Electronic Radial Ultrasound Endoscope

Setting a standard for the next generation of EUS

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Olympus Electronic Radial Ultrasound Endoscope GF-UE160/260-AL5

Introduction

Since the development of ultrasound endoscopes began in 1980, we have faced and overcome many difficult challenges in advancing endoscopic ultrasonography (EUS). The research and development (R&D) team initially succeeded in displaying EUS images with a range of 90°. The next step was 180°. And now, a full 360° can be displayed. The team's achievement was not only to enlarge the scanning range, but also to increase the frequency band and improve image quality - first from 5MHz to 7.5MHz then to 12MHz, and finally to 20MHz. In addition to the ultrasound endoscope, the R&D team also successfully developed ultrasound probes, which can be passed through the instrument channel of conventional endoscopes. Moreover, they have succeeded in increasing the probe's frequency to 30MHz, displaying a much sharper image than 20MHz probe.

One well-known EUS application is EUS-guided Fine-Needle Aspiration (FNA), which uses the electronic convex (curved-linear array) ultrasound endoscope to advance an aspiration needle into an area of interest to collect cells or tissue. However, because of the GI tract's luminal structure and close proximity to the pancreas and other organs, full 360° cross-sectional imaging is also very important. To meet this demand, OLYMPUS MEDICAL SYSTEMS CORP. has developed an electronic radial ultrasound endoscope. This scope can scan and display a full 360° and is compatible with ultrasound processors manufactured by ALOKA CO.,LTD., the same company that originally developed extracorporeal probes. The ALOKA processor offers a variety of functions for extracorporeal applications such as Color Doppler, Tissue Harmonic Echo (THE), etc. In addition, this processor is compatible with the electronic convex ultrasound endoscope used for EUS-guided FNA. The electronic radial ultrasound endoscope is destined to set the standard for ultrasound endoscopes of the next generation. Now we would like to discuss the clinical images, specifications, and clinical benefits of the electronic radial ultrasound endoscope.

Instrument

Ultrasound endoscope (OLYMPUS)

The electronic radial ultrasound endoscope, GF-UE160/260-AL5, was developed by OLYMPUS MEDICAL SYSTEMS CORP. (Table1). Appearance is similar to that of the GF-UM160/2000 mechanical radial ultrasound endoscope shown in Fig.1. However, the GF-UE160/260-AL5 does not need a DC motor, which rotates the transducer, because it uses an array to scan electronically. As a result, the weight of the ultrasound connector has been reduced. The scanning direction of both types of scope, GF-UM160/2000 and GF-UE160/260-AL5, is the same (90° perpendicular to the insertion direction) and both scopes have a full 360° scanning range. However, the GF-UE160/260-AL5 has a slightly thicker distal end and insertion tube (Fig.2). The GF-UM160/2000 scans at frequencies of 5/7.5/12/20 MHz and the GF-UE160/260-AL5 scans at 5/6/7.5/10 MHz. A comparison chart of the basic functions of both scopes is shown in Table 2.

Specifications of Electronic and Mechanical Scanning Instruments

Table 1

Specification	Electronic Radial GF-UE160/260-AL5	Mechanical Radial GF-UM160/2000	Electronic Convex GF-UC140P/UC240P-AL5 GF-UCT140/UCT240-AL5
Frequency	5/6/7.5/10MHz	C5/C7.5/C12/C20	5/6/7.5/10MHz
Scanning Range	360°	360°	180°
Scanning Method	Electronic Radial	Mechanical Radial	Electronic Curved Linear Array
Display Mode	B/Color Doppler/ Power Doppler/THE	B	B/Color Doppler/ Power Doppler
Scanning Direction	Perpendicular to insertion direction	Perpendicular to insertion direction	Parallel to insertion direction
Field of View	100°	100°	100°
Direction of View	55° forward oblique	50° forward oblique	55° forward oblique
Distal End Outer Diameter	13.8mm	12.7mm	14.2mm(P-Type) 14.6mm(T-Type)
Insertion Tube Outer Diameter	11.8mm	10.5mm	11.8mm(P-Type) 12.6mm(T-Type)
Channel Diameter	2.2mm	2.2mm	2.8mm(P-Type) 3.7mm(T-Type)
Angulation range Up/Down Right/Left	130°/90° 90°/90°	130°/90° 90°/90°	130°/90° 90°/90°
Lens Cleaning	Available	Available	Available
Ultrasound Processor	SSD-α5 SSD-5000/5000SV SSD-5500/5500SV	EU-M60 EU-M2000	SSD-α5 SSD-5000/5000SV SSD-5500/5500SV SSD-4000(Plus)

Schematic diagram of GF-UE160/260-AL5

Schematic of the scope tip

Sequential scanning by an array of transducer elements positioned circumferentially results in 360° scanning.

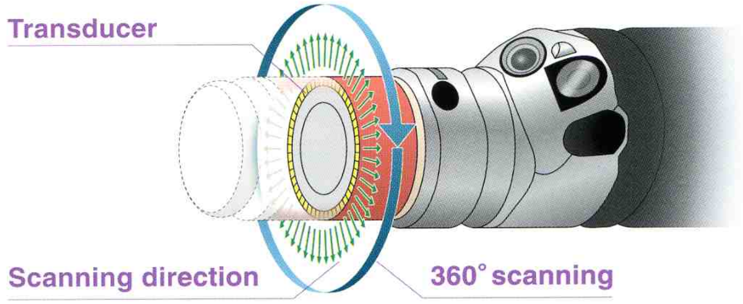


Fig. 1 GF-UE160/260-AL5 appearance

Fig. 2 Comparison of outer diameter

Left : GF-UE160/260-AL5 Right : GF-UM160/2000

Comparison of Electronic and Mechanical Radial Endoscopes

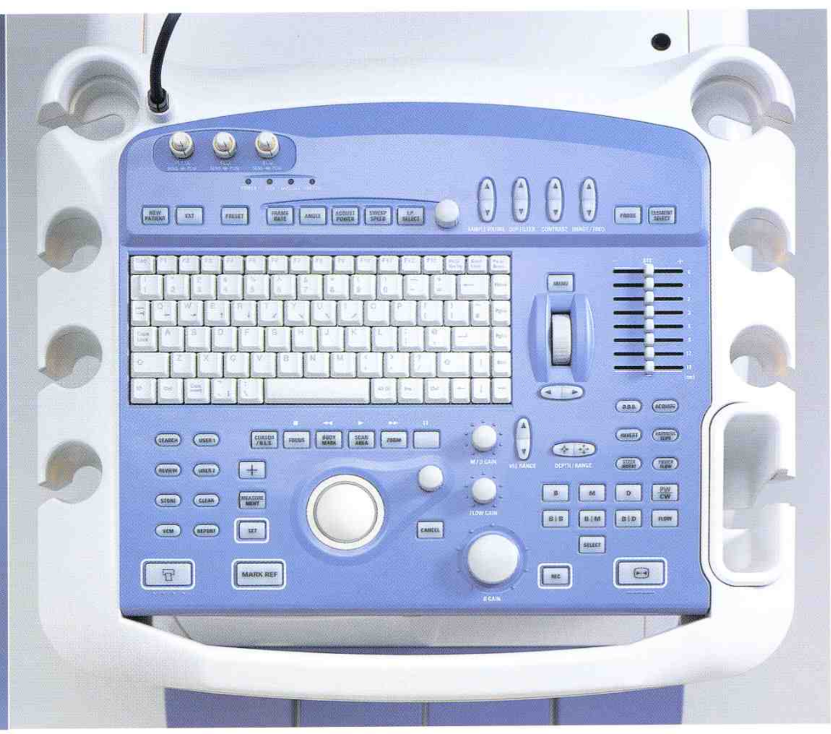
Table 2

	Electronic Radial	Mechanical Radial
Size of scanner (Transducer)	Bigger than mechanical radial	Small
Quality of Image	Good	Good
Resolution	Excellent	Better in high frequency scanner
Multi-reflection artifact by shield cap of transducer	Less	More
Color Doppler	Possible	Impossible
THE	Possible	Impossible
Manipulation of scope	Same	Same
Manipulation of Processor	Complicated	Easy
Ultrasound Processor size	Large	Small
Endoscope Unit	Stand-alone system	On same endoscopy cart

Ultrasound Processor(ALOKA)

The ultrasound processors compatible with the GF-UE160/260-AL5 are SSD-α5 (Fig. 3) and SSD-5000 Series, manufactured by ALOKA CO., LTD.. ALOKA processors are also used with extracorporeal probes, so some functions, such as Color Doppler and THE, are also available. The electronic convex ultrasound endoscopes, GF-UC140P/UC240P-AL5 and GF-UCT140/UCT240-AL5 are also compatible with ALOKA processors. Procedures with the electronic radial ultrasound endoscope and the electronic convex ultrasound endoscope can be performed using a single processor. However, the processors need to be upgraded for use with the electronic radial ultrasound endoscope.

Fig.3 Aloka SSD-α5



Radial or Convex (Curved Linear Array)?

Ultrasound endoscopes are mostly used for imaging the luminal structure of the GI tract. Radial scanning ultrasound endoscopes provide the user easier anatomic orientation compared to convex scanning ultrasound endoscopes. This is because the radial scopes can display a full 360° cross-section of the image while the convex scopes can only display a narrower scan (maximum 180° for Olympus), which is parallel to the insertion direction. In addition, the radial scopes can more easily scan organs in close proximity to the GI tract, such as the pancreas and gallbladder. Fig.4 shows differences in the display ranges of each scope.

Fig.4 Difference in the display range

Radial and Convex

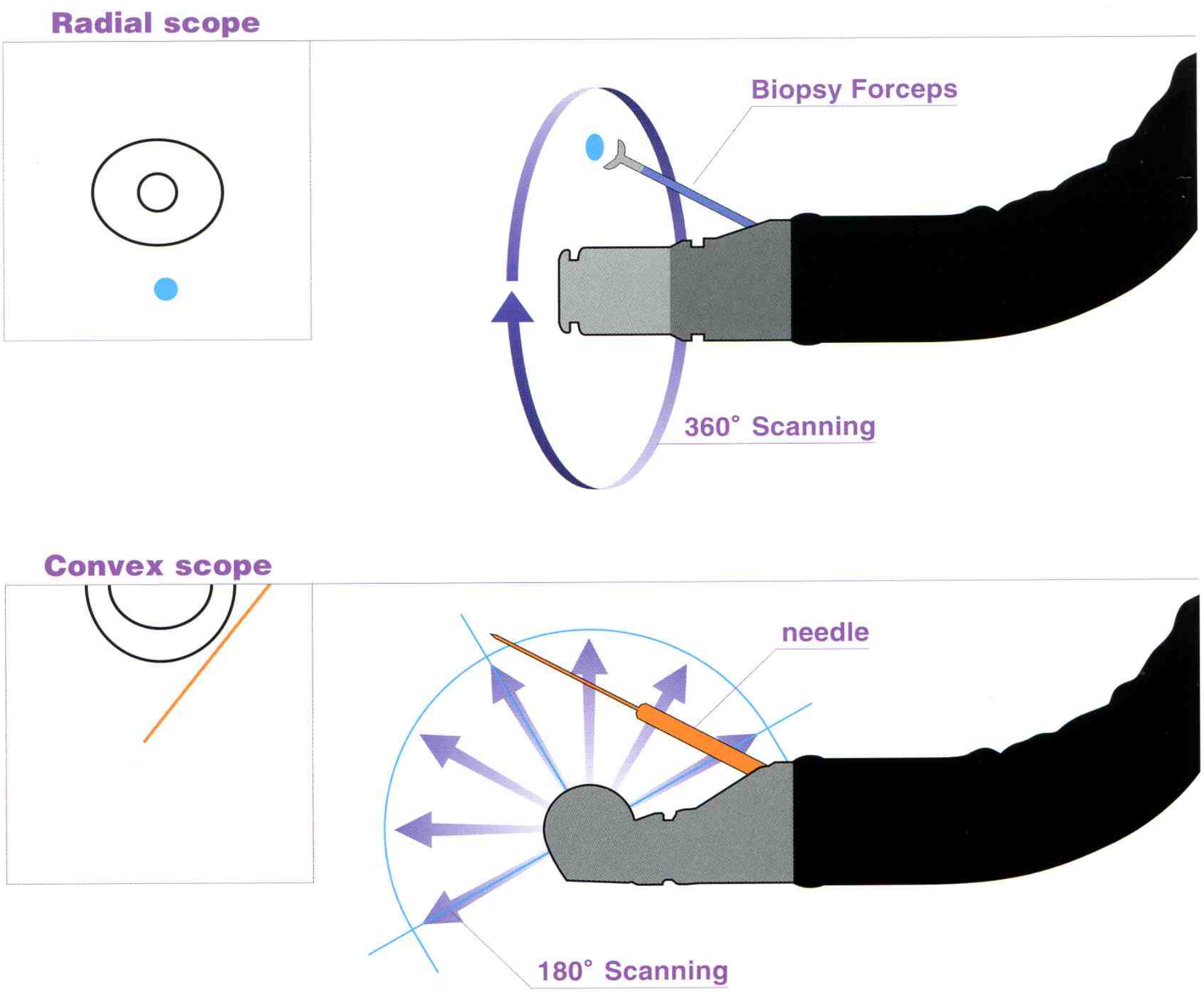


Image Quality

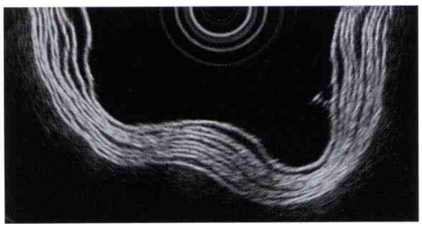
Resolution

Image comparison of Electronic and Mechanical radial scanning ultrasound endoscopes using a paper phantom

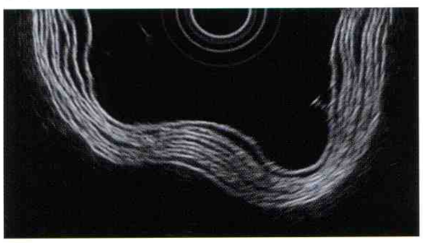
Fig.5 shows ultrasound images produced with electronic and mechanical radial scanning endoscopes operating at each frequency. The imaging phantom used was made from 10 sheets of lens-cleaning paper fixed at opposite ends and contained in a water bath. The image quality and resolution of both models are nearly equal. Since the electronic radial ultrasound endoscope cannot scan at 20 MHz, the 20 MHz image from a mechanical radial ultrasound endoscope is shown as reference. However, 20 MHz scanning can create clearer images when, for example, delineating the layer structure of the GI tract wall.

Fig.5 Electronic Radial and Mechanical Radial Images

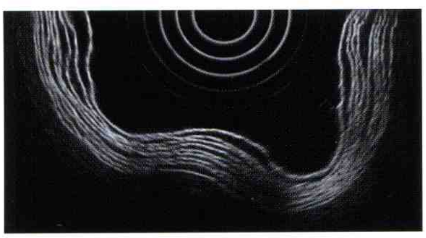
GF-UM160/2000



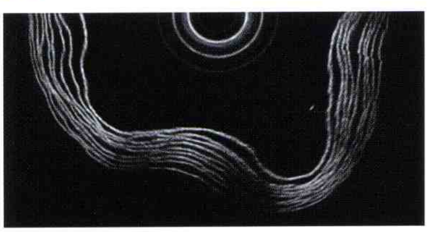
(a) Mechanical Radial C5



(b) Mechanical Radial C7.5



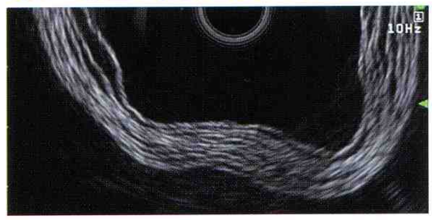
(c) Mechanical Radial C12



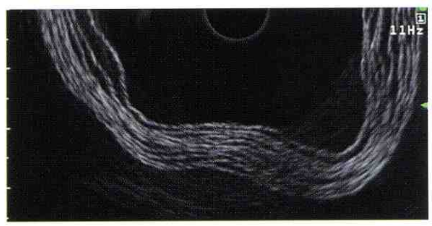
(d) Mechanical Radial C20

(a) to (d) Mechanical radial ultrasound endoscope, model GF-UM160/2000

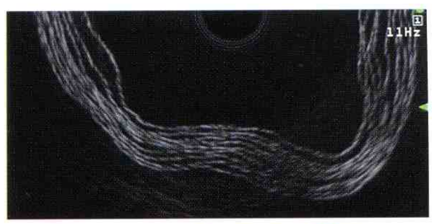
GF-UE160/260-AL5



(e) Electronic Radial 5MHz



(f) Electronic Radial 7.5MHz



(g) Electronic Radial 10MHz

(e) to (g) Electronic radial ultrasound endoscope, model GF-UE160/260-AL5

Image Quality

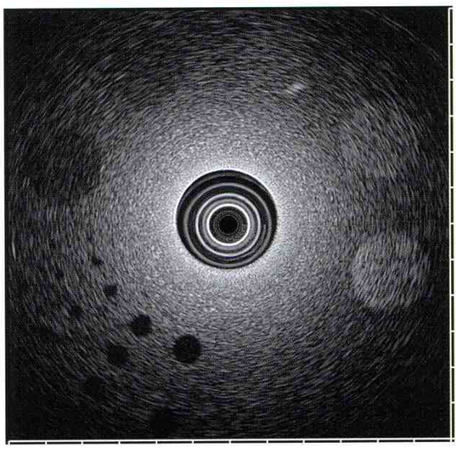
Penetration

Image comparison of Electronic and Mechanical radial ultrasound endoscopes using a tissue-mimicking phantom

Fig.6 shows an ultrasound image using electronic and mechanical radial ultrasound endoscopes. A tissue-mimicking rectal scan phantom (ATS laboratories, CT USA, Model 540) was used. In terms of penetration, both scopes are nearly equal.

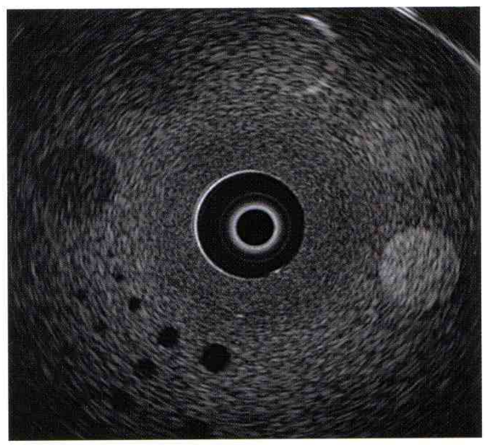
Fig.6 Electronic Radial and Mechanical Radial Images

GF-UM160/2000



(a) Mechanical Radial C5 12cm range

GF-UE160/260-AL5



(b) Electronic Radial 5MHz 12cm range

Function

Multi-frequency imaging

Four frequencies are available when using the electronic radial ultrasound endoscope in combination with the compatible ALOKA processor.

-5 MHz

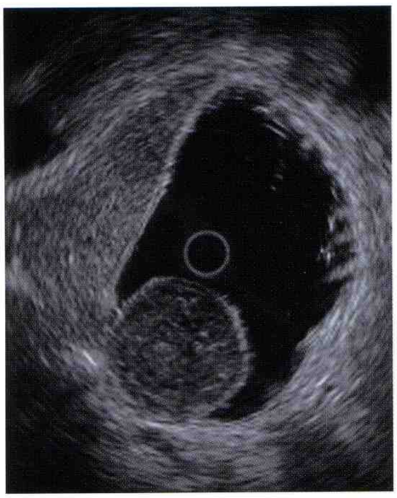
-6 MHz

-7.5 MHz

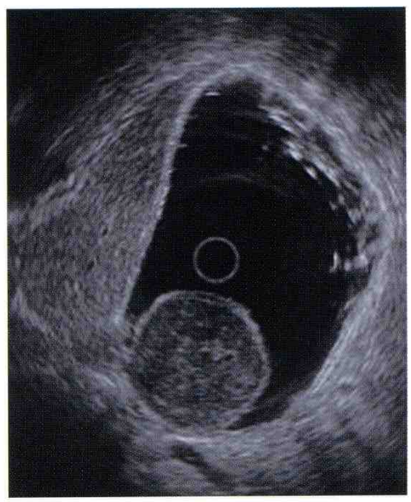
-10 MHz

Fig.7 shows clinical images. A gastric submucosal tumor of the stomach shows a hypoechoic round mass covered with an echogenic submucosal layer.

Fig. 7 Gastric SMT



(a) 5MHz



(b) 7.5MHz

(c) 10MHz

(d) Color Doppler

Ulceration can be seen at the top of the tumor.

Function

Color Doppler / Power Doppler

This function, normally used when performing EUS-guided FNA procedures, is also available with the electronic radial ultrasound endoscope. Doppler capability is useful for two reasons. First, it can help to differentiate blood vessels from lymph nodes, facilitating orientation. Second, it paves the way for new clinical possibilities, using an ultrasound contrast medium to observe blood flow within a lesion.

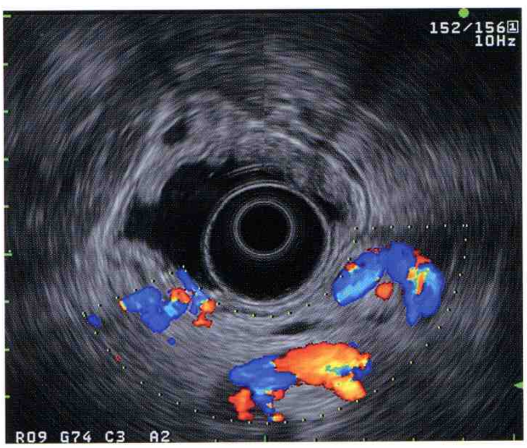
The following modes are available when using ALOKA processors.

-Color Doppler

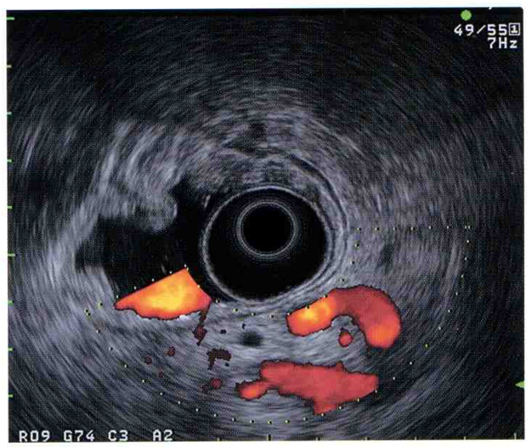
-Power Doppler

Fig.8 shows clinical images.

Fig. 8 Gastric carcinoma



(a) Color Doppler

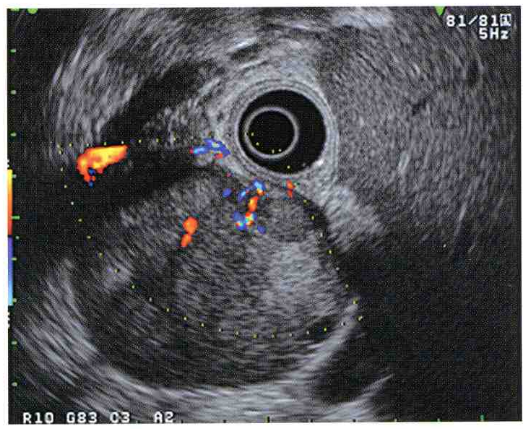


(b) Power Doppler

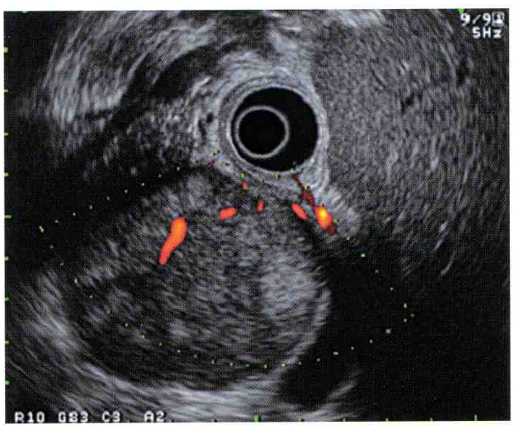
Fig. 9 shows a huge submucosal tumor in the duodenum. Ultrasound penetration was satisfactory. In addition, the blood flow in the tumor can be observed in the Color Doppler images. Though the significance of assessing blood flow in the tumor is still problematic, it will become more apparent in future studies.

Fig. 9 Submucosal tumor of the duodenum observed using electronic radial model

(a) 7.5MHz the whole view of hypoechoic round mass over 5 cm, can be clearly delineated.



(b) Color Doppler image demonstrates blood flow in the tumor.



(c) Power Doppler image demonstrates blood flow in the tumor.

Function

Tissue Harmonic Echo (THE)

THE is a technique in which the transducer receives only the second harmonic of the fundamental frequency originally transmitted. If the transmission frequency (fundamental) of the probe is f_0, the returned echo includes many harmonics ($2f_0$ and others) that are generated in the tissue. With THE, only the 2nd harmonic ($2f_0$) is received and processed. With this function, it becomes possible to more clearly delineate the outline of the lesion of interest and obtain a sharper image.

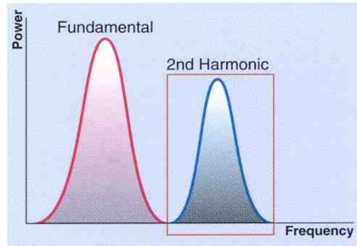
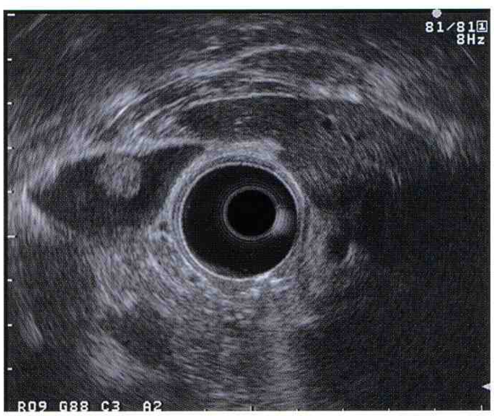


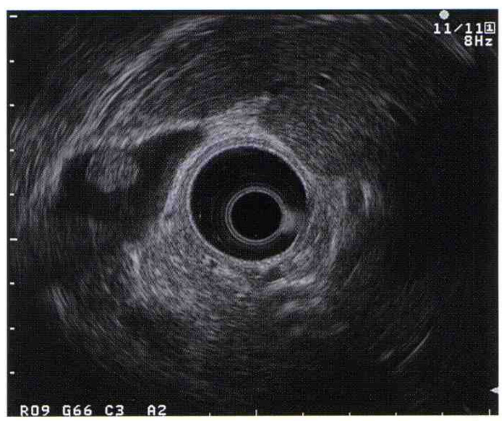
Fig. 10 Schematic diagram of THE

The THE function is typically used with extracorporeal scanning but is also available with the electronic radial ultrasound endoscope. In many cases, image quality improves when using this function.
The following modes (4 modes) are available with ALOKA processors.
-3.75S (Standard)
-3.75P (Penetration)
-5.0R (Resolution)
-5.0H (High resolution)
Fig.11 A gallbladder polyp is shown through the duodenal bulb, with the echogenic polypoid lesion clearly visible. THE, achieved clear observation the lesion. By using THE, the lesion could be clearly seen.

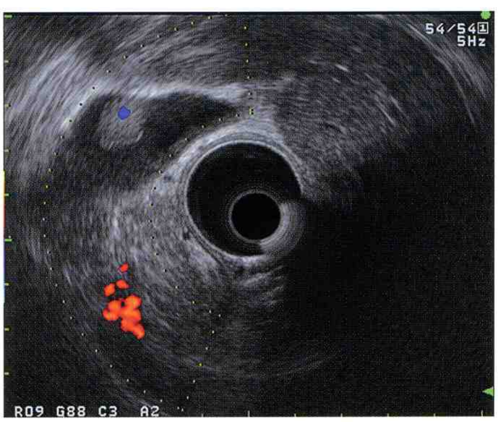
Fig. 11 Gallbladder Polyp



(a) 10MHz



(b) THE 5.0H Mode



(c) Color Doppler

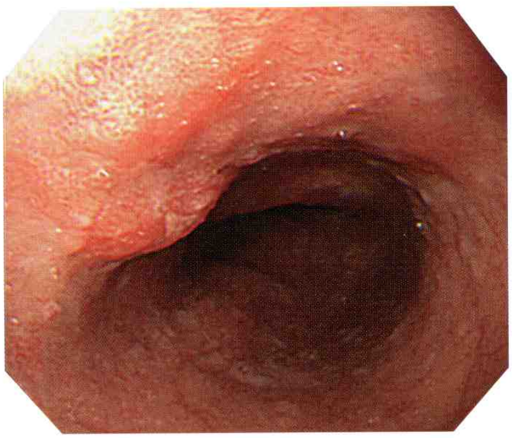
Clinical Case

Case 1

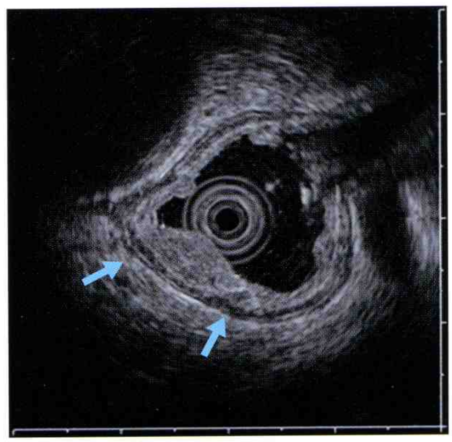
Esophageal carcinoma, sm

Fig. 12 shows a case of esophageal carcinoma observed by the electronic radial ultrasound endoscope. The endoscopic image shows the protruded lesion.
The biopsy study revealed squamous cell carcinoma.
The EUS image shows the tumor mass invading the submucosal layer.

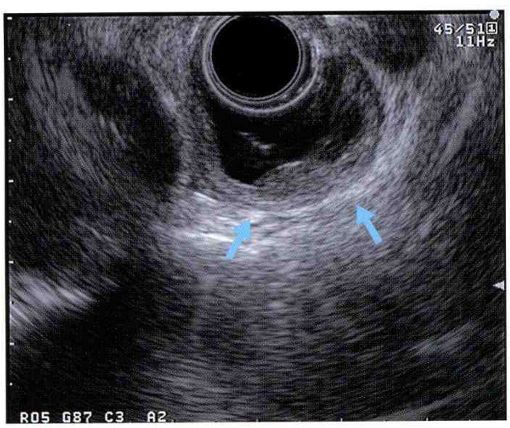
Fig.12 Esophageal carcinoma, sm



(a) Endoscopic finding.



(b) EUS image of the lesion (arrow) obtained when using the ultrasonic probe, UM-DP20-25R (20 MHz) showing the irregular submucosal layer.



(c) EUS image of the lesion (arrow) obtained when using electronic ultrasound endoscope at 7.5 MHz, showing the irregular submucosal layer.

Clinical Case

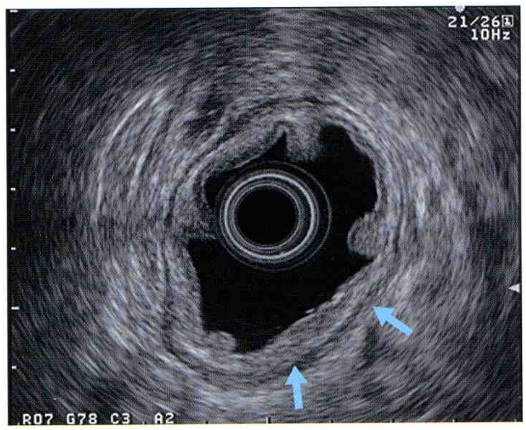
Case 2

Early gastric carcinoma

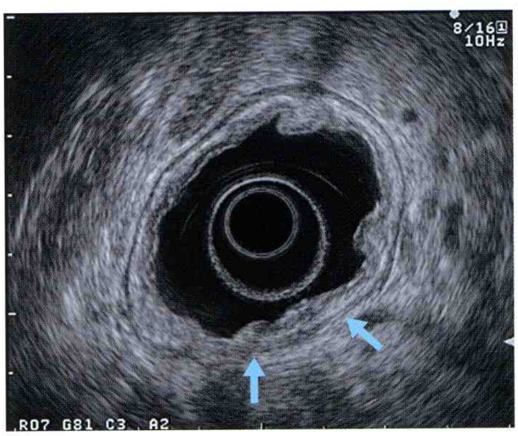
Fig. 13 shows an endoscopic and EUS images of an early gastric carcinoma.
The ultrasound image of the gastric lumen obtained by this EUS endoscope is black. The layered structure of the gastric wall can be delineated as well as it would be by a mechanical radial model. In addition, the image of the surrounding organs was clearer than that generated by mechanical radial models because there is less ultrasound attenuation with the electronic radial scanner.

Fig.13 Early gastric carcinoma (type IIc)

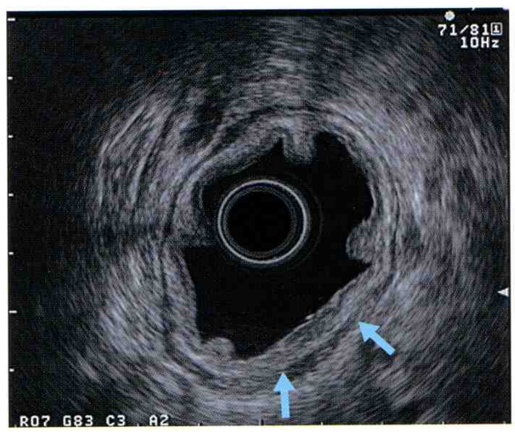
(a) Endoscopic finding



(b) EUS image of the lesion (arrow) demonstrated by the electronic ultrasound endoscope at 6 MHz scanners showing the irregular submucosal layer



(c) 7.5MHz



(d) 10MHz

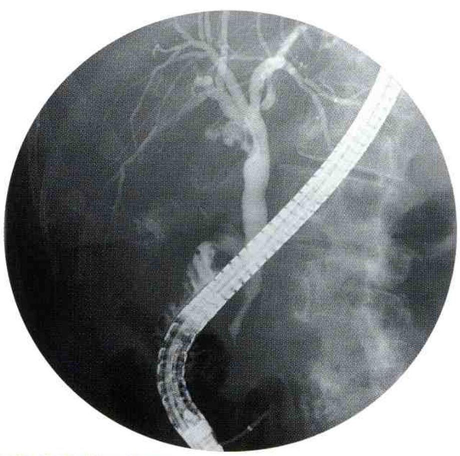
Clinical Case

Case 3

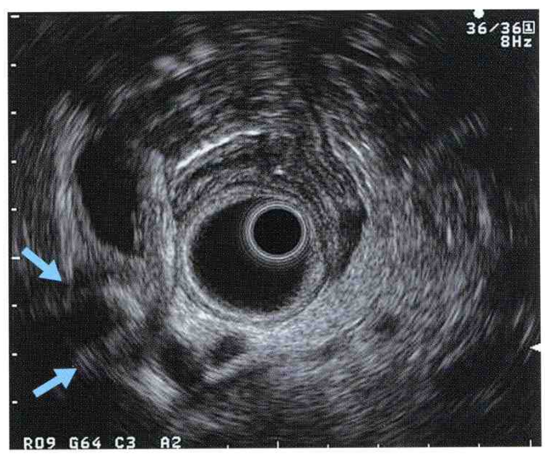
Chronic cholecystitis with gallbladder stone

Fig14 shows an ERCP finding and EUS images of chronic cholecystitis with gallbladder stone. ERCP shows the dilated CBD (common bile duct). We can obtain a clear image of a gallstone with wall and thickening of the gallbladder ((b) arrow) using an electronic radial ultrasound endoscope. This electronic radial model shows satisfactory results not only in image quality but also penetration. By using THE, the CBD ((c) arrow), gallstone with gallbladder wall, bladder thickening and PV (portal vein)((d) arrow) were clearly observed. We can confirm PV blood flow with the Color Doppler function.

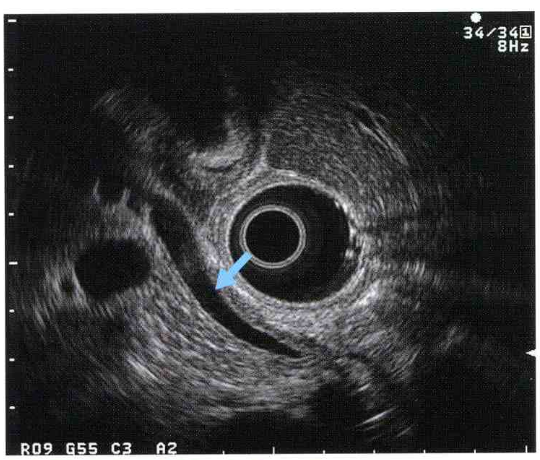
Fig.14 Chronic cholecystitis with gallbladder stone



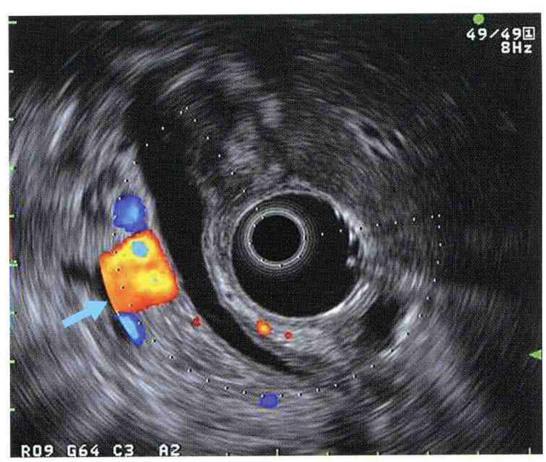
(a) ERCP finding



(b) 5MHz Fundamental image



(c) THE 5.0R Mode image



(d) Color Doppler image

Clinical Case

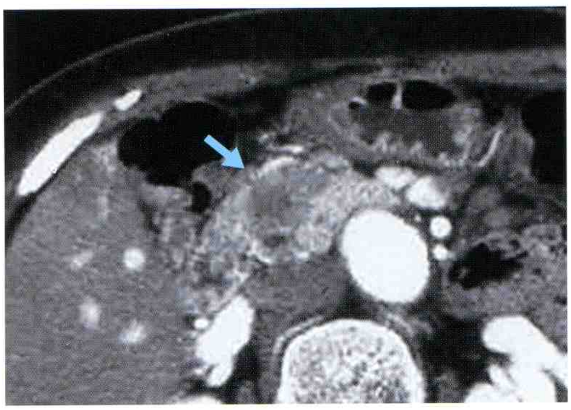
Case 4

Pancreatic head carcinoma

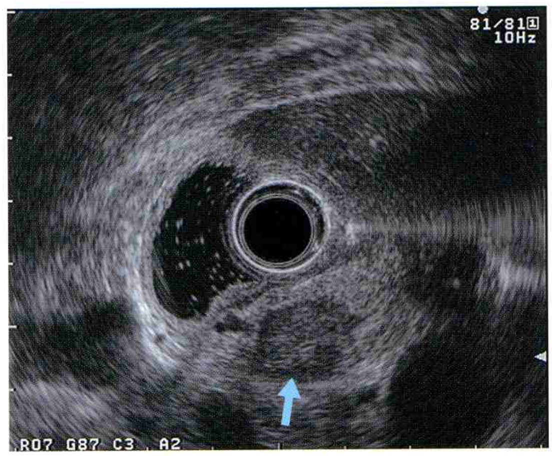
Fig.15 shows a case of pancreatic carcinoma using an electronic radial model. We can obtain clear images of the lesion using an electronic radial ultrasound endoscope. This electronic radial scan model showed satisfactory results not only in terms of image quality, but also in terms of endoscope maneuverability.

CT finding of a case of pancreatic head carcinoma shows a hypoechoic tumor mass (arrow), less than 2 cm in size with the surrounding organs by electronic radial model.

Fig.15 Pancreatic head carcinoma



(a) CT finding



(b) 7.5MHz Fundamental image

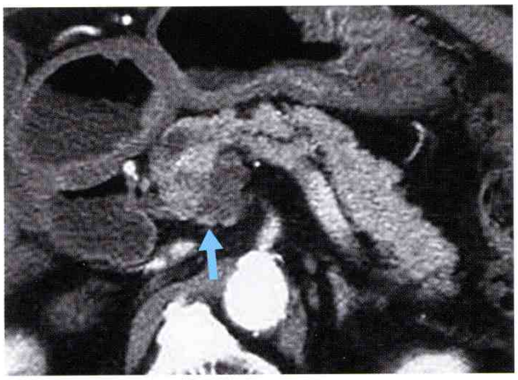
Clinical Case

Case 5

IPMT intraductal papillary mucinous tumor

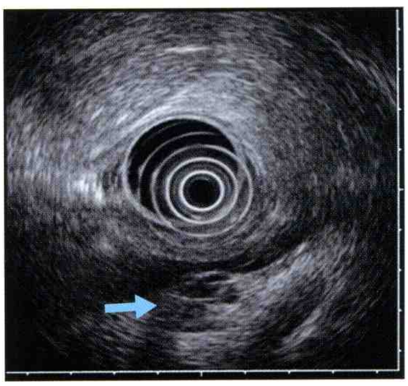
Fig.16 shows a case of IPMT using an electronic radial model. CT shows the cystic lesion at the head of the pancreas. ERCP shows the dilated main pancreatic duct. Mechanical radial EUS shows the multi-located cystic lesion (arrow). Electronic radial EUS demonstrated the same image, but we can confirm the blood vessels with Color Doppler function.

Fig.16 IPMT intraductal papillary mucinous tumor



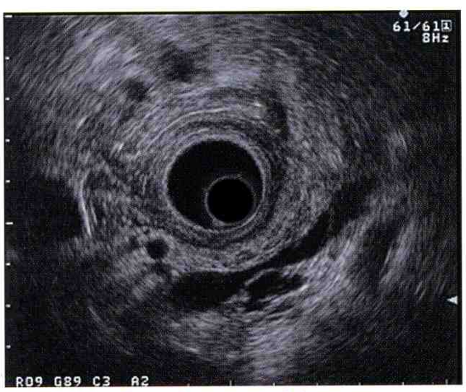
(a) CT finding

(b) ERCP finding



(c) EUS image of the lesion (arrow) at 7.5 MHz using the mechanical radial ultrasound endoscope (GF-UM160/200) showing the irregular submucosal layer

(d) EUS image of the lesion (arrow) at 5 MHz using the electronic radial ultrasound endoscope showing the irregular submucosal layer



(e) 10MHz Fundamental image

(f) Power Doppler

Conclusion

The future of the electronic radial ultrasound endoscope

Electronic radial ultrasound endoscopes are an excellent tool for imaging.
The biggest advantage in using this type of scope is the ALOKA ultrasound processor, which is the same unit that can be used with the convex ultrasound scope for EUS-guided FNA.
Furthermore, image quality is the same as that of the mechanical radial ultrasound endoscope.
I believe that this scope will become the standard for the next generation of ultrasound endoscopes for EUS imaging diagnosis.

Reference

1. Yasuda K, Ogawa M, Nakajima M, Newly developed ultrasound endoscope with an electronic radial array transducer.
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2. Ogawa M, Yasuda K, et al Clinical experience of the new developed electronic radial ultrasound endoscope.
Digestive Endoscopy (contribution process underway)

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