Two-dimensional echoencephalography with electronic sector scanning

Clinical experiences with a new method

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SUMMARY A new form of ultrasound diagnostic possibility is presented (the electroscan). The basic principles of this two dimensional method are described. Special attention is given to the probe consisting of an array of 21 elements of piezo-electric material. The results of this method in four patients are discussed (meningioma, arteriovenous aneurysm, subdural haematoma, and a baby with hydrocephalus). The baby with hydrocephalus showed diagnostic problems which could be understood from the pneumoencephalographic findings. The electroscan method seems to offer good possibilities for the diagnosis of brain lesions, if these have a consistency different from that of normal brain tissue.

Conventional echoencephalography is based on the pulse-echo method, in which a transducer transmits short ultrasound pulses, the echoes of which are received back during the intervals. These echoes are visualized as vertical excursions on an oscilloscope-screen, while the position on the screen is a measure for the distance at which the reflecting structure is situated. The direction of the emitted ultrasound pulses is always perpendicular to the surface of the probe and thus it can be changed only by moving the probe. The essential advantage of this so-called A-scan method is that the repetition-frequency of the pulses can be so high as to allow one to visualize the echo-pattern on the screen as a practically instantaneous and continuous picture. Slight variations in the position of the transducer cause variations in the echo-pattern, so that a search can be made for the optimally interpretable echo-pattern, because the oscilloscope-screen can be observed continuously for the best picture.

The essential disadvantage is that only one unidirectional exploration in depth can be made and that simultaneous multidirectional explorations are impossible. Because of this, a random echo sometimes may be distinguished with

difficulty from an echo answering from a real layer, as would be possible in a two-dimensional scanning system.

ELECTRONIC SCANNING PRINCIPLE (Somer, 1968)

Two-dimensional scanning for obtaining cross-sectional pictures can be performed both mechanically and electronically. The mechanical B-scan and compound scan do not provide the possibility of instantaneous and continuous pictures and are not suited for searching for the optimal echo-pattern. An electronic scanning system may overcome these defects, whereas it has all the advantages of the cross-sectional display.

The Research Group of Ultrasound-diagnostics of the Institute of Medical Physics T.N.O. in Utrecht has developed such an electronic scanning system, the so-called 'electroscan'. Both a mechanical compound scan and this electroscan-machine are in use now at the EEG department of the University Hospital in Utrecht. In this communication only the electronic scanning method is discussed.

Publications in the field of radar and sonar induced us several years ago to develop an

FIG. 1a. Construction of the multiple 'array' with 21 separate elements.

FIG. 1b. Principle of beam formation the direction of which can be varied electronically.

electronic sector scan system for diagnostic purposes and this resulted in the construction of a prototype which is now used experimentally by us. This system is equipped with a probe of special construction, an 'array' consisting of a series of 21 small elements, which can be excited individually. Figure 1a shows this array with elements of piezo-electric material, spaced half a wavelength apart. Each of these elements can convert a short electrical pulse into a short mechanical oscillation and thus produce an ultrasound impulse with an almost circular wave-front.

Figure 1b shows that each element is connected to an electrical source for exciting the element. This source is connected to a starting pulse generator by means of a delay circuit. This delay circuit causes the corresponding element to be excited at a required time after the starting pulse.

The delay circuits are adjusted in such a way that the first element is excited first, the second afterwards, and the following elements at subsequent equal time intervals, and reversed. At the moment that the last element is excited the wave front of the first has travelled over a certain distance, the wave front of the second element over a shorter distance, etc. According to Huygens's principle, all wave fronts together build up a resultant flat wave front with a certain angle to the probe. The angle of this resultant wave front depends on the time intervals between the subsequent excitations. The direction of the beam is perpendicular to the wave front and therefore also depends on the time delays between the subsequent excitations. Since the delays are obtained electronically, they can be varied very rapidly and thus the direction of the beam can be changed quickly. By varying the delays systematically, a sector can be scanned repetitively. In this way a sector of 90° can be scanned in about 30 different directions (at 3° steps) whereby a repetition rate of 30 scans/sec is achieved easily. When receiving the echoes, variable delays are again applied in order that the directions of reception and transmission are always the same. On the screen echoes are visualized as variations of brightness of the spot.

Because of the scanning rate of 30 scans/sec the advantage of the A-scan is retained and an instantaneous and continuous picture appears

while the probe is stationary, and again a search can be made for an optimal representation. The disadvantage of the unidirectional exploration, however, has now been overcome and larger parts of structures can be depicted.

CLINICAL INVESTIGATION

The well known unidirectional A-scan echoencephalography has proved in the last decade to be of great value in clinical neurological investigation. The method provides information which is almost exclusively limited to midline echo structures. Occasionally some information is obtained concerning the width of a ventricle but in most cases certainty on this is obtained only by means of pneumoencephalography.

The two-dimensional electronic sector scan echoencephalography (electroscan) makes it possible to obtain clear information concerning spatial relations inside the skull. The pictures obtained by the electroscan are usually complex and not easily interpreted. The midline structures are easily recognized and their location may be measured accurately, but for this determination conventional A-scan echoencephalography is more convenient. The electroscan has proved to be useful in particular for the study of abnormal structures in a cerebral hemisphere. The evaluation of the results is carried out afterwards on the basis of measurements on photographs made from the TV screen. Usually 24 to 30 photographs are taken in each case. These pictures are obtained from probe situations on homologous places on the right and left sides of the skull. The probe is placed either in a horizontal or a vertical direction.

Some results, obtained in a small series of patients in whom the echo pictures could be verified anatomically, will be described.

CASE 1

A woman, aged 55 years, had since her youth complained of headaches, localized particularly in the posterior part of the head. Lately, vision had deteriorated. The woman was obese (103 kg), loquacious, and somewhat confused. The blood pressure was 220/110 mm Hg. The ocular fundi showed hypertensive change, and, on the right side, papilloedema was noted.

The left pupil was slightly wider than the right. There was slight bilateral exophthalmos and a slight

FIG. 2. Case 1. Picture of a horizontal electroscan probe left temporal. In the right hemisphere (arrow) there is a massive shadow which was interpreted as pathological. At operation a large meningioma was encountered in this area and subsequently removed.

ptosis on the left side. No other neurological abnormalities were encountered. Elsewhere the diagnosis of pituitary tumour had been considered.

The electroencephalogram (EEG) was markedly abnormal and asymmetrical, with hypofunctional abnormalities dominating in the right frontal areas spreading over the entire hemisphere and to the left frontal area.

Conventional echoencephalography showed a displacement of midline structures to the left side, amounting to 5% in the temporocentral areas.

The electroscan investigation was carried out by an investigator who was kept ignorant of information described above. When the probe was placed on the left temporal and left central areas a massive 'shadow' was observed in the right frontotemporal area, relatively close to the skull base and side (Fig. 2). It was concluded that these reflections originated from a space occupying process. The conventional echo method had not shown echoes in the right frontotemporal area. Subsequent neurological examination (angiography, scintigraphy, Fig. 3)

revealed this mass to be a large meningioma in the right fronto-basal area. The meningioma was removed.

CASE 2

In a man aged 34 years cerebral angiography had revealed an unusually large arteriovenous aneurysm. The location of this aneurysm was not known to the electroscan investigator at the time of the examination. When the probe was placed on the right frontal area in this patient, unequivocal echo complexes were noted in the left frontal area. When the probe was placed on the right central area conspicuous shadows were also seen in the left frontocentral areas. When the probe was moved gradually to posterior parts of the skull echo complexes were visible in the left hemisphere to approximately 3 cm behind a vertical line through the trachus (Fig. 4). Moreover, in the frontocentral area the midline structures were displaced 7 to 8 mm to the right side. These pictures were obtained with the probe in a

FIG. 3. Case 1. Scintigraph.

FIG. 4. Case 2. The probe is placed horizontally in the right temporal area. (R) The streak-shaped echoes are reflections in the left hemisphere from midfrontal to approximately centrotemporal. The angiogram in this patient showed a very large arteriovenous aneurysm with voluminous varices in the area where these reflections occurred.

horizontal position. In this patient conventional echoencephalography had not shown displacement of midline structures, though it had been noted that at probe location on the right temporal area multiple echoes were obtained which made the determination of midline structures impossible.

The EEG in this patient showed slightly diffuse, non-specific abnormalities. No consistent asymmetry was noted. The left-sided carotid-angiogram (with proximal compression) showed a large angioma with voluminous branches distal to M3, in lateral direction (Fig. 5).

CASE 3

The third case concerns a patient aged 66 years who had been relieved a left frontotemporocentral subdural haematoma. Immediately after the operation his condition was satisfactory, deteriorating few days later, however. The patient became somnolent and depressed and at times was confused. A recurrent haematoma was suspected. The electroscan, with the probe in horizontal position on the right temporal area, showed a band of echoes (Fig. 6) over a large area at the left side approximately $2\frac{1}{2}$ cm from the inside of the skull. These echoes might

FIG. 5. Case 2. Angiography, subtraction technique showing the voluminous varix.

FIG. 6. Case 3. The probe is placed over the right temporal area (R). At the left side (arrow) reflections occurred ascribed to a subdural affection.

(a)

(b)

FIG. 7. Case 4. (a) A complex echo picture of the right hemisphere with the probe over the left central area (L) is shown. Under the wall of the skull clear reflections are seen banding concentrically inwards and thus appearing to form a cavity (black part in the middle of the picture). (b) The pneumoencephalogram of the right hemisphere is shown. In this picture a markedly dilated ventricle is obvious. The ventricle has a large volume in the frontal areas and narrows into a funnel shape posteriorly. Moreover, a clear displacement of midline structures is visible. After the pneumoencephalogram had been studied the electroscan findings became understandable.

possibly be caused by a haematoma. No differentiation could be made from other causes such as insufficient postoperative unfolding of the cortex. In the subsequent period the patient recovered slowly and repeated electroscan investigations demonstrated a gradual decrease of the distance between the skull and the echoes. Because of this gradual improvement no repeat-angiography was carried out.

CASE 4

The fourth case was a boy aged 8 months, who had sustained a slight head injury two days after birth. A few days later the baby showed myoclonic jerks in arms and legs. A fortnight after this incident the child was admitted to the ward of child neurology. No obvious abnormalities were found on neurological investigation except for an attack of shallow respiration combined with pronounced cyanosis. Three weeks later the skull had increased markedly in size. Radiographs of the skull showed widening of sutures. In the EEG, irritative discharges were observed in the frontal areas, independently on the right and left side. A repeat EEG, recorded a few weeks later, showed an area of relative silence in the right frontal area, and again irritative discharges over both hemispheres, more so on the right side. By puncture through the enlarged fontanelle 60 ml. of intracerebral pus was removed from the right side.

The pictures obtained by means of the electroscan were extremely complex. Particularly in the parietal area displacement of midline echo complexes to the left side was noted. On the right side, from frontal to

posterotemporal and parietal, clear reflections were seen which in the parietal areas spread to the midline. On the basis of these pictures (Fig. 7a) a subdural haematoma or hygroma on the right side was considered possible. Subsequent pneumoencephalography showed a markedly dilated right ventricle (Fig. 7b) with irregular borders. The misinterpretation of the electroscan may be understood from this pneumoencephalography.

COMMENT

At present we have investigated over 50 patients. In most of them the clinical diagnosis was difficult and therefore electroscan was asked for. A complete evaluation of the observations from this material is not possible at present, because a definitive diagnosis in most cases is not yet known. It is obvious that the electronic sector scan echoencephalography is useful as a supplementary diagnostic method. As with conventional (A-scan) echoencephalography the method is entirely harmless to the patient and can be repeated without limit, even in seriously ill and in comatose patients.

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REFERENCE

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