MR spectroscopy

DR.NIDA KANWAL RASHEED.

- MR spectroscopy provides a measure of brain chemistry. The most common nuclei that are used are
- ^{1}H (proton), ^{23}Na (sodium), ^{31}P (phosphorus).

- **Proton spectroscopy** is easier to perform.

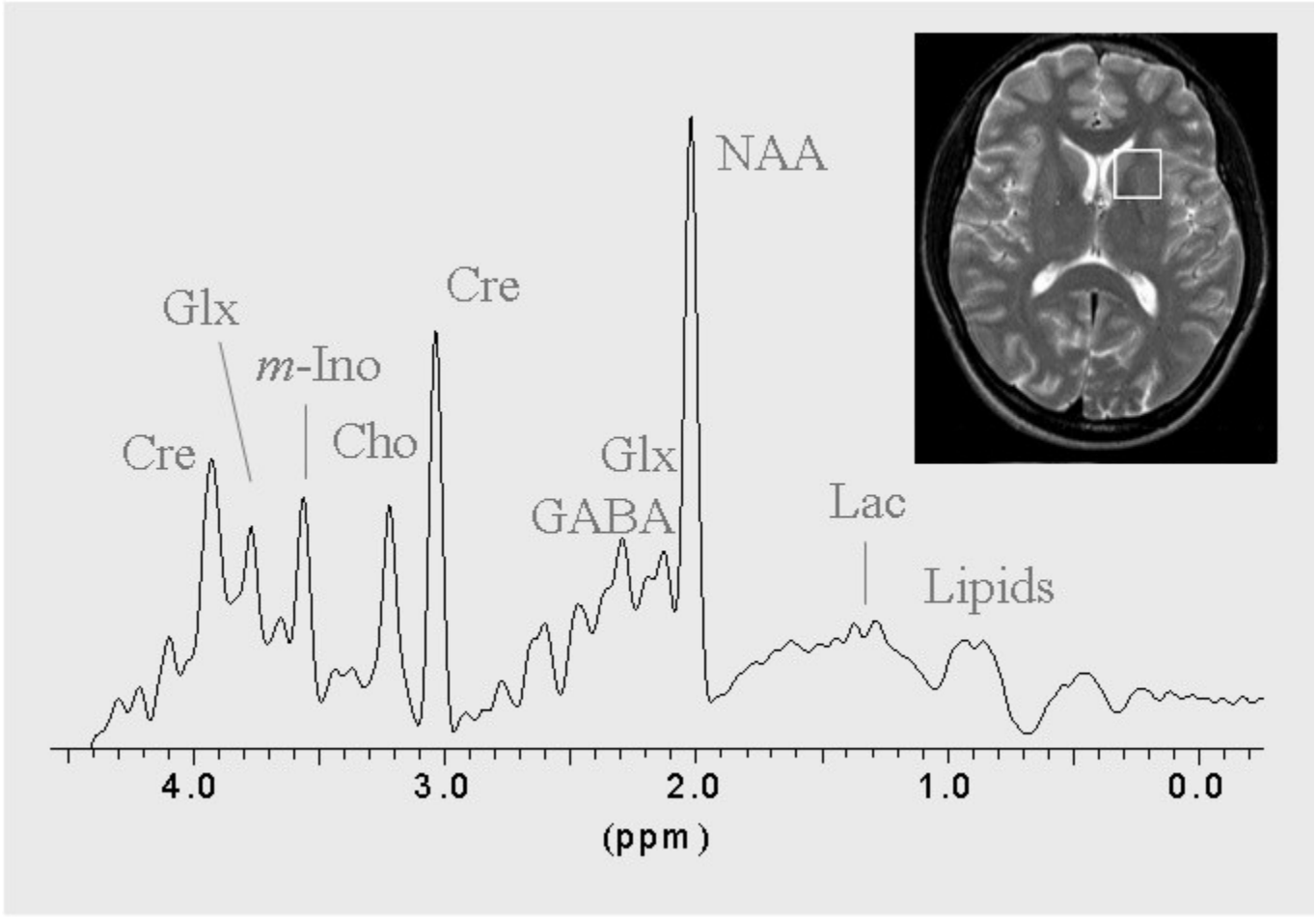
- MRS can be performed within 10-15 minutes and can be added on to conventional MR imaging protocols.
- It can be used to serially monitor biochemical changes in tumors, stroke, epilepsy, metabolic disorders, infections, and neurodegenerative diseases.
- They require interpretation and should always be correlated with the MR images before making a final diagnosis.

How does MR spectroscopy work?

- MR spectroscopy is conducted on the same machine as conventional MRI.
- Spectroscopy is a series of tests that are added to the MRI scan of brain or spine to *measure the chemical metabolism of a suspected lesion*.
- There are several different metabolites, or products of metabolism, that can be measured to differentiate between tumor types.

The brain metabolites that are commonly seen on the MR spectrum are

Metabolite	Properties
Lipids	Products of brain destruction
Lactate	Product of anaerobic glycolysis
NAA	Neuronal marker
Glutamine/GABA	Neurotransmitters
Creatine	Energy metabolism
Choline	Cell membrane marker
myo-inositol	Glial cell marker, osmolyte hormone receptor mechanisms


NAA
Cre
Glx
m-Ino
Cre
Cho
Glx
GABA
Lac
Lipids
4.0
3.0
2.0
1.0
0.0
(ppm)

- Each metabolite appears at a specific ppm, and each one reflects specific cellular and biochemical processes
- NAA→ is a neuronal marker and decreases with any disease that adversely affects neuronal integrity.
- Creatine→ provides a measure of energy stores.
- Choline→ is a measure of increased cellular turnover and is elevated in tumors and inflammatory processes.

- The common way to analyze clinical spectra is to look at *metabolite ratios*, namely NAA/Cr, NAA/Cho, and Cho/Cr.

Metabolite Ratios

	Normal	Abnormal
NAA/Cr	2.0	< 1.6
NAA/Cho	1.6	< 1.2
Cho/Cr	1.2	> 1.5

- For MR imaging, the total signal from all the protons in each voxel is used to make the image.
- If all the signal were used for MRS, the fat and water peaks would be huge and scaling would make the other metabolite peaks invisible.
- *Fat and water are eliminated*.
- Fat is avoided by placing the voxel for MRS within the brain, away from the fat in bone marrow and scalp.

Two forms

SINGLE-VOXEL MR SPECTROSCOPY

- Less advance.
- Volume averaging
- Small area of coverage.
- acquires spectra from single small voxel.
- short acquisition times.
- Histologically *simpler lesions*.

MR SPECTROSCOPIC IMAGING/MULTI-VOXEL.

- more technically advanced technique.
- small voxel size→ dec. volume averaging
- large volume of coverage
- acquires spectra from numerous small voxels.
- long acquisition times.
- For *complex lesions*

- Multi-voxel spectroscopy is best to detect *infiltration* of malignant cells beyond the enhancing margins of tumors.
- Finally, MRS can direct the surgeon to the most metabolically active part of the tumor *for biopsy* to obtain accurate grading of the malignancy.

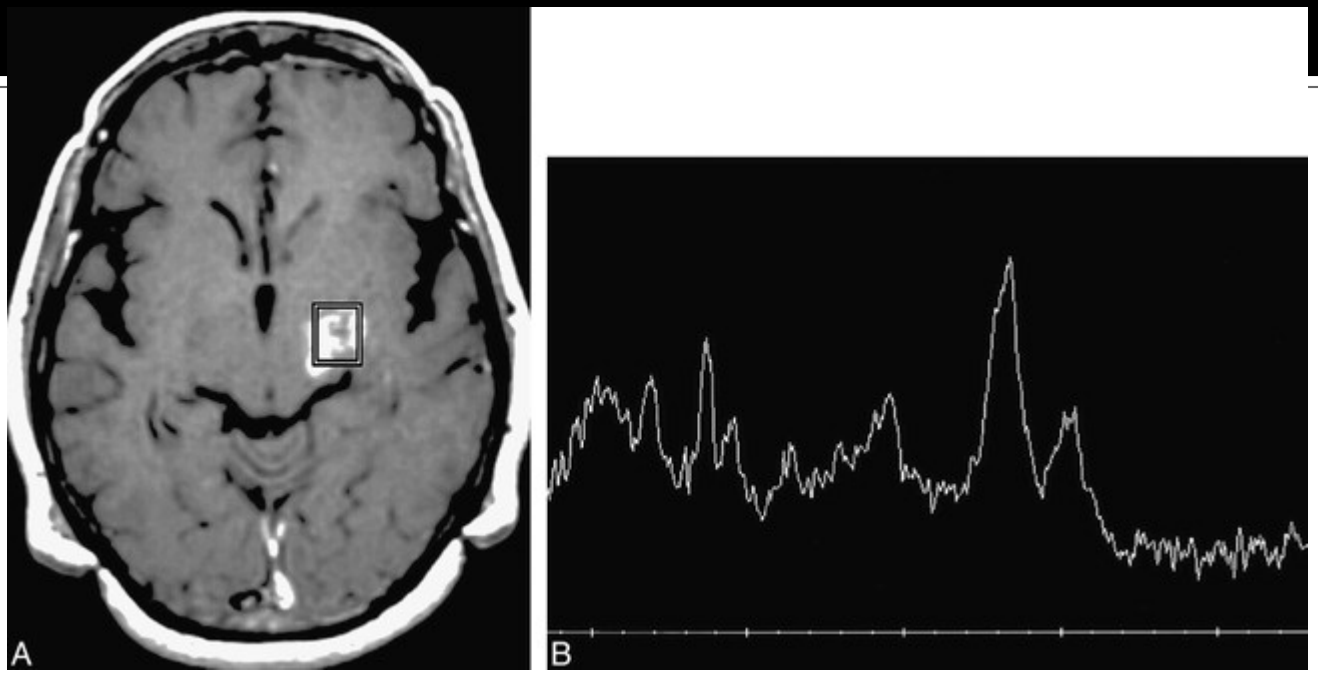
- As a general rule, the single voxel, short TE technique is used to make the initial diagnosis.
- Multi-voxel, long TE techniques are used to further characterize different regions of a mass and to assess brain parenchyma around or adjacent to the mass.
- Multi-voxel, long TE techniques are also used to assess response to therapy and to search for tumor recurrence.

MRS uses

Brain Tumors

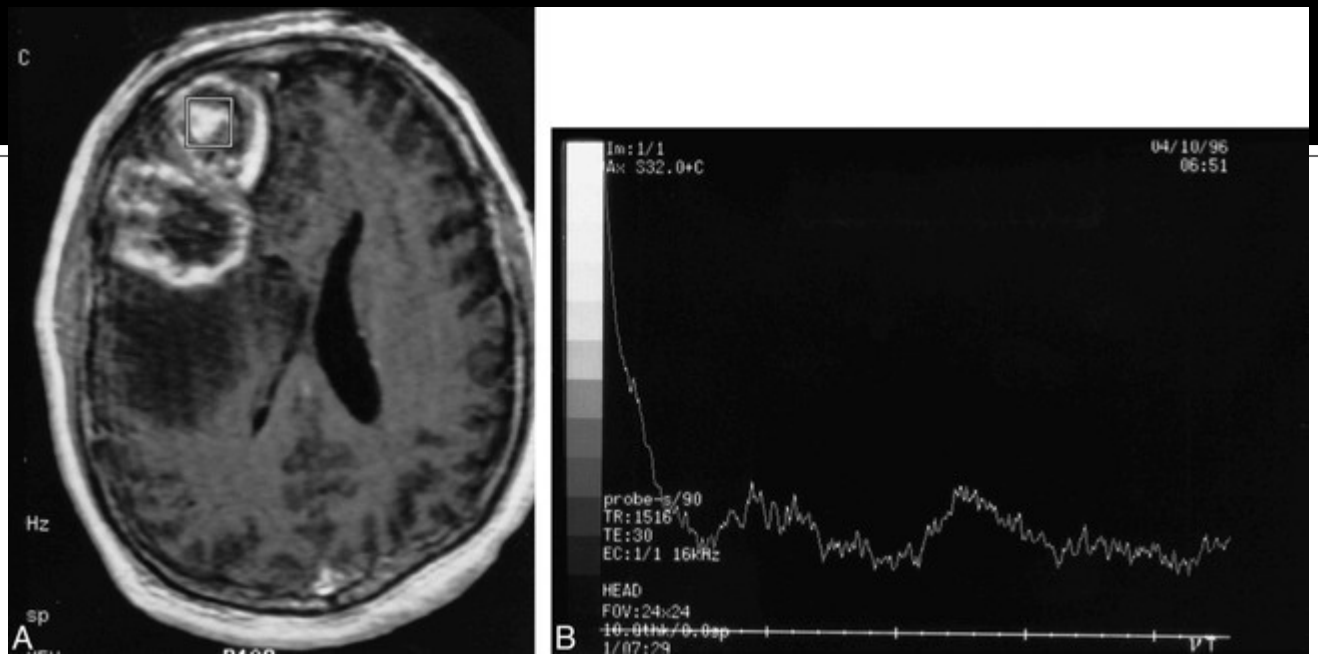
- MRS can be used to determine the degree of malignancy.
- As malignancy increases, *NAA and creatine decrease*, and choline, lactate, and lipids increase.
- ***NAA*** decreases as tumor growth displaces or destroys neurons.
- Very malignant tumors have high metabolic activity and deplete the energy stores, resulting in reduced ***creatine***.
- Very hypercellular tumors with rapid growth elevate the ***choline*** levels.
- ***Lipids*** are found in necrotic portions of tumors
- ***Lactate*** appears when tumors outgrow their blood supply and start utilizing anaerobic glycolysis.

- Key feature of gliomas is elevated ***choline*** beyond the margin of enhancement due to infiltration of tumor into the adjacent brain tissue.
- Elevated ***alanine*** is a signature of meningiomas.



Axial enhanced T1-weighted MR image reveals focal enhancement in the left cerebral peduncle and thalamus. Spectroscopy voxel is placed at the anterior margin of enhancement.

B, MR spectrum reveals elevation of the Cho/Cr ratio, elevation of the lipid/lactate peak, and marked reduction of NAA. The pattern was interpreted as consistent with tumor and was proved to be a **glioblastoma multiforme** at biopsy.



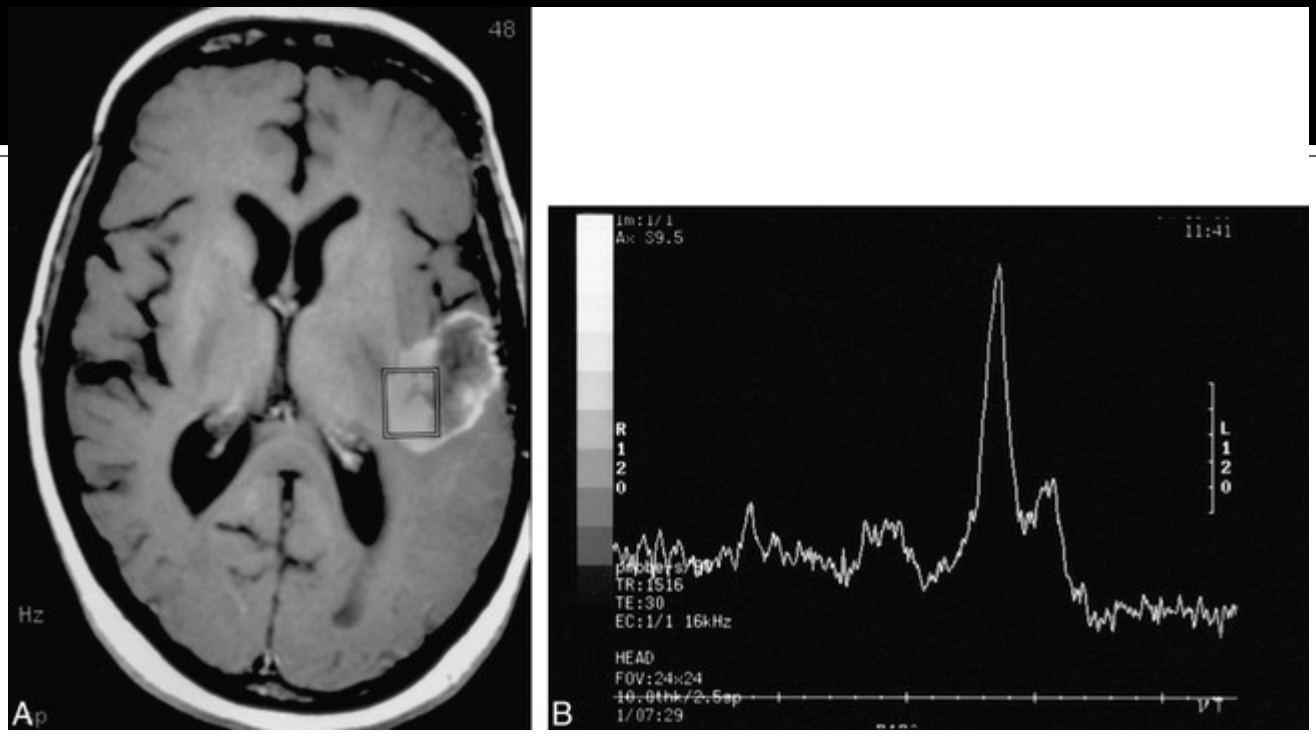
: 58-year-old man with a new right frontal lobe mass.
A, Axial T1-weighted MR image reveals a multilobular cystic and solid mass in the right frontal lobe that contains peripheral and central enhancing regions. The spectroscopy voxel is positioned centrally in an enhancing portion of the tumor and does not include the enhancing edge.
B, MR spectrum reveals absence of discernible Cho, Cr, and NAA. The pattern was thought to be consistent with no tumor. The lesion was histologically shown to be a glioblastoma multiforme after resection.

- Voxel placement in single-voxel MR spectroscopy studies of brain tumors is critical to the accurate characterization of lesion histopathology.
- Specifically, inclusion of the *edge* of an enhancing lesion in the MR spectroscopy voxel improves accuracy .
- Voxel placement in the centre of a lesion with frank cavitation increases the likelihood that cellular breakdown products will dominate the spectral pattern.

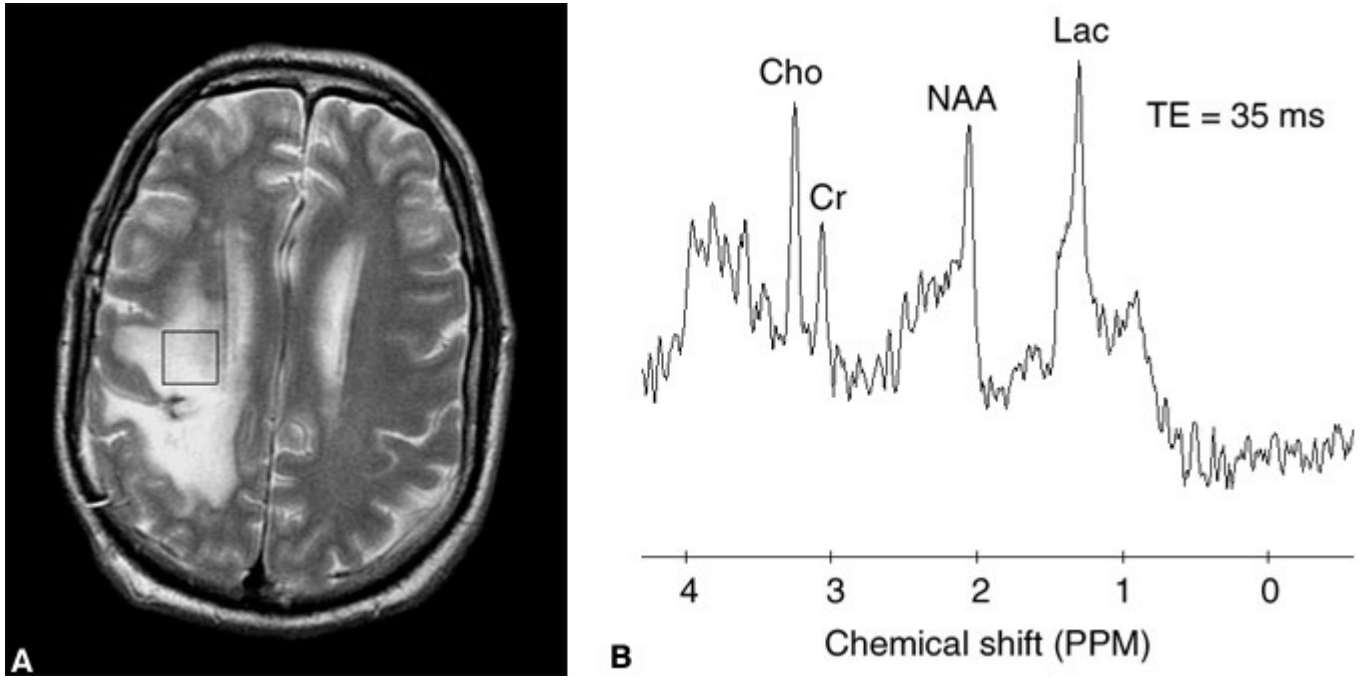
- To get an accurate assessment of the tumor chemistry, the spectroscopic voxel should be placed over an enhancing region of the tumor, avoiding areas of necrosis, hemorrhage, calcification, or cysts.

Tumour recurrence vs radiation necrosis

- A common clinical problem is distinguishing tumor recurrence from radiation effects several months following surgery and radiation therapy.
- *Elevated choline* is a marker for recurrent tumor. Radiation change generally exhibits low NAA, creatine, and choline on spectroscopy.
- If radiation necrosis is present, the spectrum may reveal elevated lipids and lactate.



Patient 2: 48-year-old woman with a history of a glioblastoma multiforme treated with surgery, external beam radiation (59 Gy), and interstitial brachytherapy (58 Gy).
A, Axial T1-weighted MR image reveals enhancement of a right frontal lobe/insular lesion that has both solid and cavitary components. The spectroscopy voxel includes the medial margin of enhancement.
B, MR spectrum shows a prominent lipid/lactate peak with minimal residual Cho and Cr; NAA is absent. The pattern was thought to be consistent with **radiation necrosis**, and this diagnosis was confirmed at resection.



MRS in a patient with a history of anaplastic astrocytoma treated with surgery and radiation.

An elevation of the choline (Cho) peak relative to the creatine and N-acetyl asparate (NAA) peaks and the presence of lactate (Lac) are consistent with recurrent tumor.

Cerebral Ischemia and Infarction

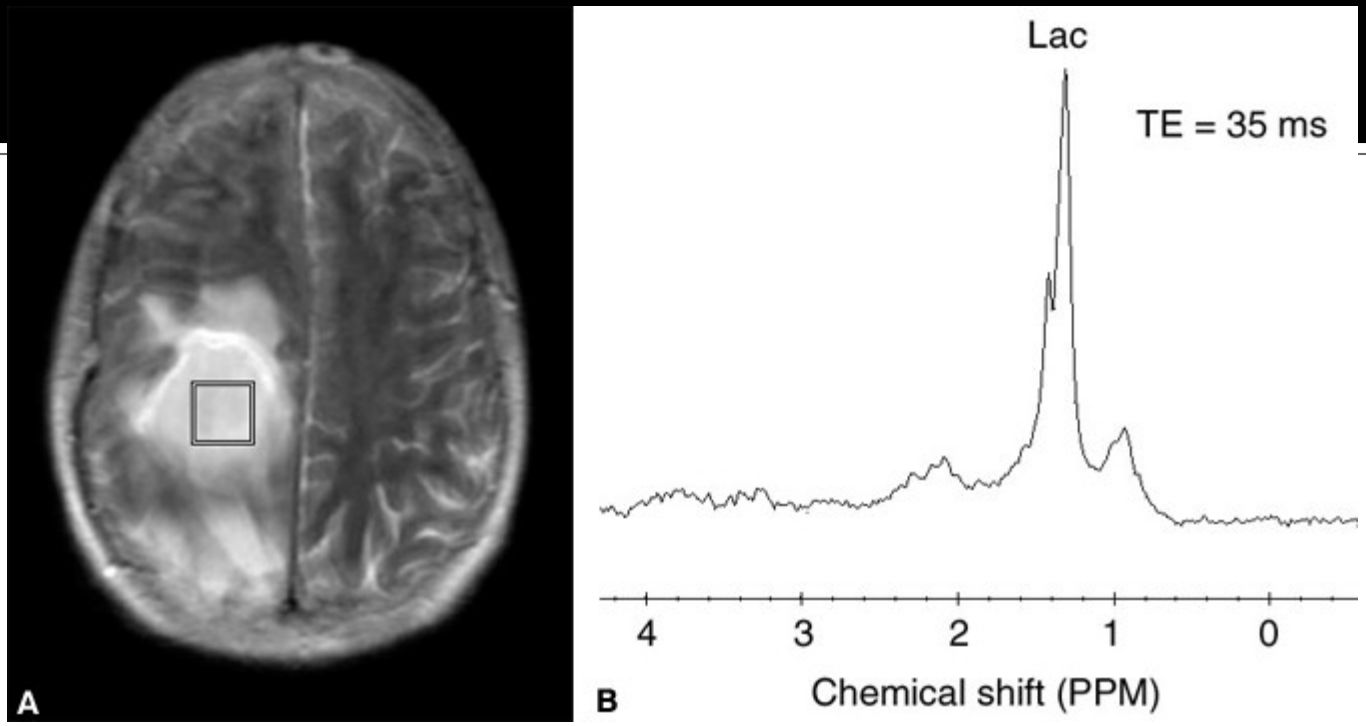
- When the brain becomes ischemic, it switches to anaerobic glycolysis and lactate accumulates.
- Markedly elevated **lactate** is the key spectroscopic feature of cerebral hypoxia and ischemia.
- If cerebral infarction ensues, lipids increase.

Trauma

- MR spectroscopy is not routinely used in the acute setting of head injuries.
- when the patient has stabilized, MRS is helpful to assess the degree of neuronal injury and predict patient outcomes.
- In the case of diffuse axonal injury, imaging often underestimates the degree of brain damage.
- Clinical outcome correlates inversely with the NAA/Cr ratio.
- The presence of any lactate or lipid indicates a worse prognosis.

Infectious Diseases

- Brain abscesses destroy or displace brain tissue, so **NAA** is not present.
- The voxel should include the abscess cavity to detect the breakdown products of these lesions.
- Lactate,succinate, alanine, and acetate are characteristic metabolites in bacterial abscesses.
- Toxoplasmosis and tuberculomas show prominent peaks from lactate and lipids.



Proton magnetic resonance spectroscopy in a treated abscess. (A) Localization of a voxel in a patient with a pyogenic abscess during the course of antibiotic therapy. (B) The marked elevation of the isolated lactate (Lac) peak is consistent with a treated abscess. A similar spectrum would be expected in a cystic or necrotic neoplasm. In an untreated abscess, the detection of bacterial metabolites such as acetate and succinate would distinguish abscess from cystic or necrotic neoplasm.

MRS in AIDS

- Extent of NAA depletion correlates directly with the degree of dementia in AIDS.
- MRS distinguishes the common focal brain lesions in AIDS patients.
- *Choline* → Elevated in lymphoma
  → Decreased in toxoplasmosis, tuberuloma cryptococcoma.
- *Lactate and lipids*→elevated in toxoplasmosis
- *Lactate*→ Decreased in Tuberculoma and cryptococcoma.

SUMMARY

- Magnetic resonance spectroscopy (MRS) is non invasive means of characterising the tissue.
- Multi-voxel technique more complex but accurate
- MRS highly sensitive but sometimes non specific
- MRS is to be reported in conjunction with conventional MR.

Thanks