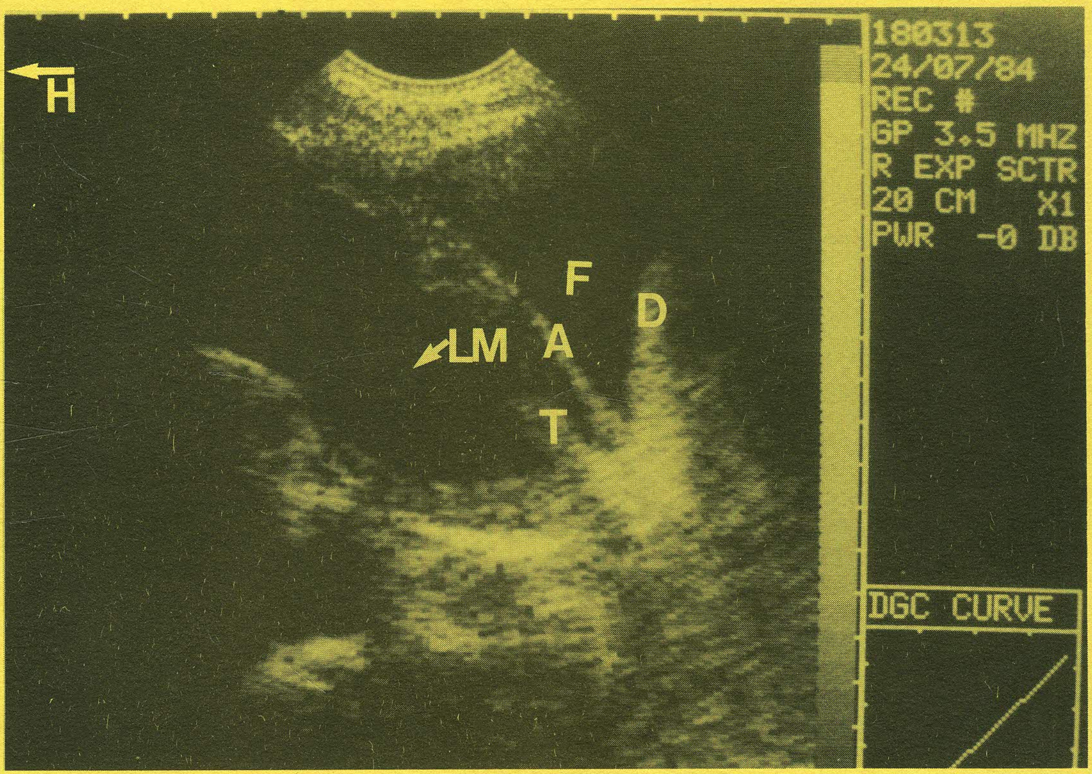
THE ROLE OF ULTRASOUND IN THE DIAGNOSIS OF PLEURO-PULMONARY AND PERIDIAPHRAGMATIC DISEASES



DR. BETHUEL NDERINGO NDOSI (M.B.CH.B. MAKERERE)

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BY

DR. BETHUEL NDERINGO NDOSI

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ABSTRACT

A total of 56 patients with peripheral pleuro-pulmonary opacities were examined with ultrasound. In 44 of these patients (79% of total) ultrasonic findings were confirmed as abnormal in 50 hemithoraces (lesions) (50 out of 88) by direct confirmatory procedures which consisted of: postmortem (15 lesions), surgery (7 lesions) and aspiration (28 lesions). Ultrasound could distinguish the abnormalities between fluids and solids with a sensitivity of 95.4% for fluids (n = 44) and a sensitivity of 85% for solids (n = 13). Considering the direct confirmatory (postmortem/surgery/aspiration), the other radiodiagnostic procedures (CT-scan and decubitus radiograph) and fluid diagnosed on clinical suspicion, the sensitivity of ultrasound to fluid was minimally reduced from 95.4% n = 44 to 95.2% n = 63 while the sensitivity of ultrasound to solids was minimally increased from 85% (n = 13) to 88% (n = 16).

Sensitivity of decubitus radiograph to fluid was demonstrated in this study to be only 67% (n = 9).

Ultrasound identified the right diaphragm with certainity in all patients (100% of 56) and the left one in 79% of all cases. Diaphragmatic motion was measured in 29 patients (52% of total) on the right and was demonstrated to be reduced in eleven patients (38% of the 29), all of whom had ipsilateral (8 out of 11) or bilateral (3 out of 11) intra-pulmonary pathologies.

Abnormalities involving the diaphragms, vessels, peritoneum and upper abdominal viscera in combination with pleuro-pulmonary diseases are demonstrated and discussed.

Ultrasonic failure in centrally located thoracic and skeletal lesions in some patients is discussed.

It is concluded that ultrasound is able to detect define extent and resolve pleuro-pulmonary and peridiaphragmatic lesions into solids and fluids with an accuracy high enough to justify its use as a complimentary diagnostic modality to the conventional radiograph.

Department of Diagnostic Radiology
(Head: Prof.Dr. J.H.J. Ruijs)
St. Radboud Catholic University Hospital
Nijmegen
The Netherlands

and

Department of Radiology
(Head: Dr. P.N. Mwanukuzi)
Muhimbili Medical Centre
University of Dar-es-Salaam
Tanzania

Supervisors:

Prof.Dr. G. Rosenbusch

Department of Diagnostic Radiology

St. Radboud Catholic University Hospital

Nijmegen

The Netherlands

and

Dr. P.N. Mwanukuzi

Department of Diagnostic Radiology

Muhimbili Medical Centre

University of Dar-es Salaam

Tanzania

DECLARATION

I declare that the work contained in this thesis is my own original and that the work has not been submitted for a similar degree in any other university.

Date 01·02·85 Signature candidate

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Bethuel Nderingo Ndosi

CONTENTS (x)

Page

Page

Page

1. INTRODUCTION

1.1. General

In 1847 Joule described magnetostriction for the first time while Piere and Curie discovered piezo-electric phenomena in 1880. Medical transducers depend on one or other of these, de Vlieger et al. (1978).

During World War I the possibility of generation and use of a sound beam to detect submerged objects was vigorously persued. In 1917 Langevin succeeded in using pulse-echo to detect submarine.

Research pioneered by Firestone (1946) and Desch et al. (1946) led into generation and detection of ultrasound at high frequencies which was applied to testing of metallic structures.

Jaffe et al. (1955) discovered the piezo-electric properties of polarized solid solutions of lead zirconate titanate. Subsequently evolved the methods of measuring ultrasonic power using thermocouples as described by Fry and Fry (1954), radiation pressure by Newell (1963) and Kossoff(1965) among other methods.

1.2. Diagnostic applications

1.2.1. Transmission method

In 1947 Dussik et al. described a scanner designed to use the principle of transmission and differential absorption as in conventional radiography. The beam was directed through the head of the patient and detected by a receiver placed in line with the transmitter. Ballantine et al. (1950), Hueter and Bolt (1951), improved the Dussik scanner the results of which still remained unsatisfactory. At this stage it was considered that the poor results were due to small reflections at the interphase between brain tissue and cerebro-spinal fluid.

However, Guttner et al. (1952) pointed out that skull distorted the ultrasonic scans and that ventricular attenuation was small compared to that of the brain and skull. Subsequently the transmission techniques made only limited progress. The time delay spectrometry is an example of the surviving transmission technique and was described by Heyser and Le Croissette (1974). In this method and system signals not arriving through the direct pathway are discriminated from those of interest.

1.2.2. The pulse-echo

Search for new avenues led to the development of the pulse-echo. The first equipment was constructed in 1947 by Howry.

The construction of a compound scanner was achieved by Howry in 1954.

Using pulse-echo, gall-stones were demonstrated for the first time by Ludwig and Struthers (1950). Wild and Reid (1952) published a paper on distinction between normal and malignant breast tissue on A-scans. Further work led into the evolution of two-dimensional scanners by Wild and Reid (1955). Brown (1960) and Donald (1964) constructed the world's first direct-contact two-dimensional scanner.

The first routine application of ultrasound in tissue identification was on placenta and amniotic fluid by Donald and Abdulla (1968). It was demonstrated that with increasing sensitivity of the system, the placenta became echogenic while the amniotic fluid remained unechoic.

Gray scale display was subsequently introduced by Kossoff and Garrett (1972) increasing the scope of qualitative tissue identification.Quantitative data analysis was further achieved by echo amplitude analysis by Montford and Wells (1972).

Two distinct transducer arrangements were described. The first was by Somer (1968) consisting of an array operated with appropriate phasing to direct the ultrasonic beam through a sector scan. The second was by Bom et al. (1971) made of an array of transducers sequentially activated as single elements. Currently real-time scanners depend on mechanically or electronically induced movements of one or multiple transducers.

1.3. Biologic effects and risks

With the original apparatus designed by Langevin the amplitude of the ultrasonic waves was so high that small fish were killed. Wood and Loomis (1927) demonstrated that ultrasound affected living systems by mechanical as well as thermal effects. Stable and transient forms of cavitation were described by Hughes and Nyborg (1962).

Ultrasound is absorbed at structural and molecular levels. Hill (1968) demonstrated that at high energy intensities ultrasound can cause tissue temperature rise of up to 10° C. per second in small tissues.

Martin (1984) stated that in the industry high ultrasonic intensity has been produced with enough heat energy to melt metals. Marmor et al. (1979) and Young et al. (1980) used ultrasonically induced hyperthermia to treat superficial cancers. Fajado et al. (1980) showed the effect of the hyperthermia to be through vascular damage. Child et al. (1981) showed that ultrasound of high intensity (outside the diagnostic limits) could kill larvae of drosophyla.

At diagnostic intensity (8 MHz) pulse ultrasound was shown by Pinamonti et al. (1982) to cause reversible erythrocyte membrane change with altered oxygen transport. Chromosomal aberration induction suggested by Macintosh and Davey (1970) and (1972) raised controversy for the subsequent four years. Watts and Hall (1972) and Braeman et al. (1974) failed to reproduce the results of chromosomal aberration as advocated by Macintosh and Davey. Buckton and Baker (1972) showed that chromosome aberration scoring was highly subjective and suggested incorporation of such error in the Macintosh/Davey study. Subsequently Macintosh et al. (1975) reported that they were unable to reproduce their results. Synergistic enhancement of biologic damage with X-rays was shown to occur by Burr et al. (1978) and Kunze-Muhl (1981).

However, Baker et al. (1978) showed that at diagnostic intensity, ultrasound has no known immediate risk. World Health Organization (WHO 1983) recognizing the great benefit of ultrasound to modern medicine and the apparent absence of known immediate risks advised continued research and judicial use of ultrasound. Stark et al. (1984) showed no biological risk in children followed for twelve years following exposure to ultrasound in utero.

1.4. <u>Role of ultrasound in the diagnosis of pleuro-pulmonary and peridiaphragmatic diseases</u>

Sutton (1980) outlines a number of pathological processes diagnosable by ultrasound, most of them intra-abdominal.

In the thorax due to attenuation by aerated lung its role has been limited.

Outlining the indications of thoracic ultrasonography Cunningham (1978) considered the modality most useful in the evaluation of the totally opaque hemithorax, apparently elevated diaphragm and opacities yielding no fluid on decubitus radiograph or thoracentesis. Taylor (1979) and Pery et al. (1983) further suggested use of ultrasound to confirm or exclude pathology additional to fluid.

1.4.1. Peridiaphragmatic regions

In conventional radiography the position of the diaphragm is asumed. Abnormalities may therefore be misinterpreted in position and extent. The importance of diaphragmatic recognition was stressed by Landay and Harless (1977). These workers incorrectly diagnosed subphrenic fluid collection as a result of misinterpretation of the position of the diaphragm.

1.4.2. Pleural spaces

Pleural abnormalities in contact with the chest wall are best suited for sonographic assessment. Doust et al. (1975) achieved 90% differentiation between pleural fluid and pleural thickening. Phillips and Baron (1981) demonstrated that high frequency transducer (5 MHz) was superior to a low frequency one in the differentiation between solids and liquids.

Landay and Cônrad (1979) demonstrated that pleural fluid was reliably diagnosed if an explicitly unechoic region was present through which the posterior costophrenic angle and diaphragm could be imaged. Further work by Marks et al. (1982) demonstrated that change of shape of lesions with respiration, posture and presence of septations within the lesion were reliable indications that a lesion contained fluid. Transudates, exudates, malignant effusions and haematomas were shown by Hirsch et al. (1981) to be sonolucent. Sandweiss et al. (1975) demonstrated that empyemas were sonolucent. However, they suggested the possibility of complication by necrotic materials, clotted blood or both producing an appearance confusible with pleural fibrosis due to internal echoes. Mahal et al. (1975) reported a case of necrotic debris, partially organized blood which was echo-free. Subsequently Phillips and Baron (1981) described low level echoes in empyema using high frequency transducer (5 MHz).

1.4.3. Lung parenchyma

In the lung parenchyma, ultrasound is limited to lesions not overshadowed by normally aerated lung. Cunningham (1978) was able to demonstrate pneumonia and atelectasis but these were indistinguishable. Landay and Conrad (1979) failed to distinguish peripheral lung abscesses from empyemas.

1.4.4. Mediastinum

Ultrasound has been less extensively used in the mediastinum but with controversial findings. Goldberg (1973) achieved 92% accuracy in differentiating between solids, cystic and complex forms. Haller et al. (1980) and Ries et al. (1982) reported controversial sonographic findings in two children with proved bronchogenic cysts. These showed internal echoes.

Fluid behind the short intrathoracic portion of the inferior vena cava was described by Lewadowski and Winsberg (1982) to be a sign of right pleural effusion rather than ascites.

1.5. Diagnostic-therapeutic use

Besides detection, localisation and differentiation of pleuro-pulmonary and mediastinal opacities into solids and liquids, ultrasound has been used by many workers to guide thoracentesis and biopsy. Among them are Goldberg and Pollack (1975), Goldberg et al. (1982) and Hansberger et al. (1983).

2. GENERATION DISPLAYS AND PROBE MOVEMENT PRINCIPLES

2.1. Generation

Some substances such as quartz are able to convert one form of energy into another. These are called transducing materials. When an electric current is passed through such substances mechanical deformation results, which constitutes the direct piezo-electric effect. On the other hand when mechanical stress is applied into the piezo-electric material, a voltage is generated constituting the converse piezo-electric effect. Medical diagnostic ultrasound is produced by lead zirconate titanate which is excited by two electrodes. The titanate crystal being incorporated in a tube with materials able to dump sound waves from the back wall of the transducer. A continuous beam is produced by mounting two transducers opposite each other, one receiving while the other produces the sound. Sectional images of internal organs are produced by use of pulse-echo in which the ultrasound is generated and repeated in very short pulses and high rates.

The higher the frequency of ultrasonic beam, the less the penetration into the tissues, but the sharper the definition of the resultant image. The frequency being inversely proportional to the wave-length of the beam.

Loss of intensity as the beam passes to the deeper structures is combated by use of time gain control. When this is properly adjusted, echoes of equal amplitude from superficial and deep tissues are displayed. This is achieved through amplification of the echoes from the deeper structures.

2.2. <u>Displays</u>

Ultrasound is produced in pulses of microsecond length at 500 to 1,000 pulses per second. In the interval between the pulses returning echoes are detected. The display modes include A-scan and B-scans. In the A-scan the echoes are displayed as vertical spikes of the spot on the cathode ray oscilloscope.

In the B-scan the echoes are displayed as bright dots along the baseline of the oscilloscope. Further the B-scan display can be subdivided into bistable, gray scale, M-mode and real-time.

In the bistable presentation, there is a threshold below which no signal is demonstrated and above which all signals no matter their strength are displayed with equal intensity. In the gray scale display the brightness of the dots is proportional to the echo-strength.Scan converters with television display are now in use. The M-mode is specifically for recording the movements of structures in the body such as the heart. This is achieved by sweeping the moving bright spots from the organs across the face of the cathode ray oscilloscope using another generator. Real-time display is produced by sequential pictures at about 40 frames per second on a non-storage display.

Mechanical and electrical real-time scanners have been developed. In the mechanical scanners different arrangements are possible. A single transducer may rotate in a waterbath or rocked pivoted on its face through 60^{o} C. Four transducers may be mounted at the point of a cross and rotated. Each transducer is activated as it comes opposite the contact area producing a sector scan.

Electronic real-time scanners are linear or phased arrays. In the linear arrays, multiple (64) transducers are sequentially activated starting at one end with a resultant tomogram the size of the length of the array. In the phased arrays the sequential activation is accompanied by varied time delay biasing the direction of the beam in such a manner that a sector scan results.

2.3. Probe movements

The transducer may be moved in multiple ways. These include linear, arc, sector, compound and radial. In the linear movement, a vertical probe moves in a line along the area under study. Using the arc method the probe is maintained at right angles to the skin surface of the area to be studied. A sector is produced by rocking the distal end of the stationary probe. A combination of above movements constitutes the compound motion while the radial motion is used with specialized transducers elsewhere in the body (prostate).

3. THE HYPOTHESIS

Ultrasound can accurately detect and differentiate pleuro-pulmonary opacities into solids and fluids replacing the decubitus radiograph and other more invasive diagnostic radiological procedures.

3.1. Objectives of the study

1. Determination of the ability of ultrasound in the detection of pleuro-pulmonary abnormalities and differentiation of these abnormalities into solids and fluids. Determination of the ability of ultrasound in the differentiation of thoracic fluid collections due to different aetiologies.
2. Determination of the ability of ultrasound in the definition of disease extent through its ability or otherwise to recognize position, shape and motion of the diaphragms and the peridiaphragmatic spaces.
3. Determination of the pitfalls of ultrasound.
4. Considering the abilities and pitfalls, determination of ultrasound as a routine diagnostic method complimentary to the thoracic radiograph and the possibility of replacement of other more sophisticated radiological diagnostic methods will be evaluated.

4. PATIENTS, METHODS AND EQUIPMENT

4.1. Patients

The study includes those patients who on routine chest radiograph were found to have pleural or peripheral pulmonary opacities. Mediastinal opacities were evaluated only when radiographically there was evidence of extension to the chest wall. When patients on routine ultrasonographic examination of the upper abdomen were found to have intra-thoracic abnormalities or elevated diaphragms, the thoracic abnormalities were subsequently evaluated with ultrasound. Premature babies were excluded as well as detailed cardiac evaluation. All examinations were performed in the Department of Radiology, Nijmegen University Hospital.

4.2. Methods

The suitable candidates were referred to the echographic room with the thorax radiographs. Clinical history and physical findings were withheld. Using the radiographs as guide the pathological area was determined and mapped on the sketches in the questionnaire (see appendix II, sketches I and II). The pathological area was sonographed through an appropriate window. All patients were studied with real-time. Some patients were studied with both, real-time and B-scan. Position of the patients depended on clinical state. Seriously sick ones were studied only in the supine while the less sick were studied in the supine, decubitus and at times sitting positions. Similarly for the less sick patients behaviour of lesions with altered respiration and position was studied.

4.2.1. Windows

Pulmonary, pleural and mediastinal lesions were approached directly through the region they were in contact with the chest wall. Right basal lesions were commonly studied through the liver while on the left base the spleen was used as window.

In the mediastinum parasternal, and suprasternal approaches were used.

Diaphragmatic identification, shape and motion on the right were studied through the liver and on the left through the spleen. On the right side the diaphragmatic motion was measured 7 cm. to the right of midline longitudinal scans. On the left attempts were made to measure the diaphragmatic motion through the spleen but without success.

The usual exposure factor required to produce optimal image on a single emulsion radiograph was reduced to a factor a little more than half the value (in this case from 28 to 18 (Diasonics)). With the transducer at the appropriate part of interest, contact effected by watery jelly, the patients were asked to breath in. At the end of the deep inspiration the first image was made and recorded on the radiograph. A second image at expiration was exposed on the same spot. The resultant space between inspiration and expiration phase images was measures. During the procedure neither the patient nor the transducer was moved.

4.2.2. Skin marking

For patients planned for diagnostic or therapeutic thoracentesis a mark was made on the skin to indicate the best position for puncture. Most patients had puncture in the ward.

4.2.3. Diagnosis confirmation

Following echographic examination and recording of the findings, clinical informations and results of relevant previous investigations were compiled from the files of patients. Follow-up investigations and therapeutic management were organized. All information gathered was compiled in a questionnaire, a sample of which is attached as appendix II.

Patients were categorized into three groups. Those patients who were subjected to a relevant direct confirmatory procedure, those subjected to relevant radiodiagnostic procedure and those with strong clinical suspicion for fluid. The confirmatory procedures consisted of aspiration, surgery and postmortem. Relevant radiodiagnostic procedures consisted of decubitus radiograph and CT-scan while clinical suspicion was based on the combination of ultrasonic findings and lesion deformation with respiration or migration on postural alteration and behaviour with follow-up in relation to aetiology and therapy.

4.3. The equipment

The equipment consisted of two apparatus. The Diasonics RA-1 and the Compound Picker 80L. In both of these the set-up consisted of controls, indicators and image recording attachments. The Diasonics is a mechanical real-time scanner with two transducers. It is purely real-time.

The Compound Picker is a B-scanner equipped with a mechanical and real-time transducer . In the subsequent text the equipments and their important components are individually described. Illustrations used for clarity.

4.3.1. <u>The Compound Picker 80L</u>

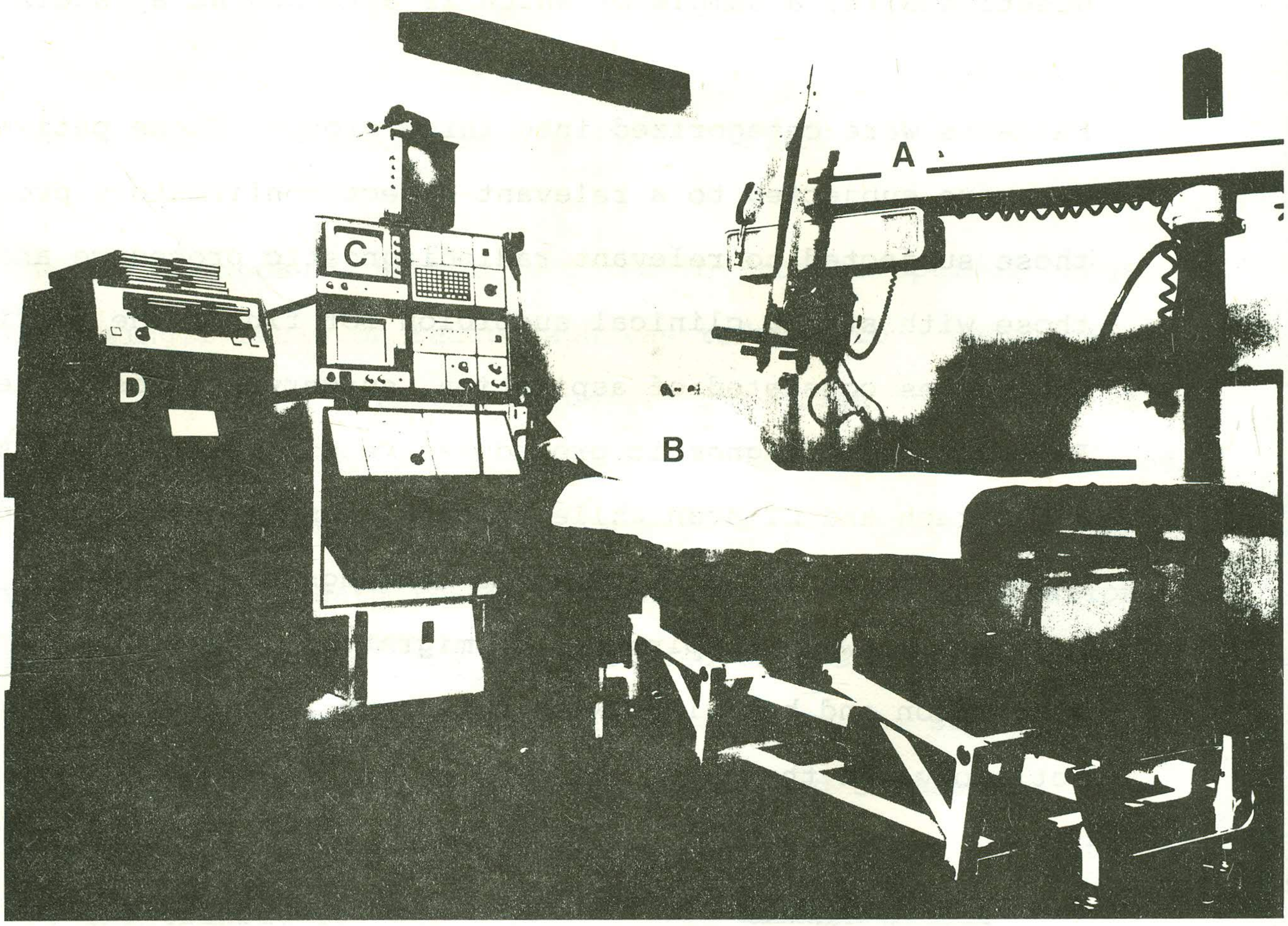


Figure 1 Overall set-up

A = Mechanical scanner arm

B = Bed

C = Indicators and control pannels

D = Image recording attachment

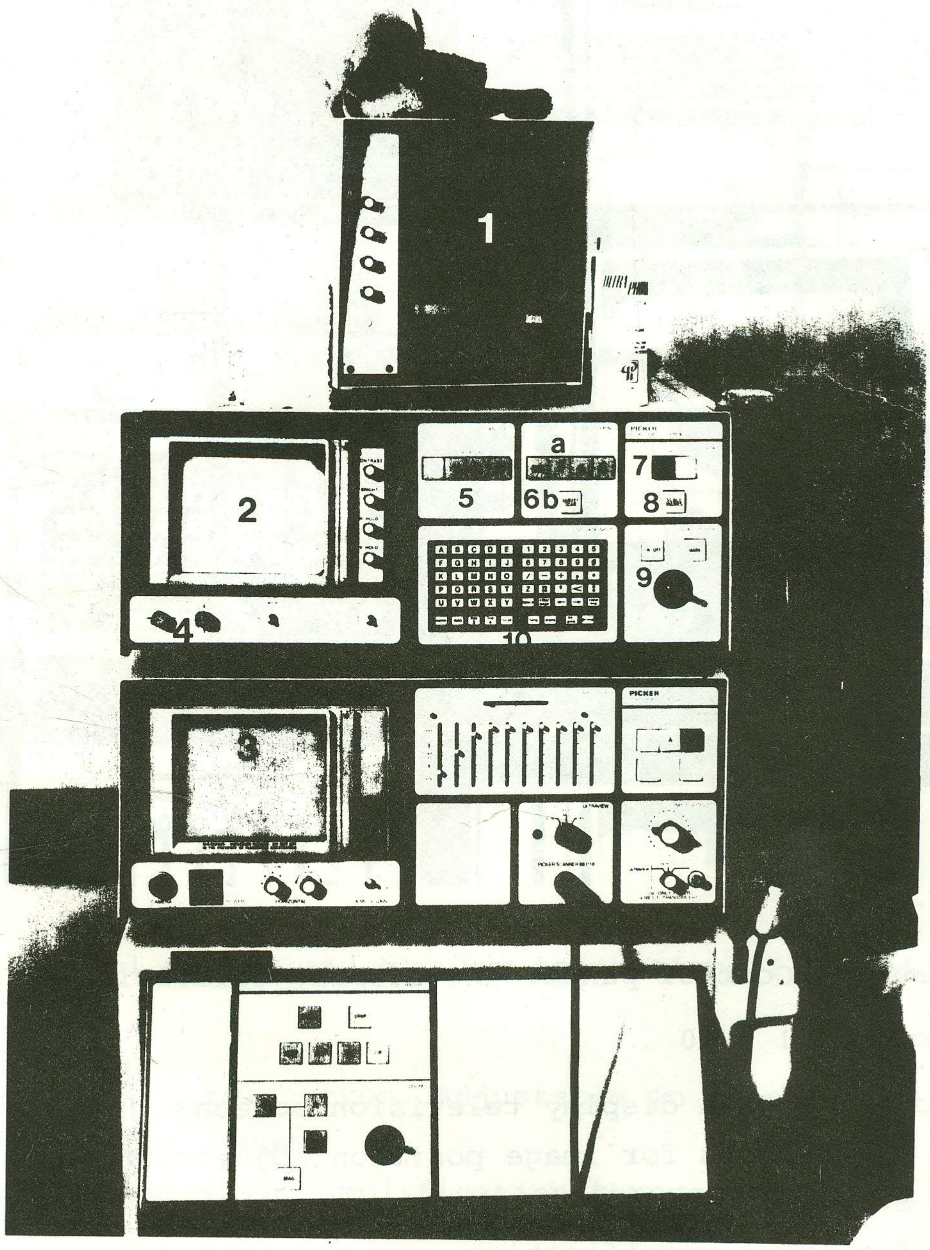


Figure 2 Control pannels and indicators (overall) Individual components illustrated in details in the subsequent text.

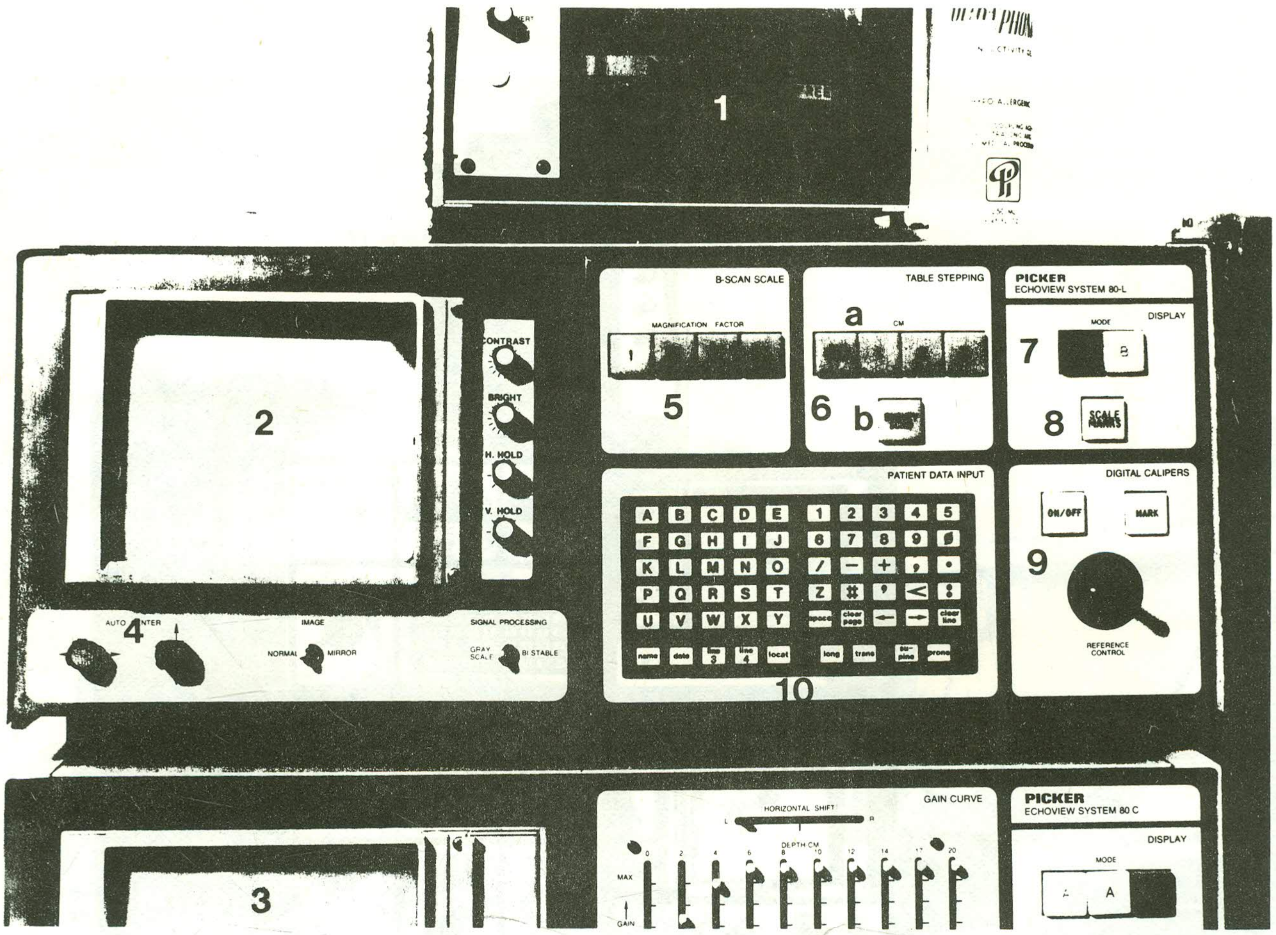


Figure 3   Control pannel and display television I (details)

Components 1 - 10

1,2 and 3 = Data display television screens

4 = Two buttons for image position adjustment on the display screens

5 = For image magnification

6a = For selection of interval of organ scanning (B-scan only)

6b = For real-time scanning

7 = For mode selection

8 and 9 = For measurements of sizes of lesions

10 = Numerals, letters and signs for patients' and transducer particulars inscription into the screen

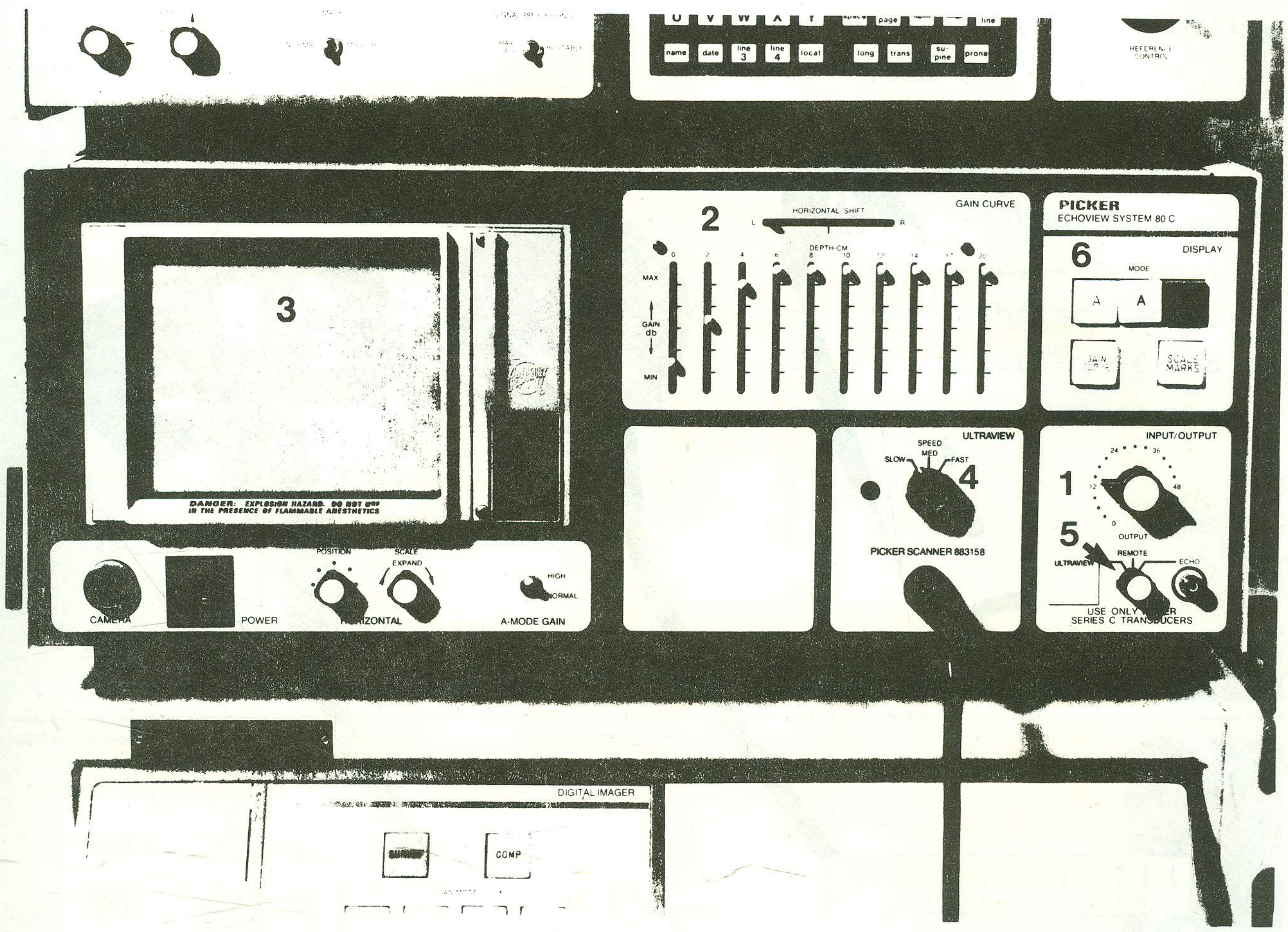


Figure 4 Control pannel and display television II (detail)

Components 1 - 6

1 = Input/output control button. Adjustable in 20 steps to attenuate output power

2 = Ten potentiometers for amplification through an overall range of 60 dB

3 = A-mode display screen

4 = For alteration of rotating real-time transducer speed

5 = Button for selection between real-time and B-mode display

6 = Press button for A-mode display

The rotating real-time transducer crystal can be varied between slow, medium and fast. In this equipment best image is obtained with slow speed.

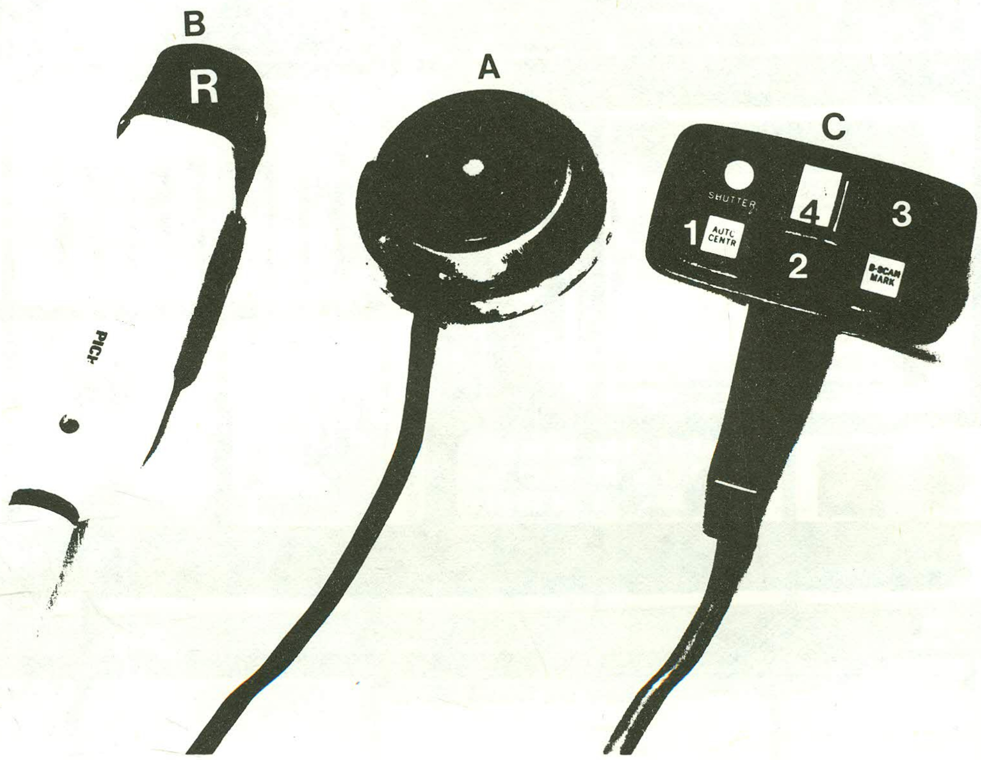


Figure 5 Transducer and switches

A = The foot switch

B = A 3.5 MHz real-time transducer

C = Remote control hand switch

With the foot switch (A) pressed and the transducer (B) in contact with the anatomic area of interest, an image is displayed on the screen (see fig. 3). Adjustments of the quality of the image are then appropriately done by alteration at the input/output button together with the depth selective amplification potentiometers (see fig. 4).

When the foot is removed from the switch during a scanning procedure, a real-time tracing is frozen and can therefore be photographed for permanent data preservation. At the same time with foot switch off further scanning with B-scan settings produces no tracings.

The hand switch works in conjunction with the foot one. The numerals 1-4 on the hand switch are for centering at the area to be scanned (1), erasure of unwanted tracings (2), movement of the mechanical scanner arm along the scale (3) (see fig. 6), and selection of direction of movement of the scanner (4). For precise resolution, table stepping is selected as in figure 3 button 6a. When button 4 is then activated, the scanner slides in callibrated steps to the right or left as biased. Its position from original centre is automatically printed on the screen. Organs can therefore be studied with optimum resolution of 0.5 cm.

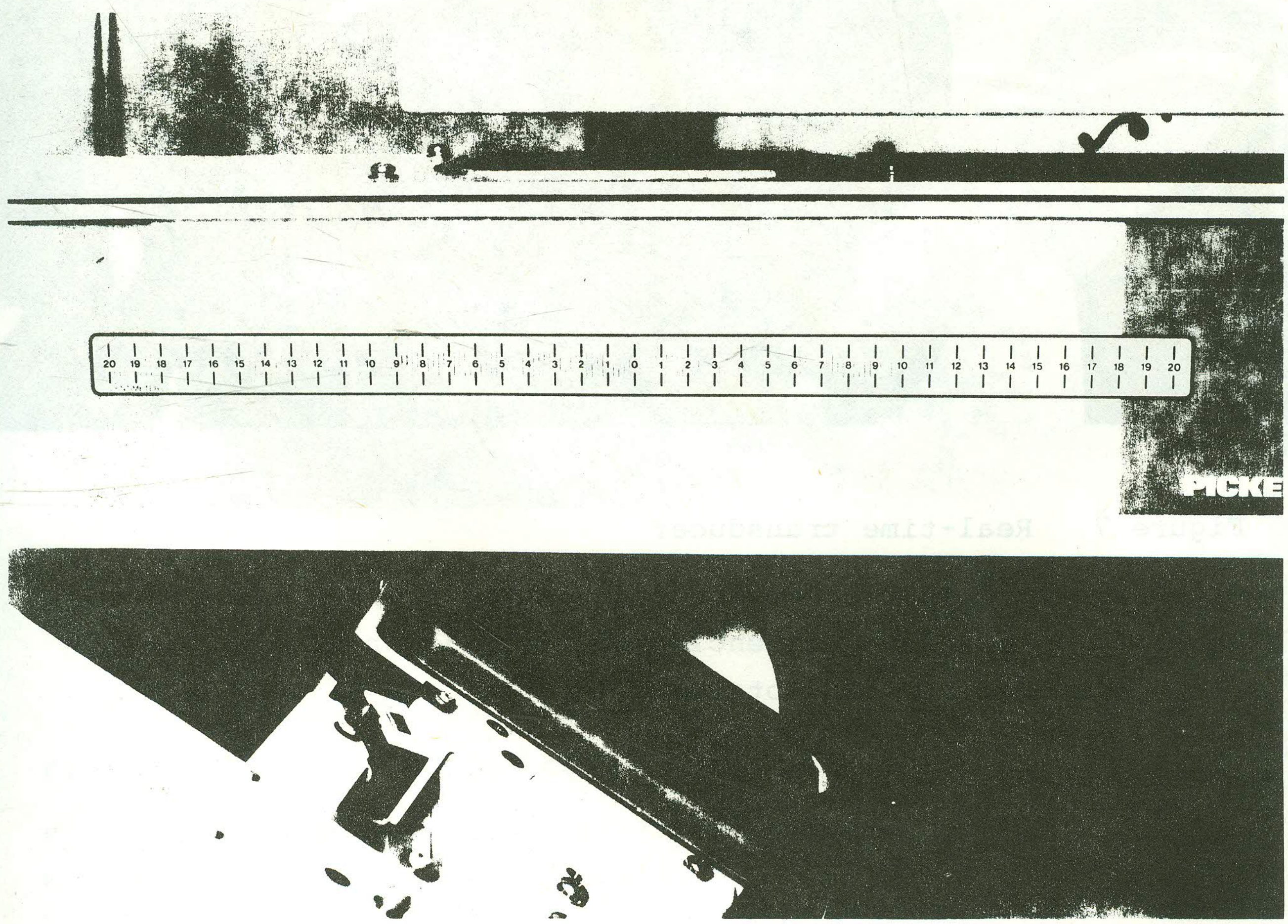


Figure 6 The B-scanner scale

The scale starts with 0 at the centre and extends to 20 cm. at either end. The mechanical scanner arm with a transducer at its tip (see T, figure 8) slides along the scale. A lighting system indicating the position of the scanner arm on the scale is provided.

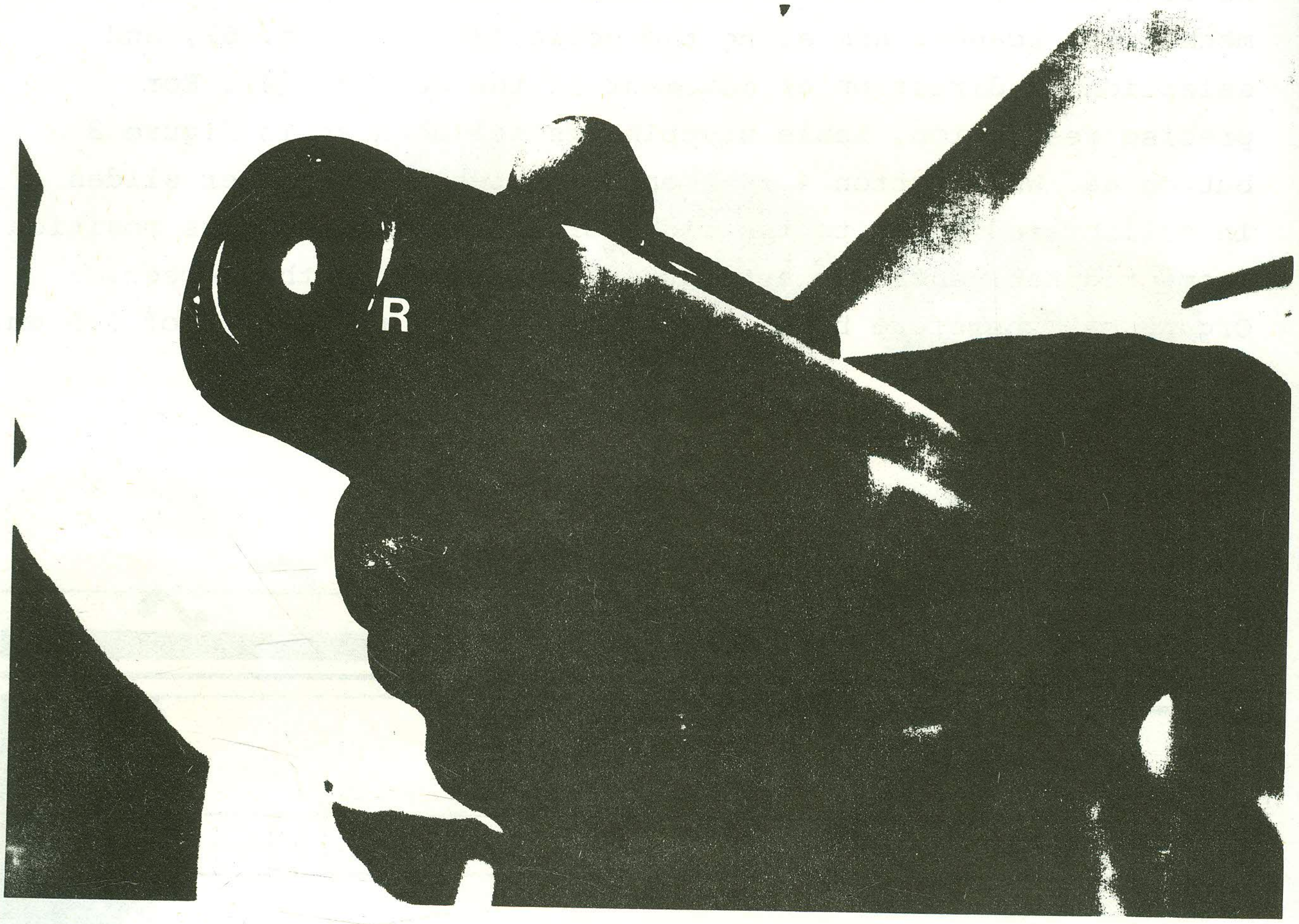


Figure 7 Real-time transducer

3.5 MHz real-time transducer as in figure 5B. The distal end is made up of rubber enclosing fluid in which the piezo-electric crystal rotates.

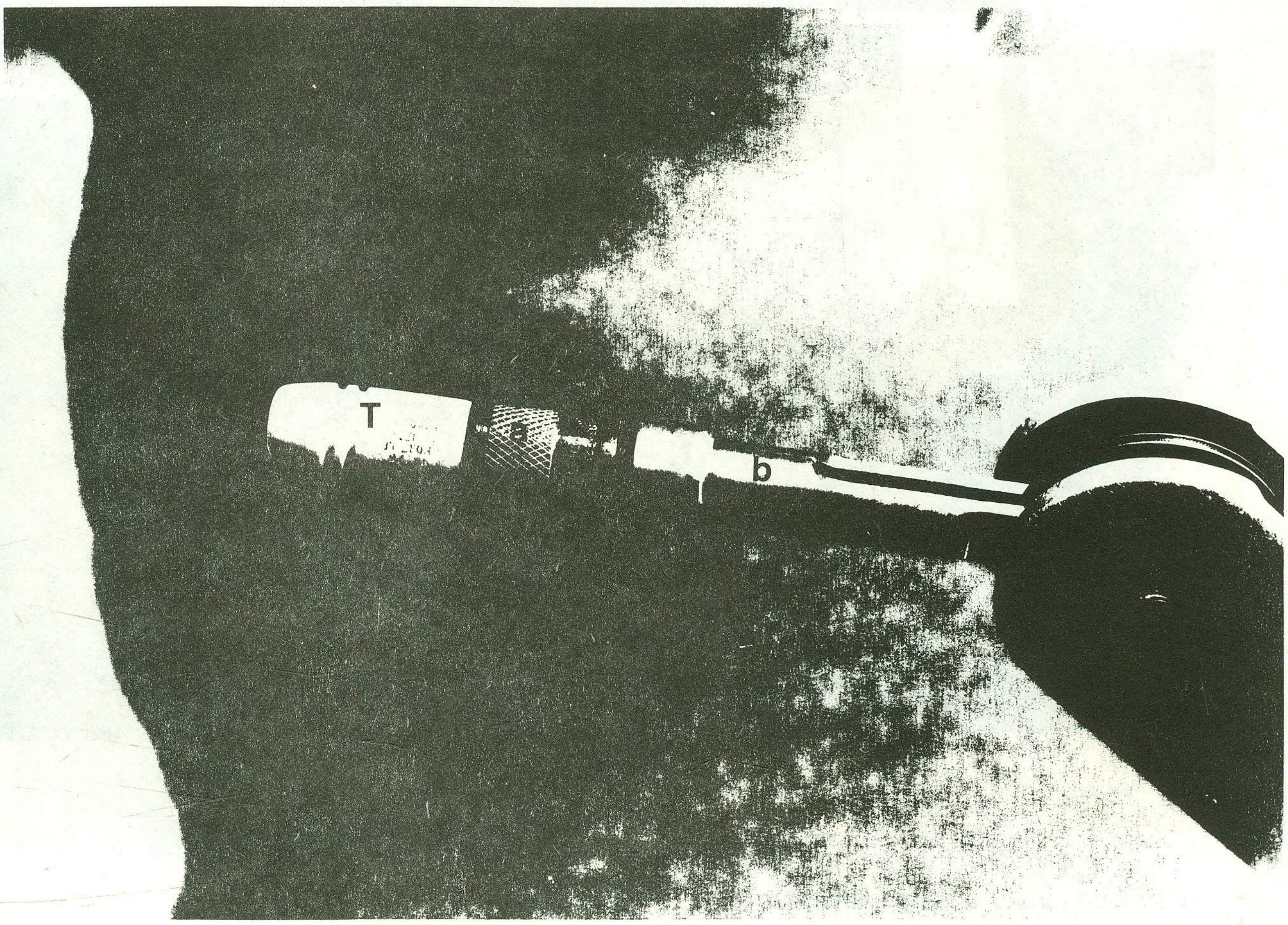


Figure 8   Distal end of the B-scanner arm (b)

By unscrewing at position (a), the transducer (T) can be removed and replaced by another.

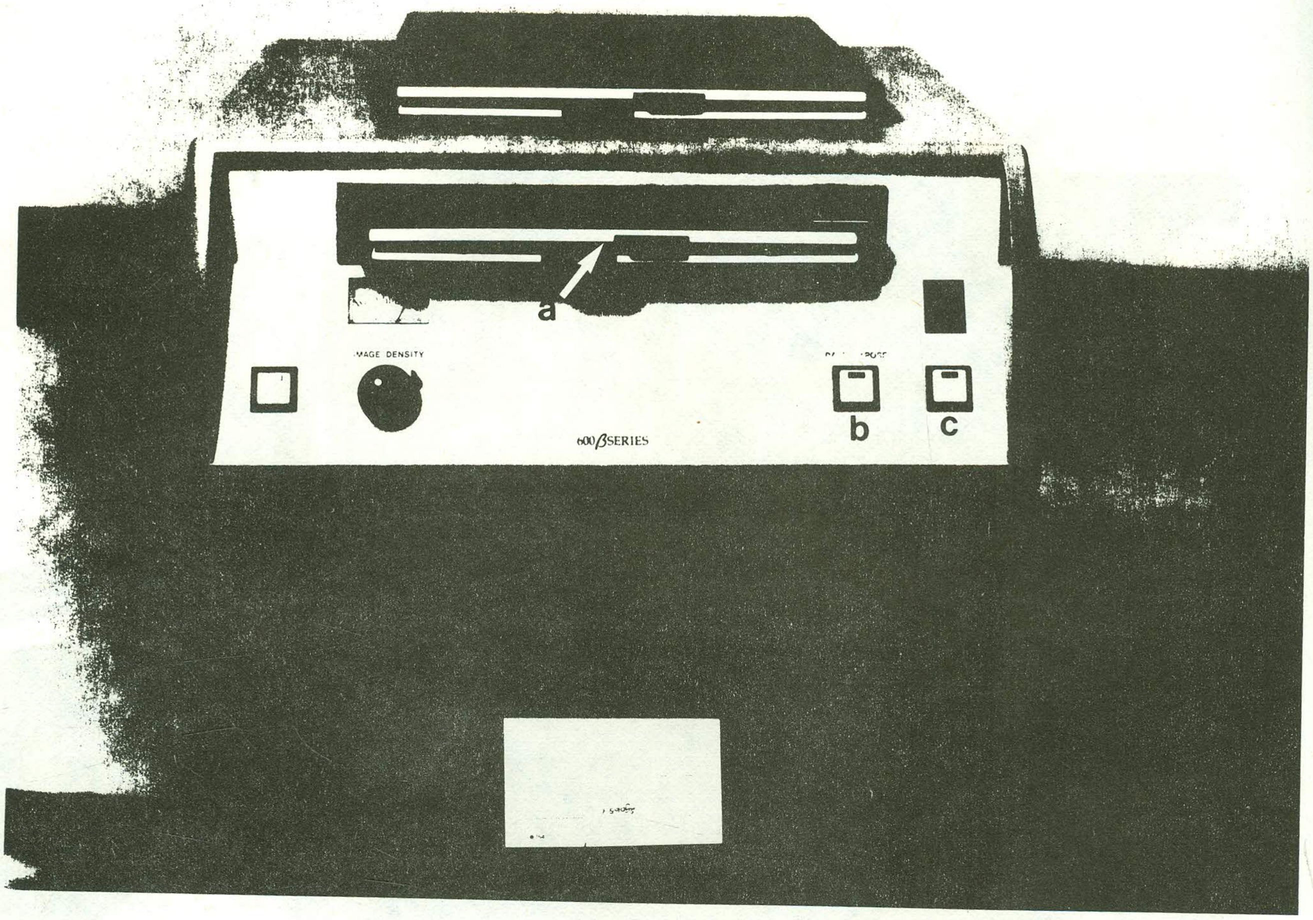


Figure 9 Image recording attachment

The cassette (a) is tucked in position almost ready for image recording. It contains two films. On each film six images can be recorded. The white lines of the cassette represent removable covers protecting the films against light. Once the cassette is properly tucked into the light proof slot, the lower film cover is removed, button (b) pressed. If an image is to be recorded button (c) is subsequently activated. This button is further used for recording images until six exposures are completed. At this point, the film cover is applied, cassette removed, turned over, reslotted, cover removed and image recording continued as described above. Single emulsion photographic film used for image recording.

4.3.2. The Diasonics RA-1

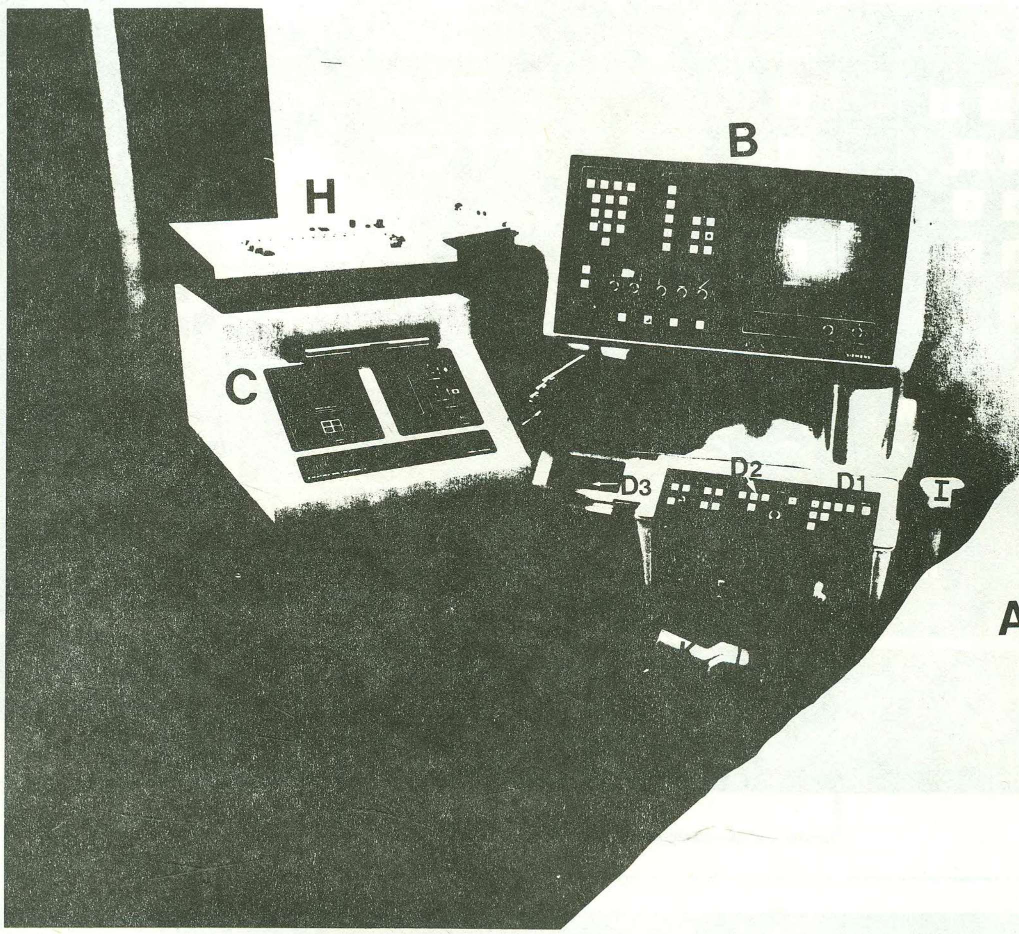


Figure 10 Diasonics RA-1 general set-up

A = The bed for the patient

B = Controls and indicators

C = The image recording attachment at the top of which rests the typewriter (H) for data inscription into the system (see fig. 12)

Among the essential parts of the control pannels here are the buttons at (D_1) and (D_2). At (D_1) are found not only the button switches for the energization of the 3.5 MHz transducer (see I in fig. 13), but also the input/output control switch. At (D_2) are button switches for energization of the 7.5 MHz transducer while at (D_3) is a polaroid camera image recording system.

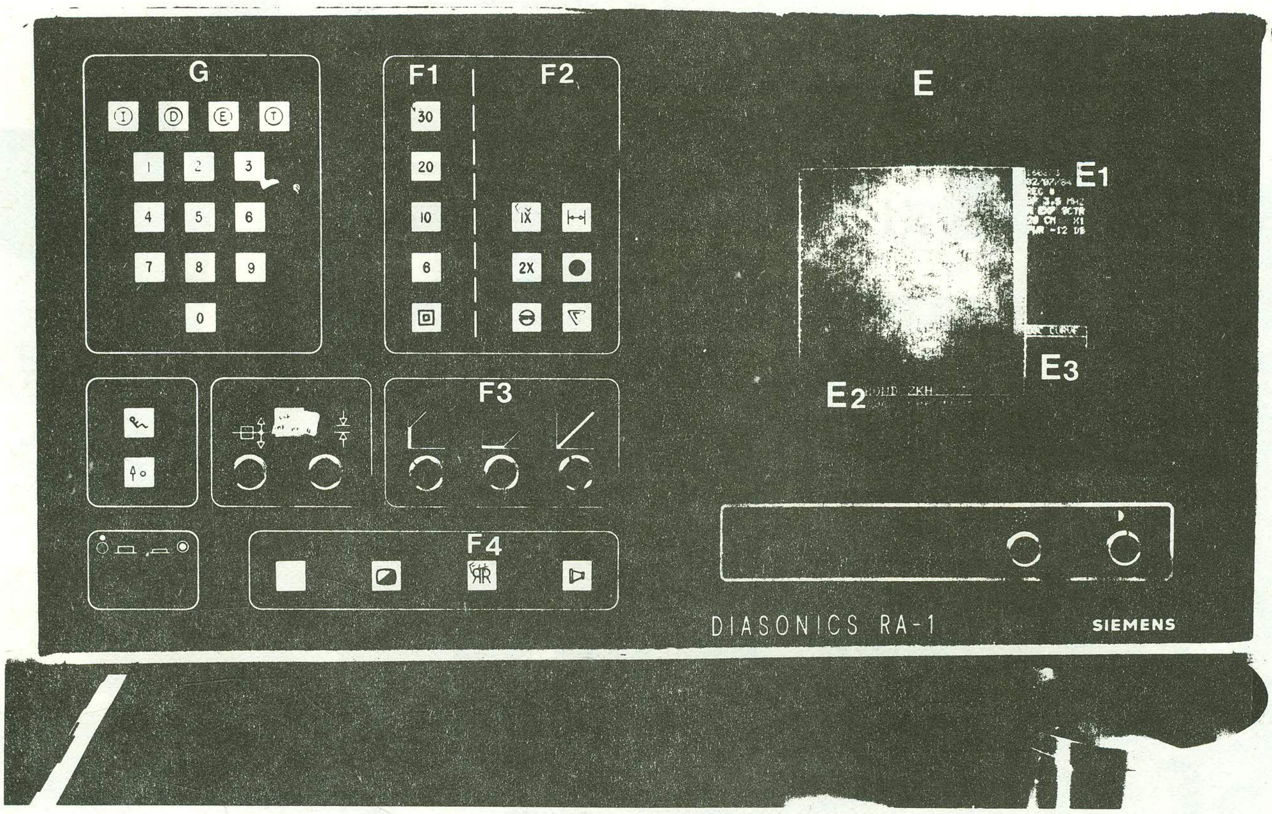


Figure 11 Control pannel and Television (detail)

E = The display screen. The image size is selected at (F_1) while at (F_2) lesion size is measurable. (F_3) consists of 3 buttons for time gain control. Amplification of echoes from tissues in different depths is adjusted here. The effect being noticed not only on the image by the change in brightness at different depths but also represented graphically at (E_3) on the screen. Orientation of the image in relation to side is achieved by use of the press switch at (F_4). The date of study and date of birth of the patients is typed at (E_1) using the letters and numerals at (G).

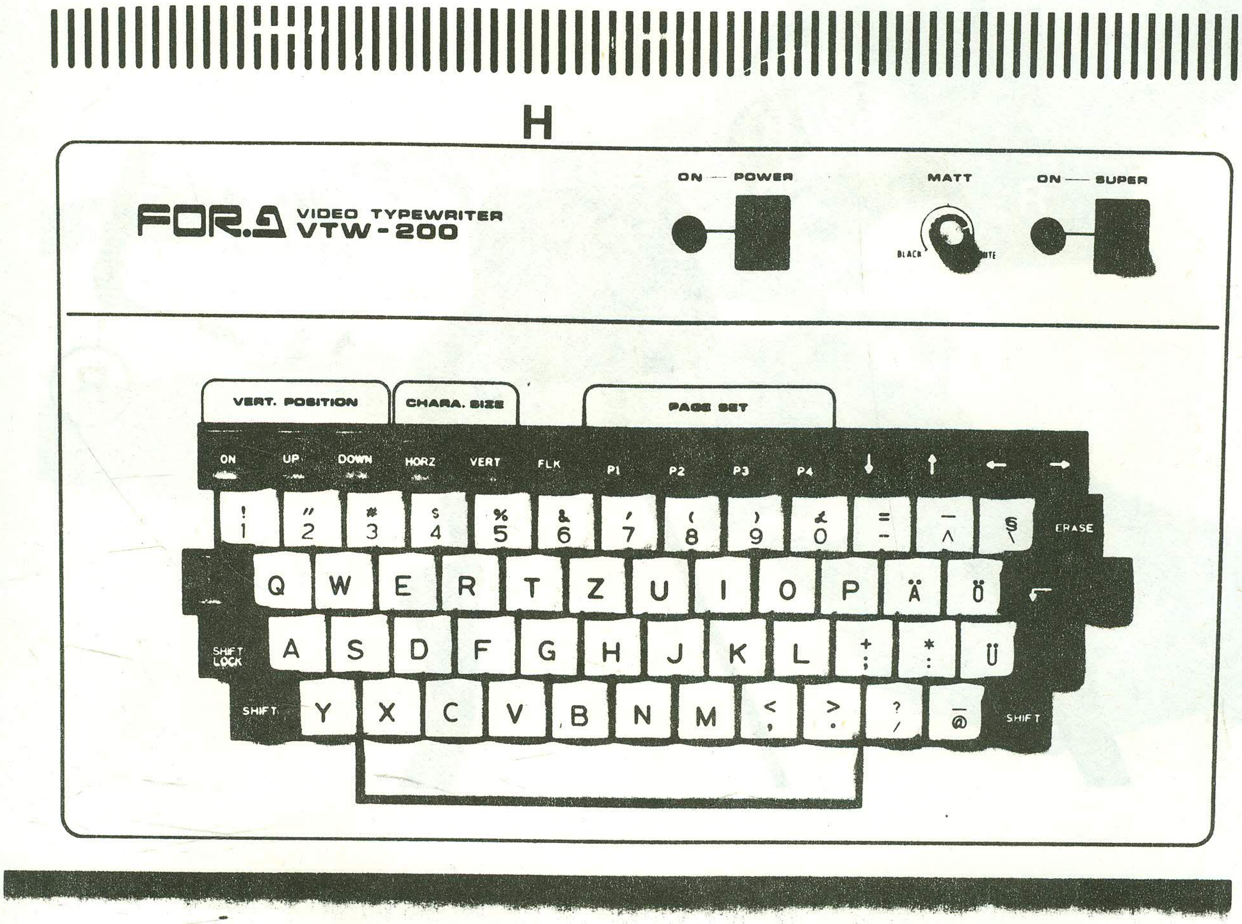


Figure 12 Data input digitals and numerals

The typing machine (H) is used for inscription of the name of the patient, particulars of the area to be studied as well as position of the patient and the technique used such as longitudinal or transverse scans. The system is equipped with facilities for shifting such typed informations eventually to occupy the bottom part of the screen (E_2 fig. 11) leaving the rest of the screen for image display.

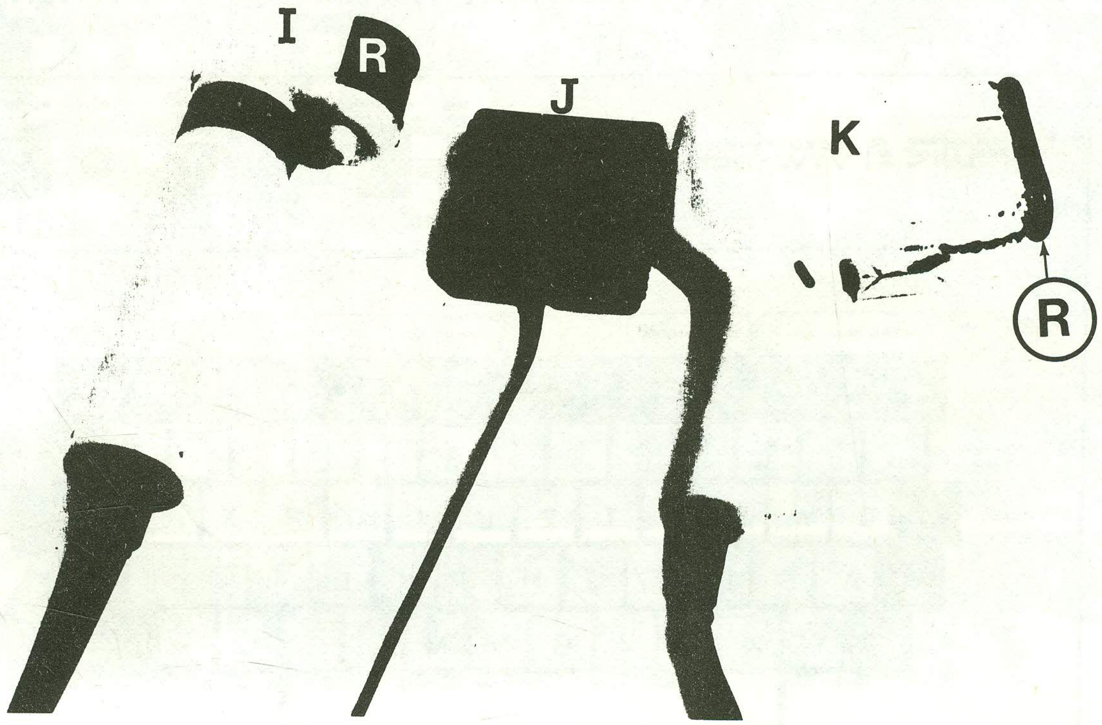


Figure 13 Transducers and switch

I = A 3.5 MHz real-time transducer (side view)

K = A 7.5 MHz real-time transducer (side view)

J = Foot switch

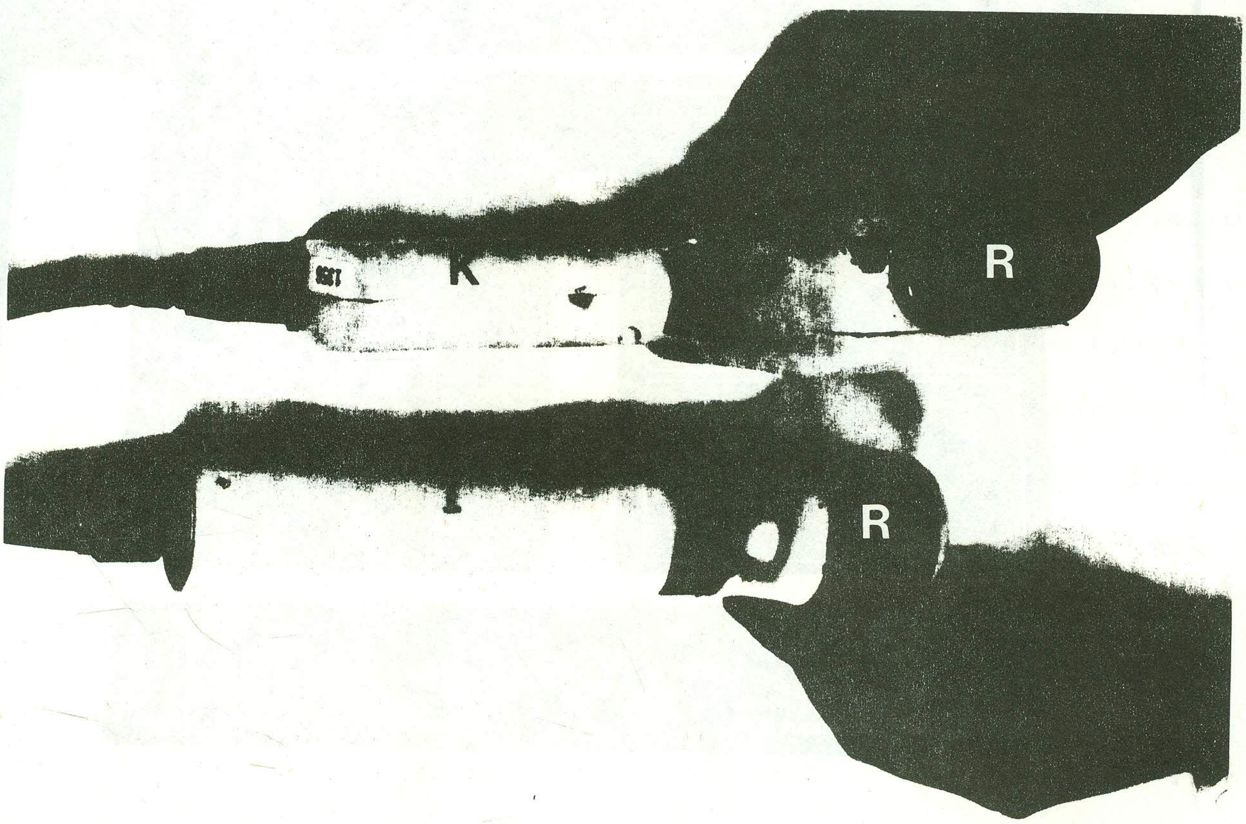


Figure 14 Transducers

Transducers I and K end-on view. The black zones (R) are formed of rubber enclosing fluid in which the transducers rotate. These are the scanning surfaces.

Following activation of a transducer, its particulars as well as the magnitude of ultrasonic energy are automatically registered at (E_1) below the date of study (see fig. 11). Scanning is controlled with aid of hand switches at (D_1) and (D_2) (fig. 10) or the foot switch (J) (fig. 13).

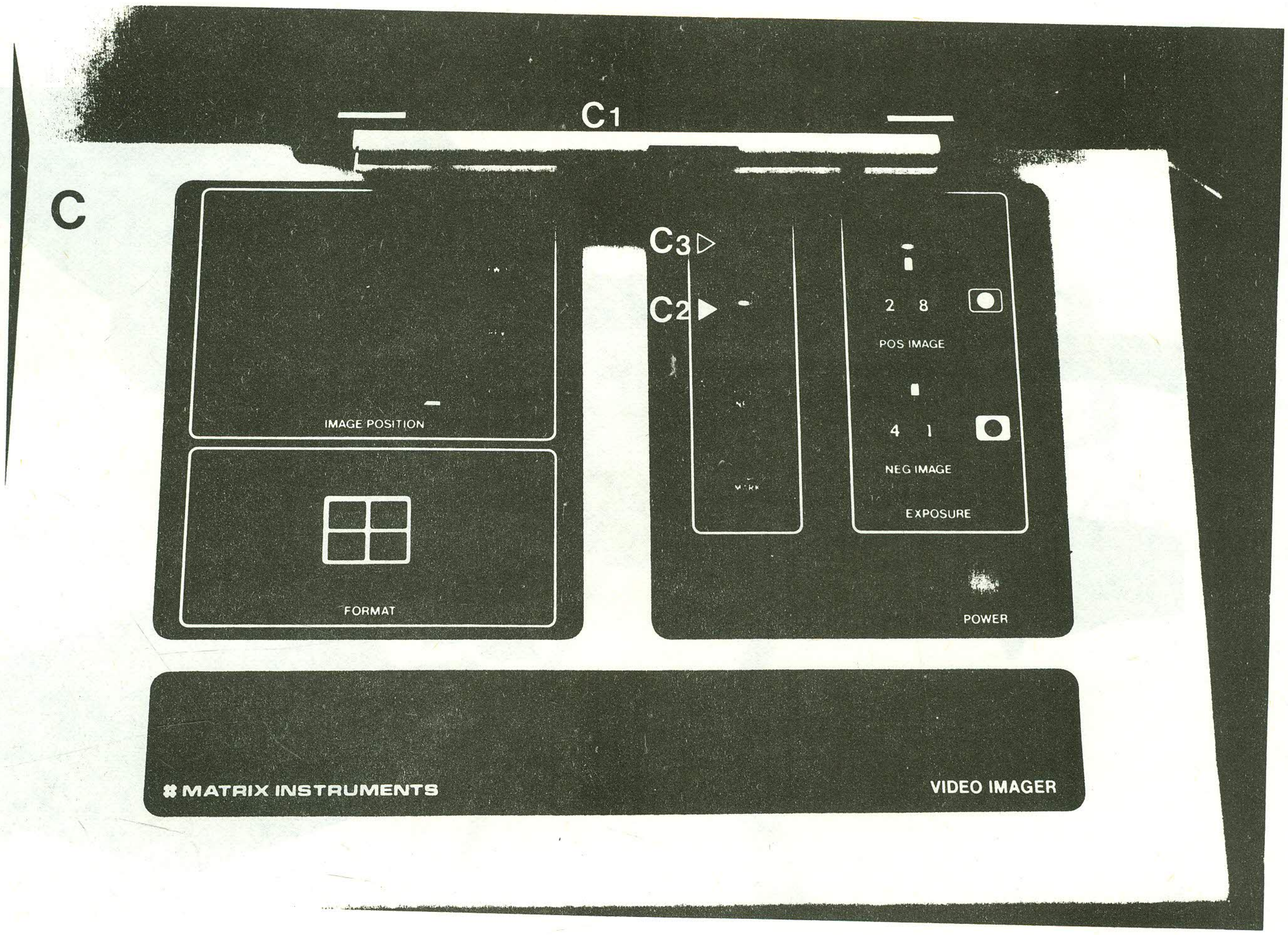


Figure 15 Image recording attachment

The cassette (C_1) as in the Picker is inserted into the light-proof slot. The cover is removed, button (C_2) is pressed ready for film recording. When an image is to be photographed (C_3) is pressed. It is subsequently pressed till 4 exposures are complete. Only 4 images can be contained on each film in this system.

At the beginning of a scanning procedure adequate contact between the transducer and the skin was effected using watery jelly. As there are no reference organs in the thorax, the equipment was standardized by scanning an intra-abdominal organ containing fluid; the gallbladder or urinary bladder. When there were no echoes emanating from the normal bile or urine, and the surrounding solid structures were clearly outlined the thorax was then scanned using the settings. The abnormal as well as the normal thoraces were scanned for comparison. In the Diasonics optimal image was achieved with -8 decibels but this varied between 0 and -14 decibels.

5. RESULTS

5.1. General: Overview of the patients and pathology

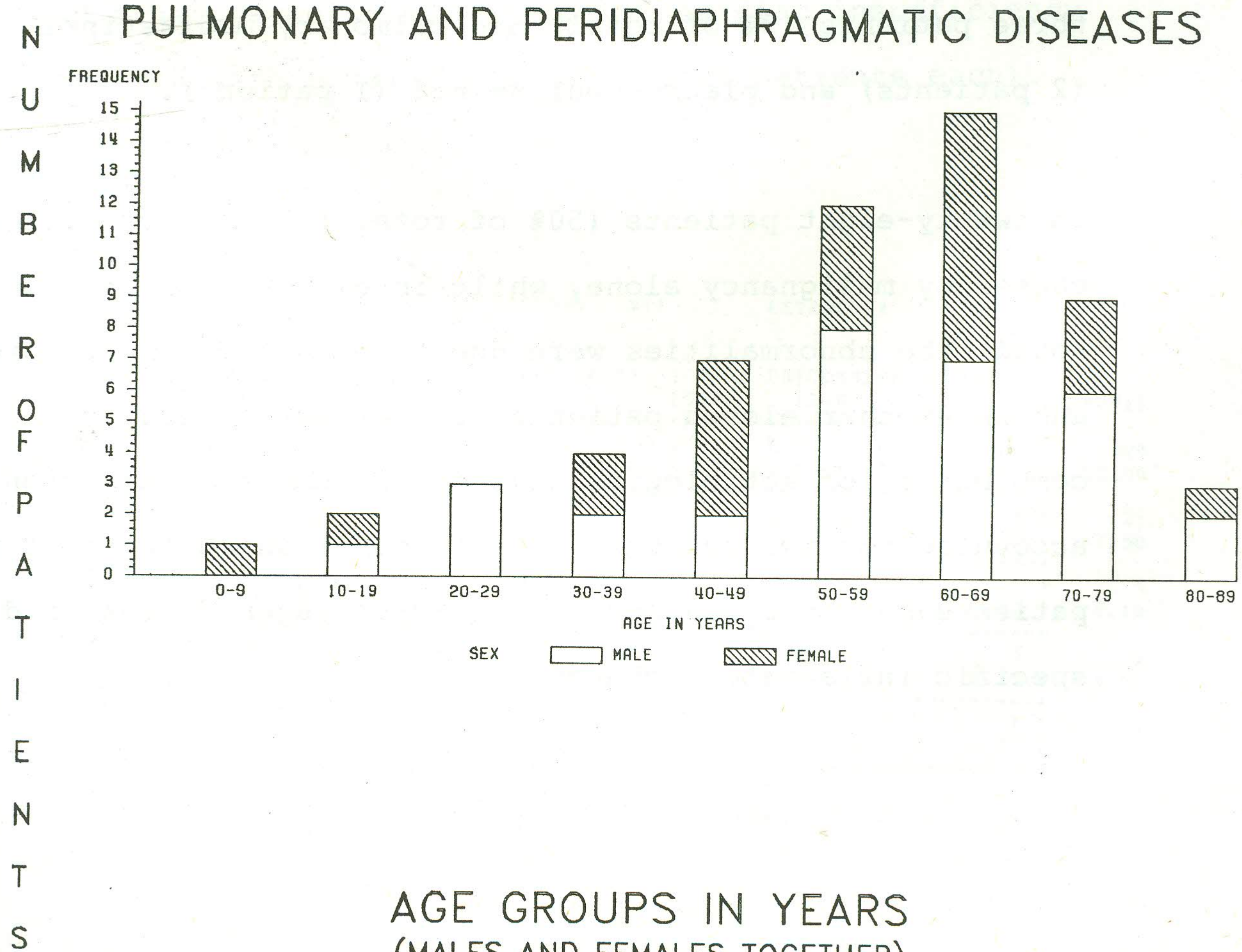
5.1.1. Sex and age

Ultrasound examination in fifty-six (56) patients with pleuro-pulmonary opacities due to different aetiologies was evaluated. Thirty-one patients (55% of total) were males, while twenty-five patients (45% of total) were females. The age ranged from minimum eight to maximum eighty-seven years. The majority of the studied population (77% of total) was within the age range between forty and seventy-nine years (graph I).

Graph I

Age and sex distribution

THE ROLE OF ULTRASOUND IN THE DIAGNOSIS OF PLEURO-PULMONARY AND PERIDIAPHRAGMATIC DISEASES



AGE GROUPS IN YEARS
(MALES AND FEMALES TOGETHER)

5.1.2. Clinical complaints and duration

Among the symptoms necessitating hospital attendance were dyspnoea, chest pain, fever, cough or combination of these. In twenty-four patients (43% of total) the duration of the symptoms ranged in months, but less than one year. In fifteen patients (27% of total) the duration of the symptoms ranged in weeks. In another fifteen patients (27% of total) the symptoms had been present for a number of days, while in the rest two patients (4% of total) the duration of the symptoms ranged in hours.

5.1.3. Anatomic position and aetiology of the lesions (table 1)

Fifty-three patients (95% of total) had pleural, pleuro-pulmonary or pulmonary abnormalities (table 1). The other three patients (5% of total) had pulmonary-mediastinal (2 patients) and pleuro-mediastinal (1 patient).

In twenty-eight patients (50% of total) the abnormalities were caused by malignancy alone, while in eleven patients (20% of total) the abnormalities were due to insufficiency of organs and in another eleven patients (20% of total) due to a combination of aetiological causes. Trauma and infection accounted for two patients (4% of total) while the last four patients had other causes including collagen disease and non-specific inflammatory change.

Among those with organ insufficiency, the heart was involved in seven patients (7 out of 11). Renal insufficiency alone occurred in three patients (3 out of 11), whereas renal and alcoholic liver failure together occurred in one patient (1 out of 11).

The abnormalities in the eleven patients with combination type aetiologies consisted of malignancy with insufficiency of organs (four patients), malignancy, organ insufficiency and respiratory infection (one patient), malignancy with respiratory infection (one patient). Multiple malignancy occurred in one patient. Other causes consisted of cardiac insufficiency with infection (one patient), while trauma with infection accounted for one patient. The last two patients had infection and other pathologies. Renal and cardiac insufficiency occurred with equal frequency (three patients each).

Table 1

V93 ANATOMIC POSITION OF LESIONS V11 AETIOLOGY

FREQUENCY PERCENT	MALIGNANT	INFECTION	TRAUMA	ORGAN INSUFF	COMBINATION	OTHER	TOTAL
PLEURA	13 23.21	0 0.00	0 0.00	7 12.50	6 10.71	2 3.57	28 50.00
PLEURAL-PULMONAR	10 17.86	1 1.79	1 1.79	3 5.36	5 8.93	1 1.79	21 37.50
PULMONARY	3 5.36	0 0.00	0 0.00	1 1.79	0 0.00	0 0.00	4 7.14
PULMONARY-MEDIAS	2 3.57	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	2 3.57
OTHER	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1 1.79	1 1.79
TOTAL	28 50.00	1 1.79	1 1.79	11 19.64	11 19.64	4 7.14	56 100.00

5.1.3.1. Types of malignancy and origin (table 2)

A total of thirty-five (63% of total) patients had malignant lesions. The most common type of malignancy was carcinoma, which was present in twenty-three (66% of 35) patients. The lesions were thoracic in origin in twenty-one patients (60% of 35) (see table 2). Ten (29% of 35) patients had extra-thoracic primaries, while in the remaining four (11% of 35) the origins of the malignant lesions were multicentric.

Of the twenty-three patients with carcinoma, ten (10 out of 23) had bronchogenic carcinoma. Five patients (5 out of 23) had carcinoma of the breast, while four patients (4 out of 23) had gastrointestinal primaries involving the colon (three patients) and stomach (one patient). Carcinoma of the ovaries occurred in two patients (2 out of 23). Fallopian tubal and renal cell carcinoma were present in one patient each.

Table 2

Types of malignancy and origin

V12 IF MALIGNANT V13 PRIMARY

FREQUENCY PERCENT	.	THORACIC	EXTRATHO RACIC	MULTICEN TRIC	TOTAL
.	21 .	0 .	0 .	0 .	. .
CARCINOMA	0 .	16 45.71	7 20.00	0 0.00	23 65.71
SARCOMA	0 .	1 2.86	2 5.71	0 0.00	3 8.57
LYMPH N-HODG	0 .	2 5.71	0 0.00	2 5.71	4 11.43
LEUKAEMIA	0 .	0 0.00	0 0.00	1 2.86	1 2.86
COMBINATION	0 .	0 0.00	1 2.86	0 0.00	1 2.86
OTHER	0 .	2 5.71	0 0.00	1 2.86	3 8.57
TOTAL	. .	21 60.00	10 28.57	4 11.43	35 100.00

5.2. Relationship between sonographic findings and pathological findings in the direct confirmatory and/or other radio-diagnostic procedures and overlaps

5.2.1. Relationship between sonographic findings and thoracentesis (tables 3 and 4)

Thirty-seven patients (66% of total) with sonographic findings suggestive of fluid were subjected to thoracentesis. Fluid was found in all patients.

The hemithoraces in which fluid was aspirated were twenty-two (59% of 37) on the right and sixteen (43% of 37) on the left (tables 3 and 4). One patient had bilateral positive thoracentesis. While most of the fluid-yielding lesions on the right (up to 30% of those aspirated) showed a "combination-type" sonographic appearance suggesting presence of solid component in addition to fluid, on the left fluid was yielded more by transonic lesions (24% of those aspirated) (table 4).

Table 3

Relationship between sonographic and aspiration findings right hemithorax

V38 FINDINGS U-S RT V64 FINDINGS ASPIRATION RT (fluid)

FREQUENCY PERCENT	.	YES	UNAPPLIC	TOTAL
TRANSONIC	12 .	8 21.62	2 5.41	10 27.03
ECHOGENIC	1 .	0 0.00	2 5.41	2 5.41
COMPLEX	0 .	3 8.11	0 0.00	3 8.11
COMB	1 .	11 29.73	1 2.70	12 32.43
NORMAL	5 .	0 0.00	10 27.03	10 27.03
TOTAL	. .	22 59.46	15 40.54	37 100.00

Table 4

Relationship between sonographic and aspiration findings left hemithorax

FINDINGS ULTRASOUND LT V100 FINDINGS ASPIRATION LT (fluid)

FREQUENCY PERCENT	.	YES	UNAPPLIC	TOTAL
TRANSONIC	3 .	9 24.32	6 16.22	15 40.54
ECHOGENIC	2 .	0 .	0 .	0 0.00
COMPLEX	1 .	2 5.41	0 0.00	2 5.41
COMB	2 .	5 13.51	2 5.41	7 18.92
NORMAL	6 .	0 0.00	13 35.14	13 35.14
TOTAL	. .	16 43.24	21 56.76	37 100.00

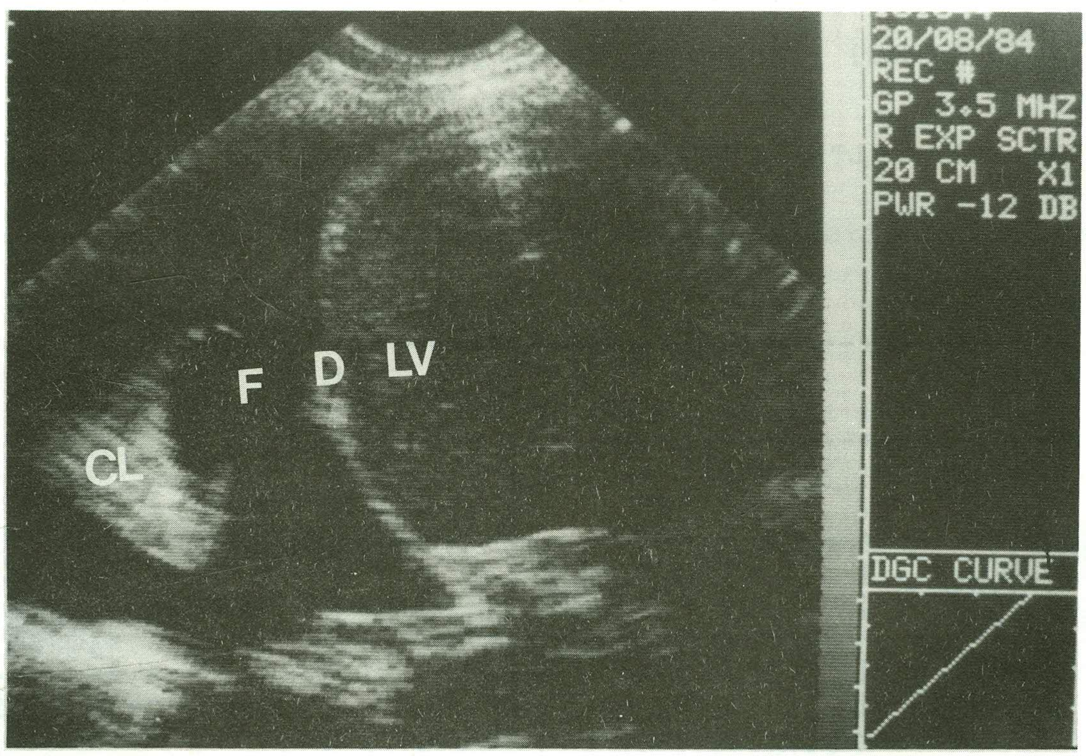


Figure 16

Echography right lung

Large right pleural effusion with collapsed right lung in a patient with ovarian carcinoma and post-transplant renal failure.

CL = Collapsed lung F = Fluid D = Diaphragm

LV = Liver (combination of transonic and echogenic lesion)

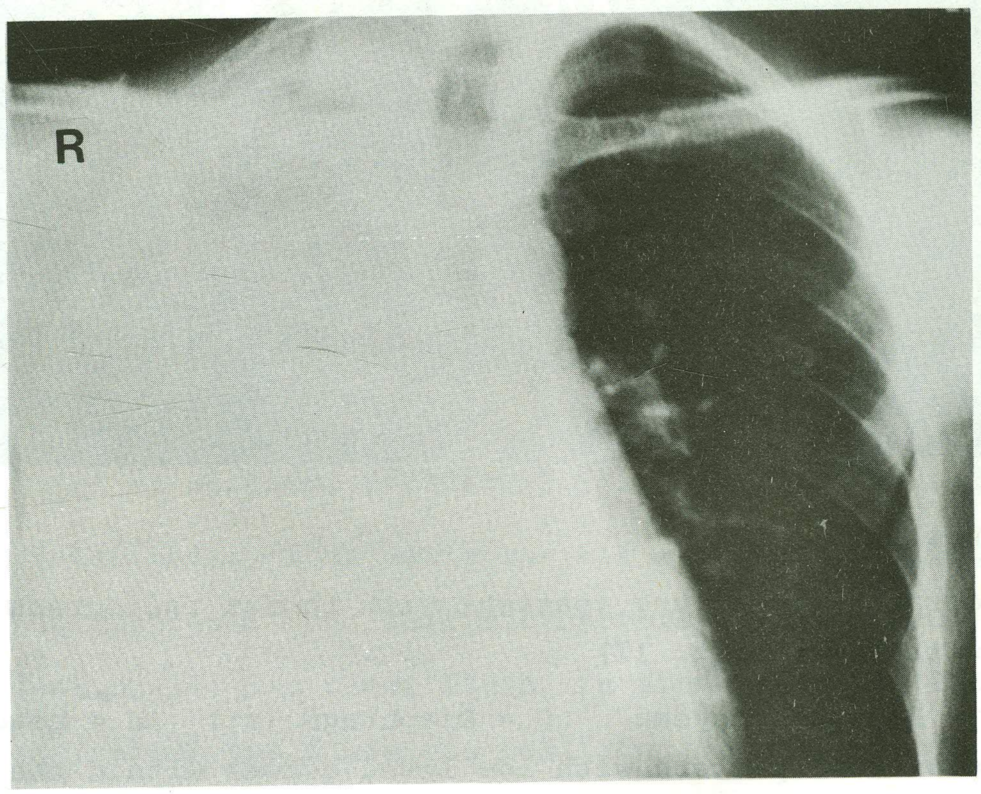


Figure 17

Chest X-ray (P.A.)

Total opacification of the right hemithorax in a 29 year old male with chest pain, fever and weight loss for about 10 months.
Decubitus radiograph yielded no fluid level.
Echography performed (see fig. 18).

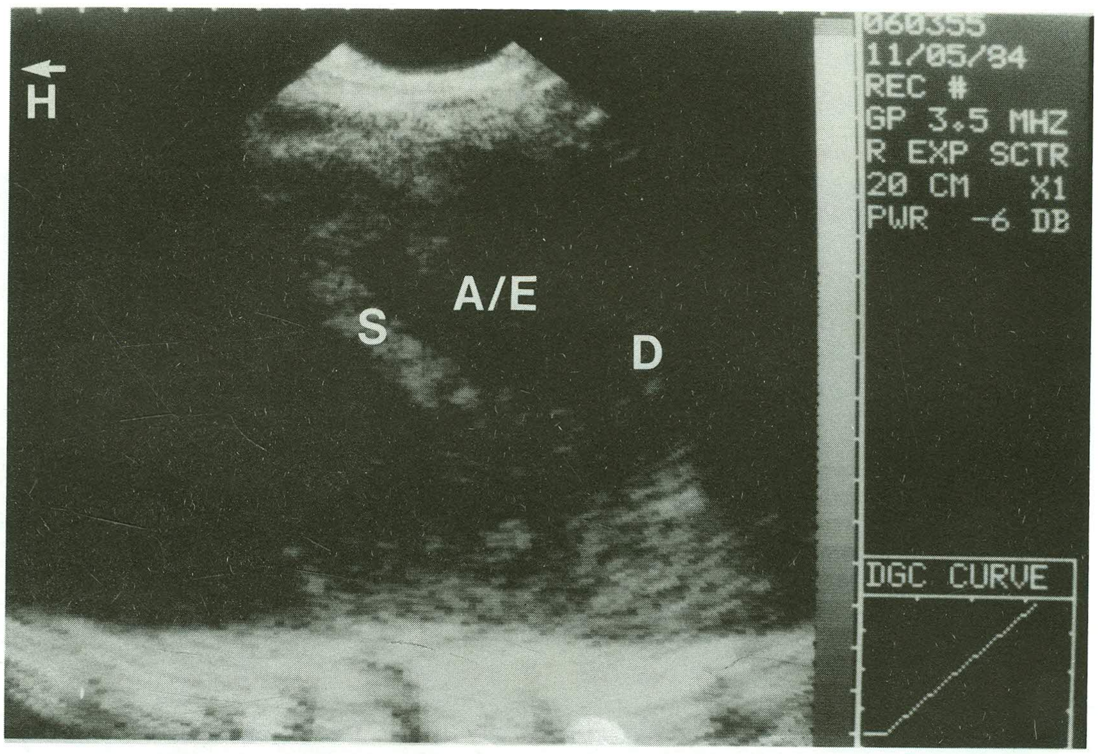


Figure 18

Echography right lung (patient with thorax radiograph illustrated in fig. 17)

A/E = Abscess/empyema D = Diaphragm (rt) H ← = head direction
Complex echo pattern with low level echoes within the lesion. A thick septum (S) is demonstrated. Surgical drainage yielded about 1,000 ml. pus. Microscopy proved tuberculous aetiology.

5.2.1.1. Quantity of aspirated fluid

Fluid was aspirated and measured in thirty patients (54% of total). The amount of aspirated fluid ranged from five to two thousand millilitres (table 5).

Table 5

Amount and number of patients aspirated

AMOUNT FLUID (MLS) S	FREQUENCY	CUM FREQ	PERCENT
.	26	.	.
0-50 MLS	11	11	36.667
51-260 MLS	5	16	16.667
261-500 MLS	3	19	10.000
501-1000 MLS	8	27	26.667
1001-1999 MLS	2	29	6.667
> 2000 MLS	1	30	3.333

5.2.1.2. Physical appearance of aspirated fluid and aetiology

Of the thirty-four patients (61% of total) subjected to thoracentesis and fluid microscopically examined, fifteen (44% of 34) had clear fluid. In nine patients (26% of those aspirated) the fluid was positive for malignancy. The twenty patients (59% of 34) included in the column for "Other" in table 6 were mostly those cases reported as "No evidence for malignant change" and those in whom the report was inconclusive.

Table 6

Appearance of fluid and aetiology

V66 MACRO-VIEW V67 FLUID MICROSCOPY

FREQUENCY PERCENT	.	INFLAMM	NEOPLAST	OTHER	TOTAL
.	19 .	0 .	0 .	0 .	. .
CLEAR	2 .	0 0.00	3 8.82	12 35.29	15 44.12
BLOODY	0 .	0 0.00	4 11.76	6 17.65	10 29.41
PUS	0 .	4 11.76	0 0.00	0 0.00	4 11.76
OTHER	1 .	0 0.00	2 5.88	2 5.88	4 11.76
5	0 .	1 2.94	0 0.00	0 0.00	1 2.94
TOTAL	. .	5 14.71	9 26.47	20 58.82	34 100.00

5.2.1.3. Complications following thoracentesis

Twenty-five patients (68% of those aspirated) had immediate thoracic radiographic examination after the thoracentesis. No pneumothorax occurred.

5.2.2. Relationship between sonographic and surgical findings

Eight (14% of total) patients were subjected to surgical procedure for diagnostic or therapeutic purpose. In four of these, the procedure was on the right, while in the other four the procedure was on the left hemithorax.

The findings at surgery were consistent with sonographic findings in all cases. Fluid was ultrasonically suspected and surgically confirmed in 5 of the 16 hemithoraces.
Solid tissue was suspected and confirmed in 6 of the 11 hemithoraces. One (1 out of 8) patient had a transonic right hemithoracic lesion not subjected to surgery. One case of recent (HRS) haematoma was transonic (+). Another case of pus showed complex echogenic pattern with thick septation (++) (tables 7 and 8 and fig. 18).

Table 7

Relationship between sonographic and surgical findings (right hemithorax)

V38 FINDINGS U-S RT V73 FINDINGS RELEVANT SURGERY RT

FREQUENCY PERCENT		HAEMATOMA	PUS	COMB	FIBROSIS	NOT DONE	TOTAL
TRANSONIC	20 .	(+) 1 12.50	0 0.00	0 0.00	0 0.00	1 12.50	2 25.00
ECHOGENIC	2 .	0 0.00	0 0.00	0 0.00	1 12.50	0 0.00	1 12.50
COMPLEX	2 .	0 0.00	(++) 1 12.50	0 0.00	0 0.00	0 0.00	1 12.50
COMB	12 .	0 0.00	0 0.00	(+) 1 12.50	0 0.00	0 0.00	1 12.50
NORMAL	12 .	0 0.00	0 0.00	0 0.00	0 0.00	3 37.50	3 37.50
TOTAL	. .	1 12.50	1 12.50	1 12.50	1 12.50	4 50.00	8 100.00

Table 8

Relationship between sonographic and surgical findings (left hemithorax)

V92 FINDINGS ULTRASOUND LT V103 FINDINGS SURGERY LT

FREQUENCY PERCENT	.	MASS	FLUID	COMB	NOT DONE	TOTAL
TRANSONIC	22 .	0 0.00	1 12.50	0 0.00	0 0.00	1 12.50
ECHOGENIC	0 .	2 25.00	0 0.00	0 0.00	0 0.00	2 25.00
COMPLEX	3 .	0 .	0 .	0 .	0 .	0 0.00
COMB	8 .	0 0.00	0 0.00	1 12.50	0 0.00	1 12.50
NORMAL	15 .	0 0.00	0 0.00	0 0.00	4 50.00	4 50.00
TOTAL	. .	2 25.00	1 12.50	1 12.50	4 50.00	8 100.00

5.2.3. Relationship between sonographic and postmortem findings

Postmortem examination was performed in ten patients (18% of total). Fluid was ultrasonically suspected and by postmortem confirmed in 9 of the 20 hemithoraces. Solid tissue was detected ultrasonically and confirmed by postmortem in 6 of the 20 hemithoraces (tables 9 and 10).

In table 9 one patient with a transonic lesion (-) was found to have a malignant tumour (hilar) with pleural effusion. In the same table (9) a second patient with complex sonographic appearance (➔) suggestive of fluid component only consolidation (inflammatory change) was found.

Table 9

Relationship between sonographic and postmortem findings (right hemithorax)

V38 FINDINGS U-S RT V39 FINDINGS POST-MORTEM RT

FREQUENCY PERCENT	.	NORMAL	TUMOR+FLUID	INFLAMM CHANGE	FIBROSIS	FLUID	TOTAL
TRANSCNIC	18 .	0 0.00	(—) 1 10.00	0 0.00	0 0.00	3 30.00	4 40.00
ECHOGENIC	2 .	0 0.00	0 0.00	0 0.00	1 10.00	0 0.00	1 10.00
COMPLEX	2 .	0 0.00	0 0.00	(→) 1 10.00	0 0.00	0 0.00	1 10.00
COMB	12 .	0 0.00	1 10.00	0 0.00	0 0.00	0 0.00	1 10.00
NORMAL	12 .	3 30.00	0 0.00	0 0.00	0 0.00	0 0.00	3 30.00
TOTAL	. .	3 30.00	2 20.00	1 10.00	1 10.00	3 30.00	10 100.00

Table 10

Relationship between sonographic and postmortem findings (left hemithorax)

V92 FINDINGS ULTRASOUND LT V105 FINDINGS POST MORTEM LT

FREQUENCY PERCENT	.	MALIGN TUM	INFLAMM CHANGE	FIBROSIS	COMB	FLUID	TOTAL
TRANSCNIC	20 .	0 0.00	0 0.00	0 0.00	0 0.00	3 30.00	3 30.00
ECHOGENIC	1 .	1 10.00	0 0.00	0 0.00	0 0.00	0 0.00	1 10.00
COMPLEX	3 .	0 .	0 .	0 .	0 .	0 .	0 0.00
COMB	7 .	(M) 1 10.00	0 0.00	0 0.00	1 10.00	0 0.00	2 20.00
NORMAL	15 .	0 0.00	(—) 1 10.00	(=) 1 10.00	0 0.00	(→) 2 20.00	4 40.00
TOTAL	. .	2 20.00	1 10.00	1 10.00	1 10.00	5 50.00	10 100.00

In table 10 one patient (-) was on sonographic examination considered normal. At postmortem, 55 days after sonographic evaluation, consolidation and cavitation of the lingular segment of the left upper lobe were found. A second patient (=) with "normal" sonographic findings was found to have pleural fibrosis ten days later.

In the same table (10) two patients (➔) considered normal ultrasonically were found to have pleural fluid. In another patient (*) with combination ultrasonic findings suggestive of cystic/solid components only malignant tumour was reported.

5.2.4. Overlap within the direct confirmatory procedures

Three patients (5% of total) were subjected to both thoracic aspiration and surgical procedure. Seven patients (12% of total) had both aspiration and postmortem examination. In all cases where aspiration overlapped with other confirmatory procedures, aspiration was unilateral. Only one patient (2% of total) had both surgical procedure and postmortem examination. Considering only one direct confirmatory procedure per individual patient, forty-four patients (78% of total) were evaluated with ultrasound and the sonographic findings compared to the findings in the direct confirmatory procedures.

5.2.5. Relationship between sonographic and other radio-diagnostic procedures (tables 11 and 12)

5.2.5.1. Relationship between sonographic and CT-scan findings

Seventeen patients (30% of total) in addition to ultrasound had CT-scan evaluation. Fluid was ultrasonically suspected and found on CT-scan evaluation in twenty-one of the thirty-four hemithoraces (tables 11 and 12). Solid tissue was suspected by both methods in seven of the thirty-four hemithoraces. Fluid was suspected by ultrasound but not found on CT-scan evaluation, four days later in one patient (* table 11). In a second patient suspected on sonographic evaluation to be normal, fluid was found by CT-scan eight days later (→ table 11). In table 12 one patient with combination (-) type of sonographic findings suggestive of a solid as well as a cystic component was found to have only fluid.

Table 11

Relationship between sonographic and CT-scan findings (right hemithorax)

V38 FINDINGS U-S RT V74 FINDINGS C-T SCAN RT

FREQUENCY PERCENT	.	NORMAL	FLUID	COMB	TOTAL
TRANSONIC	14 .	(*) 1 5.88	7 41.18	0 0.00	8 47.06
ECHOGENIC	3 .	0 .	0 .	0 .	0 0.00
COMPLEX	2 .	0 0.00	0 0.00	1 5.88	1 5.88
COMB	10 .	0 0.00	0 0.00	3 17.65	3 17.65
NORMAL	10 .	4 23.53	(→) 1 5.88	0 0.00	5 29.41
TOTAL	. .	5 29.41	8 47.06	4 23.53	17 100.00

Table 12

Relationship between sonographic and CT-scan findings (left hemithorax)

V92 FINDINGS ULTRASOUND LT V104 FINDINGS C-T SCAN (LT)

FREQUENCY PERCENT	.	NORMAL	MASS	FLUID	COMB	TOTAL
TRANSONIC	16	0	0	7	0	7
	.	0.00	0.00	41.18	0.00	41.18
ECHOGENIC	1	0	1	0	0	1
	.	0.00	5.88	0.00	0.00	5.88
COMPLEX	3	0	0	0	0	0
	.	.	.	.	.	0.00
COMB	6	0	0	(-) 1	2	3
	.	0.00	0.00	5.88	11.76	17.65
NORMAL	13	6	0	0	0	6
	.	35.29	0.00	0.00	0.00	35.29
TOTAL	.	6	1	8	2	17
	.	35.29	5.88	47.06	11.76	100.00

5.2.5.2. Relationship between sonographic and decubitus radiographic findings

Eight patients (14% of total) were further studied with decubitus radiography. Fluid was suspected by both methods in six (6 out of 16) hemithoraces (tables 13 and 14). In three hemithoraces (2 right and 1 left) the decubitus radiographs were undiagnostic in patients with sonographic appearances suggestive of fluid. In all of these patients fluid was confirmed by aspiration/drainage. Sonographic appearance suggestive of solid component in addition to fluid were observed in seven (7 out of 16) hemithoraces but not confirmed.

Table 13

Relationship between sonographic and decubitus film findings (right hemithorax)

V38 FINDINGS U-S RT V60 FINDINGS DECUBITUS FILM RT

FREQUENCY PERCENT	.	FLUID	UNDIAGN	COMB	NOT DONE	TOTAL
TRANSONIC	22 .	0 .	0 .	0 .	0 .	0 0.00
ECHOGENIC	3 .	0 .	0 .	0 .	0 .	0 0.00
COMPLEX	2 .	0 0.00	1 12.50	0 0.00	0 0.00	1 12.50
COMB	9 .	2 25.00	1 12.50	1 12.50	0 0.00	4 50.00
NORMAL	12 .	0 0.00	0 0.00	0 0.00	3 37.50	3 37.50
TOTAL	. .	2 25.00	2 25.00	1 12.50	3 37.50	8 100.00

Table 14

Relationship between sonographic and decubitus film findings (left hemithorax)

V92 FINDINGS ULTRASOUND LT V106 DECUBITUS FILM LT

FREQUENCY PERCENT	.	FLUID	UNDIAGN	NOT DONE	TOTAL
TRANSONIC	22 .	1 12.50	0 0.00	0 0.00	1 12.50
ECHOGENIC	2 .	0 .	0 .	0 .	0 0.00
COMPLEX	3 .	0 .	0 .	0 .	0 0.00
COMB	6 .	2 25.00	1 12.50	0 0.00	3 37.50
NORMAL	15 .	0 0.00	0 0.00	4 50.00	4 50.00
TOTAL	. .	3 37.50	1 12.50	4 50.00	8 100.00

5.2.6. Overlap within the other radiodiagnostic procedures (CT-scan and decubitus radiographic studies)

Three patients (5% of total) had both CT-scan and decubitus radiographic study. Thus twenty-two patients (39% of total) were evaluated with CT-scan and/or decubitus radiograph.

5.2.7. Overlap between the direct confirmatory (postmortem/ surgery/aspiration) and the other radiodiagnostic (CT-scan and decubitus radiograph) procedures

A total of forty-nine patients (88% of total) had contributive direct confirmatory or other radiodiagnostic procedures. Seventeen patients (30% of total) had both the direct confirmatory and the other radiodiagnostic procedures. Twenty-seven patients had direct confirmatory, while five had the other radiodiagnostic procedures alone. The remaining seven patients (13% of total) had neither the direct confirmatory nor the other radiodiagnostic procedures.

5.3. Fluid diagnosed on clinical suspicion

In the remaining seven patients (13% of total) there was no clinical indication for direct confirmatory or other radio-diagnostic procedural intervention. Fluid was, however, suspected on basis of position, aetiology, behaviour of the lesions with respiration and/or altered position and follow-up study.

Two patients (4% of total) with pleural disease following recent trauma to the thorax had transonic lesions which resolved on follow-up. Two other patients (4% of total) with cardiac insufficiency and pleural disease were followed up with chest X-ray and the lesions resolved with antifailure therapy. One patient with pancreatitis and transonic right pleural lesion showed resolution in one week after therapy. In all these patients together with the remaining two (4% of total) with malignant diseases, the lesions showed evidence of gravitation and deformation with altered position and respiration during ultrasonographic examination. In both patients with cardiac insufficiency the pleural opacities showed a combination of echo patterns. In one of the patients there was a combination of echogenic and transonic patterns presumed to be due to pleural fluid and collapsed lung. In the second case, there was a combination of transonic and complex patterns. The complex pattern represented an aortic aneurysm with irregular intraluminal thrombosis. The rest of the patients in this group had transonic echo patterns.

Table 15

Summary I. Relationship between sonographic findings and different types of physical abnormalities in all hemithoraces (n = 112)

	PROVED							STRONGLY SUSPECTED			SUSPECTED					
Lesions	Fluid	Solid	Fluid and Solid	H'toma	Pus and Septae	Normal	Sub-total 1	Fluid	Normal	Sub-total 2	Fluid	Fluid and Solid	H'toma	Normal	Sub-total 3	Grand total
Transonic	19		1	1			21	6		6	13		2		15	42 38%
Echogenic		4					4									4 3%
Complex	3		1		1		5				2				2	7 6%
Comb.	12	1	4				17				3	1			4	21 19%
Normal	2	2				3	7		2	2				29	29	38 34%
Total	36 (32%)	7 6%	6 5%	1 0.9%	1 0.9%	3 2.5%	54 48%	6 5%	2 1.8%	8 7%	18 16%	1 0.9%	2 1.8%	29 26%	50 45%	112 100%

Table 15 summarizes the sonographic and the different physical forms and different types of fluids proved, strongly suspected or suspected in the procedures.

The most common physical lesion was fluid occurring in 53% of all lesions (fluid alone). The most common sonographic appearance was transonic accounting for 38% of total followed by normal findings (34% of total). Proved and suspected haematomas were transonic.

Table 16

Summary II. All the findings in the different direct confirmatory radiodiagnostic procedures and clinical diagnosis with weighting of the procedures

		DIRECT CONFIRMATORY PROCEDURES				OTHER RADIODIAGNOSTIC PROCEDURES			CLINICAL	
	Physical state	Post-mortem	Surgery	Aspiration	Sub-total 1	CT-scan	Dec. radiogr.	Sub-total 2		Grand-total
Number of patients		10	7	27	44	3	2	5	7	56
Correctly Dx abnormal hemithoraces		15	7	28	50	4	2	6	12	68
Lesions State	Fluids	9	5	28	*42	4	2	6	12	→60
	Solids	6	5		**11					11
False negative	Fluids	2			* 2	1		1		→ 3
	Solids	2			** 2					2
False-false positive	Fluids	2			2	1		1		3
False-false negative	Solids	1			1					1
Proved normal		3			3					3

5.4. Sensitivity of ultrasound to fluids and solids

5.4.1. Fluids

Using only data derived from the direct confirmatory procedures (postmortem, surgery and aspiration), ultrasound correctly identified fluid in forty-two, but failed to identify fluid in two lesions (* table 16). The findings being consistent with a sensitivity of 95.4%.

Further considering the data derived from the entire study (the direct confirmatory, other radiodiagnostic procedures and clinical diagnosis), ultrasound correctly detected fluid in sixty, but was unable to diagnose fluid in three lesions (→ table 16). These findings are consistent with 95.2% sensitivity.

5.4.2. Solids

Using only data derived from postmortem and surgery, ultrasound correctly diagnosed solids in eleven but failed to detect solids in two lesions (** table 16). The findings giving a sensitivity of 85%. With the data derived from postmortem, surgery and CT-scan in that order of weighting, ultrasound correctly detected solids in fourteen, but failed in two hemithoraces, giving a sensitivity of 88%.

5.5. The peridiaphragmatic regions and upper abdomen

5.5.1. Identification of diaphragms, windows and shape

The right diaphragm was identified with certainity in 100% of all cases (56) compared to 79% on the left. On the right, most diaphragms were studied through the liver (89%), while on the left diaphragmatic identification was achieved through the spleen in 78% of the cases. The rest of the patients were studied directly through pathological lesions in the costophrenic angles. Right inverted diaphragm was found in one patient (fig. 19).

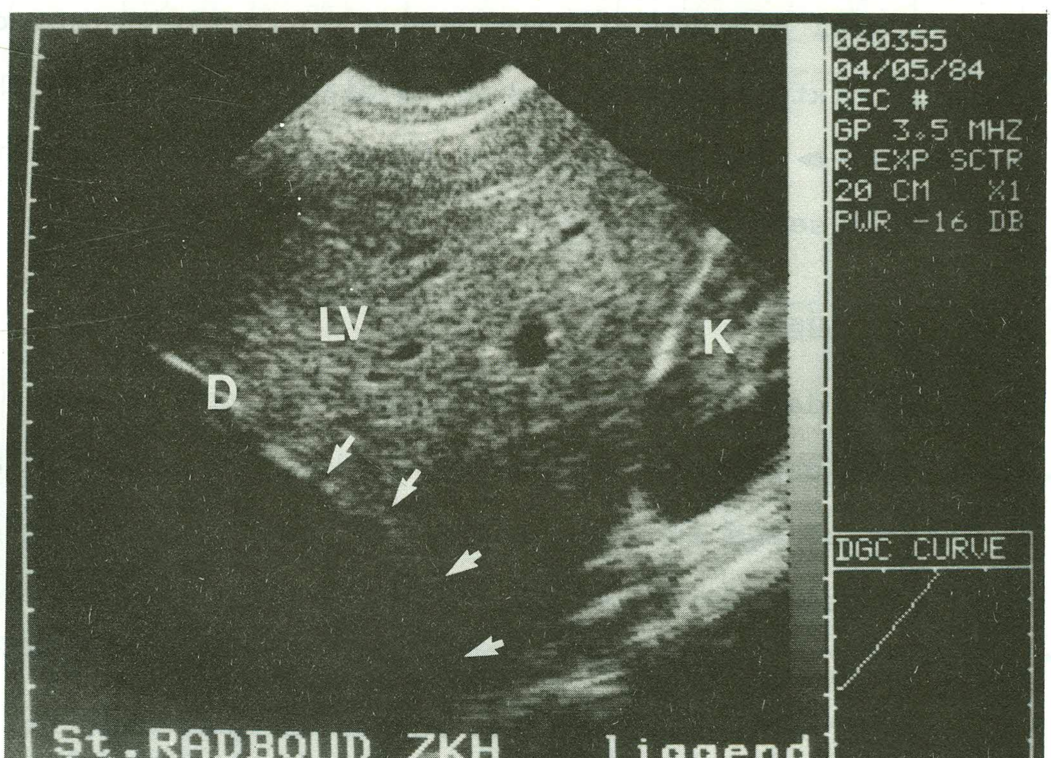


Figure 19
Inversion right hemidiaphragm due to a large empyema
D = Diaphragm LV = Liver
Arrow (◄—) demonstrates the inferior margin of the diaphragm. The diaphragm is convex towards the liver compared to the normal concave liver diaphragmatic surface.

5.5.2. Diaphragmatic motion assessment (subjective)

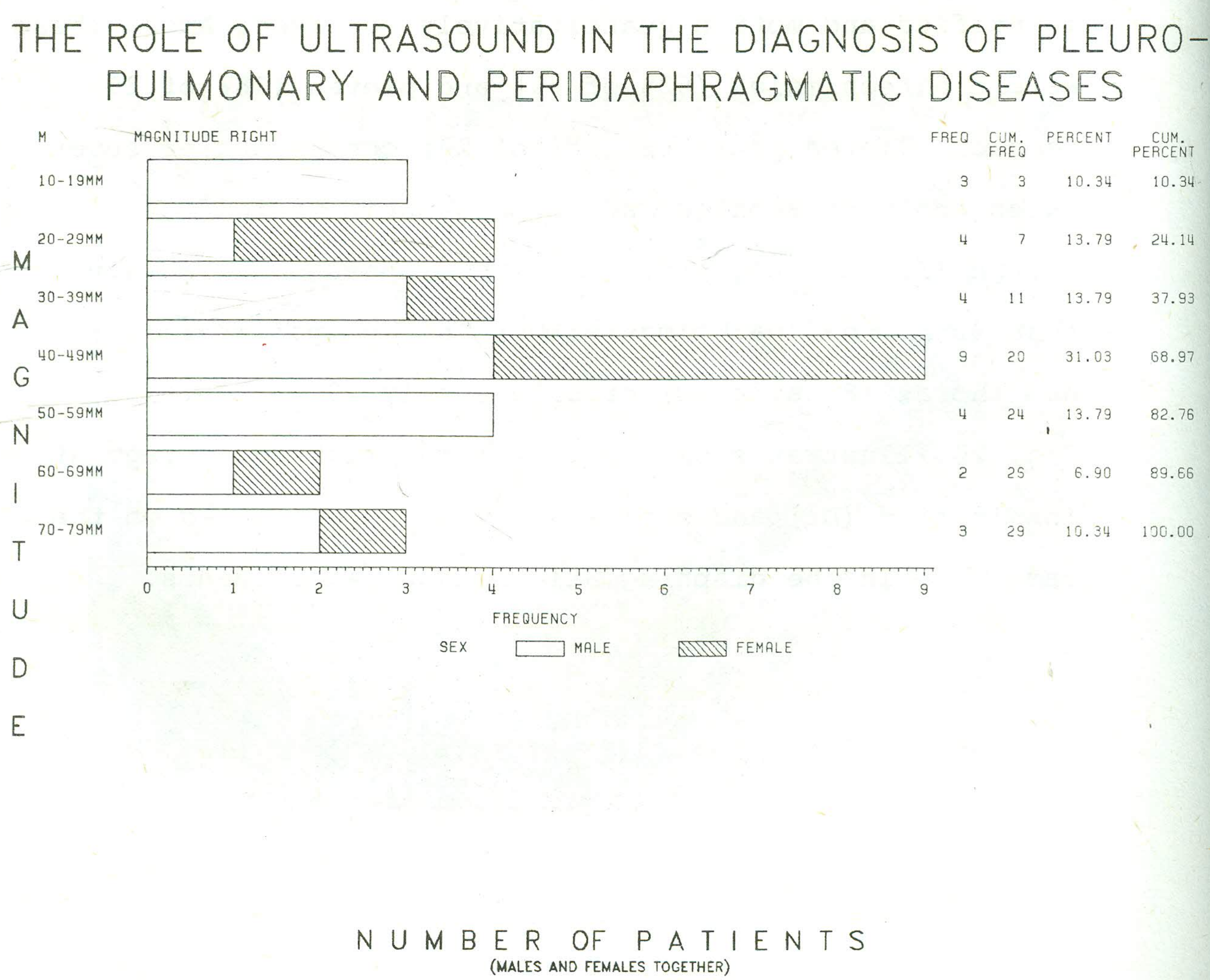
On subjective assessment of the magnitude of motion of the diaphragm, 45% of total were considered normal on the right, while thirteen patients (23% of total) had normal motion on the left. Twenty-eight (50%) patients had equivocal diaphragmatic motion findings on the left, compared to nineteen (34%) on the right.

5.5.3. Measurement of right diaphragmatic motion

Twenty-nine patients (52% of total) had the right diaphragm identified and motion quantitatively assessed. Among these were eighteen males (62% of 29) and eleven (38% of 29) females. Eleven patients (38% of 29) consisting of seven males and four females had diaphragmatic motion below 40 mm. (graph II). All the patients with diaphragmatic motion less than 40 mm. had pathology either in the ipsilateral (rt) hemithorax (8 patients) or bilaterally (3 patients).
Fig. 20 illustrates two images of the right diaphragm at inspiration (DI) and expiration (DE) superimposed on the same film in the diaphragmatic motion measurements.

Graph II

Right diaphragmatic motion measurements in males (n = 18) and females (n = 11)



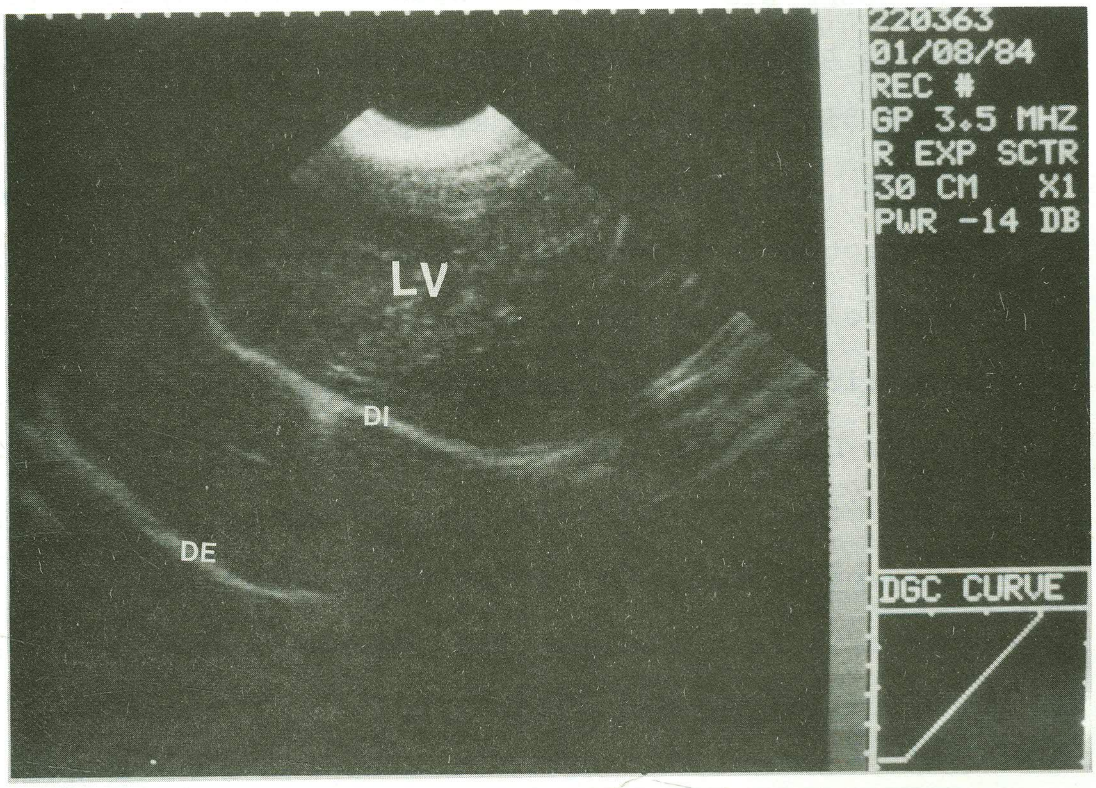


Figure 20

Diaphragmatic motion measurements (rt)

LV = Liver DI = Diaphragm inspiration

DE = Diaphragm expiration

5.5.4. Extent of pathology with reference to diaphragms

On the right, fifteen patients (27% of total) and on the left twelve patients (21% of total) showed evidence of disease above and below the diaphragms.

5.5.5. The state of the major vessels in the peridiaphragmatic regions

The inferior vena cava was studied in fifty-five patients (98% of total) and was found to be abnormal in four patients (7% of 55). In three of these patients, it was dilated while in the fourth it showed intraluminal growth of right Grawitz tumour extending to the right atrium. Cardiac insufficiency was the primary cause of the vena caval dilatation in two patients while malignancy (Grawitz tumour and non-Hodgkin's lymphoma) was the major underlying disease in the other two patients. One of the 56 patients had aneurysmal dilatation of the aorta (diameter 4.5 cm. at the level of aortic hiatus). The aneurysm showed evidence of intraluminal thrombi (fig. 21).

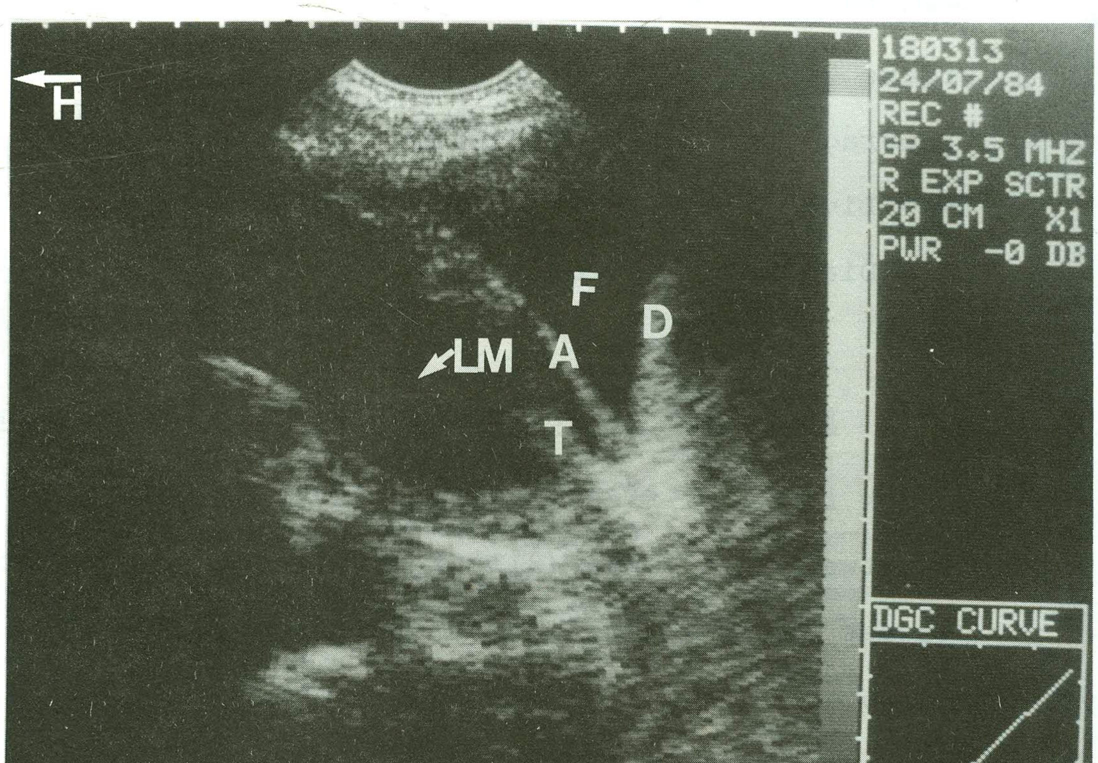


Figure 21

Aortic aneurysm diagnosed through pleural fluid

LM = Lumen A = Aortic wall D = Diaphragm

T = Thrombus H = Direction of head

5.5.6. Other upper abdominal findings

Twenty-seven patients (48% of total) were shown to have intra-abdominal abnormalities in addition to the pleuro-pulmonary diseases. In 41% of these patients, the intra-abdominal abnormalities were multiple (comb. table 17).

Table 17

Findings in the abdomen (incidental)

(n = 27)

FINDINGS V71	FREQUENCY	CUM FREQ	PERCENT
.	29	.	.
COMB	11	11	40.741
HEPATOMEG	2	13	7.407
METASTAT	5	18	18.519
ASCITES	1	19	3.704
BILL DIS	3	22	11.111
REN DIS	5	27	18.519

5.6. Pitfalls of ultrasound

Twenty-five (45% of total) patients had abnormalities considered unsuitable for ultrasonic evaluation.
Table 18 outlines the abnormalities considered unsuitable for ultrasonic detection and/or evaluation and the causes for unsuitability.

Table 18

Pitfalls of ultrasound and causes

V101 UNSUITABLE FOR US V102 CAUSE UNSUITABILITY

FREQUENCY PERCENT	.	ATTENUATION	WINDOW	COMP	OTHER	TOTAL
.	31 .	0 .	0 .	0 .	0 .	. .
CARDIOMEGALLY	0 .	0 0.00	0 0.00	0 0.00	8 32.00	8 32.00
MED SHIFT	0 .	0 0.00	0 0.00	0 0.00	2 8.00	2 8.00
HILAR TUMORS	0 .	0 0.00	6 24.00	0 0.00	0 0.00	6 24.00
PULM METAS	0 .	0 0.00	3 12.00	0 0.00	0 0.00	3 12.00
SKELET METAS	0 .	3 12.00	0 0.00	0 0.00	0 0.00	3 12.00
FRACT RIBS	0 .	1 4.00	0 0.00	0 0.00	0 0.00	1 4.00
OTHERS	0 .	0 0.00	0 0.00	2 8.00	0 0.00	2 8.00
TOTAL	. .	4 16.00	9 36.00	2 8.00	10 40.00	25 100.00

5.7. Clinical results on follow-up

Fifty-one patients (91% of total) were adequately followed-up and results of management recorded. Five patients (9% of total) could not be followed-up. Sixteen of the fifty-one patients (31% of 51) died. Fourteen of the sixteen patients who died (88% of 16) were within the age range between 40 and 79 years. 77% of those patients followed-up were within this age range (i.e. 40-79 years).

Nine of the sixteen patients (56% of 16) who died had malignant disease. Malignant disease occurred in 31 of the 51 patients (61%) who were followed-up.

6. DISCUSSION

6.1. General

In order to facilitate understanding of the findings in this study, the most significant findings have been described with the tables of results. Detection and confirmation of fluids and solids are contained in the tables showing relationships between sonographic findings and aspiration (tables 3 and 4), surgery (tables 7 and 8) and postmortem (tables 9 and 10). Fluid was confirmed by all the three methods (aspiration, surgery and postmortem).
Solids were confirmed by surgery and postmortem. Normal findings were only confirmed by postmortem.

6.1.1. Weighting of the procedures

In order to optimize detection of both fluids and solids the confirmatory procedures were weighted differently. Postmortem ranked most important not only in view of the above reason, but also because of its ability to confirm or disprove normal sonographic findings. Surgery ranked second in view of its ability to detect solids in addition to fluids. Thus patients who had aspiration, surgery and postmortem were considered confirmed by postmortem. Patients subjected to aspiration and surgery were considered confirmed by surgery. CT-scan, decubitus radiograph and fluid diagnosed on clinical suspicion were the next order of importance.

6.1.2. Clarification of the summary tables(tables 15 and 16) on basis of weighting

In tables 9 and 10 ten patients are shown to have been confirmed by postmortem. All ten patients appear in table 16. In tables 7 and 8, eight patients were subjected to surgery, however, one patient was confirmed by postmortem as well as surgery. This patient is excluded from the list of patients confirmed by surgery, but included in the postmortem cases. Thus in table 16 only seven cases appear confirmed by surgery. Similarly for aspiration tables 3 and 4 show that 37 patients were confirmed by thoracentesis. In table 16 only 27 patients are included in the aspiration in view of ten patients who in addition to aspiration had surgery (3 patients) and postmortem (7 patients).

6.1.3. Inter-confirmatory procedural discrepancies and weighting

After grouping the patients as per significance of the procedures (direct confirmatory, other radiodiagnostic and clinical) inter-procedural discrepancies and circumstances leading to the discrepancies were analysed. The lesions showing discrepancy between sonographic and the direct confirmatory and/or the other radiodiagnostic procedures were thus categorized as false negative, false positive, false-false negative, false-false positive.

6.1.4. Further details on the findings in the confirmatory procedures

6.1.4.1. Sonographic and aspiration findings (tables 3 and 4)

Eleven (11 out of 64) hemithoraces (3 on the right, table 3 and 8 on the left table 4) with sonographic appearances suggestive of fluid content were not subjected to aspiration. Sonographic appearances suggestive of fluid are defined in appendix III.

6.1.4.2. Sonographic and postmortem findings (tables 9 and 10)

Discrepancies were observed between sonographic and postmortem, as well as between postmortem and aspiration findings.

6.1.4.2.1. Right hemithorax (table 9)

One patient with a transonic lesion (-) suggestive of only fluid content, was found to have a hilar tumour. Here the cause of failure is considered to be due to lack of sonographic window (false negative solid). In a second patient (N.G.) with complex sonographic (→) findings suggesting fluid and solid components, only right basal consolidation (inflamm. change) was found fifty-five days following sonographic evaluation. This patient who had liver hilar lymphoma and right basal consolidation with pseudomonas and klebsiella pleural exudation confirmed on aspiration shortly after sonographic evaluation had antibiotic therapy and the fluid is considered absorbed in the meantime (false-false positive fluid).

6.1.4.2.2. Left hemithorax (table 10)

The same patient (N.G.) was considered sonographically normal (-), but at death was found to have consolidation and cavitation involving the lingular segment of the left upper lobe. This was not present on the radiograph during the sonographic evaluation. It is suggested that this lesion developed during the interval between ultrasound evaluation and death (55 days) (false negative solid).

A second case sonographically evaluated as normal (table 10 =) was found to have pleural fibrosis at postmortem ten days later (false negative solid). Two patients were sonographically evaluated as normal (table 10 ➔) but were subsequently on postmortem found to have pleural fluid seven (first patient) and sixteen (second patient) days later (false negative fluid). In one patient with a combination (*) of sonographic findings a malignant tumour was reported. The patient had been subjected to therapeutic aspiration with removal of 500 ml. fluid after sonographic evaluation seven days before death (false-false positive fluid due to aspiration).

6.1.4.3. The role of other radiodiagnostic procedures

Other radiodiagnostic procedures have been included in this study for different reasons. The radiodiagnostic procedures contributed in part or wholly in reaching the final diagnosis in the concerned patients. Demonstration of their limitations or otherwise was of interest. CT-scan contributed towards detection of solids in addition to fluids.

6.1.4.3.1. <u>The role of CT-scan</u>

In tables 11 and 12 three patients (*. → .-) show discrepancy between sonographic and CT-scan findings. Although these patients were all subjected to the direct confirmatory procedures, the lesions causing discrepancy were not verified by the direct confirmatory procedures. Thus the patient who was sonographically suspected to have fluid but nc fluid found by CT-scan four days later (* table 11 rt. hemithorax) had aspiration left hemithorax. The fluid in the rt. hemithorax was probably resorbed between ultrasonography and CT-scan.

The second patient sonographically suspected to be normal but fluid found on CT-scan examination eight days later (→ table 11 rt. hemithorax) also had positive thoracentesis but on the left hemithorax. This fluid probably developed during the interval between ultrasonographic and CT-scan evaluations.

The last (third) patient with controversial findings suggestive of false positive (solid) (- table 12) had carcinoma of the breast with total opacification of the left hemithorax. The CT-scan included only the costophrenic angles and abdomen. Thus the source of error is considered to be technical due to inadequate coverage of the pathological thoracic area. The fluid component in this patient was confirmed by thoracentesis.

In the derivation of the second sensitivity for solids (see 5.4.2. sensitivity = 88%), a second category of weighting as described was used. Thus all patients subjected to both thoracentesis and CT-scan were further analysed for evidence of solid tissue as shown by CT-scan.

6.1.4.3.2. The role of decubitus radiograph

In tables 13 and 14 the decubitus radiograph failed to demonstrate fluid in three (3 out of 16) hemithoraces (undiagn.). Two of these patients had total opacification of the hemithoraces, while in the third case there was almost total opacification of the right hemithorax. All the three hemithoraces were subsequently proved to contain fluid, as diagnosed by ultrasound. Fluid was confirmed in these patients through surgical drainage (one case, 1,000 ml. pus yielded immediately) and needle aspiration (2 cases 850 ml. blood stained fluid obtained in one case. Volume of fluid not stated in the third case). Decubitus radiograph demonstrated fluid levels in six hemithoraces. The findings are consistent with a sensitivity of only 67% for fluid (n = 9). Seven hemithoraces were suspected normal but not proved.

6.1.5.1. Significance of the findings considering only data derived from the direct confirmatory procedures

Ultrasound was able to detect fluid in opaque thoraces with an accuracy of 95% (n = 44), while in a limited population (n = 13) ultrasound detected solids with a reduced sensitivity (85%).

The accuracy of 95% for detection of fluids closely compares to that by Goldberg (1973) 92%; Doust et al. (1975) 90% and Gryminski et al. (1976) 93%. Doust et al. (1975) further demonstrated that fluid less than 1 cm. thick was missed by ultrasound due to reverberation artefacts in the thorax-lung interface. In this study this could have been the cause for missing the pleural fibrosis ((=) table 10).

To improve the results, Miller et al. (1984) advocate use of water-path in children rather than contact scanning to alleviate difficulties due to attenuation from bone and air. Lesions involving the chest wall, pleura, lung parenchyma and mediastinum can be studied. In this study there were only three children aged eight (one patient) and twelve (2 patients) years. Optimal results were obtained with contact sector scans in all the children and the other patients using inter-costal spaces and upper abdominal solid organs as windows.

6.1.5.2. Significance of the findings considering all procedures

6.1.5.2.1. Fluids

Considering the findings in the direct confirmatory other radiodiagnostic procedures and fluid diagnosed on clinical suspicion, the sensitivity of ultrasound to fluids was only minimally altered (reduced from 95.4% n = 44 to 95.2% n = 63).

6.1.5.2.2. Solids

With a new category of grouping patients in the order of postmortem, surgery and CT-scan, identification of solids was optimized. The sensitivity of ultrasound to solids was thus improved from 85% n = 13 (postmortem and surgery) to 88% n = 16 (postmortem, surgery and CT-scan).

6.1.6. Fluids due to different aetiologies

In table 7 one patient with a transonic (+) lesion and a short history of pain (hours) was confirmed to have haematoma. In the same table (7) a patient with combination (↑) of sonographic findings and a three month history of penetrating thoracic injury followed by immediate lobectomy was found on further thoracotomy to have a combination of empyema and organizing haematoma. Another patient with complex echo pattern (++) (table 7) and with thick septations (up to 1 cm.) was confirmed at surgery and subsequent microbiological studies to be due to tuberculous empyema.

6.1.6.1. Haematomas

Sandweiss et al. (1975) describing the echo patterns of empyema suggested the possibility of clotted blood, causing internal echoes in empyema. They, however, had not encountered such a case.

Mahal et al. (1975) subsequently reported a case of necrotic debris and partially organized blood which was echo-free.

Wicks et al. (1978) analysing 48 haematomas with ultrasound found a variable magnitude of internal echoes in the first month. Subsequently haematomas became unechoic.
Hirsch et al. (1981) reported a case of unechoic haematoma.

6.1.6.2. Empyemas

Sandweiss et al. (1975) found that empyemas were echo-free.
Hirsch et al. (1981) demonstrated low level echoes in one case of pleural exudate of klebsiella and pseudomonas aetiology.
Phillips and Baron (1981) using high frequency transducer (5 MHz) demonstrated low level echoes in empyema.
Miller et al. (1984) studying thoraces of 82 children encountered 5 cases of empyema due to haemophilus influenza, klebsiella pneumoniae and diplococcus pneumoniae. They reported regions of relative increase and decrease in echogenicity alternating with thick septae. Differentiation between transudates and inflammatory exudates was not possible.

6.1.6.3. Findings of the study in relation to literature

All haematomas in this study (1 proved, 2 suspected, table 15) were transonic supporting the findings reported by Hirsch et al. (1981). The case of thoracic injury with empyema and organizing blood (↑ comb./comb. table 7) supports the suggestion by Sandweiss et al. (1975) and the findings by Phillips and Baron (1981). The source of the echoes in this case is uncertain. These could originate from the organizing blood or empyema.

The case of tuberculous empyema (++ table 7) is similar to the findings by Miller et al. (1984).

6.2. The peridiaphragmatic regions

6.2.1. The diaphragms identification and shape

Identification of the right diaphragm through the liver (subcostally) or directly was easy. However, on the left, the combination of the rib shadows and interference from normal lung and/or bowel gas made identification of the left diaphragm tedious and time consuming. Haber et al. (1975) studying the diaphragms of patients with upper abdominal diseases reported difficulties in identifying the left diaphragm. They suggested fluid ingestion or transplenic approach with the patient in the prone position. In this study most of the patients were too sick to maintain a position other than supine long enough for identification and adequate evaluation of the diaphragm.

Inverted diaphragm due to empyema was identified in one patient on the right side (fig. 19). In the literature, inversion of the right diaphragm was considered unlikely in view of the splinting effect of the liver. However, Subramanyam et al. (1981) reported three cases due to pleural effusion. Lowe et al. (1981) reported seven cases due to variable reasons including pneumothorax, pleural effusion and soft tissue masses. Diaphragmatic inversion has been considered contributive to respiratory distress. This was reported by Adler et al. (1984)

in a neonate with persistent respiratory distress with haemo-pneumothorax and sonographically identified left hemidia-phragmatic inversion.

6.2.2. The diaphragmatic motion

On the right subjective evaluation as well as quantitative measurements of the diaphragmatic motion were made. Subjectively ten patients (18% of total) had reduced diaphragmatic motion. When quantitated motion assessment was made, eleven patients (38% of those measured (29)) were shown to have diaphragmatic motion below 40 mm. The rest eighteen patients (62% of those measured (29)) had normal (40 mm. and above) diaphragmatic motion. But subjectively twenty-five (45% of total) patients had normal diaphragmatic motion. The patients who had quantitative diaphragmatic motion assessment were biased to the less sick ones. Subjective assessment was inaccurate.
Forty mm. magnitude of diaphragmatic motion was considered the lower limit of normal; when the findings of 39.5 mm. by Wade (1954) are taken as base. Studies further performed by Harris et al. (1983) demonstrated regional as well as sex differences in the diaphragmatic motions. Greater motion was demonstrated in the posterior and middle portions. Greater motion was demonstrated in males than in females.
In this study all patients (11 out of 11) who had reduced motion (below 40 mm.) had ipsilateral (8 out of 11) or bilateral (3 out of 11) pathology.

Haber et al. (1975) demonstrated a variety of behaviours ranging from normal in the presence of ascites to localized restriction.

Malignant ascites restricted motion more than other types of ascites, while with subphrenic abscess the motion ranged from normal to total absence.

6.2.3. The importance of diaphragmatic localisation

Doust et al. (1975) reported a case with seven unsuccessful thoracentesis. Subjected to ultrasonographic evaluation, a large pleural effusion and very high left diaphragm were demonstrated. Further attempted thoracentesis in the light of the sonographic findings yielded fluid. Landay and Harless (1977) incorrectly diagnosed subphrenic fluid collection due to misinterpretation in the position of the diaphragm. The importance of recognizing the position of the diaphragm was stressed by these workers. In this study one female patient with hepatic hilar lymphoma and right basal cpacity yielding only minimal fluid on repeated thoracentesis was evaluated with ultrasound. An elevated diaphragm was readily identified with consolidation and minimal pleural fluid at the right base. Ascites was also shown. In a second patient with right basal opacity shortly following liver biopsy (patient was known with abnormal liver function) the diaphragm was readily identified on sonographic evaluation. A transonic area above the diaphragm with alteration of shape on respiration was considered to be iatrogenic haematoma.

The regions below the right diaphragm were normal. On follow-up, the pleural opacities resolved in both patients (In the first, resolution occurred in ten days while in the second (haematoma) resolution occurred in six weeks). In the first patient persistent elevation of the right hemidiaphragm remained.

6.2.4. Evidence of presence of abnormalities on both sides of the diaphragms and the state of the great vessels at the diaphragmatic hiati

6.2.4.1. Diseases above and below the diaphragms

The patients with multiple abnormalities (comb. 11 patients in table 17) were further analysed. These abnormalities consisted of ascites (9 patients), hepatomegally (5 patients), splenomegally (4 patients), renal diseases (4 patients), hepatic metastases (3 patients), biliary disease (1 patient) and others (2 patients). The renal diseases were hydronephrosis (3 patients) and renal tumour (1 patient). One patient had hydronephrosis involving a transplant kidney. The other abnormalities consisted of pancreatic pseudocyst (1 patient) and para-aortic lymphadenopathy (1 patient).

6.2.4.2. The great vessels at the diaphragmatic hiati

Significant vascular findings were observed in both the aorta and inferior vena cava. One patient was shown to have aortic diameter 4.5 cm. at the diaphragmatic crura and higher into the thorax. (The normal aortic diameter at the aortic root was stated by Cornell (1973) to be 3 cm.). When subsequently cur patient returned two weeks later for follow-up, left pleural effusion through which the aneurysm was initially studied was almost completely resorbed. The aneurysm was then studied through the upper abdomen and could not be well followed-up in the thorax due to interference by air in the lung. The striking feature in the cases with dilated inferior cava was the absence of the waves associated with respiration. In one of the patients with dilated inferior vena cava, malignancy (lymphoma) was the major underlying disease but was shown on ultrasonography to have pericardial effusion as well. There was also hepatosplenomegally. Weill and Mourat (1974) studying the behaviour of the inferior vena cava showed that loss of waves was a major feature in patients with right cardiac failure. This sign (loss of waves in I.V.C. related to respiratory phases) was able to differentiate hepatomegally of right cardiac failure from that of other causes.

6.2.4.3. Right renal tumour extending to the right atrium

When evaluating the right hemithorax of a patient with bilateral pleural opacities of unknown aetiology, a nodular echogenic focus was visualized in the right atrium at the termination of the inferior vena cava. Followed, this led into the inferior vena cava and right kidney. Tumour of the right kidney with distortion of the pelvi-calyceal systems particularly at the middle and lower thirds were demonstrated ultrasonically and angiographically. Review of the other abdominal organs demonstrated splenomegally and hepatic metastases. The left kidney was normal.

Goldstein et al. (1978) reported five cases of extension of renal cell carcinoma into the inferior vena cava demonstrated by ultrasound. These patients presented as intra-luminal echogenic nodules and caval dilatation. They advised use of ultrasound in the evaluation of the extension of renal cell carcinoma into the inferior vena cava, retroperitoneal lymph node enlargement and hepatic metastases.

6.3. Pitfalls and advantages of ultrasound

6.3.1. Pitfalls: the abnormalities (table 18)

Cardiomegally and mediastinal shift were abnormalities which were present in ten patients (10 out of 25) (diagnosed on postero-anterior radiographs) considered outside the scope of this study. Bone abnormalities were observed in seven patients (7 out of 25), but could not be evaluated with ultrasound, because of attenuation. Hilar tumours and pulmonary metastases were observed in eight patients (8 out of 25), these were unsuitable for sonographic evaluation due to lack of sonographic windows.

6.3.2. Pitfalls: Examination time

The exact time necessary for each examination was not accurately assessed. However, an estimation is possible. Adequate evaluation of pleuro-pulmonary lesions is time-consuming. Smaller lesions are more time-consuming than large ones due to problems of interference by ribs, and lung during respirations. Seriously sick patients require longer time especially when they must turn from one position to another in order to establish a window for a lesion. Review of abdominal organs in the effort to establish disease extent or aetiology may take unpredictably long time due to necessity of special manoeuvres such as water intake, in order to visualize these organs. In experienced hands the time may range between fifteen and thirty minutes per study.

6.3.3. Advantages of ultrasound

As in ultrasound no ionizing radiation is used, ultrasound can be performed even in all stages in pregnancy. Portable equipment make bed-side examination convenient for the patient and physician/surgeon. Decisions of management can be made when and where examination is performed such as theatre or ward. Advantage special to examination is the multiplicity of organs that may be studied within one examination, such as liver, spleen, pancreas, kidneys etc. Plenty of time is saved through this convenience.

6.4. Conclusions

Ultrasound detected peripheral pleuro-pulmonary abnormalities and differentiated them into fluids and solids with a high sensitivity for fluids (95% n = 63) and less sensitivity for solids (88% n = 16).

The sensitivity of decubitus radiograph to fluid ((67% n = 9) in a limited sample) was lower than that of ultrasound to fluids (95%).

Data on ultrasonic characteristics of haematomas and empyemas is limited but tends to suggest transonic recent haematomas (3 patients with haematomas of one week and less duration) and low level echoes in empyemas (two cases). Fluids due to other aetiological factors indistinguishable.

Identification and assessment of the shape and motion of the diaphragms was easier on the right than on the left sides. Even through the transplenic approach the combination of ribs and normal lung attenuation made it difficult to assess the left diaphragm optimally.

Further, ultrasound demonstrated diaphragmatic as well as disease on both sides of the diaphragm in 48% of all cases.

The above findings support the hypothesis that ultrasound can detect peripheral pleuro-pulmonary abnormalities and differentiate them into fluids and solids with a high sensitivity for fluids (95%) but probably decreased sensitivity for solids (88% small sample). As ultrasonographic examination is time-consuming, this could be a limiting factor in the replacement of decubitus radiographs by ultrasound in the presence of heavy workload. Central location and/or skeletal lesions are unsuitable for sonographic evaluation due to lack of window and/or attenuation and this may be a limiting factor in the replacement of the other more invasive radiodiagnostic procedures such as CT-scan and bronchography by ultrasound.

6.5. Recommendations

- Provided that the workload allows and with increasing experience, real-time (3.5 MHz transducer was satisfactory) ultrasonographic evaluation of peripheral pleuro-pulmonary opacities can be the first radiological investigative procedure complimentary to the conventional thoracic radiographs (P.A. and lateral).
- Evaluation of pleuro-pulmonary opacities should be accompanied by screening the upper abdominal viscera. Unsuspected abdominal findings may give an indication to the aetiology of the thoracic abnormalities.
- In the face of heavy workload ultrasonic evaluation of pleuro-pulmonary opacities is limited to those cases in which thoracentesis or decubitus radiographic examination has proved negative. In such cases, ultrasonically guided thoracentesis may be planned or the skin may be marked to indicate the best place to make thoracentesis. The depth of the lesion from the skin surface can also be measured. When thoracentesis has to be performed somewhat later in the ward, the patient has to assume the exact position for both procedures (e.g. sitting erect at ultrasound and at centesis).

- Pleuro-pulmonary opacities in known cases with extrathoracic malignant disease should be evaluated with ultrasound. Metastases in the abdominal viscera (liver in particular) may be demonstrated. Ultrasound should be used in the evaluation of pleuro-pulmonary opacities where ionizing radiation should be avoided as in pregnancy.