Plenary Address: Medico-Legal Issues in Neuro-intensive Care

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Medico-Legal Issues in Neuro-Intensive Care

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The institution of specialised Neurologic Intensive Care units has improved outcome of those who suffer Neurologic injuries; traumatic brain injury, intracranial vascular accidents, and major trauma. However, patients who survive the initial neurologic insult are often left with a major neurological deficit which has serious economic implications both for health care resources and for society, as many of the patients affected are young adults early in their working lives, and end up requiring long-term care.

Intensive care of patients who suffer brain injury aims to prevent secondary neuronal damage. Secondary injury is the damage that occurs subsequent to the original injury as a result of poor brain perfusion from hypoxia, hypotension or raised intracranial pressure. Despite the widespread compliance with published guidelines regarding the management of the head injury per se, many shortcomings remain evident in the management of these patients. In this lecture, I will provide an overview of the main pathologies seen in neurologic intensive care, factors that affect outcome, treatments that have been shown to improve outcome, and the optimal organisational structures needed to avoid worsening outcome.
Cambridge University Hospitals

• 1,000 beds, ~ 80 CC beds
• 8,000 staff
• 5,726 births
• £650m turnover
• Attendances at A/E > 110,000
• Admissions to inpatients ~ 180,000
• Outpatient attendances ~ 500,000

Healthcare – the facts!

• Healthcare has come a long way!
• People expect more:
  • live longer, survive injury, good outcome
• Doctors to be highly specialised

Improving Healthcare

• Basic programs;
  • immunisations, antenatal care, antibiotics
• Safety laws;
  • helmets, speed restrictions, seat belts
• Technological advances;
  • car design, airbags, antilock brakes, roll bars
• Better treatment at roadside and at EDs
• Outreach support;
  • ambulances, medivac teams, RRTs
**What is a “Specialist”?**

- A specialist is a person who concentrates primarily on a particular subject or activity and becomes highly skilled in a specific and restricted field.

- In medicine - a Doctor highly trained in a particular branch of medicine, thus possessing detailed knowledge and skill to treat a particular disease or group of diseases.

**General Vs Specialised**

*How do we decide?*

- Needs assessment
  - Size of population, Incidence of the disease
  - Availability of expertise
  - Complexity of the treatment
  - Cost of treatment
  - Geographic boundaries
  - Sustainability of the system

- Avoid making specialization an instrument looking for an illness to treat, rather than keeping people healthy!

**Specialisation – why?**

**Economic Considerations**
(economies of scale, spread cost, reduce duplication)

**Outcomes**
(experience, practice)

**Education**
(training doctors, AHP)

**Research**
(epidemiology, research trials, translational research)
**Pathology of Interest**

*Better Outcomes?*

- Head Trauma
- Major Trauma
- Stroke
- SAH

**Topics of Interest**

- Caseload – effect on outcome
- Management of
  - ICP
  - Blood Pressure
  - Temperature
  - Seizures
  - Antiplatelets & DVT Prophylaxis
  - Novel therapies and preventative measures

**Traumatic Brain Injury**

- Devastating outcome
- Economic costs are high
- Multidisciplinary teams
Traumatic Brain Injury: Outcome

• Primary Insult
• Secondary Insult:
  – Hypoxaemia
  – Hypotension
  – Intracranial Hypertension (mass)

Anatomy

• Cranial cavity: brain (80%), blood (10%) and CSF (10%)
• Normal ICP at foramen of Monro: 5-15 mmHg
• Increase in one of these will raise ICP unless compensated
• Several compensatory mechanisms
Raised ICP: Pathophysiology
( Depends on speed of rise and duration)

- **Effect on Cerebral Haemodynamics**
  - Collapse of bridging veins
  - Increased venous pressure
  - Reduction of CPP
  - Ischaemia

- **Direct Pressure Brain Parenchyma**
  - Obstruction of CSF flow
  - Pressure gradient across FM
  - Brain herniation

“Surgical” lesions

SDH  SDH + Contusion  SOL + contusions

“Non-surgical” lesions

Still needs ICP monitoring, and may need surgery
Mechanism of injury and therapeutic Window:
Neuronal damage over time

- Excitotoxicity
- Peri-infarct depolarization
- Inflammation
- Apoptosis

ICP: independent predictor of mortality + poor outcome

Balesteri et al. 2006
CPP: independent predictor of mortality + poor outcome

Balester et al. Neurocritical Care 2006

Prevent Secondary Damage
(Seizures, Hyperventilation, Hyperthermia)

Neuroprotective Agents
(Mg, Barb, Anaesthetics)

Optimise Physiology
(CPP, oxygenation, BG)

Neuroprotective Techniques
(Hypothermia, Decompressive craniectomy)

Aim of Treatment

- Ensure adequate oxygenation
- Optimise Cerebral Perfusion Pressure
- Prevent and Treat Raised ICP
Figure 1. ICP lowering therapies should be administered in a stepwise fashion. Starting with those with less risk/benefit profile. Treatments with a high risk/benefit profile should be reserved for cases where intracranial hypertension is associated with radiological or clinical features of impending cerebral herniation or cerebral metabolic failure. PRx: Pressure Reactivity Index; LPR: Lactate/Pyruvate Ratio; PbtO2: Brain Tissue Oxygenation; SjO2: Venous Jugular Saturation; SOL: Space-occupying lesion; CK: Creatin Kinase; EEG S.R.: Suppression Rate.

R3-Survey of traumatic brain injury management in European Brain IT Centres 2001

Management of severe head injury: Institutional variations in care and effect on outcome

Considerable national variation in the care of severely head-injured patients persists. An “aggressive” management strategy is associated with decreased mortality in patients with severe head injury.

The effect of specialist neurosciences care on outcome in adult severe head injury: a cohort study.
Fuller G, Bannister D, Woodford M, Jenkins T, Patel H, Conod T, Oates P, Nandigama AD, Thank I, Waterman J, Leary J. Trauma Audit and Research Network, Health Sciences Research Group, Manchester Academic Health Science Centre, University of Manchester, Clinical Sciences Building, Salford Royal Hospital, Salford, UK. gordonfuller@man.ac.uk

RESULTS: 5461 patients were identified with SHI between 2003 and 2009. With 1485 (27.4%) receiving treatment entirely in non-NSU centers. SHI management in a non-NSU was associated with a 1% increase in crude mortality (P<0.001) and 1.72-fold (95% confidence interval: 1.52-1.96) increase in odds of death. The case mix adjusted odds of death for patients treated in a non-NSU with SHI was 1.85 (95% confidence interval: 1.57-2.19).

CONCLUSIONS: Our data support current national guidelines and suggest that increasing transfer rates to NSUs represents an important strategy in improving outcomes in patients with SHI.
ICP/CPP Management

ICP monitoring as clinically indicated. Primary targets:
ICP ≤ 20 mmHg and CPP 50 to 70 mmHg
If advanced monitoring is available, fine-tune treatment based on multimodality targets:
Pfr x 8.2: LPR < 25; PhtO2 ≥ 15 mmHg; SpO2 > 95%

**Stage 1**

- Sedation: Propofol 2-5 mg/kg/hr, Fentanyl 1-4 µg/kg/hr; consider Atrocurium 0.5 mg/kg/hr
- Ventilation: SpO2 ≥ 84%; PaCO2 4.5-5.0 kPa (33-38 mmHg)
- Circulation: correct hypovolaemia; vasopressors titrated to CPP ≥ 50 mmHg
- Temperature: ≤ 37°C (regular paracetamol +/- automated cooling blanket)
- Nursing: 15-30° head up; avoid venous obstruction
- Antiepileptics: EEG to exclude seizures +/- institute or escalate antiepileptic therapy

**Airway**

- Intubate Early
- Rapid Sequence Induction
  - Induction agent: Any.
  - Suxamethonium is OK!
  - Oral intubation
  - Cervical spine protection
- No sedation “just for the CT”

**After Intubation**

- Maintain CPP
- Do not increase ICP
  - Neck neutral
  - No tight ties
  - No high inflation pressures
- Sedation
- Ventilation
**Why Hyperventilate?**

- Improve Cerebral Oxygenation:
  - Reduce CBV and ICP, Thus increasing CPP
  - Increase Oxygen Delivery
  - Reduce oedema - improve surgical conditions
  - Improve cerebral autoregulation?

- Assumptions:
  - Intact CO$_2$-reactivity
  - Reduction in CBV > CBF – no ischemia!
  - Response in uniform (or better - inverse steal)
  - Reversible

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**Normal range in healthy volunteers (different methodology)**


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**Hyperventilation in TBI (6 hrs post impact)**

*Areas in red show regions with rCBF < 20 ml/100g/min*  
Tissue chemistry targets

- Tissue pO$_2$ > 15 mmHg$^1$ 20/25 mmHg$^{2,3}$
- Lactate/pyruvate < 25$^4$(> 40 = late atrophy)$^4$
  (LPR)

Hutchinson Triple Bolt
- Codman ICP, 100kDa cutoff microdialysis catheter, Licox probe

References

1. Brain Trauma Foundation Guidelines

Names in italics are senior authors on publications

ICP/CPP Management

- ICP > 20 mmHg? Escalate to STAGE 4
  - consider re-scan
  - SOL evacuation

  - Burst suppression: Thioentone 5 mg/kg + 3-8 mg/Kg/h (titrate to EEG S.R. < 50%)
  - Surgical decompression: bifrontal or large fronto-temporo-parietal craniectomy

• Plain Language Summary
  - There is no evidence that hypothermia is beneficial in the treatment of head injury
Intracranial Vascular Disease

Management Aims: Prevent Cerebral Ischaemia

- **Initial Assessment**
  - Airway, Breathing, Circulation
  - Maximising CBF:
    - Prevent & treat raised ICP
    - Control of seizures
    - Prevent re-bleeds
  - Treat systemic complications; fever, cardiac, electrolytes
- **Definitive Treatment**
  - Depending on Primary Pathology

Aneurysmal SAH

- Aneurysms occur at vascular bifurcations, Circle of Willis or proximal cerebral artery
- Incidence 8-12 in 100,000 (900 cases/year)
- High morbidity and mortality:
  - 30-50% mortality; 1/3 die before reaching hospital, only 25% go back to normal life.
  - Conservative Mgx - higher mortality (40% Vs <10% within 6 months of the bleed).
  - Conservative Mgx in those > 64 years, unruptured, < 1 cm is advocated.
Cerebral Aneurysms: Age and Gender

Aneurysmal SAH Background

<table>
<thead>
<tr>
<th>Co-morbidities</th>
<th>n</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>121</td>
<td>40.2</td>
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<tr>
<td>None</td>
<td>104</td>
<td>34.4</td>
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<tr>
<td>Unknown</td>
<td>33</td>
<td>11.0</td>
</tr>
<tr>
<td>Angina, myocardial infarction, arrhythmia</td>
<td>33</td>
<td>10.6</td>
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<tr>
<td>Other</td>
<td>25</td>
<td>8.3</td>
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<tr>
<td>Diabetes</td>
<td>21</td>
<td>7.0</td>
</tr>
<tr>
<td>COPD</td>
<td>21</td>
<td>7.0</td>
</tr>
<tr>
<td>Ischemic stroke</td>
<td>19</td>
<td>6.3</td>
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<tr>
<td>Cancer</td>
<td>17</td>
<td>5.6</td>
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<tr>
<td>Dementia</td>
<td>11</td>
<td>3.7</td>
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<td>3.7</td>
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<tr>
<td>Medication</td>
<td>8</td>
<td>2.7</td>
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<tr>
<td>Sickle cell anemia</td>
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<tr>
<td>Arthritis</td>
<td>8</td>
<td>2.7</td>
</tr>
<tr>
<td>Total</td>
<td>309</td>
<td></td>
</tr>
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Definitive Treatment How and when?

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>%</th>
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<tbody>
<tr>
<td>Aneurysm clipping</td>
<td>238</td>
<td>81.9</td>
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<tr>
<td>Aneurysm clipping</td>
<td>40</td>
<td>13.2</td>
</tr>
<tr>
<td>Aneurysm clipping after attempted clipping</td>
<td>6</td>
<td>2.0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>309</td>
<td></td>
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</table>
Why definitive treatment in < 48 hours?

Risk of Rebleed

<table>
<thead>
<tr>
<th>Percentage</th>
<th>&lt;24 hours</th>
<th>&lt;24-48 hours</th>
<th>&gt;48 hours</th>
</tr>
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<tbody>
<tr>
<td>No re澤éed</td>
<td>62%</td>
<td>72%</td>
<td>40%</td>
</tr>
<tr>
<td>Mild disability</td>
<td>28%</td>
<td>24%</td>
<td>24%</td>
</tr>
<tr>
<td>Moderate disability</td>
<td>8%</td>
<td>6%</td>
<td>8%</td>
</tr>
<tr>
<td>Severe no re澤éed</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Figure 4.3 The relationship between time to intervention and the frequency of delayed cerebral ischemia, re-bleeding and hydrocephalus.

Advisory assessment form: n=248 (Insufficient data in 31; 24 hours n=150; 24-48 hours n=55; >48 hours n=48)

EVD in all poor grade patients, set initially at 10-15 cmH₂O. EVDs should be transduced to obtain ICP readings. Routine CSF samples are NOT indicated. EVDs should be "challenged" and removed as soon as possible to minimize risk of ventriculitis.

Daily TCD in all poor grade patients. NIRS monitoring when available.
PbtO₂, microdialysis can be considered in selected patients.

In case of deterioration consider additional CTH (hydrocephalus, re-bleed, infarct, oedema & infection), TCD (vasospasm), CTP (to assess salvageable penumbra and fine tune MAP targets), EEG (seizures), LP (infection, hydrocephalus).

NEURO OBS and ABP MONITORING. In ventilated patients, extubation should be attempted ASAP (consider NIV, CLONIDINE, LABETALOL).

MAP augmentation according to protocol, target MAP 80 to 100 mmHg.

Prophylactic LMWH (+/- antiplatelets following endovascular treatment).

10-15 cmH₂O in all poor grade patients, set initially in P1 or P2 (IV) rooms. 15 cmH₂O should not be considered absolute upper ICP limits. Paired ICP samples are NOT indicated. ICP will be "challenged" and removed as soon as possible after exclusion of infection.

Comparison of GCS on day 1, 2, and 7 between patients with and without aneurysms in patients treated within 48 hours.
Perioperative Fever and Outcome in Surgical Patients with Aneurysmal Subarachnoid Hemorrhage

by Michael M. Todd, M.D., Bradley J. Hindman, M.D., William R. Clarke, Ph.D., James C. Torner, Ph.D., Julie W. Weeks, M.P.T., Emine O. Bayman, Ph.D., Qian Shi, Ph.D., Christina M. Spofford, M.D., and The IHAST Investigators

Objective: Examine the incidence of perioperative fever and its relationship to 3-month outcome in 1000 patients enrolled in IHAST2.

Neurosurgery 64:897–908, 2009
CONCLUSION: Fever is common (41%) and is associated with worsened outcome in surgical subarachnoid hemorrhage patients, although, it may be a marker of other events rather than a causative factor.

Stroke

London’s Hyperacute Stroke Units

Improve Outcomes and Lower Costs

- Stroke
  - major health and health system burden
  - stroke care accounts for about 5% total spending on health care in the UK, rising to 10% when indirect costs (such as caregivers) are taken into account.
- There are 150,000 strokes per year in UK, of whom 34,000 die.
London's Hyperacute Stroke Units
*Improve Outcomes and Lower Costs*

- Prior to 2010
  - 34 hospitals in London provided acute stroke care
  - each receiving ~ 150 to 450 stroke patients/year
  - wide variation in access to specialized treatments
  - Many units were unable to provide 24/7 clot thrombolysis with < 3.5% of stroke patients across city thrombolysed

- Darzi Report
  - The strategy consolidated the treatment of all early-phase (first 72 hours) acute stroke patients in London within eight specialized high volume centers designated hyperacute stroke units or "HASUs".
  - These HASUs, treated 600 to 1,200 patients per year. Each could provide 24/7 diagnostic testing, interventions and multidisciplinary care.

- Results
  - 3 month mortality rates fallen by 25%
  - cost of treating each stroke patient reduced by 6%
  - HASUs were in the top quartile of national performance, and thrombolysis rose from 3.5% in early 2009 to 11% of all patients in 2012.
  - average length of stay fell from 15 to 11.5 days
Average number of subarachnoid hemorrhage (SAH) patients seen per year and average number of deaths within 6 months in 25 neurosurgical units in England.

McNeill L et al. Stroke. 2013;44:647-652. Copyright © American Heart Association, Inc. All rights reserved.

Comparison of 6-month mortality rates for a range of annual subarachnoid hemorrhage (SAH) caseloads.

McNeill L et al. Stroke. 2013;44:647-652. Copyright © American Heart Association, Inc. All rights reserved.
Relationship between average subarachnoid hemorrhage (SAH) caseload per year and fitted 6-month mortality rate.


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Major Trauma - Chain of Survival

Trauma: Who cares?

www.ncepod.org.uk
Conclusions

- Neuro-critical care – prevent cerebral ischaemia
- Specialisation can improve outcome, enhance education and research potential
- Specialisation necessitates centralising services
- Specialisation depends on good basic care
- A partnership approach is necessary