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Head injury – neurotological medical and legal aspects

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Introduction

Definitions

Concussion: Previously synonymous with mTBI, defined as a traumatic alteration to brain function due to a direct or indirect impulsive force applied to the brain. By definition, effects from a concussion should not last for more than 6 months

Permanent traumatic brain injury: When effects from concussion extend beyond 6 months, the brain exhibits features of a persistent traumatic brain injury

Since the inner ear consisting of the hearing and the balance apparatus (the vestibular system) is located in the head, a head injury affects these systems too. Today we shall talk about what can happen if the vestibular system is affected. *Usually a damage to the vestibular system generates dizziness.* However, a brain injury can also produce dizziness due to central vestibular damage.

Criteria for diagnosis of concussion

Traumatic brain injury TBI	Minor traumatic brain injury mTBI
Any period of loss of or a decreased level of consciousness	Any period of loss of or a decreased level of consciousness lasting 0-30 minutes
Any loss of memory for events immediately before or after the injury	Post-traumatic amnesia lasting 0 to 1 day
Any alteration in mental state at the time of the injury (confusion, disorientation , slowed thinking)	Alteration of consciousness/mental state lasting up to 24 hours
Neurological deficits (weakness, loss of balance , change in vision, praxis, paresis/plegia, sensory loss, aphasia) that may or may not be transient	Normal imaging
	GCS 13-15

Intra cranial lesion

Epidemiology

Up to 80-100% subjects with an acute traumatic head injury will show labyrinthine concussion and up to 50% show a permanent labyrinthine dysfunction at 5 years of which 25% remain undiagnosed. This is both in adults and in children. Hearing loss is observed in up to 50% of traumatic HI.

- Often misdiagnosed, underdiagnosed or not diagnosed but has huge implications to life style and if not treated progresses to a chronic prolonged phase generating a condition called PPPD or persistent postural perceptual dizziness, a difficult condition to treat
- There is a strong legal implication to any head injury and the vestibular component may lead to a significant financial compensation package

Mechanism

The head can be injured either by a direct blow to the head or by an acceleration/deceleration injury when the moving head suddenly stops but carried forward by inertia or by a blast injury

- The opposite side of the brain or the labyrinthine apparatus may be damaged by the inertia of the force applied to one side resulting in a contre-coup injury
- A whiplash may accompany a head injury, in cases where there is no associated head injury, the labyrinthine system might still be affected by the acceleration/deceleration mechanism

Following the trauma

- There is gross movement of endolymphatic fluid that shears the delicate sensory epithelia of the vestibular end organ; leads to micro-vessel haemorrhage and interferes with vestibular transduction – degeneration of sensory hair cells and Scarpa's ganglion
- Direct skeletal damage to the bony and membranous labyrinth, i.e. temporal bone fracture
- Diffuse axonal injury disrupting the central vestibular tracts and pathways
- The force of the injury **does not** determine vestibular damage

Functions involved following head injury

- Generation of reflex eye movements
- Generation of reflex muscle responses
- Effect on frontal & supplementary eye fields
- Resolving motion in darkness
- Convergence of vestibular & optic flow and somatosensory stimulation
- Effect on postural stability
- Effect on orientation
- Effect on navigation
- Role in cognition
- Role in mood
- Role in spatial awareness
- Role in affective states
- Role in neural pathways changes
- Role in trigeminal nucleus interactions
- Role in autonomic responses
- Role in dream bizarreness

Clinical features

Physical features

- Vertigo – *the illusion of movement*
- Dizziness, lightheaded, giddy
- Positional Vertigo (self-motion induced)
- Visual vertigo (symptomatic eg with computer, shops, crowds, travelling, social occasions)
- Spontaneous vertigo
- Imbalance
- Falls (if there are additional causes), drop attacks
- Third window symptoms
- Headache, neck pain, back pain
- Migraine
- Oscillopsia, blurred vision, painful eyes
- Avoidance behaviour
- Fatigue (better with activity)
- Mal de débarquement
- Motion sickness, nausea, vomiting
- Difficulties in climbing stairs, in lifts, in escalators

Cognitive and psychological effects

- Derealization, depersonalization
- Reading difficulty
- Cognitive impairment
- Space phobia, motorist's vestibular disorientation syndrome
- Situational anxiety, panic attacks
- Breathlessness
- Palpitations, diarrhoea
- Reliance on thoracic proprioceptive cues
- Sensitivity to hyperventilation
- Sleep disturbance
- Nightmares
- Bruxism
- Altered consciousness
- PTSD

The relationship between cognitive/psychological effects of head injury may merge with similar effects caused by the vestibular injury

Vestibular pathologies following head injury

- Variable vestibular damage for chronic vestibular syndrome with intermittent decompensating episodes (up to 50%)
- BPPV (up to 60%)
- Vestibular migraine and classical migraine (up to 40%)
- Vestibular processing syndromes (up to 50%)

- Post traumatic Meniere's disease (up to 25%)
- Traumatic third window lesions – PLF, SCD
- Isolated otolith damage
- Complete/incomplete transection of the VIII nerve in temporal bone fractures

Post traumatic BPPV

- More commonly bilateral
- More commonly multiple canal
- More common for canal conversion
- More commonly recurrent up to 60% after PRM

Audiological complications after head injuries

- Bony damage to external auditory canal
- Damage to middle ear especially ossicles
- Cochlear damage
- VIII nerve damage
- Central auditory pathway damage
- Tinnitus and hyperacusis

Hearing loss, tinnitus and central listening problems of varying intensities encountered – these may affect school performance and the overall psycho- cognitive state of the child

Assessment and diagnosis

History

- Details of the mechanism of the injury – LOC and/or PTA
- Immediate, subsequent symptoms up to 48 hours, evolving symptoms from 48 hours to 3 months; between 3 and 6 months; beyond 6 months and current symptoms regarding vestibular symptoms
- Other physical symptoms and details of other injuries
- Psychological and cognitive symptoms – memory, organisation and mood
- Treatment history and employment history
- Past medical history

Vestibular symptoms – key questions

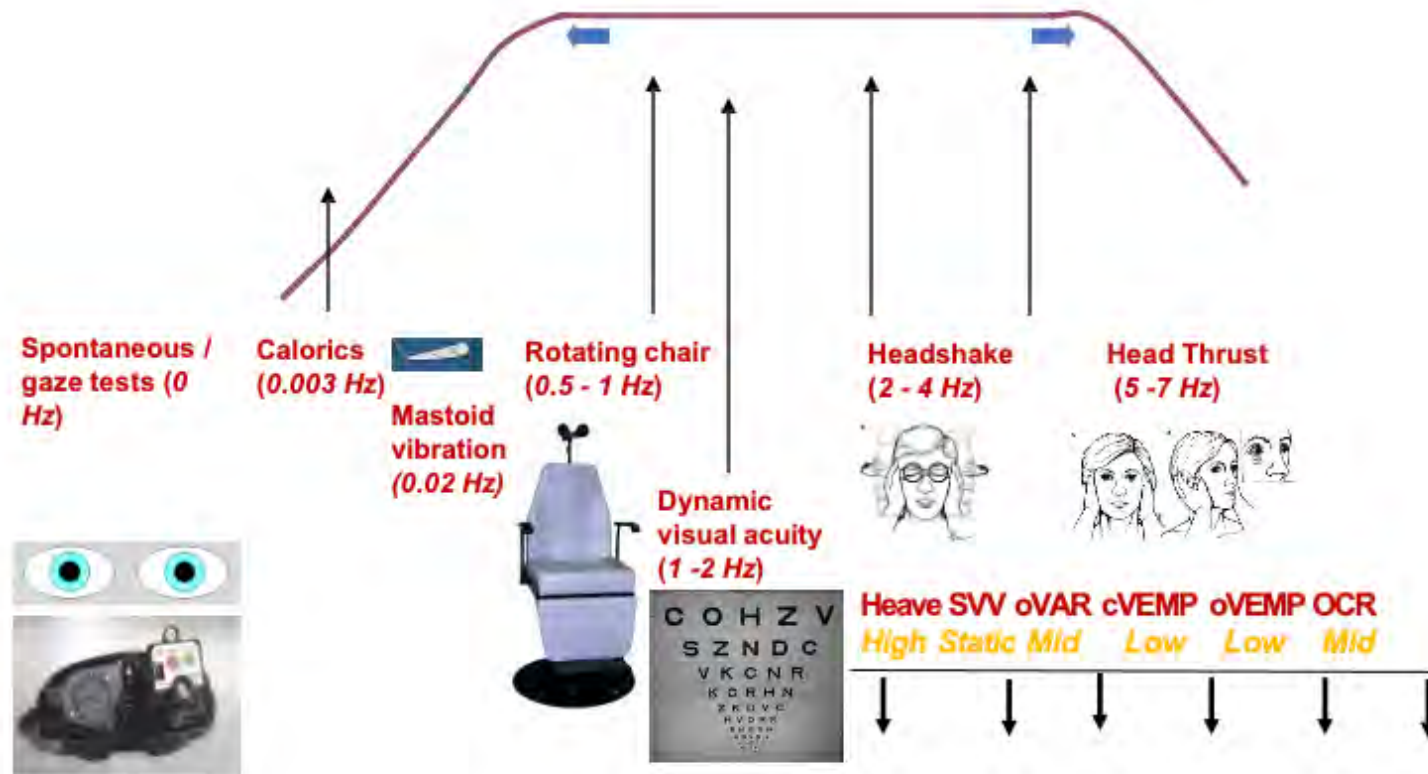
- Disorientation in space – spontaneous or provoked
- Unsteadiness/postural instability
- Ambulation in the dark
- Climbing stairs/in lifts and escalators/ driving
- Navigation and spatial awareness and recent onset motion sickness
- Symptoms of Meniere's disease and vestibular migraine
- Third window symptoms
- Otolith symptoms

Examination

- General examination
- Neurological examination
- Cardiovascular examination including blood pressure
- Musculoskeletal examination
- Audiological examination – middle ear studies, OAE, CSOAE, PTA, APD test battery, ABR in selected cases

Neurological assessment

Vestibular assessment



Other assessment

- Hyperventilation test
- Hennebert's test
- fHIT and SHIMP
- Vestibulospinal tests
- Static and dynamic posturography

Other tests

- Vestibulo-spinal tests – Romberg, Unterberger/Fukuda, sharpened Romberg +/- foam cushion, tandem gait and retropulsion
- Central tests
 - VNG ectopic eye movements
 - Smooth pursuits and saccades
 - VOR cancel test
 - Perversion of expected peripheral eye movements
 - Non vestibular movement disorders – functional gait analysis
- Static and dynamic posturography
- Hyperventilation and Hennebert's tests

Imaging

- HRCT temporal bones for third windows and occult temporal bone fractures
- MRI of brain for DAI

Medical screening tests

- To assess and diagnose medical problems for decompensation
- FBC, bone profile, Vitamin D, TFT, autoimmune screen

Questionnaires

- Dizziness Handicap Inventory
- Situational Characteristic Questionnaire for visual vertigo
- Nijmegen questionnaire for hyperventilation

At the end of this extensive assessment, one should be able to
diagnose the extent of the vestibular damage, vestibular
decompensating factors and comorbidities that will lead one to
avoid further complications and formulate an effective
management plan

Complications

- About 25% of head injuries have cryptogenic vestibular damage, i.e. undiagnosed and unfortunately the majority of subjects with head injuries will present years after the injury for vestibular assessment
- Vestibular manifestations are maintained by decompensation due to other co morbid medical factors especially cognitive and psychological factors as well as poorly treated physical factors for example pain
- The vestibular damage itself generates its own psychological effects setting up a vicious cycle complicated by the anxiety generated by a long legal process
- The vestibular manifestations proceed to the stage of 3PD which is a very difficult condition to treat

So we will have to work quick and fast and must not delay
any further

Management

It must be remembered that vestibular rehabilitation following head injury incorporates vestibular, visual and somatosensory substrates that in itself is intense activity in the brain and is only one part of the holistic management. Thus, in patients with inherent brain injury, this may lead to fatigue and therefore vestibular rehabilitation must be gradual and phased and must be tied in with other treatment to avoid fatigue.

Vestibular rehabilitation

- Accurate assessment and diagnosis of vestibular damage
- Early vestibular rehabilitation with dedicated and customised vestibular exercises
- Treatment of visual vertigo with optokinetic stimulation and/or virtual reality
- Postural stability exercises
- Treatment of BPPV
- Personal trainer and occupational therapy input; podiatry and behavioural optometry
- Alternative exercises for example Tai Chi

Other treatment

- Treatment of vestibular migraine and post traumatic headache
- Treatment of post traumatic Meniere's disease/third window
- Treatment of cognitive deficits and psychological/psychiatric conditions

- Treatment of post traumatic skeletal pain especially cervical whiplash and any joint injury
- Treatment of hearing and listening deficits and tinnitus
- Self awareness and management techniques and situational counselling

It must be remembered that vestibular rehabilitation following head injury incorporates vestibular, visual and somatosensory substrates that in itself is intense activity in the brain and is only one part of the holistic management. Thus, in patients with inherent brain injury, this may lead to fatigue and therefore vestibular rehabilitation must be gradual and phased and must be tied in with other treatment to avoid fatigue.

Measures of compensation

- Subjective by anamnesis, effects on daily living, work and perusal of hobbies
- Psychometric questionnaires like DHI, Balance scales, HAS and QOL
- Computerised static and dynamic posturography and VST recovery
- Recovery of VOR gain and saccade clustering and disappearance of overt saccades
- PSV improvement in SHIMP and reduction of asymmetry
- Recovery of VEMP rectified amplitudes
- Recovery of HS, HH, Alexander's nystagmus, MVT and OCR

However, remember that VFT might not be proportional to reported symptoms due to comorbid factors

Rehabilitation Connectome – the holistic multidisciplinary approach

Patient

Vestibular physiotherapy

Neurophysiotherapy

Personal trainer

Occupational therapy

Behavioural optometry

Nutritionist

Physical therapy

Podiatry

Audiologists

ENT, cardiology, neuroendocrinology,, neurology, neurovascular medicine, ophthalmology, CBT, neuropsychiatry, neuropsychology, rheumatology, orthopaedics and spine, haematology, radiology

Audiovestibular Physician/Neurotologists

General practice

Social services

Legal services

Employment

Education and counselling

Prognosis

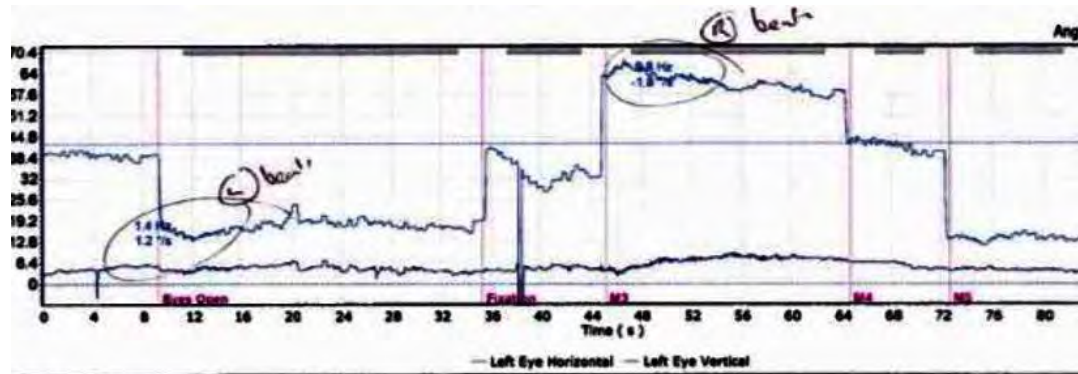
- Variable and depends on the damage, the mechanism of the injury and very importantly on comorbidity
- Must be guarded
- With vestibular rehabilitation, there is at least a 50% chance that vestibular symptoms will recover
- Age associated deterioration and future decompensation must be factored in management package

Factors adversely affecting outcome

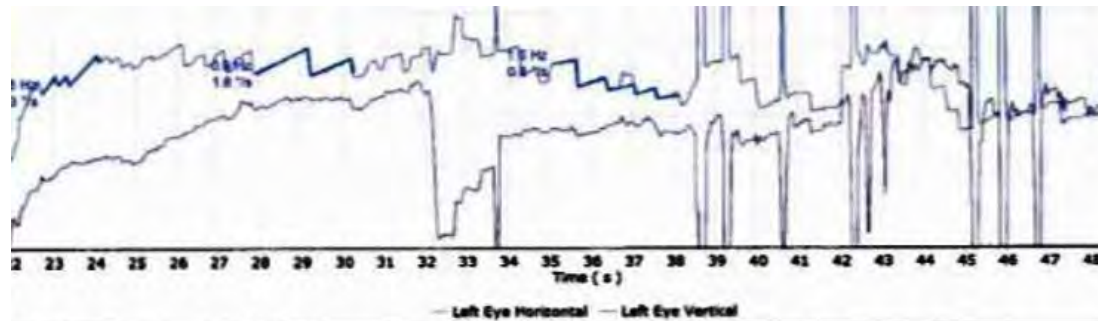
- Female gender
- P/H of concussion; psychological and cognitive problems
- Pre/post injury amnesia and/or loss of consciousness
- Dizziness immediately after injury persisting for 2 weeks
- Persistent cognitive and psychological symptoms
- Persistent headache and migraine
- Old age
- Other medical comorbidities

Case illustrations

Severe road traffic accident with multiple fractures including temporal bone fracture; complete SNHL on one side – left
coup cochleovestibular severe damage

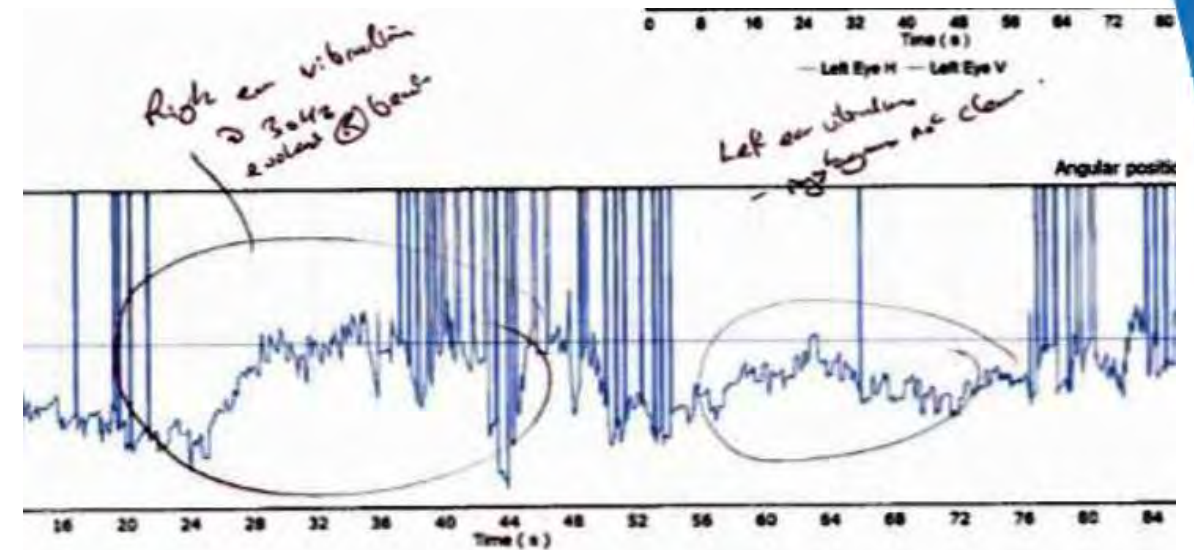


diagnosis: Nystagmus



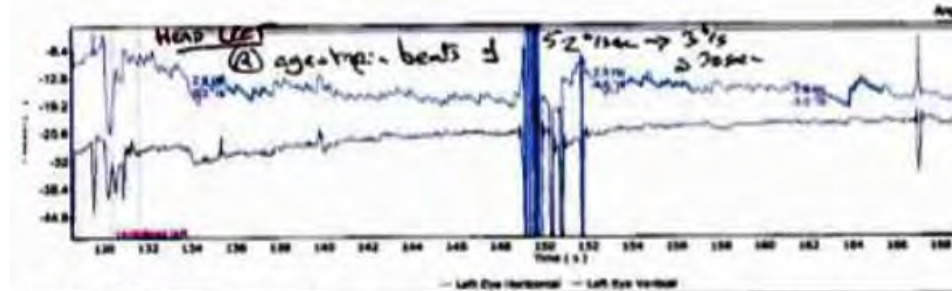
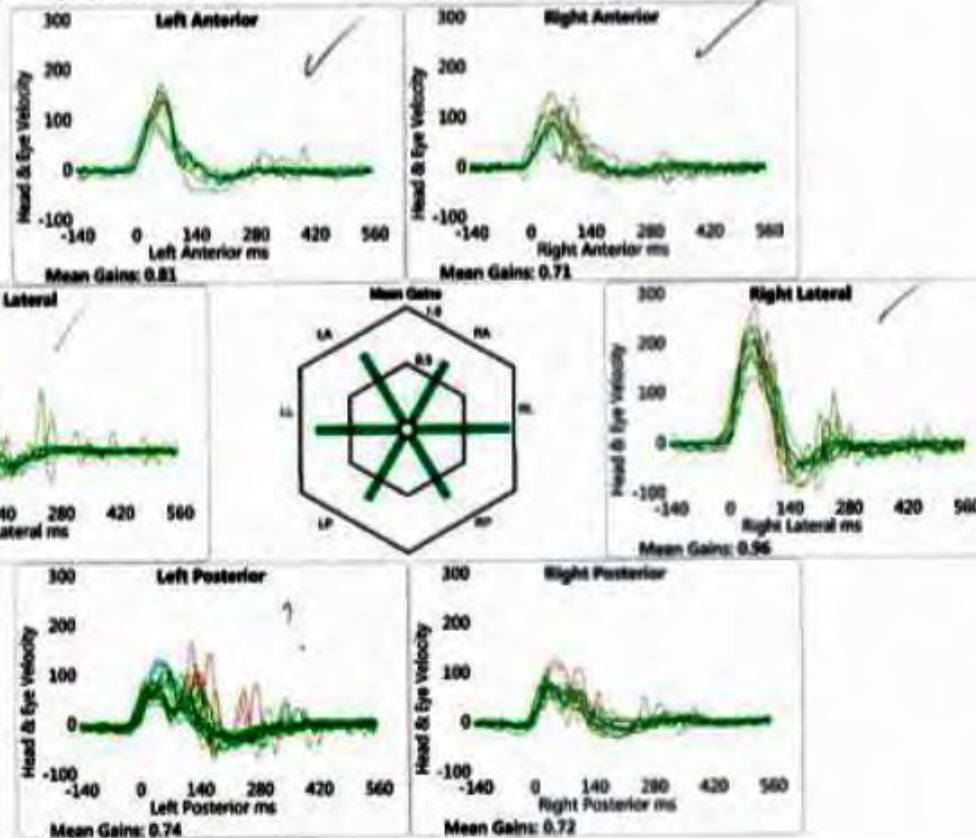
Nystagmus
Head shake (2 Hz)

Date: 1



Lateral Impulse Test: 19/02/2018 15:59
LARP Impulse Test: 19/02/2018 16:01
RALP Impulse Test: 19/02/2018 16:02

Asymmetry
Anterior: 12%
Lateral: 13%
Posterior: 3%



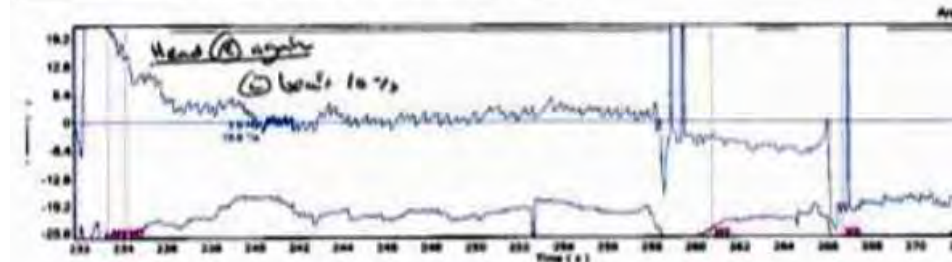
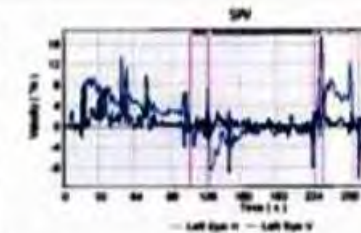
Module: Nystagmus

Test: Head roll right (1/2)

Date:

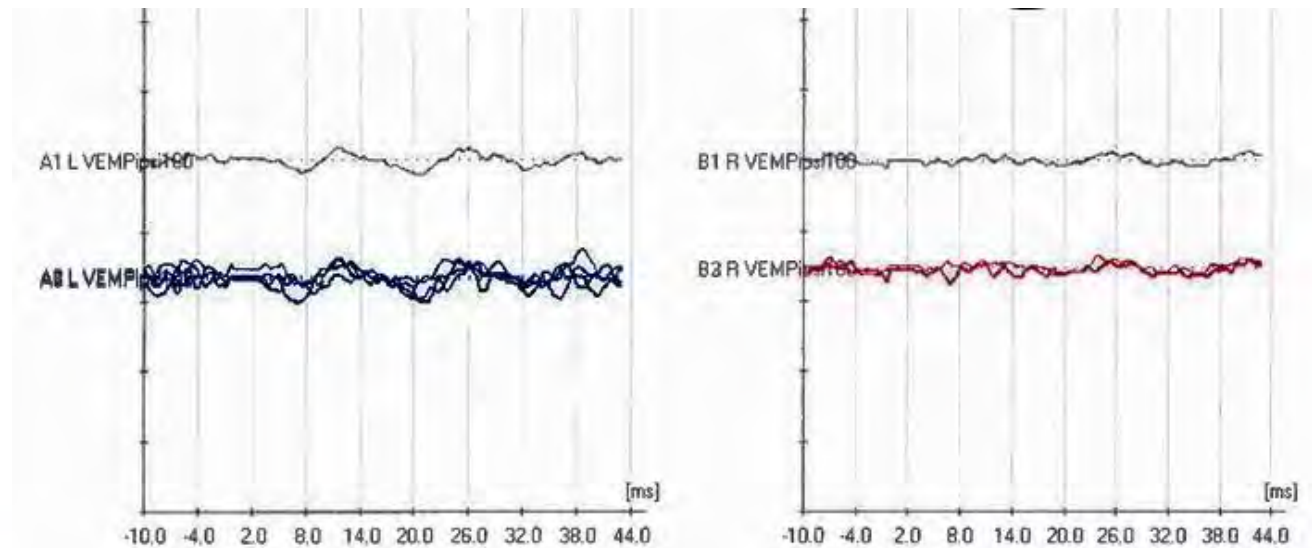
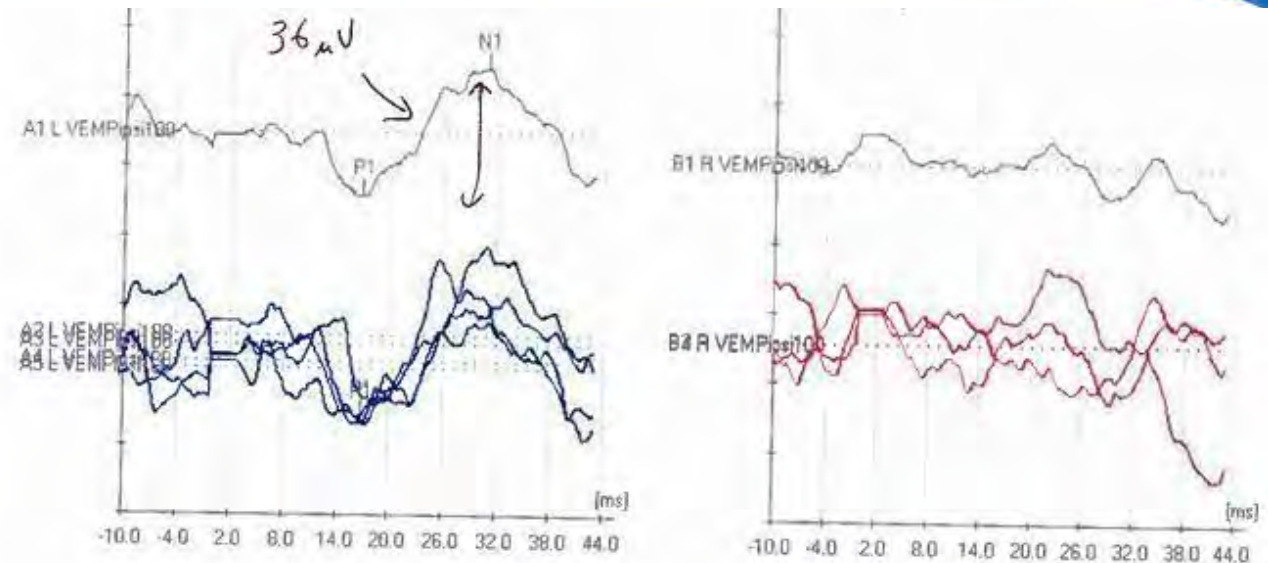
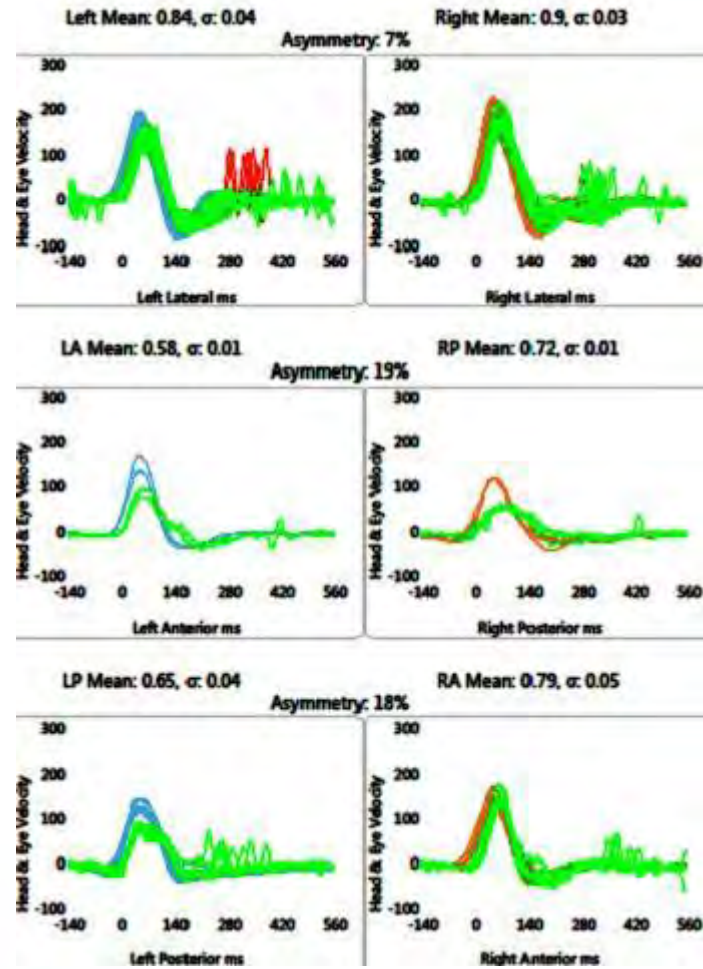
Results table (1/2)

	Mean Velocity		Mean Velocity	
	ms	↓	ms	↓
Head right	0.4 °/s (S)	0.5 °/s (S)	1.4 °/s (S)	4.0 °/s (S)
Head left	1.4 °/s (R)	0.0 °/s	7.0 °/s (R)	9.1 °/s (S)
centre	1.8 °/s (S)	0.9 °/s (S)	3.2 °/s (S)	14.5 °/s (S)
MD	6.7 °/s (S)	0.6 °/s (S)	12.3 °/s (S)	1.8 °/s (S)
MD	0.2 °/s (R)	0.0 °/s	0.4 °/s (R)	0.1 °/s (S)
MD	2.5 °/s (R)	0.1 °/s (S)	4.3 °/s (R)	2.1 °/s (S)



Acceleration/deceleration shunting from behind with pelvic injury; hearing normal – bilateral coup-contrecoup vestibular injury

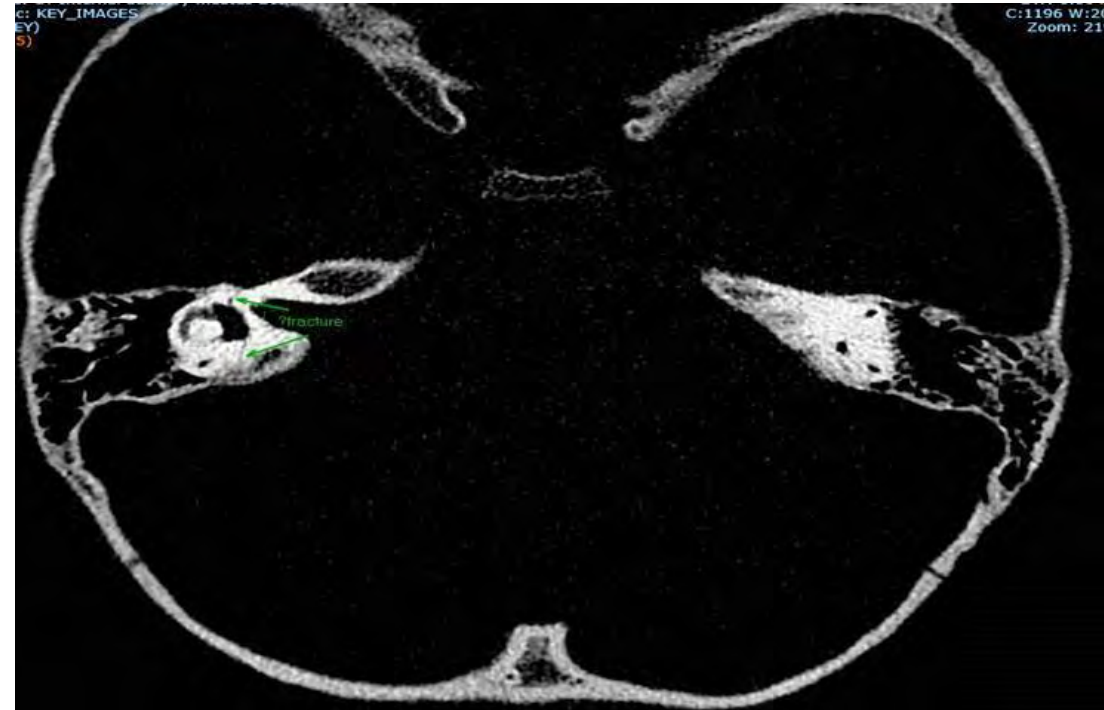
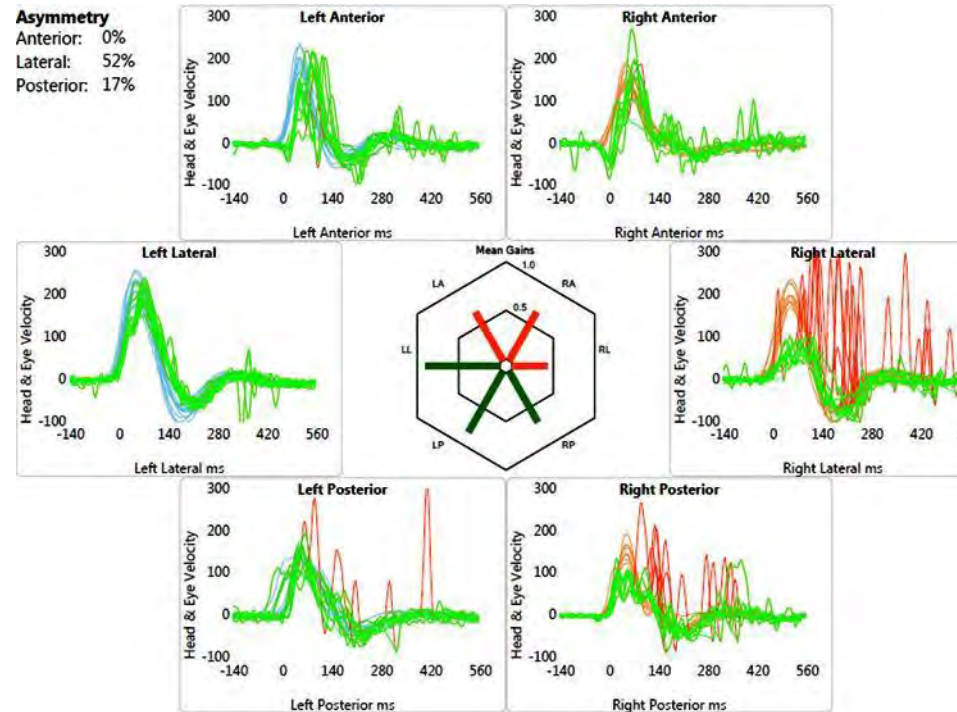
Head Impulse



Trivial injury in child, fall from less than 2 feet and hitting side of head on the right; complete SNHL on right – severe cochleovestibular deficit on the right

Asymmetry

Anterior: 0%
Lateral: 52%
Posterior: 17%

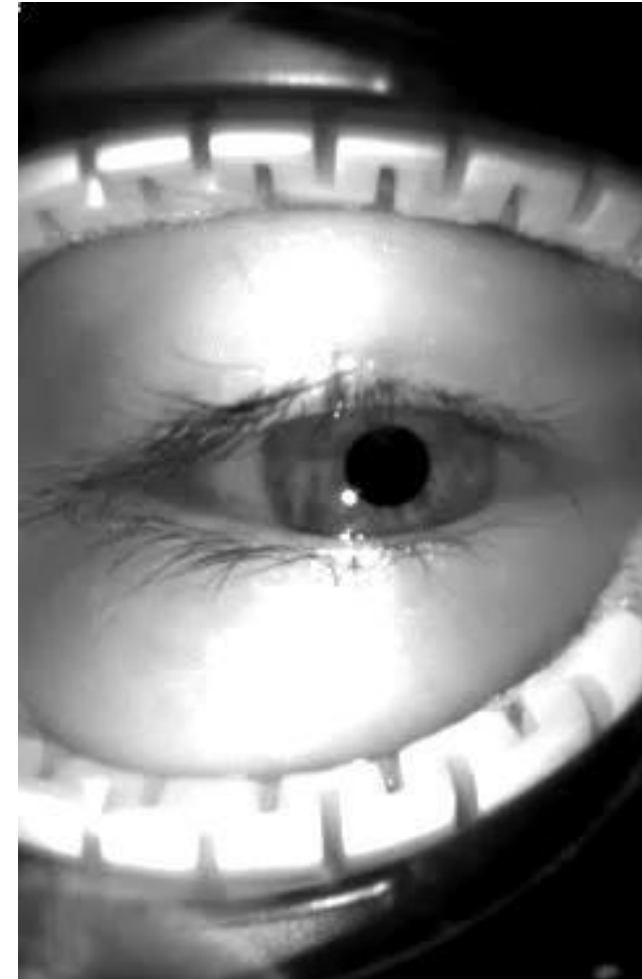
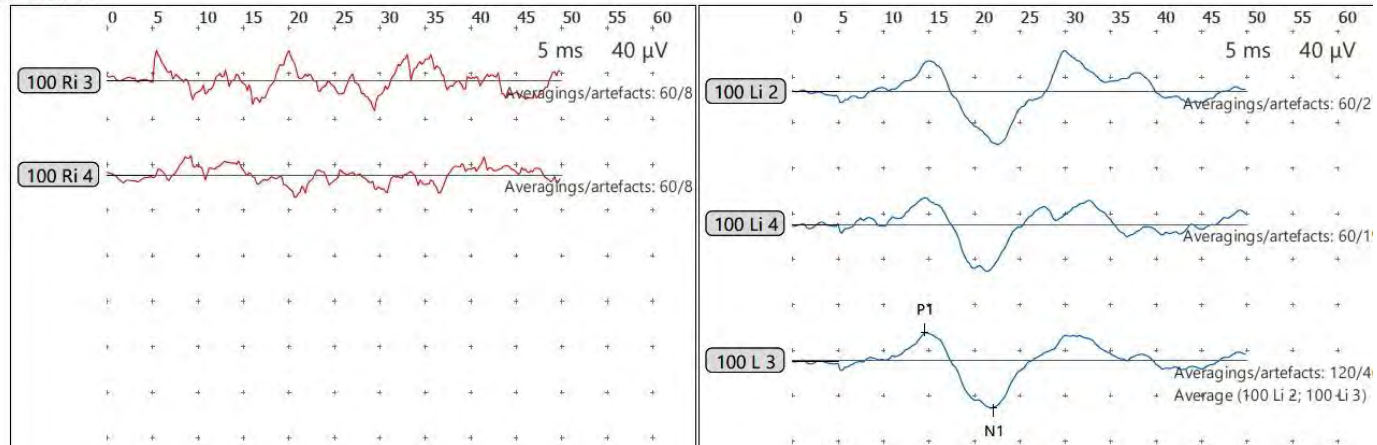


Significant injury in RTA, multiple fractures and DAI, GCS 11,
impact injury on side of head on the right; normal hearing –
isolated otolith dysfunction on the right and central
vestibular derangement

VEMP: cVEMP (cervical) Alder Hey

1: Cz-M1

2: Cz-M2

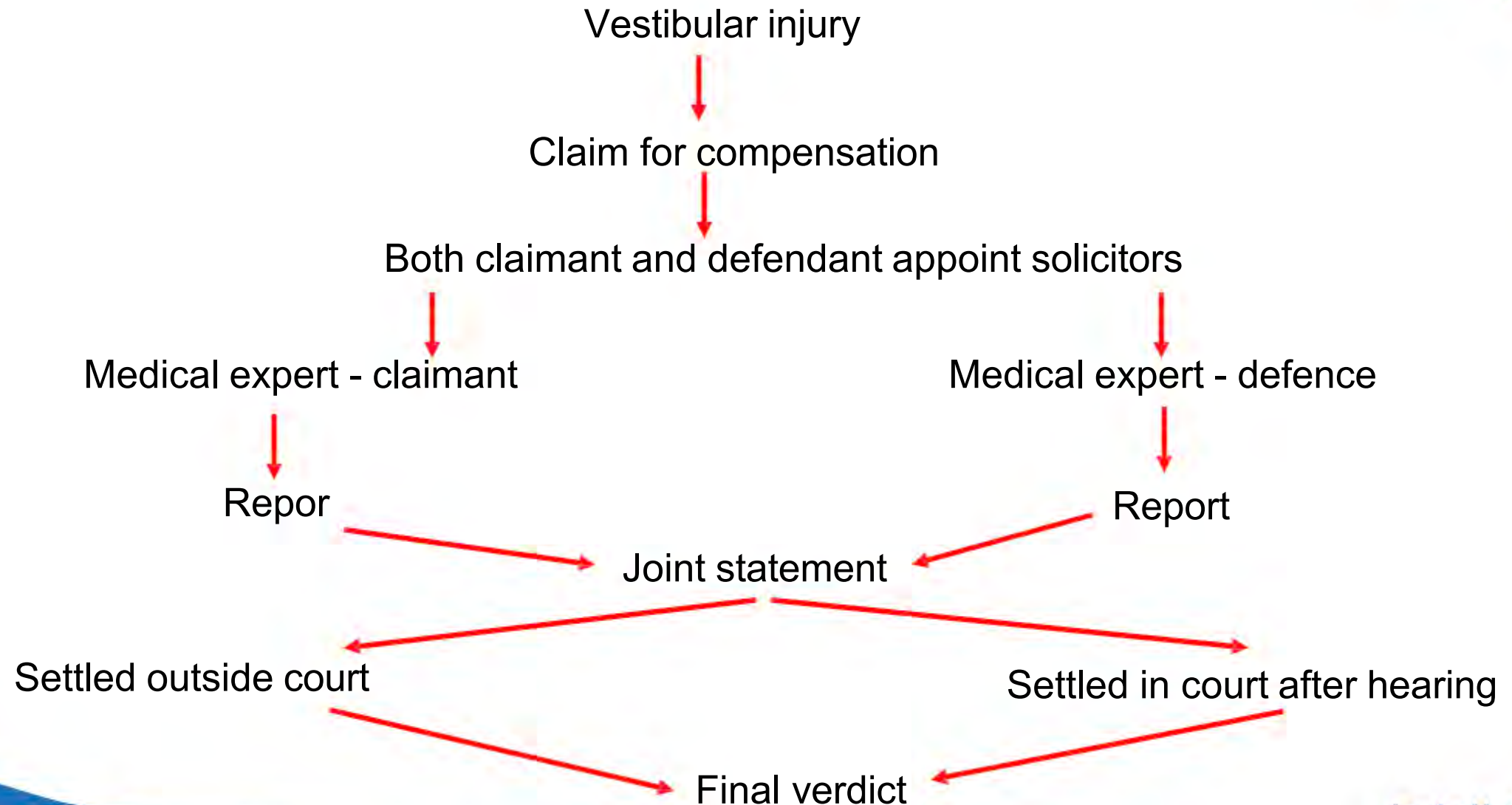


Legal aspects

- Given the significant morbidity caused by vestibular damage, these injuries may be eligible for compensation in personal injury claims
- It has to be established that a personal vestibular injury was sustained as a result of negligence or mistake by a party what is called a *liability*
- The burden of proof in causation is based *on the balance of probabilities*
- After establishing causation, the amount of significant limitation and restriction in life due to vestibular injuries needs to be ascertained that may be difficult due to confounding variables especially in the psychological and cognitive domains
- Remember these cases are often late to be referred to a neurotologist and therefore become more complicated in various stages of decompensation driven by comorbid medical factors

A medicolegal neurotology expert is called in for expert opinion on the vestibular injuries sustained at the event/accident called index injury to assess causation, extent of damage, effect on life functions, prognosis and eventualities with advancing age

Legal sequence of events after head injury



The report

- Analysis of evidence that can be voluminous
- Comprehensive history exploring beyond the vestibular system for example cognition, psychology, life function, daily activities and other simultaneous injuries
- Quantify frequency specific vestibular damage and hearing system
- Discuss findings with references
- Discuss causation, decompensation
- Discuss effects on occupation and daily life and activities including hobbies
- Discuss prognosis and effects of vestibular damage at old age

Duties of the expert

The overriding duty of the expert is to the Court and not the instructing solicitors and adhere to his expertise

I confirm that I have made clear which facts and matters referred to in this report are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. The opinions I have expressed represent my true and complete professional opinions on the matters to which they refer.

I am aware of the requirements of Part 35 and practice direction 35, this protocol and the practice direction on pre-action conduct.

I understand that proceedings for contempt of court may be brought against anyone who makes, or causes to be made, a false statement in a document verified by a statement of truth without an honest belief in its truth.

Pros of being an expert

- Intellectually stimulating
- Expand knowledge
- Financially very rewarding

Cons of being an expert

- Long hours
- Liable to scrutiny by cross examination that can be intimidating
- If inadequate or dishonest can be reported to professional body

So as a medicolegal expert your report needs to be absolutely watertight so that you can defend what you have written. You can therefore appreciate the length and breadth of knowledge that you need to possess.

Remember your report alone can sometimes swing the decision and a person's future depends on it, so there is a moral ground as well

Example

- Simulated frontal car collision with object at 15 miles an hour x 3
- Immediately balance and cognitive issues, no LOC but some PTA
- Loss of earning and incapacity to work
- Psychological issues
- Extensive medicolegal assessment over 5 years with 2000 page deliberations
- Neurological injuries with range of opinion
- Audiovestibular injury confirmed with objective vestibulometry

Went to the Royal Courts of Justice for a 14 day trial

The Judgement

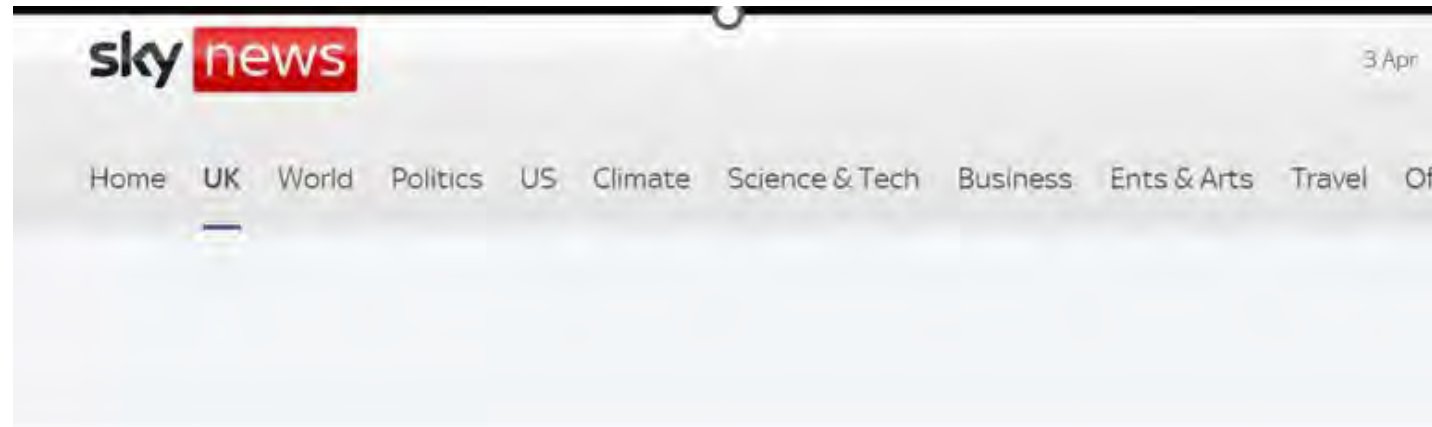
It seems to me that Dr Dasgupta was doing exactly what is expected of an expert in analysing all the evidence and being prepared to reflect on the views of his opposite number. I was entirely satisfied that he was fulfilling his duties as an expert.

I find that the claimant sustained subtle damage to the left utricle and semi-circular canal as a result of the crash tests. The vestibular injury was the cause of the early complaints of dizziness and balance problems, which I find to have been evident by the evening of the crash tests.

Dr Dasgupta considered that vestibular decompensation between 2014 and 2018 was likely to be related to the effect of comorbid conditions. It is impossible to view the audio-vestibular problems in isolation. Dr Dasgupta suggested that the waxing and waning of vestibular symptoms could be caused by a patient's reaction to stress and the impact on coping strategies.

I consider that the extent of the claimant's audio-vestibular symptomology is disproportionate to the relatively modest damage he sustained. Again, by itself, the audio-vestibular injury cannot explain the claimant's ongoing significant impairment. However, it is another piece in the jigsaw which contributes to the overall symptomology and to the claimant's complex presentation.

The Compensation

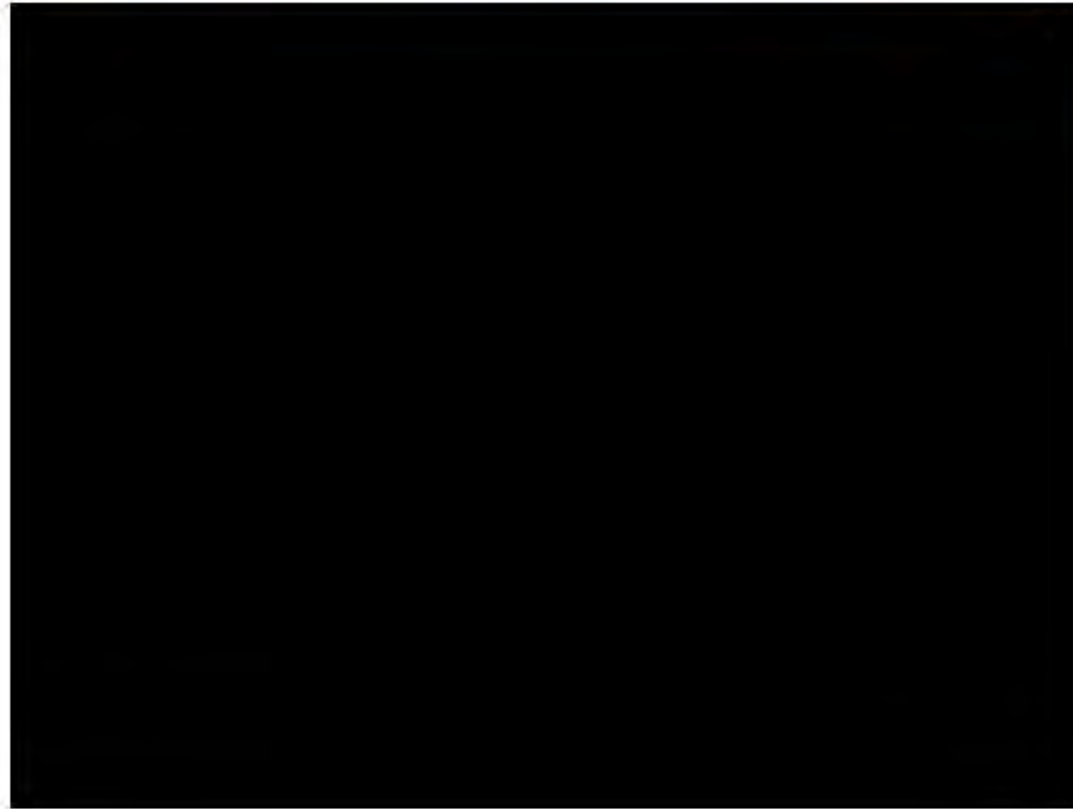


TV presenter [REDACTED]
awarded £1.6m in damages after he was
hurt during filming of BBC show

Stansfield, 50, was playing the role of a "crash test dummy" during the BBC programme Bang Goes The Theory and was injured while carrying out tests in a specially designed "rig".

Conclusions

- Managing vestibular injuries after a head injury is very complex due to multiple comorbidities
- It is essential and can be ascertained to a satisfactory certainty
- Management often leads to a rewarding outcome to improve quality of life in a vulnerable population
- Are often ignored in the grand scheme of the index head injury
- There is a strong legal implication associated



Any head injury may damage your internal GPS and thus should be given due importance

Selected bibliography and directed reading

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