TECHNICAL PROGRESS IN NEUROLOGICAL DIAGNOSTICS

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A SURVEY BASED ON PRESENTATIONS AND DISCUSSIONS AT THE SEVENTEENTH CONGRESS OF SCANDINAVIAN NEUROLOGISTS IN GÖTEBORG, AUGUST 1964, HELD UNDER THE AUSPICES OF THE *SCANDINAVIAN NEUROLOGICAL SOCIETY* AND THE *SWEDISH NEUROLOGICAL SOCIETY*

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PREFACE

Among the basic problems in today's health care two developing trends, in particular, are making themselves prominent. The one is the increasing importance of medical techniques, both diagnostic and therapeutic, and the other a progressive re-evaluation of the community's responsibility in regard to the ill and incapacitated persons psychic, economic and social needs. These two trends were therefore chosen as main themes at the 17th congress of Scandinavian neurologists in Göteborg 1964. Of the different contributions these concerning new diagnostic techniques in clinical neurology were considered worth collecting under separate cover for a wider circle of readers.

As we all know, in years past, a neurologist could get along with very simple equipment: cotton, a needle, a reflex hammer, and an ophthalmic mirror. But it also required much knowledge and experience as well as a trained analytical mind. Let us emphasize that all of this is equally important today. The new technical resources cannot replace the old — only complement them. But they help us to attain more gradations in point of view and safer and more definite conclusions. Simultaneously it is valid to take a stand on which of the new investigative methods should be developed *within* the neurological clinics and which are better suited for elaboration by independent laboratories. The latter principle has been utilized in Scandinavia in regard to neurophysiology and neuroradiology, and I believe that soon we will find that the same will be true of neurochemistry.

In the meantime we must fully understand that there is a continuously expanding number of diagnostic methods which the neurologists must have under control, either independently or in collaboration with technically erudite colleagues. In any case it rests with the neurologists to take the initiative and not remain ignorant of the various opportunities offered by medical technology. Otherwise we sell our birthright for a mess of pottage and must expect that our development will suffocate. For these reasons I believe there is good motivation that a neurologic clinic — at least in a university hospital — must have its own laboratory space and see to it that positions are set aside for technical neurologists.

In this connection I particularly want to emphasize the importance of a laboratory for screening tests where one can consider such technical methods which may lead the way toward diagnosis in patients with obscure disease conditions of the central nervous system and can be performed rapidly with comparative safety for the patient.

In the congress program pains were taken to include new investigative methods which should be initiated by neurologists themselves. This does not mean that we would disparage our most important technical collaborators, the neuroradiologists and neurophysiologists. On the contrary, these colleagues hold an unchanged key-position in the technical diagnostic services for the neurologists. But nowadays they stand independently and have their own conferences. In principle, perhaps the same may be said for the neuropathologists. A number of reports from these related technical fields, predominantly from the neurophysiologists, have we nevertheless been fortunate to include.

Göteborg, July 1965

TORE BROMAN
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ECHOENCEPHALOGRAPHY

A General Survey

Brita Lithander

Echoencephalography is a method of examining the brain by means of ultrasonic waves.

Apparatus and examination procedure

The apparatus is the same as that used in industry for testing materials. The method is the one described by Leksell. Fig. 1. The apparatus comprises a probe, an amplifier and an oscillograph. The probe consists of a piezo-electric crystal which transmits ultrasonic waves and receives them when they are reflected back as echoes. These echoes are recorded on the oscillograph as a deflection vertical to the cathode ray. Each recording is photographed with a polaroid Land-camera and developed immediately.

The examination is most easily carried out with the patient lying down. The examiner sits behind the patient's head. A suitable contact medium, e.g. liquid paraffin, is applied to the patient's temporal regions. The examiner presses the probe to the right and left temporal regions alternately. The direction of the ultrasonic waves is adjusted by small movements of the probe until distinct echoes are recorded on the screen of the oscillograph. In adults with intact skulls it is usually only possible to record echoes from the temporal regions.

RECORDINGS

Fig. 2 shows an echoencephalogram. The recordings from right and left sides are exposed on the same film. With the help of a change-over switch, the echo-encephalograms from the right and left temporal regions can be aimed in opposite directions so that the recordings from the two sides can be easily compared and distinguished from one another.

To the extreme left of the echoencephalogram we see a high, wide complex of spikes, which represents the initial pulse and the echoes from the borderline area between probe and skin and also between bone, meninges and brain. The different components cannot be distinguished in the initial complex (I). A considerably weaker echo is recorded at the extreme right of the echoencephalogram (B), originating in the borderline between brain, meninges and the inner surface of the skull. In normal cases a relatively distinct echo, the so-called midline echo (M), is generally recorded between I and B. This

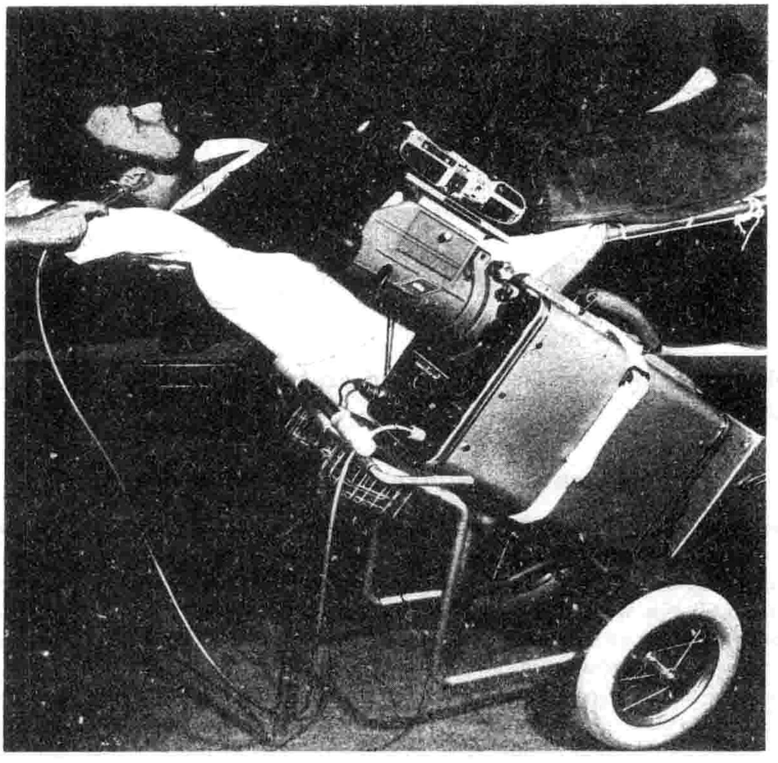

Fig. 1. Echoencephalography.

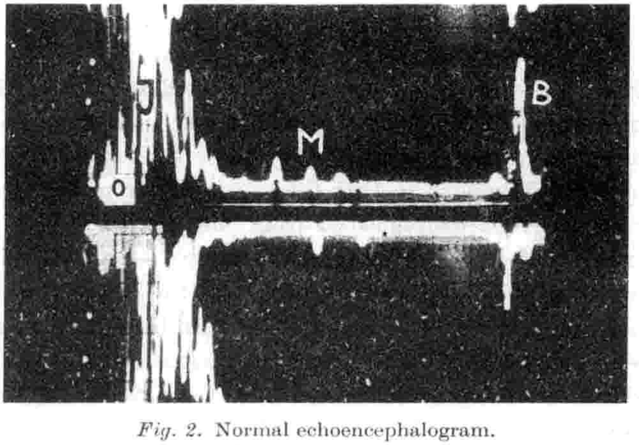

Fig. 2. Normal echoencephalogram.
I = initial complex
M = midline echo
B = bottom echo

echo may be single, double or a complex of three to four spikes. The midline echo occurs on reflection on structures in the midsagittal plane of the skull. There is disagreement in Sweden concerning the significance of the pineal body. Leksell and Jeppsson consider that the pineal body gives rise to the midline echo, while other researchers in the field, including myself, are of the opinion that the third ventricle is mainly responsible for the midline echo. According to my investigations, which were confirmed by Ford and Ambrose, several structures in the midline, including the septum pellucidum and the longitudinal fissure, produce the midline echo. The structure responsible for the midline echo depends on the shape of the skull and the location of the probe in the individual case. Echoes arising from the lateral ventricular walls grouped on both sides of the midline echo may also be recorded.

If the midline structures are displaced by expansive or atrophic processes, the midline echo will also be displaced in the echo-encephalogram. The magnitude of this displacement is measured and is used for diagnostic purposes (Fig. 3). However, echoes other than the midline echo may dominate and be misinterpreted as midline echoes. To avoid these errors one can make several recordings in slightly different areas but at the same level of the temporal region. The midline echo is the most constant echo. A special check using two probes simultaneously should also be exercised. This will give a control deflection (c) with which the midline echo can be correlated.

Infants have thin skulls, and in them echoes can be recorded from the sinciput also (Fig. 4). Figure 4. shows a series of recordings in an infant with hydrocephalus with the probe applied to the skull approximately 2 cm lateral to the midline and the beam aimed at the base of the skull. The recordings were made at a distance of 1.5—2 cm from each other in an anteroposterior direction. The areas with no echoes correspond to the cerebrospinal fluid.

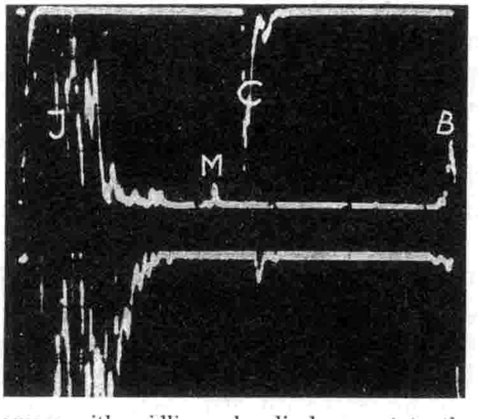

Fig. 3. Echoencephalogram with midline echo displacement to the left. On the top of the figure control deflection (C).

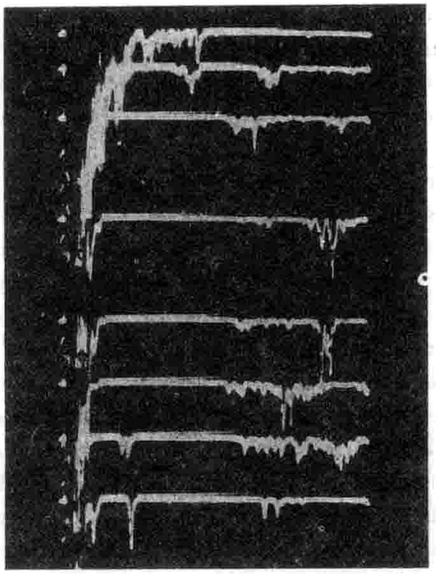

Fig. 4. Echoencephalograms from a child with severe hydrocephalus recorded with the probe on the vertex at different points in the anteroposterior direction. The size and shape of the lateral ventricles are indicated by the echo-poor zones on the echoencephalogram.

DISCUSSION AND CONCLUSIONS

Displacements of the midline brain structures can be diagnosed with echoencephalography. Expansive or atrophic processes in the lateral part of the cerebrum may cause displacements of the midline echo. On the other hand, a displacement of the midline echo in cerebellar processes is extremely rare. Obviously a displacement of the midline structures and the midline echo is also unusual in cases with frontal or parasagittal expansive processes.

The information yielded by echoencephalography thus corresponds with that obtained by observing a calcified pineal body in an ordinary film of the skull. One of the advantages of echoencephalography compared with skull roentgenography is that a midline echo can be recorded in practically all cases regardless of whether the pineal body is calcified.

Echoencephalography does not permit exact localization of the expansive process, although it may indicate the side on which it is situated. This is of value particularly in unconscious patients with skull injuries. The midline echo can be recorded over a larger area in some cases in which the temporal regions are relatively flat. One sometimes finds in these cases that the displacement of the midline echo varies in magnitude if the recording is made at different sites but at the same level. This finding may indicate whether the displacement is greater frontally or dorsally.

The method has proved to be particularly valuable in the diagnosis of subdural hematoma. In a material consisting of 373 adults with neurological sdieases, I found 40 patients with subdural hematoma. Of these, 31 had displacements of the midline echo. No displacement could be revealed in nine cases, in some of them due to the presence of bilateral hematomas.

At first glance these figures might suggest that overly many subdural hematomas were overlooked with echoencephalography. It should be emphasized, however, that a number of subdural hematomas were diagnosed purely as a result of echoencephalography, or at least were found earlier than otherwise would have happened. These cases had such insignificant symptoms that angiography would not have been considered called for had echoencephalography not revealed a displacement in the midline structures.

If a displacement of the midline echo is observed, it is practically certain that the midline structures are displaced by some cerebral condition. A normal echoencephalogram, on the other hand, does not exclude the possibility of an expansive process, since expansive processes do not necessarily displace the midline structures.

Since the examination does not inconvenience the patient, echoencephalography can be used to follow the postoperative development of processes such as edema or hematoma.

In adults echoencephalography will sometimes reveal whether the lateral ventricles and the third ventricles are greatly enlarged. In infants it is generally possible to form a clear opinion of the size and shape of the lateral ventricles and of the thickness of the cerebral parenchyma.

The method is simple and is very easy on the patient. The correlation between echoencephalography and neuroradiologic examinations is good. The risk of overlooking a displacement with echoencephalography is small; it is greatest in patients with a frontal or cerebellar expansive process.

The risk of over-diagnosis, i.e. finding a displacement that cannot be verified by roentgen, is negligible on the condition that the abovementioned controls are used.

It is the opinion in industry that the method can be mastered in approximately three months. This is about the time it takes a physician to become thoroughly familiar with the method and to be able to judge whether a displacement is true or false.

SUMMARY

Description of the method of echoencephalography. Useful as a screening method for the diagnosis of displacements of the midline structures of the brain e.g. in tumors and subdural haematomas. Can also be used to measure hydrocephalus and the thickness of the brain substance in children.

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OPEN DISCUSSION

BRITA LITHANDER: In my doctoral thesis I pointed out that one can evaluate the size and shape of the lateral ventricles and the thickness of the cerebral parenchyma in infants by making recordings in the vertical plane on the sinciput. A series of recordings are made 1.5 to 2 cm apart in the anteroposterior direction, 2 cm from the midline. In this way the lateral ventricles can be accurately charted. Echo-encephalography can be used to check the size of the ventricles in children with ventro-aricular shunt in which pneumo-encephalography cannot be used. This figure shows an echo-encephalogram in a child with hydrocephalus immediately before a shunt operation. The maximum depth of the ventricle in the vertical plane was 7 cm. The next figure shows an echo-encephalogram in the same child a few days after the shunt operation. The maximum depth of the ventricle was then 3 cm. Three weeks later (third fig.) the depth was 2.5 cm. It is hard to say whether the cerebral parenchyma had increased in thickness in this case, since the brain may not have been in contact with the roof of the skull following the operation. When the brain is reduced in volume after a shunt operation a space may develop between the skull and brain. This cannot be observed on the echo-encephalogram, since the initial pulse conceals the first echoes in the echo-encephalogram. What is very noticeable and interesting is the speed with which the basal structures of the brain rise when there is more space in the skull.

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THE USE OF THE M-ECHO IN CLINICAL ECHOENCEPHALOGRAPHY

Stig Jeppsson

Echoencephalography has proved a useful supplementary method in neurological diagnostic practice. Originally, the diagnostic principle was, and still is based on the M-echo shift caused by deviation of the midline structures of the brain (*Leksell* 1955). According to clinical and experimental investigations the pineal body constitutes the principal M-echo source in adults (*Leksell* 1958, *Jeppsson* 1960). In children, the walls of the third ventricle, the septum pellucidum and the inferior portion of the longitudinal cerebral fissure are the structures responsible for the M-echo. In adults with a reasonably thin skull bone the latter structures are also important M-echo sources (*Jeppsson* 1961, *Lithander* 1961).

M-echo shift

Clinical as well as experimental investigations confirm what we can expect from the laws governing ultrasound physics, *viz.* that we are dealing with an integration of several factors, the most important ones being: 1) the difference in specific acoustic impedance between the two media at whose interface reflection occurs; 2) the attenuation of the ultrasound beam when it passes through the head, above all through the skull bone; 3) the geometrical relationships governing reflection — even at a very small angle away from the perpendicular the amount of ultrasound energy reflected falls off very sharply (this applies, of course, only to transceiver units, which have been used in all the above investigations); 4) the properties of the apparatus used, above all its sensitivity. Fig. 1 illustrates the interplay between these main factors.

Experience now allows us to narrow down and define the proper fields of application of echoencephalography. By virtue of its simplicity and rapidity it qualifies as a very useful diagnostic aid in neurotraumatology, where the time factor is often of prime importance. It supplements the neurological routine examinations for tumours of "silent regions", making an early diagnosis possible. Its simplicity and infinite repeatability also make it a most convenient method for neurological check-up both in acute phases — post-operative hæmatoma and brain swelling — and chronic ones — recurrencies, chronic

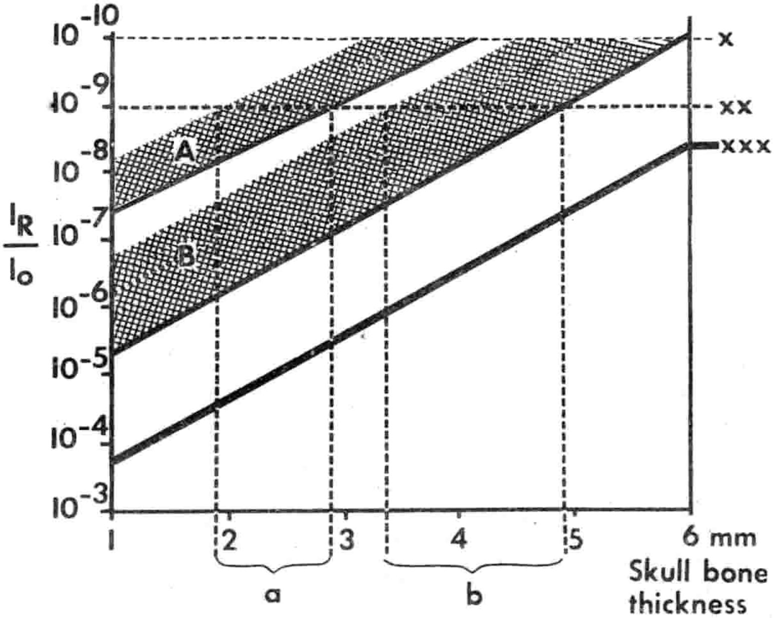

Fig. 1. Factors influencing echo response.

x Recordable echo intensity limit value
xx Optimally recordable echo intensity limit value
xxx Skull bone and brain tissue attenuation
B Recordable pineal body/c. s. f. echo intensity
A Recordable brain tissue/c. s. f. echo intensity
b Max. skull bone thickness for recordable pineal body/c. s. f. echoes
a Max. skull bone thickness for recordable brain tissue/c. s. f. echoes

subdural hæmatoma, "silent" tumours &c. The method is an accurate one: in a series of 579 echoencephalographies, twelve were found inaccurate when compared to the findings at neurological, surgical, pathological-anatomical and clinical examinations: an accuracy of 97.9±0.6 per cent. (*Jeppsson* 1961). *Lithander* (1961) in 252 patients checked by radiology found a correlation coefficient between M-echo position and the position of the internal cerebral veins of 0.94±0.02. In three series, each comprising *circa* 50 patients, *de Vlieger & Ridder* (1959), *Jefferson* (1959) and *Newell* (1960) arrived at accuracy figures of 95, 84 and 84 per cent. respectively. Finally, *Ford and Ambrose* (1963) report 96.8 per cent. accuracy in a series of 300 patients.

All these applications of echoencephalography are based on the lateral shifting of the M-echo by a supratentorial expansivity. The method's inability to demonstrate infratentorial expansivities has stimulated further development and recently brought another diagnostic principle to light.

M-echo pulsation

At an early stage it was observed that the M-echo pulsates: *i.e.* its amplitude varies in time with the heart beat (*Leksell* 1955). This observation posed the question: is there one characteristic pattern for the M-echo pulse in the normal patient and another in the patient with increased intracranial pressure — and if so: is this of diagnostic value?

The M-echo pulsations are probably caused by a geometric change in the reflecting structures during the cardiac cycle, producing a periodic variation in the reflecting conditions. The morphological basis for this change may be the change in volume, position and shape of the intracranial contents following cerebral blood inflow during systole and the attendant intracranial pressure rise. Compressed intracranial tissue, such as occurs in a "tight brain" — from tumours, hæmatomata &c. — has less damping effect, *i.e.* less ability to reduce the pressure variations produced by the arterial pulse. It is reasonable to assume that a raised intracranial pressure should be mirrored in a changed M-echo pulse pattern. And, as infratentorial expanding lesions produce a raised intracranial pressure at an early stage, observation of the M-echo pulse pattern should enable us to make an early diagnosis through echoencephalography.

A method has been devised whereby the amplitude variations of the M-echo are recorded selectively and studied (*Jeppsson* 1964); the principles of the apparatus are outlined in figs. 2 and 3. A well-defined and characteristic M-echo pulse pattern is recorded in normal subjects (fig. 4). A rise in intra-

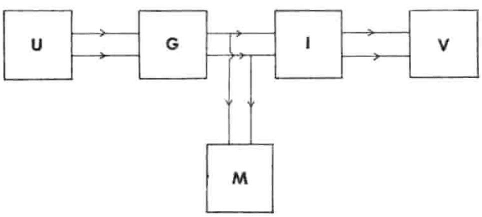

Fig. 2. Block diagram showing the arrangement for recording the M-echo amplitude variations.

U — ultrasonic apparatus
G — gate
I — integrator
V — visicorder
M — monitor

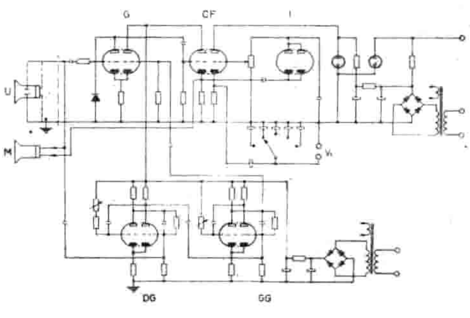

Fig. 3. Diagram showing the electronic construction of the gate, univibrators and the integrator.

G — gate
CF — cathode follower
I — integrator
DG — univibrator (delay period)
GG — univibrator (gate period)
U — ultrasonic apparatus
M — monitor

TABLE I. *Normal cases.*

Case	Age (yrs)	No. of examination	T_1 (msec)	T_1/C_0	T_1/C_1
S.-E. A.	14	1	90	0.094	*0.225*
		2	80	0.095	*0.220*
G. B.	20	1	70	0.092	*0.225*
		2	70	0.093	*0.225*
T. N.	38	1	80	0.094	*0.258*
		2	80	—	*0.250*
T. P.	52	1	75	0.080	*0.225*
		2	70	—	*0.220*
		3	70	—	*0.220*
		4	70	—	*0.220*

T_1 = Rise time (see text).
C_0 = Time between two adjacent R-peaks in ECG (= cardiac cycle).
C_1 = Time between the R- and T-peaks in one ECG complex (= systole).

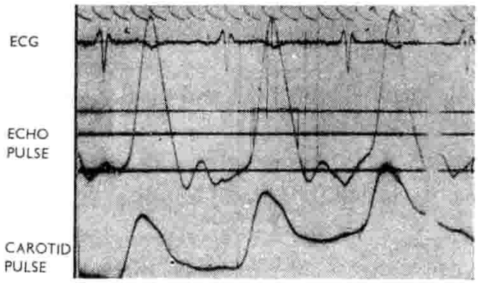

Fig. 4. Normal echo pulse pattern.

cranial pressure changes this pattern: the initial part of the curve becomes steeper: the rise time becomes shorter. In normal subjects this rise time, calculated as part of the systolic period, lies closely around 0.225 (table 1). In patients with increased intracranial pressure the rise time becomes shorter and the value lower in all instances (table 2). When the intracranial pressure is reduced — by surgical or other methods — the value reverts to normal (fig. 5). The data from this investigation make it probable that this value expresses the magnitude of the damping effect and that it is directly related to the intracranial pressure.

SUMMARY

Echoencephalography can employ the M-echo produced by median brain structures in two ways. The lateral M-echo shift is utilized for diagnosing supratentorial expansivities. This method is reviewed and its proper fields of application are narrowed down and defined as neurotraumatology, early tumour diagnosis in neurological practice and check-ups for acute and chronic