Endorectal ultrasound: instrumentation and clinical aspects

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Abstract. During the period 1983 to April 1986, 129 patients with rectal cancer were treated. In 76 of these depth of penetration of the rectal wall by tumour was assessed by ultrasound. T stage determined by ultrasound (uT) corresponded with the pathological stages (pT) in 67 patients. In the remaining 9 cases, ultrasound overstaged the tumour and in only one patient was the growth understaged. Lymph nodes could be visualised in 12 out of 27 patients in whom nodes were looked for but only six cases were found to be positive on histological examination. Of 22 recurrences detected or proven by ultrasound there was a group of 6 patients who had no other sign of recurrence.

Wild and Reid in 1956 [1] were the first to visualise the rectal wall by ultrasound with a probe introduced into the rectal lumen. Since the equipment at that time was inadequate this technique was neglected until 1983. With an ultrasound scanner designed for urological use we started scanning rectal cancers to assess the depth of infiltration of the tumours [2, 3]. In a small series of 25 cases in which digital examination was compared with rectal sonography we demonstrated that the assessment of tumour infiltration depth by ultrasound was superior to clinical evaluation [4]. Based on our ultrasonic finding we proposed a staging system designated uTNM which corresponded to the TNM system. The prefix “u” denoted that tumour infiltration had been estimated by ultrasonography. Initially we used a 4 MHz transducer but the differentiation between T1 and T2 tumours, i.e., those invading the submucosa versus those involving the muscularis, was difficult. With the advent of the 7 MHz transducer we were able for the first time to differentiate by ultrasound the mucosa from the muscularis propria [5]. It was also possible to visualise lymph nodes with this higher frequency probe.

Technique

Examinations were performed using a 7 MHz radial scanner (Type 1846, Bruel and Kjaer, Denmark). Total length of the rigid probe with the transducer fitted on top of the rod was 24 cm. The transducer rotated mechanically at a rate of 4–6 cycles per second. The reflections of transmitted ultrasonic waves were received at a 90° angle. Scanning radially to the rectal tube axis it provided a 360° display of the rectum and the surrounding tissues. A thin rubber balloon was attached over the transducer. Filled with approximately 60 ml of degassed water it inflated the rectum and provided the acoustic path for the ultrasonic wave. After an enema to empty the rectum the patient was placed in the lithotomy position. The probe was covered with scanning gel and inserted into the rectum either blindly or through a proctoscope. Using the 7 MHz transducer five lines of the rectal wall could be discerned sonographically. Three of these were of high and two of low echo density.

In order to analyse the sonographic appearance of the rectal wall and refer the different lines to anatomic layers we performed in vitro examinations. The excised fresh rectum was scanned in a water bath with the following experimental modifications of technique. A window was cut into the rectal wall to determine the role that the rubber balloon might play in sonographic visualisation. Saline was injected into the submucosa and the specimen was scanned with and without the needle lying in the submucosa. The mucosa and as much submucosa as possible were removed over a quarter of the circumference of the rectum.

The acoustic impedance z, defined as the product of the density of the medium and the sound velocity, were determined for mucosa, muscularis, tumour and fat by both pulse echo and transmission mode.

Preoperative staging

From 1983 to April 1986 we treated 129 patients with rectal cancer. Eighteen had no sonogram and in 19 preoperative endorectal sonography could not be fully achieved owing to stenosis of the bowel lumen. Fifteen patients were treated palliatively and in 76 both preoperative staging by endorectal ultrasound and postoperative histological staging of the excised specimen were carried out. Preoperative staging comprised an assessment of the depth of penetration by the tumour, its topographic relationships to adjacent structures and visualisation of lymph nodes. Based on the TNM system proposed by the UICC [6] we defined the tumours as follows: uT1 confined to the mucosa and submucosa, uT2 confined to the rectal wall, uT3 penetrating into the perirectal tissues and uT4 penetrating into surrounding organs. The pathologist examined a transverse sec-
tion of the fixed rectal specimen at the point of the deepest infiltration and determined the pT stage. Preoperative assessment of lymph nodes uN was compared to the histopathological lymph node stage pN.

Postoperative follow-up

The standard protocol for the postoperative follow-up of patients operated on for cure was supplemented by endorectal ultrasound. Of the 129 patients treated between 1983 and 1986, 86 were suitable for sonographic follow-up. Ultrasound examinations were performed every 3 months. The probe was inserted via a proctoscope as far as possible and special emphasis was placed on examining the anastomosis, the perianastomotic region, the iliac vessel and the presacral space. Women who had undergone an abdominoperineal resection were examined per vaginam. Structures suspicious of recurrence were biopsied under sonographic guidance or repeatedly scanned at 6-week intervals. In some patients a CT scan was performed.

Interpretation of the image

With the 7 MHz transducer it was possible to discern five lines of echo density in the intact rectal wall. From the center to the periphery these showed as a high echoic white line, a low echoic dark line, a high echoic white line, a low echoic dark line and a high echoic white line (Fig. 1). This appearance is consistent with the following explanation. A single anatomic layer has two interfaces which appear on the sonogram as white lines. The imaging of an anatomic layer is only possible if the axial resolution is high enough to distinguish between the transmitted and the reflected ultrasound beam of the layer. Thus the layer has to have a minimum thickness corresponding to the frequency used. When a second anatomic layer which is also confined by two interfaces is added, and the second layer has a common interface with the first, then there will be three interfaces which will correspond with three white lines on the sonogram. The anatomic layers will appear as dark lines between the interfaces (Fig. 2). To generalise, if n layers have n + 1 interfaces, then they will be represented by n + 1 white lines. As far as the rectum is concerned, the two dark layers of mucosa and muscularis are accompanied by three white lines.

The in vitro studies revealed that the balloon alone when filled with water or saline was imaged as a thin white line. In the rectum the interface between mucosa and the balloon itself appeared as one white line. This could be demonstrated when a window was cut into the rectum. The thin white line of the balloon which was seen in the aperture continued without thickening beyond the window when it came in contact with the mucosa. On scanning the rectal wall without using a balloon the inner white line was shown to represent the interface which arose when part of the wave was reflected at the surface of the mucosa. On injection of saline into the submucosa we were able to demonstrate that the resulting thickened plane belonged to the inner low echoic line representing mucosa and submucosa. The reflection of the needle tip could also be located to this region. After removal of the mucosa and submucosa disruption of the inner low echoic line was observed while the outer low echoic line remained unchanged.

The fact that the rectal wall as shown in Figure 1 did not exactly conform to the above explanation may be due to the focal length of the 7 MHz transducer which ranges from 2 to 5 cm. Because the transducer does not lie in the center of the rectal lumen, not all of the rectal wall may be within the focal area. Furthermore the rectal wall is not exactly at 90° to the transducer throughout its circum-

Fig. 1. Sonographic appearance of the rectal wall. Black cavity = water filled balloon. White circle in the black area = transducer. The three white interfaces and the layers mucosa and muscularis are visible between five and nine o'clock

Fig. 2. Interpretation of the sonographic appearance of the rectal wall. I1 = interface between water and mucosa (mu) I2 = interface between mucosa and muscularis (mc) I3 = interface between muscularis and fat. T = transducer