Imperial College London

CNS Trauma Imaging

Professor David Sharp, NIHR Research Professor,

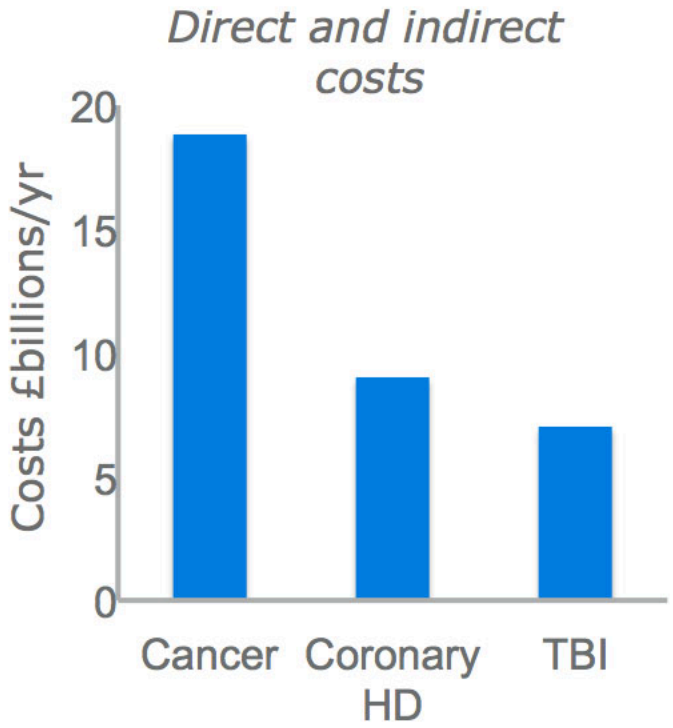
Computational Clinical and Cognitive Neuroimaging Laboratory, Imperial College London

Imperial College London

C3NL

Traumatic brain injury: the hidden costs

TBI is the biggest cause of death and disability in the under 40s.



Imperial College London

C3NL

Poor long-term outcome after TBI

Death after head injury: the 13 year outcome of a case control study

T M McMillan,[1] G M Teasdale,[2] C J Weir,[3] E Stewart[1]

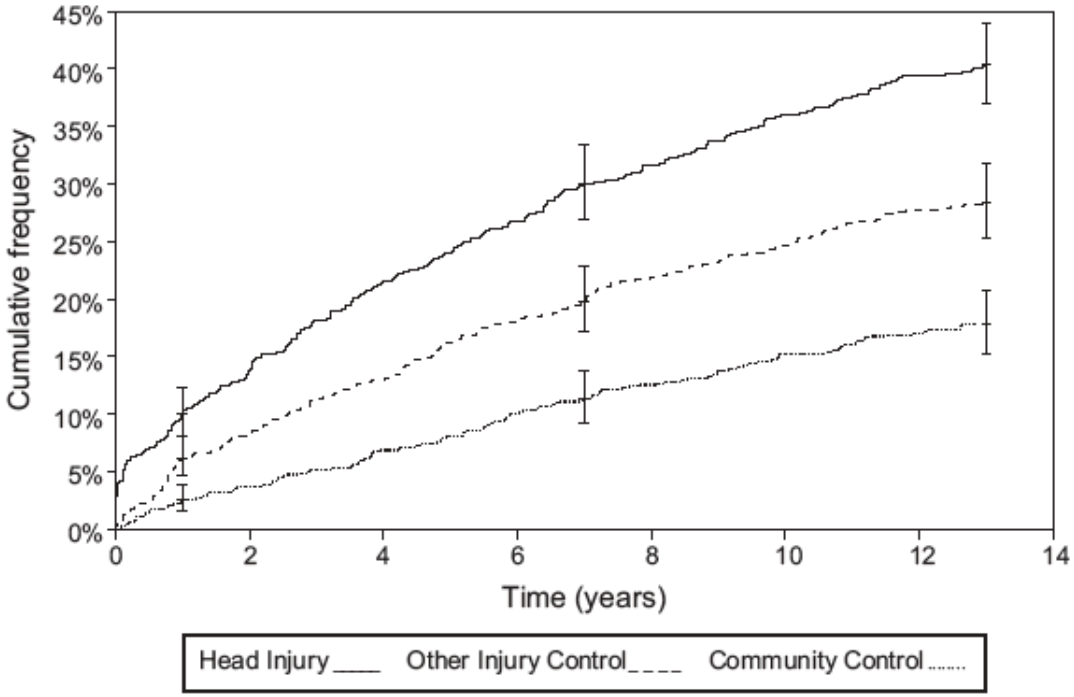
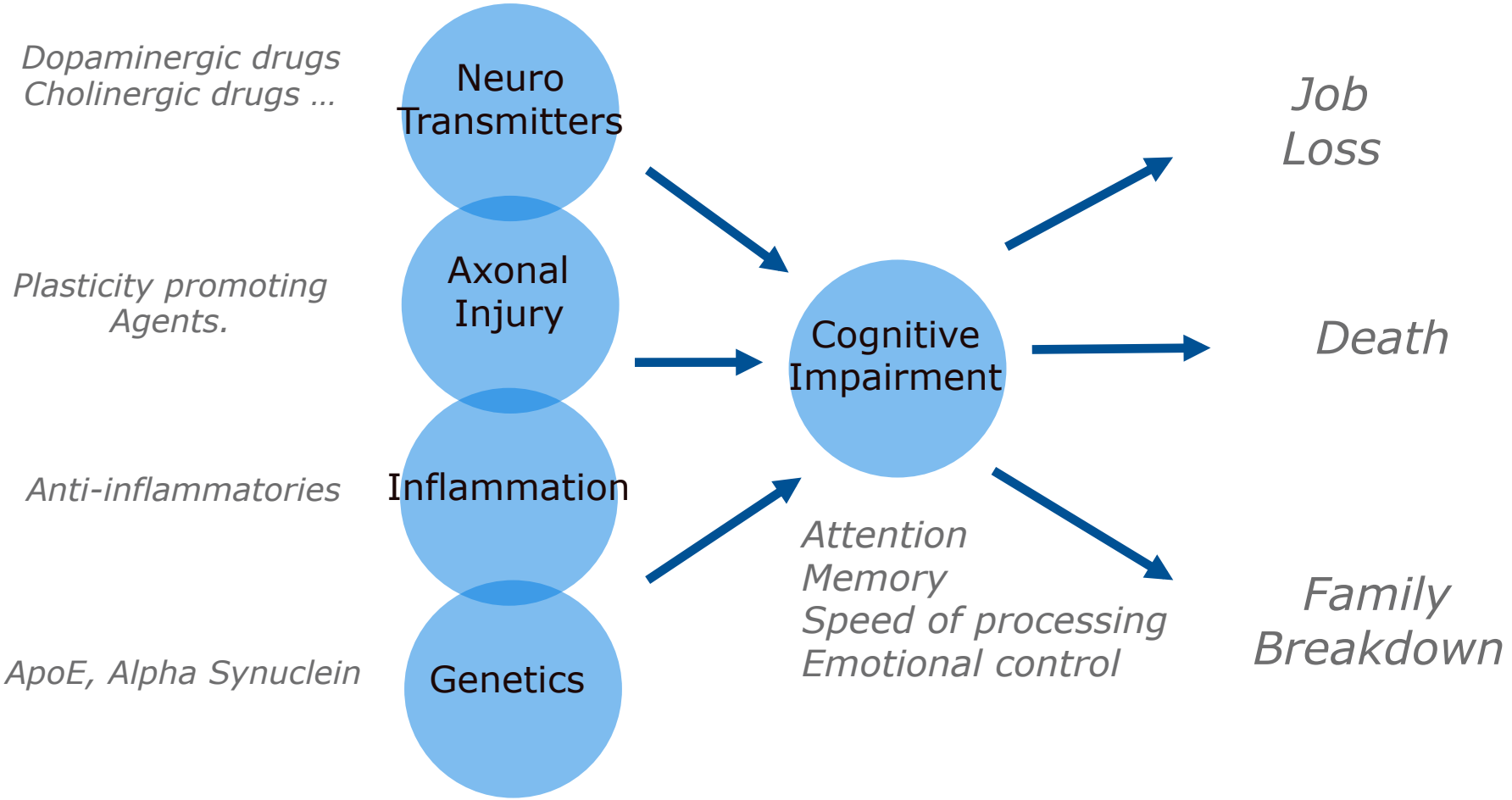


Figure 1 Kaplan–Meier curves with CIs for cumulative deaths over 13 years in head injury and control groups (n=757 per group at time 0).

Imperial College London

C3NL

Cognitive problems after TBI have many causes

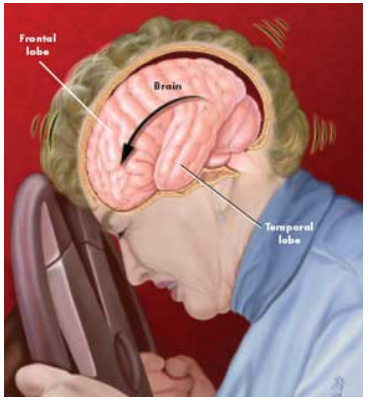


Imperial College London

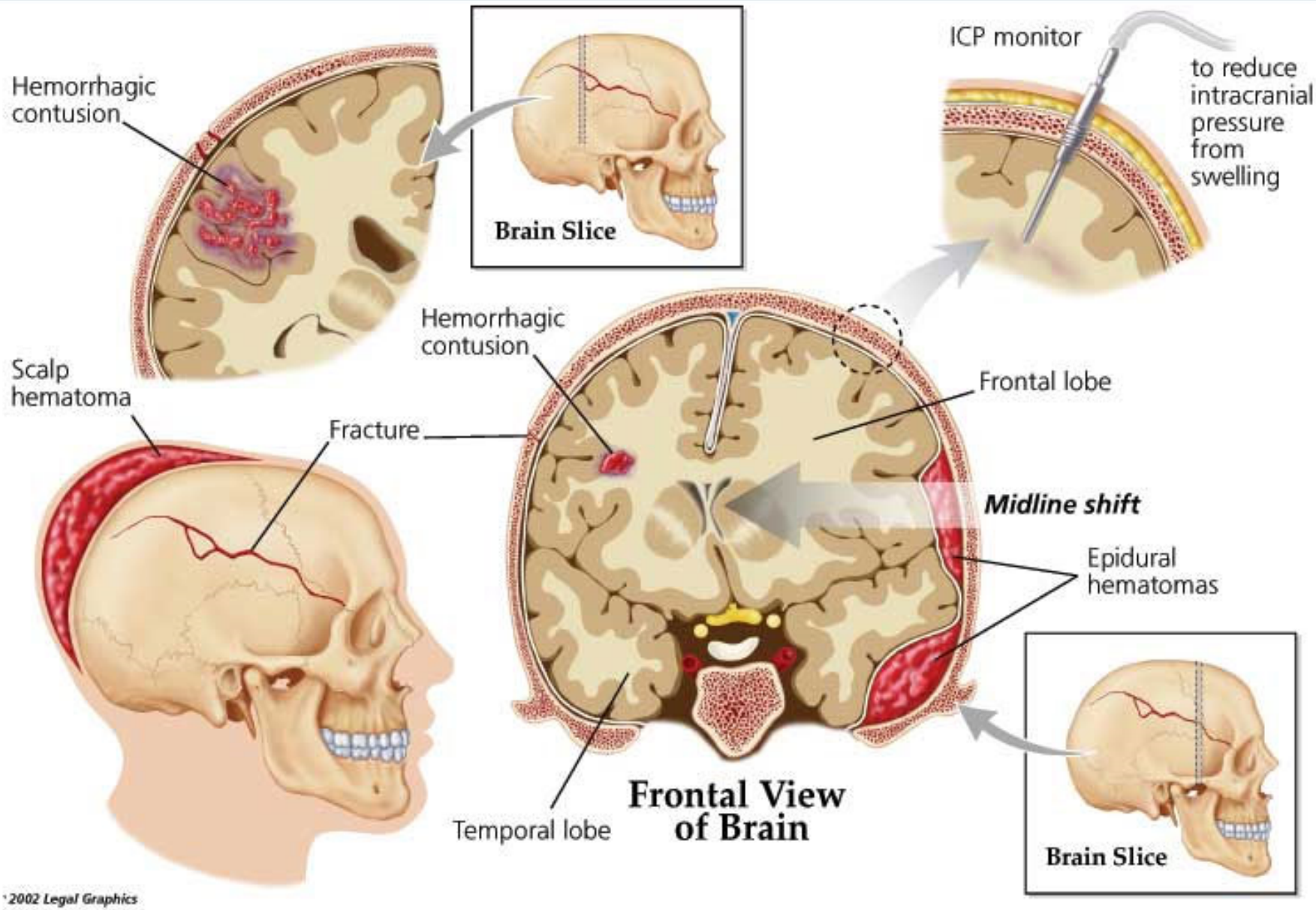
C3NL

Types of traumatic brain injury

- Two broad types:
  - Focal damage
    - » Fractures
    - » Intracerebral contusions
    - » Bleeding
      - subarachnoid haemorrhage
      - extradural and subdural haematomas
      - Intracerebral haemorrhage
  - Diffuse axonal injury (DAI)
    - » Damage to the connections between regions



Traumatic Brain Injury

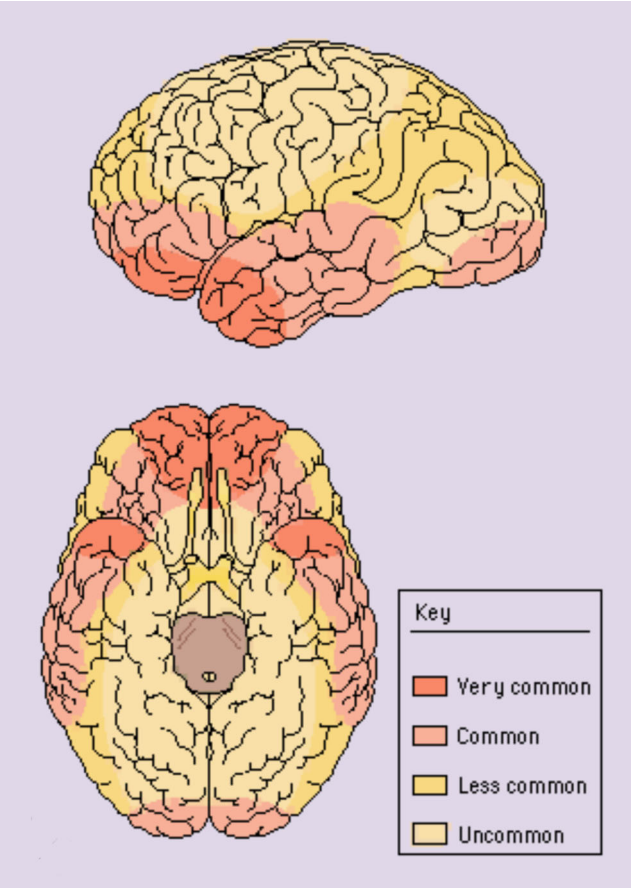


Imperial College London

C3NL

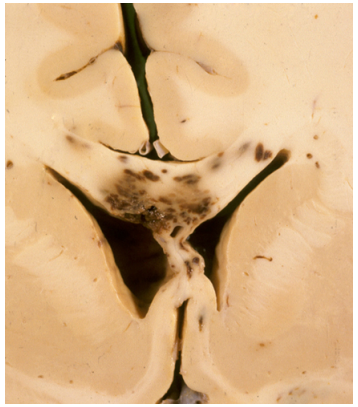
Types of traumatic brain injury

Focal contusions

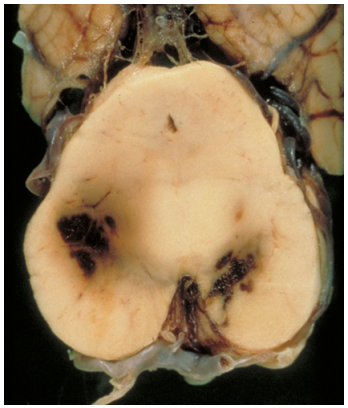


Love & Ellison: Neuropathology

Diffuse axonal injury



Grade 2: lesions in corpus callosum



Grade 3: lesions also in brainstem

Adams et al '85

Imperial College London

C3NL

Case 1

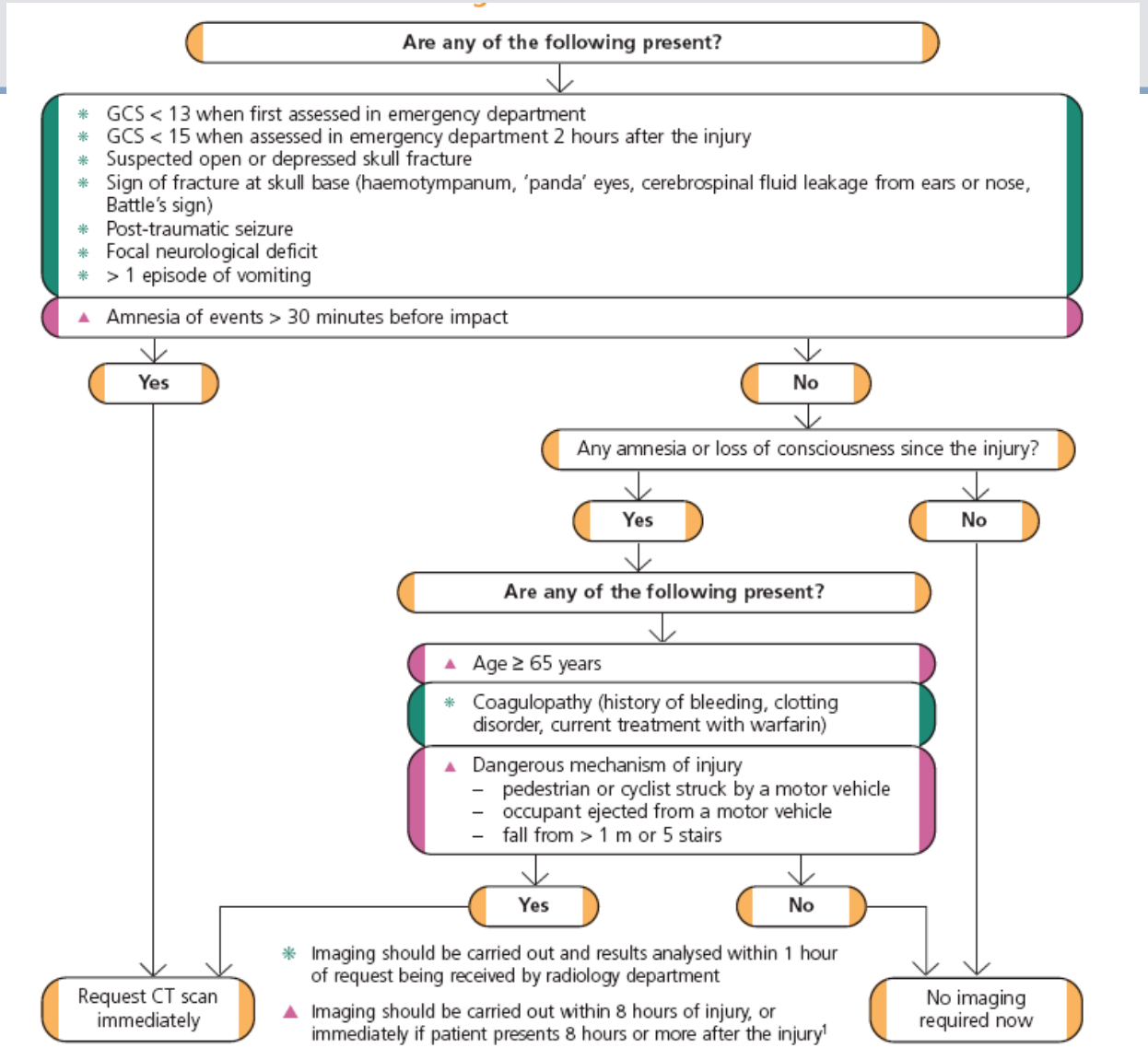
28 year old man brought in from a nightclub after being hit by a bouncer. He fell and hit hit head on the pavement. You are the A+E SHO, what do you do?

Acute – CT

Chronic – CT or MRI

Imperial College London

C3NL



Types of traumatic brain injury

When to involve the neurosurgeon

- Discuss the care of all patients with new, surgically significant abnormalities on imaging with a neurosurgeon (definition of 'surgically significant' to be developed by local neurosurgical unit and agreed with referring hospitals).
- Regardless of imaging, other reasons for discussing a patient's care plan with a neurosurgeon include:
  - persisting coma (GCS ≤ 8) after initial resuscitation
  - unexplained confusion for more than 4 hours
  - deterioration in GCS after admission (pay greater attention to motor response deterioration)
  - progressive focal neurological signs
  - seizure without full recovery
  - definite or suspected penetrating injury
  - cerebrospinal fluid leak.

Types of traumatic brain injury

Traumatic brain injury – CT imaging

Imperial College London

C3NL

Computed tomography (CT)

- *First CT in Hounsfield's EMI lab in London – 1972 (Nobel in 1979)*
- *X-rays pass in multiple directions through 'object'*
- *3-D reconstruction based on the differential attenuation the beams*
- *Relative degree of attenuation expressed in Hounsfield units*
- *Water = zero*
  - *CSF = 3*
  - *White matter = 30*
  - *Gray matter = 38*
  - *Fresh blood = 81*
  - *Bone >1000*

Imperial College London

C3NL

CT – advantages

- *Quick*
- *Cheap*
- *Better than MR at identifying*
  - *Blood*
  - *Bony abnormalities*
  - *Calcification*
- *Less claustrophobia*
- *But relatively poor resolution and limited by artefacts*

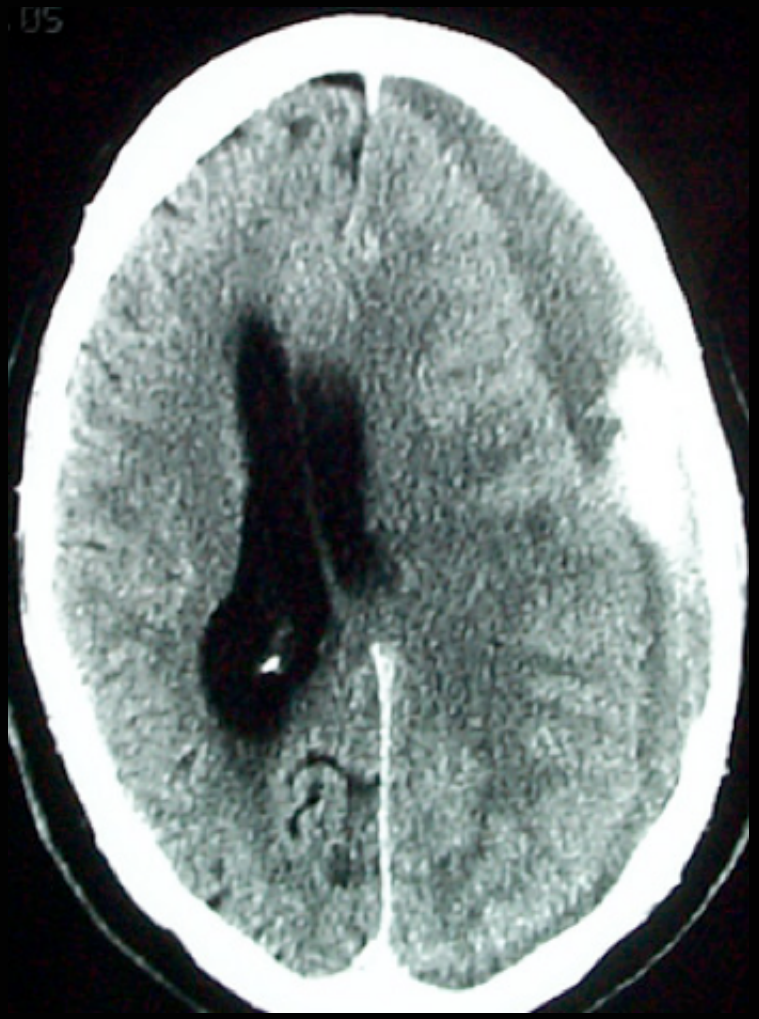
Imperial College London

C3NL

CT examples

Extradural

Acute on chronic subdural



Imperial College London

C3NL

CT examples

Haemorrhagic Contusion

Imperial College London

C3NL

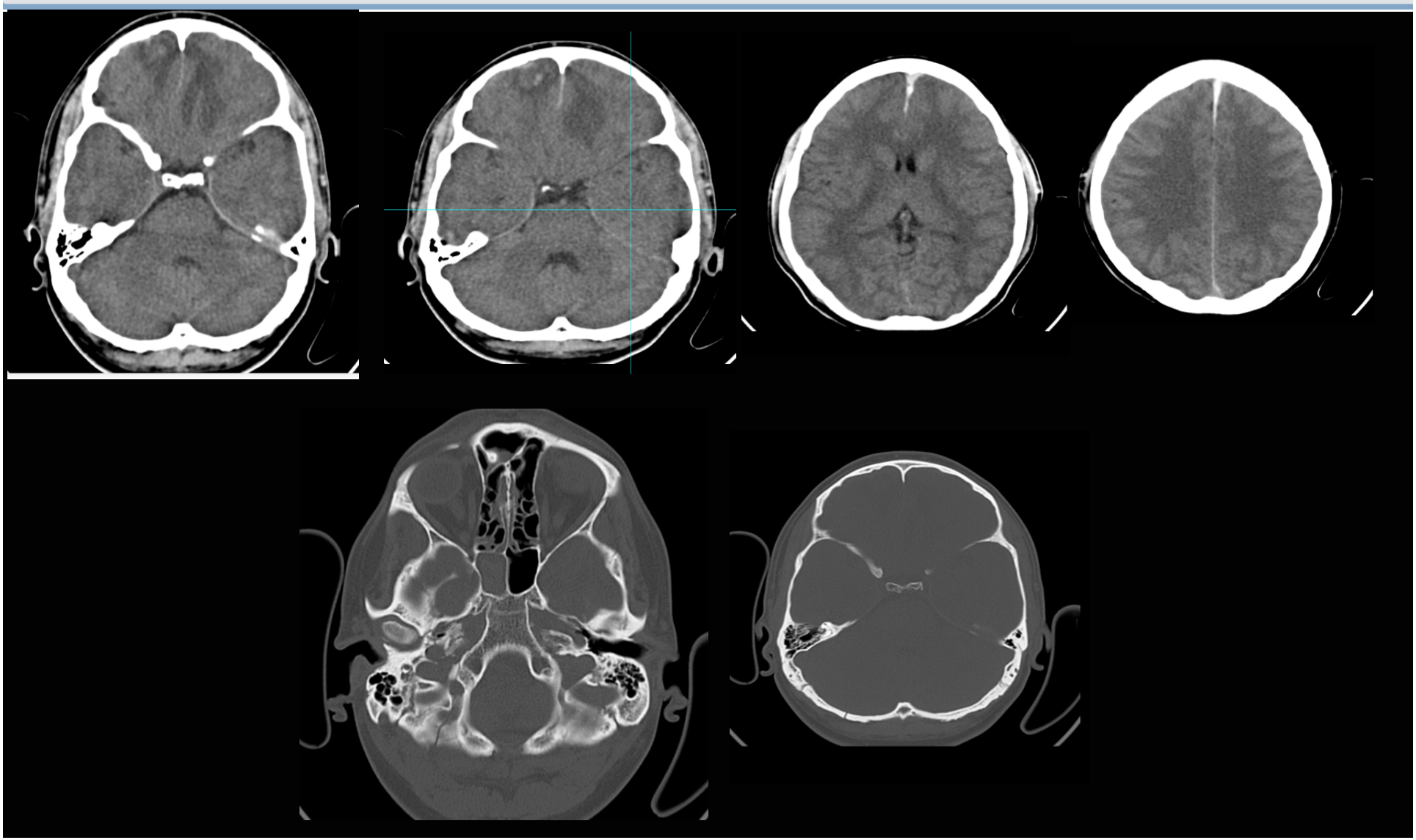
Case 1

28 year old man brought in from a nightclub after being hit by a bouncer. He fell and hit hit head on the pavement. You are the A+E SHO, what do you do?

Imperial College
London

C3NL

CT



Imperial College London

C3NL

Case 1

28 year old man brought in from a nightclub after being hit by a bouncer. He fell and hit hit head on the pavement. You are the A+E SHO, what do you do?

He is referred to the TBI follow-up clinic from A+E. You see him as an SPR. He is now complaining of memory impairment, difficulty concentrating and uncontrollable bursts of anger. How do you proceed?

Imperial College London

C3NL

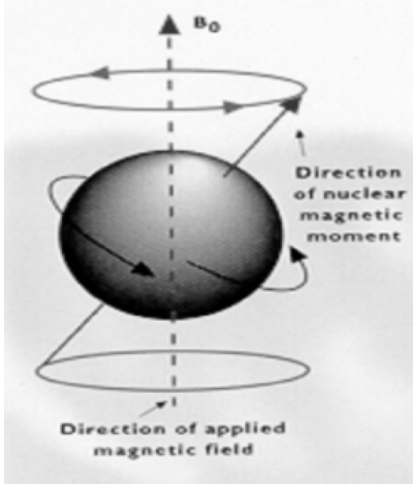
Magnetic resonance imaging

Imperial College London

C3NL

MRI - principles

- *Signal results from interplay of tissues and applied magnetic fields.*
- *Most MR imaging based on proton imaging of the hydrogen nucleus.*
- *Hydrogen nuclei are aligned by the presence of a primary static magnetic field within the scanner.*
- *Within the magnetic field the hydrogen nucleus precesses at its own unique resonant frequency (Lamor frequency).*
- *Applying an RF pulse at the this frequency knocks the hydrogen nucleus out of alignment, before it gradually relaxes back to original position.*
- *T1 and T2 relate to different measures of this relaxation time.*



Imperial College London

C3NL

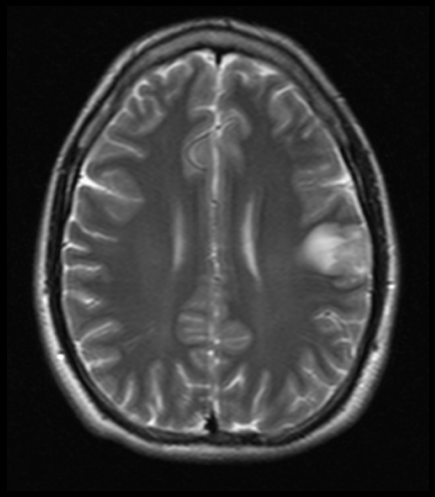
Structural imaging findings

T1

- Good tissue discrimination
- Used in conjunction with gadolinium
- Dark CSF
- Bright fat
- Dark lesions

T2

- Sensitive to the presence of increased water
- Visualises oedema
- Bright CSF
- Dark (suppressed fat)
- Bright lesions



Imperial College London

C3NL

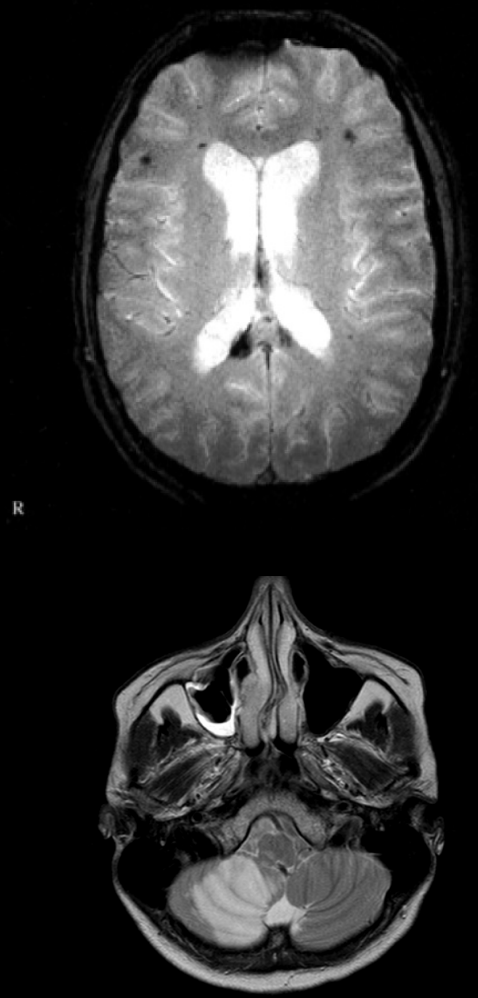
Structural imaging findings

Gradient echo imaging (T2*)

- Increased susceptibility to magnetic field inhomogeneities
- Blood, iron, calcium and manganese produce artefact
- This can be useful to detect clinically e.g. to detect microbleeds

Flair

- Fluid attenuation inversion recovery
- Developed at The Hammersmith
- T2 weighted contrast with a dark CSF
- Changes the dynamic range of the image
- Better a delineating pathology, particularly around the ventricles



Imperial College London

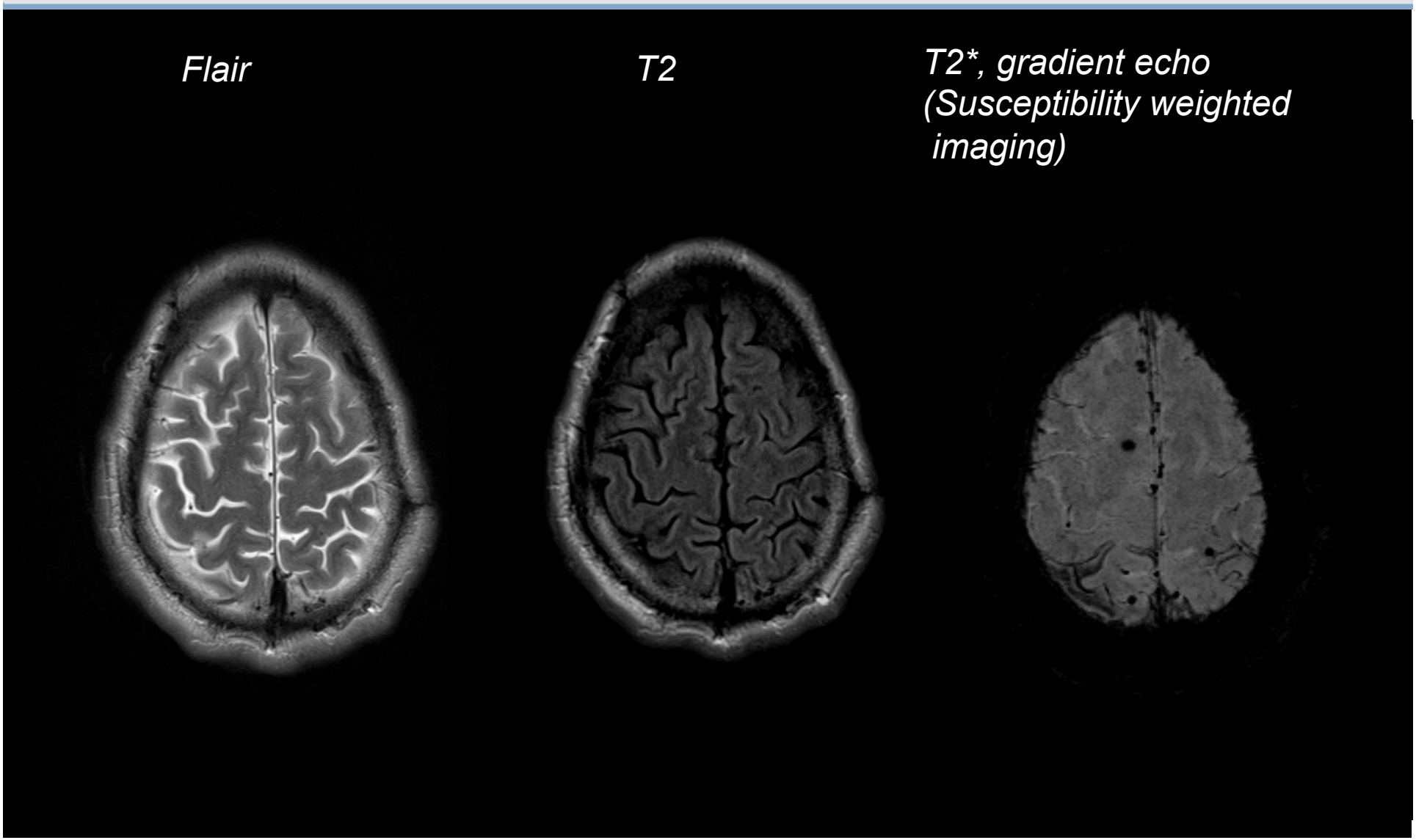
C3NL

Microbleeds

Flair

T2

T2, gradient echo (Susceptibility weighted imaging)*

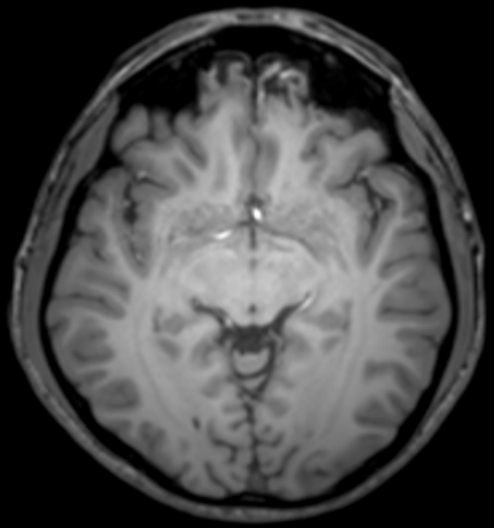


Imperial College London

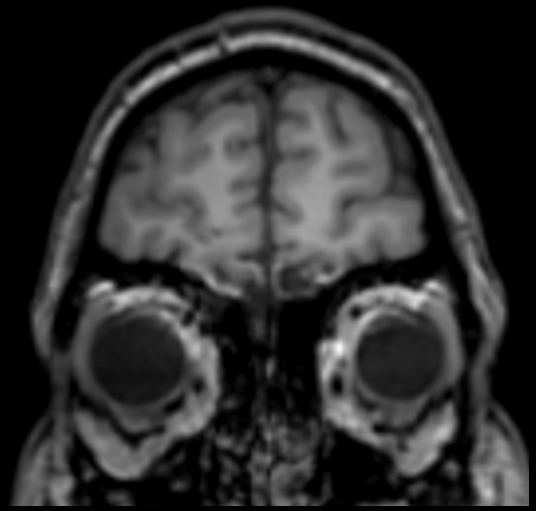
C3NL

Case 1

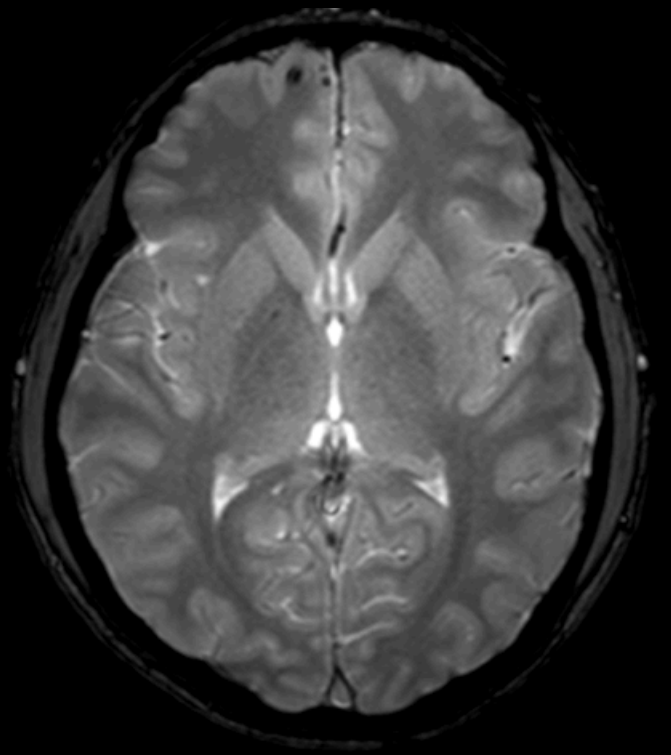
T1 Axial



T1 Coronal



T2, gradient echo*



Imperial College London

C3NL

Case History 2

30 yr old man

History of substance misuse. Paranoid schizophrenic.

TBI new years day 2011.

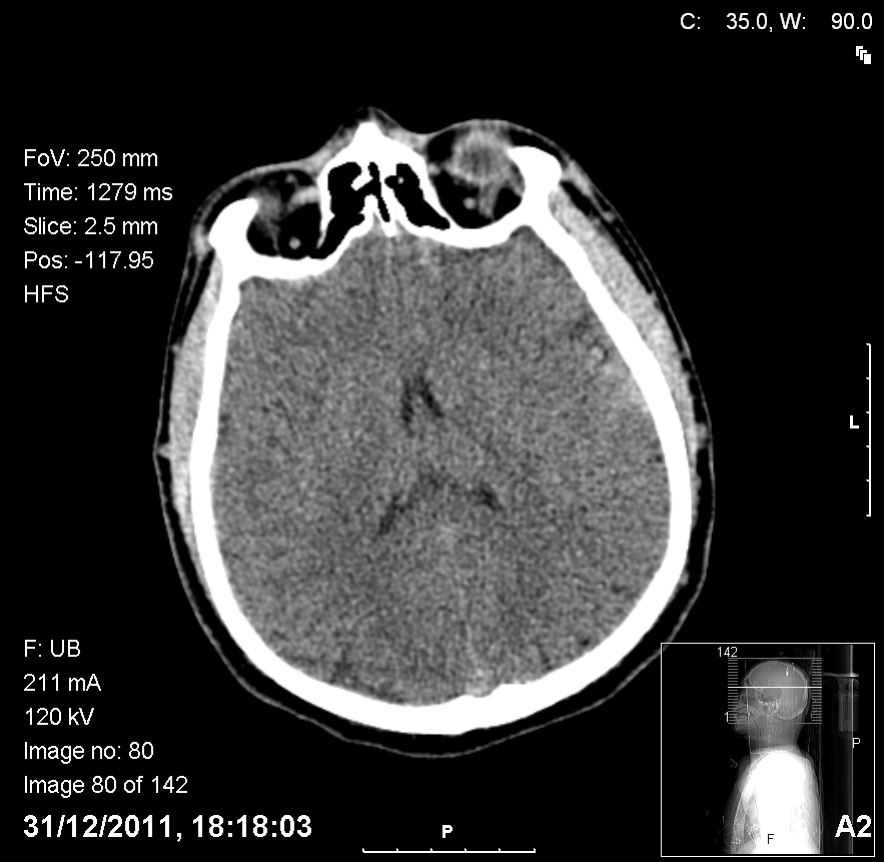
Admitted Major Trauma Unit at SMH.

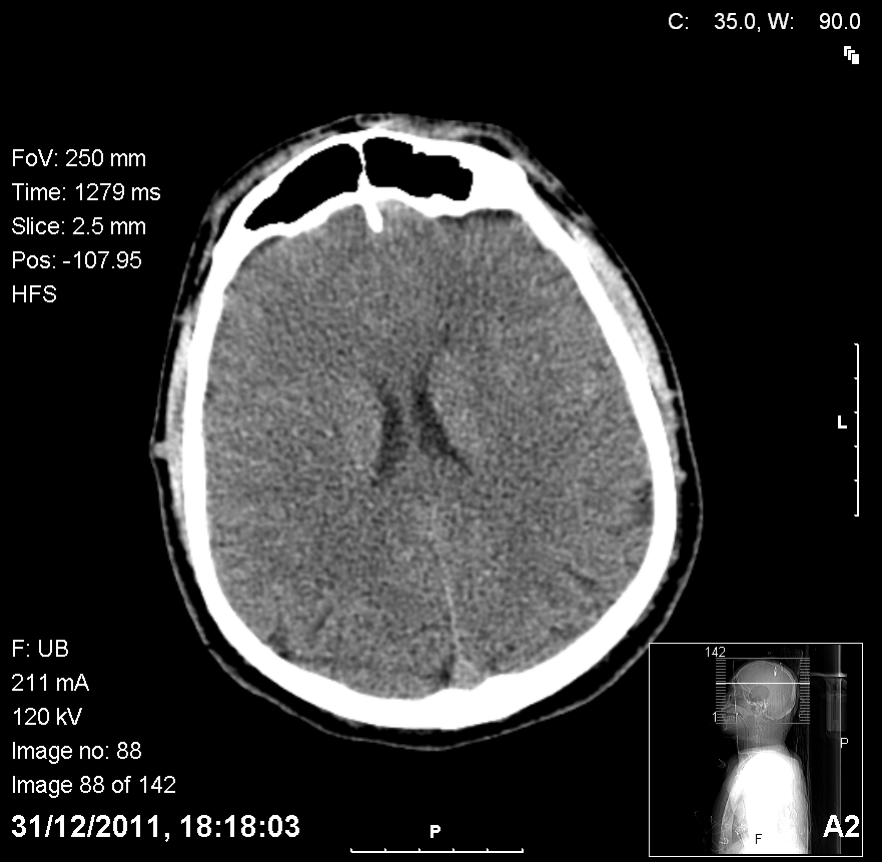
Imperial College London

C3NL

Structural imaging findings

CT imaging: day 1



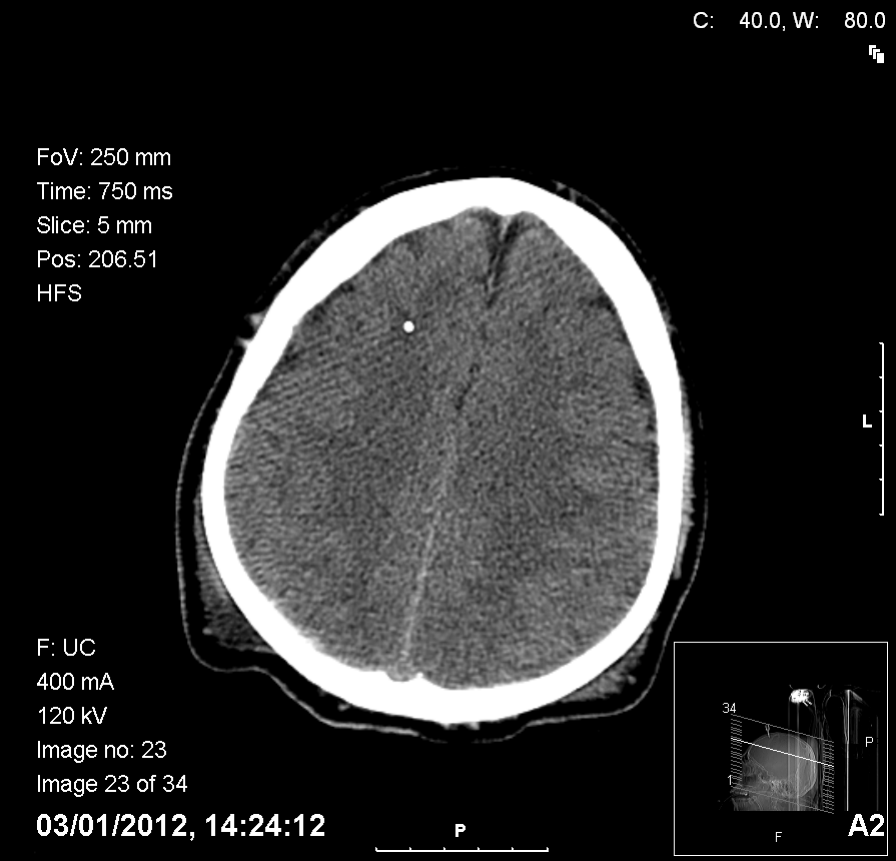


Imperial College London

C3NL

Structural imaging findings

CT imaging: day 3

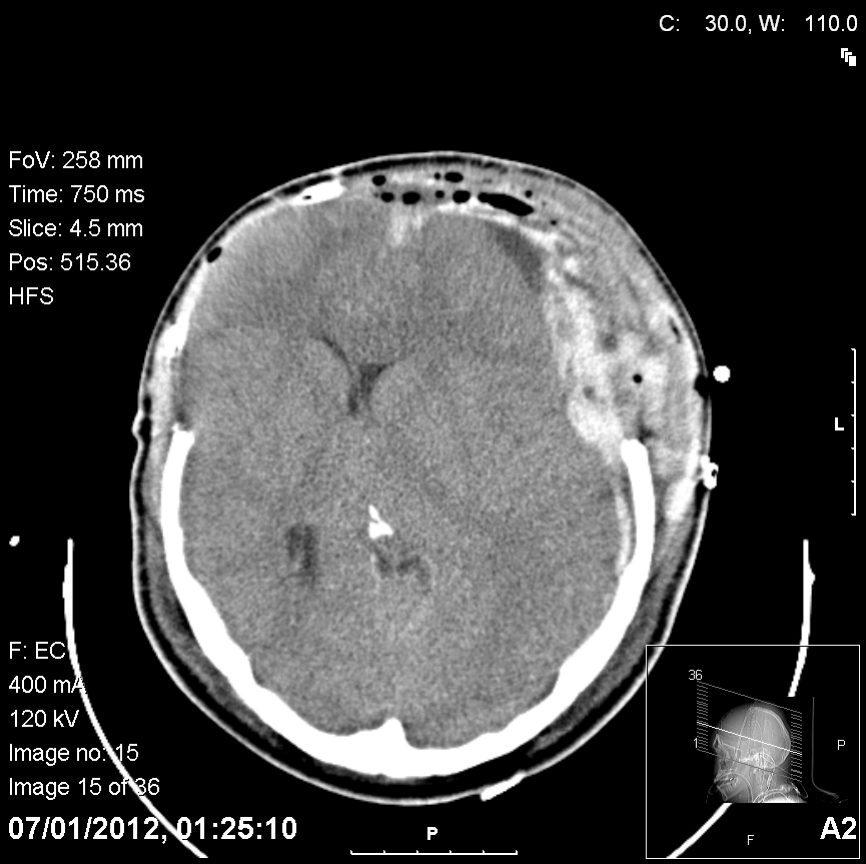


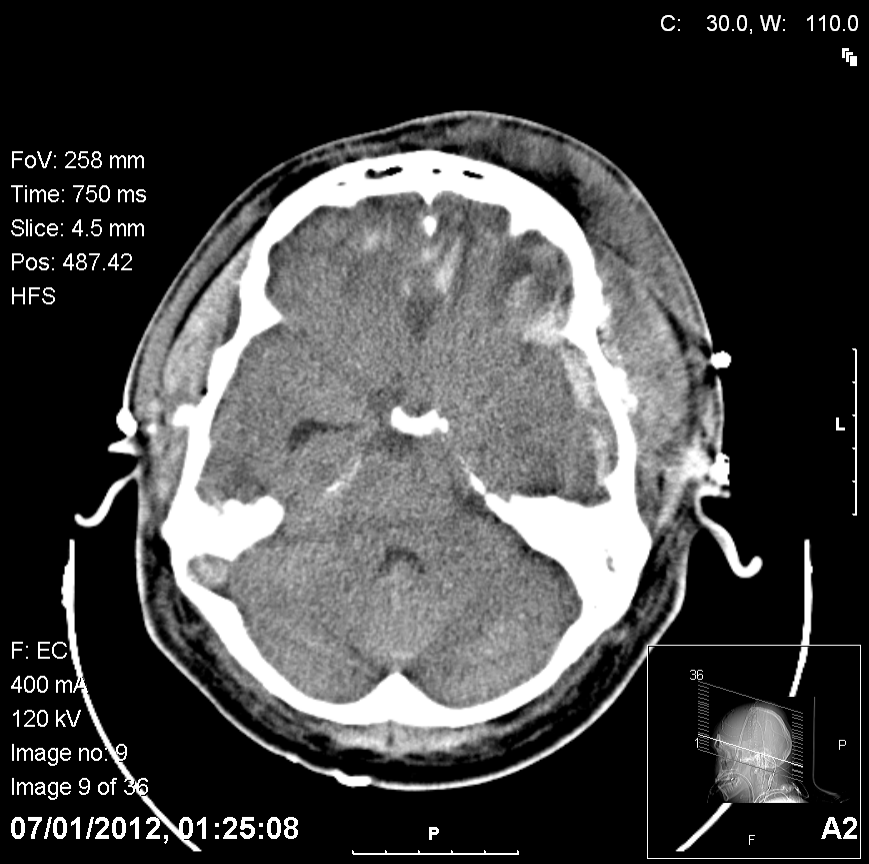
Imperial College London

C3NL

Structural imaging findings

CT imaging: day 7





Imperial College London

C3NL

Surgical decompression?

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 APRIL 21, 2011 VOL. 364 NO. 16

Decompressive Craniectomy in Diffuse Traumatic Brain Injury

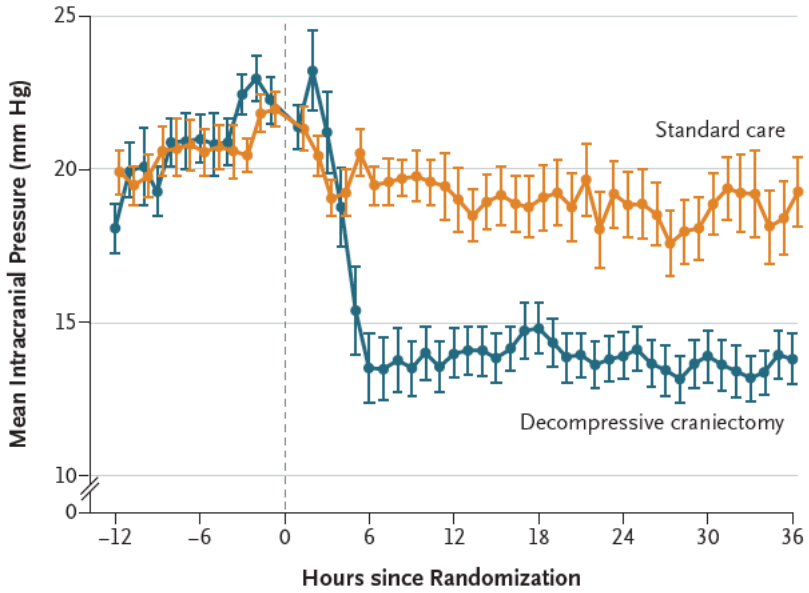
D. James Cooper, M.D., Jeffrey V. Rosenfeld, M.D., Lynnette Murray, B.App.Sci., Yaseen M. Arabi, M.D., Andrew R. Davies, M.B., B.S., Paul D'Urso, Ph.D., Thomas Kossmann, M.D., Jennie Ponsford, Ph.D., Ian Seppelt, M.B., B.S., Peter Reilly, M.D., and Rory Wolfe, Ph.D., for the DECRA Trial Investigators and the Australian and New Zealand Intensive Care Society Clinical Trials Group*

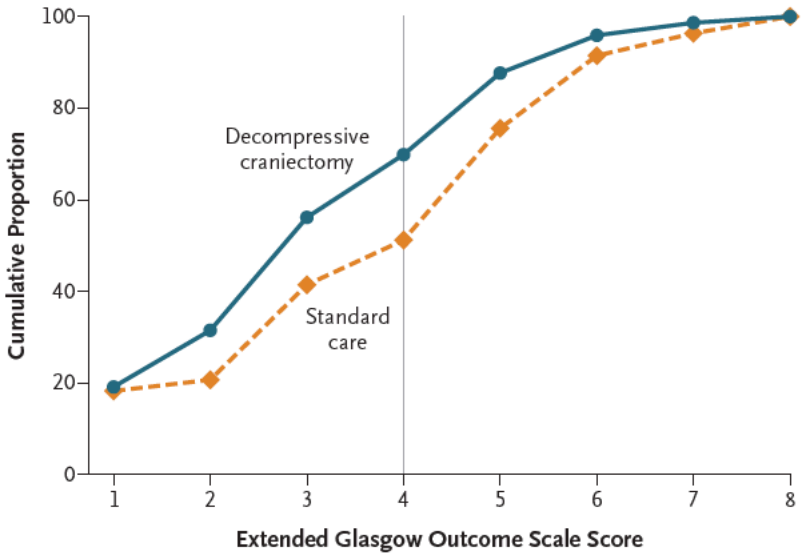
Imperial College London

C3NL

Surgical decompression?

- Severe TBI with uncontrolled ICP
- 3478 assessed 158 enrolled
- Bifrontotemporoparietal craniectomy or standard care





Imperial College London

C3NL

Case History 3

28yr male

Top cover

Wearing body armour, Helmet and eye protection

50 Kg IED.

Multiple fractures. Superficial lacerations. Left sided pneumothorax.

Initial GCS 12/15

2 weeks of retrograde amnesia

6 weeks of post-traumatic amnesia

On neuropsychological assessment;

- Impaired executive function, memory and processing speed

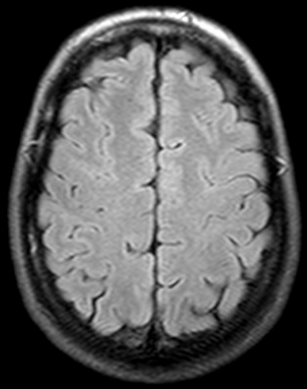
Unable to carry on in the Army.

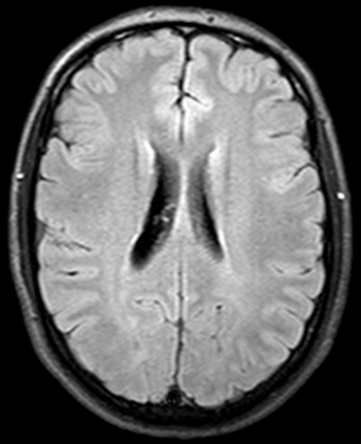
Imperial College London

C3NL

Structural imaging findings

T2Flair





Imperial College London

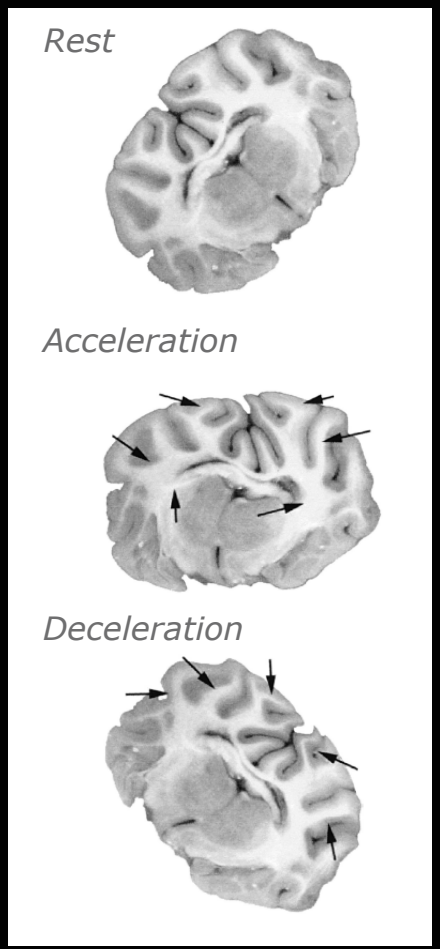
C3NL

Imperial College London

C3NL

Traumatic axonal injury pathology

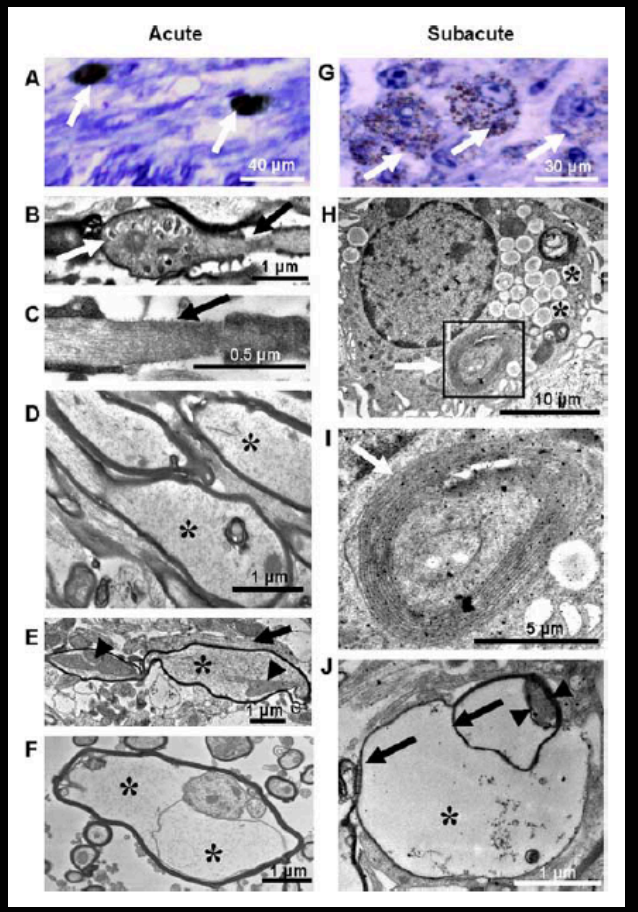
Shear, tensile, compressive strain



White matter pathology

Grade 2: lesions in corpus callosum

Grade 3: lesions also in brainstem

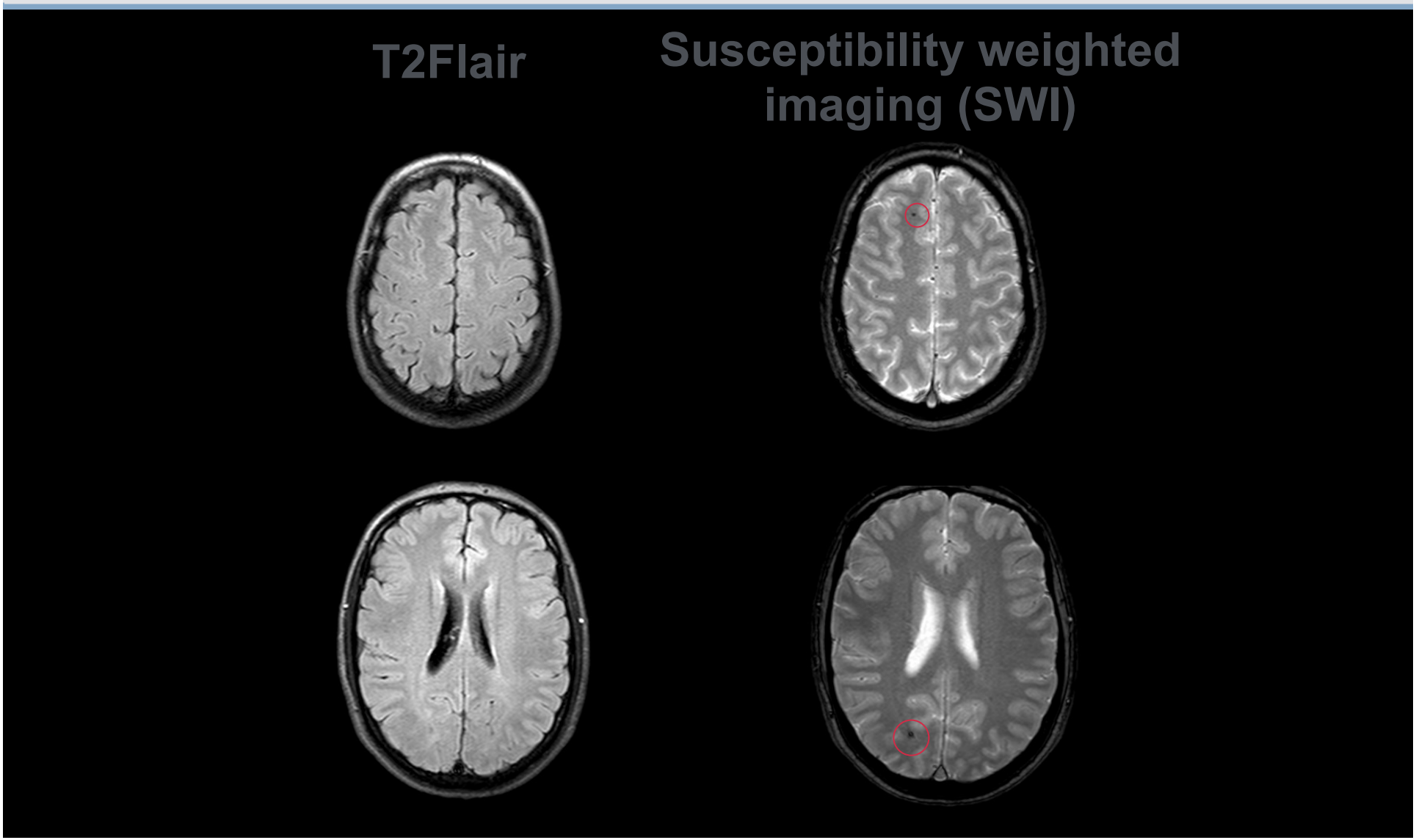


Mac Donald et al J Neurosci '07

Imperial College London

C3NL

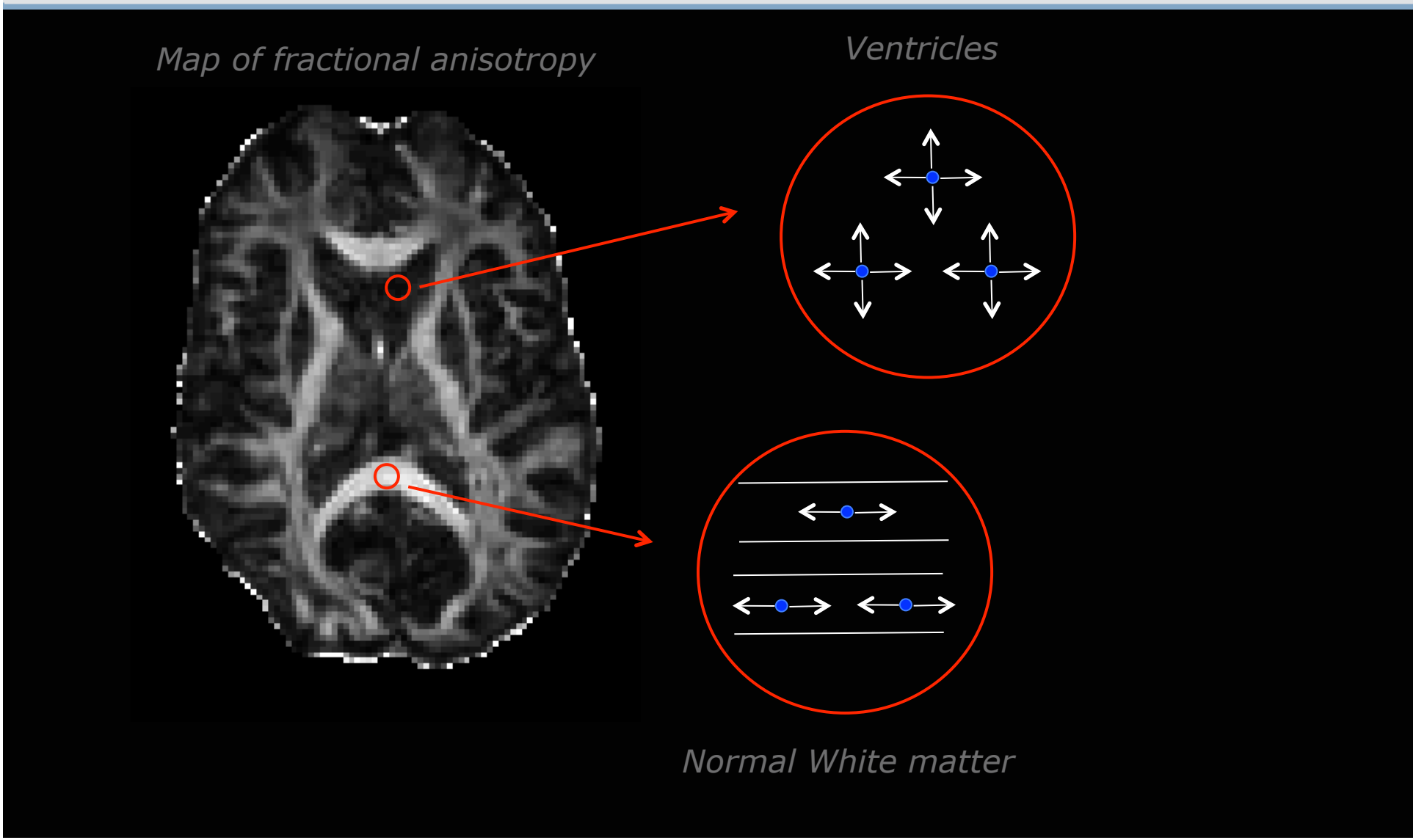
Microbleeds: an MRI marker of white matter injury



Imperial College London

C3NL

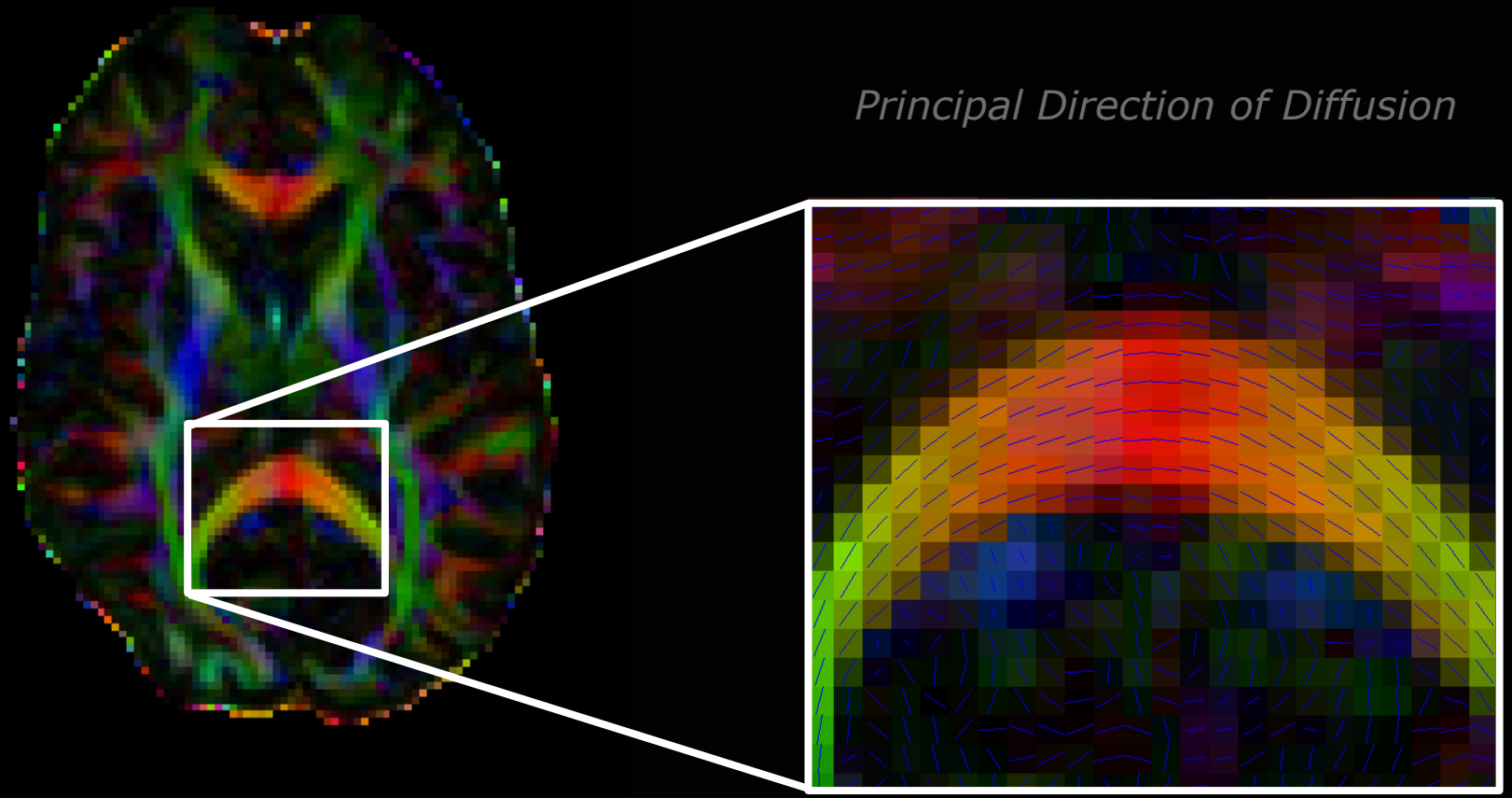
Diffusion tensor imaging and structural connectivity



Imperial College London

C3NL

Diffusion tensor imaging and structural connectivity



Imperial College London

C3NL

Diffusion tensor imaging and structural connectivity

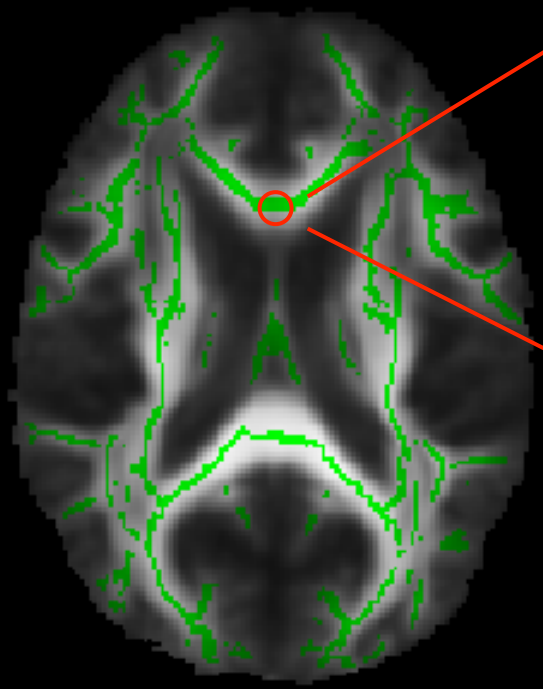
Traumatic axonal injury

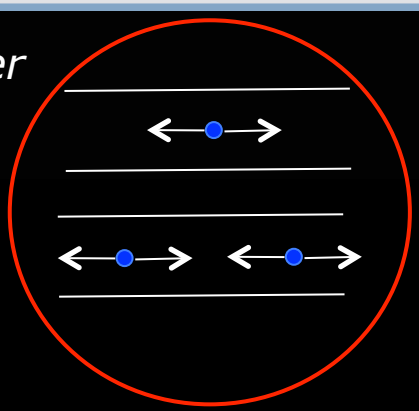
Grade 2: lesions in corpus callosum

Grade 3: lesions also in brainstem

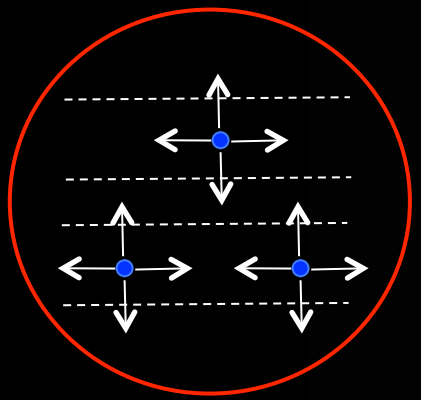
Adams et al '85

Normal White matter





White matter - TBI

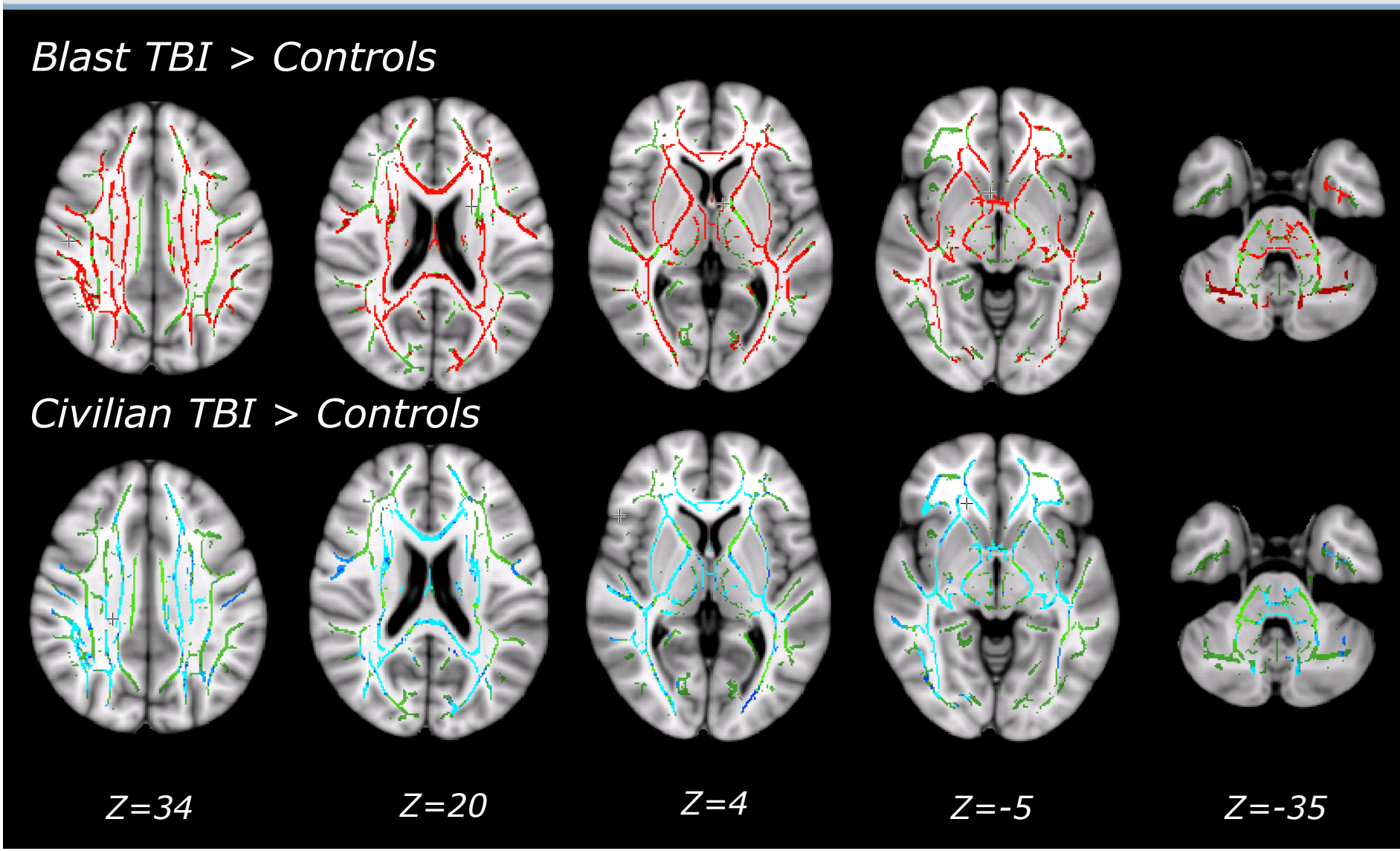


Traumatic axonal injury
Low fractional anisotropy

Imperial College London

C3NL

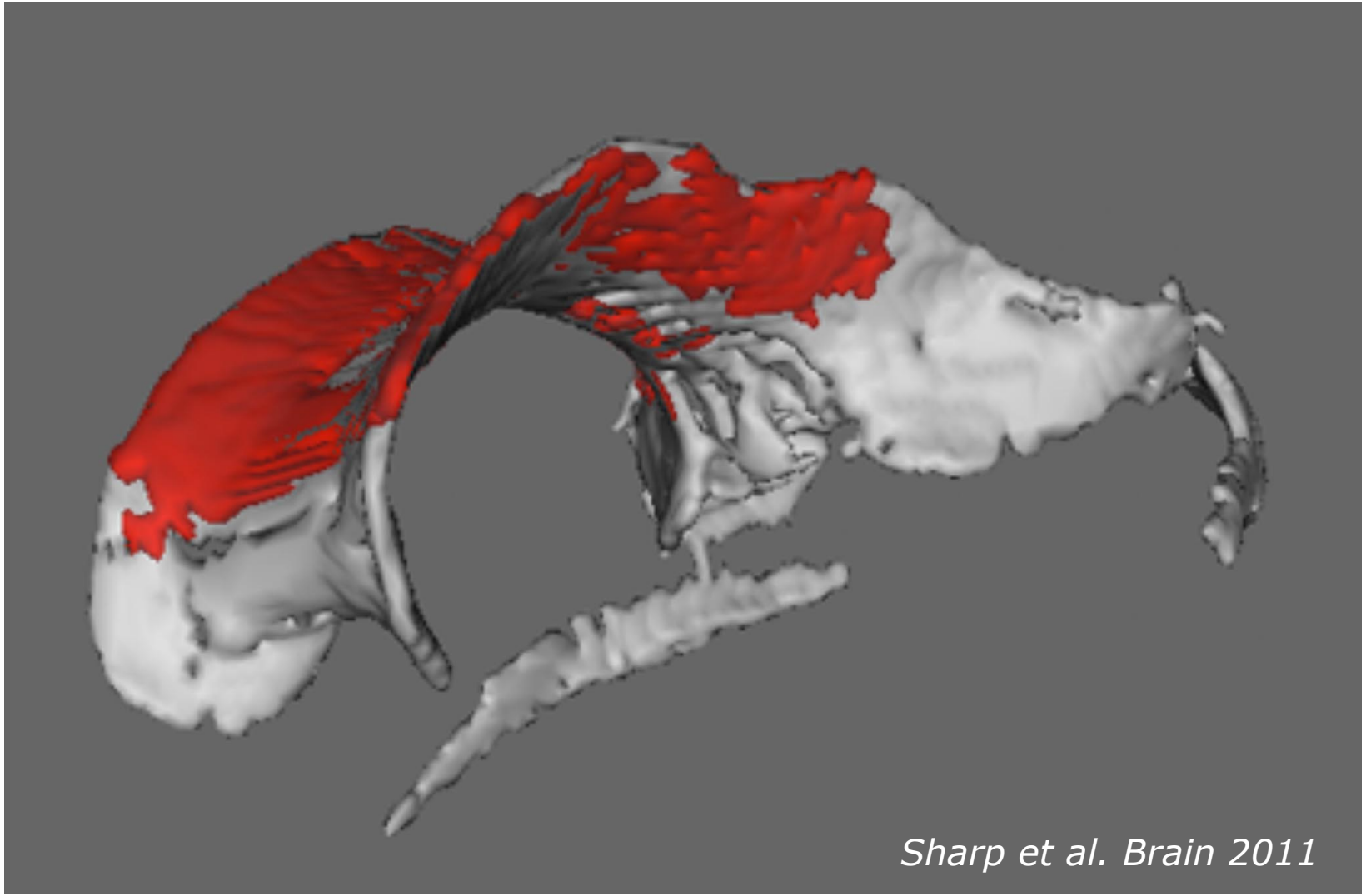
White matter damage after blast and civilian TBI



Imperial College London

C3NL

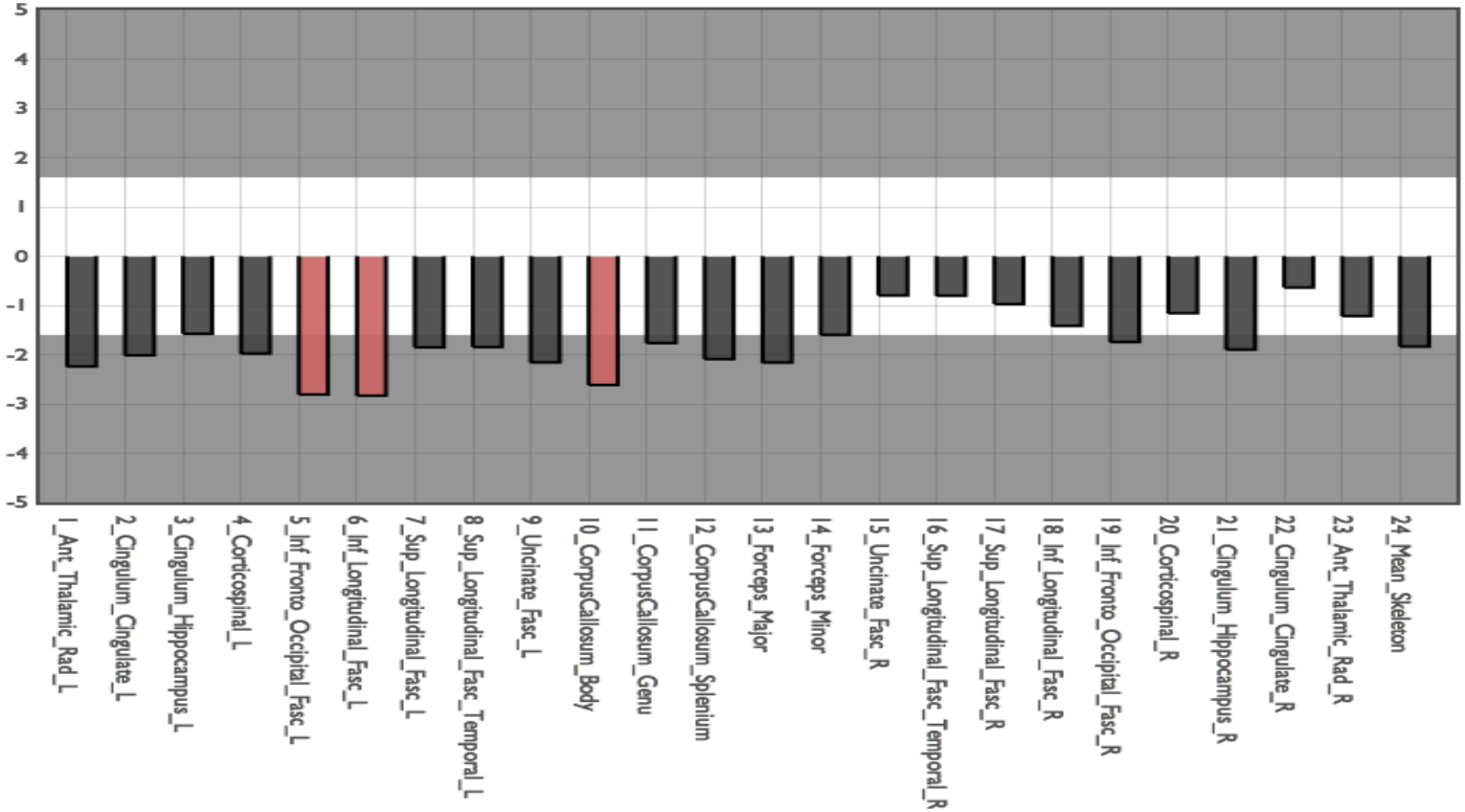
White matter damage in mild TBI



Imperial College
London

C3NL

Case - DTI Diagnostic Data



Imperial College London

Overview

C3NL

Structural Brain Injury

Traumatic axonal injury

Clinical problems

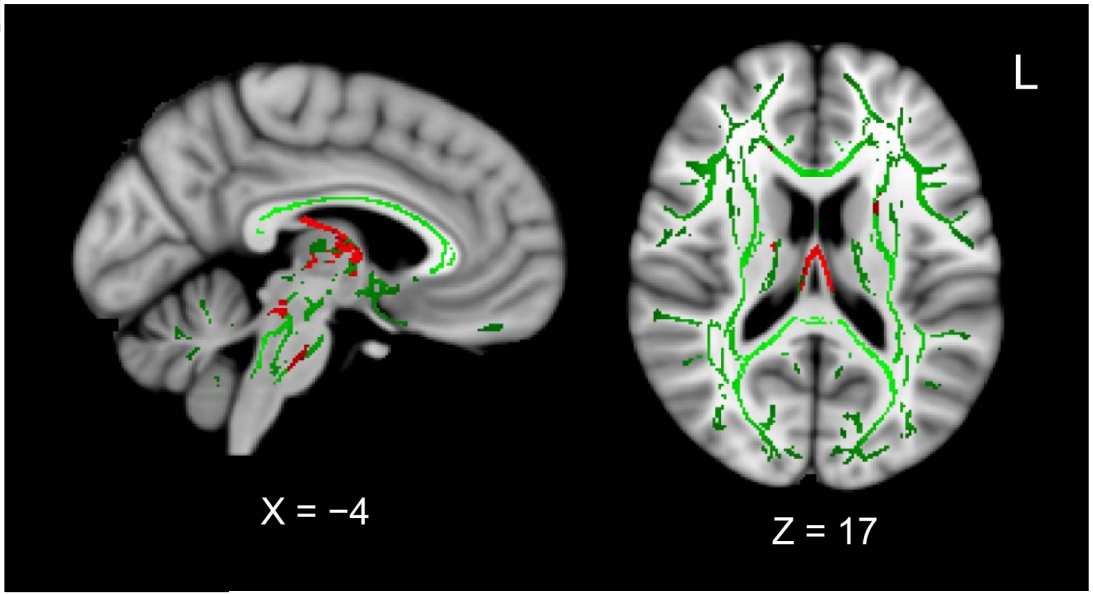
Cognitive impairment

Attention
Information processing speed
Memory

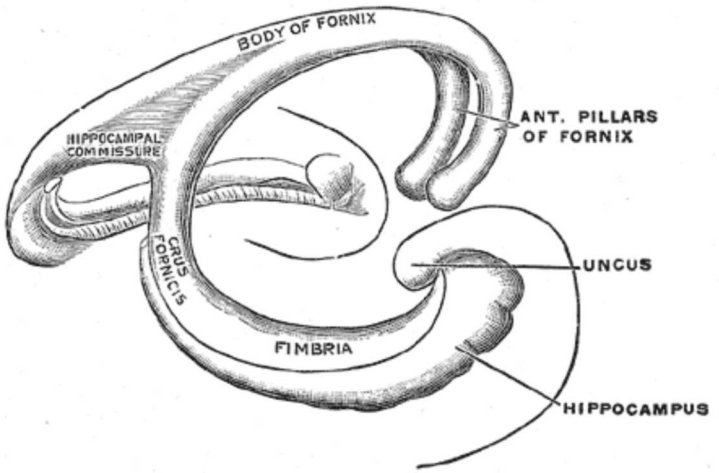
Imperial College London

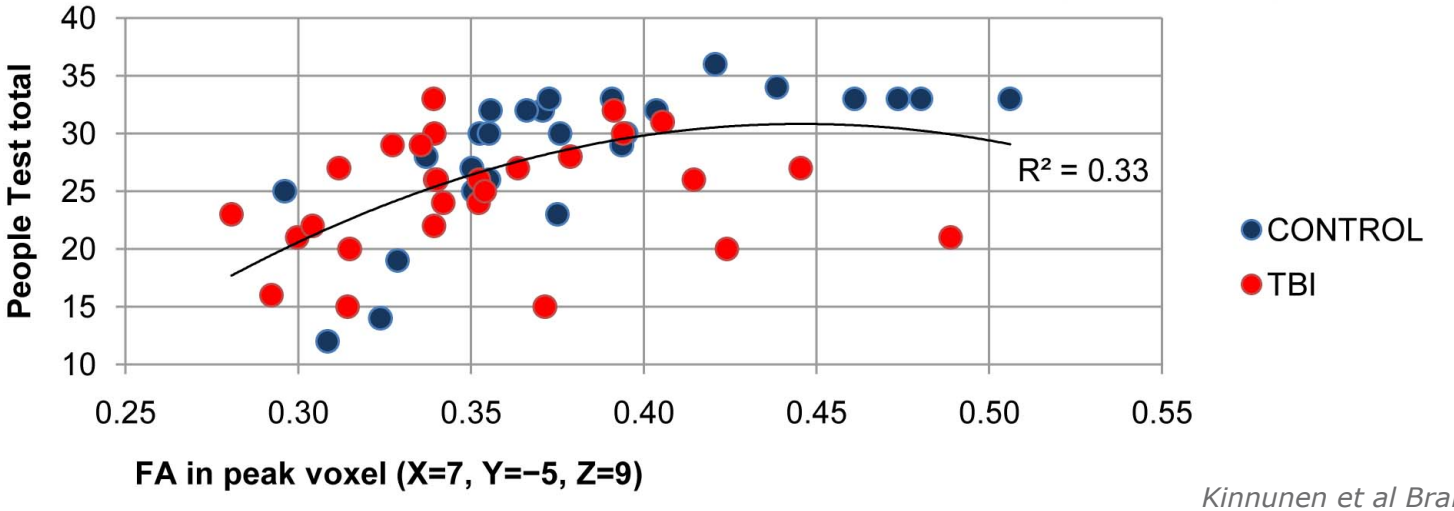
C³NL

Fornix damage and memory impairment



Hippocampal formation





Kinnunen et al Brain '11

Imperial College London

C3NL

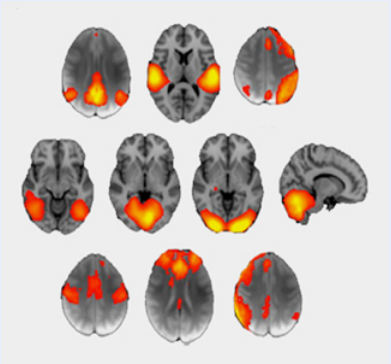
Brain network function

Structural Brain Injury

Traumatic axonal injury

Brain Network Dysfunction

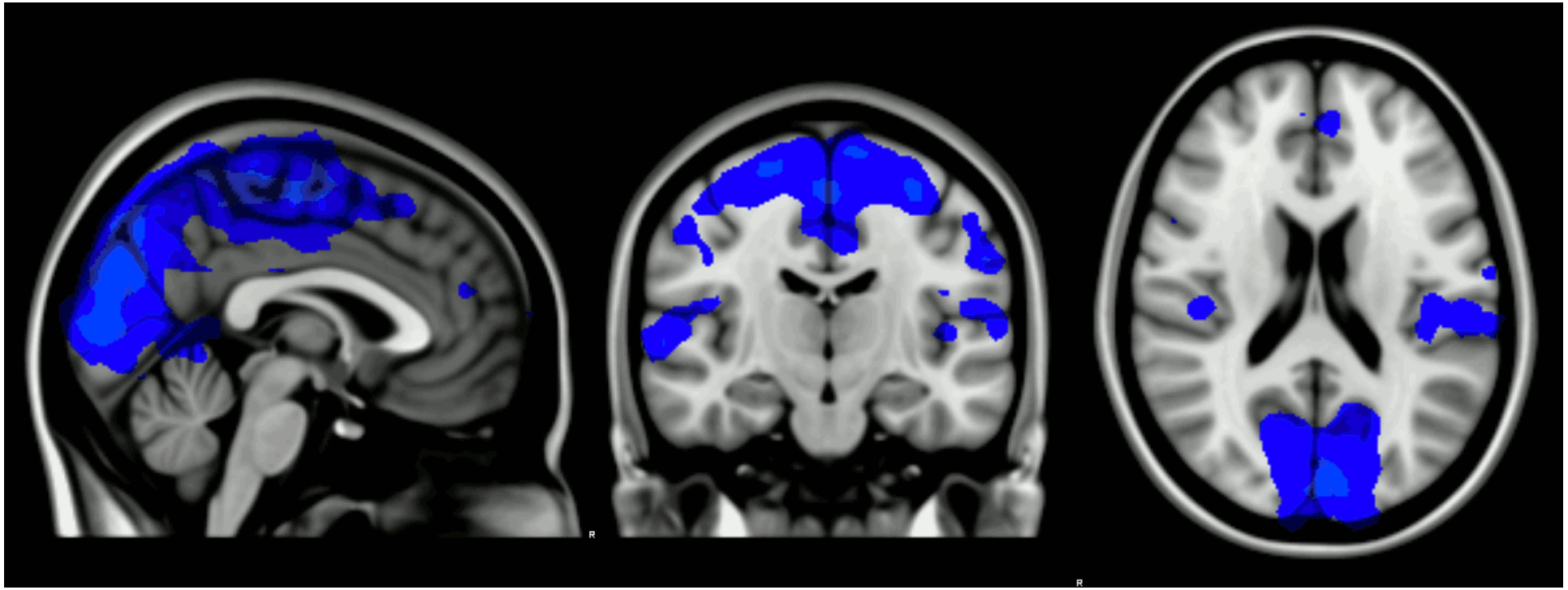
Network activation



Imperial College London

C3NL

The restless brain

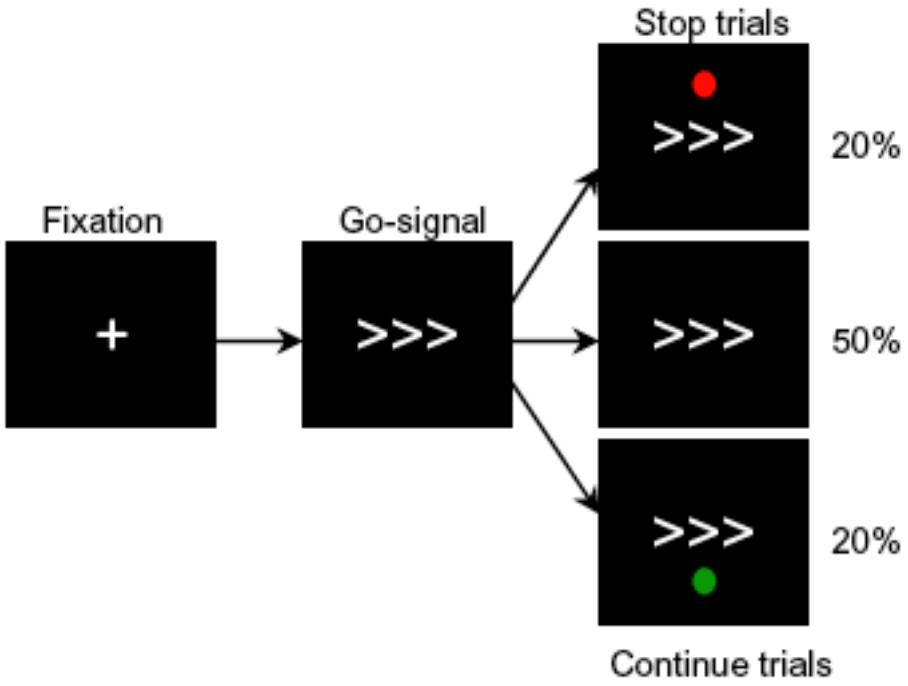


Fluctuating intrinsic connectivity networks from a single subject at rest

Imperial College London

C³NL

Measuring executive function after TBI

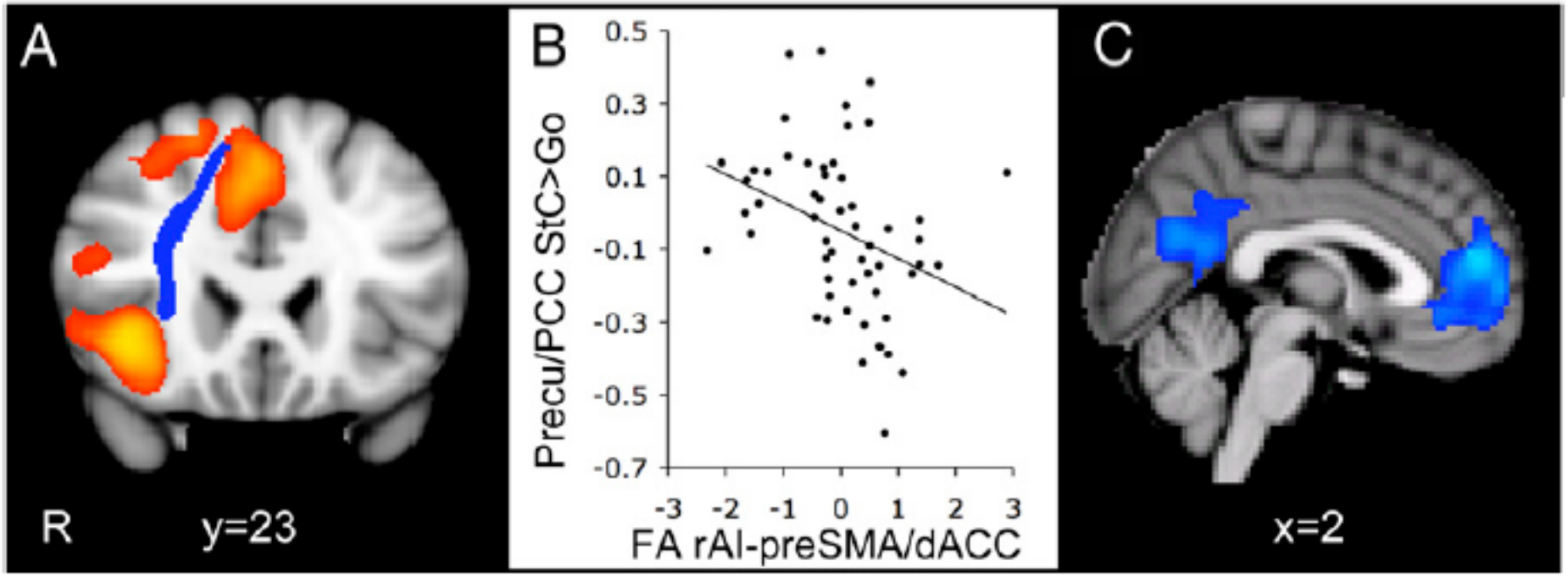


Bonnelle et al. PNAS 2012

Imperial College London

C3NL

White matter damage and network function



Bonnelle et al. PNAS 2012