NEUROPHYSIOLOGICAL AND NEUROIMAGING METHODS FOR DIAGNOSING DISEASES OF THE NERVOUS SYSTEM

Study guide for medical higher education institution students, clinical residents, neurologists and family physicians

МІНІСТЕРСТВО ОХОРОНИ ЗДОРОВ'Я УКРАЇНИ
Харківський національний медичний университет

NEUROPHYSIOLOGICAL AND NEUROIMAGING METHODS FOR DIAGNOSING DISEASES OF THE NERVOUS SYSTEM

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НЕЙРОФІЗІОЛОГІЧНІ ТА НЕЙРОВІЗУАЛІЗАЦІЙНІ МЕТОДИ ДІАГНОСТИКИ ЗАХВОРЮВАНЬ НЕРВОВОЇ СИСТЕМИ

Навчальний посібник для студентів медичних вищих навчальних закладів, клінічних ординаторів, неврологів та сімейних лікарів

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Study guide is devoted to modern instrumental methods for diagnosing diseases of the nervous system**.** Special attention is paid to research methods and clinical significance of electrophysiological, ultrasound, radiological, magnetic resonance and radioisotope methods. The presented material allows toincrease the level of knowledge regarding the optimal set of diagnostic methods and the sequence of their application for various diseases of the nervous system. To improve the process of mastering the material, illustrations of our own observations are provided. To control knowledge, test tasks, situational tasks and answers to them are given.

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Н45 Нейрофізіологічні та нейровізуалізаційні методи діагностики захворювань нервової системи, англійською мовою : навчальний посібник для студентів медичних вищих навчальних закладів, клінічних ординаторів, неврологів та сімейних лікарів / О. Л. Товажнянська, Н. О. Некрасова, О. К. Різниченко та ін. Харків : ХНМУ, 2022, 80 с.

Навчальний посібник присвячений сучасним інструментальним методам діагностики захворювань нервової системи. Особлива увага приділяється методам дослідження та клінічному значенню електрофізіологічних, ультразвукових, магнітно-резонансних методів. Представлений матеріал дозволяє підвищити рівень знань щодо оптимального набору методів діагностики та послідовності їх застосування при різних захворюваннях нервової системи. Для покращення процесу засвоєння матеріалу подано ілюстрації власних спостережень. Для контролю знань даються тестові завдання, ситуаційні завдання та відповіді на них.

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CONTENTS

ABBREVIATIONS

A	–	Amplitud
BAEP	–	brainstem auditory evoked potential
BAER	–	brainstem auditory evoked response
CNS	–	Central Nnervous System
CSF	–	Cerebrospinal fluid
CT	–	Computed Tomography
CMAP	–	compound muscle action potential
DL	–	distal latency
EDX	–	electrodiagnostic
EEG	–	Electroencephalography
EMG	–	Electromyography
ENMG	–	electroneuromyography
MRI	–	Magnetic Resonance Imaging
MCA	–	Middle Cerebral Artery
MUP	–	Motor unit potentials
PET	–	Positron Emission Tomography
PL	–	proximal latency
RMP	–	Resting Membrane Potential
REG	–	Rheoencephalography
SPECT	–	Single-photon Emission Computed Tomography

PREFACE

Modern diagnostics of neurological diseases, pathogenetic therapy and its control are impossible without the use of modern paraclinical research methods. However, the doctor should always intermute the data of additional methods of investigation only in the context of the clinical manifestations of the disease and try to avoid unreasonable research, which leads to additional costs of time and money and in some cases – to the development of complications.

To recognize diseases of the nervous system, many different instrumental diagnostic methods of research are used today. They are divided into non-invasive (atraumatic), which do not require direct penetration of the instrument through the skin of the subject and invasive, involving a surgical element of action, usually in the form of a bone puncture and subsequent performance of certain manipulations.

NEUROPHYSIOLOGICAL AND NEUROIMAGING METHODS FOR DIAGNOSING DISEASES OF THE NERVOUS SYSTEM

- Non-invasive (atraumatic), which do not require direct penetration of the instrument through the skin of the subject;
- Invasive, which involve a surgical element of influence, usually in the form of a bone puncture and subsequent performance of certain manipulations**.**

APPLICATION

- to obtain objective information that provides recognition of the pathological process;
- to track the dynamics of pathological changes;
- to monitor the course of treatment and the selection of rational therapy;
- to transform, if necessary, some invasive diagnostic methods into therapeutic measures.

DIAGNOSTIC FOCUS

1) methods that provide visual information about structural changes in the central nervous system associated with the pathological process;
2) methods that reflect violations of the functions of the nervous system or blood circulation in it;
3) methods that simultaneously objectify structural and functional changes in the brain.

FORMATION OF THE PLAN OF INSTRUMENTAL EXAMINATION (THE OPTIMAL SET OF DIAGNOSTIC METHODS AND THE SEQUENCE OF THEIR APPLICATION)

In each specific case, it is determined by the results received by the doctor:

- indicative clinical and neurological data on the probable type of pathology;
- the general condition of the patient;
- the availability of appropriate diagnostic equipment in the medical institution.

NEUROLOGIC INVESTIGATIONS

1. ***Electrophysiologic studies***:
   - Electroencephalography;
   - Evoked potentials;
   - Electromyography & nerve conduction studies;
   - F-response studies;
   - Repetitive nerve stimulation.
   - Rheoencephalography
2. ***Spinal imaging studies:***
   - Plain x-rays;
   - Myelography;
   - Computed tomography;
   - Magnetic resonance imaging;
3. ***Ultrasonography:***
   - B-mode ultrasonography;
   - Doppler ultrasonography;
4. ***Cranial imaging studies:***
   - Plain x-rays;
   - Computed tomography;
   - Magnetic resonance imaging;
   - Positron emission tomography;
   - Single-photon emission computed tomography;
   - Functional magnetic resonance imaging;
   - Magnetic resonance spectroscopy;
   - Arteriography;
   - Magnetic resonance angiography
5. ***Radioisotope method:***
   - Encephaloscintigraphy
   - Encephaloangioscintigraphy
6. ***Lumbar puncture***
7. ***Biopsies:***
   - Brain biopsy;
   - Muscle biopsy;
   - Nerve biopsy;
   - Artery biopsy.

PARTS 1
ELECTROPHYSIOLOGIC STUDIES

Charter 1. ELECTROENCEPHALOGRAPHY

The electrical activity of the brain can be recorded noninvasively from electrodes placed on the scalp (*Image 1.1.1*). Electroencephalography (**EEG**) is easy to perform, is relatively inexpensive, and is helpful in several different clinical contexts.

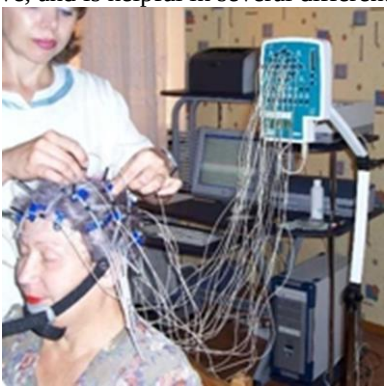


Image 1.1.1. Electroencephalography

Evaluation of Suspected Epilepsy

EEG is useful in evaluating patients with suspected epilepsy. The presence of electrographic seizure activity (abnormal, rhythmic electrocerebral activity of abrupt onset and termination) during a behavioral disturbance that could represent a seizure, but about which there is clinical uncertainty, establishes the diagnosis beyond doubt (*Image 1.1.2*).

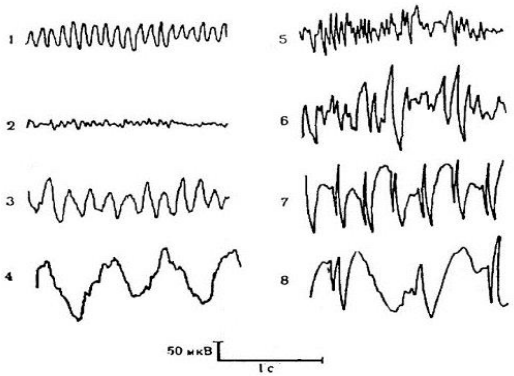
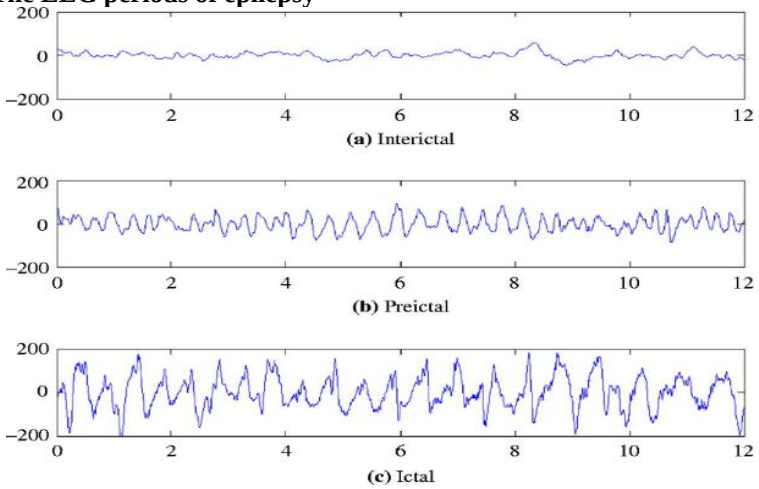


Image 1.1.2. The main types of EEG activity
1 – α-activity; 2 – β-activity; 3 – θ-activity; 4 – δ-activity; 5 – multiple spikes;
6 – sharp waves; 7 – «spike-wave» complexes; 8 – complexes «sharp wave-slow wave

As seizures occur unpredictably, however, it is not often possible to obtain an EEG during them. Despite that, the EEG findings may be abnormal interictal (at times when the patient is not experiencing clinical attacks) and are therefore still useful for diagnostic purposes. The interictal presence of epileptiform activity (abnormal paroxysmal activity containing some spike discharges) is of particular help in this regard. Such activity is occasionally encountered in patients who have never had a seizure, but its prevalence is greater in epileptics than in normal subjects. Epileptiform activity in the EEG of a patient with an episodic behavioral disturbance that could on clinical grounds be a manifestation of seizures markedly increases the likelihood that the attacks are indeed epileptic, thus providing support for the clinical diagnosis.

The EEG periods of epilepsy



Classification of Seizure Disorders

In known epileptics, the EEG findings may help in classifying the seizure disorder and thus in selecting appropriate anticonvulsant medication. For example, in patients with the typical absences of petit mal epilepsy the EEG is characterized both ictally and interictally by episodic generalized spike-and-wave activity (*Image 1.1.3*). In contrast, in patients with episodes of impaired external awareness caused by complex partial seizures, the EEG may be normal or show focal epileptiform discharges interictally. During the seizures there may be abnormal rhythmic activity of variable frequency with a localized or generalized distribution, or, in some instances, there may be no electrographic correlates. The presence of a focal or lateralized epileptogenic source is of particular importance if surgical treatment is under consideration.

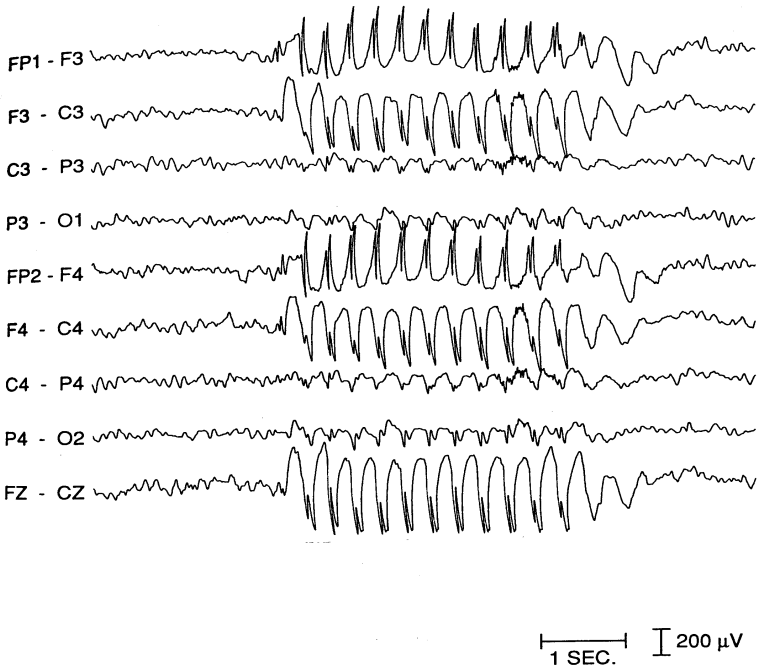


Image1.1.3. An example of the EEG recording of absence epileptic seizure. Paroxysmal 3 Hz spike and wave pattern emerges abruptly out of normal background and suddenly ceases after few seconds

Assessment & Prognosis of Seizures

The EEG findings may provide a guide to prognosis and have been used to follow the course of seizure disorders. A normal EEG implies a more favorable prognosis for seizure control, while an abnormal background or profuse epileptiform activity (*Image 1.1.4, 1.1.5, 1.1.6*) implies a poor prognosis. The EEG findings do not, however, provide a reliable guide to the subsequent development of seizures in patients with head injuries, stroke, or brain tumors. Some physicians have used the electrophysiologic findings to determine whether anticonvulsant medication can be discontinued in patients who have been seizure-free for several years. While patients are more likely to be weaned successfully if the EEG is normal, the findings provide only a general guide, and patients can certainly have further seizures, despite a normal EEG, after withdrawal of anticonvulsant medication. Conversely, they may have no further seizures despite a continuing EEG disturbance.

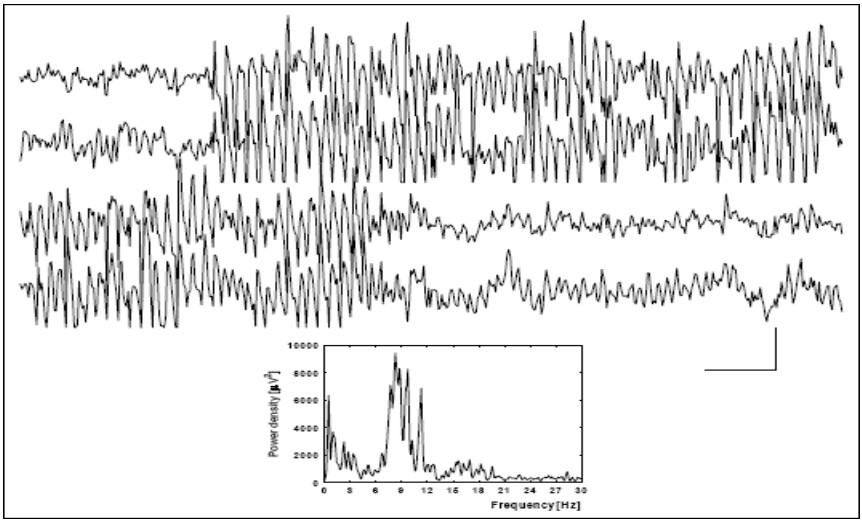


Image 1.1.4. Representative EEG correlate and the corresponding power spectra (bottom diagram) of generalized clonic-tonic convulsions obtained 5 min after lindane (8 mg/kg, i.p) injection Tracings represent paroxysmal high-voltage spiking activity

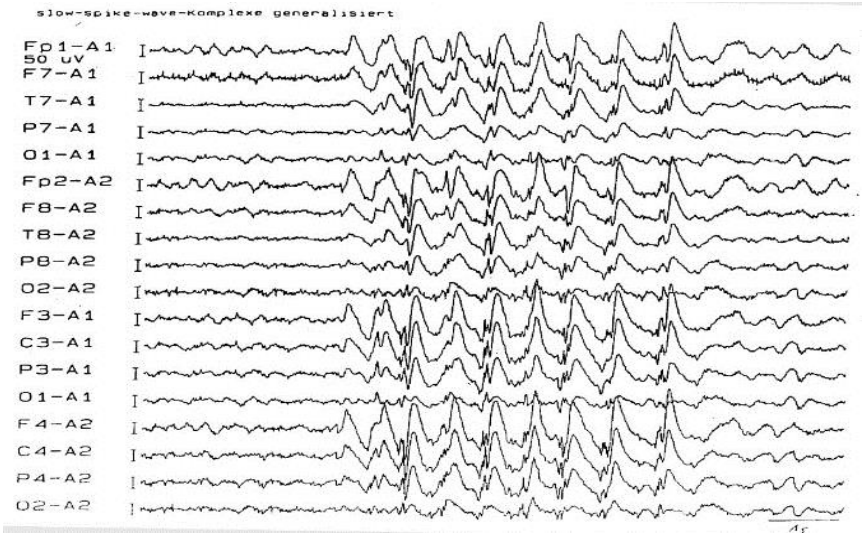


Image1.1.5. Generalized «spike- slow wave» complexes

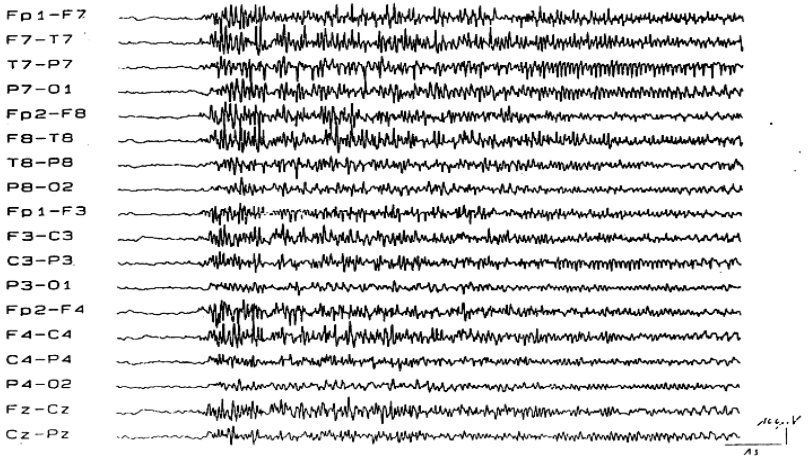


Image 1.1.6. Tonic phase of generalized tonic-clonic convulsions

Management of Status Epilepticus

The EEG is of little help in managing tonic-clonic status epilepticus unless patients have received neuromuscular blocking agents and are in pentobarbital induced coma. In this case, the electro physiologic findings are useful in indicating the level of anesthesia and determining whether the seizures are continuing. The status itself is characterized by repeated electrographic seizures or continuous epileptiform (spike-and-wave) activity. In patients with nonconvulsive status epilepticus, the EEG findings provide the only means of making the diagnosis with confidence and in distinguishing the two main types. In absence status epilepticus, continuous spike-and wave activity is seen, while repetitive electrographic seizures are found in complex partial status.

Detection of Structural Brain Lesions

Electroencephalography has been used as a noninvasive means of detecting focal structural abnormalities, such as brain tumors. There may be a focal slow-wave disturbance, a localized loss of electrocerebral activity, or a more generalized EEG disturbance that probably relates in part to an altered level of arousal. Noninvasive imaging procedures such as computed tomography (CT) and magnetic resonance imaging (MRI) have supplanted the use of EEG in this context.

Diagnosis of Neurologic Disorders

Certain neurologic disorders produce characteristic but nonspecific abnormalities in the EEG. Their presence is helpful in suggesting, establishing, or supporting the diagnosis. In patients presenting with an acute disturbance of cerebral function, for example, the presence of repetitive slow-wave complexes over one or both temporal lobes suggest a diagnosis of herpes simplex encephalitis. Similarly, the presence of periodic complexes in a patient with an acute dementing disorder suggests a diagnosis of Creutzfeldt-Iakob disease or subacute sclerosing panencephalitis.

Evaluation of Altered Consciousness

The EEG tends to become slower as consciousness is depressed, but the findings depend at least in part upon the etiology of the clinical disorder. The findings, such as the presence of electrographic seizure activity, can suggest diagnostic possibilities that might otherwise be overlooked. Serial records permit the prognosis and course of the disorder to be followed. The EEG response to external stimulation is an important diagnostic and prognostic guide: electrocerebral responsiveness implies a lighter level of coma. Electrocerebral silence in a technically adequate record implies neocortical death, in the absence of hypothermia or drug overdose. In some patients who appear to be comatose, consciousness is, in fact, preserved. Although there is quadriplegia and a supranuclear paralysis of the facial and bulbar muscles, the EEG is usually normal in such patients with locked-in syndrome and helps in indicating the correct diagnosis.

Charter 2. EVOKED POTENTIALS

Overview

Evoked potentials (EPs), or evoked responses, measure the electrophysiologic responses of the nervous system to a variety of stimuli. In theory, almost any sensory modality can be tested; however, in clinical practice, only a few are used on a routine basis. The EPs most frequently encountered are the following:

- Visual evoked potentials (VEPs; these include both flash and checkerboard types)
- Short-latency somatosensory evoked potentials (SEPs)
- Short-latency brainstem auditory evoked potentials (BAEPs)

Late evoked responses are generally used for studying higher cortical functions (eg, P300 in Alzheimer disease).

Visual Evoked Potential

A visual evoked potential is an evoked potential caused by a visual stimulus, such as an alternating checkerboard pattern on a computer screen. Responses are recorded from electrodes that are placed on the back of your head and are observed as a reading on an electroencephalogram (EEG). These responses usually originate from the occipital cortex, the area of the brain involved in receiving and interpreting visual signals (*Image 1.2.1*).

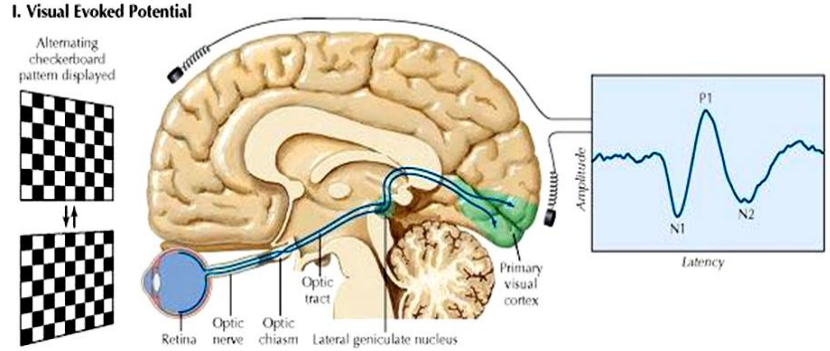


Image 1.2.1. Generators of main visual evoked potential (VEP) waves

The generator site for VEPs is believed to be the peristriate and striate occipital cortex. Prolongation of P100 latency is the most common abnormality and usually represents an optic nerve dysfunction. VEP is clearly more sensitive than physical examination in detecting optic neuritis. Example of normal and abnormal VEP on *Image 1.2.2*.

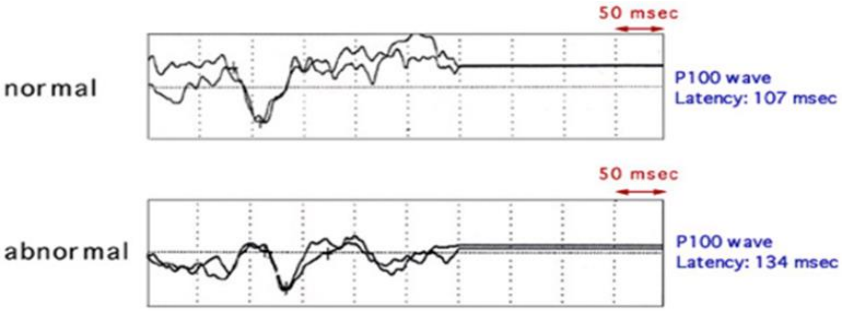


Image 1.2.2. Examples of normal and abnormal VEP curevs

Normal visual evoked potentials P100 wave latency less than 110 ms. Abnormal VEP P100 wave latency more than 110 ms, amplitude also decreased.

Ikeda et al investigated current source generators (dipoles) of human VEP to pattern-onset stimuli. A visual stimulus (a checkerboard pattern) was presented for 250 msec in each of the 8 quadrants. Central and peripheral parts of each of the 4 quadrant fields were evaluated. The VEPs, consisting of initial positive-late negative waves, were recorded mainly on the occipital region contralateral to stimulated visual fields. The initial positive waves of VEP were divided into the following 2 components:

- Early component with an approximate peak latency of 70–90 msec
- Late component with an approximate peak latency of 100–120 msec

The results from these analyses of VEP indicated topographic localization of the dipoles around the calcarine fissure. [1] This was comparable to the retinotopy of the human occipital lobe based on clinicopathologic studies.

Clinical utility

With an abnormal VEP, the differential diagnostic considerations include the following: optic neuropathy; optic neuritis; Ocular hypertension; Glaucoma; Diabetes – Szabela et al found abnormal VEP in 22 % of type 2 diabetics; Toxic amblyopia; Leber hereditary optic neuropathy; Aluminum neurotoxicity; Manganese intoxication; Retrobulbar neuritis; Ischemic optic neuropathy; MS; Tumors compressing the optic nerve - Optic nerve gliomas, meningiomas, craniopharyngiomas, giant aneurysms, and pituitary tumor.

Brainstem Auditory Evoked Potentials

The brainstem auditory evoked potential (BAEP), or brainstem auditory evoked response (BAER), measures the functioning of the auditory nerve and auditory pathways in the brainstem (see the image below).

Physiologic basis

BAEPs predominantly activate the pathways in the brainstem that are ipsilateral to the side of click stimulation. In particular, lesions in the middle to upper pons tend to lead to ipsilateral BAEP abnormalities. The structures involved in the generation of BAEPs may be concerned more with sound localization than with hearing itself.

Scheme of generation and curve of short latency auditory evoked potentials *Image 1.2.3.*

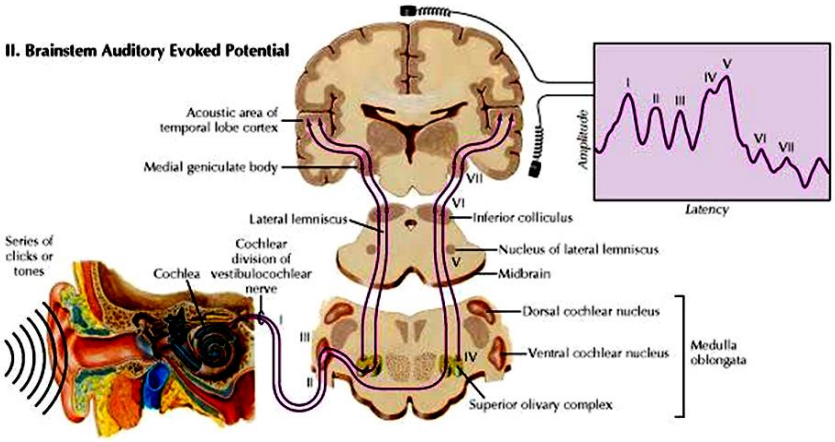


Image 1.2.3. Generation of BAEP waves after stimulation of contralateral ear by loud sound clicks

Whether nuclei, tracts, or both generate the peak latencies is not known. Currently, the generators are postulated to be as follows:

- Wave I – Action potential of cranial nerve (CN) VIII
- Wave II – Cochlear nucleus (and CN VIII)
- Wave III – Ipsilateral superior olivary nucleus
- Wave IV – Nucleus or axons of lateral lemniscus
- Wave V – Inferior colliculus

Normal brainstem auditory evoked potentials waves (*Image 1.2.4*).

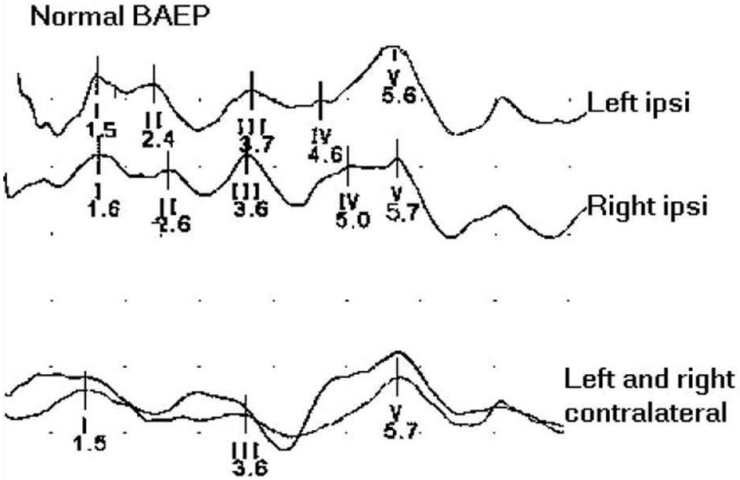


Image 1.2.4. Normal brainstem auditory evoked potentials

The short-latency BAEP generally is used for clinical purposes. The test can be performed with the patient under either sedation or general anesthesia. Standard broadband monaural click stimulation is used on the ear tested while a masking noise 30–40 dB lower in intensity is used on the contralateral ear.

Clinical utility

The most common uses of the BAEP are in multiple sclerosis (MS) and in acoustic neuroma. It is a useful screening test, though it has some limitations; magnetic resonance imaging (MRI) may be preferable when a small lesion is under consideration.

Indication for using BAEP: Cerebellopontine angle lesions (acoustic neuromas); Demyelinating diseases (multiple sclerosis, demielinating encephalomyelitis); Brainstem tumor; Migraine; Outcome prediction in coma; Respiratory insufficiency after encephalitis; Outcome prediction in perinatal asphyxia; Childhood speech disorders; Dementia.

All of above conditions accompanies by increasing latency of main waves and intervals

Somatosensory Evoked Potentials

The first evoked potential (EP) measurement is credited to Richard Caton of Liverpool, England, in 1913, but he could not record his results because he had no camera.

The actual somatosensory EP (SEP) is considered to be the result of summated effects of action potentials and synaptic potentials in a volume conductor. The short-latency SEP (SLSEP) is considered to be generated from volleys traversing the large-fiber sensory system (ie, the posterior columns and medial lemnisci). Sceme of generation of median nerve somato-sensory evoked potetials by stimulating of median nerve (*Image 1.2.5*).

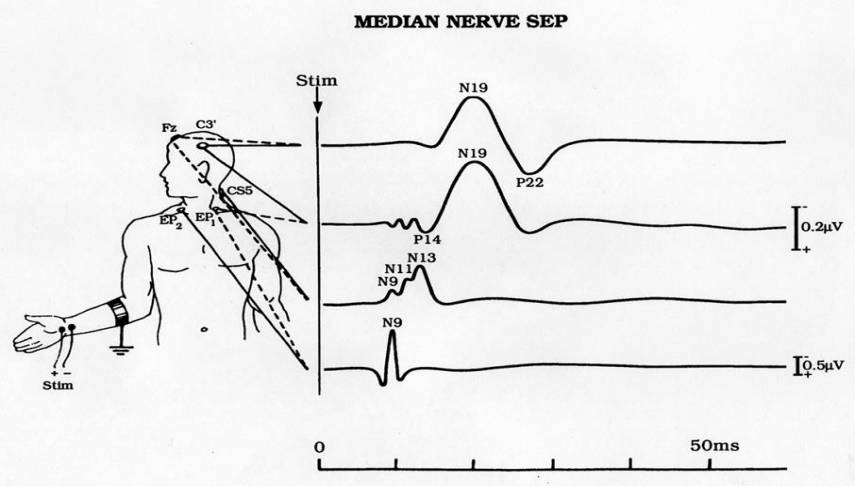


Image 1.2.5. Generation of Median nerve SEP waves

Physiologic basis

Large-diameter group Ia fibers and group II cutaneous afferents are primarily responsible for SEPs. Because of the ease of delivery and quantification, electrical stimulation is typically used, though other types of sensory stimuli have been tried with success. When a mixed nerve is stimulated, Ia muscle afferents are activated. In the spinal cord, the dorsal columns are mainly responsible for conduction of the activity that generates the SEP. In the brain, the lemniscal and thalamocortical pathways are involved. Extralemniscal pathways also may play a role.

The generators of median nerve SEP are as follows:

- Erb point – Brachial plexus
- N11, N13 – Dorsal column, nucleus cuneatus
- P14 – Medial lemniscus
- N18 – Subcortical

- N20 – Primary sensory cortex
- P22 – Primary motor cortex

The generators of tibial SEP are as follows:

- N22 – Dorsal gray and root entry zone at lumbosacral spine
- N29 – Nucleus gracilis
- P31 – Brainstem
- N34 – Brainstem
- P37 – Primary sensory cortex

Sceme of generation of tibial nerve somato-sensory evoked potetials by stimulating of tibial nerve (*Image 1.2.6*).

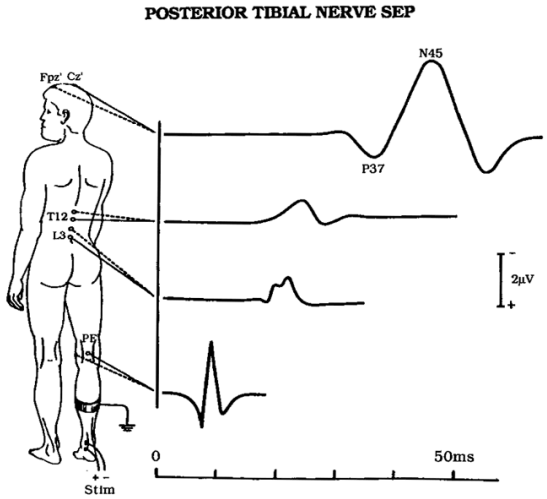


Image 1.2.6. Generation of tibial nerve SEP

Clinical utility

Multiple sclerosis. Abnormalities may include prolonged latencies or lack of development of the SEP. Lower-extremity studies are more often abnormal because of the longer pathway. Upper-limb SLSEPs are abnormal in about 40–60 % of MS patients; lower-limb SLSEPs have an abnormality rate of about 70 %, presumably because of the greater length of white matter involved. American Academy of Neurology (AAN) guidelines suggest that SEPs may be useful for diagnosing clinically silent MS lesions.

Lumbosacral disk disease. Sitzoglou et al identified clear dermatomal SEP abnormalities that correlated with radiculopathy in as many as 83 % of the cases studied.

Cervical syringomyelia. Patients with cervical cord syrinxes may show abnormalities in median nerve SEPs, indicating a lesion in the upper cervical

cord, with relative sparing of lower-limb SEPs. Wagner et al monitored median nerve SEPs intraoperatively in 28 patients with cervical or cervicothoracic syringomyelia. Analysis was focused on SEP components: N13 (spinal cord), P14 (brain stem), and N20 (cortex).

Intraoperative SEP. The basis of intraoperative SEP as a representative index of motor function is based on the fact that the vascular compromise that may cause motor dysfunction or loss also affects the lateral corticospinal tract and the dorsal spinocerebellar tract. In general terms, the regions of both motor and sensory pathways (lateral corticospinal tract and dorsolateral spinal cord and the alpha motor neurons) are served by the same vascular supply.

Acute transverse myelitis. Few studies have evaluated the role of EP changes in acute transverse myelitis. Misra et al assessed 10 patients who had lower-limb and upper-limb weakness by using detailed clinical, MRI, and neurophysiologic evaluation in conjunction with median and tibial SEPs, upper- and lower-limb MEPs, and concentric needle EMG; they found that MRI and MEPs were useful in assessing clinical outcome but that SEP played only a limited role.

Tuberculous myelopathy. Misra et al investigated the value of SEP and MEP changes in patients with Pott paraplegia and found that MEP and SEP correlated with respective motor and sensory impairments, as well as with outcome.

Diabetic polyneuropathy. SEP is used in the context of diabetes mainly for purposes of confirmation, though it can also be used in selected cases when the central conduction time is needed. In general, the SEP is prolonged in patients with clinically significant diabetic neuropathy. Although SEP may be confirmatory, it is not used often, since routine nerve conduction studies readily yield the diagnosis in diabetic neuropathy.

Vitamin B-12 deficiency. Both upper- and lower-limb SEPs have been found to be abnormal in patients with vitamin B-12 deficiency, often showing either no components or only the peripheral EP peak. Puri et al reported that serum vitamin B-12 level correlated well with the latencies of P37 and sural SNAP. On treatment, normalization of P100, MRI signal, and N20 and partial recovery of P37 latencies were seen at 6 months, 9 months, and 1 year, respectively.

Hyperthyroidism. Takahashi and Fujitani studied median SEPs in 14 patients and found that the N19-P23 amplitude was significantly higher in the patients than in the healthy control subjects.

Myotonic dystrophy. Patients with myotonic dystrophy have a prolonged interpeak latency between the Erb point and N/P13, indicating a sensory system involvement in this disorder.

Cardiac arrest. Wijdicks et al reviewed several studies evaluating the use of SEPs and prognosis after cardiac arrest.

Charter 3. ELECTROMYOGRAPHY & NERVE CONDUCTION STUDIES

The electrodiagnostic (EDX) is an important adjunct to the neurologic examination for diagnosis and management of disorders affecting the peripheral nervous system.

Components of the EDX examination include: 1) nerve conduction studies (NCSs, or electroneuromyography); 2) needle electrode examination (NEE, or electromyogram), and 3) special studies (e.g., H reflexes, F waves). Each part of the examination has specific advantages and limitations. Diagnosis is best facilitated when these components are used in combination. Although all complete studies include at least an NCS and NEE, the relative value of each test varies depending on the goal of the examination.

The electrophysiological examination of central and peripheral nervous system, neuromuscular transmission and the muscles with electroneuromyography (ENMG) is important in the assessment of neuromuscular disorders.

The basic function unit of the skeletal muscle is the muscle fiber. In adults a diameter of muscle fiber is about 10–100 microns, and a length is to 20 cm. The muscle fiber is contracted due to stimulation, which is transferred on the motor nerve fibers. A stimulus is conducted from the nerve fiber to the muscular fiber in the neuromuscular synapse with a temporary delay of 0,5–1 micro second. Inside the muscle the fibers and united into the functional groups, the so-called neuromuscular motor units (MU); each of them is innervated by one motor neuron of the anterior horns of the spinal cord. The muscle fibers of one separate MU are identical on structure and functional features. Upon activation of the motorneuron, all muscle fibers innervated by it are exited respectively. As a result, the recorded action potential of MU (APMU), which represents the sun of action potential of many muscle fibers and has greater amplitude, than the atrial potential (the atrial potential is the action potential of one or several muscle fibers located near the needle electrode introduced into the muscle).

The potentials recorded on volitional effort are derived from motor units of the muscle, hence known as motor unit potentials (MUPs). The principle of the method is based on ability of muscle fiber during contraction to general electric potentials.

Two different methods are used:

– **Electroneurography (ENG)** investigates nerve conduction in the peripheral nerves (hands and feet). The nerves are stimulated using surface electrodes. Simultaneously, measurements are taken of the speed with which a nerve transmits electrical signals and the strength of nerve stimulation in the corresponding muscle. An ENG may, for example, be carried out in cases of polyneuropathy (damage to the peripheral nerves) or to localise and determine the extent of the damage when nerves have been injured or pinched (e.g. carpal tunnel syndrome).

– **Electromyography (EMG)** is used to record electrical activity in a muscle. Thin needle electrodes are inserted directly into the patient's muscle. The activity of individual muscle fibres can thereby be determined. This examination method can, for example, determine whether muscle weakness is due to the muscle itself being diseased or whether the flow of information from the nerve to the muscle is disrupted. An EMG can also indicate the likelihood of recovery when muscles have become paralysed due to nerve damage or nerve inflammation. Nerve damage can also be localised by means of an EMG.

Components of an electrodiagnostic examination

Nerve conduction studies (NCS) can be divided into motor, sensory, and mixed studies (*Image 1.3.1*). Motor and sensory NCSs are considered part of a routine EDX evaluation, whereas mixed studies are typically used only in special situations (e.g., median, ulnar, or tibial nerve entrapment). Although both surface and needle electrodes can be used for stimulating and recording, most EDX laboratories select noninvasive surface electrodes for NCSs.

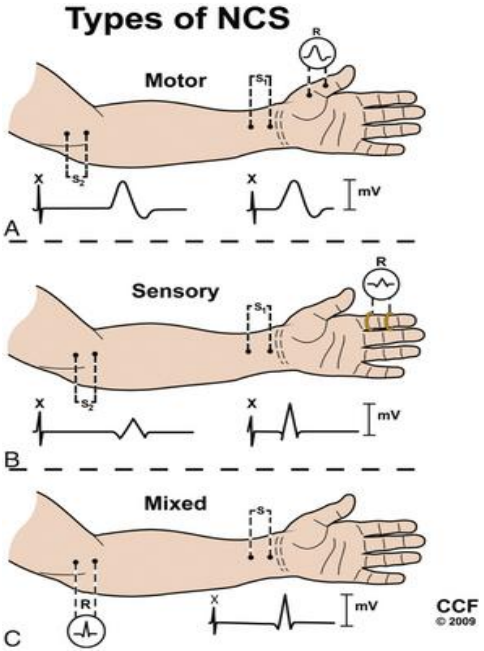


Image 1.3.1. Basic nerve conduction studies performed on the median nerve.
A – Motor nerve conduction studies, measured at the abductor pollicis brevis muscle.
B – Sensory nerve conduction study measured at the second digit.
C – Mixed study. R, recording site; S_1 and S_2, stimulation sites; X, stimulus artifact on each response tracing.

Motor Conduction Studies

Motor NCSs are typically performed using an "active" recording electrode over the center of a muscle belly and reference electrode distally over the tendon of the muscle ("the belly-tendon montage"). A two-pronged (anode-cathode) stimulator is placed over the nerve supplying the muscle, with the cathode oriented closer to the recording electrode. Current is applied over the nerve to induce an action potential in the underlying nerve fibers.

The recorded potential, known as the compound muscle action potential (CMAP), represents the summation of all underlying individual muscle fiber action potentials.

In most electrodiagnostic laboratories, routine motor NCSs of the arm include median nerve (recording the abductor pollicis brevis muscle) and ulnar nerve (recording the abductor digiti minimi muscle), and in the leg, the tibial nerve (recording the abductor hallucis muscle) and peroneal nerve (recording the extensor digitorum brevis muscle).

Compound muscle action potential in median motor nerve conduction study. Active recording electrode is over the abductor pollicis brevis (APB) muscle, with stimulation at the wrist, elbow, axilla, and brachial plexus. The more proximal stimulation is performed at a measured distance from the first. The difference between the proximal latency (PL) and distal latency (DL) in milliseconds reflects the conduction time along the fastest nerve fibers between the sites, eliminating the travel time from the distal site and across the neuromuscular junction (NMJ), as well as muscle fiber depolarization time. The distance between the sites in millimeters divided by the nerve conduction time (PL minus DL) is known as the conduction velocity.

Several key aspects of the CMAP waveform are analyzed (*Image 1.3.2*).

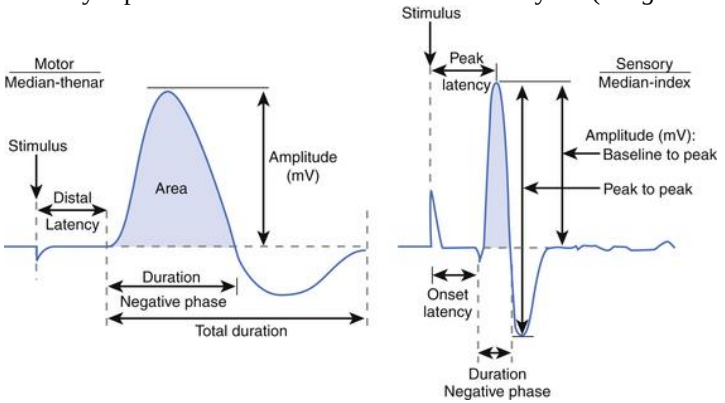


Image 1.3.2. Compound muscle action potential (left) and sensory nerve action potential (right) examples, both obtained from the median nerve. Note that by convention, deflection above the line is referred to as the "negative" phase and below the line as «positive»

First, the distal latency is measured in milliseconds from the stimulus artifact to the initial baseline deflection. This measurement combines the action potential travel time from the stimulus site to the neuromuscular junction (NMJ), time across the NMJ, and time required for the muscle fibers to depolarize.

Second, the duration of the negative phase is assessed as a measure of muscle fiber discharge synchrony in response to the stimulus. Third, the amplitude and area of the negative phase are measured, providing an index of the number of muscle fibers depolarizing within the range of the recording electrode.

Further analysis of motor nerve conduction requires a second, more proximal stimulus over the nerve recording at the same location, using the technique just described. The more proximal stimulation is performed at a measured distance from the first. The difference between the proximal latency (PL) and distal latency (DL) in milliseconds reflects the conduction time along the fastest nerve fibers between the sites, eliminating the travel time from the distal site and across the NMJ, as well as muscle fiber depolarization time. The distance between the sites in millimeters divided by the nerve conduction time (i.e., PL minus DL) is known as the conduction velocity (*Image 1.3.3*).

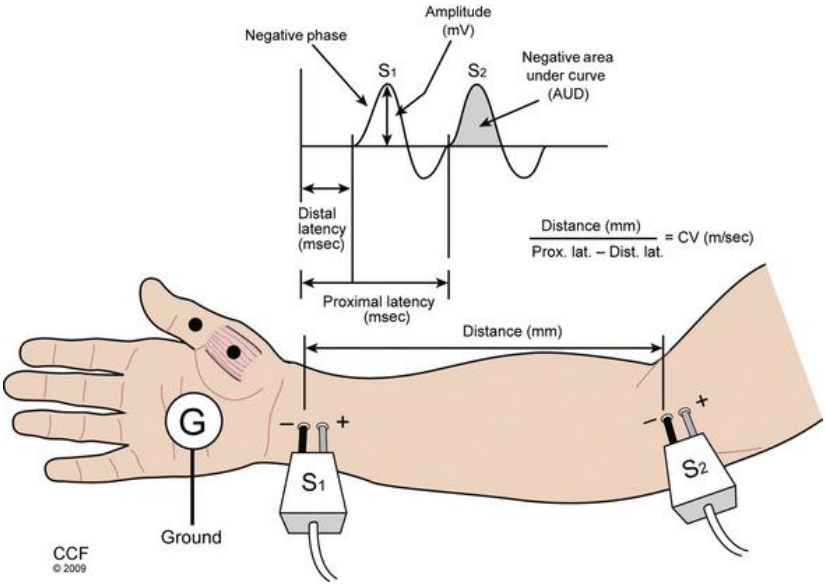


Image 1.3.3. Motor conduction velocity calculation example, performed on the median nerve. S_1 (distal) and S_2 (proximal) are stimulation sites, (–) is cathode and (+) is anode of the stimulator

The configuration of the CMAP generated by the proximal stimulation is also compared with that of the distal CMAP. Assuming supramaximal stimulus at both sites, the CMAPs should be essentially identical. A proximal stimulation

CMAP amplitude less than 50 % of the distal CMAP amplitude is consistent with conduction block, or a very early focal axon loss lesion in which wallerian degeneration has not yet occurred.

Sensory Conduction Studies

Sensory NCSs are performed with the two-pronged stimulator and pair of recording electrodes over the nerve. These studies may performed antidromically (stimulating proximally and recording adjacent to the sensory receptor) or orthodromically (stimulating distally and recording proximally). These responses are relatively small and are measured in microvolts (μV, 1/1000 of the unit used to measure a CMAP). As with motor NCSs, current is applied over the nerve to induce an action potential and is gradually increased with subsequent stimulations. At supramaximal stimulation, the combined action potentials of the sensory fibers are recorded as a sensory nerve action potential (SNAP). SNAP latency, duration, and amplitude are measured. Latency is measured to onset (representing the conduction of the fastest fibers) or, more commonly, to the peak of the negative deflection (*see Image 1.3.1*).

Routine sensory NCSs in most laboratories include the median nerve (recorded over digit 2) and ulnar nerve (recorded over digit 5) in the arm and are supplemented by studies of the radial, dorsal ulnar cutaneous, lateral antebrachial cutaneous, medial antebrachial cutaneous, and median sensory responses recorded over digit 1 or 3, as indicated. In the leg the sural sensory response (recorded over the lateral ankle) is routine, and supplemented by the lateral/medial plantar, superficial peroneal, saphenous, and lateral femoral cutaneous sensory responses, depending on the clinical indication for the study. For example, the superficial peroneal SNAP is of particular importance when differentiating between an intraspinal canal lesion affecting the L5 root and a common peroneal mononeuropathy.

Needle Electrode Examination

The NEE allows rapid, widespread assessment of the motor component of the PNS (*Image 1.3.4*). The procedure involves inserting an electrode into individual muscles and evaluating the insertional, spontaneous, and volitional electrical activity present, both visually on an oscilloscope, which displays voltage as a function of time, and aurally. NEE is particularly sensitive for identifying axon loss when compared with a motor NCS. Importantly, an optimal NEE requires patient cooperation and can be uncomfortable for patients, occasionally limiting its usefulness due to poor patient tolerance.

The first step of the NEE of a muscle is to evaluate "insertional activity," which is generated by needle movement within a muscle at rest. When an electrode is quickly moved through normal muscle, the fibers depolarize, generating a brief burst of electrical activity lasting 100 to 200 msec. This finding confirms that the electrode is in viable muscle. Although increased insertional activity lasting more than 300 msec is nonspecific, it is the earliest NEE finding in a partially denervated muscle, typically consisting of unsustained trains of positive sharp waves. These spontaneous electrical potentials have a characteristic

initial positive phase followed by a long negative phase. Conversely, insertional activity may be decreased or absent in chronic neuromuscular conditions because the muscle has been replaced by electrically silent fat and fibrous tissue.

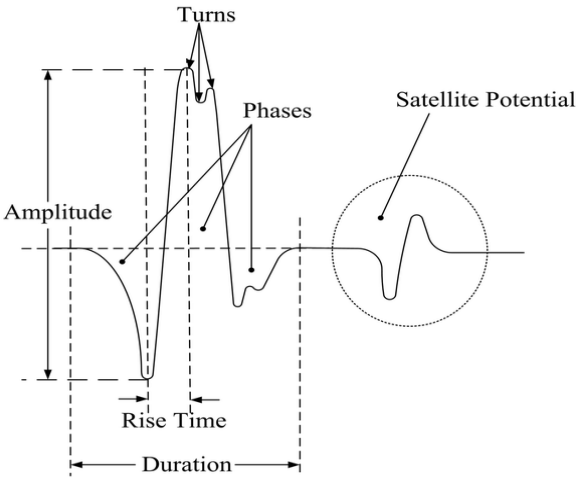


Image 1.3.4. The potential of motor units

Next, the examiner assesses for spontaneous electrical activity with the needle electrode at rest within the muscle. Normal muscle should be electrically silent during this phase. *Fibrillation potentials* are an important electrophysiologic marker of denervation. This form of spontaneous activity is characterized by regularly firing potentials, most commonly of a brief sharp spike configuration, derived from a single denervated muscle fiber. Larger-amplitude potentials are observed in acute disease[9] and are present in greater density in more severe disorders. Fibrillation potentials are sensitive to denervation because disruption of a single motor axon results in fibrillation of all muscle fibers within that motor unit. They can thus be seen when motor axon loss is insufficient to cause clinical weakness. Although these potentials are most commonly associated with injury to motor axons, they may also be found in inflammatory myopathies and rarely in other neuromuscular disorders. Importantly, in the setting of denervation, fibrillation potentials require an average of 21 days to appear after injury and persist until reinnervation occurs or the muscle fibers degenerate at around 18 to 24 months after axon loss.

Other forms of spontaneous activity can be observed during the resting phase. *Fasciculation potentials*, which are irregularly firing spontaneous discharges of an entire motor unit, are a marker of nerve fiber irritation as opposed to denervation. Complex repetitive discharges, which are recurrent, cyclic discharges of a series of muscle fibers, are a marker of chronicity, typically seen in neurogenic or myopathic disorders of at least 6 months' duration.

Late Responses

H Reflex

The H reflex is the electrophysiologic equivalent of the Achilles tendon muscle stretch reflex ("ankle jerk") and is unique in its ability to assess the preganglionic sensory fibers of the S1 nerve root. The reflex is elicited by stimulating the tibial nerve within the popliteal fossa at a progressively greater stimulus intensity, while recording the soleus muscle. Beginning at a submaximal stimulus intensity, lower-threshold sensory fibers are discharged first, resulting in an afferent (proximally directed) action potential, which synapses at the anterior horn cells of the S1 root. This initiates an efferent (distally directed) motor action potential, which is recordable as an H response at the soleus muscle. As the strength of the stimulus intensity is increased by the examiner, the tibial motor fibers at the stimulation site are depolarized, directly resulting in a measurable direct motor response, the *M wave*. Further increases in stimulus intensity depolarize additional motor fibers and thus result in a progressively higher-amplitude M wave. Direct discharge of these motor fibers results in a lower-amplitude H response because the orthodromic H response is blocked by an antidromic motor fiber discharge from the stimulation site. At supramaximal stimulus, only the M wave is apparent.

The H response amplitude and latency can be compared contralaterally and to values in normal controls adjusted for age and height, providing evidence of nerve fiber injury within the S1 reflex arc. Although H reflex abnormalities are considered sensitive for root impingement caused by S1 radiculopathy, the finding lacks specificity, also being found in patients with polyneuropathy, proximal tibial or sciatic mononeuropathies, and lumbosacral plexopathy. Absent H reflexes are also commonly observed in patients older than age 65 and in patients with a history of lumbar laminectomy and are thus of unclear clinical significance in this context. Overall, the usefulness of an absent H reflex is limited when the remainder of the EDX examination is within normal limits.

Depending on the clinical problem, different ENMG examinations may be applied:

- Electroneurography (ENG)
  Determination of nerve conduction with electrical stimulation.
- Electromyography (EMG)
  Analysis of electrical muscle activity with needle examination.
  Examination of neuromuscular transmission
  Analysis of signal transmission form the nerve to the muscle with repetitive nerve stimulation and stimulated single fiber EMG (ssFEMG)
- Examination of autonomic functions
  Analysis of the vegetative nervous system with determination of the sudomotor sympathetic skin response (SSR) and determination of R-R-interval variation.
- Motor-evoked potentials (MEP)
  Determination of central motor conduction time with magnetic impulses for examination of the pyramidal tract function.

Nerve conduction studies are particularly helpful in the following contexts (*Image 1.3.5; 1.3.6; 1.3.7*).

1. Determining whether sensory symptoms are caused by a lesion proximal or distal to the dorsal root ganglia (in the latter case, sensory conduction studies of the involved fibers will be abnormal) and whether neuromuscular dysfunction relates to peripheral nerve disease.

2. Detecting subclinical involvement of other peripheral nerves in patients who present with a mononeuropathy.

3. Determining the site of a focal lesion and providing a guide to prognosis in patients with a mononeuropathy.

4. Distinguishing between a polyneuropathy and a mononeuropathy multiplex. This distinction may not be possible clinically, but it is important because the causes of these conditions differ.

5. Clarifying the extent to which the disabilities experienced by patients with polyneuropathy relate to superimposed compressive focal neuropathies which are common complications.

6. Following the progression of peripheral nerve disorders and their response to treatment.

7. Indicating the predominant pathologic change in peripheral nerve disorders. In demyelinating neuropathies, conduction velocity is often markedly slowed and conduction block may occur; in axonal neuropathies, conduction velocity is usually normal or slowed only mildly, sensory nerve action potentials are small or absent, and electromyography shows evidence of denervation in affected muscles.

8. Detecting hereditary disorders of the peripheral nerves at a subclinical stage in genetic and epidemiologic studies.

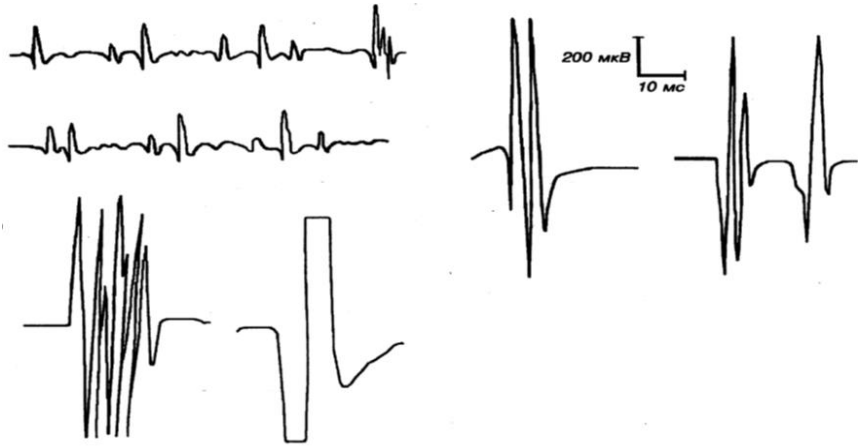


Image 1.3.5. Motor unit potentials recorded in pathology – A-when myopathy, B-in case of axons of motor neurons, D-in case of motor neurons of the spinal cord

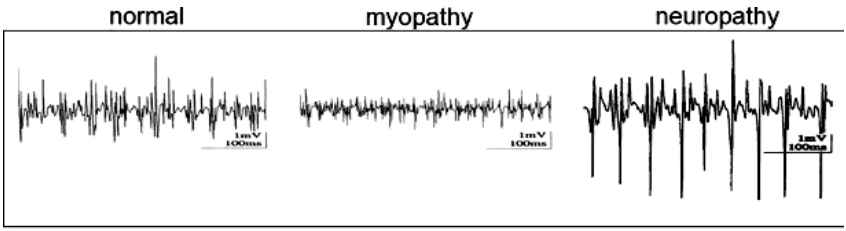


Image 1.3.6. Examples of three different EMG recordings (Tib.Ant.) showing original signals (above) and TA from each muscle (below). Note the low amplitudes with some high number of turns in myopathy and the opposite in neuropathy

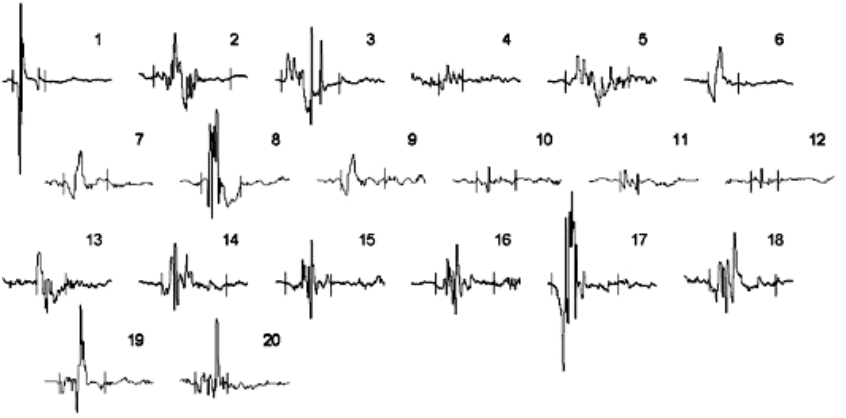


Image 1.3.7. Recording from tibialis anterior muscle in a patient with myopathy. MUPs are very polyphasic (upper panel). IP analysis shows low amplitudes of individual spikes and increased number of turns, as expected in myopathy. Amplitude and duration parameters appear within normal limits (right lower corner)

A combination of methods (visual inspection, MUP analysis, IP analysis) is usually necessary for correct interpretation.

F-response studies

When a stimulus is applied to a motor nerve, impulses travel antidromically (toward the spinal cord) as well as orthodromically (toward the nerve terminals) and lead to the discharge of a few anterior horn cells. This produces a small motor response that occurs considerably later than the direct muscle response elicited by nerve stimulation. The F wave so elicited is sometimes abnormal in patients with lesions of the proximal portions of the peripheral nervous system, such as the nerve roots. These studies may be helpful in detecting abnormalities when conventional nerve conduction studies are normal.

Response in Disorders of Neuromuscular Transmission

A. Myasthenia Gravis: In myasthenia gravis, depletion of postsynaptic acetylcholine receptors at the neuromuscular junction makes it impossible to

compensate for the reduced release of acetylcholine that follows repetitive firing of the motor neuron. Accordingly, repetitive stimulation, particularly between 2 and 5 Hz, may lead to a depression of neuromuscular transmission, with a decrement in the size of the compound muscle action potential recorded from an affected muscle. Similarly, an electrical stimulus of the motor nerve immediately after a 10-second period of maximal voluntary activity may elicit a muscle response that is slightly larger than before, indicating that more muscle fibers are responding. This postactivation facilitation of neuromuscular transmission is followed by a longer-lasting period of depression that is maximal from 2–4 minutes after the conditioning period and lasts up to 10 minutes or so. During this period, the compound muscle action potential is reduced in size.

Decrementing responses to repetitive stimulation at 2–5 Hz can also occur in congenital myasthenic syndromes.

B. Myasthenic Syndrome and Botulism: In Lambert-Eaton myasthenic syndrome, in which there is a defective release of acetylcholine at the neuromuscular junction, the compound muscle action potential elicited by a single stimulus is generally very small. With repetitive stimulation at rates of up to 10 Hz, the first few responses may decline in size, but subsequent responses increase and their amplitude is eventually several times larger than the initial response. Patients with botulism exhibit a similar response to repetitive stimulation, but the findings are somewhat more variable and not all muscles are affected. Incremental responses in Lambert-Eaton syndrome and botulism are more conspicuous with high rates of stimulation and may result from the facilitation of acetylcholine release by the progressive accumulation of calcium in the motor nerve terminal.

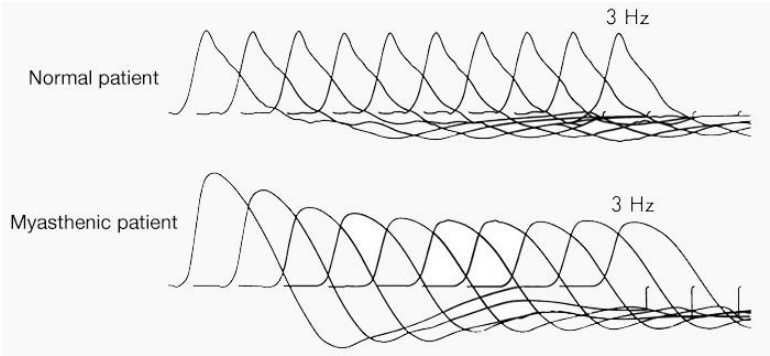


Image 1.3.8. Myasthenic Syndrome

Charter 4. RHEOENCEPHALOGRAPHY

Rheoencephalography (REG) is a non-invasive method of studying the vascular system of the brain, based on recording the changing value of the electrical resistance of tissues when a weak high-frequency electric current is passed through them.

The REG method allows you to obtain objective information (*Image 1.4.1*):

- about the tone;
- elasticity of the wall and reactivity of the brain vessels;
- about peripheral vascular resistance;
- about the magnitude of pulse blood filling; allows you to get separate information;
- about the state of the arterial and venous systems of the brain and about intracerebral vessels of different diameters.

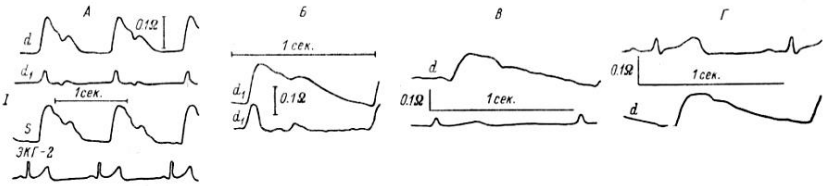


Image 1.4.1. REG of healthy people in the fronto-mastoid lead d-right, s-left, d1-first derivative; A-a healthy person of 22 years, B-35 years old, B-45 years, D-58 years

REG technique. Rheographs have 2–6 or more channels and allow you to simultaneously record rheoencephalograms (REG) of the corresponding number of vascular areas. REG is recorded by applying electrodes to the surface of the head.

– When applying the electrodes to the bridge of the nose and mastoid process, the state of the vessels in the basin of the internal carotid artery of the corresponding side of the head is mainly recorded. REG technique when applying one electrode to the mastoid process, and the second-in the area of the large occipital opening, the state of the vertebral artery basin is recorded.

– When the electrodes are applied in front of the auditory canal and at the outer edge of the brow arch, the state of hemodynamics in the basin of the external carotid artery is recorded.

Functional tests used in REG.

- The most commonly used test is nitroglycerin (in small doses, sublingually);
- head-turning test;
- a test with a change in body position.
- Acute shifts in blood pressure are reflected in the reoencephalogram by changes in the tone and even the level of pulse blood filling, which also needs to be taken into account when analyzing the curves.

Clinical significance of REG

- in intracranial hypertension (*Image 1.4.2*), corresponding venous and cerebrospinal fluid disorders are recorded.

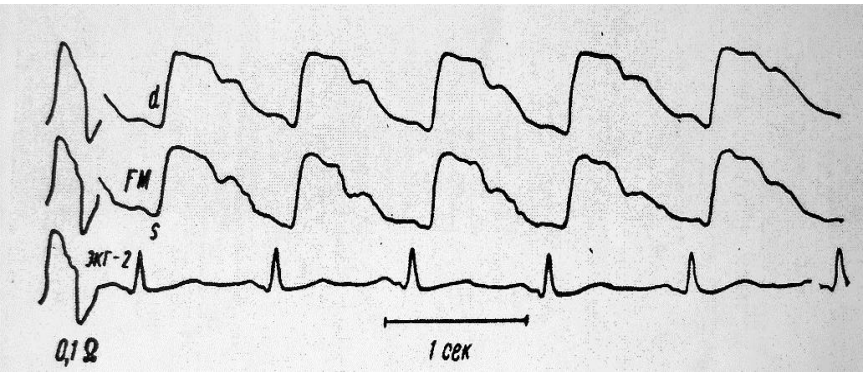


Image 1.4.2. REG for hypertension. Right and left frontal leads

- in vascular dystonia, an unstable vascular tone is recorded, changing over a short period of time.
- in acute and chronic vascular lesions (*Image 1.4.3*), violations of the patency of the main vessels are recorded (it allows you to determine the degree of development of atherosclerosis, identify subdural hematoma in TBI, objectify the effect of vasomotor drugs, diagnose migraines, etc.)

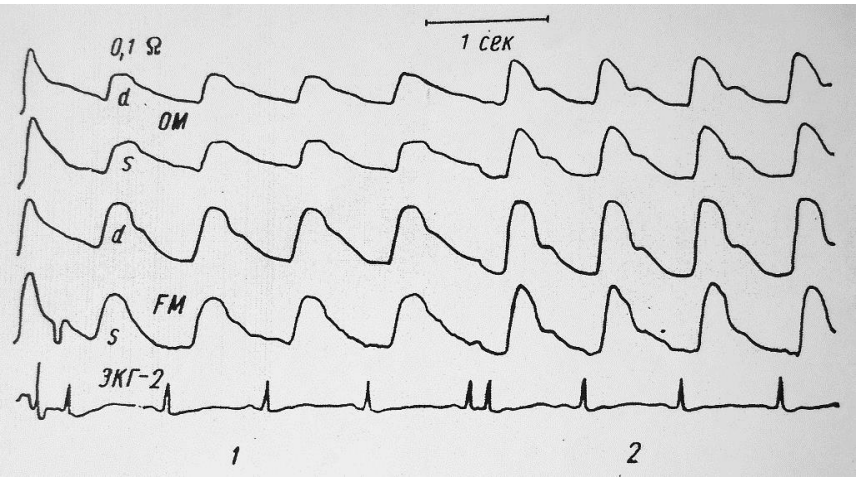


Image 1.4.3. REG in the initial manifestations of cerebral atherosclerosis.
1 – before, 2 – 2 minutes after sublingual application of nitroglycerin

PARTS 2
CRANIAL IMAGING STUDIES

Charter 1. PLAIN X-RAYS

Abnormalities of bone may be visualized by plain x-rays of the skull. Such abnormalities include metastatic deposits, fractures, and the changes associated with Paget's disease or fibrous dysplasia. In addition, plain films can show areas of abnormal intracranial calcification, alterations in size of the sella turcica, and inflammatory disease of the paranasal sinuses. The advent of CT scanning (which permits visualization of cerebral tissue as well as bone) has led to a marked decline in the use of plain films.

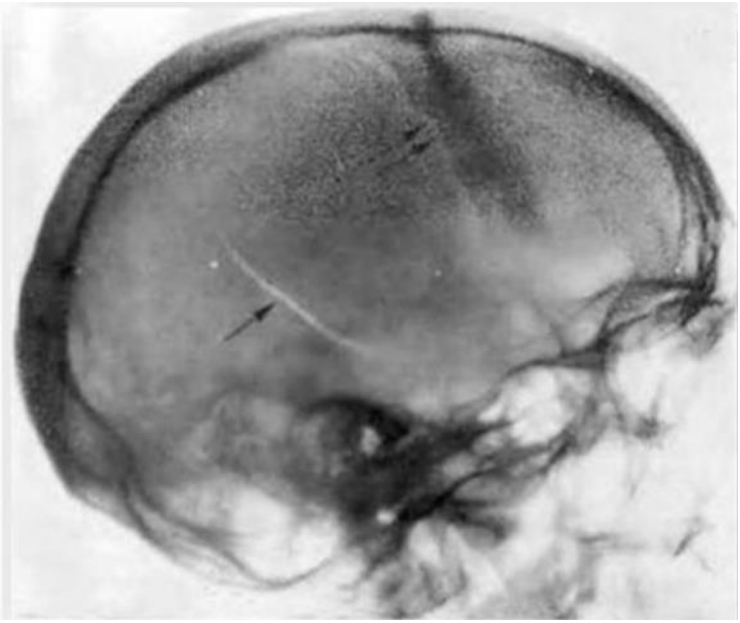


Image 2.1.1. Overview x-ray of the skull in lateral projection.
Linear fracture of the dark-tempole region

Charter 2. COMPUTED TOMOGRAPHY

Description. Computed tomographic (**CT**) scanning is a noninvasive computer-assisted radiologic means of examining anatomic structures (*Image 2.2.1*).

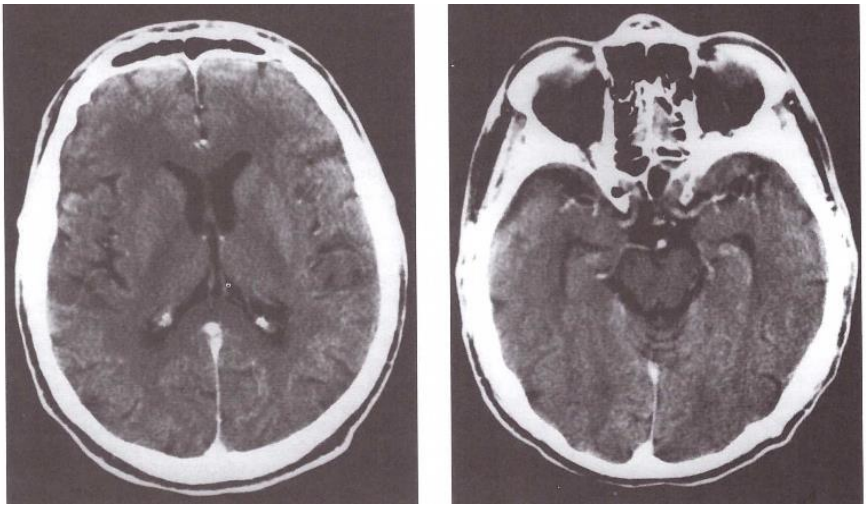


Image 2.2.1. Contrast-enhanced CT brain scans from a 62-year-old man, showing the normal anatomy. Images at the level of the mid-brain and lateral ventricles are illustrated

CT permits the detection of structural intracranial abnormalities with precision, speed, and facility. It is thus of particular use in evaluating patients with progressive neurologic disorders or focal neurologic deficits in whom a structural lesion is suspected as well as patients with dementia or increased intracranial pressure. Intravenous administration of an iodinated contrast agent improves the ability of CT to detect and define lesions, such as tumors (*Image 2.2.10, 2.2.11*) and abscesses (*Image 2.2.13, 2.2.14*), associated with a disturbance of the blood-brain barrier. Because the contrast agents may have an adverse effect on the kidneys, they should be used with discrimination. Other adverse effects of the contrast agents in common use are pain, nausea, thermal sensations, and anaphylactoid reactions that include bronchospasm and death. Contrast-enhanced scans may provide more information than that obtained by unenhanced scans in patients with known or suspected primary or secondary brain tumors, arteriovenous malformations (AVMs) (*Image 2.2.16*), multiple sclerosis, chronic isodense subdural hematomas or hydrocephalus.

Indications for Use

A. **Stroke:** CT is particularly helpful in evaluating strokes (*Image 2.2.3*) because it can distinguish infarction from intracranial hemorrhage; it is particularly sensitive in detecting intracerebral hematomas, and the location of such lesions may provide a guide to their cause.

B. **Tumor:** CT scans can indicate the site of a brain tumor (*Image 2.2.12*), the extent of any surrounding edema, whether the lesion is cystic or solid, and whether it has displaced midline or other normal anatomic structures.

C. **Trauma:** The CT scan is an important means of evaluating patients following head injury-in particular for detecting traumatic subarachnoid or intracerebral hemorrhage (*Image 2.2.5, 2.2.6, 2.2.7, 2.2.8, 2.2.9*) and bony injuries. It also provides a more precise delineation of associated fractures than do plain x-rays.

D. **Dementia:** In patients with dementia, CT scan may indicate the presence of a tumor or of hydrocephalus (enlarged ventricles), with or without accompanying cerebral atrophy. The occurrence of hydrocephalus without cerebral atrophy in demented patients suggests normal pressure or communicating hydrocephalus. Cerebral atrophy can occur in demented or normal elderly subjects.

E. **Subarachnoid Hemorrhage:** In patients with subarachnoid hemorrhage, the CT scan generally indicates the presence of blood in the subarachnoid space (*Image 2.2.4*) and may even suggest the source of the bleeding. If the CT findings are normal despite clinical findings suggestive of subarachnoid hemorrhage, the CSF should be examined to exclude hemorrhage or meningitis (*Image 2.2.15*).

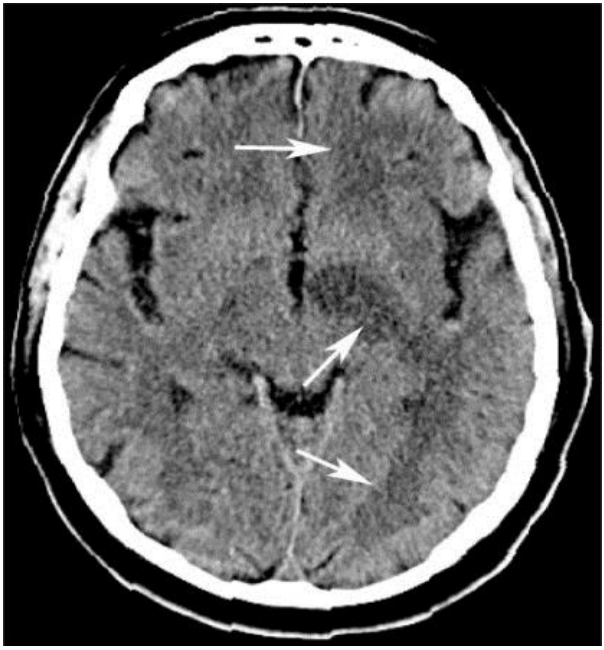


Image 2.2.3. Left middle cerebral artery (MCA) infarction. Axial nonenhanced computer tomography demonstrates hypoattenuating foci throughout the left sided white matter (arrows) and sulcal effacement in the left MCA territory, consistent with infarction

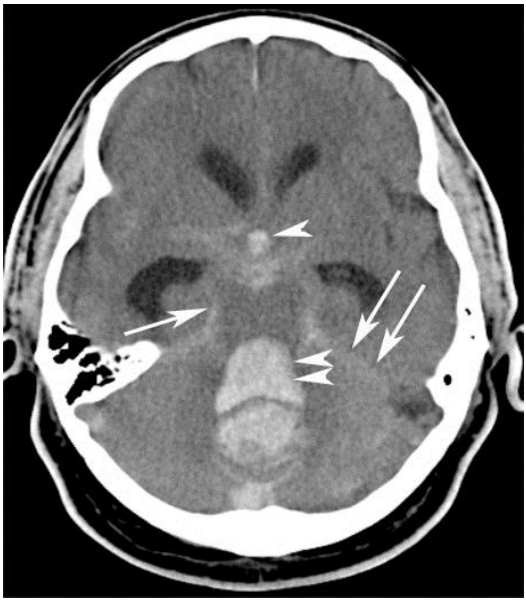


Image 2.2.4. Massive subarachnoid and intraventricular hemorrhage. Axial nonenhanced computer tomography demonstrates a large "bright" or hyper attenuating dense subarachnoid hemorrhage throughout the perimesencephalic cistern

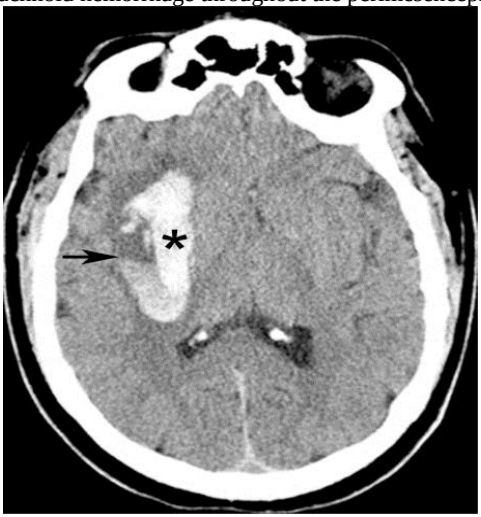


Image 2.2.5. Hypertensive intraparenchymal hematoma. Nonenhanced computed tomography shows a large right basal ganglionic hematoma (*) containing a fluid/fluid level (arrow)

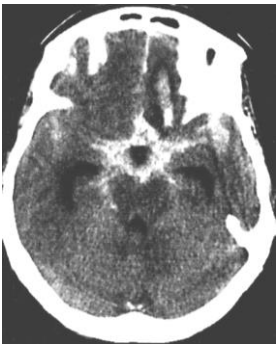


Image 2.2.6. Massive subarachnoid hemorrhage with a intracranial haematoma in the left frontal lobe of the brain

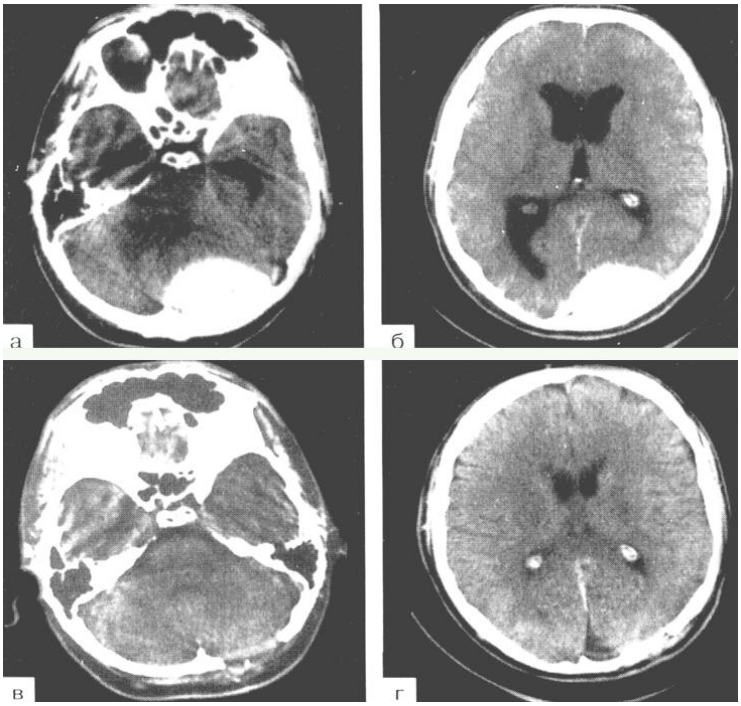


Image 2.2.7. Computed tomography.
Subacute epidural hematoma in posterior fossa with supratentorial penetration: **а, в** – before surgery. Lenticular hypertensive area of homogeneous structure with clear contours, adjacent to the left occipital bone scales. Impaction of the IV ventricle. Occlusal hydrocephalus with the third and lateral ventricles; **в, г** – through 10 days after the removal of the hematoma. The full unfolding of the left hemisphere of the cerebellum and visualization of IV ventricle, regressing of Occlusive hydrocephalus

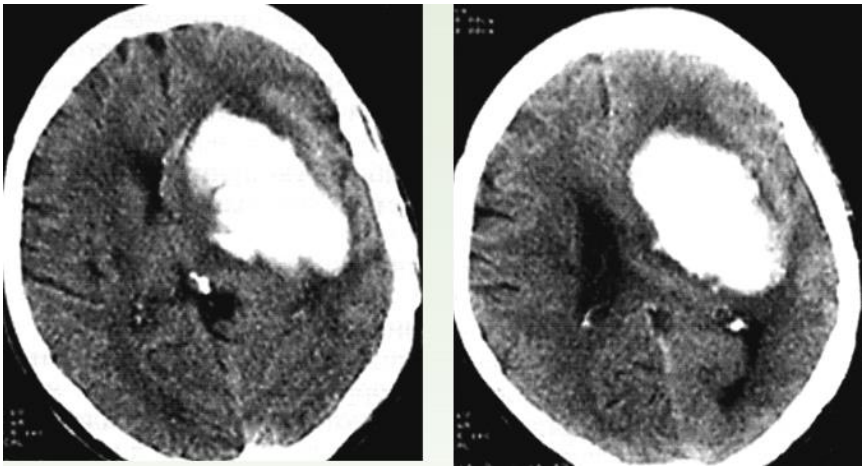


Image 2.2.8. Intracranial hematoma of the left frontal and parietal lobes with the penetraition on subcortical nuclei Before the surgery

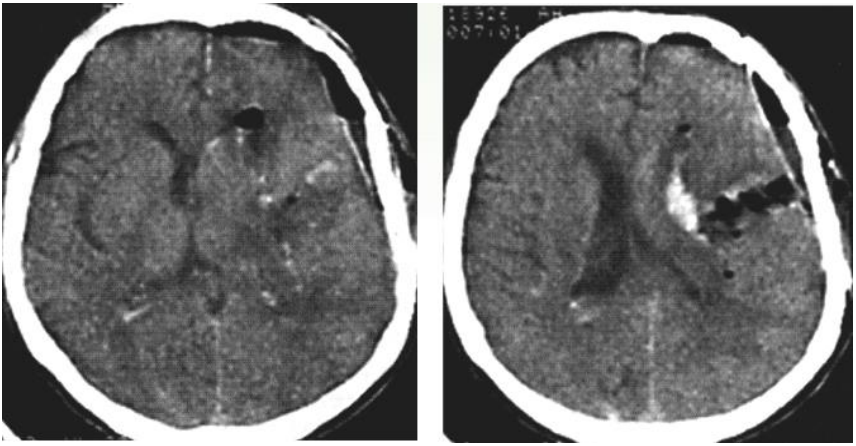


Image 2.2.9. Intracranial hematoma of the left frontal and parietal lobes with the penetraition on subcortical nuclei. In 1 day after removal of the hematoma

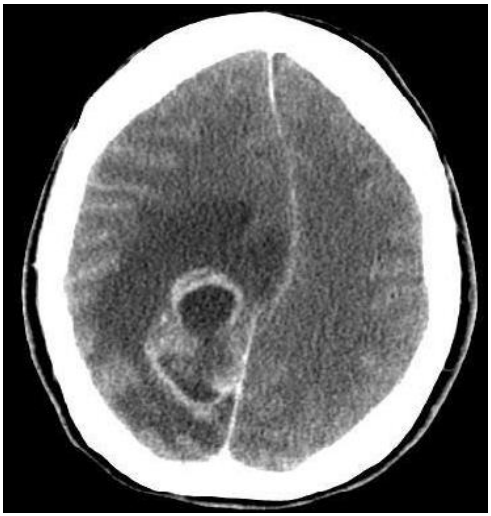


Image 2.2.10. CT scan of the head shows a glioblastoma (bottom left of image), which is an aggressive type of brain tumor

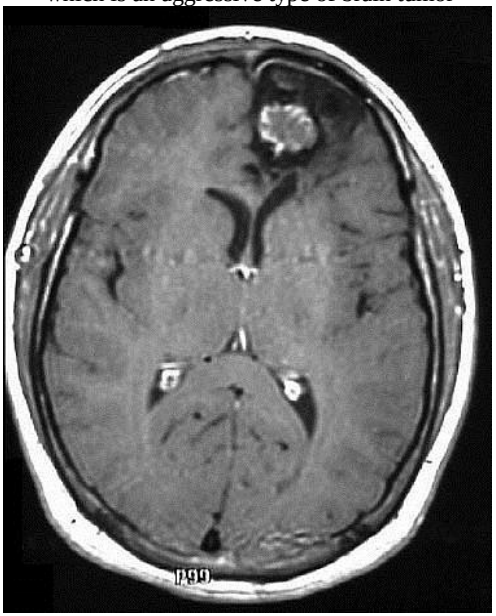


Image 2.2.11. A CT scan of the brain showed a tumor mass involving the anterior aspect of the left frontal lobe. It was associated with edema of the white matter. MRI studies confirmed the presence of a tumor mass and suggested high content of calcium and iron

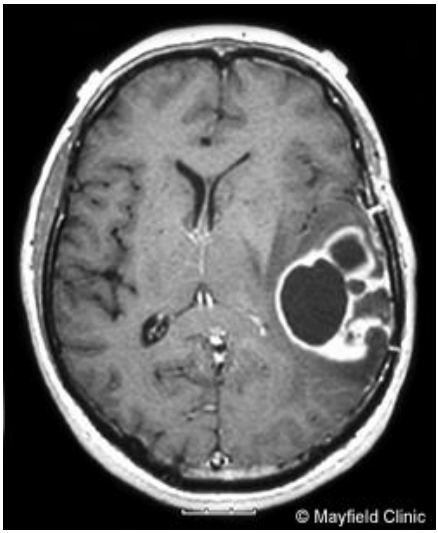


Image 2.2.12. CT Scan of a brain with a glioma

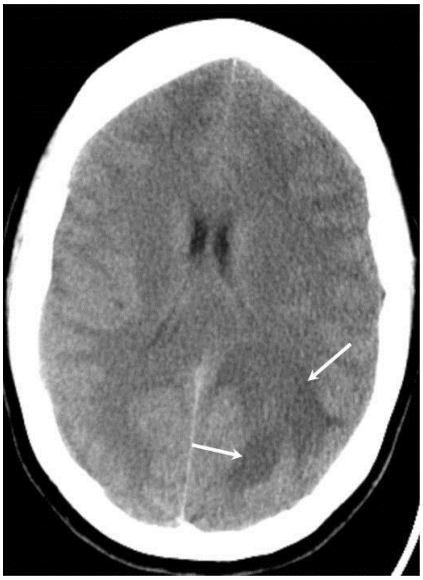


Image 2.2.13. Brain abscess.
Axial CT scan in a patient who presented with a headache, fever, and a history of a recent pneumonia demonstrates a poorly defined area of posterior parietal brain edema (arrows). Early cerebritis may not outline a focal mass clearly

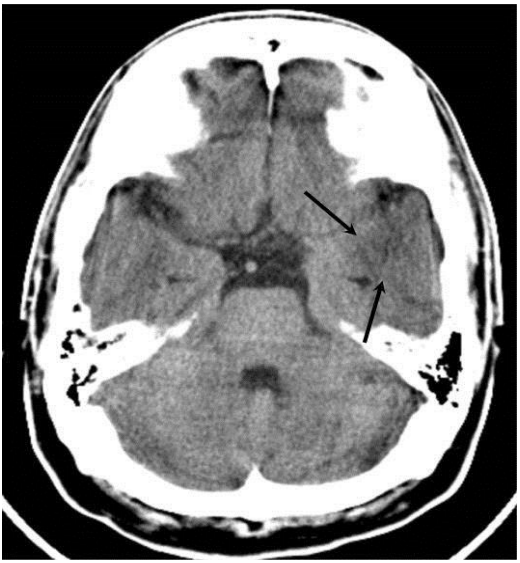


Image 2.2.14. Brain abscess.
Axial nonenhanced cranial CT scan in a patient who presented with fever, headache, and a previous paranasal sinus infection demonstrates a poorly defined pattern of mass effect and low attenuation in the left temporal lobe

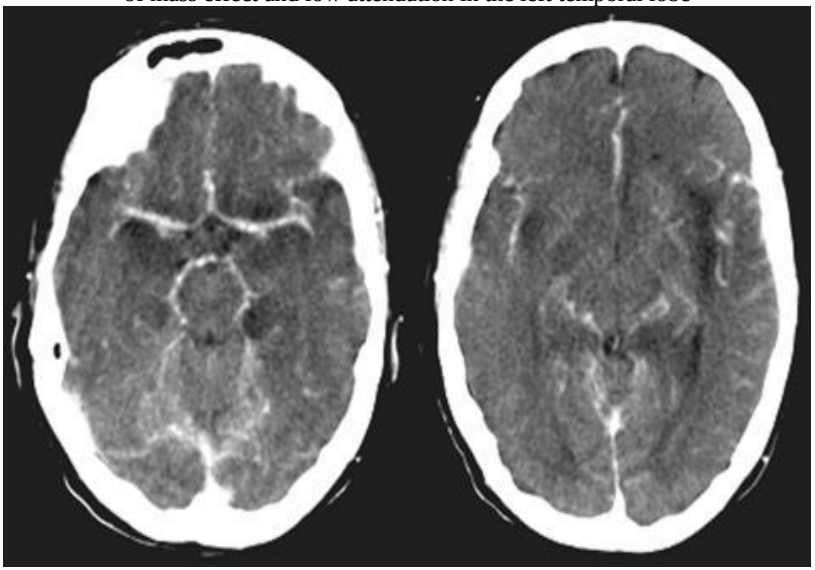


Image 2.2.15. Enhanced CT of a patient with tuberculous meningitis showing perivascular inflammatory changes and temporal infarction due to vasculitis

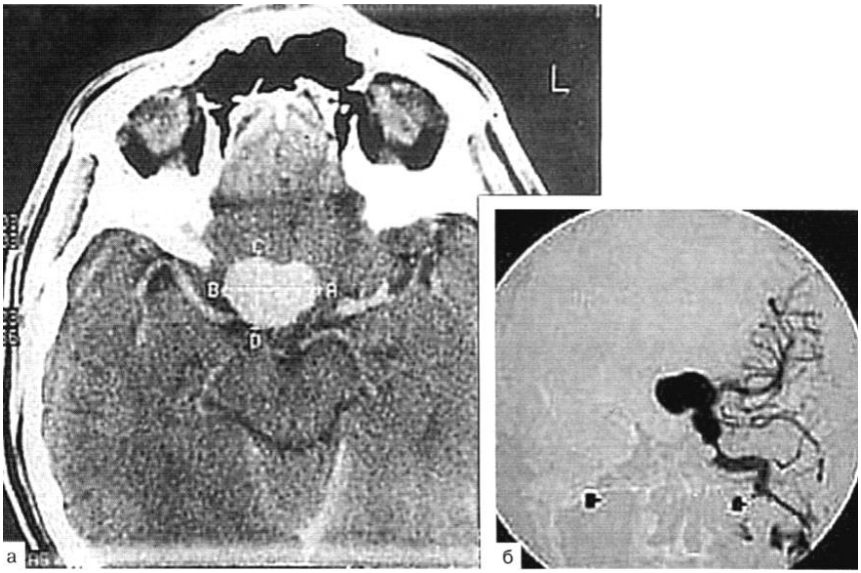


Image 2.2.16. Giant aneurysm of the left internal carotid artery:
а – spiral CT, б – Left-sided angiography in direct projection

Charter 3. MAGNETIC RESONANCE IMAGING

Description

Magnetic resonance imaging (MRI) is an imaging procedure that involves no radiation. The patient lies within a large magnet that aligns some of the protons in the body along the magnet's axis. The protons resonate when stimulated with radio-frequency energy, producing a tiny echo that is strong enough to be detected. The position and intensity of these radio-frequency emissions are recorded and mapped by a computer (*Image 2.3.1, 2.3.2*).

Image 2.3.1. MRI machine

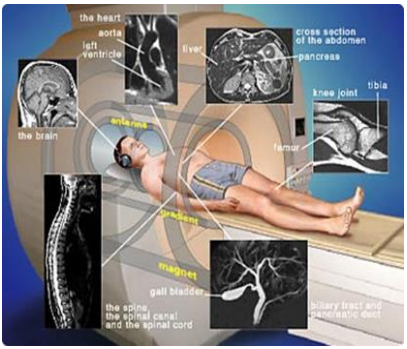


Image 2.3.2. MRI scan

The signal intensity depends upon the concentration of mobile hydrogen nuclei (or nuclear-spin density) of the tissues. Spin-lattice (Tl) and spin-spin (T2) relaxation times are mainly responsible for the relative differences in signal intensity of the various soft tissues; these parameters are sensitive to the state of water in biologic tissues (*Image 2.3.3, 2.3.4*). Pulse sequences with varying dependence on Tl and T2 selectively alter the contrast between soft tissues (*Image 2.3.6*).

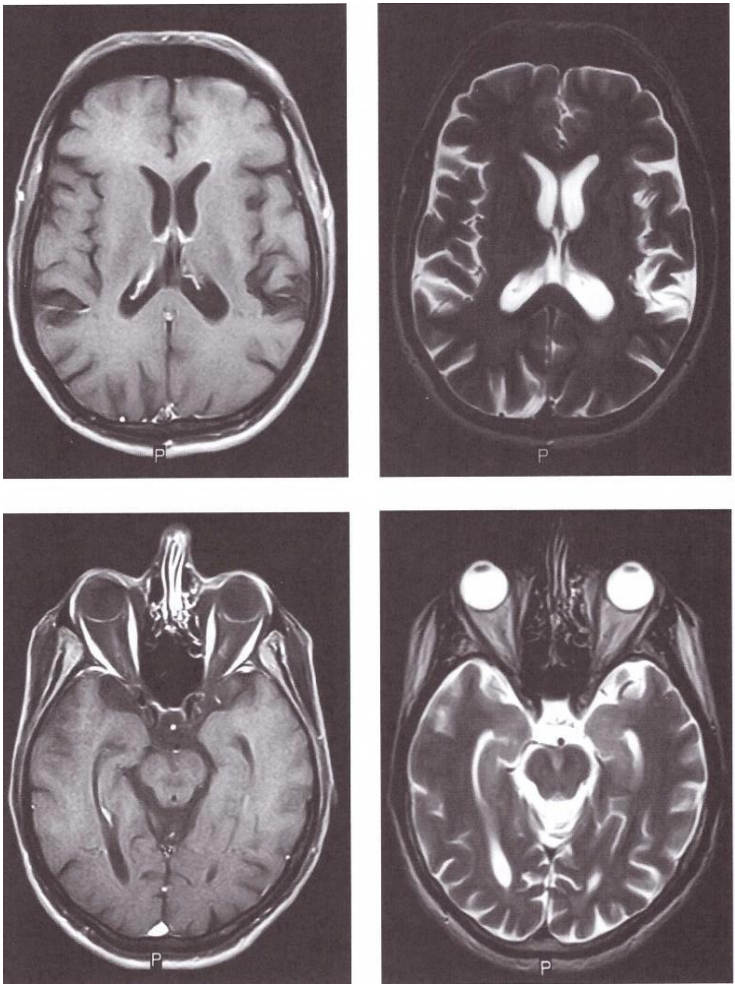


Image 2.3.3. Brain MR images from a 62-year-old man, showing the normal anatomy. Left panels: gadolinium-enhanced T1-weighted (CSF dark); right panels: T2-weighted (CSF white) images. Images at the level of the lateral ventricles (top panels) and midbrain (lower panels)

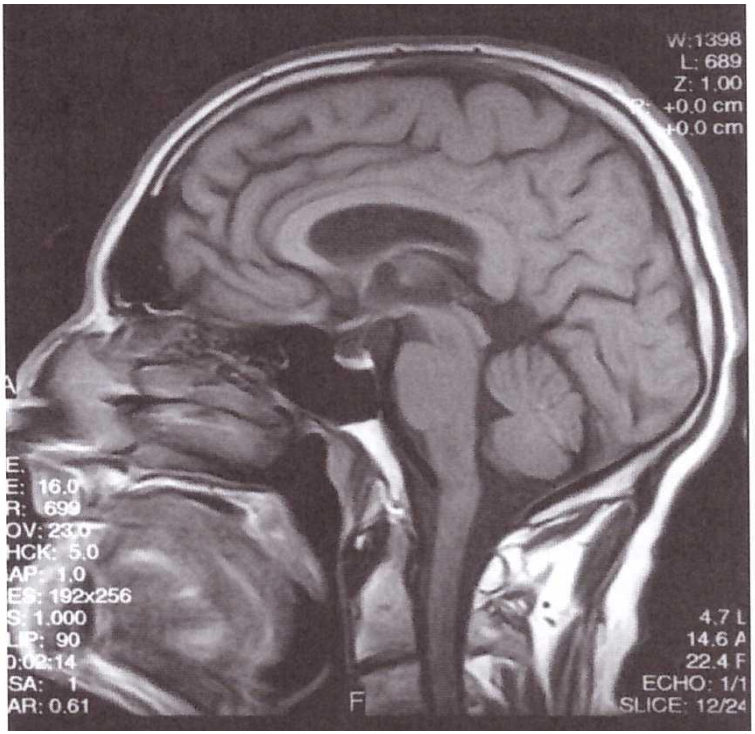


Image 2.3.4. Midsaggital T1-weighted image from same patient

The soft-tissue contrast available with MRI makes it more sensitive than CT scanning in detecting certain structural lesions. MRI provides better contrast than does CT between the gray and white matter of the brain; it is superior for visualizing abnormalities in the posterior fossa and spinal cord (*Image 2.3.9, 2.3.10*) and for detecting lesions associated with multiple sclerosis (*Image 2.3.8*) or those that cause seizures. In addition to its greater sensitivity, it is also free of bony artifact and permits multiplane (axial, sagittal, and coronal) imaging with no need to manipulate the position of the patient (*Image 2.3.5*). Because there are no known hazardous effects, MRI studies can be repeated in a serial manner if necessary. Occasional patients cannot tolerate the procedure because of claustrophobia, but sedation usually alleviates this problem.

Gadopentetate dimeglumine is stable, well-tolerated intravenously, and an effective enhancing MRI agent that is useful in identifying small tumors (*Image 2.3.7*) that, because of their similar relaxation times to normal cerebral tissue, may be missed on un enhanced MRI. It also helps to separate tumor from surrounding edema, identify leptomeningeal disease, and provide information about the blood-brain barrier.

Indications for Use & Comparison with CT

A. Stroke: Within a few hours of vascular occlusion, it may be possible to detect and localize cerebral infarcts by MRI; CT scans, on the other hand, may be unrevealing for up to 48 hours. After that period, there is less advantage to MRI over CT scanning except for the former's ability to detect smaller lesions and its superior imaging of the posterior fossa. Nevertheless, CT scanning without contrast is usually the prefeITed initial study in patients with acute stroke, in order to determine whether hemorrhage has occurred. Intracranial hemorrhage is not easily detected by MRI within the first 48 hours, and CT scan is more reliable for this purpose. Hematomas of more than 2–3 days' duration, however, are better visualized by MRI. While MRI is very effective in detecting and localizing vascular malformations, angiography (*Image 2.3.1, 2.3.2*) is still necessary to define their anatomic features and plan effective treatment. In cases of unexplained hematoma, a follow-up MRI obtained 3 months later may reveal the underlying cause, which is sometimes unmasked as the hematoma resolves.

B. Tumor: Both CT scans and MRI are very useful in detecting brain tumors, but the absence of bone artifacts makes MRI superior for visualizing tumors at the vertex or in the posterior fossa and for detecting acoustic neuromas. Secondary effects of tumors, such as cerebral herniation, can be seen with either MRI or CT scan, but MRI provides more anatomic information. Neither technique, however, permits the nature of the underlying tumor to be determined with any certainty. Pituitary tumors are often visualized more easily by MRI than CT because of the absence of bone or dental metal artifacts.

C. Trauma: In the acute phase following head injury, CT scan is preferable to MRI because it requires less time, is superior for detecting intracranial hemorrhage, and may reveal bony injuries. Similarly, spinal MRI should not be used in the initial evaluation of patients with spinal injuries because nondisplaced fractures are often not visualized. For followup purposes, however, MRI is helpful for detecting parenchymal pathology of the brain or spinal cord.

D. Dementia: In patients with dementia, either CT or MRI can help in demonstrating treatable structural causes, but MRI appears to be more sensitive.

E. Multiple Sclerosis: In patients with multiple sclerosis (*Image 2.3.8*), it is often possible to detect lesions in the cerebral white matter or the cervical cord by MRI, even though such lesions may not be visualized on CT scans. The demyelinating lesions detected by MRI may have signal characteristics resembling those of ischemic changes, however, and clinical correlation is therefore always necessary. Gadolinium-enhanced MRI permits lesions of different ages to be distinguished. This ability facilitates the diagnosis of multiple sclerosis: the presence of lesions of different ages suggests a multiphasic disease, whereas lesions of similar age suggest a monophasic disorder, such as acute disseminated encephalomyelitis.

F. Infections: MRI is very sensitive in detecting white-matter edema and probably permits earlier recognition of focal areas of cerebritis (*Image 2.3.11*) and abscess formation (*Image 2.3.5*) than is possible with CT.

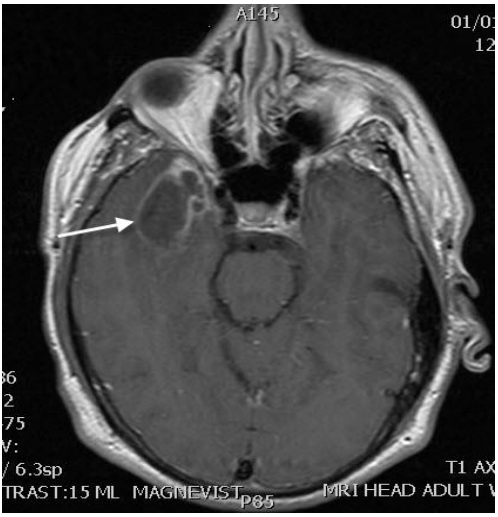


Image 2.3.5. Cerebral abscess.
This T1 contrast-enhanced MRI of a right temporal abscess demonstrates an irregular mass with moderate peripheral enhancement. This image was obtained early in the clinical course. The etiology of the brain abscess was an abscessed tooth

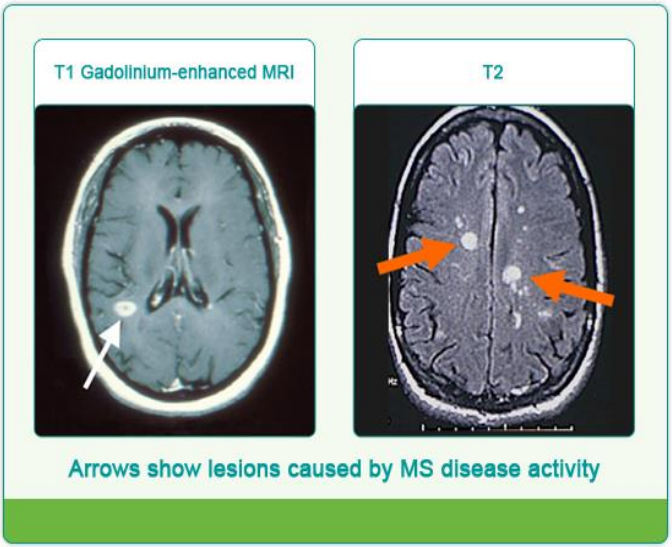


Image 2.3.6. These scans show both the number and size of new lesions. They also show older, inactive lesions. It's important to note, however, that they do not reveal new lesions as accurately as T1 scans. Regular T2 MRIs can be important for tracking long-term disease progression

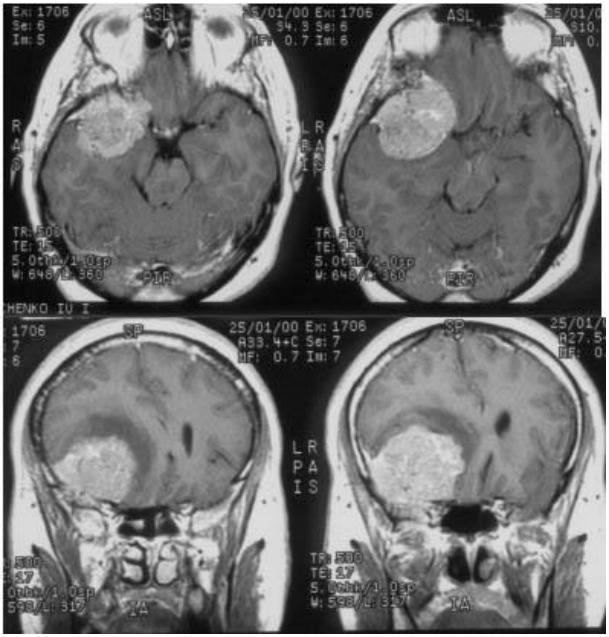


Image 2.3.7. Basal meningiomas MRI

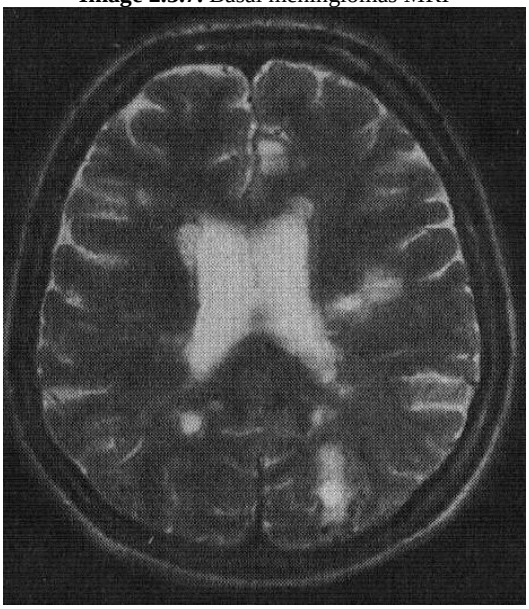


Image 2.3.8. Multiple sclerosis MRI

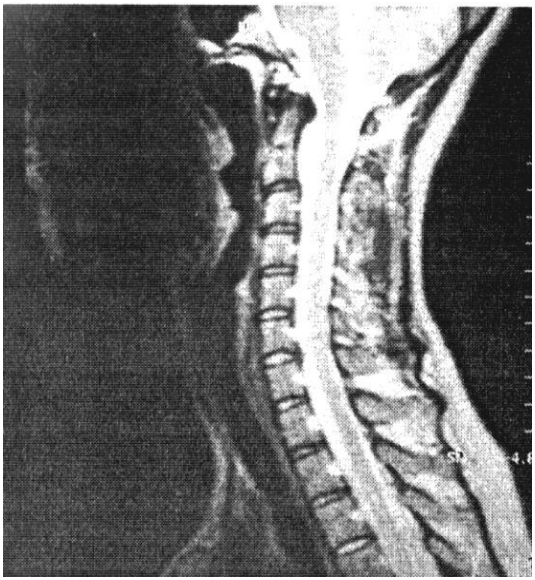


Image 2.3.9. Spine is normal, the cervical MRI

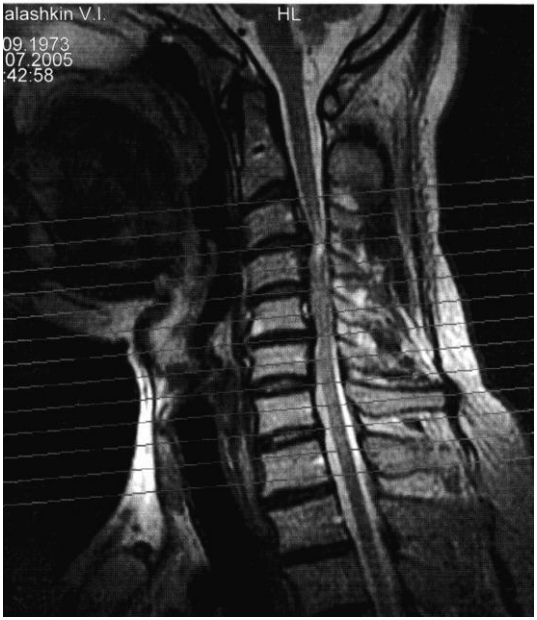


Image 2.3.10. MR signs of compression-ischemic

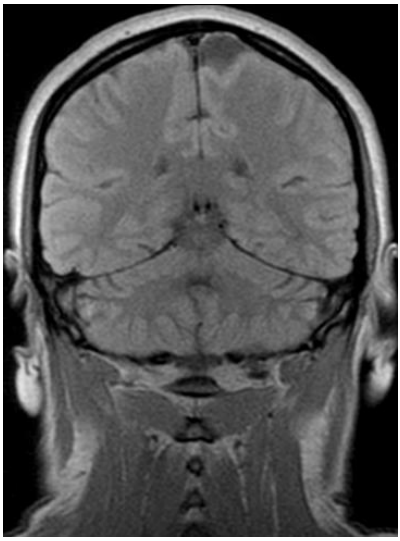


Image 2.3.11. A cyst of convexital area

Contraindications

Contraindications to MRI include the presence of intracranial clips, metallic foreign bodies in the eye or elsewhere, pacemakers, cochlear implants, and conditions requiring close monitoring of patients. Furthermore, it can be difficult to image patients with claustrophobia, gross obesity, uncontrolled movement disorders, or respiratory disorders that require assisted ventilation or carry any risk of apnea. Advances in MRI-compatible mechanical ventilators and monitoring equipment now allow even critically ill patients to be scanned safely.

Charter 4. POSITRON EMISSION TOMOGRAPHY

Positron emission tomography (PET) is an imaging technique that uses positron-emitting radiopharmaceuticals, such as 18F-fluoro-2-deoxY-D-glucose or lSF-L-dopa, to map brain biochemistry and physiology. PET thus complements other imaging methods that provide primarily anatomic information, such as CT and MRI, and may demonstrate functional brain abnormalities before structural abnormalities are detectable.

Although its availability is currently limited, PET has proved useful in several clinical settings. When patients with medically refractory epilepsy are being considered for surgical treatment, PET can help identify focal areas of hypometabolism in the temporal lobe as likely sites of the origin of seizures. PET can also be useful in the differential diagnosis of dementia, since common dementing disorders such as Alzheimer's disease and multi-infarct dementia exhibit different patterns of abnormal cerebral metabolism. PET can help distinguish between clinically similar movement disorders, such as Parkinson's

disease and progressive supranuclear palsy, and can provide confirmatory evidence of early Huntington's disease. PET may also be of value in grading gliomas, selecting tumor biopsy sites, and distinguishing recurrent tumors from radiation-induced brain necrosis. PET has also been an important tool with which to investigate the functional involvement of different cerebral areas in behavioral and cognitive tasks. The major problems associated with PET are its expense, the requirement that radioactive isotopes are produced near the site of imaging, and the exposure of subjects to radiation (*Image 2.4.1, 2.4.2*).

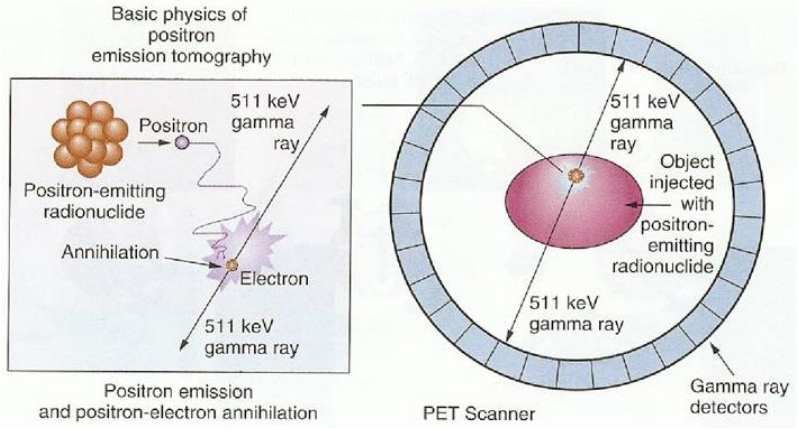


Image 2.4.1. Principle of Positron Emission Tomography

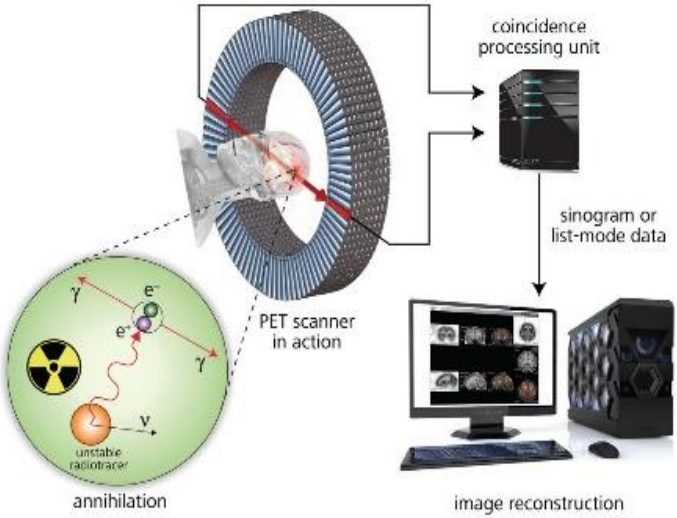


Image 2.4.2. Principle of Positron Emission Tomography

Charter 5. SINGLE-PHOTON EMISSION COMPUTED TOMOGRAPHY

Single-photon emission computed tomography (SPECT) involves the administration intravenously or by inhalation of chemicals containing isotopes that emit single photons in order to image the brain (*Image 2.5.1)*. SPECT has been used, in particular, for perfusion studies, the investigation of receptor distribution, and the detection of areas of increased metabolism such as occurs with seizures. At present the technique is more of academic interest than clinical relevance, but it is considerably cheaper than PET and the isotopes in use do not have to be produced near the site of imaging.

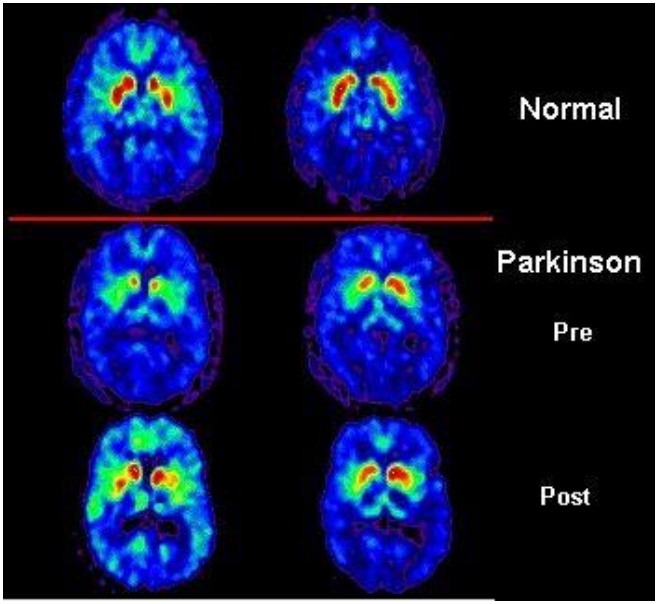


Image 2.5.1. PET scan for Parkinson Disease

Charter 6. FUNCTIONAL MAGNETIC RESONANCE IMAGING

Functional MRI (fMRI) involves the intravenous administration of contrast material that lowers signal intensity on MRI in relation to blood flow as the material passes through the cerebral vasculature. Studies are performed with the subject at rest and then after an activation procedure (Image 6.1), so that the change in signal intensity reflects the effect of the activation procedure on local cerebral blood flow.

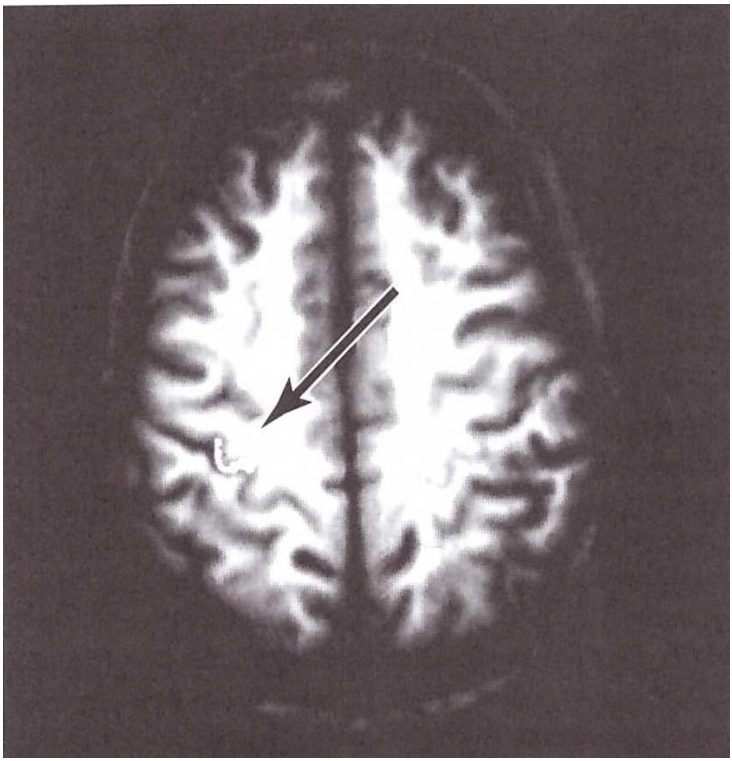


Image 2.6.1. A functional MR brain image obtained from a patient during rapid finger tapping of the left hand. An increase in relative blood flow in the region of the right motorstrip is imaged (arrow) and superimposed upon a T1-weighted MR scan

Charter 7. MAGNETIC RESONANCE SPECTROSCOPY

Magnetic resonance spectroscopy is an investigational tool available in some centers; it provides information about chemical composition of tissue (*Image 2.7.1*). Proton magnetic resonance spectroscopy (IH-MRS) may be used to determine levels of N-acetylaspartate exclusive to neurons or choline creatinine and lactate (glia and neurons). Measurements of brain concentration may be useful to detect specific tissue loss in diseases such as Alzheimer's disease or hypoxicischemic encephalopathy, or to classify brain tumors or lateralize temporal lobe epilepsy. Phosphorus magnetic resonance (31P-MRS) may be useful in the evaluation of metabolic muscle diseases.

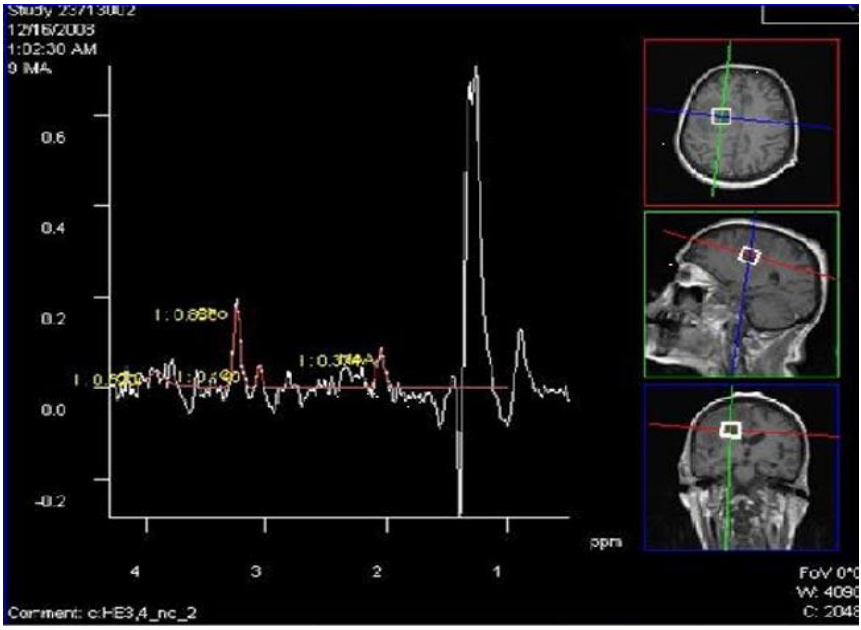


Image 2.7.1. MR Spectrum of Abscess cavity in the right periventricular region. Large lactate peak was noted

Charter 8. MAGNETIC RESONANCE ANGIOGRAPHY

Several imaging techniques that have been used to visualize blood vessels by MRI depend upon certain physical properties of blood to generate contrast (*Image 2.8.1, 2.8.2, 2.8.3*). These properties include the rate at which blood is supplied to the imaged area, its velocity and relaxation time, and the absence of turbulent flow. MR angiography has been most useful in visualizing the carotid arteries and proximal portions of the intracranial circulation, where flow is relatively fast. The images are used to screen for stenosis or occlusion of vessels and for large atheromatous lesions. It has particular utility in screening for venous sinus occlusion. Resolution is inferior to that of conventional angiography and, in vessels with slow flow, it may be difficult to recognize occlusive disease. Although current techniques allow visualization of arteriovenous malformations and aneurysms greater than 3 mm in diameter, further research is needed to explore the usefulness of the technique, improve its sensitivity, and define its limitations.

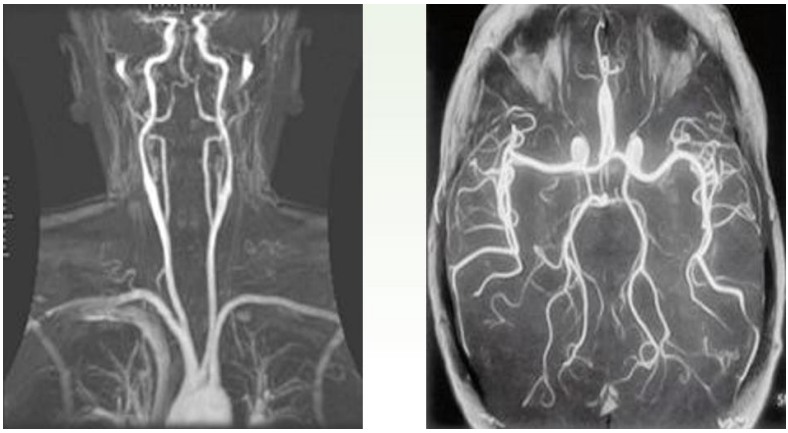


Image 2.8.1. MRI in the vascular mode

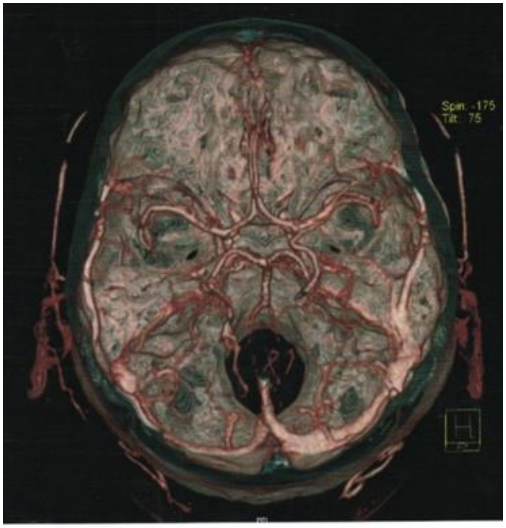


Image 2.8.2. SCT-angiography of a healthy person, 39 years old

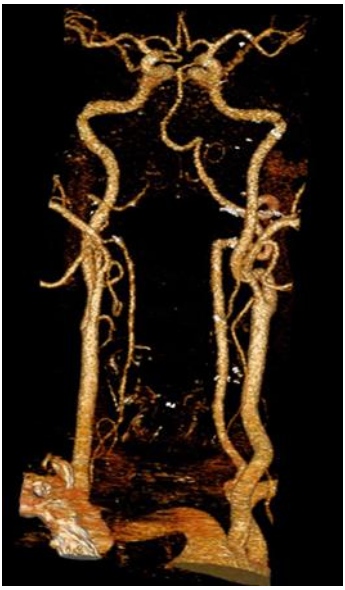


Image 2.8.3. SCT-angiography of the neck, lateral projection

Charter 9. MYELOGRAPHY

Injecting radiopaque contrast medium into the subarachnoid space permits visualization of part or all of the spinal subarachnoid system. The cord (Image 2.9.1) and nerve roots, which are silhouetted by the contrast material in the subarachnoid space, are visualized indirectly. The procedure is invasive and carries the risks of headache, low back pain, confusion, arachnoiditis, inadvertent intravenous injection of contrast material, and vasovagal reactions. Rarely, traumatic herniated intervertebral disks have occurred because of poor technique, as has damage to nerve roots.

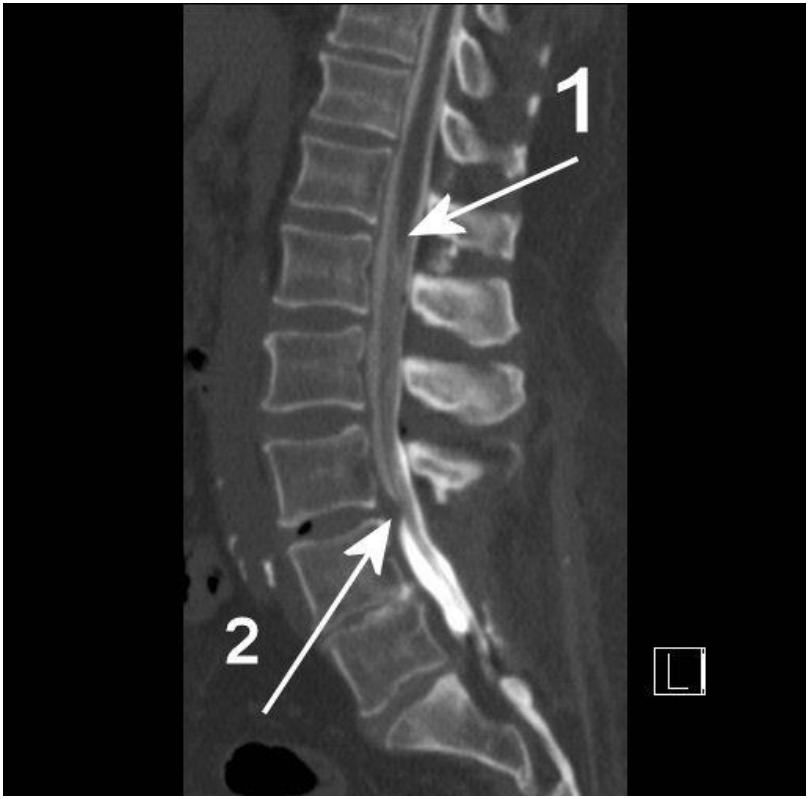


Image 2.9.1. Arrow number (1) points to the normal spinal cord at its lower end. Arrow number (2) points to a disc herniation (also sometimes referred to by the non-scientific term "slipped disc"). This narrows the spinal canal and compresses the nerve roots. This patient had pain and difficulty walking.

Charter 10. DOPPLER ULTRASONOGRAPHY

Over the past four decades, a variety of non-invasive tests and clinical applications have been developed for detection and monitoring of cerebrovascular disease.

The goals of non-invasive cerebrovascular testing are to differentiate normal (*Image 2.10.1, 2.10.2*) from diseased arteries, identify all categories of stenosis (*Image 2.10.8, 2.10.9*), localize the disease process including occlusions, detect progression of disease, detect and quantify cerebral embolism, demonstrate the morphologic characteristics of an atherosclerotic plaque, and assess the potential of the collateral circulation to maintain cerebral blood flow. Although not all of these goals are currently met by a single test procedure, a combination of extracranial and intracranial tests can meet the demand. Skepticism towards ultrasonography is based largely on the lack of knowledge how to perform, interpret and use the results of ultrasound tests in research and clinical practice. In addition, the accuracy of ultrasound testing is dependent on the skill, knowledge and experience of sonographers. The practice of ultrasound (both performance and interpretation) should be a mandatory part of the residency training for physicians of different specialties. Interpreting physicians have to demonstrate competence by completing the required number of hours of continuing medical education in ultrasound methods and supervised interpretation of a set number of cases for each imaging modality.

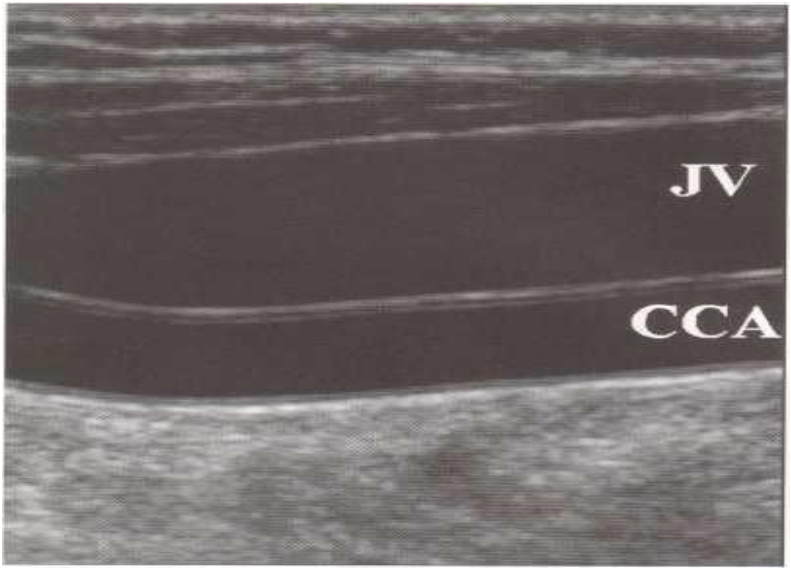


Image 2.10.1. Brightness-modulated (B-mode) image
of the common carotid artery (CCA) and the jugular vein (JV)

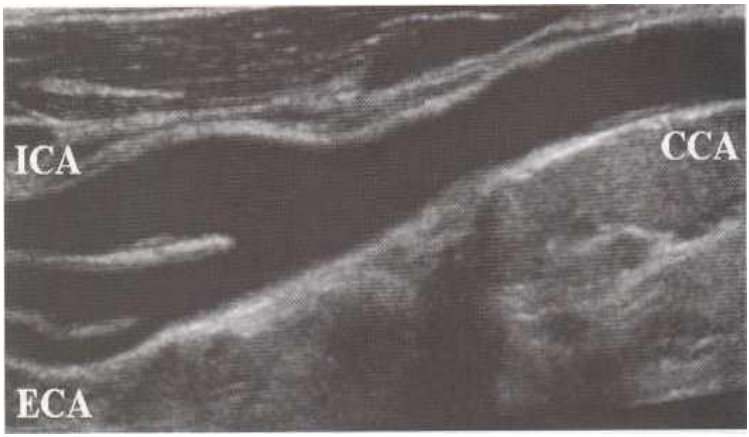


Image 2.10.2. Longitudinal B-mode image of the internal carotid artery (ICA) bulb, external carotid artery (ECA) and the distal portion of the common carotid artery

In this technique, echoes reflected from anatomic structures are plotted on an oscilloscope screen in two dimensions. The resulting brightness at each point reflects the density of the imaged structure. The technique has been used to image the carotid artery and its bifurcation in the neck, permitting evaluation of the extent of extracranial vascular disease. Blood flowing within an artery does not reflect sound, and the lumen of the vessels therefore appears black. The arterial wall can be seen, however, and atherosclerotic lesions can be detected. Note that with severe stenosis or complete occlusion of the internal carotid artery, it may not be possible to visualize the carotid artery bifurcation.

Mastering cerebrovascular ultrasound requires knowledge of anatomy, physiology of cardiovascular and nervous systems, fluid dynamics and pathologic changes in a variety of cerebrovascular disorders, as well as basic ultrasound physics and instrumentation Ultrasound can be used to measure the velocity of blood flow through an artery (*Image 2.10.3*). Sound waves within a certain frequency range are reflected off red blood cells, and the frequency of the echo provides a guide to the velocity of the flow. Any shift in frequency is proportional to the velocity of the red cells and the angle of the beam of sound waves. When the arterial lumen is narrowed, the velocity of flow increases; increased frequencies are therefore recorded by Doppler ultrasonography. Spectral analysis of Doppler frequencies is also used to evaluate the anatomic status of the carotid artery.

Transcranial Doppler (*Image 2.10.4, 2.10.7*). studies are now used routinely in many centers to detect intracranial arterial lesions or vasospasm (eg, after subarachnoid hemorrhage) and to assess the hemodynamic consequences of extracranial disease of the carotid arteries

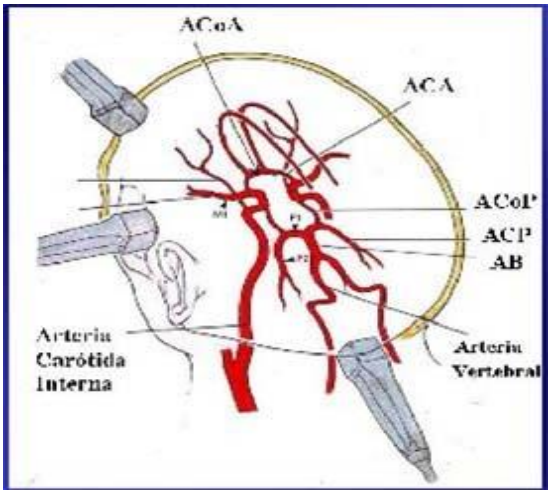


Image 2.10.3. Principle of examining cerebral vessels with an ultrasound transducer for Doppler sonography

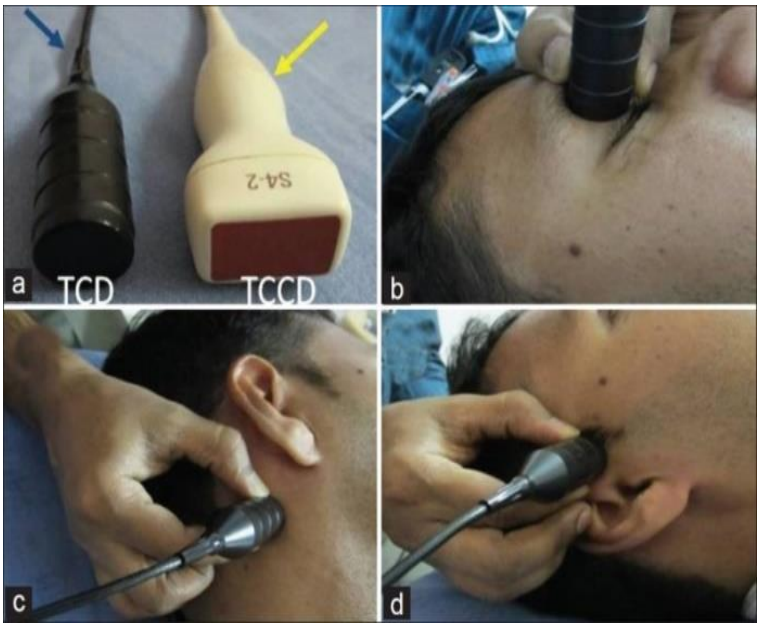


Image 2.10.4. Depending on the region to be evaluated, transcranial Doppler ultrasound is performed by holding the transducer up to one of three windows in the head, including the orbital window (top) temporal window (left), and suboccipital window (bottom). Image courtesy of Dr. Orlando Valls Pérez

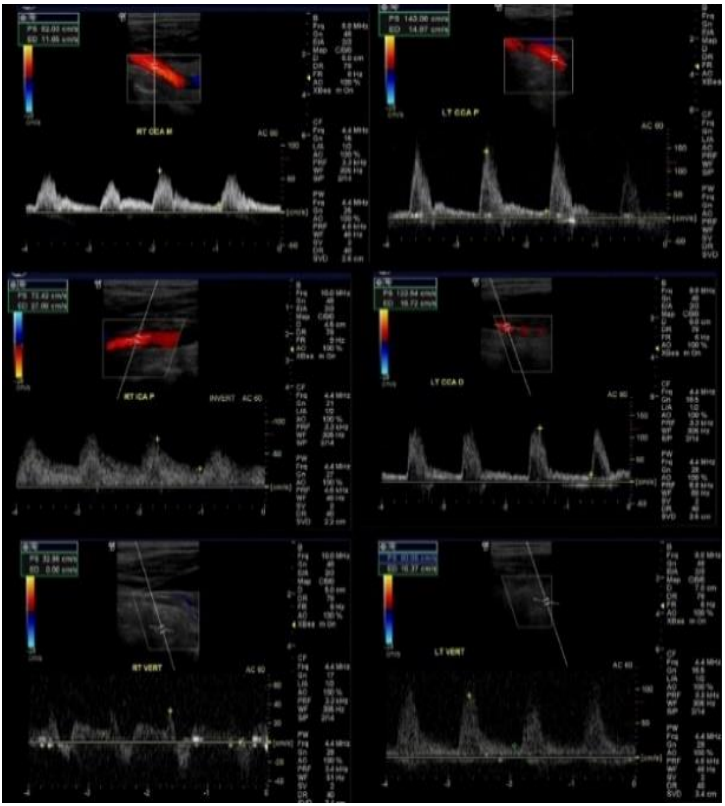


Image 2.10.5. Right innominate artery stenosis

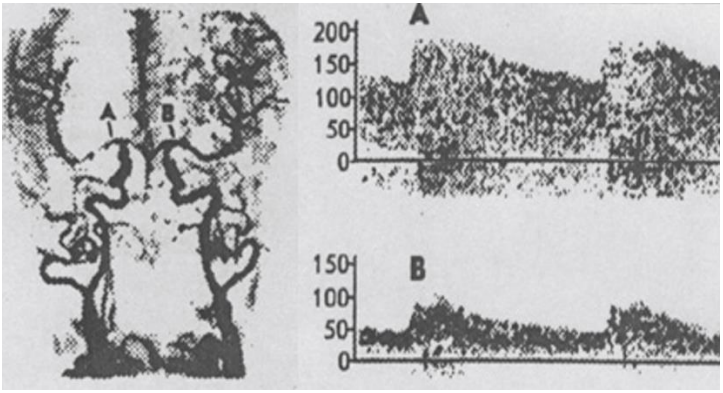


Image 2.10.6. Angiography of the head vessels and the spectrogram of the middle cerebral artery A – compression of the right; B – norm

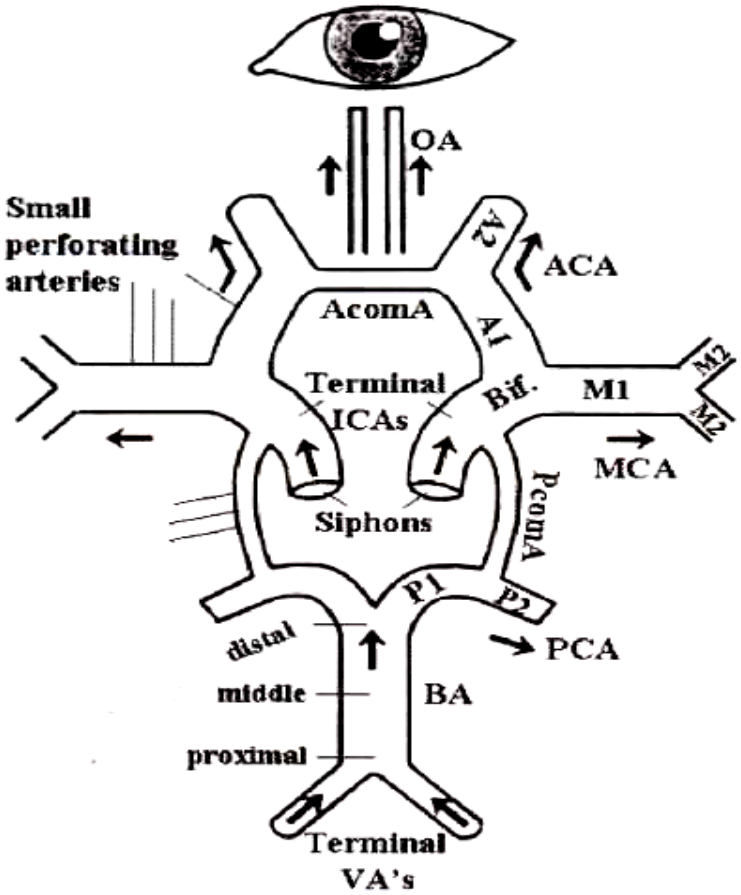


Image 2.10.7. A schematic drawing of the circle of Willis, siphons and intracranial posterior circulation vessels.
OA, ophthalmic artery; ICA, internal carotid artery; AcomA, anterior communicating artery; PcomA, posterior communicating artery; A1, A2, segments of the anterior cerebral artery; M1, M2, segments of the posterior cerebral artery; P1, P2, segments of the posterior cerebral artery; VA, vertebral arter

Ultrasonic stream images, whether color streams or spectral Doppler images (*Image 2.10.5*), are obtained from motion measurements. In ultrasound scanners, a series of pulses are transmitted to detect the movement of blood. The echo from motionless tissue does not change. Echoes from moving scatterers reflect slight differences in time during which the signal returns to the receiver. These differences can be measured as a direct time difference or, commonly, in terms of the phase shift from which the "Doppler frequency" is obtained.

They are then processed to produce a color flow image or Doppler sonogram (*Image 2.10.6*). The movement should be in the direction of the beam; if the flow is perpendicular to the ray. The size of the Doppler signal depends on:

• the blood flow velocity: as the velocity increases, the Doppler frequency also increases;

• Ultrasound frequency: Higher ultrasound frequencies result in an increase in Doppler frequency. As with B-mode, lower ultrasound frequencies penetrate better.

• Frequency choice is a result between better flow sensitivity or better penetration;

• Angle of dispersion: Doppler frequency increases as the ultrasonic Doppler beam becomes more aligned with the direction of flow (the angle between the beam and the direction of flow becomes smaller). This is extremely important when using ultrasound Doppler.

Doppler signals are received from all vessels in a path of the ultrasound beam (until the ultrasound beam is weak enough due to the depth). Continuous wave Doppler Ultrasound cannot locate specific velocities within the beam and cannot be used to produce color images of the flow. Relatively inexpensive ultrasound Doppler systems are available that use Continuous wave Doppler transducers to obtain a Doppler signal without adding B-mode images. Continuous Wave Doppler is also used in cardiac scanners to examine high velocities in the aorta.

Modes of the ultrasonic flow. Since the color image of the stream provides a limited amount of information in a large area, and the spectral Doppler provides more detailed information about a small area, these two modes complement each other and are used in practice. The color flow image can be used to identify vessels requiring inspection, to determine the presence and direction of flow, to highlight general circulation anomalies in the color flow image, and to provide beam / vessel angle correction for velocity measurements. Pulse-wave Doppler analysis is used to analyze flow in specific areas of a vessels. When using a color flow image with a pulsed wave Doppler mode, the color flow / B-mode image remains stationary while the pulsed wave doppler is activated. Some firms provide simultaneous color flow and pulse wave imaging.

When these modes are used at the same time, the performance of each is degraded. Because transducer elements are used in three modes (B-mode, color flow and pulsed wave Doppler), the frame rate decreases, the color flow decreases in size, and the available pulse repetition rate decreases, resulting in increased susceptibility.

Power Doppler mode displays the output color flow, not the Doppler signal. Power Doppler does not indicate flow direction. It is often used in conjunction with frame averaging to increase sensitivity to low flow rates and speeds.

Combined color flow modes include power and speed data. They can also be sensitive to low flow. Most of these factors are adjusted for a specific mode when the application is selected (for example, fetal scan), although the operator usually changes many of the controls during the scan to optimize the image.

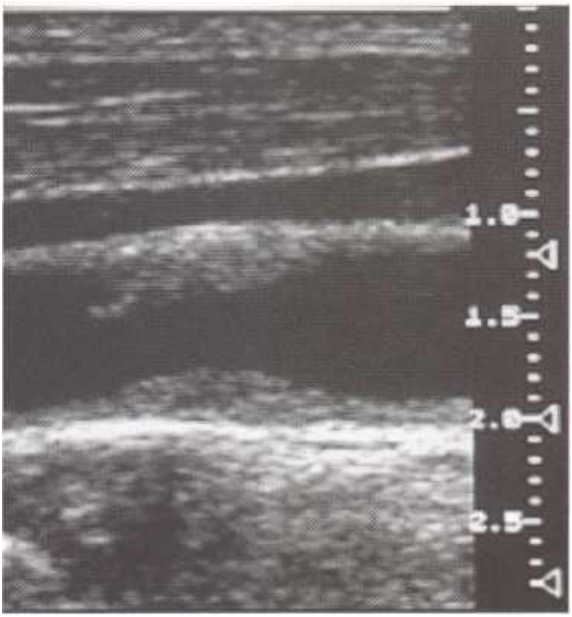


Image 2.10.8. Homogeneous plaque.A concentric plaque is present on both sides of the longitudinal arterial projection

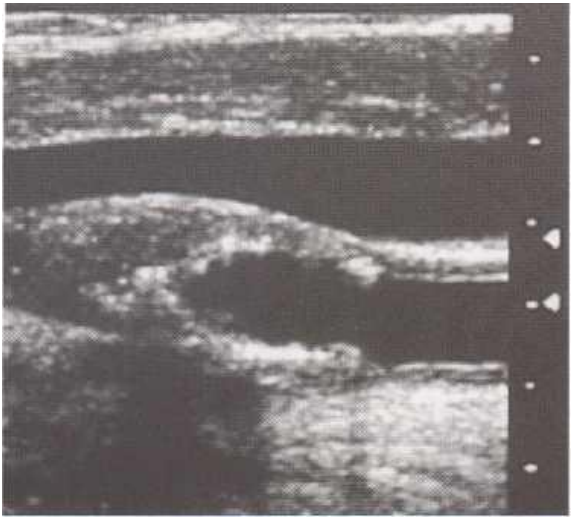


Image 2.10.9. Heterogeneous plaque. The B-mode image of the internal carotid artery (ICA) bulb shows a plaque with areas of increased and decreased echogenicity as well as shadowing at the distal wall

COLOR IMAGE OF THE STREAM

Flow Doppler ultrasound creates a color-coded Doppler map superimposed on a B-mode ultrasound image (color flow maps). Although a pulsed ultrasound signal is used to visualize a color stream, its processing differently from the processing used to obtain a Doppler sonogram. When rendering a color stream image, it may be necessary to generate several thousand color points of stream information for each frame superimposed on the B-mode image.

Color stream rendering uses fewer shorter pulses along each color scan line of the image to obtain an average frequency shear and variance in each small measurement area. This frequency offset is displayed as a color pixel. The scanner then repeats this for several lines to create a color image that is superimposed on the B-mode image. The converter elements quickly switch between B-mode and color image flow to give the impression of a combined simultaneous image. The pulses used to produce a color image of a stream are typically three to four times longer than for a B-mode image, with a corresponding loss in axial result. Color assignment to frequency shifts is usually based on direction (for example, red for Doppler shifts towards the ultrasound beam and blue from) and amplitude (different hues or lighter saturation for higher frequency shifts). The color Doppler image depends on general Doppler factors, especially the need for a good beam / flue angle.

In practice, an experienced operator will change the scanning approach to obtain good angles in order to obtain unambiguous images of the stream.

SPECTRAL OR PULSE-WAVE

Doppler Pulse-wave Doppler ultrasound is used to obtain a sonogram of the artery or vein being examined. The sonogram allows you to measure the change in speed during the cardiac cycle and the distribution of speeds in the volume. If an accurate angular correction is made, absolute velocities can be measured. The best sonogram is obtained when the B-mode image and the color image are frozen, allowing spectral Doppler to be used all the time. If simultaneous imaging (real-time duplex or triple imaging) is used, the temporal result of the sonogram is impaired.

Flow Waveform Analysis Dimensionless flow waveform and spectrum analysis has proven to be a useful technique in vascular studies. Its advantage is that the derived indices are independent of the beam / flux angle. Blood flow waveform changes have been used to study peripheral arterial circulation in adults and distal changes (fetal circulation and uterine arteries). While the breadth of possible applications shows that this variant of technique is versatile, it also serves as a reminder of a number of factors that cause changes in the local Doppler spectrum.

FLOW WAVEFORM SHAPE: MEASUREMENT INDICES.

Many different indices have been used to quantitatively describe the Flow waveform shape. In general, this is a trade-off between simplicity and the amount of information obtained. The following indicators are commonly used: • Systolic / diastolic ratio: (S / D); • Resistance Index: (S-D) / D, also called Purselot Index; • Pulsatility index: (S-D) / Vm. PI is the only useful indicator when end-diastolic flow is not available (Image 10.10).

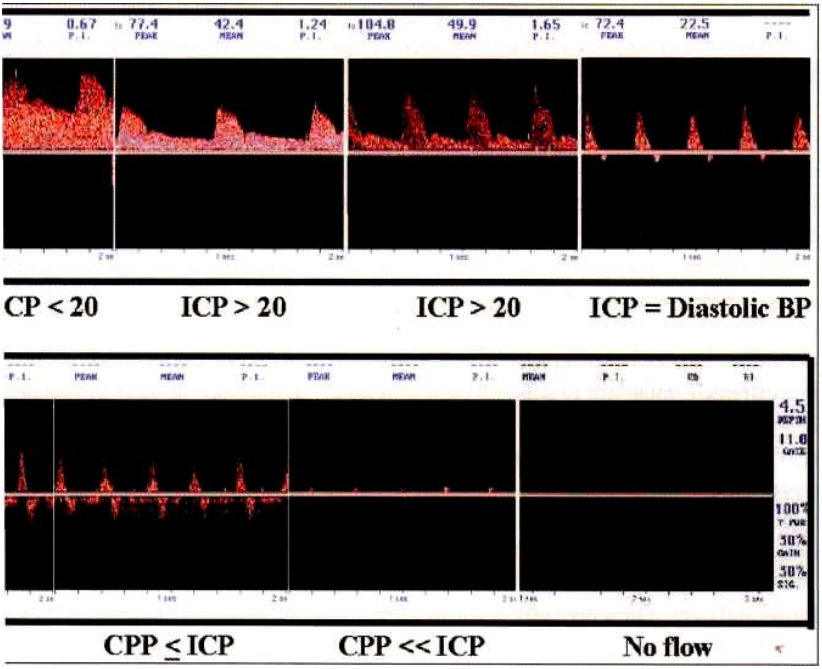


Image 2.10.10. IP and cerebral circulatory arrest. ICP, intracranial pressure; CPP, cerebral perfusion pressure

In addition to these measures, the flow waveform can be described or classified by the presence or absence of a particular feature, such as the absence of end-diastolic flow and the presence of a postsystolic notch. Typically, a low pulsation waveform indicates low distal resistance, and high pulsation waveforms occur in high resistance vascular zones, although the presence of proximal stenosis, vessel stealing, or arteriovenous fistulas may alter the waveform. Care should be taken when trying to interpret indices as absolute measurements of upstream or downstream factors. For example, a change in heart rate can change the shape of the flow curve and cause significant changes in readings.

PARTS 3. OTHER METHOD OF INVESTIGATION

Charter 1. RADIOISOTOPE METHOD: encephaloscintigraphy and encephaloangioscintigraphy

They are among the methods for diagnosing CNS pathology that use radioactive indicators (usually technetium). The information content of these methods is high in intracranial well-vascularized tumors (meningiomas, gliomas with malignancy features).

Currently, the methods of ultrasonic location are becoming more and more widespread, the diagnostic information content of which, thanks to the technical improvement of the devices, is constantly increasing.

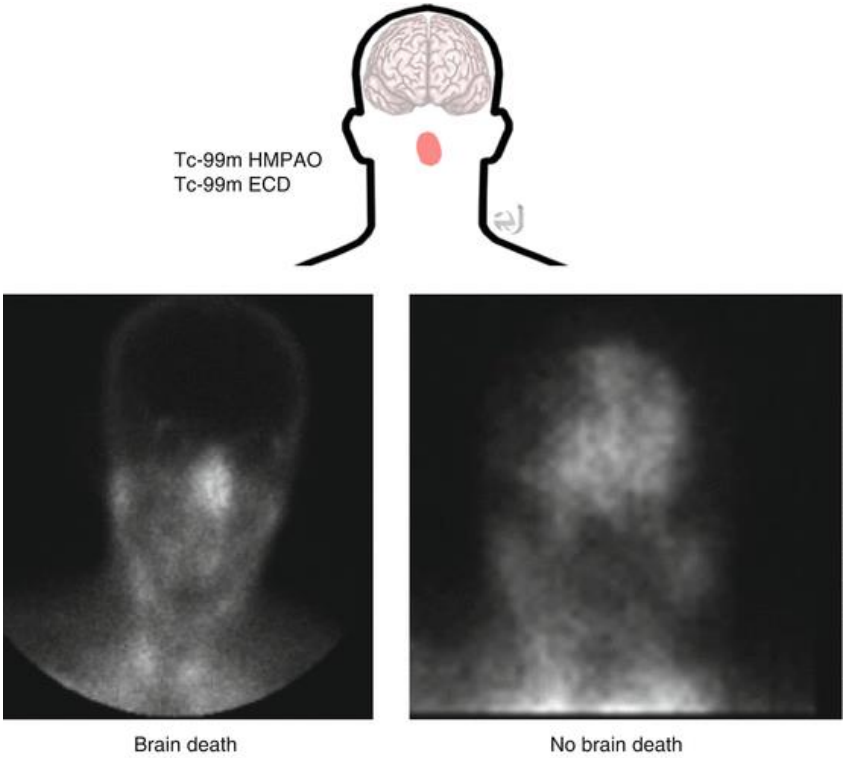


Image 3.1.1. Distribution and Clearance: Brain-Specific Agents

Charter 2. LUMBAR PUNCTURE

Indications

Lumbar puncture is indicated for the following purposes:

1. Diagnosis of meningitis and other infective or inflammatory disorders, subarachnoid hemorrhage, hepatic encephalopathy, meningeal malignancies, paraneoplastic disorders, or suspected abnormalities of intracranial pressure.

2. Assessment of the response to therapy in meningitis and other infective or inflammatory disorders.

3. Administration of intrathecal medications or radiologic contrast media.

4. Rarely, to reduce cerebrospinal fluid-(CSF) pressure.

Contraindications

1. Suspected intracranial mass lesion. In this situation, performing a lumbar puncture can hasten incipient trans tentorial herniation.

2. Local infection overlying the site of puncture.

Under this circumstance, cervical or cisternal puncture should be performed instead.

3. Coagulopathy. Clotting-factor deficiencies and thrombocytopenia (below 20,000/mm^3 or rapidly falling platelet counts) should be corrected before lumbar puncture is undertaken, to reduce the risk of hemorrhage.

4. Suspected spinal cord mass lesion. Lumbar puncture in this case should be performed only in association with myelography, which is used to determine the presence and level of structural spinal pathology.

Preparation

A. Personnel: With a cooperative patient, lumbar puncture can generally be performed by one person. An assistant can be helpful in positioning the patient and handling CSF samples, of course, especially if the patient is uncooperative or frightened.

B. Equipment and Supplies: The following items, which are usually included in pre~ lumbar puncture trays, are required. All must be sterile.

1. Gloves.
2. Iodine-containing solution for sterilizing the skin.
3. Sponges.
4. Drapes.
5. Lidocaine (1 %).
6. Syringe (5 mL).
7. Needles (22- and 25-gauge).
8. Spinal needles (preferably 22-gauge) with stylets.
9. Three-way stopcock.
10. Manometer.
11. Collection tubes.
12. Adhesive bandage.

C. Positioning: Lumbar puncture is usually performed with the patient in the lateral decubitus position (*Image 3.2.1*), lying at the edge of the bed and facing away from the person performing the procedure. The patient's lumbar spine should be maximally flexed to open the intervertebral spaces. The spine should be parallel to the surface of the bed and the hips and shoulders aligned in the vertical plane.

Occasionally, it is desirable to perform lumbar puncture with the patient seated. In this case, the patient is seated on the side of the bed, bent over a pillow that rests on a bedside table, while the physician reaches over the bed from the opposite side to perform the procedure.

D. Site of Puncture: The usual practice is to enter the L3-4 or L4-5 interspace, since the spinal cord (conus medullaris) terminates at about the Ll-2 level in adults. Thus, the procedure is performed without danger of puncturing the cord. The L3-4 interspace is located at the level of the posterior iliac crests.

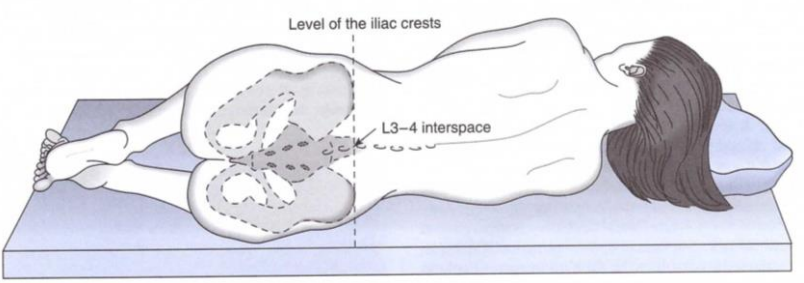


Image 3.2.1. Lateral decubitus position for lumbar puncture.

Procedure

1. If a comparison between blood and CSF glucose levels is planned, venous blood is drawn for glucose determination. Ideally, blood and CSF glucose levels should be measured in samples obtained simultaneously after the patient has fasted for at least 4 hours.

2. The necessary equipment and supplies are placed within easy reach.

3. Sterile gloves are worn by the person performing the procedure.

4. A wide area surrounding the interspace to be entered is sterilized, using iodine-containing solution applied to sponges; the solution is then wiped off with clean sponges.

5. The area surrounding the sterile field may be draped.

6. The skin overlying the puncture site is anesthetized using lidocaine, a 5-mL syringe, and a 25-gauge needle. A 22-gauge needle is then substituted to anesthetize the underlying tissues.

7. With the stylet in place, the spinal needle is inserted at the midpoint of the chosen interspace. The needle should be parallel to the surface of the bed

and angled slightly cephalad, or toward the umbilicus. The bevel of the needle should face upward, toward the face of the person performing the procedure.

8. The needle is advanced slowly until a pop, from penetration of the ligamentum flavum, is felt. The stylet is withdrawn to determine whether the CSF space has been entered, which is indicated by flow of CSF through the needle. If no CSF appears, the stylet is replaced and the needle advanced a short distance; this is continued until CSF is obtained. If at some point the needle cannot be advanced, it is likely that bone has been encountered. The needle is withdrawn partway, maintained parallel to the surface of the bed, and advanced again at a slightly different angle.

9. When CSF is obtained, the stylet is reinserted.

The patient is asked to straighten his or her legs, and the stopcock and manometer are attached to the needle. The stopcock is turned to allow CSF to enter the manometer to measure the opening pressure. The pressure should fluctuate with the phases of respiration.

10. The stopcock is turned to allow the CSF to be collected, and the appearance (clarity and color) of the fluid is noted. The amount obtained and the number of tubes required varies, depending on the tests to be performed. Typically, 1-2 mL are collected in each of five tubes for cell count, glucose and protein determination, VDRL, Gram's stain, and cultures. Additional specimens may be collected for other tests, such as oligoclonal bands and glutamine, and for cytologic study. If the CSF appears to contain blood, additional fluid should be obtained so that the cell count can be repeated on the specimen in the last tube collected. Cytologic studies, if desired, require at least 10 mL of CSF.

11. The stopcock and manometer are replaced to record a closing pressure.

12. The needle is withdrawn and an adhesive bandage is applied over the puncture site.

13. It has been customary to have the patient lie prone or supine for 1 or 2 hours after the procedure to reduce the risk of post-lumbar-puncture headache. Current evidence suggests this is unnecessary.

Complications

A. **Unsuccessful Tap:** A variety of conditions, including marked obesity, degenerative disease of the spine, previous spinal surgery, recent lumbar puncture, and dehydration, can make it difficult to perform lumbar puncture in the conventional manner. When puncture in the lateral decubitus position is impossible, the procedure should be attempted with the patient in a sitting position. If the tap is again unsuccessful, alternative methods include lumbar puncture by an oblique approach or guided by fluoroscopy; lateral cervical puncture; or cisternal puncture. These procedures should be undertaken by a neurologist, neurosurgeon, or neuroradiologist experienced in performing them.

B. Arterial or Venous Puncture: If the needle enters a blood vessel rather than the spinal subarachnoid space, it should be withdrawn and a new needle used to attempt the tap at a different level. Patients who have coagulopathy or are receiving aspirin or anticoagulants should be observed with particular care for signs of spinal cord compression (see Chapter 6) from spinal subdural or epidural hematoma.

C. Post-lumbar-Puncture Headache: A mild headache, worse in the upright position but relieved by recumbency, is not uncommon following lumbar puncture and will resolve spontaneously over a period of hours to days. Frequency is directly related to the size of the spinal needle. Vigorous hydration or keeping the patient in bed for 1 or 2 hours after the procedure apparently does not reduce the likelihood of such headache. The headache usually responds to nonsteroidal anti-inflammatory drugs or caffeine (*see Chapter 3*). Severe and protracted headache can be treated by an autologous blood clot patch, which should be applied by experienced personnel.

Analysis of Results (Table 1)

A. Appearance: The clarity and color of the CSF should be observed as it leaves the spinal needle, and any changes in the appearance of fluid during the course of the procedure should be noted. CSF is normally clear and colorless. It may appear cloudy or turbid with white blood cell counts that exceed about 200/flL, but counts as low as about 50/flL can be detected by holding the tube up to direct sunlight and observing the light-scattering (Tyndall) effect of suspended cells. Color can be imparted to the CSF by hemoglobin (pink), bilirubin (yellow), or, rarely, melanin (black).

B. Pressure: With the patient in the lateral decubitus position, CSF pressure in the lumbar region does not normally exceed 180–200 mm water. When lumbar puncture is performed with patients in the sitting position, they should assume a lateral decubitus posture before CSF pressure is measured. Increased CSF pressure may result from obesity, agitation, or increased intra-abdominal pressure related to position; the latter factor may be eliminated by having the patient extend the legs and back once the CSF space has been entered and before the opening pressure is recorded. Pathologic conditions associated with increased CSF pressure include intracranial mass lesions, meningoencephalitis, subarachnoid hemorrhage, and pseudo tumor cerebri.

C. Microscopic Examination: This may be performed either by the person who performed the lumbar puncture or by a technician at the clinical laboratory; it always includes a cell count and differential. Gram's stain for bacteria, acid-fast stain for mycobacteria, an India ink preparation for Cryptococcus, and cytologic examination for tumor cells may also be indicated. The CSF normally contains up to five mononuclear leukocytes (lymphocytes or monocytes) per microliter, no polymorphonuclear cells, and no erythrocytes. Erythrocytes may be present,

however, if the lumbar puncture is traumatic (see below). Normal CSF is sterile, so that in the absence of central nervous system infection, no organisms should be observed with the various stains listed above.

D. Bloody CSF: If the lumbar puncture yields bloody CSF, it is crucial to distinguish between central nervous system hemorrhage and a traumatic tap. The fluid should be watched as it leaves the spinal needle to determine whether the blood clears, which suggests a traumatic tap. This can be established with greater accuracy by comparing cell counts in the first and last tubes of CSF obtained; a marked decrease in the number of red cells supports a traumatic cause. The specimen should be centrifuged promptly and the supernatant examined. With a traumatic lumbar puncture, the supernatant is colorless. In contrast, following central nervous system hemorrhage, enzymatic degradation of hemoglobin to bilirubin in situ renders the supernatant yellow (xanthochromic).

Blood in the CSF following a traumatic lumbar puncture usuaUy clears within 24 hours; blood is usually present after subarachnoid hemolThage for at least 6 days. In addition, blood related to traumatic puncture does not clot, while clotting may occur with subarachnoid hemorrhage. Crenation (shriveling) of red blood cells, however, is of no diagnostic value.

In addition to breakdown of hemoglobin from red blood cells, other causes of CSF xanthochromia include jaundice with serum bilirubin levels above 4–6 mg/dL, CSF protein concentrations greater than 150 mg/dL, and, rarely, the presence of carotene pigments.

White blood cells seen in the CSF early after subarachnoid hemolThage or with traumatic lumbar puncture result from leakage of circulating whole blood. If the hematocrit and peripheral white blood cell count are within normal limits, there is approximately one white blood cell for each 1000 red cells. If the peripheral white cell count is elevated, a proportionate increase in this ratio should be expected. In addition, every 1000 red cells present in CSF will increase the CSF protein concentration by about I mg/dL.

Table 1

Cerebrospinal Fluid Abnormalities in Various Disorders (Merck Manual)

Condition	Pressure	Wbc/μL	Predominant Cell Type	Glucose	Protein
Normal	100–200 mm H_2O	0–3	L	50–100 mg/dL (2.78–5.55 mmol/L)	20–45 mg/dL
Acute bacterial meningitis	↑	100–10,000	PMN	↓	> 100 mg/dL*
Acute syphilitic meningitis	N or ↑	25–2000	L	N	↑
Lyme disease of CNS	N or ↑	0–500	L	N	N or ↑
Brain abscess or tumor	N or ↑	0–1000	L	N	↑
Viral infections	N or ↑	100–2000	L	N	N or ↑
Cerebral hemorrhage	↑	Bloody	RBCs	N	↑
Cerebral thrombosis	N or ↑	0–100	L	N	N or ↑
Spinal cord tumor	N	0–50	L	N	N or ↑
Guillain-Barré syndrome	N	0–100	L	N	> 100 mg/dL
L = lymphocyte; N = normal; PMN = polymorphonuclear leukocyte; ↑ = increased; ↓ = decreased.					

Procedure Notes

Whenever a lumbar puncture is performed, notes describing the procedure should be recorded in the patient's chart. These notes should provide the following information:

1. Date and time performed.
2. Name of person or persons performing the procedure.
3. Indication.
4. Position of patient.
5. Anesthetic used.
6. Interspace entered.
7. Opening pressure.
8. Appearance of CSF, including changes in appearance during the course of the procedure.
9. Amount of fluid removed.
10. Closing pressure.
11. Tests ordered, eg:

Tube #1 (1 mL), cell count.

Tube #2 (1 mL), glucose and protein levels. Tube #3 (1 mL), microbiologic stains.

Tube #4 (1 mL), bacterial, fungal, and mycobacterial cultures.

12. Results of any studies, such as microbiologic stains, performed by the operator.
13. Complications, if any.

CONCLUSION

Despite the significant possibilities of modern instrumental methods for diagnosing diseases of the nervous system, the primary importance should still belong to the direct communication of the doctor with the patient.

Only in this case, in each specific case, the optimal diagnostic complex and the sequence of individual research methods can be chosen, as well as a confidential contact with the patient, which is so necessary for successful treatment.

TESTS

1. Epileptic activity on the electroencephalography may indicate:

A. Inflammation of the brain.
B. Tumor
C. Intracerebral bleeding.
D. Subarachnoidal hemmorage.
E. Everything above.

2. Electroencephalography (EEG) is:

A. A method for investigating central hemodynamics.
B. A method that allows to study the bioelectric activity of the brain.
C. A method that allows to record muscle activity.
D. A method that allows to make images of brain vessels.
E. A method that allows estimating the processes that occur in organism.

3. The best method for diagnosing brain tumors:

A. Brain magnetic resonance imaging.
B. Brain computed tomography.
C. Skull X-ray.
D. Ultrasound.
E. Electroencephalography.

4. With the help of Magnetic resonance imaging, you can diagnose an ischemic stroke in time

A. Up to 3 hours.
B. Up to 1 hour.
C. Up to 16 hours.
D. Up to 24 hours.
E. Up to 8 hours.

5. What is the most informative method for monitoring vasospasm in a patient with subarachnoid hemorrhage

A. CT-angiography.
B. Magnetic resonance imaging.
C. Rheoencephalography.
D. Computed tomography.
E. Ultrasound.

6. An 18-year-old patient suddenly lost consciousness. For one minute, he had tonic-clonic convulsions, tongue bite, and urine discharge. He doesn't remember anything after the attack. Objectively somewhat inhibited adynamic. There are bite marks on the tongue, a bruise on the forehead. Which study is most informative in this case?

A. Magnetic resonance imaging of the head.
B. Computed tomography of the head.
C. Lumbar puncture.
D. Electroencephalography.
E. Echoencephaloscopy.

7. The patient, 32 years old, complains of darkening and "stars" in front of the eyes with sharp turns of the heads. Twice during the year, there was a short-term loss of consciousness without convulsions, which was preceded by a turn of the head and dizziness. What kind of research should the patient do first?

A. Electroencephalography.
B. Ultrasound Dopplerography.
C. Magnetic resonance imaging of the brain.
D. Electromyography.
E. Computed tomography of the brain.

8. The patient, 67 years old, was taken to the emergency department by ambulance. According to the daughter, it is known that about 1 hour ago, the father fell at home, lost consciousness, came to himself in a minute, but his face was distorted, there was weakness in the left limbs. From the anamnesis, it is known that the patient suffers from hypertension, coronary heart disease, and arrhythmia attacks. In the neurological status, deep left-sided hemiparesis, central paresis of the facial muscles on the left, deviation of the tongue to the left. What is the most appropriate method of hardware diagnostics?

A. Intracranial Dopplerography.
B. Computed tomography of the brain.
C. Magnetic resonance imaging of the brain in vascular mode/
D. Echoencephaloscopy.
E. Electroencephalography/

9. The patient was suspected of having Farah's disease. What research should be done to detect calcifications in the brain?

A. Computed tomography.
B. Magnetic resonance imaging.
C. Echoencephaloscopy.
D. Electroecephalography.
E. Intracranial Dopplerography.

10. The patient, 27 years old, has been working as a programmer for 4 years, complains of weakness and numbness of the right hand. What is the first study to be performed on the patient?

A. Radiography of the right hand.
B. Electroneuromyography of the right upper limb.
C. Ultrasound Dopplerography.
D. Radiography of the right shoulder joint.
E. Magnetic resonance imaging.

11. A method for studying brain activity by registering the activity of brain cells:

A. Electroneuromyography.
B. Ultrasound Dopplerography.
C. Electroecephalography.
D. Ehoencephalography.
E. Magnetic resonance imaging.

12. Method for studying the electrical activity of muscles:

A. Electroecephalography.
B. Magnetic resonance imaging.
C. Echoencephalography.
D. Electroneuromyography.
E. Electrocardiography.

13. Specify the disease in which the encephalographic complexes «spike – wave» appear:

A. Acute myelitis.
B. Meningitis.
C. Multiple sclerosis.
*D. Epilepsy.**
E. Stroke.

14. What is the normal rhythm in adults in the waking state with their eyes closed:

A. Spikes.
B. Theta rhythm.
C. Sharp waves.
D. Delta rhythm.
E. Alpha rhythm.

15. Electromyography is an additional diagnostic method of:

A. Epilepsy. *C. Stroke.* *E. Myopathy.*
B. Brain tumors. *D. Meningitis.*

16. The electroencephalogram of the patient revealed a 3-second complex «peak-slow wave». What disease is characterized by the changes?

A. Stroke. *C. Meningitis.* *E. Multiple sclerosis.*
B. Epilepsy. *D. Brain tumor.*

17. The young man complains of weakness in the muscles of the left arm, as well as atrophy and fibrillary twitching in these muscles. What additional tests should be assigned?

A. Electromyography and Magnetic resonance imaging.
B. Lumbar puncture, Magnetic resonance imaging.
C. Ultrasound Dopplerography, Magnetic resonance imaging.
D. Electroencephalography, Computed tomography.
E. Angiography, electromyography.

18. For the study, the cerebrospinal fluid of a patient suffering from prolonged headache and papillary edema was taken. The study showed 2.3 g/l of 5-cell protein in 1 mm3 of CSF. What are the changes in the CSF in this patient?

A. Protein dissociation. *C. Hemorrhagic syndrome.* *E. Ischemic stroke.*
B. Cell-protein dissociation. *D. All of the above.*

19. What additional method is used to determine stenosis or occlusion of the cerebral vessels?

A. Electroencephalography. *D. Ultrasound.*
B. Electroneuromyography. *E. Computed tomography.*
C. Magnetic resonance imaging.

20. A 15-year-old patient has been suffering from partial epilepsy for 2 years. What research method should he be assigned?

A. Electroencephalography. *D. Electroneuromyography.*
B. Magnetic resonance imaging. *E. Angiography.*
C. Computed tomography.

21. What additional diagnostic method can confirm the diagnosis of epilepsy?

A. Myelography. *D. Electroencephalography.*
B. Magnetic resonance imaging. *E. Angiography.*
C. Radioisotope method.

22. The most informative additional method of examination for specific parasitic diseases of the nervous system?

A. Cerebrospinal fluid analysis. *D. X-Ray.*
B. Electroencephalography. *E. Computed tomography.*
C. General blood test.

23. What additional diagnostic method can confirm subarachnoid hemorrhage?

A. Cranial x-ray. *C. Echoencephaloscopy.* *E. Lumbar puncture.*
B. Electroencephalography. *D. Ophtalmoscopy.*

24. Specify additional diagnostic methods in patients with myopathy?

A. X-ray. *C. Myelography.* *E. Lumbar puncture.*
B. Electromyography. *D. Brain CT and MRI.*

25. The patient has been suffering from optic neuritis for three years. Diplopia appeared after mental stress, weakness in the limbs, pelvic disorders. Visual: discoloration of the temporal part of the disc. Preliminary diagnosis: Multiple sclerosis. What research method should be more informative for making a diagnosis?

A. Computed tomography. *D. Electroencephalography.*
B. Lumbar puncture. *E. Ultrasound Dopplerography.*
C. Magnetic resonance imaging.

26. The patient has a preliminary diagnosis: Syringomyelia. What is the most informative method needed to diagnose this disease?

A. X-ray. *D. Magnetic resonance imaging.*
B. Electroencephalography. *E. Lumbar puncture.*
C. Electromyography.

27. What method of investigation allows you to identify the sources of blood supply to a brain tumor?

A. Angiography. *D. Computed tomography with contrast.*
B. Magnetic resonance imaging. *E. Computed tomography.*
C. Radioisotope scintigraphy.

28. Echocephaloscopy is used to diagnose:

A. Brain tumors, subcranial and intracranial hematomas.
B. Syringomyelia.
C. Toxic brain lesions.
D. Demyelinating diseases of the nervous system.
E. Syringobulbia.

29. What are additional methods for studying the subarachnoid space and ventricles of the brain?

A. Pneumoencephalography. *D. Rheoencephalography.*
B. Electroencephalography. *E. CT.*
C. Electromyography.

30. Specify the level of lumbar puncture in adults:

A. L1-L2. *B. S1-S2.* *C. L3-L4.* *D. Th12-L1.* *E. L2-L3.*

31. What methods of examination can be used to verify stroke?

A. Ultrasound Dopplerography. *D. Study of blood coagulation properties.*
B. Contrast angiography. *E. Echoencephaloscopy.*
C. Computed tomography.

32. The most informative method of additional examination for lumbosacral compression syndromes is:

A. Electromyography.
B. Magnetic resonance imaging of the spinal cord.

C. Computed tomography of the spinal cord.
D. Myelography with positive contrast.
E. Radiography of the spine.

33. What electrographic signs are not pathognomonic for epilepsy?
A. Semi-peak-wave complex. *D. Peak.*
B. Paroxysmal activity. *E. Peak-wave complex.*
C. Acute wave.

34. What are the research methods for the diagnosis of cervical radiculitis?
A. Angiography. *D. Computed tomography.*
B. Myelography. *E. Magnetic resonance imaging tomography.*
C. Spondylography.

35. Electroencephalography data are most informative in the case of:
A. Hematomas. *D. Traumatic brain injury.*
B. Epilepsy. *E. Lesion of the cerebral vessels.*
C. Inflammatory diseases.

36. Normally, in the supine position of the patient, the pressure of the cerebrospinal fluid is?
A. About 200–250 mm. water. V. *D. 100–200 mm. v.*
B. 200 mm. water. V. *E. About 75–100 mm. Hg.*
C. 100–180 mm. Hg.

37. Lumbar lumbar puncture in neurosurgical patients is performed in all cases, except:
A. Suspicion of supratentorial neoplasm.
B. Presence of hyperkinesis.
C. Volumetric processes in the posterior cranial fossa.
D. Increased acute phase blood parameters.
E. Presence of a frontal lobe tumor.

38. The patient, 41 years old, after a holiday at the sea, had uncertainty and unsteadiness when walking, speech slowed down. In the neurological status: small-scale horizontal nystagmus, chanted speech, intentional tremor when performing finger-nasal and heel-knee tests. What additional methods of examination will confirm the diagnosis of multiple sclerosis?
A. Magnetic resonance imaging of the brain, examination of the cerebrospinal fluid, examination of the fundus.
B. Magnetic resonance imaging of the brain, examination of the cerebrospinal fluid, electroencephalography.
C. Brain magnetic resonance imaging, cerebral angiography, electroencephalography.
D. Brain magnetic resonance imaging, cerebral angiography, head radiography.
E. Magnetic resonance imaging, radiography.

39. Doppler Ultrasound/sonography can be useful for identify next pathology:
A. Hematomas. *C. Inflammatory disease.* *E. Meningioma.*
B. Occlusion. *D. Epilepcy.*

40. A worker was admitted to the emergency unit after syncope. It is known that after examination, he was found vertigo and ataxia. What method of investigation you should prescribe this patient?

A. Ultrasound sonography. *C. CT.* *E. MRI.*
B. ENMG. *D. Lumbur puncture.*

41. A patient came to hospital with the complains of periodically appeared losing of consciousness, with signs of dizziness, general weakness before seizures. After falling he remember what's happened with him. The doctor also checked and discovered no pathology in neurological status. What method of investigation you should prescribe this patient?

A. Ultrasound sonography. *C. MRI.* *E. CT.*
B. ENMG. *D. PET.*

42. A 28 year old girl complains of attacks of palpitation, headache, elevation of blood pressure to 165/85 mm Hg, increased perspiration, chills, feeling of fear. An attack ends with massive urination. The consciousness at attack is not disturbed. What method of investigation you should prescribe this patient?

A. EEG. *B. ENMG.* *C. CT.* *D. PET.* *E. X-ray.*

43. A 49 year old man complains of attacks of acute pain in the right half of the face that occurs while talking, chewing, touching. The duration of attack is 5–10 min. During the attack there is a spasm of the facial muscles of the right half of the face, the skin of half face flushed. Between attacks the pain and increased sensitivity in the right half of the face is observed. Other pathology was not found. What method of investigation you should prescribe this patient?

A. EEG. *C. Ultrasound dopplerography.* *E. MRI.*
B. ENMG. *D. PET.*

44. A 66 year old man complains of attacks of throbbing pain in the right side of the head. Before the attacks of headaches left-sided hemianopsia occurs. The attack lasts about 5 hours and ends nausea and vomiting. What method of investigation you should prescribe this patient?

A. EEG. *C. Ultrasound dopplerography.* *E. MRI.*
B. ENMG. *D. PET.*

45. Transcranial dopplerography can identify next pathological states:

A. Hematomas. *C. Inflammatory disease.* *E. Meningioma.*
B. Occlusion. *D. Epilepcy.*

46. The most informative method of additional examination for. Steal syndrome diagnostics is?

A. Ultrasound dopplerography. *D. Myelography.*
B. ENMG. *E. Radiography.*
C. Computed tomography.

47. The most informative method of additional examination for evaluation of cerebrovascular reactivity is:

A. Ultrasound dopplerography. *D. Myelography.*
B. ENMG. *E. Radiography.*
C. Computed tomography.

48. A 48 year old woman complains of attacks of vertigo, headache, nausea, vomiting, increased perspiration. The movements in the neck provoke attacks. The consciousness at attack is not disturbed. What method of investigation you should prescribe this patient?

A. Myelography. *C. Ultrasound dopplerography.* *E. MRI.*
B. ENMG. *D. PET.*

49. A 33-year-old woman complains of speech impairment, weakness in the lower extremities, unsteadiness when walking. Neurologic examination: lower central paraparesis and Charcot's triad (nystagmus, intentional tremor, chanted speech). A preliminary diagnosis was established: multiple sclerosis. The preliminary clinical diagnosis: the multiple sclerosis. What diagnostic methods should be used to confirm the diagnosis?

A. Examination of the eye fundus, visual evoked potentials, CT, EEG, lumbar puncture
B. The ENMG, examination of the eye fundus, visual evoked potentials, detection of oligoclonal immunoglobulins in the cerebrospinal fluid
C. USDG, MRI, lumbar puncture, ophthalmoscopy
D. CT, ENMG, examination by a therapist, ophthalmoscopy
E. USDG, MRI, ophthalmoscopy, EEG

50. Patient T., 50 years old, complaints of acute intense headache, nausea, vomiting, according to the ambulance doctor the patient lost consciousness. Status praesens objectivus: BP 200/130 mm Hg., Pulse 94 per minute. The face is hyperemic. Neurologic examination: The stiffness of the occipital muscles, Kernig's and Brudzinsky's symptoms. Preliminary diagnosis: The subarachnoid hemorrhage. What diagnostic methods should be used to confirm the diagnosis?

A. MRI, lumbar puncture. *C. EEG, lumbar puncture, ophthalmoscopy.*
B. CT, USDG, ENMG. *D. Ophthalmoscopy, USDG, lumbar puncture.*
E. EEG, lumbar puncture, ophthalmoscopy.

51. Patient D., 62 years old complaints of weakness and numbness in the lower extremities. Acutely fell ill after physical overstrain. Neurologic examination: lower central paraparesis, sphincter disorders, impaired superficial sensitivity from the T6 level. Diagnosis: The spinal stroke. What diagnostic methods should be used to confirm the diagnosis?

A. USDG. *D. The selective spinal angiography.*
B. ENMG, lumbar puncture. *E. USDG, EEG.*
C. X-ray, lumbar puncture.

52. The patient, 42 years old is in the hospital with a diagnosis of the craniocerebral trauma, brain contusion, linear fracture of the left temporal bone. The level of consciousness is 10 points on the Glasgow coma scale, bradycardia, left-side mydriasis, sluggish photoreaction, right-sided hemiparesis. What diagnostic methods should be used to confirm the diagnosis?

A. ENMG, Echo ES. *C. X-ray, Echo ES.* *E. EEG, USDG.*
B. USDG, MRI, Echo ES. *D. MRI, Echo ES.*

53. The patient 45 years old was taken to the hospital after the generalized tonic-clonic attack, involuntary urination, excretion of foam from the mouth, biting of the tongue and lips, bruises and the skin injuries. Indicate the research method?

A. CT. *B. MRI.* *C. EEG.* *D. REG.* *E. ENMG.*

54. Which electrophysiological method of investigation will allow detecting the lateral amyotrophic sclerosis?

A. TMS. *B. EEG.* *C. REG.* *D. ENMG.* *E. MRI.*

KEYS FOR THE TESTS

1	E	**15**	E	**29**	A	**43**	A
2	B	**16**	B	**30**	C	**44**	A
3	A	**17**	A	**31**	C	**45**	B
4	D	**18**	A	**32**	B	**46**	A
5	A	**19**	D	**33**	B	**47**	A
6	D	**20**	A	**34**	E	**48**	C
7	B	**21**	D	**35**	B	**49**	B
8	C	**22**	E	**36**	D	**50**	A
9	B	**23**	E	**37**	C	**51**	D
10	B	**24**	B	**38**	A	**52**	D
11	D	**25**	C	**39**	B	**53**	C
12	D	**26**	D	**40**	A	**54**	D
13	D	**27**	A	**41**	A		
14	E	**28**	A	**42**	A		

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НЕЙРОФІЗІОЛОГІЧНІ ТА НЕЙРОВІЗУАЛІЗАЦІЙНІ МЕТОДИ ДІАГНОСТИКИ ЗАХВОРЮВАНЬ НЕРВОВОЇ СИСТЕМИ

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