Introduction to Neurosurgery
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Outline and Objectives
1. History of neurosurgery and overview of current capabilities
2. Intracranial pressure, blood brain barrier, cerebral edema, brain compliance, cerebral autoregulation
3. Spinal stenosis, disc herniation, instability
4. Future direction of neurosurgery
What is Neurosurgery?

- Surgical treatment of disorders of the CNS, PNS, their supporting structures and vascular supply
- Includes surgery of the brain, spinal cord, nerves, CSF, skull, spinal column and blood vessels supplying spinal cord and brain
- Operate ONLY if you can beat the natural history of the disease process

H&P

Investigations (Time, reevaluation)

Dx

Rx

Neuroradiology, Neuroradiology, neurology

Neuropathology

Rx

Defend

History of Neurosurgery

“Do not attempt to run from the past, it is always behind you”
In the beginning.....

“Okay, Bob! Go! Go!”

Trepanation

Lighthouse Man
1st Neurosurgery textbook: von Bergmann (Germany, 1870)
1st surgery based on localization of function: Broca (Paris, 1876)
1st detailed study of human cortex: Krause (Germany, 1908-1911)
1st specialized neurological surgeon: Sir Victor Horseley (London, late 1800s-early 1900s)

In North America....

Pioneer neurosurgeon: WW Keen Jr. (Philadelphia)
1st brain tumour surgery Dec 15 / 1887
Father of American Neurosurgery: Harvey Cushing (1869 – 1939)
Harvey Cushing

- Neurosurgery as a specialty – 1904
- 1st to map the brain with electrical stimulation in a conscious patient

Neuroradiology in early 1900s

- X-rays only 10 years old
- Pneumoencephalogram the main diagnostic modality starting 1918
Spinal injuries commonly treated with prolonged bedrest in early 1900’s

Such was the state of Neurosurgery, “before paper and scissors”......
1965 – 1990 most critical quarter century in history of modern neurosurgery

- Microsurgery
- CT scan
- MRI scan

Microsurgery

- Revolutionary concept requiring use of intraoperative microscope
- More precise surgery
- Allowed improved results at lower risk
- Resident education

Microneurosurgery
Intraoperative image guidance
- "Minimally invasive" device
- Analogous to "smart bomb"

Intraoperative mapping

Functional MRI
Awake craniotomy

- Most useful for operating near the speech center
- Allows “live” intraoperative monitoring of function on continuous basis
- Can combine with other diagnostic modalities

Endovascular therapy

3-D CT Angiography
Endoscopic Surgery

Other Technological Advances

- Stereotactic radiosurgery
- ICP monitoring
- Brain oxygenation monitoring
- Continuous EEG
- Intraoperative EMG monitoring
Key Neurosurgical Concepts - Brain

- Intracranial Pressure (ICP) and cerebral perfusion pressure (CPP)
- Blood Brain Barrier (BBB)
- Cerebral Edema
- Cerebral Autoregulation

Intracranial Pressure

Monro-Kellie hypothesis

- Sum of volumes of intracranial contents (blood, brain, water, foreign materials) is constant
- Increase in any one must be offset by equal decrease in another, or pressure will rise
- These volumes contained in a closed rigid container
Blood Brain / CSF Barriers

- The passage of water soluble substances from blood to the CNS is limited.
- BBB- tight junctions (zonulae accludentes) at the capillary level endothelial cells
- Blood-CSF barrier due to tight junctions between choroid plexus epithelial cells.
- Specialized transporter mechanisms to carry substances across the barriers
Cerebral Edema

- Vasogenic:
  - Disruption of BBB
  - Expansion of extracellular space
  - Amoebic pseudopods of edema in white matter
  - Seen in inflammatory conditions (e.g. tumor, abscess).
  - Rx with steroids

Sarcoid granuloma with vasogenic edema, contrast enhancement

- Cytotoxic
  - BBB closed
  - Loss of cellular ionic pump function
  - Cellular swelling
  - Seen in head injuries, ischemia
Pedestrian struck by car. Severe diffuse edema, c/w top right appearance.

Note lack of diffuse edema. Compare right (Sturge-Weber) to CT below.

- Osmotic
  - Extracellular space expansion due to osmotic forces
  - Seen in hyponatremia

- Hydrostatic
  - Fluid forced out of blood vessels due to hydrostatic forces
  - Seen in severe hypertension
Effect of cerebral edema on brain compliance

Cerebral autoregulation

Key Neurosurgical Concepts - Spine
- Spinal stenosis – cervical, lumbar
- Spinal disc herniation – cervical, lumbar
- Spinal instability
  - acute vs. chronic
Spinal Stenosis

- Narrowing of AP dimension spinal canal; in L-spine, also lateral gutter stenosis
- Congenital, acquired, or combination
- Most commonly C or L spine
- Natural hx: slow progressive worsening, (sudden paralysis with C-spine trauma)
- Rx – decompressive surgery +/- fusion
- Prognosis – **partial** improvement in most

Cervical Spinal Stenosis - clinical

- Radiculopathy- radiating arm pain, numbness, paresthesias
- Myelopathy- sensory and motor arm/leg deficits, bilateral hand numbness and fine motor deficits, hyperreflexia, hypertonia, Babinski, Hoffman, urinary incontinence
- Vague pain, paresthesias in head, neck, shoulders, arms. Beware of other causes.
C-spine stenosis with kyphosis, pre- and postop (with instrumented arthrodesis)

Expansion of cervical canal after laminoplasty for stenosis

Lumbar Spinal Stenosis - clinical
- Lower back pain, unilateral or bilateral leg pain/numbness/paresthesias
- **Neurogenic claudication** (vs. vascular claudication) – leg pain with walking
- Leg symptoms typically improve with forward bending
Lumbar spinal stenosis

<table>
<thead>
<tr>
<th>Neurogenic Claudication</th>
<th>Vascular Claudication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relief with rest slow despite standing/resting</td>
<td>Standing helps, relief almost immediate</td>
</tr>
<tr>
<td>Prolonged posture, variable amount of walking triggers</td>
<td>Fixed/predictable distance of walking, pain rare at rest</td>
</tr>
<tr>
<td>Back, leg discomfort with bending, lifting</td>
<td>Not usually</td>
</tr>
<tr>
<td>Sciatic nerve distribution pain, dermatomal numbness</td>
<td>Muscle group distribution, stocking sensory loss</td>
</tr>
<tr>
<td>Coughing, back extension can increase, forward flexion</td>
<td>Not usually</td>
</tr>
<tr>
<td>No foot pallor on elevation, present pedal pulses, skin temp normal</td>
<td>Foot pallor on elevation, absent pedal pulses. Femoral bruits, skin temp decreased</td>
</tr>
</tbody>
</table>

Cervical / lumbar disc herniation

- In C-spine roots exit **above** the pedicle of its like-numbered vertebra, i.e. C7 root in C6-7 foramen
- In C-spine, disc impinges on root exiting same level foramen, i.e. C6-7 disc impinges C7 root
- In L-spine roots exit **below** the pedicle of its like-numbered vertebra, i.e. L4 root in L4-5 foramen
- In L-spine also disc usually impinges higher numbered root, for different anatomical reasons, i.e. L4-5 roo impinges L5 root most commonly
L4-5 disc impinges L5 root unless far lateral disc

Cervical Disc herniation - clinical

- Radiating pain / paresthesias in distribution of root (C6 most common)
- Beware of left arm pain from cardiac ischemia
- Sensory, motor deficits in root distribution
- Spurling's sign, traction test, shoulder abduction test (C-spine)

Left C5-6 disc herniation on CT-myelography
Lumbar Disc herniation - clinical

- Unilateral leg pain worse with Valsalva, improved with hip or knee flexion
- Distribution sciatic or anterior thigh/groin
- Straight leg raise test, femoral stretch test, Laseque’s test (L-spine)
- Crossed straight leg raise test

Disc herniation - Rx

- Conservative – NSAIDS, muscle relaxants, judicious rest, ice, temporary orthosis, TIME
- Activity modification
- Cervical traction for C-spine
- Epidural injections
- Surgery
Disc herniation - prognosis

- Better than spinal stenosis
- Sensory deficits often persist to varying degrees
- Overall excellent relief of pain in >80% of patients
- Possibility of recurrence

Spinal Instability

- Failure in performance of two functions: to protect neural contents and to uphold structural support without pain

Spinal Instability

- Acute – trauma
- Chronic – old trauma, spondylolisthesis, tumor, osteomyelitis
- Rx – bracing, halo-vest (C-spine), surgery, (prolonged bed rest)
Acute traumatic C5-6 dislocation

G.B. Jan 2002. MRI T1. T2-3 NSCLC contiguous spread

G.B. Jan 2002 T2-3 NSCLC (contiguous)

L5-S1 lytic spondylolisthesis
The Future

"The best way to predict the future is to invent it"

Intraoperative MRI combined with....

....neuronavigation: A new concept

Neurosurgical operating room...in the 21st century

- Simplified computer, imaging, sensor and display systems
- Miniaturization
Anatomy – Function Correlation...in real time

“Surgeons who have learned to use the scalpel so expertly that they can take anything out of anywhere without a fatality...cut the currents of intellect and leave a man who is still capable of walking...”

Wilder Penfield

? Thought – Function Correlation?

Anatomy – Function Correlation: The challenge

Robotics

- Haptics
- Bionic integration
- Telerobotic surgery
Virtual Reality Neurosurgery

- Heads-up display and headset connected to operative instruments
- Allows surgeon precision control without ever touching the patient
- Training applications

Telemedicine

Related: Virtual Reality Neurosurgery

Neurology's Science Times

Title: Brain Meets Machine: A New Neurosurgical Frontier

NIH Program Announcement: Nanoscience and Nanotechnology in Biology and Medicine (PAB-05-045)
Nanoneurosurgery

The Mars Pathfinder

Mouth of a dust mite and a micromachine the diameter of a human hair; gears turn at 1000s rpm

NIH Program Announcement: Nanoscience and Nanotechnology in Biology and Medicine (PAR-03-045)

On December 12, 2002, the National Institutes of Health (NIH) issued a Program Announcement (PA) aimed at enhancing nanoscience and nanotechnology research with implications for biology and medicine. This is an initiative of the trans-NIH Bioengineering Consorition (ECON). Nanotechnology refers to objects at the atomic, molecular or macromolecular scale. Nanometers is 10^-9 meters. Developments in science and engineering have led to the reality of characterizing and manipulating matter at this scale; it is used as building blocks for larger structures using a "bottom-up" approach such as that which exists in nature. Examples of natural nanomachines include molecular motors and pumps which catalyze chemical reactions, produce information, and transport molecules across membranes. The purpose of this PA is to stimulate cross-disciplinary research study the capabilities of these devices in their natural environment, and to improve understanding of basic biology and physiology. Furthermore, these nanomachines may have diagnostic and therapeutic applications, as directed delivery of drugs. Nanotechnology is predicted to play a major role in future treatment of human diseases, including the nervous system. The mechanism of application for this PA are to R15 (investigator initiated research project grant) and the R21 (exploratory developmental research grant) awards. The deadline for grant submission under this PA is February 18, 2004. More information about this can be found at [http://grants.nih.gov/grants/guide/files/PAR-03-045.html](http://grants.nih.gov/grants/guide/files/PAR-03-045.html).

Toward Cellular Neurosurgery

Cellular manipulation using laser “tweezers” and “scissors”
Gene therapy
- Specific genes inserted into cells to alter their genetic repertoire for therapeutic purposes; examples include:
  - DNA chip for normalcy and pathology
  - Immuno-gene therapy in fight against cancer
  - BMP gene therapy to enhance spinal fusion

Neural Regenerative Therapy
- The next revolution in neuroscience
- Restoration of function – the “holy grail” of neurobiology!
- Transplant..............? science fiction?

The Molecular Basis of Neural Regeneration

The central nervous system (CNS) is incapable of significant regeneration of tissue following injury and disease, making it one of the most difficult organ systems in the body to repair. However, recent advances in our understanding of the molecular mechanisms underlying CNS regeneration have provided new insights into the potential for regenerative medicine in the CNS. Several key factors, including the presence of glial scar tissue, the limited ability of cells to migrate and differentiate, and the inherent plasticity of CNS neurons, contribute to the limited regenerative capacity of the CNS. Despite these challenges, progress has been made in developing therapeutic strategies to enhance CNS regeneration.

References:

For more information, please consult the above references.
Role of PAs in Neurosurgery

- New and f/u pts in clinic
- Assist during surgery, close wound
- Rounding on patients
- New inpatient consults
- Preop H&P, counseling patients, postop f/u
- Help develop departmental protocols
- Call, depending on setting

Why Neurosurgery?

10. Affable colleagues
9. Never a dull day

8. Opportunity to innovate

7. Develop unparalleled confidence
6. Stay busy, rarely an idle moment

5. Fertile ground for inventive thinking

4. Thinking “out of the box” encouraged
3. Collaboration in an interdisciplinary setting

2. Opportunities for heart pounding action

1. There are worse jobs out there