Vertebral Fracture/Luxation

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Spinal Biomechanics

- Vertebral motion unit
  - Osseous and soft tissue contributors to stability
- Fractures tend to occur at junction of immobile/mobile areas
  - Resistance of bending forces of vertebral bodies
  - Lowest around T9 and rising to L2
  - Rising bone mineral density
  - Adaptation to bending stress
Spinal Biomechanics

- **Forces acting on the spine**
  - Dorsoventral bending (disc, vertebral body, dorsal elements)
  - Lateral bending (disc, facets, vertebral body, rib head)
  - Torsion (disc, facets, rib head)
  - Shear
  - Axial compression (disc, vertebral endplates)
- **Relative contribution of each force in normal movement unknown**
  - Disc most important in bending and rotation (Schulz et al AJVR 1996, Shires et al Prog Vet Neurol 1991)
Anatomical Influence

- Thoracic spine
  - Inherently stable
  - Small articular facets but large dorsal structures
- Thoracolumbar junction (50% of VFL)
  - Highly mobile
  - Large facets
  - Facets change orientation from ventrodorsal to saggital
- Lumbar spine (25-30% of VFL)
  - Relatively rigid
  - Dorsoventral flexion
3 Column Model (Dennis Spine 1983)
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- **Dorsal column**
  - Articular facets, laminae, dorsal spinous processes, interspinous ligaments, ligamentum flavum

- **Middle column**
  - Dorsal longitudinal ligament, dorsal annulus fibrosis, dorsal vertebral cortex

- **Ventral column**
  - Ventral longitudinal ligament, remainder of intervertebral disc, ventral vertebral cortex
3-Column Model – Fracture Configurations

- Compression
  - Failure of the ventral column under compression
  - Intact middle column acts as the hinge
  - Flexion injury
3-Column Model – Fracture Configurations

- **Burst**
  - Failure of vertebral body (ventral and middle columns) under compression
  - Dorsal column is the hinge
  - Flexion injury
3-Column Model – Fracture Configurations

- **Seat-Belt**
  - Failure of dorsal and middle columns under tension
  - Ventral column may also be involved but maintains role as the hinge
3-Column Model – Fracture Configurations

- Fracture-Dislocation
  - Failure of all columns
  - A: flexion/rotation
  - B: shear (hyperextension)
  - C: flexion/distraction
3 Compartment Model (Sharp & Wheeler)

- 3-column model
  - Based on mode of injury (stability inferred)
  - Indications for surgery in humans different to quadripeds
- Assesses ability of vertebral column to resist applied forces
- Addresses integrity of:
  - Intervertebral disc
  - Vertebral body
  - Articular facets
- Serves as a guide to the fixation best suited to each fracture
3 Compartment Model (Sharp & Wheeler)

- I – Disc failed, facets and body intact
  - Rotation, lateral bending, extension
- II – Facets failed, disc and body intact
  - Rotation
- III – Body failed, facets and disc intact
  - Bending, compression
- IV – Two or more components fail
  - Generally all forces
Imaging

- Plain radiology (Kinns et al Vet Rad Ultrasound 2006)
  - 72% sensitivity for fractures
  - 77.5% sensitivity for luxations
  - 58% NPV for canal narrowing
  - 52% NPV for fragments in canal
  - Poor for fractures involving dorsal/middle compartments
Imaging

- Significance of displacement
  - Not associated with outcome (McKee et al Vet Rec 1990) unless 100% (Bagley Vet Clin North Am 2000)
  - Displacement + axis deviation significantly associated with outcome in dogs (Bali et al VCOT 2009)
Advanced Imaging

- CT gives greatest bone detail
  - Safe implant corridors
- MRI
  - Cord compression
  - Disc extrusion
  - Signal change – T2W hyperintensity
    - Correlation with outcome
    - Levine et al JVIM 2009
Treatment

- Prevent ongoing injury
  - Limit instability
- Relieve spinal cord compression
  - Realign spinal canal
    - Apposition or near-apposition
  - Intervertebral disc
    - Hemilaminectomy?
- Fragments
  - Human studies suggest unnecessary
  - Must retropulsed and resorbed
Conservative Therapy

- Non-surgical management
  - Indications poorly defined – ‘stable’ fractures
  - Isolated facet fractures or disc extrusions
  - Some body fractures
- Difficult to immobilise thoracolumbar spine
  - Patterson & Smith VCOT 1992
- Selcer et al JAVMA 1991
  - Shorter hospitalisation
  - Longer recovery
  - Surgically treated animals improved more but no difference in eventual long term outcome
Surgical Management

- Ventral stabilisation
  - Pins or screws/PMMA
  - Plates
  - ESF

- Dorsal Stabilisation
  - Spinous process plating
  - Tension band/modified segmental spinal fixation
  - Laminar plating
Implant Corridors

- Watine et al JSAP 2006
  - Thoracic vertebrae
    - Insertion angle opens from 22° to 44.5°
    - Azygous vein 1mm away
  - Lumbar vertebrae
    - Insertion angle 60°
    - Vital structures more protected
Pin Penetration of the Canal

- Hettlich et al Vet Surg 2010
- Left/right accuracy 93.1%

Radiographs
- Sensitivity 50%
- Specificity 83%

CT
- Sensitivity 93.4%
- Specificity 86%
Pins + PMMA

- Versatile
- Strong in flexion, extension, torsion
  - At least that of intact spine (Walker et al Vet Surg 2002)
  - Depends on configuration (David Hall, pers comm)
- Threaded pins preferred
  - Less pull-out
  - Less migration
  - Firm anchorage of cement
- 3+ implants per vertebra, screws inferior to pins
  - Garcia et al Vet Surg 1994
Vertebral Body Plating

- Swaim JAVMA 1971
  - Technical feasibility of small dorsolateral body plates on adjacent vertebrae
  - Recommended sacrificing nerve roots
- Clinical use substantiated
  - Downes et al JSAP 2009
- Conventional plates superseded by locking plates?
  - SOP (McKee & Downes JSAP 2006)
  - PAX?
Internal Fixation Systems

- Walter et al Vet Surg 1986
  - Dorsal + vertebral body plate strongest followed by vertebral body plate

- Waldron et al Prog Vet Neurol 1991
  - Pins + PMMA strongest
External Skeletal Fixation

- Blunt tipped pins ideal + arches
- Open
  - Lanz et al Vet Neurology Neurosurgery 2009
  - 3 dogs – good reduction with no complications
  - Poor follow-up
- Closed
  - 5 dogs – good to excellent function in all
  - Fixators in place up to 282 days
External Skeletal Fixation

- Open vs closed
  - Wheeler et al Vet Surg 2002
  - Both open and closed application different from the ideal angle/depth
  - Better bone purchase in closed
  - Difficult to apply to thoracic especially open

- Strength - Walker et al Vet Surg 2002
  - Eight pin/arch combo stiffer than bilateral type I ESF
  - Comparable to Eight pin/PMMA combo
Modified Segmental Spinal Stabilisation

- Longitudinal Steinmann pins held in place with wire through spinous processes
- McAnulty et al, Vet Surg 1986
  - 4 dogs 10-56 kg, all unstable fractures
  - 1 broken pin at 18 months
- Not recommended?
  - Wire pull-out
  - No ventral support
  - Suited to thoracic fractures
Tension Band Fixation

- Voss & Montavon JAVMA 200
  - Modification of MSSS
- 38 dogs/cats up to 45kg
- Unstable fractures
  - Vertebral body involvement
- 78% complete or functional
- 11% implant or fixation failure
  - Dogs >16kg
Laminar Plating

- Benefit of dorsal stabilisation
- Potentially more cortices
- Knell et al AJVR 2011
  - Lower ROM and NZ than vertebral body plating
  - VBP constructs: bone failure at facet joints
  - LP constructs: construct failure
  - Less screw loosening in LP (1/9) than VBP (5/9)
Laminar Plating

- Knell et al AJVR 2011
- Angles of insertion L1/L2
  - Lamina = approx 20° ventral, 10° dorsal
  - Facet = 24° ventral, 12° dorsal
- Screw penetration 1/24
  - Screw did not follow drill hole
Spinous Plating

- **Krauss et al VCOT 2012**
  - Similar function to tension band stabilisation
  - 15 unstable fractures
  - 80% complete or functional outcome
  - No implant failure
  - Spinous process demineralisation

- **Rischen et al Vet Surg 1987**
  - No change in underlying vascularity
  - Demineralisation by 8 weeks
  - Foreign body reaction
Prognosis

- **Surgical technique**
  - Results seem fairly comparable across techniques
  - 80-100%
  - Complication rates vary
- **Significance of absent nociception**
  - Very poor recovery rates – avg 5%
  - Spinal walking – rim of peripheral surviving tracts?
References


