Review

Forward-view Endoscopic Ultrasound: A Systematic Review of Diagnostic and Therapeutic Applications

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ABSTRACT
Endoscopic ultrasound (EUS)-guided fine needle aspiration (FNA) and therapeutic procedures have been performed by a curved linear array (CLA) echoendoscope since the early 1990's. This particular echoendoscope, allowing real time visualization of aspiration needles and other devices, has substantially remained unchanged since its introduction to the market. In a context of rapidly expanding indications for EUS-guided procedures, a dedicated forward view (FV) echoendoscope has been developed and tested under different clinical conditions. The FV echoendoscope is equipped with front endoscopic and EUS view, allowing deployment of needles and other devices through the working channel in straight direction. Several new diagnostic and therapeutic applications may thereby potentially be feasible with the FV echoendoscope and the established ones may prove easier to accomplish. The published literature with the FV echoendoscope has been systematically reviewed and the results are presented analytically and discussed in detail. EUS-FNA and therapeutic procedures, including pancreatic pseudocyst drainage, treatment of gastric fundal varices, celiac plexus neurolysis, and duct drainage were reported. The FV echoendoscope showed some unique advantages, opening new possibilities such as EUS-FNA in difficult gastrointestinal tracts and combined endoscopic/EUS treatment with frontal approach. However, no statistically significant evidence of superiority of the FV echoendoscope vs the CLA echoendoscope was found in pancreatic pseudocyst drainage. No complications specifically attributable to the use of the FV echoendoscope were reported.

Keywords: endoscopic ultrasonography; fine needle aspiration; linear echoendoscope; forward view echoendoscope; forward viewing

INTRODUCTION
Endoscopic ultrasound (EUS) and EUS-guided fine needle aspiration (FNA) have a significant impact on the clinical outcome in pancreaticobiliary lesions, esophago-gastric cancer, lung cancer, and extraintestinal masses and lymph nodes of unknown etiology. EUS-FNA was introduced at the beginning of the 1990’s thanks to the development of a curved linear array (CLA) echoendoscope allowing real time visualization of aspiration needles. The design of CLA echoendoscopes and the technique of EUS-FNA have substantially remained unchanged since then.

A prototype forward view (FV) echoendoscope has been recently developed (Tab. 1). Its ultrasound field of view is almost coaxial to the exit path of the working channel, allowing the use of needles and other devices in straight direction acting like a gastroscope. Thus the penetration force into the target tissues is expected to be greater with the FV echoendoscope than with the CLA echoendoscope, which provides only tangential approach.

The FV echoendoscope was originally designed for therapeutic procedures, particularly for pseudocyst drainage. However, it has become evident that it can be very useful for other therapeutic interventions and for regular EUS-FNA too. The aim of this study was to review systematically the available published experience with the use of the FV echoendoscope.

METHODS
We specifically aimed to retrieve all the publications in which the FV echoendoscope (XGF-UCT160J-AL5, Olympus Medical Systems Corp., Tokyo, Japan) was used in the whole
or in part of the patient population. All articles relevant to the topic were extracted by searching several databases, including PubMed, Web of Science, Scopus, and Google Scholar. Additionally, we utilized the journal search function of Gastrointestinal Endoscopy and Endoscopy websites.

The following search terms were matched with the Boolean operator “AND” in all the possible combinations: forward viewing, forward view, prototype, echoendoscope, EUS, endoscopic ultrasonography, and endoscopic ultrasound.

Moreover, the bibliography of reviewed articles was scrutinized to find any other reference that might have been missed at the initial search.

Original research articles (randomized controlled trials–RCTs, prospective and retrospective studies), case series, case reports and pre-clinical studies were included. Non-English language articles and abstracts were not considered for review.

RESULTS

The initial search identified 220 articles; after exclusion of non-pertinent papers and abstracts, 18 relevant articles were selected and reviewed for the purpose of this article (Fig. 1). Two papers reported about non-human preliminary experience with the FV echoendoscope, in a porcine and a phantom model, respectively.16,22 Another paper was a clinical review on the initial experience with the FV echoendoscope.23 Fifteen articles reporting clinical applications of the FV echoendoscope in human beings were analyzed in detail (Tab. 2).17-21,24-33

| Table 1. Comparison between FV and CLA echoendoscope features |
|---------------------------------------------------------------|
| **FV echoendoscope**                                         | **CLA echoendoscope** |
| XGF-UCT160J-AL5                                              | GF-UCT180             |
| Optical system                                               |                        |
| Direction of view                                            | Forward view           | Oblique view          |
| Field of view                                                 | 120°                   | 100°                  |
| Insertion tube                                               |                        |
| Distal end outer diameter (mm)                               | 14.2                   | 14.6                  |
| Insertion tube outer diameter (mm)                           | 11.8                   | 12.6                  |
| Working length (mm)                                          | 1250                   | 1250                  |
| Instrument                                                   |                        |
| Working channel diameter (mm)                                | 3.7                    | 3.7                   |
| Elevator function                                            | No                     | Yes                   |
| Exit trajectory of devices                                   | Parallel to the scope axis | Oblique to the scope axis |
| Angulation range                                             | Up 180°, down 100°, right/left 90° | Up 130°, down 90°, right/left 90° |
| Ultrasound function                                          | Scanning range         |                        |
| Frequencies (MHz)                                            | 90°                    | 180°                  |
|                                                        | 5, 6, 7.5, 10           | 5, 6, 7.5, 10         |

FV: forward view; CLA: curved linear array.

Small numbers of patients were enrolled in the majority of studies such as case series and case reports; however, larger retrospective cohort studies as well as prospective trials were published too (Tab. 3). The highest level of evidence pertained to a multicenter randomized controlled trial comparing FV and CLA echoendoscope performance in pancreatic pseudocysts drainage.50

Overall, 230 patients underwent EUS with the FV echoendoscope. Its diagnostic performance was rated non-inferior to that of the CLA echoendoscope; in particular, a better visualization of the bile duct at the liver hilum was reported. In regard to operative and therapeutic procedures, EUS-FNA at various sites were reported, including upper and
lower gastrointestinal tract \( (n = 103) \), pancreatic pseudocyst drainage \( (n = 49) \), embolization coil + cyanoacrylate injection in gastric fundal varices \( (n = 28) \), celiac plexus neurolysis \( (n = 6) \), biliary drainage \( (n = 4) \), pancreatic duct drainage \( (n = 2) \), pelvic abscess drainage \( (n = 1) \), fiducials implantation \( (n = 1) \), and bowel recanalization at the level of a completely obstructed colorectal anastomosis \( (n = 1) \).

The operative performance of the FV echoendoscope was systematically compared to that of the CLA echoendoscope only in one randomized controlled trial of pancreatic pseudocyst drainage,\(^{30}\) which failed to demonstrate any significant superiority of the former vs. the latter in terms of intervention time and ease of procedure. Other non-controlled studies reported some unique advantages of the FV echoendoscope including: frontal approach to the target allowing maximal device deployment force; simultaneous endoscopic and EUS control of operating field obviating the need for scope exchange; and possibility to explore the entire

| Article            | Topic                                        | Patients/SEX | Mean age | Procedures performed                     | Diagnostic outcomes | Therapeutic outcomes | Complications                        |
|--------------------|----------------------------------------------|--------------|----------|------------------------------------------|---------------------|----------------------|--------------------------------------|
| Voermans, 2007     | Pancreatic pseudocysts                        | 7 (5M/2F)    | 52       | Pseudocyst drainage (7)                  | 7/7 (100%)          | 7/7 (100%)           | 1 delayed melena                    |
| De Lusong, 2008    | Complete colorectal anastomotic obstruction   | 1 (F)       | 40       | Bowel recanalization                     | 1/1 (100%)          | 1/1 (100%)           | None                                 |
| Larghi, 2009       | Hilar biliary strictures                      | 4 (2M/2F)    | 63       | FNA (4)                                  | 4/4 (100%)          | -                    | None                                 |
| Trevino, 2009      | Bile-duct obstruction Pelvic abscess          | 3 (3M)       | 66       | Biliary drainage (1)                     | 3/3 (100%)          | 2/2 (100%)           | None                                 |
| Eloubeidi, 2010    | Pancreatic lesions Lymph nodes Liver lesions  | 30           | 59       | FNA/TCB (29) CPN (5)                    | 28/29 (97%)         | 5/5 (100%)           | 1 tachycardia and vomiting (FNA of pheocromocytoma) |
| Larghi, 2010       | Benign pancreaticobiliary diseases            | 2 (1M/1F)    | 49       | Biliary drainage (1)                     | 2/2 (100%)          | 2/2 (100%)           | None                                 |
| Uchida, 2010       | Extracolonic lesions proximal to the sigmoid  | 2(2F)        | 56       | FNA (2)                                  | 2/2 (100%)          | -                    | None                                 |
| Nguyen-Tang, 2010  | Right-sided colon lesions                     | 15 (6M/9F)   | 53       | FNA (6)                                  | 15/15 (100%)        | -                    | None                                 |
| Binnmoeller, 2011  | Gastric varices                               | 28           | 54       | Embolization coil + cyanoacrylate injection (28) | 28/28 (100%)       | 23/24 (96%)           | None                                 |
| Fusaroli, 2011     | Pancreatic lesions Gastrointestinal lesions    | 13 (7M/6F)   | 65       | FNA (13)                                 | 12/13 (92%)         | -                    | None                                 |
| Kida, 2011         | Pancreatic diseases SMTs Gastrointestinal neoplasms | 47         | 63       | FNA (38) Pseudocyst drainage (6) CPN (1) Biliary drainage (1) Pancreatic duct drainage (1) | 37/38 (97%)         | 8/9 (89%)            | None                                 |
| Voermans, 2011     | Pancreatic pseudocysts                         | 26 (17M/9F)  | 56       | Pseudocyst drainage (26)                | 26/26 (100%)        | 24/26 (92%)          | 1 severe bleeding 1 suspected perforation |
| Diehl, 2012        | SMTs (whole gastrointestinal tract)           | 22 (10M/12F) | 62       | FNA (5)                                  | 20/22 (91%)         | -                    | None                                 |
| Itoi, 2012         | Pancreatic pseudocysts Acute cholecystitis     | 9 (6M/3F)    | 61       | Pseudocyst drainage (8) Gallbladder drainage (1) | 9/9 (100%)         | 9/9 (100%)           | 1 stent migration                    |
| Iwashita, 2012     | Pancreaticobiliary diseases                   | 21 (8M/13F)  | 58       | FNA (6) Pseudocyst drainage (2)          | 21/21 (100%)        | 7/8 (88%)            | None                                 |

SMTs: submucosal tumors; FNA: fine needle aspiration; TCB: tru-cut biopsy; CPN: celiac plexus neurolysis. \(^{1}\)Specific to the FV echoendoscope, such as capability of reaching/visualizing the target lesions/organisms.
colon up to the cecum.

On the other hand, one study reported increased difficulties in intubating the upper esophagus with the FV echoendoscope due to the modified tip design, which required predilatation with 15-mm bougie in 3 patients.31

No complications specifically related to the FV echoendoscope design were reported.

**DISCUSSION**

Along with well-established diagnostic indications of EUS, EUS-guided therapeutic procedures have become increasingly popular with still expanding applications.34 In this respect, the development of a dedicated therapeutic echoendoscope is warranted. The FV echoendoscope was developed a few years ago to overcome some limitations of the CLA echoendoscope such as oblique approach to the target lesions, with diminished penetration force, and angling at the echoendoscope tip with reduced possibility of deploying large bore devices in difficult scope positions.

A randomized controlled trial failed to demonstrate any significant advantage of the FV echoendoscope compared...
to the CLA echoendoscope in performing pancreatic pseudocyst drainage, both in terms of intervention time and of ease of procedure performance. However, this study was conducted at referral tertiary care institutions, whose experienced endosonographers are expected to be already very proficient with the conventional CLA echoendoscope. It remains to be seen if less experienced endosonographers might take advantage of the FV echoendoscope in this respect. Nevertheless, this review of the literature demonstrated that the above mentioned peculiar features of the FV echoendoscope were deemed useful in several instances. In particular, it was reported that the perpendicular access and lack of angulation at the exit of the working channel allowed introducing 19-G needles easily at all sites and passing 10-French stents without indentation. Penetration of needles and other devices inside the target was judged to be effortlessly, with no tendency either to push the lesions away from the echoendoscope or to elongate the tract traversed inside the gastrointestinal wall as it may happen by the oblique access with the CLA echoendoscope. Furthermore, precise orientation of the needle was obtained just with up/down angulation of the tip with no need for the elevator (which is not provided with the FV echoendoscope).

Other advantages of the FV echoendoscope regarded the forward view optics, allowing both for combined endoscopic/EUS visualization of the operating field and for reaching gastrointestinal tracts that are not easily accessible with the CLA echoendoscope, such as the colon proximal to the rectum, the third/fourth portion of the duodenum and the gastric cardia/fundus. These advantages were demonstrated by EUS-FNA of deep duodenal and cecal submucosal tumors, by injection of embolization coils + cyanoacrylate in gastric fundal varices, and by recanalization of a colorectal anastomosis completely obstructed due to fibrosis.

EUS-FNA of submucosal tumors located right below the pylorus and the cardia can be hampered by the interposition of folds between the needle and the lesion itself. In our own experience with the FV echoendoscope, there was a good correspondence between the endoscopic and the EUS targeting, making FV EUS-FNA quite straightforward unlike standard EUS-FNA. Another advantage was the ease of insertion of the needles that could be advanced through the working channel also in the retroflexed position allowing EUS-FNA of lesions in the gastric fundus (Fig. 2).

Some limitations of the FV echoendoscope were described. Firstly, difficult intubation of the cervical esophagus, requiring predilatation with 15-16 mm Maloney or Savary dilators, and difficult passage from the bulb into the second duodenal portion were reported. This was attributed to the modified design of the echoendoscope tip which is somewhat blunter than that of the CLA echoendoscope. It is also experience of the authors of the present review that the above mentioned passages, along with the passage through the pylorus, are perceived differently by the operator than with the CLA echoendoscope and that a short learning curve is required. Secondly, difficult control was reported during one pancreatic pseudocyst drainage because of lack of fixation of the guide wire due to absence of the elevator.

Shifting from the CLA echoendoscope to the FV echoendoscope and vice versa was necessary in some cases. We described instances in which EUS-FNA was accomplished by means of the FV echoendoscope after failure with the CLA echoendoscope due to difficult or impossible access. Other authors reported successful pancreatic pseudocyst drainage using the FV echoendoscope in 2 patients in whom it had been impossible to achieve a satisfactory position with the CLA echoendoscope.

On the other hand, pancreatic pseudocyst drainage from the gastric antrum was not feasible in 2 cases with the FV echoendoscope but it was successfully accomplished by crossing over to the CLA echoendoscope. Lastly, it was possible to perform EUS-FNA of a pancreatic head cyst only with the CLA echoendoscope because of inability to adjust the needle trajectory enough with the FV echoendoscope. The use of the FV echoendoscope was proved to be safe and there were no complications specifically attributable to it. Nevertheless, a few complications were reported which were related to the therapeutic interventions performed rather than to the type of echoendoscope used. All complications were managed conservatively except for one severe bleeding, occurring after dilatation during a pancreatic pseudocyst drainage, which required urgent angiographic coil embolization.
It may be argued that the narrower field of EUS view with the FV echoendoscope (90° as opposed to 180° with the CLA echoendoscope) represents a limitation to the diagnostic accuracy. However, no difficulties were reported in imaging all the main stations that are regularly explored with EUS, and experienced endosonographers had no problem in identifying the target lesions and organs in all cases. On the other hand, a unique advantage was attributed to the FV echoendoscope in imaging the common hepatic duct and the common bile duct at the level of the hilum,21,25 a region that is often difficult to investigate with the CLA echoendoscope.

In conclusion, the use of the FV echoendoscope appeared to facilitate some EUS-FNA and therapeutic procedures thanks to its peculiar features. Additionally, reaching difficult locations of the gastrointestinal tract, such as the cecum, and performing therapeutic procedures in which the front endoscopic and EUS view were necessary, were unique to the FV echoendoscope. However, there was no statistically significant evidence that the FV echoendoscope was superior to the CLA echoendoscope in pancreatic pseudocyst drainage.

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