small-cell lung cancer: Patients with suspected lung cancer often undergo further imaging to help with staging, as up to 26% of newly diagnosed lung cancers present with mediastinal lymph node involvement[18,19]. Imaging modalities may vary between CT, MRI, or US. A 2003 CHEST systematic database review evaluated the accuracy of mediastinal staging in CT compared to positron emission tomography (PET), MR, and EUS[19]. The analysis of EUS assessment consisted of five studies for a total of 163 patients and exhibited a pooled sensitivity of 78% (95%CI: 0.61-0.89) and specificity of 71% (95%CI: 0.56-0.82). However, PET scan demonstrated the highest accuracy in detecting malignant metastases to mediastinal nodes with sensitivity and specificity of 84% (95%CI: 0.78-0.89) and 89% (95%CI: 0.83-0.93), respectively. As EUS is often limited in its inability to image all node stations, this may partially explain its inferiority to PET imaging of the mediastinum[19]. Specifically, EUS is unable to visualize anterior upper mediastinal nodes as a result of air within the trachea obstructing US imaging[18,20].

While CT and PET detect mediastinal lymphadenopathy and suspicious masses on imaging, a lack of tissue sampling results in a presumptive diagnosis only. Thus, obtaining tissue samples is necessary to definitively confirm and stage a possible pulmonary malignancy. The American Society of Thoracic Surgery currently recognizes mediastinoscopy as the favored modality for biopsy[18]. However, the 2011 ASGE Standards of Practice state that linear echoendoscopy can perform EUS-guided FNA of the posterior and inferior mediastinum with success in obtaining specimens from nodes 5 mm in size or larger. Additionally, nodal stations 8 and 9 and posterior nodes at station 7 are accessible by EUS with a sensitivity of 90% in confirming diagnosis. This accuracy drops to 66% for station 5 nodes based on one retrospective series by Eloubeidi *et al*[21] due to logistical difficulties when inserting the biopsy needle in attempts to reach this sub-aortic locations[18]. One prospective cohort study of 104 patients with malignant posterior mediastinal lymph nodes assessed the yield and precision of EUS-FNA using pathologic confirmation *via* thoracotomy[21]. The accuracy of EUS-FNA was 97%, which was significantly increased from PET imaging alone. More invasive surgical intervention was

avoided in 57% of the patients to determine malignant spread to lymph nodes. No patients experienced major complications peri-procedurally or at 30-d follow up[21]. EUS-FNA has been recommended by Maluf-Filho *et al*[4] to detect metastasis to the posterior mediastinum in non-small-cell lung cancer (Grade A, evidence level 1). EUS-FNA of mediastinal lymphadenopathy averages a complication rate of 0.2%, compared to 1.3%-3.0% with mediastinoscopy. The American Society of Thoracic Surgery does recognize EUS-FNA as an efficient, minimally invasive alternative method to confirm and stage lung cancer involving mediastinal lymph nodes.

Choledocholithiasis, suspected: CBD stones remain a common complication related to the presence of gallstones, occurring in nearly 20% of patients with known cholelithiasis. Identifying CBD stones remains a challenge, as laboratory findings and clinical presentation is often nonspecific[22]. EUS has been studied over several years in its ability to accurately detect choledocholithiasis. Endoscopic retrograde cholangiopancreatography (ERCP) remains standard of care, as rates for successful identification of bile duct stones approaches 100%, compared with abdominal CT and US where diagnostic accuracy approximates to 50%[22,23]. ERCP is also not purely diagnostic, as it allows for CBD stone removal at time of detection; however, complication rates occur in up to 11% of patients[23,24]. Various studies performed in the 2000s evaluated EUS ability to diagnose suspected choledocholithiasis, as this could negate ERCP and its associated risks in certain patient cases. However, the data was widely variable in rates of sensitivity and sensitivity[22,23].

In order to more precisely estimate diagnostic accuracy of EUS for choledocholithiasis, Tse *et al*[22] identified 27 prospective cohort studies consisting of EUS results compared with ERCP, intraoperative cholangiogram (IOC), or surgical exploration. Included studies also had a minimum of three months follow up if initially negative EUS results with suspicion of CBD stones based on history, exam, laboratory findings, or trans-abdominal US imaging. Studies were excluded if they lacked a comparison group, demonstrated possible bias, or insufficient data. Pooled diagnostic accuracy was 98% (area under the curve). EUS decisively ruled in and ruled out CBD stones with a positive likelihood ratio (LR) of 22.41 (95%CI: 12.53-40.08) and negative LR of 0.09 (95%CI: 0.06-0.12)[22]. This impressive diagnostic ability of EUS is likely related to its high resolution down to 0.1 mm compared to ERCP or MRCP[22].

IOC is often performed during laparoscopic cholecystectomy to evaluate biliary patency. CBD stones are present in up to 15% of these patients, but the false positive rate of IOC approaches 60% in some studies[23]. Given the combination of IOC's high false positive detection of choledocholithiasis and the complication rates of ERCP, it would be ideal to have an alternative, less invasive modality of confirming CBD stones with decreased risk in patients with low suspicion for requiring stone extraction. EUS may have a potential role in a diagnostic algorithm to stratify patients proceeding to ERCP *vs* EUS initially. EUS is felt to be as sensitive and more specific than ERCP or MRCP for the diagnosis of CBD stones, especially those of smaller size (Grade A, Evidence Level 1)[4].

The use of EUS as the primary diagnostic tool, however, may be limited. While it is less invasive than ERCP resulting in lower rates of post-procedure pancreatitis, patients still require sedation. As with ERCP, EUS requires an experienced endoscopist to obtain acceptable images. Unfortunately if CBD stones are discovered on EUS imaging and require removal, these patients would require ERCP, an additional procedure.

Therapeutic indications

Pancreatic fluid collection drainage: Potential indications for intervention in pancreatic pseudocysts include abdominal pain, gastric outlet obstruction, early satiety, weight loss, jaundice, infection, or progressive enlargement[3]. Surgery has historically been accepted as the standard of care for draining pancreatic pseudocysts and walled-off pancreatic necrosis. In recent years, multiple studies examining the success of EUS-guided drainage has resulted in this becoming an established technique with comparable outcomes and significantly lower medical costs[17]. This procedure was first described in a 1992 case report by Grimm *et al*[25] with management of a pancreatic tail pseudocyst[17]. A randomized controlled trial conducted in 2009 directly compared surgical *vs* EUS-guided endoscopic pancreatic fluid collection (PFC) drainage in 40 patients[26]. A pseudocyst was defined as "a fluid collection in…pancreatic…area (with) a well-defined wall and…no solid debris or recognizable parenchymal necrosis" [26]. One-half of the patients were randomized to surgical cystogastrostomy under a single pancreatic surgeon while the other half underwent EUS with fluoroscopy. Endoscopic cystogastrostomy was achieved *via* EUS-guided 19-guage-needle access of the fluid collection with subsequent deployment of two plastic stents to allow PFC contents to drain into stomach. ERCP was performed in the experimental arm following EUS in order to identify and treat pancreatic duck leaks, if present. Traditional surgical drainage resulted in a 100% successful treatment. However, several of these patients experience postoperative complications, including recurrent pseudocyst, surgical wound infection, inability to tolerate oral intake, and pancreatic tail stricture. EUS-guided pseudocyst drainage was efficacious in 95% of patients with pseudocyst resolution by 8 wk in all 20 patients. Most importantly, these patients did not experience peri- or post-procedural complications[26]. Additional studies have since demonstrated clinical success rates of PFC drainage *via* EUS imaging approach 90% with complication rate of less than 5%[17,24,26,27]. PFC drainage under EUS guidance is a minimally

invasive procedure, resulting in a shorter hospital length of stay, lower overall healthcare costs, and feasibility in vast majority (more than 90%) of patients[24,26].

Prior to the establishment of EUS-guided PFC drainage, transmural drainage *via* esophagogastroduodenoscopy (EGD) had been accepted as a reputable technique to manage PFCs. This was attributable to data from two prospective nonrandomized trials in the early 2000s that revealed no statistical difference in treatment success or complication rates when compared with surgery[26,27]. EGD identified the location of a PFC by evaluating for a site of stomach or duodenal lumen compression. The site was punctured by a needle to allow aspiration of pseudocyst fluid and placement of double pigtail stents to allow intraluminal drainage of PFC contents[27]. Varadarajulu *et al*[27] conducted the first randomized control trial directly pitting EUS against EGD for transmural drainage of pancreatic pseudocysts in 42 patients. All patients initially underwent contrast-enhanced CT imaging to exclude those without a pseudocyst, then ERCP to assess and manage CBD stones or pancreatic duct stricture, if present. Patients were subsequently randomized to the EGD or EUS arms with treatment failures crossing over to the opposite arm. Ultimately, complete resolution of pseudocysts was achieved in 91% of the EGD arm *vs* 97% in the EUS group (10 of which crossed-over from EGD arm). Although no statistical significance was noted in improved safety with EUS, it did reveal a significantly higher technical success rate[26,27]. This is likely due to the ability of directly imaging extramural lesions.

EUS provides additional benefits over EGD beyond definitive drainage of PFCs. EUS imaging can more clearly differentiate pseudocysts from cystic neoplasms and visualize pseudocysts that spontaneously resolved, thus negating a need for PFC drainage[27]. Bleeding is one of the most common complications of endoscopic PFC drainage, occurring in up to 10% of patients. This often occurs due to the presence of gastric varices or collaterals not visible with EGD. As EUS allows real-time visualization of vasculature near a pseudocyst, one can identify a safe window for transmural puncture to achieve drainage[26,27].

Celiac plexus neurolysis: Chronic pain is a common, and at times, debilitating complication of intra-abdominal malignancies and chronic pancreatitis. It is often difficult to control with opioid analgesics, and these medications have various adverse effects. Wiersema *et al*[28] first described a technique of treating intractable pain with EUS-guided celiac plexus neurolysis (CPN) in a prospective study of 30 patients with pancreatic carcinoma or intra-abdominal metastases in 1996[17,24]. This procedure consisted of identifying the celiac trunk, as the celiac plexus is located anterolateral to this site, and injecting a local anesthetic such as bupivacaine followed by dehydrated ethanol[24,28]. Data was notable for a 79%-88% improvement in the patients' pain scores at a mean 10 wk post-procedure. Furthermore, 91% of these patients did not require increased dosages of their opioid analgesics, with nearly half using less pain medication by the last study follow up. The only complication was self-resolving diarrhea in four patients[28].

While CPN was found to provide pain relief in patients with pancreatic and intra-abdominal malignancies, Levy *et al*[29] considered whether directly injecting the celiac ganglia with a local anesthetic might result in enhanced efficacy[24]. Seventeen patients with unresectable pancreatic carcinoma and moderate to severe narcotic-dependent pain underwent EUS-guided direct celiac ganglia injections with bupivacaine and dehydrated alcohol. Immediate partial pain relief was experienced by 94% of patients. Opioid medication use decreased for 3 patients, while remaining equivalent in 13 patients. There were no major complications, suggesting this new technique for pain relief in certain patients is a safe alternative and potentially more efficacious than CPN[29].

The most recent data demonstrates substantial pain relief coupled with a reduction in narcotic dosage for patients with intra-abdominal malignancies undergoing EUS-guided CPN or celiac ganglia neurolysis (CGN). A large meta-analysis from Puli *et al*[30] in 2014 pooled data from 8 studies (approximately 300 patients) comparing EUS-CPN to analgesics in unresectable pancreatic carcinoma[24,30]. Review of data revealed EUS-guided CPN achieved pain relief in 80% of patients with bilateral celiac plexus injection. A majority of the studies again resulted in a reduction of opioid analgesic use and no major complications, thus reiterating this is a safe and effective treatment for pancreatic cancer-related pain[24,30]. Another review of 6 studies consisting of 358 patients revealed statistically significant reduction in pain at four and eight weeks and superiority in pain reduction compared to narcotic medications[24].

A multicenter randomized controlled trial by Doi *et al*[31] was the first to directly compare efficacy of EUS-guided CPN to EUS-guided CGN in reducing pain from upper abdominal malignancies. Four of the 34 patients randomized to the CGN arm crossed over to CPN due to inability to visualize the celiac ganglia. The EUS-CGN group had improved response (73.5% with decreased pain) relative to the EUS-CPN arm (45.5%), and EUS-CGN attained complete pain relief in 50% of patients compared to only 18.2% who underwent EUS-CPN[24,31].

EUS-guided CPN and CGN both inhibit the transmission of pain signals from the pancreas and abdominal viscera to the central nervous system. The celiac plexus location permits successful direct EUS visualization, and allows a method of palliation for those with unresectable pancreatic carcinoma[24,28-30]. Patients may thus require less opioid medications, which translates into fewer medication side effects of anorexia, constipation, nausea, and vomiting.

The celiac plexus is also accessible percutane-

ously when combined with CT or fluoroscopy imaging. Prior to the 1990s, this was the primary manner of performing CPN in settings of chronic abdominal pain secondary to intra-abdominal malignancies and chronic pancreatitis[24,32]. Given EUS capability to visualize vascular structures in real-time and ability to perform FNA, EUS-guided CPN using ethanol was first developed in the late 1990s[24]. To further assess this new technique, Gress *et al*[32] performed a randomized-controlled trial involving 22 patients receiving either CT-guided or EUS-guided CPN for persistent, uncontrolled abdominal pain due to chronic pancreatitis. Patients in the EUS arm had statistically significant (P = 0.02) reduced pain score. Neither group experience serious complications. Diarrhea was noted in three subjects (one from the EUS group, two from the CT arm) and attributed as a direct side effect of CPN[32]. Nine patients in the experimental group had a prior CT-guided CPN; the majority preferred the EUS technique citing less post-procedure back pain and "more completed sedation"[32]. Furthermore, the use of EUS in guiding CPN resulted in lower cost per patient relative to CT-guided CPN[24,32].

FUTURE ENDEAVORS

Anti-tumor injection therapy

Several malignancies metastasize to the liver, which often complicates treatment with intent to cure. Patients with diffuse hepatic metastases have therapy options limited to systemic chemotherapy. In the recent years, drug-eluting microbeads have been introduced as a means of delivering treatment, primarily chemotherapy), into a target tissue[24]. A relatively new study conducted by Faigel *et al*[33] evaluated the use of EUS-guided Portal Injection of Chemotherapy (EPIC) with irinotecan-containing microbeads in porcine subjects in comparison to the conventional systemic administration of irinotecan. EPIC achieved double the concentration of chemotherapy within the liver, and halved its concentration in plasma, bone marrow, and skeletal muscle, relative to what is seen with systemic irinotecan[33,34]. This new method of delivery chemotherapy to target malignant lesions of the liver has the potential of increasing the efficacy of treatment while decreased adverse effects. It may be possible to extrapolate this technique in developing alternative management strategies for primary liver malignancies, such as hepatocellular carcinoma.

Anal sphincter dyssenergia

A hypertensive anal sphincter may result in severe constipation due to defecatory dyssynergia and subsequent rectal outlet obstruction. Biofeedback therapy to correct patient contraction of the pelvic floor muscles and external anal sphincter often results in clinical improvement superior to that of laxatives alone[35]. Byrne *et al*[36] used EUS to guide injection of Botulinum toxin (Botox) into the internal anal sphincter of nine patients who had failed biofeedback therapy for anal dyssynergia. Patients underwent anal manometry prior to the procedure and again at two weeks post-injection. Within the 8-wk follow-up, 89% of these patients had improvement in their constipation. Objective findings at this time included decreased anal sphincter pressure in all patients as well as improved defecatory index with balloon expulsion. A single patient developed fecal incontinence, which was the only associated complication from this procedure. While a larger study is needed, this novel technique may prove to be a formidable therapy option for those with constipation due to a hypertensive anal sphincter with alternative treatment failure[34].

Novel peri-procedure analgesia

Traditional Chinese Medicine has included the use of electro-acupuncture for treatment of pain. Electro-acupuncture needles are placed in particular sites on the body to correlate with the specific source of pain. While endoscopic procedures such as EUS are minimally invasive, they are often uncomfortable for patients and necessitate the use of pain control and sedation with intravenous opioid analgesics and benzodiazepines, respectively. Teoh *et al*[37] hypothesized that electro-acupuncture could be used during EUS in order to decrease associated pain and the use of additional analgesics. This randomized, double-blind, sham-controlled trial applied electro-acupuncture to three acupoints related to upper abdominal pain and anxiety in 64 patients undergoing EUS. This study ended early as all patients in the electro-acupuncture group required lower doses of propofol, decreased use of patient-controlled analgesia pumps, and lower pain scores. These data points were all statistically significant[34]. As administration of sedative analgesics is not without potentially dangerous adverse events, this novel technique could lead to fewer associated complications in patients undergoing endoscopic evaluation.

CONCLUSION

EUS has continued to evolve since its conception several decades ago. It is persistently at the forefront of gastroenterological procedures in expanding its diagnostic and therapeutic use for a variety of diseases and clinical presentations. EUS often provides a marginally invasive alternative to many treatments previously requiring surgical intervention, which ultimately may result in lower healthcare costs and fewer complications in patients.

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