A-Mode

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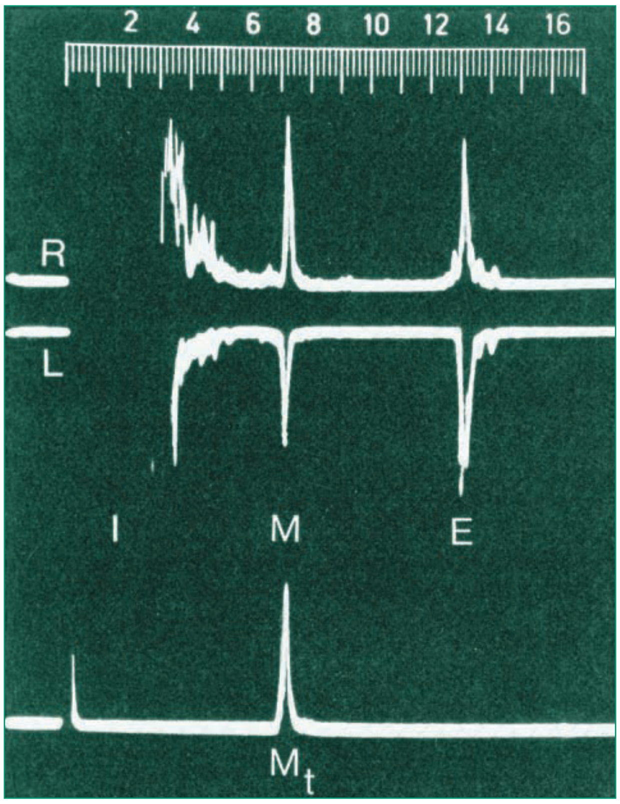


Echoencephalogram (normal finding)

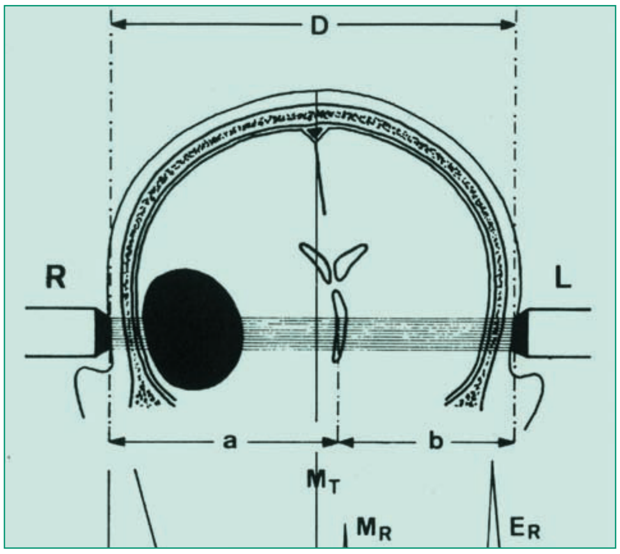
A-mode was the first ultrasound method, used for medical diagnosis. The piezoelectric transducer emits very short ultrasound pulses (1 ms), periodically (PRF 0.3 – 10.0 kHz), which travel through the object.

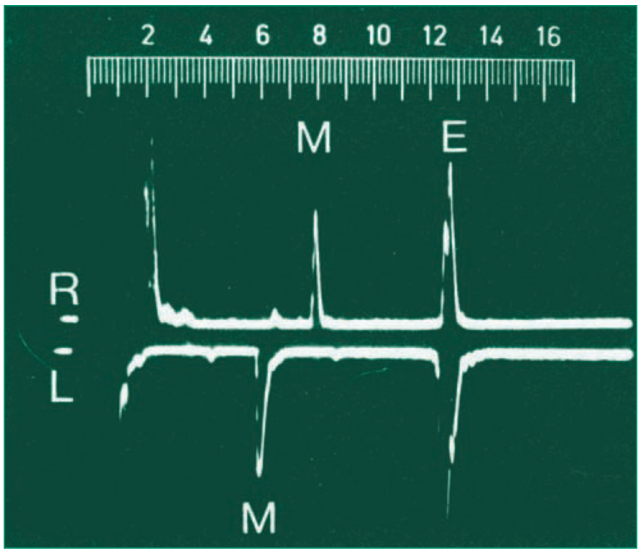
Each pulse results in a horizontal deflection of the electronic beam of a cathode ray tube on a fluorescent screen indicating the time which the pulse needs to travel through the object. The echoes are displayed as vertical deflections of the electronic beam on the screen. The position of an echo indicates the distance of its source (echo-ranging), the amplitude its intensity.

Echo-ranging devices were first developed as sonars for navigation **1912**. The same principle was used for non-destructive material testing since **1929**.

Ludwig and **Struthers** adopted such a device for medical diagnostics, **1949**. For many years the one-dimensional A-mode was especially used in ophthalmology and neurology.

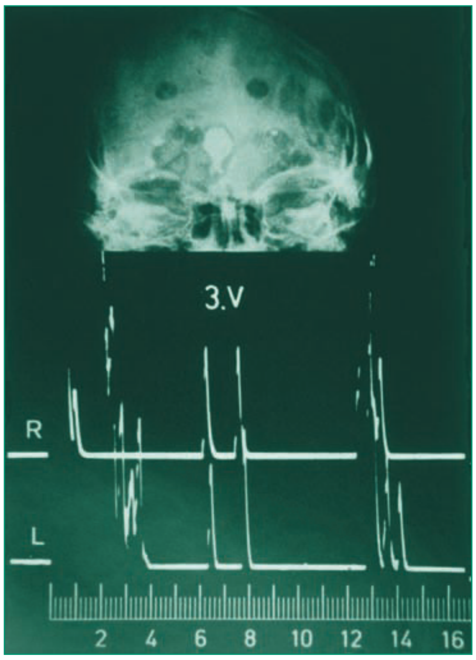
But for an examination of more complex structures (e. g. the abdomen), the development of two-dimensional imaging was necessary.



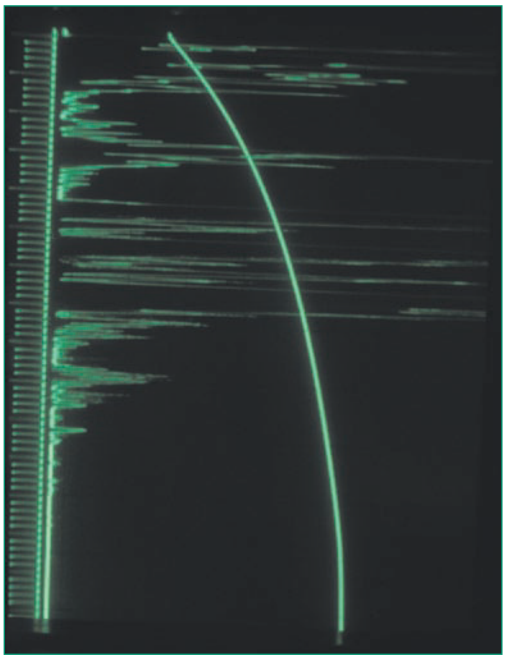


The tumor on the right shifts the midline line echo (M) to the opposite side

From A-Mode to B-Scan



A-mode Measurement of the 3th ventricle



A-mode of the liver

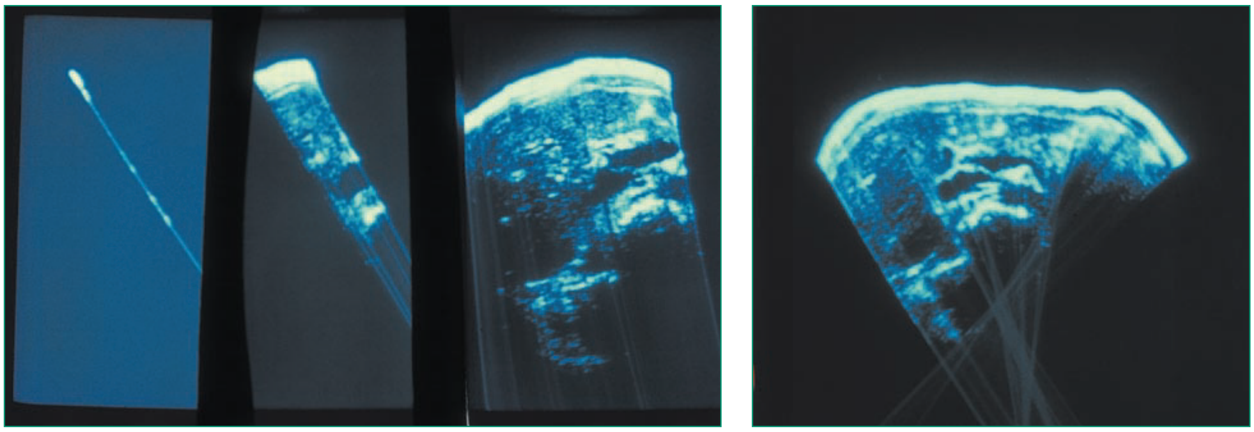
The one-dimensional A-mode, **1949** introduced by **Ludwig** to detect gall stones and adopted **1954** by **Leksell** as “echoencephalography”, never seemed suitable for the diagnosis of complex regions, like the abdomen. Instead, an imaging modality was necessary for topographic orientation. Two steps lead to the development of two-dimensional ultrasound imaging:

1. The echoes were displayed as dots with modulated brightness on the nearly invisible time-base-line (*Bright*ness-*mode*).

2. Multiple scan lines were arranged to form a two-dimensional plane.

The transducer was moved manually in the beginning (compound scan). Because of the low sensitivity of the probes, the region of interest was scanned several times in various directions to get echoes also from weak reflectors (**Howry 1952**).

Position encoders in the scanning arm were used for the exact geometric localization of the echoes within the image. The echoes were displayed on a storage oscilloscope. Thus the composition of a single ultrasound image needed several seconds at least; moving of the areas scanned lead to distortions.



Construction of the two-dimensional ultrasound image with a hand hold probe on a storage screen .
Note the different scanning lines (right- compound scanner)

From Bistable Images to Gray Scale

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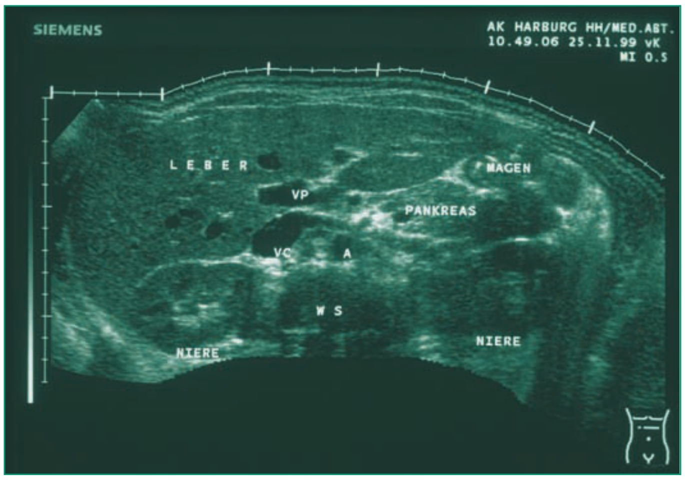
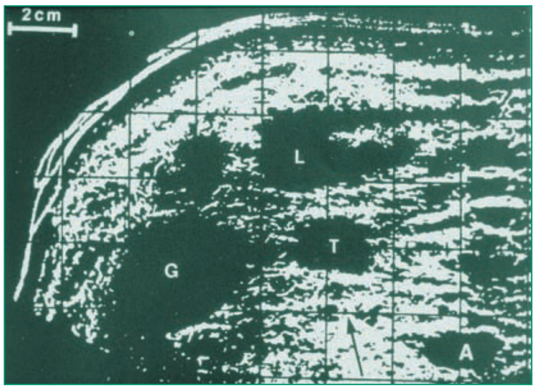
The first ultrasound images were “black and white“: the echoes above a (adjustable) threshold were displayed as uniformly bright dots on a dark background (bistable). Weak echoes below the threshold were lost.
Informations by complimentary A-mode were necessary, e. g. to distinguish between solid and cystic lesions.
The introduction of the gray scale technique was an important step forward:
Now the echoes were displayed as dots varying in brightness according to the intensity of the reflected echoes. Modulated brightness was an integral part of the real time scanners from the beginning. In compound scanners, using scan converters, gray scale imaging was intruduced about 1973.

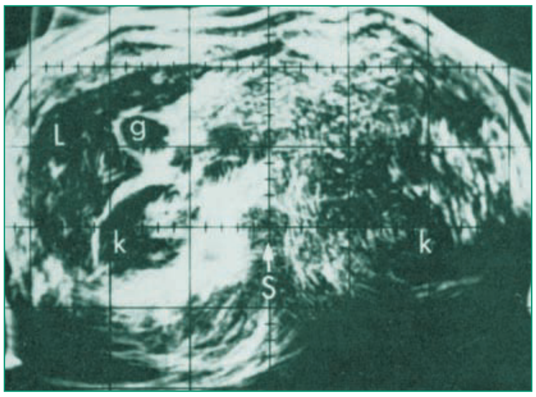


Transverse scan of the abdomen (1999)

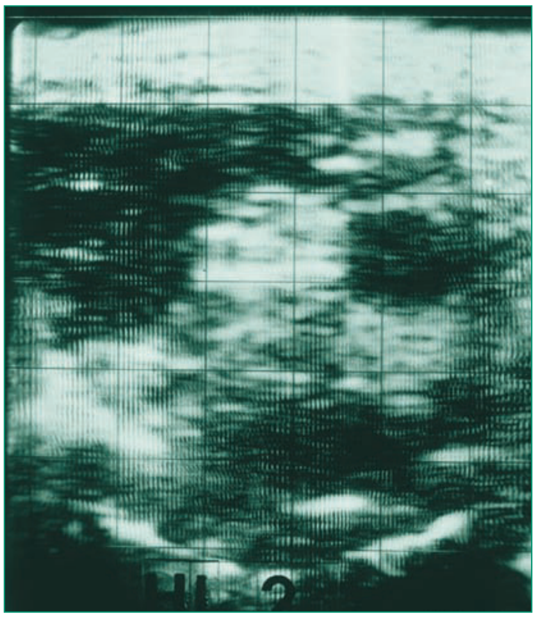
3 D image of a fetus (1999)



Pancreatic tumor (T)
Compound scan
bistable image
(~ 1970)



Transverse scan
of the abdomen
Compound scanner,
gray scale (1975)



Pancreatic tumor
Real time-gray scale
(Vidoson 1973)

Further technical improvements, as electronic focusing of the ultrasound beam, suppression of artifacts, digitalization, harmonic imaging and the ever increasing speed of data processing redulted in a remarkable improvement of the image quality.
The integration of the Doppler-technique into the B-mode image leads to duplex- and triplex techniques. The 3D- and 4 D-depictions and the development of contrast agents characterize the standards of the beginning of this century.

From Compound Scanning to Real Time

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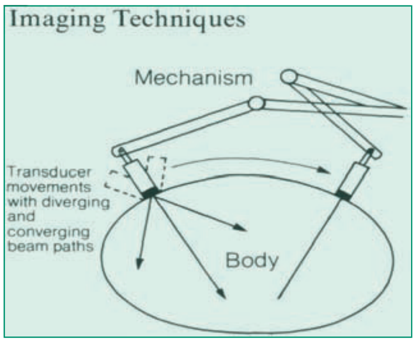
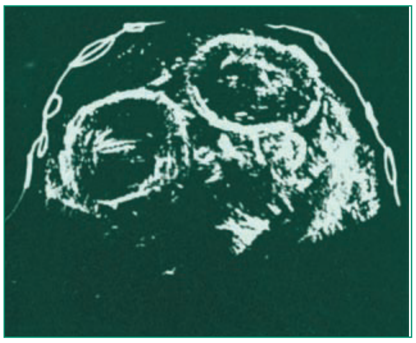
Originally, the *compound scanners* had disadvantages: A rather complex technique for the correct arrangement of the echoes was needed and – not least – no real time-viewing was possible, as the composition of the images was slow and movements of the patient or the organs scanned produced severe artifacts. Furthermore the images gained by manually operated compound scanners were hard to reproduce. These disadvantages were partially overcome by the development of automatic scanners. These mechanical or electronic devices worked faster and the results were better reproducible.

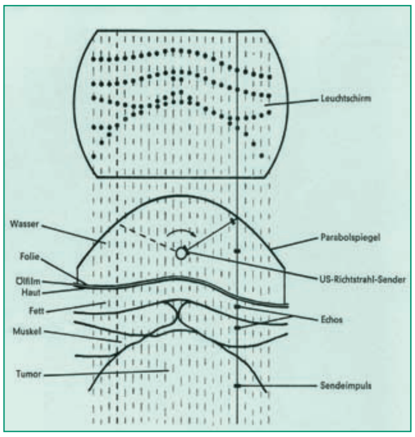
The first commercially available *real time-scanner* was the *Vidoson* (Siemens). The pulses of two or three rotating transducers within a water path were reflected by a parabolic mirror, leading to 15 cm of parallel shifting of the ultrasound beam.



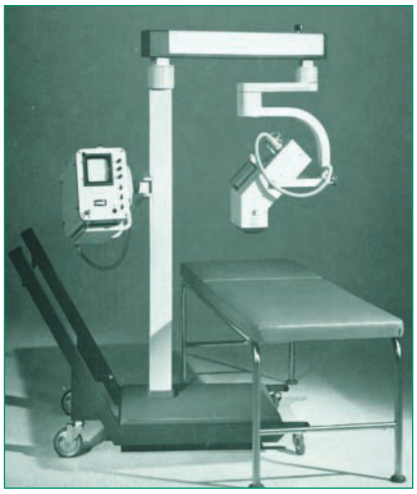
Principle of compound scanners

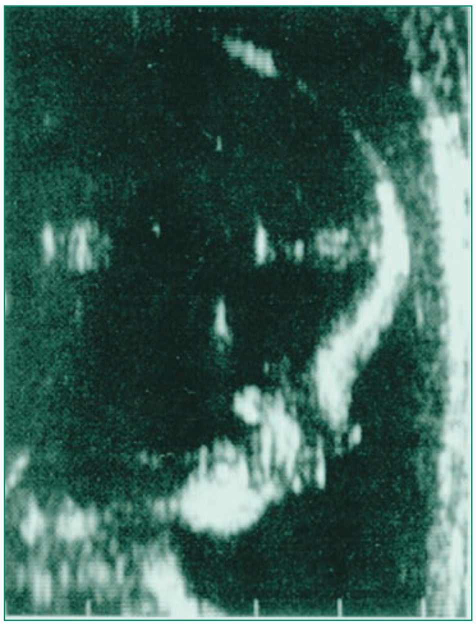


Twins (bistable compound scan)



Vidoson technique





Compound scan, gray scale (1976)

Real time (Combison 100, Kretz), 1980

The real time technique made its way, finally, because of its automatic, reproducible and fast image construction. Dynamic examinations enabled quick examinations and direct observation of movements.
The further technical development lead to mechanical and electronic scanners with parallel or sector scanning, which are still in use today.