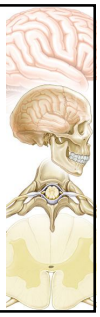
V.N.Karazin Kharkiv National University
Department of Neurosurgery

ONCOLOGY OF THE NERVOUS SYSTEM



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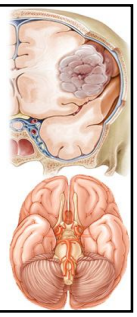
Brain & CNS Tumors

Definition

A brain tumor is an abnormal growth of cells (neoplasm) in the skull. A spinal tumor is a growth associated with the spinal cord. Tumors are classified as noncancerous tumors (benign tumors) or cancerous tumors (malignant tumors)



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Epidemiology of brain tumors

- About 40.000 people are diagnosed with a brain tumor each year in the United States
- Gliomas account for more than 70% of all brain tumors
- Caucasians have a higher incidence than African or Asian populations
- Fewer than 3% of glioblastoma patients are still alive at 5 years after diagnosis, older age being the most significant and consistent prognostic factor of poorer outcome
- Brain and spinal cord tumors in children are the second most common form of childhood cancer, with about 1.500 children developing these tumors each year
- Almost 10.000 Americans are diagnosed each year with a spinal cord tumor

Kernohan grading

The Kernohan grading system defines progressive malignancy of astrocytomas as follows:
Grade 1 tumors are benign astrocytomas.
Grade 2 tumors are low-grade astrocytomas.
Grade 3 tumors are anaplastic astrocytomas.
Grade 4 tumors are glioblastomas.

St Anne-Mayo grading

The St Anne-Mayo grading system also is used to grade astrocytomas; however, this system uses four morphologic criteria to assign a grade:
a) *nuclear atypia*,
b) *mitosis*,
c) *endothelial proliferation*-'piled-up' endothelial cells. NOT hypervascularity
d) *necrosis*.
The St. Anne-Mayo grade has four categories of tumors:
Grade 1 tumors do not meet any of the criteria.
Grade 2 tumors meet one criterion, usually nuclear atypia.
Grade 3 tumors meet two criteria, usually nuclear atypia and mitosis.
Grade 4 tumors meet three or four of the criteria

WHO grading

The World Health Organization (WHO) grading system is contained in the volume *Histological Typing of Tumours of the Central Nervous System*, whose first edition dates back to 1979, the second to 1993 and last one to 2007.
The WHO grade has four categories of tumors:
Grade I tumors are slow-growing, nonmalignant, and associated with long-term survival.
Grade II tumors are relatively slow-growing but sometimes recur as higher grade tumors. They can be nonmalignant or malignant.
Grade III tumors are malignant and often recur as higher grade tumors.
Grade IV tumors reproduce rapidly and are very aggressive malignant tumors.

From the histological point of view the WHO system is based on the same criteria as the St Anne-Mayo system

ICD-O scale

The first edition of the International Classification of Diseases (ICD) dates back to 1893, the current review (ICD-10) dates 1994.
In 1976 the World Health Organization (WHO) publishes the first edition of the International Classification of Diseases for Oncology (ICD-O), now at the third edition (ICD-O-3, 2000).
In this last edition, the Arabic numeral after the character "/" indicates the "behavior" of the neoplasia, with the following meaning:
/0 benign neoplasia
/1 uncertain neoplasia (benign or malignant)
/2 neoplasia *in situ*
/3 primary infiltrative malignant neoplasia
/6 secondary malignant neoplasia
/9 malignant neoplasia, uncertain if primitive or secondary

A brain tumor composed of benign cells, but located in a vital area (as the brain is), can be considered to be life-threatening — although the tumor and its cells would not be classified as malignant

WHO classification of the tumors of the CNS

For each tumor there are the WHO official name, the ICD-O code (with Arabic numeral, where /0 indicates "benign" tumor, /3 malignant tumor and /1 borderline tumor), and with Roman numeral the WHO Grade (a parameter connected with the "aggressiveness" of the tumor). **It defines histologist after histological assessment**

1. *Tumours of neuroepithelial tissue*

- 1.1. **Astrocytic tumors**
  - 1.1.1 Pilocytic astrocytoma (ICD-O 9421/1, WHO grade I)
    - 1.1.1a *Pilomyxoid* astrocytoma (ICD-O 9425/3, WHO grade II)
  - 1.1.2 Subependymal giant cell astrocytoma (ICD-O 9384/1, WHO grade I)
  - 1.1.3 Pleomorphic xanthoastrocytoma (ICD-O 9424/3, WHO grade II)
  - 1.1.4 Diffuse astrocytoma (ICD-O 9400/3, WHO grade II)
  - 1.1.5 Anaplastic astrocytoma (ICD-O 9401/3, WHO grade III)
  - 1.1.6 Glioblastoma (ICD-O 9440/3, WHO grade IV)
    - 1.1.6a *Giant cell glioblastoma* (ICD-O 9441/3, WHO grade IV)
    - 1.1.6b Gliosarcoma (ICD-O 9442/3, WHO grade IV)
  - 1.1.7 Gliomatosis cerebri (ICD-O 9381/3, WHO grade III)
- 1.2. **Oligodendroglial tumors**
  - 1.2.1 Oligodendroglioma (ICD-O 9450/3, WHO grade II)
  - 1.2.2 Anaplastic oligodendroglioma (ICD-O 9451/3, WHO grade III)
- 1.3. **Oligoastrocytic tumors**
  - 1.3.1 Oligoastrocytoma (ICD-O 9382/3, WHO grade II)
  - 1.3.2 Anaplastic oligoastrocytoma (ICD-O 9382/3, WHO grade III)
- 1.4. **Ependymal tumors**
  - 1.4.1 Subependymoma (ICD-O 9383/1, WHO grade I)
  - 1.4.2 Myxopapillary ependymoma (ICD-O 9394/1, WHO grade I)
  - 1.4.3 Ependymoma (ICD-O 9391/3, WHO grade II)
  - 1.4.4 Anaplastic ependymoma (ICD-O 9392/3, WHO grade III)

- 1.5. **Choroid plexus tumors**
  - 1.5.1 Choroid plexus papilloma (ICD-O 9390/0, WHO grade I)
  - 1.5.2 Atypical choroid plexus papilloma (ICD-O 9390/1, WHO grade II)
  - 1.5.3 Choroid plexus carcinoma (ICD-O 9390/3, WHO grade III)
- 1.6. **Other neuroepithelial tumors**
  - 1.6.1 Astroblastoma (ICD-O 9430/3, WHO grade I)
  - 1.6.2 Chordoid glioma of the third ventricle (ICD-O 9444/1, WHO grade II)
  - 1.6.3 Angiocentric glioma (ICD-O 9431/1, WHO grade I)
- 1.7. **Neuronal and mixed neuronal-glial tumors**
  - 1.7.1 Dysplastic gangliocytoma of cerebellum (Lhermitte-Duclos) (ICD-O 9493/0)
  - 1.7.2 Desmoplastic infantile astrocytoma/ganglioglioma (ICD-O 9412/1, WHO grade I)
  - 1.7.3 Dysembryoplastic neuroepithelial tumor (ICD-O 9413/0, WHO grade I)
  - 1.7.4 Gangliocytoma (ICD-O 9490/0, WHO grade I)
  - 1.7.5 Ganglioglioma (ICD-O 9505/1, WHO grade I)
  - 1.7.6 Anaplastic ganglioglioma (ICD-O 9505/3, WHO grade III)
  - 1.7.7 Central neurocytoma (ICD-O 9506/1, WHO grade II)
  - 1.7.8 Extraventricular neurocytoma (ICD-O 9506/1, WHO grade II)
  - 1.7.9 Cerebellar liponeurocytoma (ICD-O 9506/1, WHO grade II)
  - 1.7.10 Papillary glioneuronal tumour (ICD-O 9509/1, WHO grade I)
  - 1.7.11 Rosette-forming glioneuronal tumour of the fourth ventricle (ICD-O 9509/1, WHO grade I)
  - 1.7.12 Paraganglioma (ICD-O 8680/1, WHO grade I)
- 1.8. **Tumors of the pineal region**
  - 1.8.1 Pinocytoma (ICD-O 9361/1, WHO grade I)
  - 1.8.2 Pineal parenchymal tumour of intermediate differentiation (ICD-O 9362/3, WHO grade II, III)
  - 1.8.3 Pineoblastoma (ICD-O 9362/3, WHO grade IV)
  - 1.8.4 Papillary tumour of the pineal region (ICD-O 9395/3, WHO grade II, III)
- 1.9. **Embryonal tumors**
  - 1.9.1 Medulloblastoma (ICD-O 9470/3, WHO grade IV)
    - 1.9.1b *Medulloblastoma with extensive nodularity* (ICD-O 9471/3, WHO grade IV)
    - 1.9.1c *Anaplastic medulloblastoma* (ICD-O 9474/3, WHO grade IV)
  - 1.9.2. CNS Primitive neuroectodermal tumour (ICD-O 9473/3, WHO grade IV)
    - 1.9.2a *CNS Neuroblastoma* (ICD-O 9500/3, WHO grade IV)
  - 1.9.3 Atypical teratoid/rhabdoid tumour (ICD-O 9508/3, WHO grade IV)

2. *Tumors of cranial and paraspinal nerves*
3. *Tumors of the meninges*
- 3.1 **Tumors of meningothelial cells**
- 3.2 **Mesenchymal tumors**
- 3.3 **Primary melanocytic lesions**
- 3.4 **Other neoplasms related to the meninges**

4. *Tumors of the haematopoietic system*
5. *Germ cell tumors*
6. *Tumors of the chiasmosellar area*
7. *Metastatic tumors*

Comparison of the grading systems

In the following table the various grading systems are compared (the IDC-O scale is not comprised because it is not considered a real grading system):

Name WHO	WHO *grade*	Kernohan *grade*	St Anne/Mayo *grade*	St Anne/Mayo criteria
Pilocytic astrocytoma	I	-	1	0 criterion
Diffuse astrocytoma	II	1	2	1 criterion (a)
Anaplastic astrocytoma	III	2	3	2 criteria (a+b)
Glioblastoma	IV	3/4	4	3-4 criteria (a+b[+/-c]+d)

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Symptoms and Signs

The clinical manifestations of a brain tumor may range from a virtually asymptomatic state to a constellation of symptoms and signs that is specific for a particular type and location of lesion

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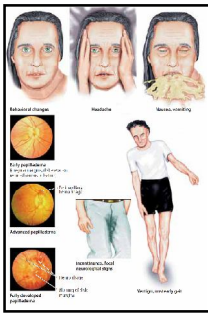

Symptoms and Signs

The symptoms are related to an increase in pressure in the brain

Headache
Vomiting (usually in the morning)
Nausea
Personality changes
Irritability
Drowsiness
Depression
Incontinence
Decreased cardiac and respiratory function and, eventually, coma if not treated

What are the symptoms of a brain tumor?

The symptoms of brain tumors in the cerebrum (front of brain):

- Increased intracranial pressure (ICP)
- Seizures
- Visual changes
- Slurred speech
- Paralysis or weakness on half of the body or face
- Drowsiness and/or confusion
- Personality changes/impaired judgment
- Short-term memory loss
- Gait disturbances
- Communication problems

What are the symptoms of a brain tumor?

Symptoms of brain tumors in the brainstem (base of brain) may include:

- Increased intracranial pressure (ICP)
- Headaches
- Seizures
- Endocrine problems (diabetes and/or hormone regulation)
- Visual changes or double vision
- Paralysis of nerves/muscles of the face, or half of the body
- Respiratory changes
- Clumsy, uncoordinated walk
- Hearing loss
- Personality changes

What are the symptoms of a brain tumor?

Symptoms of brain tumors in the cerebellum (back of brain) may include:

- Increased intracranial pressure (ICP)
- Vomiting (usually occurs in the morning without nausea)
- Headache
- Uncoordinated muscle movements
- Problems walking (ataxia)

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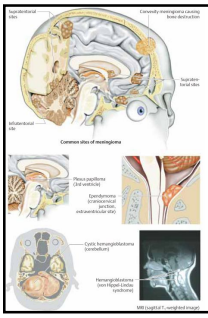
How is a brain tumor diagnosed?

- **Neurological examination**
- **Computed tomography scan (CT scan)**
- **Magnetic resonance imaging (MRI)**
- **X-ray**
- **Arteriogram (Angiogram)**
- **Myelogram**
- **Spinal tap (Lumbar puncture)**
- **Positron emission tomography (PET)**
- **Magnetic resonance spectroscopy (MRS)**
- **Biopsy of tumor**



Common sites of meningioma

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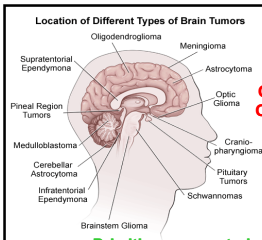

Gliomas:
Astrocytomas
Brain stem gliomas
Ependymomas
Optic nerve gliomas
Oligodendrogliomas

Metastatic tumors
Meningiomas
Schwannomas
Pituitary tumors
Medulloblastomas
Primitive neuroectodermal tumors (PNET)
Craniopharyngiomas
Pineal region tumors

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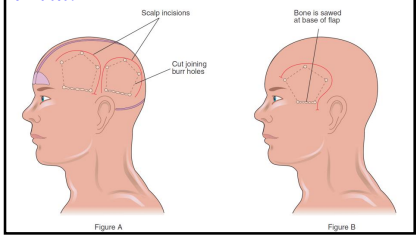
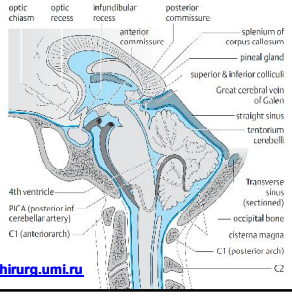
In a craniotomy, the skin over a part of the skull is cut and pulled back. Small holes are drilled into the skull, and a special saw is used to cut the bone between the holes. The bone is removed, and a tumor or other defect is visualized and repaired. The bone is then replaced and the skin closed



Midsaggital anatomic diagram of the pineal and foramen magnum regions



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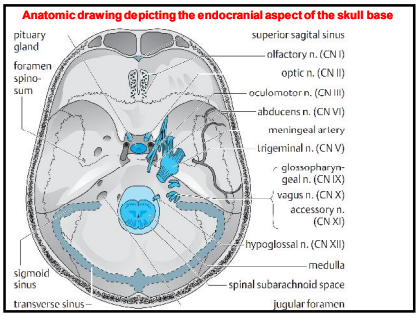
Anatomic drawing depicting the endocranial aspect of the skull base



Common Primary and Metastatic Spinal Cord Tumors

Primary Tumors	Metastatic Tumors
Extramedullary (89%)	Breast (22%)
Neurofibroma (29%)	Lung (15%)
Meningioma (25%)	Prostate (10%)
Sarcoma (12%)	Lymphoma (10%)
Other (10–15%)	Sarcoma (9%)
Dermoid	Kidney (7%)
Epidermoid	Gastrointestinal tract (5%)
Intramedullary (11%)	Melanoma (4%)
Ependymoma (55%)	Unknown primary (4%)
Astrocytoma (31%)	Head and neck (3%)
Vascular tumors (4%)	
Other (5–10%)	
Mixed glioma	
Oligodendroglioma	

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Craniography makes it possible to identify a number of X-ray symptoms: 1) Changes in bones caused by increased intracranial pressure (depending on the developmental stage of the process and the patient's age): the deepening of "finger" depressions, thinning of the bones of the skull, widening of the sutures (in infants); osteoporosis of back of the sella turcica and of sphenoid wing, strengthening vascular pattern, expanding diploic channels, deepening pits pacchionian granulations; 2) Focal signs (corresponding to the tumor site): calcification, osteosclerosis, hyperostosis, local thinning, osteoporosis, atrophy, osteolysis, destruction, increasing the local vascular pattern; 3) Indirect symptoms (due to mass effect of a growing tumor): dislocation - the pineal gland, choroid plexus, falx of the brain, brain vessels

23

Computed tomography (CT) based on detected changes in optical density makes it possible to diagnose tumors, to determine the topography of the process, the size of the tumor, detect calcifications, cystic components, the zone of necrosis, verify the fact of spontaneous hemorrhage in the parenchyma of the tumor and adjacent brain structures, an idea histostructure of the tumor, differentiate tumor tissue from edema of the brain substance. The additional (indirect) diagnostic CT signs of tumor mass effect are: the shift of median structures of the brain, the sickle of the brain, choroid plexus, ventricles and aqueduct of the brain, the deformation of subarachnoid space and cisterns of the brain, and compression in a limited area of lateral, III and IV ventricles , presence of hydrocephalus, local destructive changes in the bones of the skull

24

Magnetic resonance imaging (MRI) is substantially complementary to the results of CT with respect to the location and spread of tumors to determine topographic and anatomical features of its growth, the nature and extent of tumor involvement in the process of adjacent brain structures. MRI is superior to CT in the diagnosis of tumors did not accumulate the contrast agent (eg, low-grade gliomas). In the diagnosis of calcifications, bone-destructive changes, delineation of the tumor and perifocal edema MRI features are limited. Addition to the standard MRI neurooncology used **functional MRI** (preoperative mapping of areas of the brain), **MR angiography** (study of the great vessels of the brain, determination of the degree of vascularization of the tumor) **MR spectroscopy** (the study of regional metabolism)
MR thermography (check the temperature gradient during the thermal degradation of the tumor)

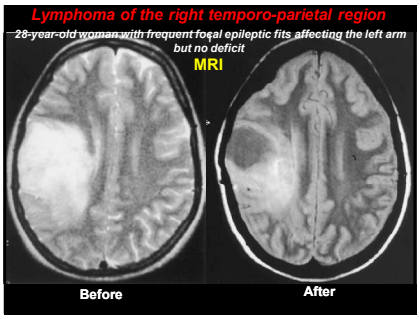
25

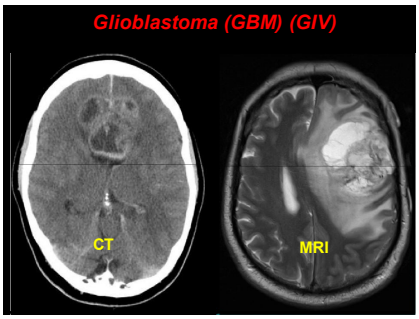
Positron emission tomography (PET) allows non-invasively investigate the biological properties of the local tumor and the substance of the brain, to map functionally important areas, timely detection of recurrent tumor growth, tumor differentiation grade
Single photon emission computed tomography (SPECT) is carried out with the introduction of radiopharmaceuticals (99mT pertechnetat, 99mTcGMPAO, 99mTcMIBI). SPECT can identify and localize the tumor, to get an idea of the degree of malignancy and vascularity, diagnose multifocal neoplastic lesions of the brain to carry out dynamic monitoring in the postoperative period
Angiography (carotid, vertebral, selective) is carried out to visualize cerebral vessels, to clarify their relationship topografoanatomicheskih with the tumor, determine the degree of vascularization and to identify sources of blood supply to tumors?

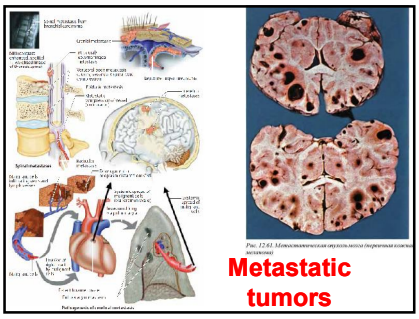
26

Survival prognosis

Histology	Treatments	Time to tumor recurrence	Median survival
GBM (IV)	Srgry/RT/CT	6 months	11 mon
AA (III)	Srgry/RT/CT	18 months	3 years
Astrocyt II	Srgry/RT	3 years	6 years
Astrocyt I	Surgery	8 years	10 year
Lung met	Surgery/RT		12 wks
Breast met	Surgery/RT		25 wks
Colon met	Surgery/RT		48 wks
Melanoma	Surgery/RT		26 wks
Renal met	Surgery/RT		8 wks

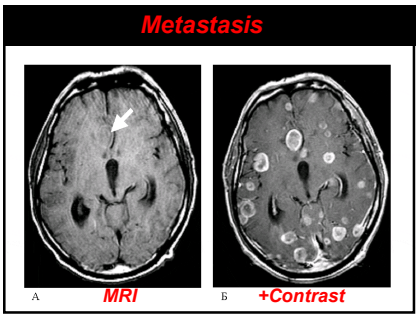


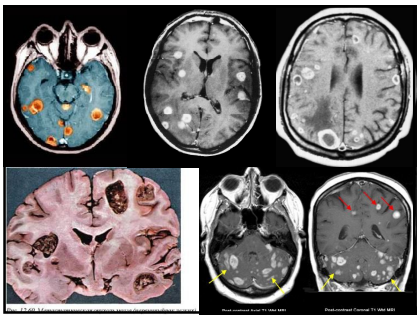


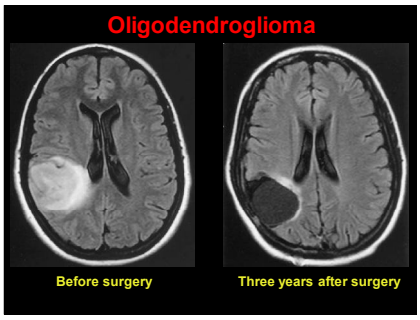


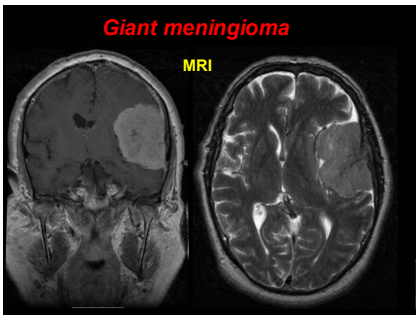
Common Primary and Metastatic Brain Tumors

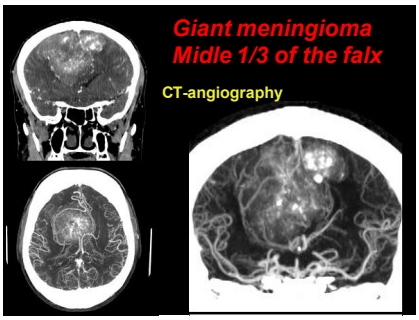
Primary Tumors	Metastatic Tumors
Adults	
Glioblastoma multiforme (35–40%)	Lung (64%)
Astrocytoma grades I–III (18–20%)	Breast (14%)
Meningioma (18%)	Unknown primary (8%)
Pituitary adenoma (9%)	Melanoma (4%)
Oligodendroglioma (5%)	Colorectal (3%)
Schwannoma (5–5%)	Hypernephroma (2%)
Ependymoma (2%)	
Children	
Astrocytoma, low-grade (15–30%)	Wilm's tumor (18.6%)
Astrocytoma, high-grade (8–15%)	Rhabdomyosarcoma (18.6%)
Medulloblastoma (18–25%)	Osteogenic sarcoma (16.3%)
Brainstem glioma (6–15%)	Germ cell tumors (16.3%)
Ependymoma (6–13%)	Ewing's sarcoma (9.3%)
Craniopharyngioma (6–9%)	Neuroblastoma (4.6%)
Pineal region (2–5%)	Hepatocellular carcinoma (4.6%)

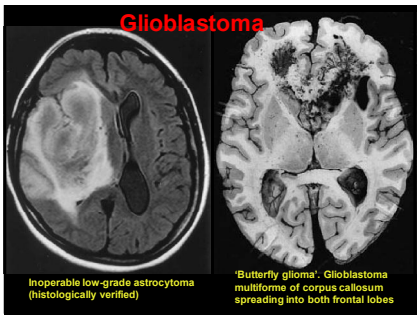


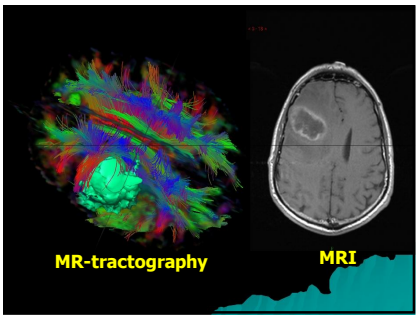


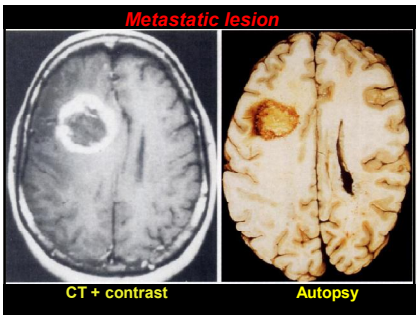







Glioblastoma
Inoperable low-grade astrocytoma (histologically verified)
'Butterfly glioma'. Glioblastoma multiforme of corpus callosum spreading into both frontal lobes

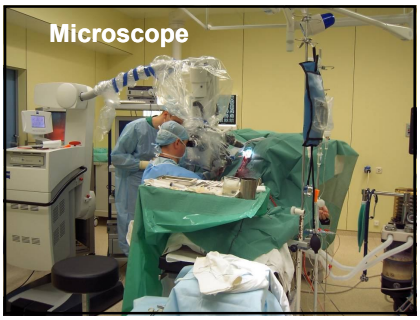

MR-tractography
MRI

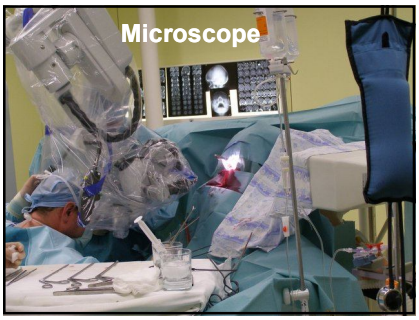

Metastatic lesion
CT + contrast
Autopsy


Navigation system


Intraoperation USI


Stereotaxis


Microscope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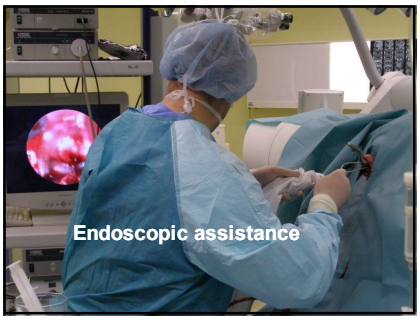
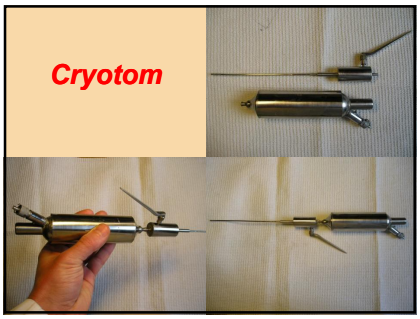
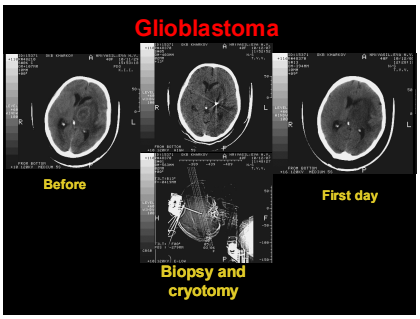
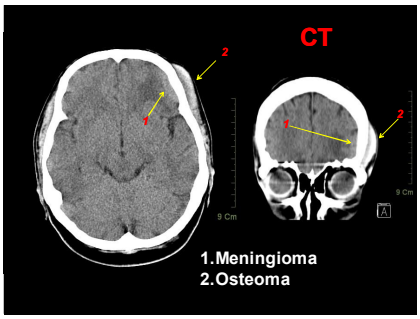
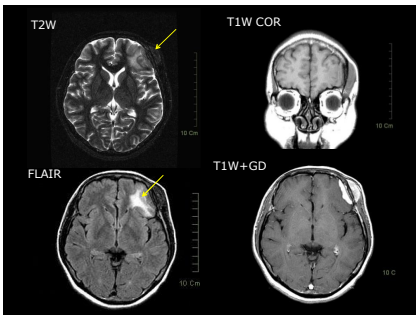

Endoscopic assistance

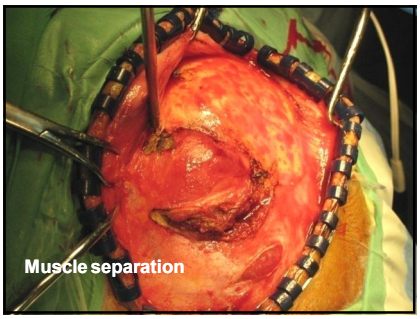

Cryotom

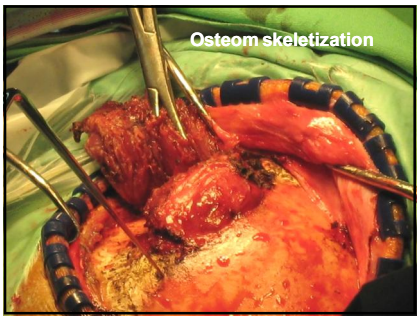

Stereotactic tumor-cryotomy controlled computed tomography intraoperative electrophysiological monitoring

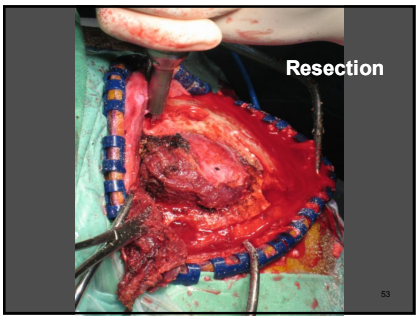

Glioblastoma
Before
First day
Biopsy and cryotomy

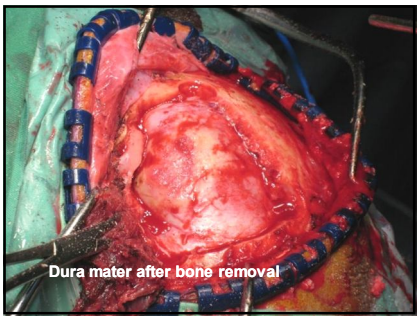

CT
1.Meningioma
2.Osteoma

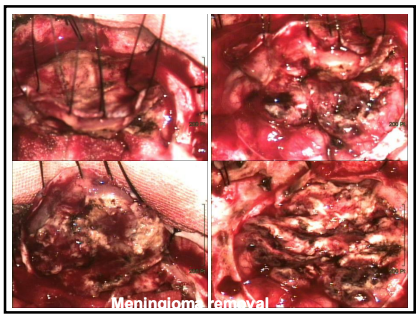

T2W
T1W COR
FLAIR
T1W+GD

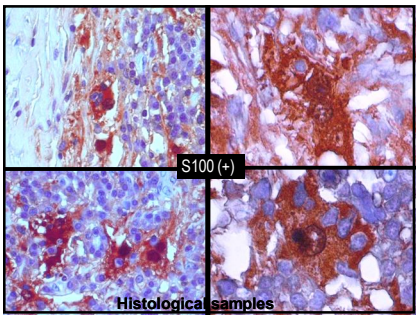

Muscle separation

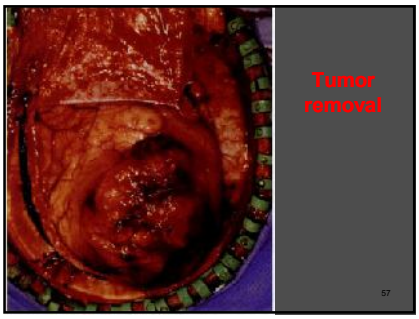

Osteom skeletization

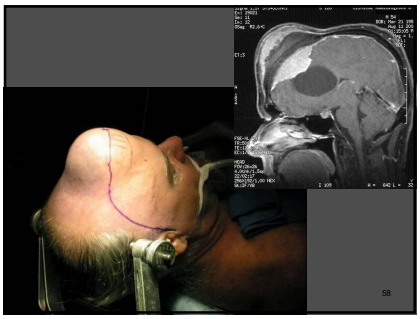

Resection

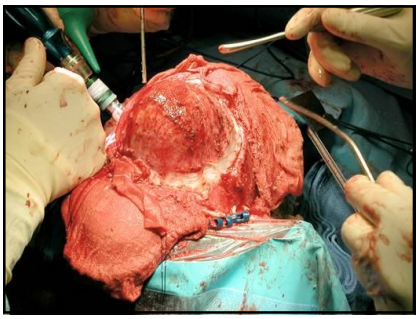

Dura mater after bone removal

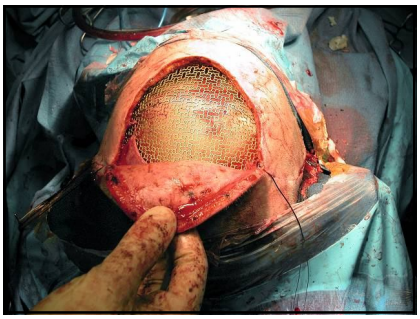

Meningioma removal

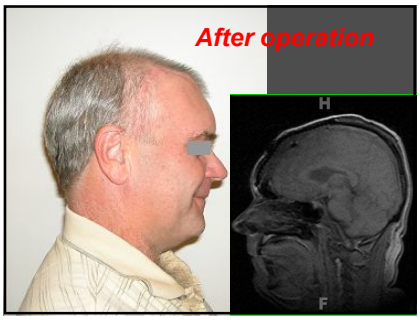

S100 (+)
Histological samples

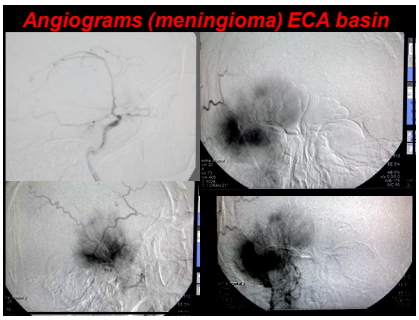

Tumor removal

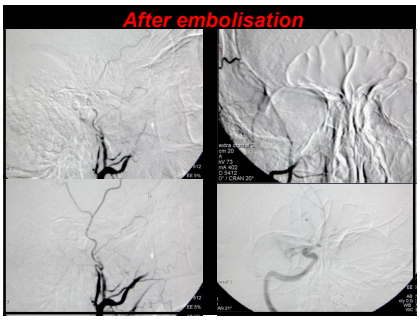


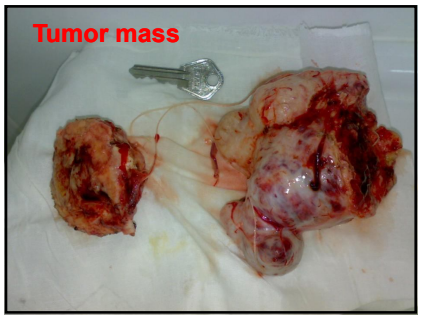


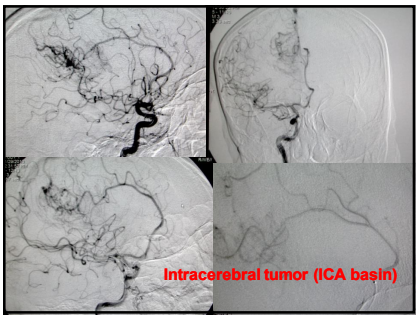


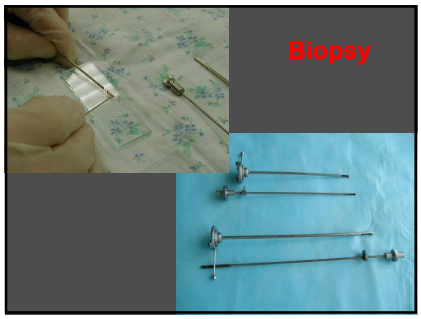

After operation

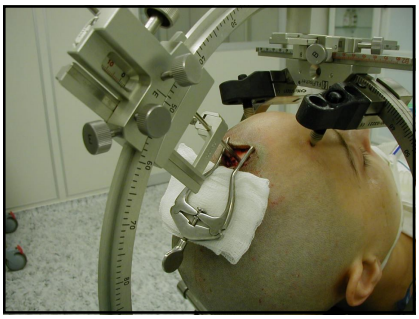

Angiograms (meningioma) ECA basin

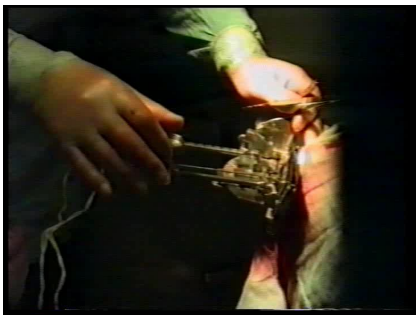

After embolisation

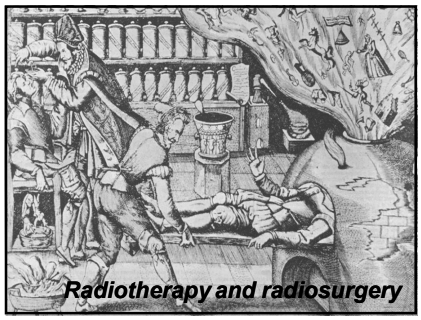






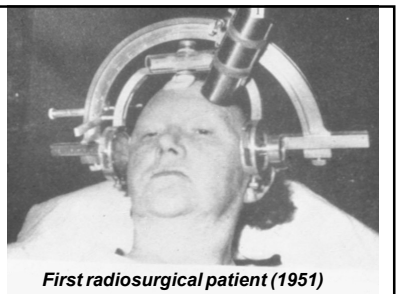






There are several types of devices for stereotactic radiosurgery: Gamma Knife, LINAC, XKnife, SynergyS, Trilogy, CyberKnife, Novalis, and Syclotron.
The principle of operation is the same for all machines, and they differ in energy sources and methods of targeting radiation to the target. So for example a linear accelerator LINAC, which basically uses X-rays and electromagnetic waves of energy all the way allowing to reach 46 MeV. During the procedure, the treatment unit rotates around the patient, providing accurate radiation, focusing on the tumor? The phone Gamma Knife uses 201 radioactive cobalt source and electromagnetic wave, with the ability to achieve the maximum energy of up to 1,25 MeV

71



First radiosurgical patient (1951)

First «Leksell GammaKnife» (1968)

73