RECENT ADVANCES IN ULTRASOUND DIAGNOSIS 5

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Foreword

The first five meetings 'Recent Advances in Ultrasound Diagnosis' discussed general aspects of the significant advances in diagnostic ultrasound. For the sixth one we have chosen two more specific topics: interventional ultrasound and measurements of human blood flow.

The first ultrasonically guided puncture, using a specially designed transducer, was performed in 1969 at the ultrasonic laboratory in Gentofte, now Herlev Hospital, Copenhagen. Since that first attempt, the new technique has proven invaluable for the wide variety of therapeutic purposes, such as drainage of intraabdominal abscesses, percutaneous nephrostomies, urinary obstetrical applications, etc. There is no doubt that the future will bring an enormous expansion in the number of performers and users of this promising technique. We therefore, have asked a number of experts to review their specific areas of interest and experience. We are especially grateful to H.H. Holm, a pioneer and world top expert for his two excellent chapters.

On the other hand, ultrasonic measurements of human blood flow have brought about significant changes in obstetrics and cardiology, fundamentally because of the tremendous amount of new information quite easily provided by this technique. Gill and his co-workers have been pioneers in blood flow measurements with the pulsed Doppler technique in pregnancy. However, a significant progress is made by the recent introduction of the measurements in the fetal aorta, umbilical vessels, uterine arteries and ovarian vessels. The readers will find several chapters from this field. The new colour Doppler technique is described by C. Kasai, who originally designed the procedure and published the first clinical results.

For both of us it was a real pleasure to work together on these proceedings. However, editorial work would have been very difficult without great help of the secretaries Vesna Balija and Snježana Kvesić.

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INTERVENTIONAL ULTRASOUND

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The last ten years have supplied the medical world with a number of extraordinary imaging techniques such as dynamic ultrasound scanning, CT-scanning and NMR scanning, which on completely different physical basis provide high resolution sectional images with precise morphological information.

However, despite of that and despite attempts of socalled "tissue-characterization" by the above techniques, there will undoubtedly also in the future be a need for a precise percutaneous procedure which virtually without risk can provide minute tissue samples for cytological or histological examination and thereby form the basis for optimal therapy and prognostic evaluation. Furthermore, the percutaneous route represents in an increasing number of cases an important therapeutic alternative in surgery, oncology and obstetrics.

The need for tissue sampling can only to a rather limited extent be fulfilled by gastroscopic, coloscopic and laparoscopic biopsies and explorative laparotomy with biopsy should be avoided if possible.

An imaging technique which can disclose most space occupying lesions and at the same time act as a practical puncture guide would be highly effective and timesaving, especially if the puncture routinely is performed in the same setting as the imaging procedure.

Fluoroscopy in two planes has been found useful but is certainly not especially easy. CT-scanning has also been used to visualize the needle after its insertion.

However, the method can hardly be called rapid or convenient and as stated by Ferruchi and Wittenberg - the procedure takes 1-2 hours.

To use NMR for needle guidance would probably be disastrous.

Dynamic ultrasound scanning on the other hand represents such an ideal method for percutaneous puncture guidance.

The principle in ultrasonically guided puncture is simply that

some kind of needle steering device restricts the movement of the needle to the image plane. The scanner is moved and tilted until the target is transsected by the markerline indicating the needle path. When the needle is inserted to the appropriate depth - apparent from the image - the needle will inevitably hit the target. The echo from the needle tip is in most cases directly visible during the insertion.[1,2,3]

A new puncture guide principle is applicable for all dynamic scanners. The image plane is angulated by refraction and thereby the needle can be inserted through a puncture canal directly in the center of the image plane.

Rather few needles are sufficient for all purposes. A lumbar type 1.2 mm needle for all fluidfilled lesions. A o.6 mm needle to obtain cytological material from solid lesions. And one of several types of special fine needles for histological sampling. A fine needle aspiration biopsy is routinely performed when malignancy is suspected in a solid lesion.

After sterilization of the skin and application of local anaesthetic an outer guide needle is inserted just through the abdominal wall to stabilize and allow multiple passes of the fine needle.

The fine needle attached to a lo cc syringe mounted in an aspiration handle is then inserted through the guide needle into the target.

Full suction is then applied and the needle tip is moved up and down five to six times inside the tumor.

The suction is released and the aspiration device withdrawn and handled to the nurse. Procedure is repeated four to five times in different directions.

The material - usually only a small drop - is smeared and stained according to the usual routine.

Based on the usual cytological criteria it is possible with a satisfactory accuracy to differentiate between benign and malignant tissue - but nothing more.

We have used this technique the last 15 years.

The last 2 years we have added a fine needle histological biopsy to our armamentarium. We have used the sure-cut® needle providing microcore biopsies.

The advantages of this technique which has a slightly higher sampling error are that it sometimes can improve the typing of

malignant tumors and provide better information about the benign lesions which have caused the suspicious ultrasonic finding. Furthermore, that the tiny histological sections are much faster to screen than the numerous cytological smears. Finally, since usual histological knowledge is sufficient a specialized cytologist is unnecessary.

Based on the fact that complications in more than 5ooo abdominal punctures have been extremely rare we now routinely perform all punctures without any preparations at all. In special cases, however, when a coagulation defect is suspected bleeding time and coagulation time are checked. With large core liver and kidney biopsies the standard precautions are still used.

Only a few restrictions exist regarding puncture routes. Hundred of punctures performed through the gastrointestinal tract and many through the urinary bladder have in our laboratory proved to be quite safe.

Puncture of the pancreas is preferably carried out below the liver edge. However, if the pancreas is not accessible without transhepatic puncture such punctures are performed without hesitation. It is recommended, however, to avoid the very edge of the liver which may be lacerated by the needle during respiratory motion.

Since puncture through the pleura or lung should be avoided a cephalad angulated puncture route is selected for focal lesions in the dome of the liver.

For the same reason upper renal pole lesions are also punctured in a cephalad direction.

The patient should be asked to avoid extensive respiratory movements during the puncture. In some instances - as when the target is very small - it is an advantage to suspend respiration during the puncture.

Finally, it is not wise to puncture aneurisms, but it seems to be safe to puncture pheochromocytomas.

In the following I would like to describe various indications for needle intervention in abdominal diseases and some results obtained in our institution.

A solid focal liver lesion may be a benign hepatic hemangioma or another benign lesion, or it may be a metastasis, f.ex. from a colonic cancer or it may be a primary livercancer.

Occasionally the guided liver biopsy reveals surprising results.

E.g. cytological as well as histological biopsy from an echopoor as well as from an echodense liver pattern in an asymptomatic man showed completely normal findings and a round echopoor area in the liver from a man with a pancreatic cancer revealed slight steatosis.

Even very small focal lesions are detectable by up to date dynamic ultrasound scanning. E.g. biopsy taken from a single 1 cm metastases. The needle tip is clearly visible. An autopsy specimen a week later confirmed the ultrasonic and microscopic findings.

Table I summarizes the results of 247 fine needle aspiration cytology biopsies. The final diagnoses were obtained from surgery, autopsy or compelling clinical evidence.

TABLE I
FINE NEEDLE ASPIRATION FROM SOLID LIVER LESIONS

			Cytology		
			+	-	Insuff.
Final diagnosis	Malignant mass:	222	2o3	17	2
	Benign condition:	25	o	25	o
	Total:	247	2o3	42	2

PV_{pos} = loo%

PV_{neg} = 6o%

In a comparative study where each of 77 solid liver lesions had 3 aspiration biopsies as well as 3 sure-cut biopsies performed the sure-cut biopsy gave extra information in 17 cases.

A cystic lesion in the liver may be a simple livercyst or may e.g. be a metastasis with cystic degeneration f.ex. from an ovarian cancer. There are quite a number of other cystic lesions in the liver. For the differentiation of these various possibilities a guided puncture with a 1.2 mm needle is indicated. Puncture through liver tissue is advisable to prevent leakage.

It has previously been considered contraindicated to puncture ecchinococcus cysts. However, recently Sevinc and collaborators from Turkey in 29 cases where they performed fine needle puncture of ecchinococcus cysts had no complications at all. The same result has been found by others.

The puncture technique may also be used as an aid in percutaneous transhepatic cholangiography as introduced by dr. Makuuchi from Japan. With ultrasound dilated intrahepatic bile radicles can be demonstrated and act as a puncture target.

Thereby various irregularities of the biliary tree can be seen after injection of radiopaque contrast medium.

Pancreas, when enlarged locally, is an obvious puncture target.

Since 1974 it has been routine in our institution to perform ultrasonically guided fine needle biopsy of the pancreas to demonstrate possible malignancy. Punctures are performed whenever the scanning shows a solid mass lesion, since it is not possible with sufficient reliability to distinguish between a malignant pancreatic mass and a swelling caused by chronic pancreatitis.

Table II summarizes the result of pancreatic biopsies in 19o cases where ultrasound show a solid mass lesion of the pancreas.

TABLE II

FINE NEEDLE ASPIRATION FROM SOLID PANCREATIC LESIONS

			Cytology		
			+	-	Insuff.
Final diagnosis	Malignant mass:	117	84	27	6
	Benign condition:	73	2	64	7
	Total:	19o	86	91	13
	PV_{pos} = 98%				
	PV_{neg} = 7o%				

Simultaneous sure-cut biopsies in 47 patients differentiated almost equally well between benign and malignant lesions but

revealed extra information in 15 cases.

When a pancreatic cyst is disclosed a puncture with a 1.2 mm needle is more or less considered an integral part of the study. The puncture is diagnostic as well as therapeutic. Diagnostic since echopoor or echofree lesions may be pseudocysts, abscesses or rarely malignant cysts of the pancreas. Therapeutic since cysts may be treated temporary or definitively through fluid aspiration by single or repeated punctures with possible catheter implacement.

A catheter may be placed directly into the cyst or through the stomach if this is located anteriorly to the cyst. Hancke[4] has treated 19 patients succesfully by percutaneous insertion of a small double pigtail catheter between the stomach and the cyst.

Relief of pain is an important indication for pseudocyst aspiration. In fact, a rather large number of patients are referred to our department for puncture because of pain which usually is releaved immediately.

In a series of 148 patients who had ultrasound performed in our institution during their first attack of acute pancreatitis 19 had developed a pseudocyst of the pancreas. 2 cysts resolved spontaneously, 8 were cured after puncture or catheterdrainage, 1 refused treatment and 8 went to surgery after unsuccesful puncture.

In the last few years it has also proved possible to do ultrasonically guided puncture of the pancreatic duct directly when dilated, pioneered by the Japanese. With subsequent contrast injection and fluoroscopy this technique may give valuable information of the duct morphology and site of stenosis.

Renal mass lesions have been obvious puncture targets since the early days of the ultrasonically guided puncture technique.

However, out of 3o1 biopsies in which 83 were from benign lesions, 14 false positive diagnoses occured. These 14 cases, which included chronic pyelonephritis, renal infarctions and adenomas represent far the highest false positive rate experienced in our laboratory. It reflects the wellknown difficulties in renal cytology.

It is therefore of special interest to find out whether a histological fine needle biopsy from renal masses can improve the results. The first series with a o.6 mm sure-cut needle

showed too many insufficient biopsies. We have recently for this particular purpose increased the needle size to o.8 mm which seems to improve the results.

A small mass lesion suspicious of an enlarged lymph node adjacent to the aorta as well as a large retroperitoneal tumour represent a clear indication for an ultrasonically guided fine needle biopsy.

From a urological point of view e.g. it is of great importance to be able to detect with certainty dissemination of bladder cancer or prostatic cancer to the retroperitoneal lymph nodes.

A positive fine needle biopsy is a contraindication for a cystectomy and total prostatectomy or seed implantation, respectively.

Table III shows the result of a series of loo fine needle aspiration biopsies from retroperitoneal solid tumours. 1/3 were primary malignant tumours while 2/3 were metastases from a wide variety of organs. No false positives.

TABLE III
FINE NEEDLE ASPIRATION FROM RETROPERITONEAL MASSES

			Cytology		
			+	-	Insuff.
Final diagnosis	Malignant	78	67	6	5
	Benign	22	o	21	1
	Total	loo	67	27	6

PV_{pos} = loo%
PV_{neg} = 78%

Since the ultrasound pattern named a "target lesion" simply indicates thickening of the bowel wall and are non-specific it is not possible with certainty to differentiate between a benign and a malignant lesion. Sometimes this distinction may be difficult clinically, radiologically as well as endoscopically.

By ultrasonically guided fine needle aspiration it is possible to make such a distinction on sonographically demonstrated lesions.

During a 5 years period we have performed ultrasonically guided fine needle biopsy in 78 patients with an ultrasonic finding suggesting gastrointestinal pathology. In approximately half of the cases the lesions was detected primarily by ultrasound. The material gives no information about the number of gastrointestinal masses overlooked by ultrasound in the same period.

In 19 cases the lesion were located in the stomach, in 3 cases in the small intestine and in 56 cases in the colon. The verification was obtained in all cases - the majority by operation and in a small group from the clinical course.

Among the 18 malignant lesions in the stomach verification of the malignant nature of the lesion could not be obtained by gastroscopy including biopsy in 5 patients, although repeated attempts in 2 cases were performed.

Surprisingly 7 of the 4o patients with primary or secondary cancer of the colon were not disclosed by the barium enema.

On the basis of this material we therefore recommend ultrasonically guided fine needle biopsy in cases of incidentally disclosed abnormal bowel pattern. To distinguish between benign and malignant colonic stricture. Also where an equivocal barium study or unsuspected negative endoscopic biopsy is found.

Because of fear of tumor seeding patients with gynecological tumours have previously not been sent to ultrasonically guided fine needle biopsy. However, in our institution this attitude has changed a year ago and solid gynecological tumours are now routinely subjected to fine needle biopsies.

Torben Larsen[5] from our department and co-workers have performed fine needle aspiration biopsy for cytology as well as a 23 gauge sure-cut biopsy from a consecutive series of patients referred to the ultrasound department for evaluation of a suspected gynecological tumour. The two types of specimen were evaluated separately and independantly by two competent pathologists.

The total material includes 13o referred patients. However, in 87 patients the ultrasound examination was either normal or showed no solid lesion.

In the remaining 43 patients the examination revealed tumours with solid parts which could be biopsied transperitoneally without puncturing cystic parts.

26 were performed in local anaesthesia. The remaining 17 tumours were biopsies in general anaesthesia in connection with the

sceduled curettage.

The final diagnoses were obtained by laparotomy in 38 cases which include 18 malignant and 2o benign tumours.

One diagnosis of myeloma was verified by haematological and radiological findings.

Four patients with cytological and histological findings indicating fibromyoma did not undergo operation and have been followed clinically for 8 months, with no evidence of malignancy.

The results of the cytological specimens concerning malignancy were in accordance with the final diagnosis in 16 out of 18 cases. Two were false positives described as suspicion of malignancy and were proved to be a uterine and an ovarian fibroma, respectively. The predictive value of a malignant cytology is thus 89%.

Concerning the benign cytological results 15 were true negatives, one was false negative as the lesion was proven to be a cystadenocarcinoma. The predictive value of a benign cytology is thus 94%.

Finally, 9 biopsies were found to be insufficient. None of the patients had the procedure repeated. The final diagnosis of these patients were malignancy in one case and benign conditions in the remaining 8.

The supplementary histological biopsies in these patients gave a true benign result in 7 cases, 1 was false negative and finally, one was still insufficient.

The correlation between the histological biopsies and the final diagnoses was as follows:

- The 11 positives were true, none were false positives, so the PV of a malignant histologic answer was 1oo% (72-1oo).
- Out of 22 benign answers 19 were true, so the PV of a benign histology was 86% (65-99).
- 3 were false negatives - all cystadenocarcinomas.
- 1o were insufficient of which
- 4 were malignant - these were all detected by the cytological procedure and
- 6 were benign
- 4 of these were diagnosed correctly by the cytology, 1 was false positive and 1 insufficient.

If we add the results of the two types of fine needle biopsies with implicit confidence to a malignant or suspicious answer, whether cytology or histology, we still have 2 false negatives -

the most serious group from a clinical point of view - and 2 false positives. But the total number of insufficient biopsies is reduced significantly.

We feel that the method deserves a prominent position among the preoperative procedures in patients with tumours in the small pelvis.

Another serious challenge for the gynecologist is the follow-up after surgery or irradiation of patients with gynecological tumours. The main problem is to differentiate between post-treatment sequelae and tumour recurrence.

In the posttherapeutic stage the cervical part of the uterus and the rectovaginal area in particular are often difficult to evaluate by pelvic palpation as well as by abdominal ultrasound - which easily disclose tumours of the uterine body and the ovaries.

In this situation transrectal ultrasound scanning represent a useful diagnostic tool which often provides informative trans-sectional images of the pathology in the deep pelvis.

An abnormal ultrasonic finding, however, is non-specific and microscopic verification is mandatory before treatment can be instituted.

In 1981 - together with Gammelgaard - I[6] described a method for precise transperineal biopsy of the prostate guided by transrectal ultrasound.

Torben Larsen and co-workers from Herlev have applied this technique to pelvic masses and used the sure-cut fine needle biopsy system which provides a tissue core for histological evaluation - as well as a conventional fine needle aspiration biopsy for cytological evaluation.

The ultrasound examination is carried out with the patient in the lithotomy position.

After rectal palpation the transrectal scanner is introduced into the rectum - a Brüel and Kjær rotating transducer is used - the balloon covering the transducer is inflated with water. The scanner is started and mounted in a fixture. A sterile needle guiding attachment with several puncture canals is mounted on the rectal tube close to the perineum. A vertical row of dots on the monitor indicates the position of each puncture canal.

The scanner is rotated until the target is transsected by the puncture line. The needle is introduced through the appropriate canal and is seen as a bright echo as it enters the

scanning plane. The procedure is performed in local anaesthesia.

The biopsies are performed transperineally avoiding the rectum and vagina. A 21 or 23 gauge sure-cut needle is used and the specimens prosessed for histological investiation using standard procedures.

Furthermore, material for cytological evaluation is aspirated through a 23 gauge fine needle mounted on a lo cc syringe.

The method has been used in lo cases.

1. example

A 52 years old female patient operated in 1978 for an ovarian adenocarcinoma.

In july 1984 the routine pelvic examination gave suspicion of a small tumours behind the rectum. No abnormallity was found by the abdominal ultrasound.

By the transrectal ultrasound examination a solid echopoor lesion 2 x 2 x 2 cm behind the rectum was disclosed.

Fine needle aspiration cytology showed adenocarcinoma and fine needle histology revealed infiltrative adenocarcinoma. Recurrence from the patients ovarian carcinoma (serous type) was thereby confirmed.

2. example

A 4o years old female. Operated July and November 1983 and irradiation therapy was started. The histological diagnosis was squamous cell carcinoma.

In 1984 infiltration in the right side of the top of the vagina was found by pelvic examination. A surgical biopsy transvaginally was therefore performed in May and September showing no malignancy.

Abdominal ultrasound showed no abnormallity. Rectal ultrasound showed a small solid lesion in the left side of the vaginal top.

Aspiration biopsy shows carcinoma of squamous cell type and the fine needle histological specimen shows infiltrating squamous cell carcinoma.

Although our experience with this application is limited it shows that transrectal ultrasound examination allows visualization of the deep pelvic area - where abdominal ultrasound is insufficient - and where palpation may be difficult.

Furthermore, by combining the visualization with a guided biopsy a microscopic diagnosis of the lesion can be obtained. The method seems to be useful in selected cases.

Puncture of fluid collections has been performed for several centuries, carried out with indwelling lead tubes for drainage of ascites fluid.

Nowadays ultrasound has proven most valuable in evaluation of patients with possible fluid collections e.g. intraabdominal abscesses.

A 1.2 mm needle (18 gauge) is used routinely. The diagnostic puncture often provides the physician with important, clinical information.

In a series of 4o4 patients ultrasonically guided aspirations were performed for a diagnostic purpose.

The fluid collections have been distributed everywhere in the abdoman. The size of these collections varies from a few cc's to more than 2ooo cc.

There is no doubt that an abscess should be drained. However, the conventional surgical treatment of intraabdominal abscesses has a few, but important drawbacks. It is stressing to the patients, timeconsuming and it contaminates the hospital environment.

To reduce these drawbacks we have for the past 7 years used the following procedure when a diagnostic puncture has revealed pus from an intraabdominal abscess: An ultrasonically guided puncture is performed. The abscess is emptied completely if possible and the aspirated pus cultivated. The cavity is irrigated with saline several times and antibiotics are installed. A control scanning is performed after 3 days and the procedure repeated if necessary.

Depending on the size and localization of the abscess a polyethylencatheter is introduced guided by ultrasound using the Seldinger technique.

Insertion of catheters through the gastrointestinal tract and urinary bladder are omitted. It should, however, be emphasized that the needle puncture itself is not impeded by the organs mentioned.

It is recommended that the cavity be irrigated with saline the following days, and daily installation of antibiotics continues until the next ultrasound control.

In order to show the position of the catheter and to visualize the morphology of the cavity contrast media may be injected through the catheter.

A series of 108 intraabdominal abscesses have been treated according to the principles mentioned. The retroperitoneal group includes pancreatic as well as kidney abscesses and lower quadrants consists mainly of periappendicular abscesses. True pelvis includes Douglas- and gynecological abscesses.

Of these 108 abscesses 47 were treated with one or more punctures and 61 drained by means of a catheter. 42 and 50 respectively were cured. A total of 85% were cured.

In 15% healing of the abscess could not be accomplished by ultrasonically guided drainage alone.

After the drainage, approximately 75% of the patients showed a marked fall in the temperature and clinical improvement the following days.

Of possible complications 5 patients had shaking chills a few hours after the puncture and one was treated because of bacteriemia.

E.g. a typical periappendicular abscess containing 30 cc of pus was treated successfully by 2 punctures and antibiotics locally.

In another patient a huge liver abscess was found. The abscess was drained for 800 cc of pus. A catheter was left in place and the discharged stopped after one week, whereupon it was removed. A control scanning 2 weeks after showed complete healing of the abscess.

We considered ultrasonically guided puncture of intraabdominal abscesses a very important alternative to conventional surgical treatment and it is a routine procedure in our institution.

Ultrasonically guided percutaneous insertion of radioactive Iodine-125 seeds in malignant abdominal lesions and especially pancreatic cancers represents another new interventional ultrasound technique.

A special procedure in which a dynamic scanner mounted in a x-y-z coordinate system is applied.

A maximum of 102 seeds were inserted in a pancreatic cancer under direct monitoring using 19 punctures.

Besides ultrasonically the seeds can be visualized radiographically and their irradiation effect demonstrated on a gamma-