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The Sonographic Appearance and Contrast Enhancement of Puncture Needles

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Abstract: Investigations on the ultrasonic appearance of puncture needles in vitro and in vivo are reported. The images from the waterbath phantom correspond closely to those seen in the human body. The surfaces of smooth puncture needles reflect the ultrasonic beam so that, in most cases, the shaft is not visible. Surface roughnesses and small air bubbles enhance echogenicity and contrast of such needles. These roughnesses or inhomogeneities may be extraluminal or intraluminal. The phenomenon of the needle tip echo and its modifications are interpreted as physical and technical artifacts. **Indexing Words:** Ultrasound · Puncture needles · Contrast enhancement

The development of ultrasonic puncture techniques during the last decade has led to an improvement in the diagnosis and treatment of intra-abdominal diseases.[1–3]

The basics of ultrasonically guided puncture have been developed by means of compound B scanning.[4,5] With this technique, localization of pathologic structures in relation to the skin surface, measurement of the distance from the skin to the structures of interest, and angulation of the puncture instrument became possible.

The development of real-time ultrasonic puncture transducers afforded further improvement and new possibilities for puncture guidance.[2,6,7] Dynamic visualization of the structure to be punctured and the advancing needle tip were now possible.

In this article we will describe the sonographic appearance of some puncture needles. Special attention will be paid to the possibilities of contrast enhancement.

MATERIALS AND METHODS

Puncture Needles

We examined four different puncture needles with an outer diameter of 1.0 mm : a CHIBA needle (Dickinson & Co., Rutherford NJ), a NORDENSTRØM needle (Ursus Consult AB, Stockholm, Sweden), a JONATHA needle (Ullrich, Ulm, West Germany), and a TSK-supra needle (TSK Laboratories, Tokyo, Japan). The NORDENSTRØM needle is characterized by a special stylet which is 28 mm longer than its cannula. The distal 17.5 mm of the stylet is constructed like a screw with 1 turn/mm. The JONATHA needle is provided with a spiral groove of 1.2 turns/mm on its distal two-thirds. All the needles have beveled tips. The tip of the TSK-supra needle is provided with a faceted bevel.

For enhancement of echogenicity, the TSK-supra needle was used with an angiographic guide wire instead of an obturator, and the CHIBA needle with either an obturator roughened by sandblasting or an echogenic air-jelly mixture.

Ultrasound Scanners

For ultrasonic imaging we used a linear array real-time scanner SAL 20 A (Toshiba Corp., Düsseldorf, West Germany) with a 2.4 MHz puncture transducer with central puncture slit. Gain setting was constant for the in vitro experiments. A sector scanner SONODIAGNOST R 2000, 3,5 MHz (Phillips Corp., Düsseldorf, West Germany) was used in some studies.

A polyurethane ether phantom with a cyst-like hole immersed in a waterbath consisting of a plastic tank containing 15 liters of degassed water was used for the in vitro studies.

In one patient, an abscess that occurred in the

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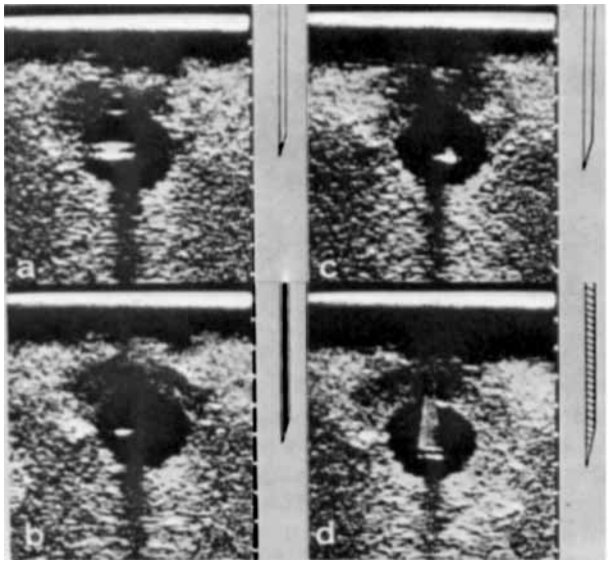

FIGURE 1. Waterbath phantom with cyst-like hole. (a) TSK-supra needle. (b) CHIBA needle. (c) NORDENSTRØM cannula. (d) JONATHA needle.

right lower abdomen after choledochojejunostomy and cystojejunostomy of a pancreatic pseudocyst was punctured and aspirated. The puncture procedure was done with a TSK-supra needle with and without the guide wire obturator.

RESULTS

Inside the cyst-like hole of the in vitro model, the tip of the TSK-supra needle is seen as a double line [Fig. 1(a)]. The elliptic needle tip echoes are elongated on both sides forming a thin arched artifact when the gain setting is elevated. At the tip of the CHIBA needle, a single echo is seen which is smaller than either echo from the TSK-supra needle [Fig. 1(b)]. The NORDENSTRØM cannula without stylet shows an echo on the ultrasonic screen similar to that of the CHIBA needle [Fig. 1(c)]. No shaft echoes are seen with any of these instruments.

The tip of the JONATHA needle [Fig. 1(d)] shows a double line reflection like the TSK-supra needle, but the two echo lines are less intense and shaft echoes are clearly seen when the JONATHA needle is scanned.

Whenever the stylet of the NORDENSTRØM needle is introduced into the cannula, a mace-like echo complex appears running down the needle and below the tip [Fig. 2(a,b)].

Echogenicity enhancement of the shaft of the CHIBA and TSK-supra needle was achieved by introduction of an angiographic guide wire into the TSK-supra needle, by use of the air-jelly mixture or an obturator roughened by sandblasting with the CHIBA needle. All these modifications

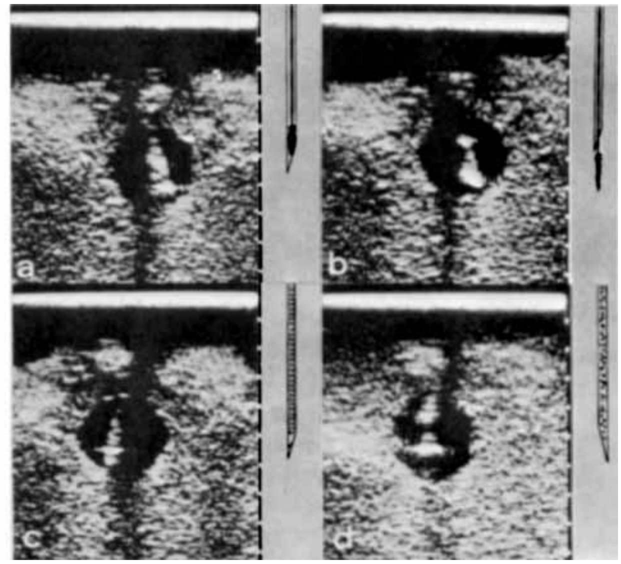

FIGURE 2. Waterbath phantom with cyst-like hole. Puncture needles with enhanced echogenicity. (a) NORDENSTRØM needle, stylet inside the lumen of the cannula. (b) Echogenic tip of the stylet below the tip of the cannula. (c) TSK-supra needle with guide wire obturator. (d) CHIBA needle with intraluminal air-jelly mixture.

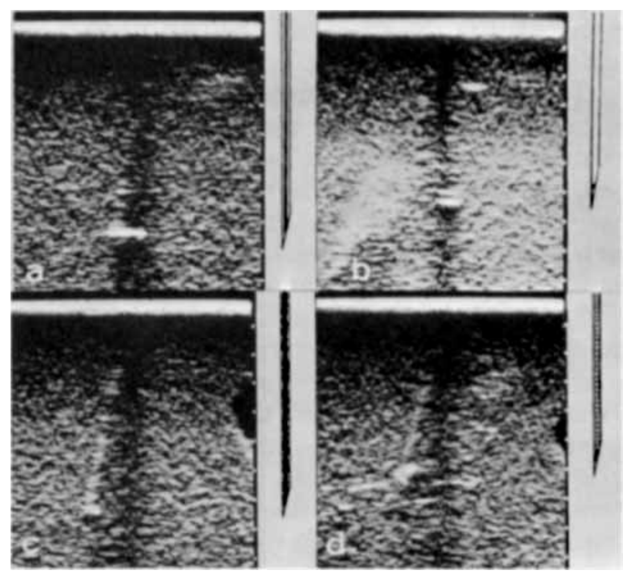

FIGURE 3. Waterbath phantom, solid area. (a) CHIBA needle. (b) TSK-supra needle. (c) CHIBA needle with obturator roughened by sandblasting. (d) TSK-supra needle with guide wire obturator.

result in marked enhancement of echogenicity and contrast [Fig. 2(c,d,3.c,d)].

In solid echogenic material the CHIBA and the TSK-supra needle may be visualized as a bright, high amplitude needle tip echo surrounded by an area of lower amplitude echoes of the solid tissue [Fig. 3(a,b)]. With the JONATHA needle, the screw-like end of the NORDENSTRØM stylet inside the cannula, the TSK-supra needle with guide wire obturator, or the CHIBA needle with roughened obturator, even the course of the shaft is seen in the echogenic material [Fig. 3(c,d)].

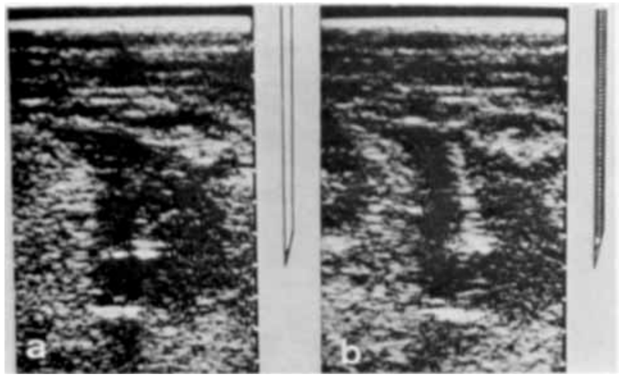

FIGURE 4. Echogenic abscess. (a) TSK-supra needle. (b) TSK-supra needle with guide wire obturator.

The sonographic findings in the puncture of an echogenic abscess correspond closely to those of the solid areas of the phantom. The TSK-supra needle shows a double-lined needle tip echo [Fig. 4(a)]. Shaft echoes appear after introduction of the guide wire obturator [Fig. 4(b)].

As can be seen in Fig. 5, results similar to those obtained with the linear array scanner were also obtained with sector scanning.

DISCUSSION

Using the NORDENSTRØM cannula, the CHIBA, and the TSK-supra needle, only the tip of the needle is visualized. The lack of shaft echogenicity is due to the reflecting surfaces of the instruments; the ultrasonic beam is reflected geometrically so that it will not arrive at the same transducer element from which it is emitted.[8] The arched echo line at the tip of the needle is probably caused by a combination of several physical and technical effects; incomplete electroacoustic separation of the transducer elements, oscillation in more than one axis, reflection within the material of the puncture needle,[9] and transformation of longitudinal waves into transverse and surface waves.[10,11] The latter two enhance the intensity of the ultrasonic energy with regard to time and space, and thereby enable the former to be recognized. Oscillation in more than one axis and incomplete electroacoustic separation are responsible for the form of the artifact.

The needle tip echo itself allows two hypotheses: (1) the factors expressing the arched echo line are not intense enough to form a long echo line so that only a spot-like echo is seen; and (2) a local, spot-like inhomogeneity, such as a needle tip, will cause only a spot-like echo on the screen.

Visualization of the shaft of an instrument is possible only if the ultrasonic beam is scattered by inhomogeneities.[12–15] Such an inhomogeneity can be produced by surface roughnesses or microbubbles on the outer or inner surface of an otherwise smooth instrument. The spiral windings of the NORDENSTRØM stylet, the

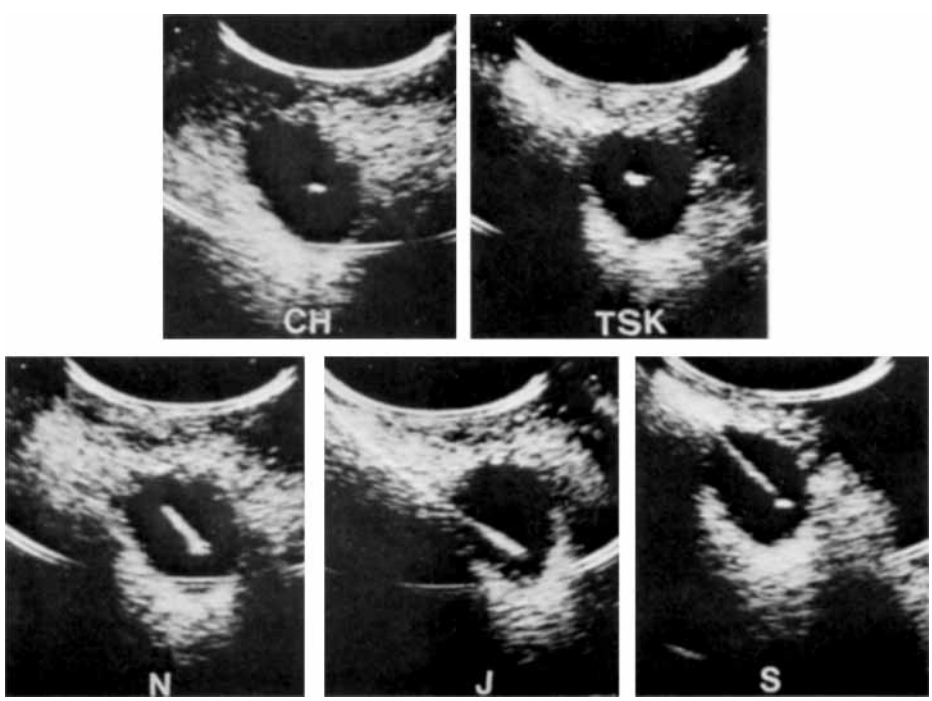

FIGURE 5. Images of various puncture needles obtained with the Phillips sector scanner in an oblique plane. CH = CHIBA needle, single needle tip echo. TSK = TSK-supra needle, double-lined needle tip echo. N = NORDENSTRØM needle with stylet inside the cannula. J = JONATHA needle, marked shaft echoes even with the echogenic tissue. S = CHIBA needle with obturator roughened by sandblasting.

JONATHA needle, or the angiographic guide wire, as well as the roughened obturator of the CHIBA needle represent ultrasonic roughnesses which cause scattering of the sound beam. This phenomenon is basic for the enhanced echogenicity of these and similar structures. Inhomogeneity leads to enhanced echogenicity and contrast from scattering if it is small compared to the wavelength.

The sonographic images found in the waterbath phantom are likewise seen in parenchymal organs and echogenic fluids, as is demonstrated in the case of abscess puncture.

It should be emphasized that extraluminal and intraluminal inhomogeneities of the needle surface result in equal echogenic contrast effects. Thus, the traumatizing effect of outer surface roughening may be avoided without loss of contrast effect.

This ultrasonic contrast effect of scattering material is not limited to linear array scanners, or even to parallel scanners, but it can be observed with any ultrasonic pulse echo technique, because it is adapted to the combined transmitter-receiver function of the single transducer element.

These facts will be important for ultrasonically guided percutaneous manipulations. Furthermore, because the scattering contrast effect depends primarily on the surface and not so much on the material of an instrument, any alloplastic material may be given such a contrast effect to improve its control with ultrasound.

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