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|---|---|---|
| | **Spinal Trauma**<br>**Clinical Practise Guidelines** | |
| **Scope** | • Acute Inpatient Areas | • Medical<br>• Nursing<br>• Allied health |
| **Responsible Department and Position** | Emergency Department : Director or Emergency | |
| **Approved By** | Trauma Committee | 20/4/2016 |
| **Authorised By** | Group Clinical Standards Committee | 16/06/2016 |

## Contents

**PURPOSE**

To ensure that the patient suspected of a traumatic spine injury is appropriately assessed and managed. Staff at Bendigo Health (BH) will utilise a standardised, evidence-based approach in the management of spinal trauma.

**PREAMBLE**

The incidence of acute cervical spine injuries (bone, cord, ligaments) following blunt trauma is 2.8% overall.[1] This increases to 8% in the unconscious/ obtunded (GCS< 3-8) population. For *major* blunt trauma, recent incidence is 14% at one Victorian trauma centre (RMH) - of those 92% are fractures.[2] Less than 1% will suffer a cord injury but for those that do it can be devastating to both the individual and their family.

Thoracolumbar injuries are even more common than cervical fractures after blunt trauma (4-5%).[3] For *major* blunt trauma, the incidence is 28% at RMH.[2] The most common site of thoracolumbar injury is where the natural transition from kyphotic to lordotic curvature occurs, between T11 and L4. To disrupt the column at this level requires great force and are commonly the result of high velocity deceleration mechanisms such as motor vehicle crashes, high falls, pedestrians stuck by motor vehicles, and motorcyclists. The reported incidence of neurological deficit in patients with TL spine fractures is as high as 19-50%.[3]

Few acute treatments for spinal injuries have been subjected to controlled clinical trials and the emergency care of patients who may have spinal injuries has become highly ritualised.[4] It is clear that at least some methods commonly used in the field and emergency department can also cause harm. One example of this is the widely-adopted practice of immobilising a patient’s neck and body following blunt trauma. Because spinal trauma may not be immediately obvious during the initial evaluation of a trauma patient, presuming a spinal injury and employing proper immobilization (“spinal precautions”) of the entire spine at the primary survey is currently the rule after blunt trauma. This approach to blunt spinal trauma—to empirically immobilize the entire spine until a clearance protocol can be performed—is in contrast to penetrating trauma where standard spinal precautions are associated with a doubling of the mortality rate and a more selective approach based on injury patterns is often more appropriate.[5] Far more patients will be treated with spinal immobilisation than eventually turn out to have injuries to their spine but unfortunately all of these patients are at risk for side effects of immobilisation. Established protocols that clearly delineate an established routine for how spinal clearance should be carried out are particularly important. The absence of an institutional evidence-based spinal protocol can increase the rate of missed injuries and also lead to inappropriate and unsafe patient care.[6]

There are two main goals in spinal clearance after blunt trauma: avoid missed injuries and identify patients without significant injuries. The process of spinal clearance aims to accomplish these goals as efficiently as possible. Timely assessment is needed as delays in diagnosis of spinal injuries is associated with worse outcomes.[7,8] Also, spinal immobilisation is not without consequences for the 98% or so who do not have a significant spine injury.  Prolonged time in spinal precautions without an injury is associated with increased nursing workload, increased workplace injuries, increased complications of immobilisation, and worse patient outcomes.[9]

**POLICY**

All patients with a suspected spine injury must be managed according to the BH:

**Spinal Trauma Assessment and Management Policy &**

**Disposition of the spinal trauma patient Admission and Transfer Policy**

***If in doubt, consult a senior clinician.***

**INITIAL CLINICAL MANAGEMENT**

**Basic exam components**

As for all trauma patients, evaluation begins with the primary and secondary surveys. Completion of the primary and secondary survey is the first step in the complete evaluation of the spine and an attentive examiner can sometimes identify patterns of injury that can be associated with blunt spinal injury:  facial trauma (cervical spine), face or neck abrasions from seat belts (cervical), lap belt contusion (thoracolumbar), and calcaneal fractures (thoracolumbar/lumbar).

**Initial spinal precautions**

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| *The clinician should be aware of the lack of an evidence base behind the standard practice of immobilising the spine to reduce exacerbating an unstable injury - specifically the use of cervical collars.  Instead of the traditional emphasis on minimisation of visible post injury motion, there is growing opinion in favour of concentrating efforts on minimising energy deposition to the injured site while minimising treatment delays.  Some studies demonstrate that a significant amount of movement of the cervical spine can still occur with a perfectly fitting collar.  However, the collar serves as a reminder that the neck has not been cleared and does provide some protection against large movements of the cervical spine.  Also, when neurological deterioration occurs after the initiation of emergency care it is not currently possible to discriminate between possible aetiologies, one of which is post-injury movement.  Cervical collar use should continue in the blunt trauma patient with the unevaluated C-spine.  This document reflects the current practice of the Victorian State Trauma System* |

First responders should suspect a spinal column injury in every trauma victim.  For any patient with a possible spine injury, spinal immobilization should be initiated at the scene.  This typically includes a backboard, rigid cervical collar, and lateral head supports.  Upon arrival at the hospital the patient should be removed from the backboard and placed them on a trauma trolley to prevent potential complications.[10]

For those patients who arrive without spinal precautions in place, immobilization of the spine should occur concurrently with the initiation of the primary survey. A rigid cervical collar and a trauma trolley are a bare minimum, but careless patient handling will put any patient - regardless of immobilization devices - at risk for injury. Spinal immobilization and protection should be maintained until an unstable spinal injury is excluded. Patient handling should reflect the presumption of a spinal injury. See BH: C-Spine Collar Sizing, Fitting and Patient Care

Trauma victims may not think clearly due to head injury, shock, or drug/alcohol intoxication, making cooperation difficult and spinal movement likely. The focus of spinal precautions on reducing visible movement is least rational when treating an uncooperative or seizing patient. Tightly strapping these patients down does nothing to reduce the force they generate and in many cases will increase it if they panic or fight the restraints, either voluntarily or involuntarily. These patients may need to be calmed, sedated or paralysed. In select cases, management without ‘immobilisation’ is much preferable to increasing their leverage by use of restraints.

The treating clinician must ensure that the patient has an appropriate, properly fitted hard-collar.
If the patient is expected to be in the collar for an extended period of time, consider changing the hard collar to a padded collar (i.e. Philadelphia collar) for comfort and pressure injury prevention. This must only be performed by staff with training and local credentials to fit collars.

Manual control of the head is required at all times with any patient movement including during transfer and log roll. Avoid using force to stabilise the neck e.g. during intubation. Log roll is permitted as required for ongoing care and a “Pat Slide” is required for bed-to-bed transfer.

## Pearls and Pitfalls of Spinal Precautions

### Backboards

It should be noted that while the backboard often used for spinal immobilization is helpful for transporting trauma patients, there is no high quality evidence demonstrating that it prevents spinal injury or improves outcome.[10] Observational evidence suggests that backboards and cervical collars may be associated with complications, such as decubitus pressure ulcers, respiratory compromise, and altered examination findings, and **therefore it is recommended that trauma patients be removed from their backboard as quickly as possible**.[9]
For bariatric patients, hover mats can be used as long as the patient is temporarily on a rigid backboard.

### Penetrating trauma

Spinal injury is uncommon in patients with penetrating trauma, and rare in those without evidence of neurologic injury.[11] Spinal immobilization is only necessary when a neurologic deficit is present or a proper physical examination cannot be performed e.g. the unconscious patient. However, clinicians must remain cautious when they consider removing spinal immobilization in this setting because victims of penetrating trauma may simultaneously sustain blunt head or neck trauma during an assault. Immobilization may hinder management in some cases by impeding visualization of the airway or obscuring other injuries. Spine immobilization must not be performed at the expense of an accurate examination or the treatment of life-threatening conditions in a patient with penetrating trauma.[12] Patients in need of C-spine immobilization who have difficulty breathing due to haemorrhage may need their stretcher placed on its side, or may need to sit upright while C-spine precautions are maintained as best as possible.

### Hanging

Cervical spine injuries are uncommon in cases of self-hanging. Morbidity is primarily due to asphyxiation with cerebral anoxia or soft tissue injury.[13] Spinal column injury from hanging is seen in executions involving a drop from a height against a knotted rope ('judicial-style' hanging).

### Paediatric immobilisation

The heads of children <8 years of age are somewhat large in proportion to their bodies, resulting in neck flexion when they are placed supine on a standard backboard. To avoid this, padding can be placed under the child's back or a special backboard with an occipital recess may be used (Fig 1).

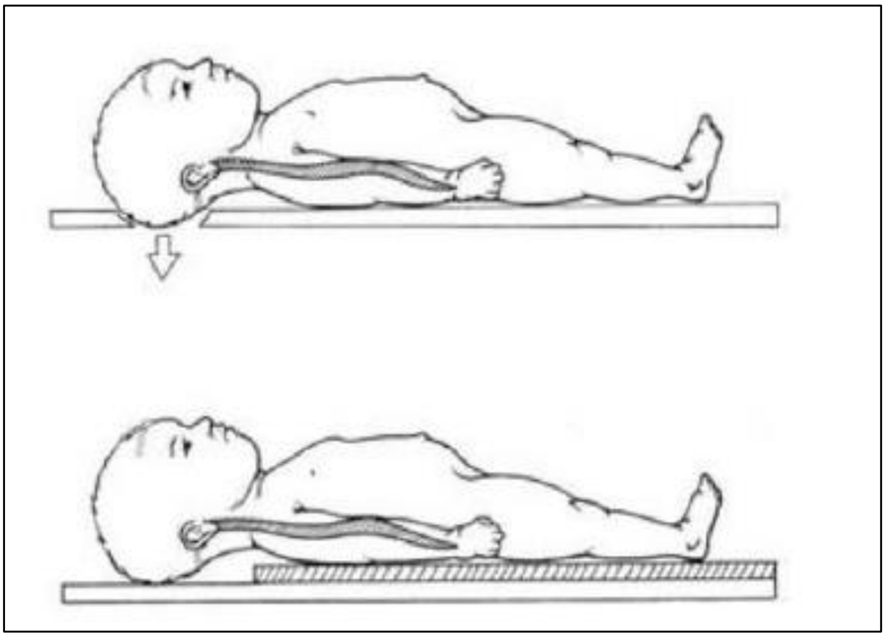

Figure 1: Thoracic elevation or occipital recess for optimal positioning of the child <8y

## CERVICAL SPINE ASSESSMENT AND CLEARANCE – ADULT 16y+

The aim in cervical spine clearance is to remove the cervical collar as quickly as possible from patients who do not benefit from them. For some patients this can be accomplished by history and examination alone (“clinical clearance”), however additional radiographic studies (“radiographic clearance”) may be necessary.

In more severe cases of trauma, the clinical condition of the patient mandates the timing of the cervical spine clearance (see Fig 2).

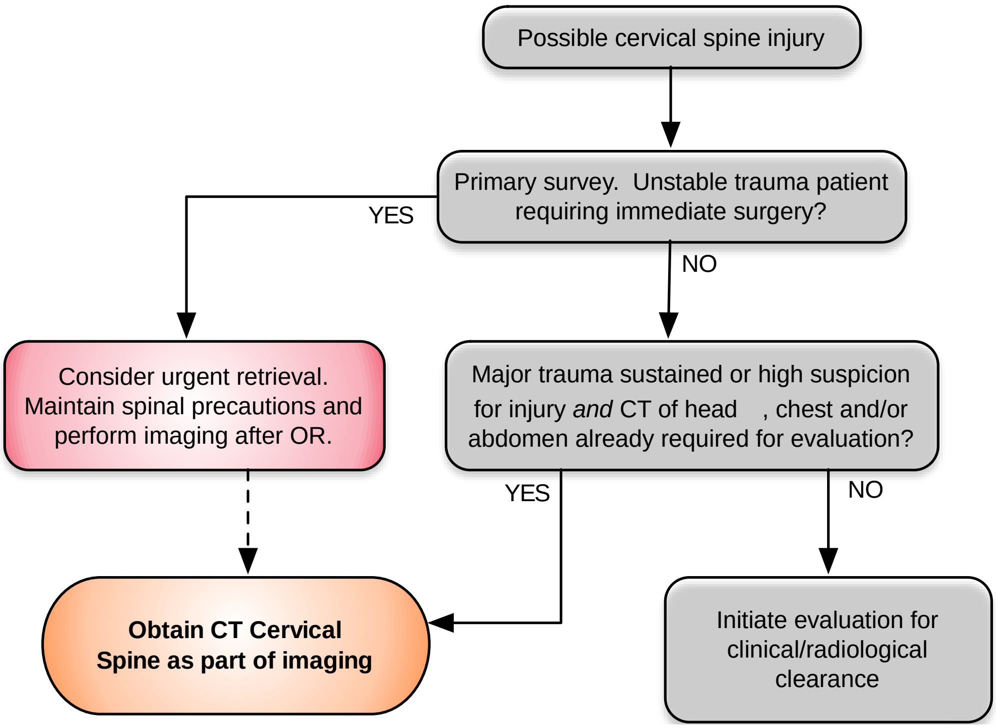


Figure 2: Timing of imaging and cervical spine clearance following trauma[14]

### Clinical Clearance – Adult cervical spine

There are 3 key steps in clearing the cervical spine, all of which require some degree of clinical judgment:

1. Initial clinical assessment
2. Historical risk factor assessment
3. Range of movement assessment

*See Fig 4 for adult flowchart*

Many stable young trauma patients with normal mental status and previously normal cervical spines can have their cervical spines “clinically cleared” without requiring medical imaging. Obtunded patients and patients whose mental status precludes evaluation require further workup and radiographic clearance.

***Validated imaging rules: NEXUS v. CCR***

The Canadian C-spine Rule (CCR)[15] and the National Emergency X-Radiography Utilization Study (NEXUS) low risk criteria[16] have both been used to identify patients at low risk for cervical spine injury who do not benefit from radiographic imaging. Both the CCR and NEXUS studies were developed after the observation of significant practice pattern variability and indiscriminate use of imaging in these low-risk patients. NEXUS is validated for age's 0-101y while the CCR has an age range of 16-64y.
Both of these clinical decision rules are evidence based and the question of which is preferable is the subject of debate.

In 2003, the authors of the original CCR study conducted a direct comparison in that remains the only major study comparing the two protocols.[17] The major finding was missed injuries in the NEXUS group. Overall, the CCR was found to be both more sensitive and more specific (Table 1).

| | Sensitivity | Specificity | |
|---|---|---|---|
| CCR | 99.4% | 45.1% | $P < 0.001$ |
| NEXUS | 90.7% | 36.8% | $P < 0.001$ |

Table 1: Comparison of Canadian C-Spine Rule with NEXUS Low Risk Criteria

Subsequent systematic reviews and meta-analysis of the major studies comparing cervical spine clearance protocols suggested that it was the functional evaluation (range of motion) component of CCR which contributed the most to its diagnostic accuracy and that this could be added to the NEXUS protocol to improve its accuracy in cervical spine clearance.[18,19] While an evidence base does not exist for combining these criteria during spinal clearance, the UK NICE guidelines[20] and the Eastern Association for the Surgery of Trauma[3] suggest the use of the neck movement assessment from the Canadian C-spine rule in addition to the NEXUS criteria.

Components of both rules have been incorporated into this spinal clearance protocol.

**Step 1 - Initial clinical assessment (NEXUS criteria)**

Patients who meet ANY of these five criteria require radiographic imaging:

i. posterior midline cervical spine tenderness
ii. evidence of intoxication
iii. altered level of consciousness
iv. focal neurologic deficit
v. painful distracting injuries (long bone fracture, significant visceral injury, large laceration, a degloving or crush injury, large burn, or any other injury causing functional impairment)

⇨ If no criteria are met, proceed to step 2.

**Step 2 – Historical risk factor assessment**

In patients with **any neck pain**, are there any **high risk factors** favouring imaging?[15,21]

- Dangerous mechanism
    - high impact MVA (combined impact >50kph / rollover / ejection / death at scene)
    - MBA
    - cyclist/pedestrian hit by car
    - an axial load to the head (e.g. dive into surf, falling tree branch)
    - fall (from height ≥ 1m / ≥ 5 stairs / off horse / off bicycle)
- Immediate onset severe neck pain
- Injured more than 48 hours ago
- Abnormal c-spine (surgery/prior injury/congenital deformity/rheumatoid/ankylosing spondylitis)
- Age ≥ 65 (osteoporosis/degenerative changes)

Are there **low risk factors** favouring clinical clearance?

- Low impact mechanism e.g. simple rear end MVC shunt. (*MVC not simple if: pushed into traffic, hit by bus/large truck, rollover, hit by high-speed vehicle*)
- Mobilised at scene or since injury
- Delayed onset mild neck pain
- Sitting position in ED

⇨ If neck pain plus high risk factors are present then the patient will require c-spine imaging

⇨ If unsure then consult senior clinician (clinical judgment required if dangerous mechanism is the only risk factor in a young adult who has mobilized)

⇨ If no high risk factors are identified and particularly if low risk factors are also present, then proceed to step 3

*Note that steps 1 and 2 are performed to allow collar removal for safe testing of range of movement.*

**Step 3 – Range of movement assessment**

Can the patient move their neck without any **significant bony pain or restriction?**

- Able to rotate neck 45° to left and right
- No midline bony pain on neck rotation 45° to left and right
- No midline bony pain on neck flexion and extension

*The most clinically useful indicators of significant bony cervical spine injury are:*

*a) increased midline bony pain on movement or*

*b) restriction of movement*

⇨ If there is significant midline bony pain on movement or restriction of movement then the patient is likely to require c-spine imaging
⇨ If no significant pain on movement or restriction of movement then the cervical spine is cleared. Remove the cervical spine collar and proceed to post clearance care.

**Post clearance care**

Once the cervical spine collar has been removed allow patient to sit up (if no thoracolumbar injury present).
Provide simple analgesics (paracetamol/ibuprofen).
Reassure patient and reassess in 30 minutes.
Patient should feel better and be moving neck without significant pain especially when distracted by friends and relatives. A mild amount of paravertebral soft tissue soreness is often present.

⇨ If patient is complaining of persistent significant pain consult senior clinician
⇨ If patient has improved, no further assessment is required.

**Pearls and Pitfalls of Clinical Clearance of the Adult Cervical Spine**

**Alertness/alcohol/analgesia**
The key question is whether the patient can focus on your examination sufficiently to tell you whether they have pain in their cervical spine on palpation and movement. Potential pitfalls include dementia, language barriers, confusion, pre-hospital analgesia, drug or alcohol ingestion and painful distracting injuries (multi-trauma). Bedside clinical judgment is required. Pre-hospital analgesia may mask clinical symptoms in patients and should always be considered.
**Distracting injuries**
The original NEXUS criteria study in 1998 defined distracting pain as:

- long bone fracture
- significant visceral injury
- large laceration
- a degloving or crush injury
- large burn
- any other injury causing functional impairment.

This remains the most commonly used definition. Controversy exists, however, as to what truly constitutes a distracting injury, but these patients are at risk for prolonged immobilization and cervical collar placements that can result in pressure ulcers and skin infections as well as other sequelae of immobilization like deep venous thromboses. The concept of distracting pain was recently questioned by a study which found that clinical judgment was 98% accurate in determining the significance of distracting pain and concluded that patients with asymptomatic cervical examination should be considered for clinical clearance even in the presence of distracting pain.[22] Practice patterns vary with regard to how these patients are evaluated, but repeat clinical evaluations as well as MRI are common modalities. Where potential doubt exists decision making should be documented e.g. ‘patient X has a fractured femur but following femoral nerve block and splinting is pain free and not a distracting injury’ or ‘patient Y has ingested one beer but is not intoxicated’.

**Transient parasthesiae/tingling (<5 min)**

Brief transient parasthesiae/tingling in limbs is common following trauma and usually not predictive of serious neck injury unless it persists. **Any persistent parasthesiae or tingling (>5 min) should be treated with concern**, particularly if present when assessed by Ambulance Officers or on arrival at hospital, and medical imaging should be performed.

Cervical cord neurapraxia (CCN), also known as transient neurapraxia, is a rare cervical spine injury that is often considered a "concussion" of the cervical spinal cord, thought to be caused by axial loading of the neck in flexion or extension, commonly in contact sports. The patient has sudden posttraumatic onset of *bilateral* sensory, motor, or combined neurologic deficit. Sensory findings include burning, numbness, tingling, or loss of sensation; motor findings include weakness or complete paralysis. ‘Burning hands syndrome’ is a variant of this central cord injury, consists only of upper-extremity symptoms, most notably temporary burning dysaesthesias and weakness of the arms and hands. By definition, the symptoms of CCN are transient and completely resolve within 10 minutes to 48 hours. The majority of patients with CCN will have pre-existing spinal stenosis or some other cervical spine abnormality. Burning hands syndrome is associated with a bony or ligamentous spinal abnormality in approximately one-half of cases

Transient symptoms (e.g., paraesthesias, weakness) also may be the only indication of spinal cord injury without radiographic abnormality (SCIWORA).

**Age >65**

This the most significant historical risk factor. Elderly patients are more likely to have abnormal cervical spines and require less force to cause injury. Dementia and stoicism are also common. Beware elderly patients with simple falls and bruised faces.

**Midline tenderness**

Most cervical spine fractures will produce focal midline bony tenderness that is worse on movement or restricts movement in stable alert young patients. Diffuse non-midline bony pain that is not worse on movement in a stable alert young patient is unlikely to be clinically significant. Assessment of pain or restriction on movement is probably the best clinical discriminator.

Adult cervical spine clinical clearance summary - Awake Asymptomatic Patient

Radiological Clearance - Adult cervical spine

Radiographic clearance is necessary for any patient whose cervical spine cannot be cleared clinically

> In the awake, asymptomatic patient who is without neck pain or tenderness, is neurologically intact without an injury detracting from an accurate evaluation and who is able to complete a functional range of motion examination, radiographic evaluation of the cervical spine is not recommended.[1] The discontinuance of cervical immobilization in this patient population is recommended.

**Imaging Modalities available at Bendigo Health**

**Computed Tomography**

CT of the cervical spine is the mainstay of current radiographic clearance. Over the past 15 years, CT has become the standard evaluation for all patients whose cervical spine cannot be cleared clinically. This practice shift has been supported by a number of clinical trials and systematic reviews. In the modern era, CT is the radiographic test of choice when a patient cannot be cleared clinically. CT angiography is necessary to identify cerebrovascular injuries.

**X-ray**

Plain 'cervical spine series' x-rays (AP, lateral and peg views) are not helpful for cervical spine clearance in adults and should not be used for cervical spine evaluation after blunt trauma in adults unless CT is unavailable; their relevance is historical.[23] Plain films still do still have a role in paediatric cervical spine clearance however.[24]

> There is no role for plain films of the cervical spine in adult trauma (unless CT is unavailable).

Cross table lateral cervical spine film. The Victorian Trauma guidelines state this test 'may be indicated when assessing a poly-trauma patient'. Generally this refers to situations involving the obtunded patient with loss of vital signs where identification of a non-survivable high c-spine injury (e.g. atlantoaxial dissociation) may assist the decision to cease resuscitation early. The cross table lateral Xray was previously part of the bedside 'trauma series' but is no longer in routine use because it is time consuming and is not useful as a standalone test to clear the cervical spine.

Flexion and extension films – the utility of these views to evaluate ligamentous injury is debatable, and their role in current practice is waning. Recent research suggests they should be removed from spinal clearance protocols.[25,26] Flexion-extension films were largely used in patients with persistent neck pain despite negative CT, with the ostensible purpose of evaluating for ligamentous injury that may be missed on CT. Although flexion-extension films are still a suggested option in the latest EAST guidelines(ref), it is considered higher risk both because it is difficult to perform correctly and because of the theoretical risk of removing cervical immobilization in a patient with potential cervical injury.

### Magnetic Resonance Imaging

MRI can be useful when an injury has already been diagnosed, but its role in clearance has yet to be defined in the literature. MRI is less sensitive than CT for the detection of fractures of the posterior elements of the spine and injuries to the craniocervical junction. However, MRI is widely accepted as the imaging modality that best delineates the integrity of the spinal cord and nerve roots, intervertebral discs, surrounding soft tissue, ligamentous structures, and vertebral arteries.

MRI is most sensitive for ligamentous injury when done <72h after trauma.
In general, MRI is a reasonable consideration in screening for injuries in patients who:

- Have symptoms but negative CT
- Are obtunded or otherwise unevaluable,
- Have a concomitant cerebral injury
- Have a neurologic deficit.

All of these clinical scenarios, however, are controversial, and more research needs to be done to determine MRI's role. The strongest evidence in support of MRI as a screening modality is in the obtunded patient.
MRI and magnetic resonance arteriography (MRA) can also play an important role in the assessment of vascular injury of the neck, which can be associated with cervical spine injury (e.g., vertebral artery injury)

### *CT vs. Plain films*

The superiority of CT over plain cervical spine films has been established since at least 2006.
Compared to CT, plain films are significantly less sensitive (table 2), less specific, have a lower negative predictive value, are less efficient, and less cost effective.

| Author Group | Sensitivity of Plain Films | Sensitivity of Computed Tomography |
|---|---|---|
| Nuñez et al[29] | 37.5% | 100% |
| Berne et al[21] | 60% | 90% |
| Schenarts et al[30] | 54% | 96% |
| Griffen et al[28] | 64% | 100% |

Table 2: Detection of Cervical Spinal Injury Following Blunt Trauma (from Sixta et al.[3)])

**Efficiency** - a series of studies evaluating the efficiency of plain radiographs compared to CT found that the average time involved to obtain a cervical CT scan was 11 to 12 minutes, approximately half the time required to obtain a full radiographic series of the cervical spine.[27]

**Cost-effectiveness** - cost-effectiveness analysis for high risk subjects has concluded that the higher short-term cost of CT would be offset by the increased sensitivity of CT for fracture detection, the shortened time required for the evaluation, and a decreased need for additional imaging.[28]

**Radiation risk** - a 2009 assessment based on a meta-analysis and systematic review of the literature and current organ-specific radiation risk concluded that the high diagnostic accuracy of CT outweighed the increase in dose compared to radiography or radiography followed by CT regardless of patient age, sex or, mechanism of injury or fracture risk.[29] It is also important to recognise that since 2009 the dose of ionising radiation from a CT c-spine has decreased significantly.

There are conflicting recommendations from international evidence based guidelines, stemming from concerns over radiation exposure and the paucity of evidence of the clinical effectiveness and cost-effectiveness of CT over radiography in lower risk patients.[20,30] Recommendations for the ongoing use of plain films in adults often reflect the population based funding structure of health services where demonstration of cost-effectiveness is required (e.g. UK), where radiation doses from older scanners are still higher, and where they may be more appropriate for lower acuity centres with a lower prevalence of C spine injury and lower availability of CT.

If CT is unavailable, plain films are still recommended as they still have a substantial level of evidence in alert, symptomatic patients.

### Adult cervical spine radiological clearance summary - Awake Symptomatic Patient

High quality CT imaging of the cervical spine in the symptomatic trauma patient has been proven to be more accurate than plain films, with higher sensitivity and specificity for injury following blunt trauma. If high quality CT is available, 3-view plain films are not necessary. If high quality CT is not available, a 3-view cervical spine series (anteroposterior, lateral, and odontoid views) is recommended.

### Persistent Symptoms, Negative CT

The question of “what to do?” if anything for the awake patient with persistent symptoms and a normal CT remains less clear. Clinicians should suspect a **cervical ligamentous injury** in an alert patient if severe neck pain, persistent midline tenderness, upper extremity paraesthesias, or focal neurologic findings (eg, upper extremity weakness) are present despite a normal CT scan. **SCIWORA** (Spinal Cord

Injury Without Obvious Radiological Abnormality) is thought by some to occur primarily in children, however several studies published subsequent to the increased use of MRI report higher rates of SCIWORA among adults.

Only lower level evidence is available to guide treatment decisions for these patients. Further studies need to be done to delineate the optimal management of spine clearance for these patients, but clinical judgment should determine the need for further workup in these patients. There is evidence in the current literature to support *any* of the 3 following strategies in the awake but symptomatic patient: (1) continue cervical immobilization until asymptomatic, (2) discontinue cervical immobilization following normal MRI study obtained within 48 hours of injury, or (3) discontinue immobilization at the discretion of the treating physician.[3]

The use of MRI for clearance following a negative CT is supported by several studies including a local prospective study performed at The Alfred of consecutive alert patients who experienced persistent midline cervical tenderness following their initial ED evaluation.[31] Of the 178 eligible patients, 38 were reported to have soft tissue cervical spine injuries identified by MRI that needed intervention, including five that required surgical fusion.

**Adult cervical spine radiological clearance summary - Obtunded or Unevaluable Patient**

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| High-quality (≥64 slice multi-detector) CT imaging is recommended as the initial imaging study of choice. If high-quality CT is not available, a 3-view cervical spine series (anteroposterior, lateral, and odontoid views) is recommended. The plain cervical spine x-ray studies should be supplemented with CT (when it becomes available) if necessary, to further define areas that are suspicious or not well-visualized on the plain cervical x-rays. |

**The Obtunded Patient with a Negative CT C-spine**

The most controversial issue in the obtunded/unevaluable patient group is the recommendation on the discontinuation of immobilization. The current recommendation is that in the obtunded or unevaluable patient who has normal high-quality CT imaging, *any* of the following strategies be considered: (1) continue cervical immobilization until asymptomatic, (2) discontinue cervical immobilization following a normal MRI study obtained within 48 hours of injury, or (3) discontinue immobilization at the discretion of the treating physician.[3]

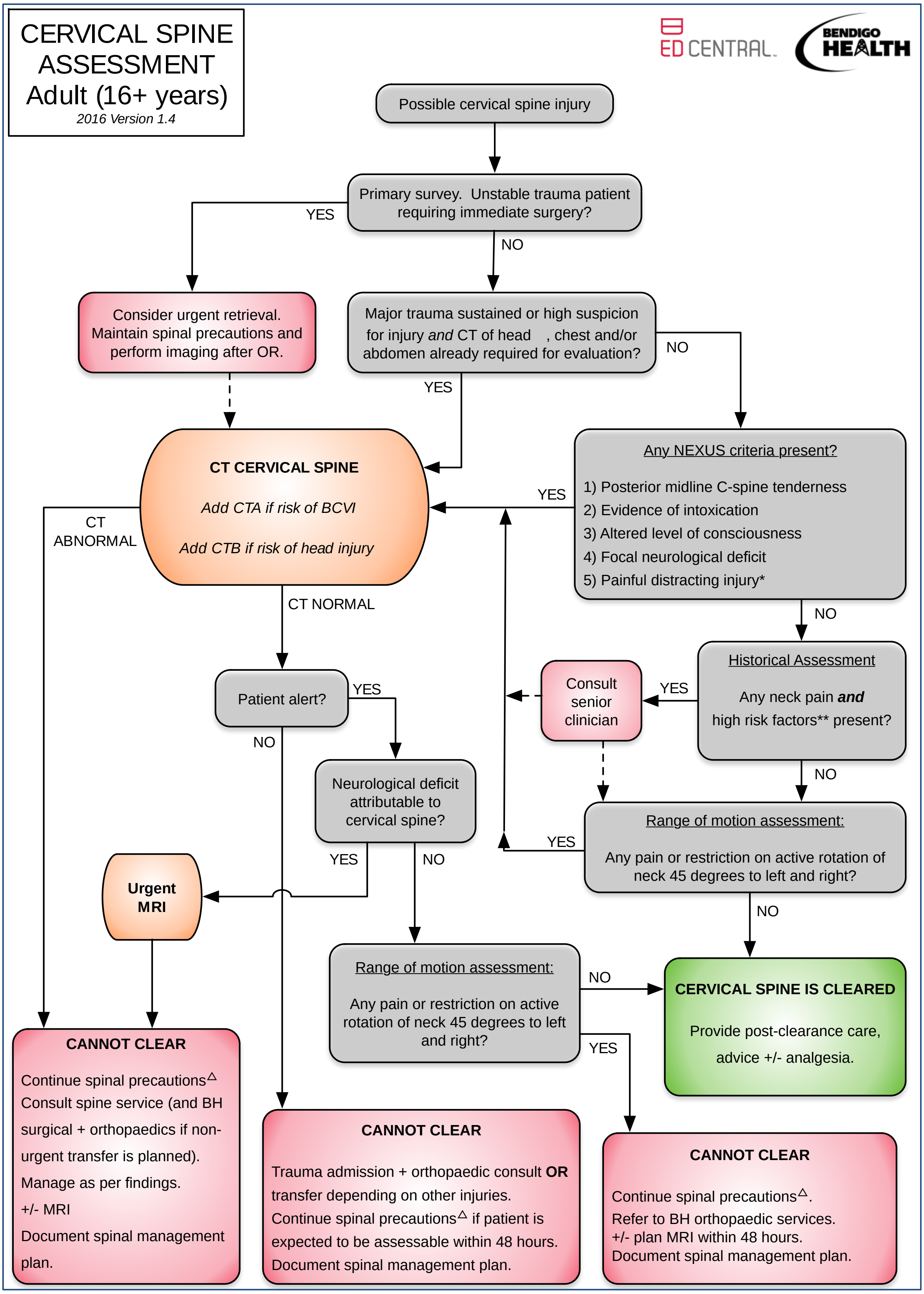
Evidence is conflicted on whether a negative CT is sufficient to rule out clinically significant spinal injury in this patient group. Previous studies have shown miss-rates between 0 and 7%.[32,33] However when improved resolution is utilised (multidetector CT

≥64 slices) the accuracy appears to be equivalent to MRI in this setting.[34] MRI still appears to be the imaging modality of choice in this situation based on the small incidence of clinically significant injuries identified.

Performing an MRI entails risks to the unresponsive patient, including aspiration, secondary brain injury, and the increased difficulty of monitoring and performing a resuscitation in the MRI suite. The financial cost of performing an MRI in all unresponsive blunt trauma patients is also substantial, particularly given that unstable injuries are uncommon in the setting of a negative CT. However, MRI does not subject the patient to ionizing radiation.

Regardless of the method employed, clearance of the cervical spine should be performed as soon as possible (ideally within 48 hours) in obtunded patients. Prolonged use of a hard cervical collar increases the difficulty of pulmonary toilet and the risk for developing occipital decubitus ulcers. In addition, findings associated with soft tissue injury (e.g. oedema) may resolve if studies are delayed.

Figure 3a: Adult cervical spine assessment flowchart



## Figure 3b: Qualifiers for adult cervical spine assessment flowchart

* Painful Distracting Injuries are defined as any of the following:

- long bone fracture
- significant visceral injury
- large laceration
- degloving or crush injury
- large burn
- any other injury causing significant functional impairment

** High-Risk Factors for cervical spine injury:

i) Dangerous mechanism:
- high impact MVC (combined impact >50kph / rollover / ejection / death at scene)
- MBA / accident involving motorised recreational vehicle
- pedestrian / cyclist versus car
- axial load to head (e.g. dive into surf, falling tree branch)
- significant fall (from height >1m / >5 stairs / off horse / off bicycle)

ii) Immediate onset severe neck pain **OR** presentation >48h after injury **OR** representation with same injury

iii) Age 65y and older

iv) Abnormal C spine (surgery/prior injury/congenital deformity/rheumatoid arthritis/ankylosing spondylitis

Low-Risk Factors favouring clinical clearance (senior clinician judgement required):
- low impact mechanism e.g simple rear end MVC shunt
  *(MVC not simple if: pushed into traffic, hit by bus/large truck, rollover, hit by high-speed vehicle)*
- Mobilised at scene or since injury
- Delayed onset mild neck pain
- Sitting position in ED

† Risk factors for blunt cerebrovascular injury (BCVI):

i) Patients sustaining blunt trauma who have the following clinical symptoms or signs:
- Arterial hemorrhage from the neck, mouth, nose, or ear.
- Expanding cervical hematoma.
- Cervical bruit in patients <50 years old.
- Focal or lateralizing neurologic deficits.

Ii) Asymptomatic patients who have risk factors:
- Injury mechanism compatible with severe cervical hyperextension/rotation or hyperflexion.
- LeFort II or LeFort III midface fractures.
- Basilar skull fracture that involves the carotid canal.
- Closed head injury consistent with diffuse axonal injury with GCS <6.
- Cervical vertebral fracture, subluxation, or ligamentous injury at any level.
- Near-hanging resulting in cerebral anoxia.
- Clothesline injury or seat-belt abrasion associated with significant cervical pain, swelling or altered mental status.

△ Change hard collar to long-term cervical spine collar as soon as possible

†† CT Head required if:

**a) Major or potentially severe head injury:**
- Persistent GCS <13
- Loss of consciousness >5 mins
- Focal neurological deficit
- Post-traumatic seizure
- Palpable depressed skull fracture
- Any sign of basal skull fracture
- Warfarin use or coagulopathy

**OR**

**b) Minor head injury with medium to high risk**
***(for patients with GCS 13-15 after witnessed traumatic LOC and any of the following:)***
- GCS < 15 at 2 hours post injury
- Age > 65 y
- Amnesia before impact of > 30 mins
- Dangerous mechanism (pedestrian vs car, MVA with ejection, fall >1m or > 5 stairs)

## CERVICAL SPINE ASSESSMENT AND CLEARANCE – PAEDS <16y

### Introduction

There are distinct, unique aspects of the management of children with potential injuries of the cervical spinal column and cervical spinal cord compared to adult patients that warrant specific recommendations:[35]

- The methods of pre-hospital immobilization necessary to approximate "neutral" cervical spinal alignment in a young child differ from those methods commonly employed for adults.
- The spinal injury patterns among young children differ from those that occur in adults.
- The diagnostic studies and images necessary to exclude a cervical spine injury in a child may be different than those for adults.
- The interpretation of paediatric radiographic studies must be made with knowledge of age-related development of the osseous and ligamentous anatomy.
- The evidence base for paediatric cervical spine clearance after blunt trauma is less robust than that available for adults.
- Methods of reduction, stabilization, and subsequent treatment, surgical and non-surgical, must be customized to each child, taking into account the child's degree of physical maturation and his/her specific injury.

Cervical spine injuries are rare in childhood. It is seen primarily in those who sustain significant, severe blunt trauma, occurring in 1- 2% of such cases.[36] The potential consequences of cord injury may be devastating. The injury may involve bones, ligaments, blood vessels, or the spinal cord, and must be rapidly recognized and treated to avoid permanent disability or death. Missed injuries can result in additional cervical cord or nerve root injury. Up to 30% of traumatic spine injuries in children present as a traumatic myelopathy known as spinal cord injury without radiographic abnormality (SCIWORA).[37] Head injuries often accompany cervical spine injury, especially in the young child where the rate has been reported as about 50%.[38]

Excellence in early trauma care is essential to decrease morbidity and mortality particularly in rural and remote areas hours away from paediatric trauma centres. It is often challenging to assess and immobilise children when a cervical spine injury is suspected, especially with altered consciousness, and worsening of paralysis has been reported during evaluation of cervical spine injuries in the emergency department. Any child who is suspected of having a cervical spine injury must be correctly immobilized in a neutral position until the injury is excluded.[39] The diagnosis or high suspicion of cervical spine injury requires prompt consultation with a specialist spinal team.

## Anatomical Differences

The child's cervical spine is very different from the adult.  The young child's cervical spine is hypermobile, more mobile than the cord. This hypermobility, coupled with the large head of the young child, renders the young child's upper cervical spine particularly vulnerable.  60-80% of paediatric spinal injury occurs in the cervical spine compared with 30-40% in adults.  Most, but not all series, report that the upper cervical spine is most often injured in the young child, with up to 87% of injuries occurring at or above C3 in children <8 years old.[40]  Adolescent cervical spine injury patterns are more approximate to those seen in adults, occurring more commonly in the lower cervical spine.

### <8 years old

The pediatric cervical spine does not become adult-like until about the age of 8 years.  Children younger than eight years of age are more susceptible to injury of the upper cervical spine (C1 to C3) than older children and adults because of certain features of their anatomic development.
In addition, younger children may also incur fractures of the growth plate and ligamentous injuries.[41]

Unique anatomical features of children <8 years old:

- Large head-to-body ratio, increasing flexion, extension and shearing forces on the cervical spine
- Ligamentous laxity and increased spinal column elasticity
- Relative paraspinal muscle weakness
- Horizontal, shallow facet joints
- High water content of vertebral disks, increasing vertical loading effect over several adjacent segments
- Incompletely ossified vertebrae
- Fractures traverse vertebral body growth plate

These factors increase the risk of injury at the level of the occiput, C1 and C2, with an associated increased risk of fatality.   The increased ligamentous laxity allows the paediatric spinal column to stretch up to 5 cm without disruption whereas the spinal cord may only stretch 5-6mm before injury or disruption of the vascular supply, predisposing to SCIWORA.

### 8-16 years old

At 12 years the age-related fulcrum of the cervical spine settles at C5-C6 where it remains throughout adulthood.  The most common injuries in older children are vertebral body and arch fractures.  These fractures usually are in the lower cervical spine, below the level of C4.  Typically these fractures are associated with a much lower fatality rate.

**Conditions predisposing to cervical spine injury**

In addition, cervical spine injury should be suspected in those children who have an underlying predisposition to such injuries: [42]

- Trisomy 21 (approximately 15% have atlanto-axial instability)
- History of cervical spine surgery
- History of cervical spine arthritis
- Klippel-Feil syndrome (congenital fusion of variable numbers of cervical vertebrae and associated defects including scoliosis, renal anomalies, elevated scapula, congenital heart disease, and deafness.
- Morquio syndrome (mucopolysaccharidosis IV), which is associated with hypoplasia of the odontoid
- Larsen syndrome, which may have associated cervical vertebrae hypoplasia and is otherwise characterized by multiple joint dislocations, flat facies, and short fingernails
- Other syndromes affecting the cervical spine

**Clinical Examination**

As for all trauma patients, evaluation begins with the primary and secondary surveys. Cervical spine injury must be suspected in all children who are severely injured or have high-risk injuries. Serious head injury and multiple-system trauma are commonly associated with spinal injuries and may distract the child (and medical provider) from recognizing and appreciating cervical pain or other important symptoms.

It is often challenging to assess and immobilise children when a cervical spine injury is suspected.
Constant reassurance is required to help keep the child still and reduce their anxiety levels. Clinicians need to be aware that immobilisation of a distressed/mobile child may be counterproductive and can have negative consequences e.g. airway compromise, increased pain, and pressure areas. Immobilised patients must have a nurse or doctor with them at all times.
If the child is anxious or uncooperative and a thorough examination is not possible, try and maintain in line C-spine immobilisation with or without a collar.

**History**

Obtain the history from multiple sources - ask the child, the carers, and the ambulance staff who may have crucial information from the scene. Elements of the history that are critical include the cause of trauma, the mechanism of injury and the presence of any symptoms at the time of injury.

The usual triad of symptoms of paediatric cervical spine injury is:

- local pain
- muscle spasm
- decreased range of motion

Patients also may complain of transient or persistent paraesthesias or weakness. The distribution of transient symptoms is variable and ranges from involvement of the hands or feet to dramatic neurologic deficits, including quadriplegia. The patient's ability to walk does not exclude cervical spine injury because some patients with cervical spine injuries are able to walk immediately after the event. The history should include the presence of neurological symptoms at any time after the injury, even if they have resolved. It is critical to have a high index of suspicion and to ask specifically about transient symptoms in any patient whose mechanism of injury is consistent with potential cervical spine injury, as these symptoms may be associated with SCIWORA or central cord neurapraxia.

Children who have symptoms suggestive of spinal injury should have immobilization maintained during initial evaluation and management and undergo rapid radiologic evaluation.

Imaging should also be performed up to four days post-injury if symptoms were transient after the injury. If symptoms have been persistent since injury, imaging should be performed at first presentation, no matter how long after the injury.

Not all children who have spinal cord injuries complain of symptoms; some are asymptomatic, whereas others are unable to express their symptoms (e.g. preverbal or severely injured) or have a distracting injury. A retrospective review of 72 previously normal children with cervical spine injury found that all those with asymptomatic injuries had both a high-risk injury mechanism and a distracting injury.[43]

The major causes of cervical spine injury include blunt trauma associated with:[44,45,46]

- high speed MVC
- bicycle injury
- pedestrian v car
- diving or other mechanism with hyperflexion or hyperextension of neck (e.g. tackling)
- falls greater than body height
- other acceleration-deceleration injuries
- significant injury above the clavicles
- multiple traumatic injuries
- suspected non-accidental injury

**Physical Examination**

The principal elements of the physical examination of a child suspected of having a cervical spine injury are the vital signs, neck examination, and neurologic examination. This is complemented with a thorough secondary survey. Radiologic evaluation must ensue if any abnormalities suggestive of cervical spine injury are detected during the examination.

**Vital signs** — Apnoea or hypoventilation may result from injuries at the spinal level of diaphragmatic control (C3, C4, C5). Hypotension, bradycardia, or temperature instability may result from spinal shock. Unexplained hypotension after blunt trauma is an indication for cervical spine imaging.

**Neck examination** — The spinous processes are palpated for local tenderness, muscle spasm, or deformity while inline stabilization of the neck is maintained. With a cervical spine injury, midline cervical tenderness is more common than paraspinous muscular spasm or tenderness. Midline posterior bony cervical spine tenderness is present if the patient complains of pain on palpation of the posterior midline neck from the nuchal ridge to the prominence of the first thoracic vertebra. Range of motion assessment should only be attempted when the child is conscious and cooperative and an unstable injury is not suspected. In toddlers and infacts, decreased active ROM of the neck or apparent tenderness requires immobilization and imaging.

**Neurologic examination** — A neurologic examination should be completed with evaluation of tone, strength, sensation, and reflexes. Up to 50% of children with cervical cord injuries have neurologic deficits.[47,48] An isolated sensory deficit is the most common neurologic finding in patients with cervical spine injury. Paralysis may be difficult to evaluate in infants and children, however the level of paralysis, if present, localizes the injury. Mass withdrawal movements may occur as a reflex in infants or children with paralysis and may complicate the evaluation in the immediate post injury phase.

Altered level of consciousness is present if any of the following is present:
(a) GCS or paediatric GCS = 14 or less; or any score other than alert on the AVPU scale
(b) Disorientation
(c) Persistent anterograde amnesia
(d) Delayed or inappropriate response to external stimuli.

Patients should be considered intoxicated if they have either of the following:
(a) A recent history of intoxication or intoxicating ingestion or
(b) Evidence of intoxication on physical examination.

Neurological examinations are limited in patients with altered level of consciousness, however as much of the neurological examination as possible should be performed providing that safety of the patient is maintained during the exam. If a child is likely to remain unconscious for a prolonged period of time (>48 hours) an MRI scan is recommended to diagnose any possibilities of a significant injury.

## CLINICAL CLEARANCE OF THE PAEDIATRIC C-SPINE

At present there are *no validated decision instruments* for the clearance of paediatric cervical spines after blunt trauma (such as NEXUS or Canadian C-spine rules) as there are in adults.

There is some retrospective data[49,50] that the NEXUS criteria can be used in older children (≥9y) with a negative predictive value of 100%:

- Midline cervical tenderness
- Focal neurological deficit
- Altered level of consciousness
- Intoxication
- Painful, distracting injury

For those patients >3y, recognising the rarity of paediatric cervical spine injuries as well as the near-impossibility of isolated cervical spine injuries, additional high risk features for cervical spine injury, in addition to those derived from NEXUS, have been determined: [1,51]

- torticollis / ‘cock-robin’ posture
- unexplained hypotension

For children that are non-communicative due to age (<3y), it is difficult to apply NEXUS. In addition to the above, high risk features in this age group are: [52]

- GCS = 13 or less
- High-risk mechanism:
    - MVC
    - Fall from height >10 feet (3m)
    - Suspected non-accidental injury

For patients without the above high risk features, range of motion assessment is the next step. For children who are able to follow instructions, this involves removing the collar and observing active neck rotation to 45 degrees bilaterally. For preverbal children unable to follow instructions, the collar can be removed and neck movement observed. Those with normal movement and no restriction or pain can be clinically cleared. Those children who initially have poor cooperation for any reason should be considered for reassessment if an accurate evaluation is thought to be possible.

There is some weak evidence from several small, retrospective studies that if the patient (particularly the younger patient <5y) has normal mental status, a normal neurological exam, is not guarding and is freely ranging their neck on their own, the likelihood of a clinically significant ligamentous or bony injury is exceedingly small and radiology is not required in this group. The data supports a very reasonable conclusion regarding the rarity of paediatric injuries – and the near impossibility of isolated cervical spine injuries. [50,51,53]

See Figures 5 and 6 for Paediatric Cervical Spine assessment flowcharts.

## RADIOLOGICAL CLEARANCE OF THE PAEDIATRIC C-SPINE

In adults, the use of plain radiography has largely been replaced by CT over concerns regarding missed injuries - and some literature even argues that, given the right clinical circumstances, even a normal CT scan is inadequate. But in children, the harms of exposure to ionising radiation are more significant the younger the patient, so paediatrics has been more hesitant to move to CT as the first imaging study of the cervical spine in blunt trauma. Most missed cervical spine injuries in children fall into two general categories: either subtle and non-morbid, or occurring in patients with altered conscious state.[54] It is still reasonable to start with screening plain-film radiography and use clinical judgment to determine when CT may be necessary, but cervical spine injury in children is too rare to generate airtight evidence to guide decision-making. As a general principle, if radiology is required, it should be completed using the lowest possible dose of ionising radiation (i.e. plain films and, if required, CT localised to the area of concern).

### Imaging Modalities

#### Plain radiographs

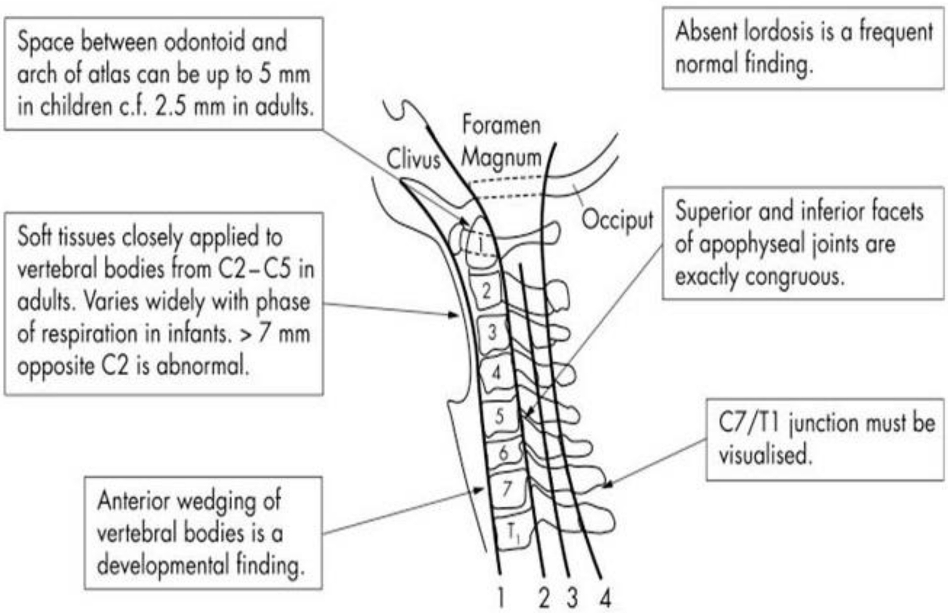
The three-view spine series (cross-table lateral and AP views for all age groups, plus open-mouth odontoid for children 5y and older) provides the most sensitive evaluation of cervical spine stability. Cross-table lateral views identify approximately 80% of fractures, dislocations, and subluxations. The addition of the AP and when obtainable, odontoid views, increases the sensitivity. The most frequent cause of a missed or unappreciated vertebral injury is an inadequate film series.

The interpretation of cervical spine radiographs in children may be difficult. Although the bony anatomy of the paediatric cervical spine is similar to that of an adult by 8 to 10 years of age, radiographic findings may differ until 15 years of age. In younger children, avulsions and epiphyseal separation are more common than are fractures. Also, normal anatomic variants of the cervical spine in children must be distinguished from pathological finding (Fig 4 and Tables 3-5). If in doubt, seek a report from the duty radiologist.

Table 3: Normal parameters of the paediatric cervical spine

| Parameter | Normal Value |
|---|---|
| C-1 facet-occipital condyle distance | ≤ 5 mm |
| Atlanto-dens interval | ≤ 4 mm |
| Pseudosubluxation of C2 on C3 | ≤ 4 mm |
| Pseudosubluxation of C3 on C4 | ≤ 3 mm |
| Retropharyngeal space | ≤ 8 mm (at C-2) |
| Retrotracheal space | ≤ 14 mm (at C-6, under age 15 yr.) |
| Tong ratio (canal to vertebral body) | ≥ 0.8 |
| Space available for cord | ≥ 14 mm |

Figure 4: Interpretation of the cervical spine Xray in children <8 years




The four lines shown in the figure are:
1. Anterior vertebral line.
2. Posterior vertebral line (anterior wall of the spinal canal).
3. Facet line.
4. Spino-laminar line (posterior wall of spinal canal).

All 4 lines should be smooth with no steps or angulation. The spinolaminar line remains smooth even in the presence of pseudosubluxation.

Table 4: Normal anatomical variants of the cervical spine in children that may be misinterpreted as injuries.

| Developmental feature | Misinterpretation |
|---|---|
| Lordosis may be absent in normal children up to the age of 15y and in children wearing a cervical spine collar. | Muscle spasm from c-spine injury |
| The posterior arch of C1 fuses by 3y. | Subluxation of C1 overridding dens |
| The anterior arch of C1 fuses by 10y. | Subluxation of C1 overridding dens |
| The epiphyseal plate at the base of the odontoid fuses with the body of C2 by 6 years, but a fusion line may be evident in normal children up to the age of 10y. | Odontoid fracture |
| Anterior vertebral wedging due to secondary growth centres may be seen up to the age of 7y. | Compression fracture |
| Posterior laminar fusion lines present up to the age of 6 years. | Lamina fracture |
| Pseudosubluxation of C2 anterior to C3 is seen in approximately 40% of children under the age of 8 years. | Subluxation injury |

Table 5: Selected Congenital Vertebral Anomalies

| Anomaly | Characteristic | Radiographic significance |
|---|---|---|
| Os odontoideum | Rounded hypoplastic apical segment of dens. Remnant of axis at base | Can be confused with dens fracture. May represent non-union. May require fusion |
| Klippel-Feil syndrome | Congenital fusion of two or more vertebrae | Longer lever arm may lead to higher incidence of fractures |
| Down syndrome | Ligamentous laxity leads to decreased atlanto-dens interval / space available for the cord. | Atlanto-axial instability, myelopathy |

**Flexion-extension views**

These are recommended by some publications as a follow up assessment for those patients who have ongoing pain, tenderness or muscle spasm despite normal initial imaging. They have no role in the initial radiological investigation of blunt cervical spine injury and have largely been supplanted by MRI.

**Computed tomography**

The sensitivity and specificity of computed tomography (CT) for detecting cervical spine bony injury are 98% or better. It is therefore a valuable adjunct for identifying an injury in some patients who require radiographic evaluation.

A CT should be obtained in any of the following circumstances:

- Inadequate cervical spine radiographs (three views in children 5 years of age or older, inadequate lateral or open mouth view in children under five years of age), especially if there is a high likelihood of injury based upon mechanism or physical findings
- Suspicious plain radiographic findings
- Fracture/displacement seen on plain radiographs
- High clinical index of suspicion of injury despite normal radiographs

CT of the cervical spine may also be appropriate as the initial study instead of plain cervical spine radiographs in children who require urgent CT of the brain. In children less than 8y old having concurrent CT brain, the CT C-spine can be limited to C1-C3.

However, routine use of CT for the initial evaluation of cervical spine injuries in children is not justified for the following reasons:

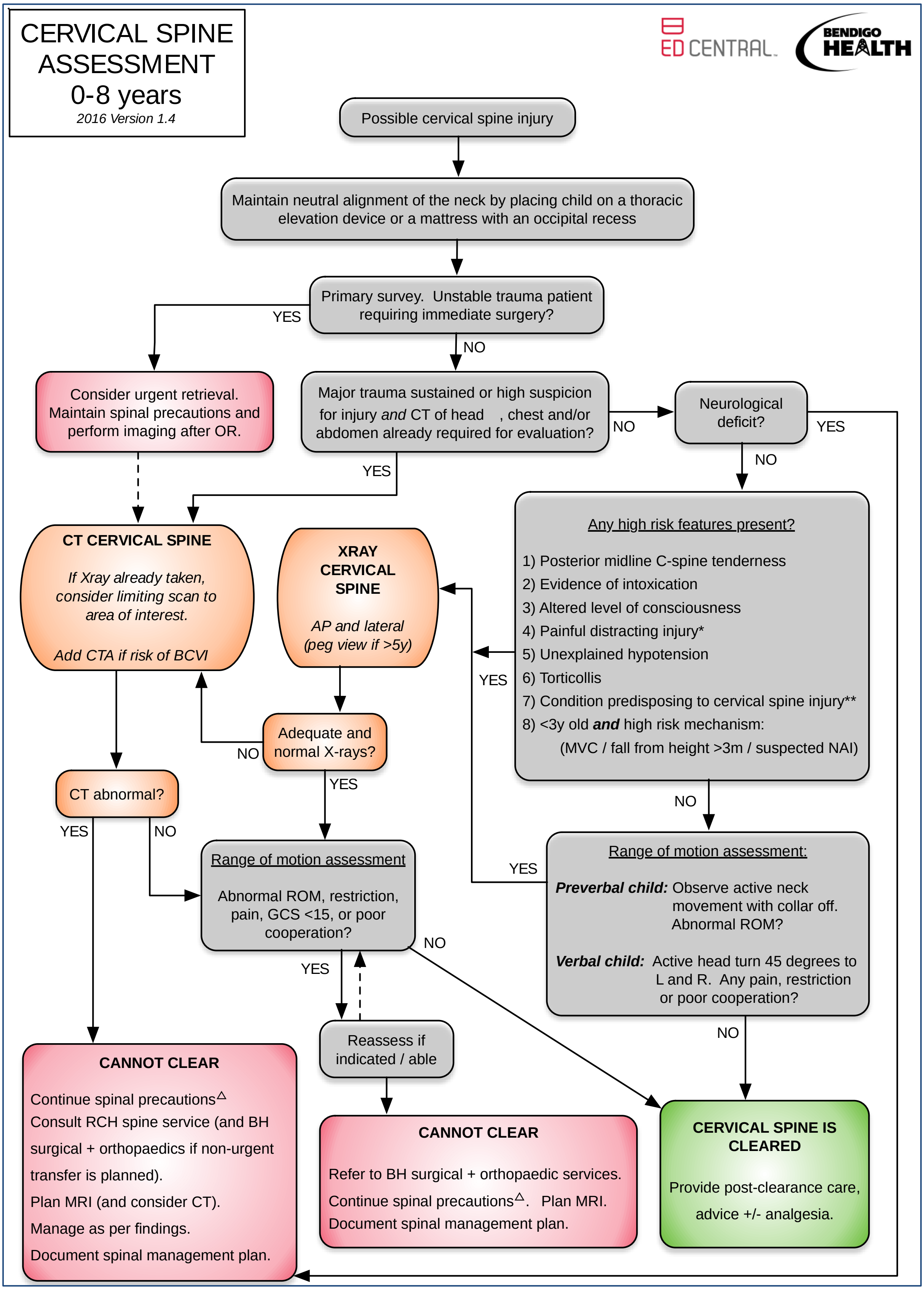
- A helical cervical spine CT delivers 50% increase in mean radiation dose to the cervical spine in paediatric patients relative to conventional radiography. In addition, the radiation dose to the skin and thyroid for CT evaluation of the cervical spine is approximately 10 times and 14 times, respectively, that of a five view cervical spine series.
- Children, especially those younger than five years, are more prone to radiation-induced malignancies due to increased radiosensitivity of certain organs and a longer time during which to develop a cancer. Estimated lifetime cancer mortality risks attributable to the radiation exposure from a CT for a one year old is approximately 0.07 to 0.18%, which is a risk that is an order of magnitude higher than that for adults who are exposed to a CT of the cervical spine.
- Although cervical spine CT has high diagnostic utility for bony injuries, it is not ideal for ligamentous injuries that are more common in children than in adults.

**Magnetic resonance imaging**

MRI is the imaging procedure of choice in any patient with neurologic signs or symptoms and normal plain radiographs and/or CT. MRI is superior to CT for visualizing soft tissues and identifying intervertebral disk herniation, ligamentous injuries and spinal cord oedema, haemorrhage, compression, and transection. It is the modality of choice to evaluate SCIWORA.

MRI has limited utility in the emergency setting as it may not be immediately available, requires prolonged investigation time for adequate evaluation and is not easily accessible to the critically ill child.

Figure 5a: Paediatric cervical spine assessment flowchart (0-8y)



## Figure 5b: Qualifiers for Paediatric cervical spine assessment flowchart (0-8y)

* Painful Distracting Injuries are defined as any of the following:

- long bone fracture
- significant visceral injury
- large laceration
- degloving or crush injury
- large burn
- any other injury causing significant functional impairment

** Conditions predisposing to cervical spine injury:

- previous cervical spine surgery
- history of cervical spine arthritis
- ankylosing spondylitis
- congenital syndrome (trisomy 21, Klippel-Feil syndrome, Morquio syndrome, Larsen syndrome)

† Risk factors for blunt cerebrovascular injury (BCVI):

i) Patients sustaining blunt trauma who have the following clinical symptoms or signs:

- Arterial hemorrhage from the neck, mouth, nose, or ear.
- Expanding cervical hematoma.
- Cervical bruit in patients <50 years old.
- Focal or lateralizing neurologic deficits.

Ii) Asymptomatic patients who have risk factors:

- Injury mechanism compatible with severe cervical hyperextension/rotation or hyperflexion.
- LeFort II or LeFort III midface fractures.
- Basilar skull fracture that involves the carotid canal.
- Closed head injury consistent with diffuse axonal injury with GCS <6.
- Cervical vertebral fracture, subluxation, or ligamentous injury at any level.
- Near-hanging resulting in cerebral anoxia.
- Clothesline injury or seat-belt abrasion associated with significant cervical pain, swelling or altered mental status.

△ Change hard collar to long-term cervical spine collar as soon as possible

†† Paediatric Head Trauma Decision guide (PECARN):

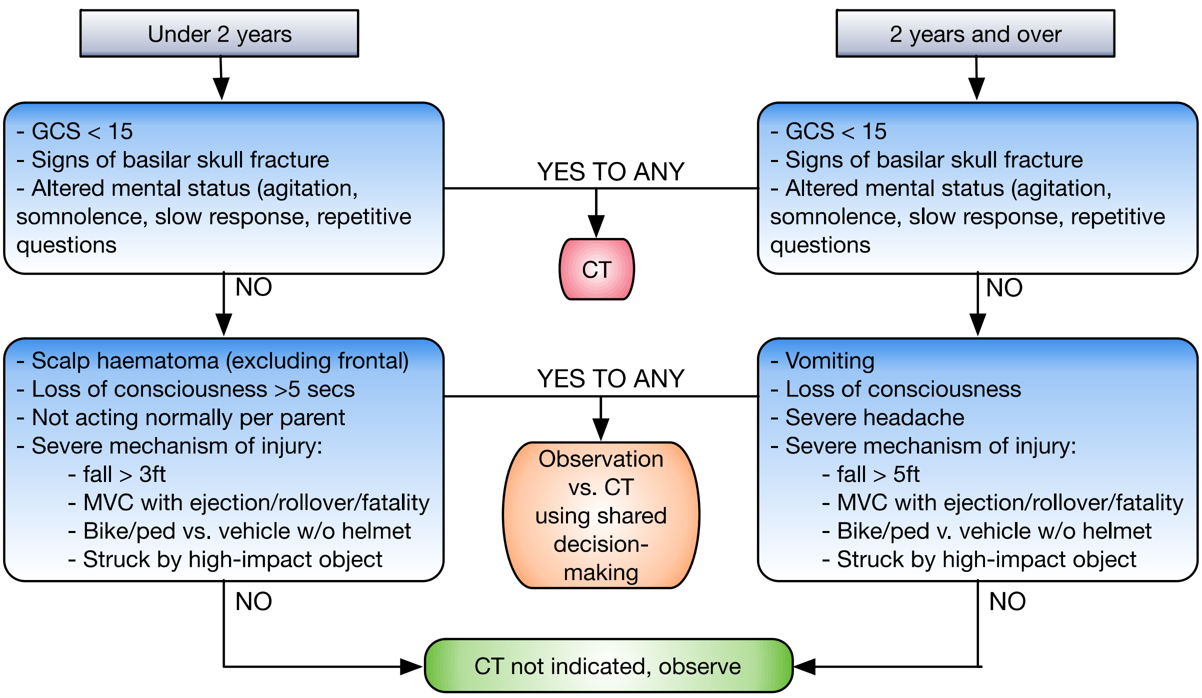
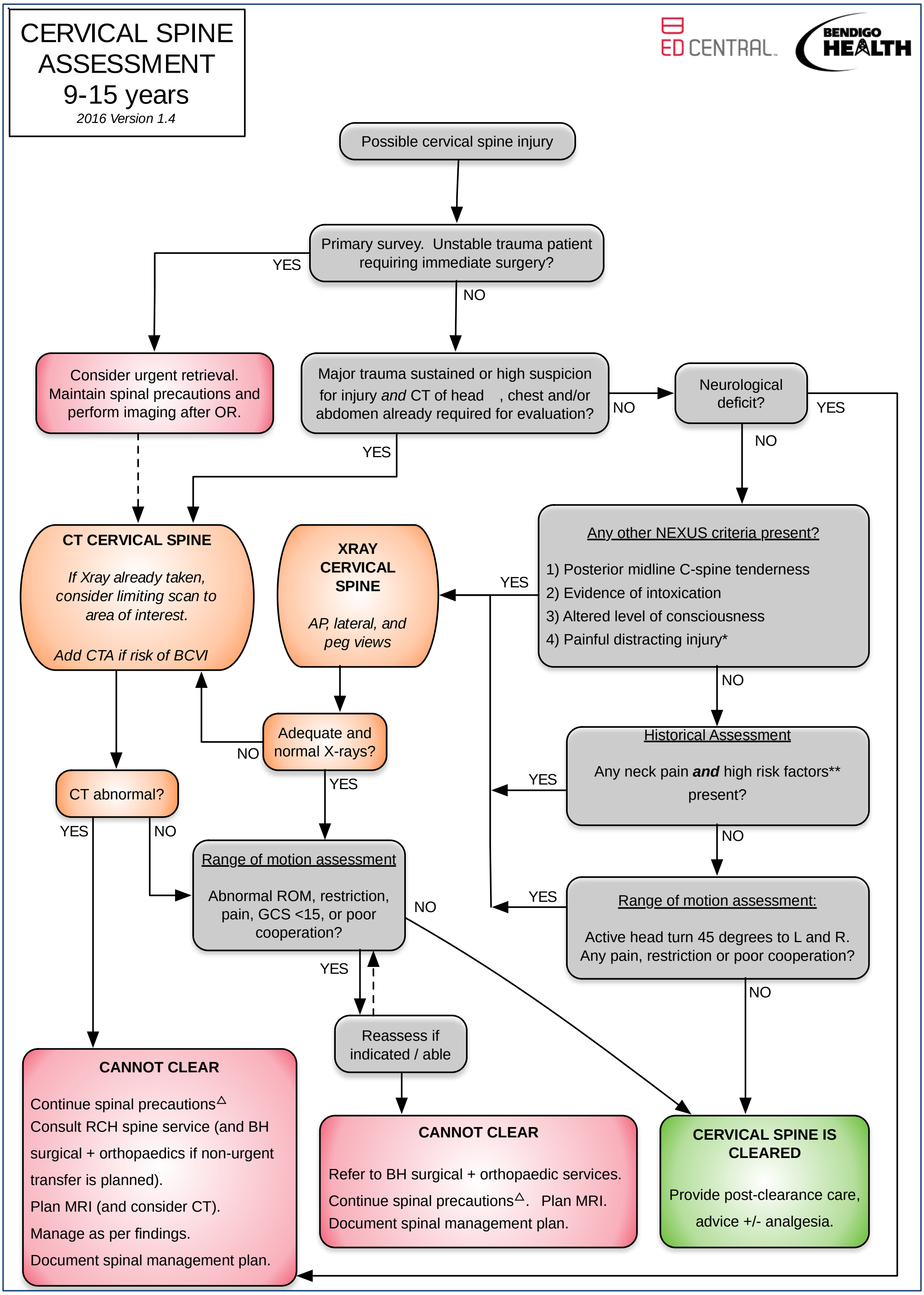


Figure 6a: Paediatric cervical spine assessment flowchart (9-15y)



## Figure 6b: Qualifiers for Paediatric cervical spine assessment flowchart (9-15y)

* Painful Distracting Injuries are defined as any of the following:

- long bone fracture
- significant visceral injury
- large laceration
- degloving or crush injury
- large burn
- any other injury causing significant functional impairment

** High-Risk Factors for cervical spine injury:

i) Dangerous mechanism:
- high impact MVC (combined impact >50kph / rollover / ejection / death at scene)
- MBA
- pedestrian / cyclist versus car
- cycling injury
- diving or other mechanism with hyperflexion or hyperextension of the neck
- significant fall (from greater than body height / off horse / off bicycle)
- other acceleration / deceleration injury
- suspected non-accidental injury

ii) Immediate onset severe neck pain

iii) Unexplained hypotension

iv) Condition predisposing to cervical spine injury:
- previous cervical spine surgery
- history of cervical spine arthritis
- ankylosing spondylitis
- congenital syndrome (trisomy 21, Klippel-Feil syndrome, Morquio syndrome, Larsen syndrome)

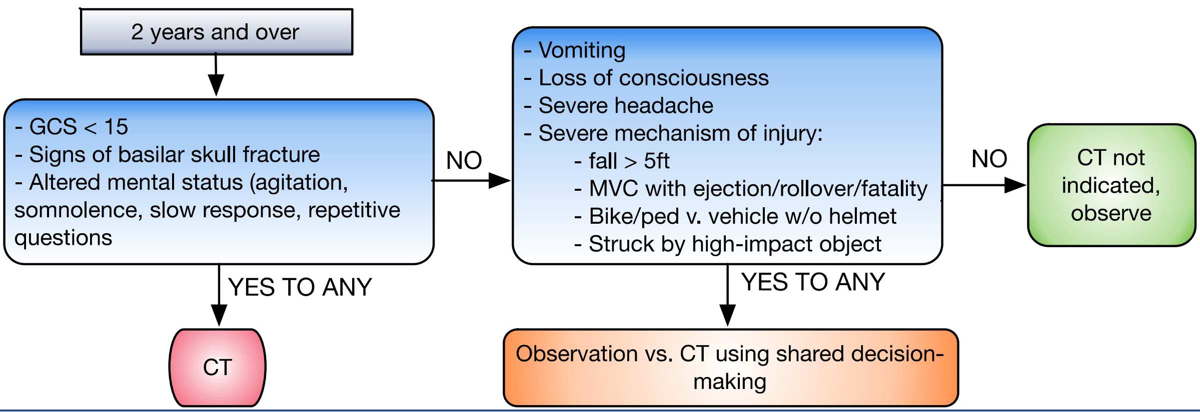
† Risk factors for blunt cerebrovascular injury (BCVI):

i) Patients sustaining blunt trauma who have the following clinical symptoms or signs:
- Arterial hemorrhage from the neck, mouth, nose, or ear.
- Expanding cervical hematoma.
- Cervical bruit in patients <50 years old.
- Focal or lateralizing neurologic deficits.

Ii) Asymptomatic patients who have risk factors:
- Injury mechanism compatible with severe cervical hyperextension/rotation or hyperflexion.
- LeFort II or LeFort III midface fractures.
- Basilar skull fracture that involves the carotid canal.
- Closed head injury consistent with diffuse axonal injury with GCS <6.
- Cervical vertebral fracture, subluxation, or ligamentous injury at any level.
- Near-hanging resulting in cerebral anoxia.
- Clothesline injury or seat-belt abrasion associated with significant cervical pain, swelling or altered mental status.

△ Change hard collar to long-term cervical spine collar as soon as possible

†† Paediatric Head Trauma Decision guide (PECARN):



**Suspected Blunt Cerebrovascular Injury (BCVI)**

Blunt carotid and vertebral artery injury are collectively termed blunt cerebrovascular injury and are rare but potentially disastrous injuries. Blunt carotid injury is associated with a mortality rate of 25% with up to 58% of survivors suffering permanent severe neurologic deficits. Clinical studies in the early 1990s suggested that these injuries were being under-diagnosed.[55] Subsequently, increased recognition through screening (arteriography, computed tomographic angiography) based upon specific clinical criteria has increased the reported incidence to about 1% in all patients with blunt trauma and as high as 2.7% in patients with an Injury Severity Score ≥16.

Regardless of the underlying mechanism of injury, the pathologic insult in most cases is an intimal tear. This promotes thrombus formation, which may occlude the vessel altogether or embolise to the cerebral circulation. The intimal tear may remain static or there may be a sub-intimal dissection that progresses cranially, which can cause luminal narrowing or acute vessel occlusion. Less commonly, pseudoaneurysm formation or free rupture occurs. Rupture may result in intracranial or extracranial haemorrhage, or formation of an arteriovenous fistula.

The neurologic presentation of BCVI can vary greatly depending upon the vessel affected, site of injury, injury grade and any pre-existing cerebrovascular disease. Adding to this variability are the anatomical inconsistencies in the circle of Willis found naturally in 80% of the population. Approximately 80% of patients with BCVI have no obvious neurologic manifestations at presentation. A latent period between the time of injury and the appearance of clinical manifestations is typically seen. Unless the vessel immediately occludes, time is required for thrombus formation that might limit flow or lead to distal embolization. Up to 50% of patients first develop signs or symptoms of blunt carotid injury >12 hours after the traumatic event.[56]

Radiological screening for BCVI can be achieved with CT angiogram in selected patients. This can easily be integrated into the multidetector CT protocol for haemodynamically-stable trauma patients without additional contrast material nor an additional dose exposure, because it substitutes the plain acquisition of the cervical spine.

Percutaneous digital subtraction angiogram is the 'gold standard' test and enables therapeutic interventions. This requires an angiography suite and an interventional radiologist and is available at Royal Melbourne Hospital.

Clinical screening criteria with a sensitivity approaching 100% are yet to be defined. The most commonly used Modified Denver Screening Criteria[57] miss ~20% of BCVI.

**Which patients are of high enough risk, so that diagnostic evaluation should be pursued for the screening and diagnosis of BCVI?**[58,59,60]

**Patients sustaining blunt trauma with the following clinical symptoms or signs:**

- Arterial haemorrhage from the neck, mouth, nose, or ear
- Expanding cervical hematoma
- Cervical bruit in patients <50 years old
- Focal or lateralizing neurologic deficits

**Asymptomatic patients who have risk factors:**

- Injury mechanism compatible with severe cervical hyperextension/rotation or hyperflexion
- LeFort II or LeFort III midface fractures
- Basilar skull fracture that involves the carotid canal
- Closed head injury consistent with diffuse axonal injury with Glasgow Coma Score <6
- Cervical vertebral fracture, subluxation, or ligamentous injury at any level
- Near-hanging resulting in cerebral anoxia
- Clothesline-type injury or seat-belt abrasion associated with significant cervical pain, swelling or altered mental status

**Blunt Cerebrovascular Injuries in Children**

**Paediatric trauma patients should be evaluated using the same BCVI criteria as adults.**

There is a relative paucity of information on the screening, diagnosis, and management of BCVI in children, and what is available primarily consists of isolated case reports and small case series. In one review of the National Pediatric Trauma Registry, Lew et al. found an overall incidence of 0.03%, which is lower than that of the adult trauma population and speculated that it may be because of the increased elasticity of the younger children's blood vessels. They did note that another possibility was that the difference was secondary to decreased detection in children and the retrospective nature of the study.[61] Children aged younger than 6 years seemed to be at higher risk. Chest trauma (in particular clavicle fracture) and severe head injury (basilar skull fracture, intracranial haemorrhage) are associated with a higher risk of BCVI in the paediatric population.

**Disposition of patients with BCVI**

All patients with BCVI or with positive findings on CT angiogram assessment for BCVI will require a neurosurgical opinion. Transfer for further imaging may be required. Treatment options are mostly conservative with anticoagulation but endovascular therapies are available for more severe grades of injury. The EAST guidelines recommend that initial treatment of arterial injury in children be the same as in adults. Where recommendations differ is that they go on to recommend aggressive management of intracranial hypertension in children up to and including resection of infarcted tissue because of improved outcome in paediatric patients in contradistinction to the dismal outcome of post-ischemic intracranial hypertension in adults.[62]

- Focal neurological deficit
- Post traumatic seizure
- Suspected open or depressed skull fracture
- Multi-trauma
- Therapy with warfarin/direct thrombin inhibitor/factor Xa inhibitor, or known coagulopathy

OR

**Minor Head Injury with Medium to High Risk** (The Canadian Head CT Rules[63])

Minor head injury is defined as witnessed LOC, definite amnesia or witnessed disorientation in patient with GCS 13-15.

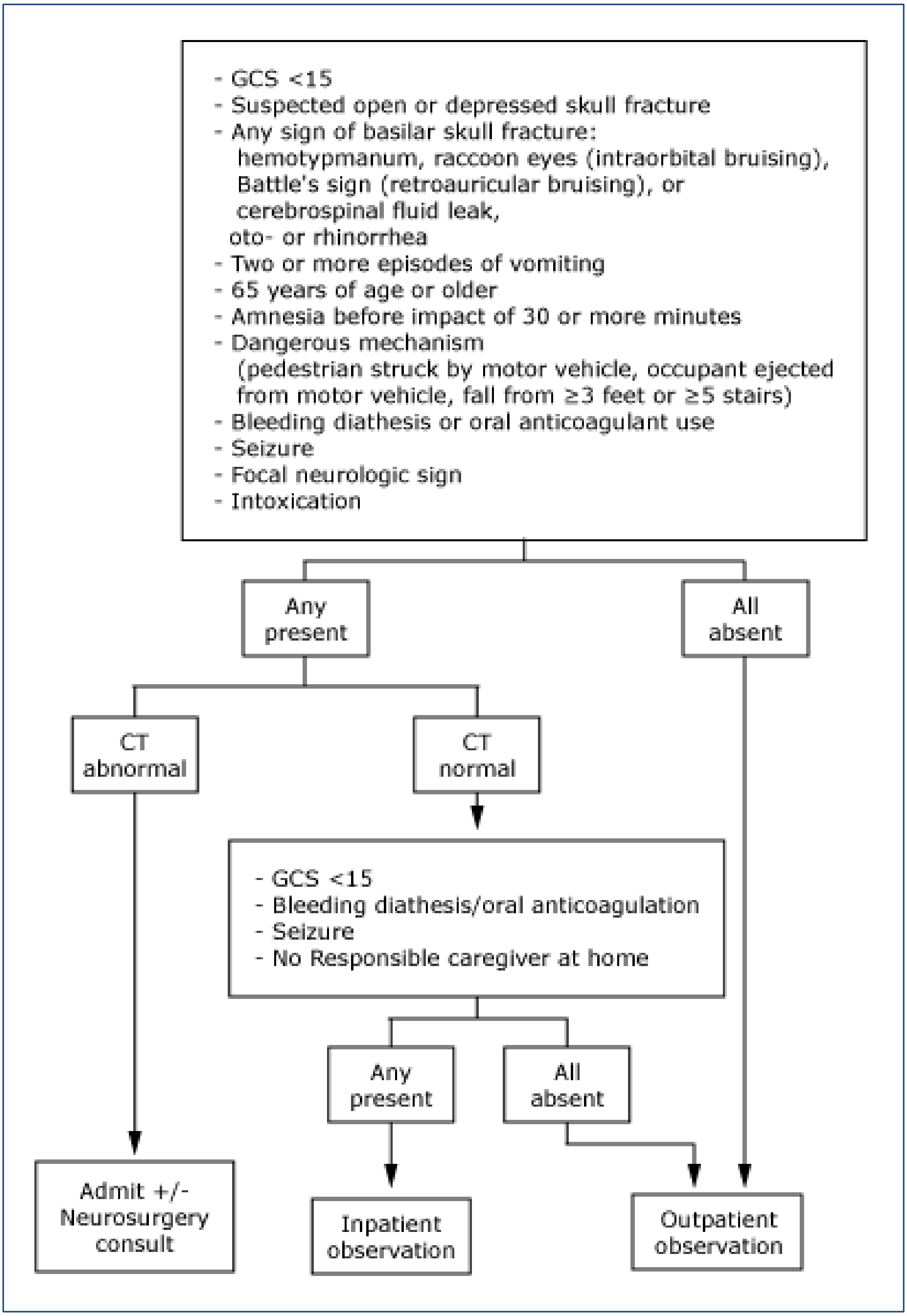
High Risk:

- GCS < 15 at 2 hours post injury
- Suspected open or depressed skull fracture
- Any sign of base of skull fracture
- Vomiting > 2 episodes
- Age > 65 years

Medium Risk:

- Amnesia before impact > 30 minutes
- Dangerous mechanism (pedestrian struck by motor vehicle; occupant ejected from motor vehicle)
- Fall from height > 3 feet or five stairs

Figure 7: Assessment of head injury in Adults ≥16y (from UpToDate[64])

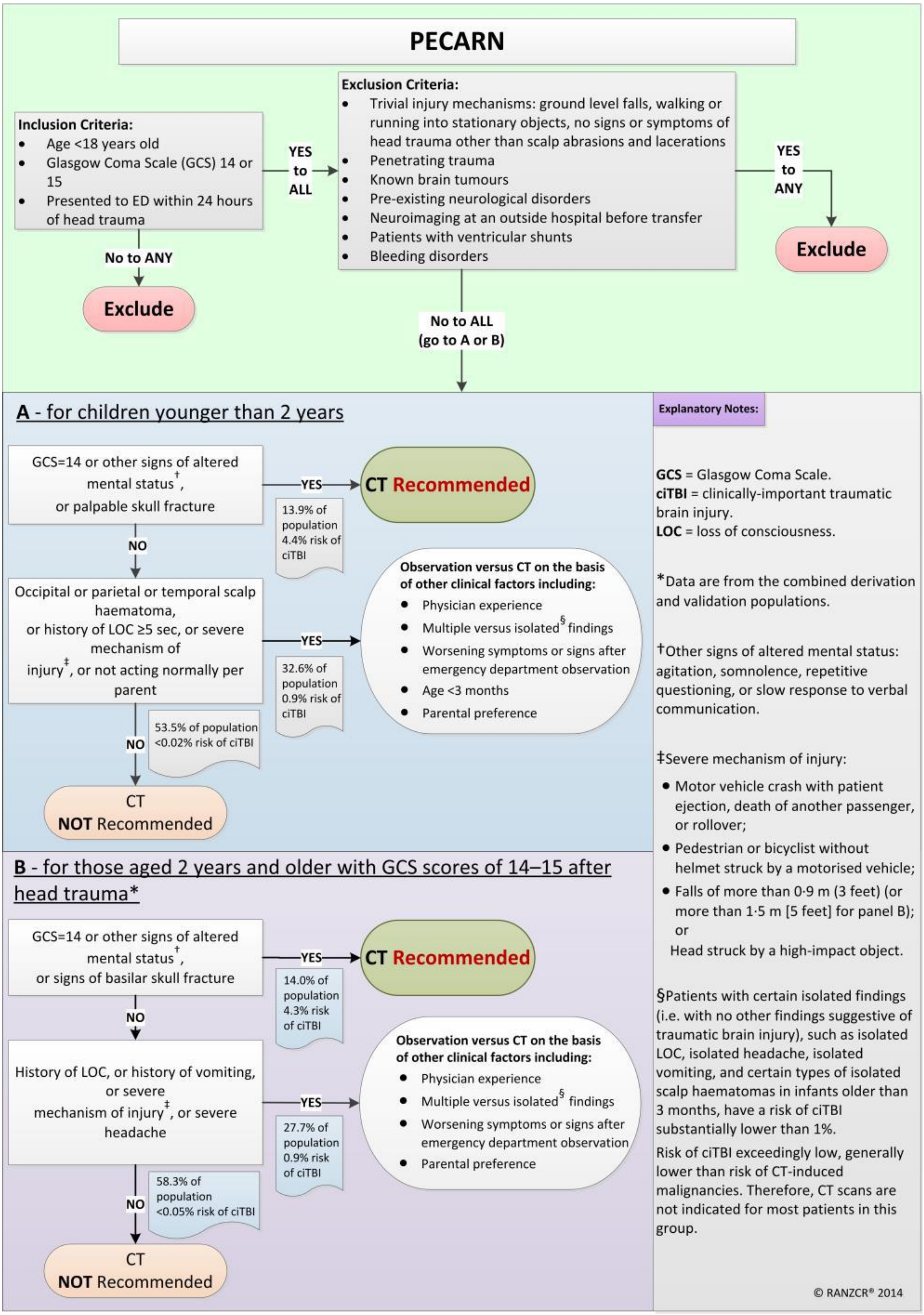


## Indications for Head CT in Paediatrics (<16y):

The PECARN Paediatric Head Trauma Algorithm[65,66] is a well-validated clinical decision aid that allows physicians to safely rule out the presence of clinically important traumatic brain injuries (defined as death, neurosurgical intervention, intubation more than 24 hours, or admission of 2 nights or more due to traumatic brain injury) without the need for CT imaging. The PECARN clinical decision rule consists of 2 age specific rules: one for children less than 2 years of age, one for children 2 years and older (Fig 8). The elements for both age groups overlap but are not identical.

- In the less than 2 year old group, the rule was 100% sensitive.
- In the greater than 2 year old group, the rule had 96.8% sensitivity.
- In those under 2 with GCS=14, AMS, or palpable skull fracture, risk was 4.4% and CT imaging is recommended.
    - Risk with any of the remaining predictors was 0.9%, and less than 0.02% with no predictors.
- In those over 2 with GCS=14, AMS, or signs of basilar skull fracture, risk was 4.3% and CT imaging is recommended.
    - Risk with any of the remaining 4 predictors was 0.9%, and less than 0.05% with no predictors.
- PECARN prediction rule outperformed both the CHALICE and the CATCH clinical decision aids in external validation studies.

Figure 8: PECARN Algorithm for Paediatric Head Trauma (from RANZCR[67])



**SCIWORA**[68]

Spinal cord injury without radiographic abnormality (SCIWORA) refers to spinal injuries, typically located in the cervical region, in the absence of identifiable bony or ligamentous injury on complete, technically adequate plain radiographs or computed tomography. SCIWORA is somewhat of a misnomer since when these children are assessed with MRI, two thirds of them actually do have demonstrable injury of the spinal cord, spinal ligaments, or vertebral body end plate.

SCIWORA should be suspected in patients subjected to blunt trauma who report early (immediate) or transient symptoms of neurologic deficit that have resolved by the time of initial evaluation or who have existing findings upon initial assessment. Treatment and prognosis are based upon neurologic presentation and MRI findings.

Four mechanisms of injury have been described for SCIWORA:

- Hyperextension
- Hyperflexion
- Distraction
- Spinal cord infarction

SCIWORA is a rare injury that is more likely to occur in young children however it has been described in victims of all ages after blunt trauma. Most cases of SCIWORA occur in the cervical spine in both children and adults. Thoracic SCIWORA has also been described, but is less common than in the cervical region due to the splinting reinforcement provided by the rib cage and is primarily associated with extreme traumatic forces (e.g., high-speed motor vehicle collisions).

SCIWORA occurs with greater severity in children younger than eight years of age. Depending upon the study population and reference standard, reported incidence is approximately 0.2 % of all paediatric trauma patients but among children with spinal injuries it ranges from 4.5 to 35%.

SCIWORA in young children under eight years of age is most commonly caused by motor vehicle collisions, falls, and child abuse. In older children, motor vehicle collisions and sports, especially gymnastics, diving, horseback riding, and contact sports predominate.

**Clinical Features**

SCIWORA may present as definite evidence of spinal cord injury on physical examination as manifested by:

- abnormal vital signs e.g. apnoea or bradycardia with hypotension [spinal shock]
- neck or back pain
- and/or neurologic deficits (e.g. paraesthesias, paralysis, or loss of pain sensation) without evidence of bony abnormality on plain radiographs and/or computed tomography of the spine.

However, transient neurologic symptoms (e.g., paraesthesias, weakness) by history or resolving during emergency evaluation may be the only indication that the cervical or thoracic spinal cord has been injured. Approximately one-quarter of affected children may experience delayed onset of neurologic signs minutes to days after injury, which can range from complete paralysis to partial neurologic deficits. The latent period may range from 30 minutes to four days, making prompt diagnosis difficult.

It is critical to have a high index of suspicion and to ask specifically about transient symptoms in any verbal child whose mechanism of injury is consistent with cervical or thoracic spine injury.

**Radiological Evaluation**

All patients with suspected spine or spinal cord injury should undergo plain radiographs of the cervical spine and any other portion of the spine with evidence of injury and computed tomography of the cervical spine and/or other region based on physical examination and plain radiographs.

Magnetic resonance imaging (MRI) should be performed in children who are suspected of having spinal cord injury, but have normal plain radiographs, CT, or both.

In patients who report transient neurologic symptoms by history but have a normal neurologic examination, observational evidence suggests that MRI should be promptly performed if the patient is presenting within four days of the initial injury.

Evaluation with imaging should occur up to 4 days after the initial injury if transient neurologic symptoms are reported.

Small observational studies and case reports suggest that the frequency of abnormal spinal cord findings on MRI in patients with SCIWORA is significant and that lesions requiring operative intervention (e.g., epidural hematoma, ligamentous disruption) are frequently demonstrated. In addition, the spinal cord findings can be used to predict clinical outcomes.

**Treatment**
Definitive therapy should be based on the MRI findings and provided in consultation with a paediatric neurosurgeon.

**THORACOLUMBAR SPINE ASSESSMENT AND CLEARANCE – Adult 16y+**

The thoracolumbar spine (TLS) is the most rigid and strong of all the vertebrae and to disrupt the column at this level requires great force. TLS fractures are more common than cervical fractures after blunt trauma. The most common site of TLS injury is where the natural transition from kyphotic to lordotic curvature occurs, between T11 and L4.[69] Like cervical spine fractures, there are patterns and types of fractures that are typical to the TLS and relate to the mechanism of injury. Spine instability correlates with the type of fracture, and is best evaluated by CT imaging.

The true incidence of TLS injuries is still unknown, but there is substantial evidence that previous clinical clearance practices result in significant missed injuries. In 2011, Inaba et al. published a prospective observational study evaluating clinical clearance of the TLS after blunt trauma and found that of 666 patients with known TLS fracture, more than half (52 %) had a negative clinical exam.[70]

The aim of the TLS guideline is to assist in the decision making, assessment and identification of TLS injuries and to ensure appropriate and timely referral and care of these patients. Delayed or missed injuries result in an eight fold increase in neurological deficits and lead to complications related to patient positioning and immobilisation in addition to long term pain and diminished quality of life.

The approach to anyone with suspected TLS injury is immediate immobilization and careful patient handling that aims to minimize movement of the spinal column. At a bare minimum, patients should be placed in spinal precautions until an adequate assessment can be completed.

**Differential diagnoses and associated injuries**

Patients with possible TLS injuries have often been involved in high-energy trauma (e.g., motor vehicle collision) and sustained multiple injuries. Thus, the differential diagnosis for upper or lower back pain in these patients is broad. In addition to severe intrathoracic (e.g., aortic injury), intraabdominal, and pelvic injuries, clinicians should consider spinal cord injury, spinal epidural hematoma, paraspinal hematoma, retroperitoneal hematoma and kidney injury, and soft tissue injuries. Diagnostic imaging must be obtained to differentiate among these entities.

**Clinical findings of TL spine injury**

It is important to note the limitations of the physical examination in the setting of TLS injury. Compared to the cervical spine, the TLS is difficult to examine. The TLS is relatively immobile, usually deeper to the overlying soft tissue, and initial evaluation by visual inspection and palpation requires adequate log roll and exposure which is an often an unreliable part of the initial trauma examination in the ED. Depending upon the body habitus of the injured patient, the ability to palpate any deformity or step-off of the spine may be difficult, particularly in an uncooperative patient.

In one large prospective study, over twenty percent of patients with a TLS injury requiring surgical management or fixed immobilization had no significant findings on physical examination.[71]
Diagnostic imaging may still be required despite an unremarkable physical examination.

As part of the secondary survey, the entire back, chest, and abdomen should be inspected and palpated. Patients with major injuries to the chest, abdomen, or pelvis often sustain injuries to the TLS as well. Back pain and neurologic dysfunction are clinical findings associated with TLS injuries. Advanced imaging of the involved region is warranted if the clinician detects focal tenderness, a neurologic deficit, or spinal deformity. Other signs suggestive of spinal column injury include contusions, abrasions, lacerations, open wounds, or muscle spasm in the general area of the spine. Any deviations from normal spinal curvature should be noted. Fractures can cause a kyphotic or scoliotic deformity; muscle spasms can cause a straightening of the spine and loss of lordosis.

Whenever feasible, a focused, but systematic neurologic evaluation should be performed in all patients with a possible TLS injury. Ideally, this examination includes assessment of motor function, sensation, reflexes, and position sense. A significant portion of TLS fractures damage the distal spinal cord or cauda equina to some degree[72], and such injuries can present with lower extremity paresis, lower extremity or saddle anaesthesia, or loss of bladder or anal sphincter function.
Decreased rectal tone is thought to be a late finding of the cauda equina syndrome and is often absent immediately following an acute injury. Although previous iterations of Advanced Trauma Life Support advocated performing a digital rectal examination on all trauma patients during the secondary survey, there is no clear evidence that the examination is an accurate means for detecting spinal cord injury.[73] The most recent edition of Advanced Trauma Life Support (ATLS) does not mandate a rectal examination during the secondary survey.[74]

Among patients who sustain high-energy trauma, scapular contusions suggest a rotation or flexion-rotation injury of the thoracic spine. Close evaluation of the TLS, generally including spinal reconstructions from a CT of the chest, is prudent in such cases. Large contusions in the lumbosacral area following trauma are associated with shear fractures in this region. The classic presentation for a flexion-distraction injury (e.g., Chance fracture) of the TLS is that of a backseat passenger restrained by a lap belt only, without a shoulder strap. Such a patient may manifest ecchymosis on the lower abdomen and tenderness at the lumbar fracture site, but the absence of these signs does not preclude the diagnosis. Although neurologic deficits occur in fewer than 5 percent, patients with Chance fractures often sustain intraabdominal injury, such as intestinal perforation, hematoma, or contusion. The pelvis and lower extremities should be examined, paying particular attention to pelvic stability, signs of injury, and neurologic function. Approximately 10 percent of calcaneal fractures are associated with lumbar fractures when the mechanism of injury involves axial compression, such as a fall from a significant height.

Although performance of a careful physical examination remains important, the findings of several observational studies suggest that clinical examination alone is **not** sufficiently sensitive or specific to rule out or identify significant TLS injuries.[70,75,76] Therefore, preliminary rules for determining the need for imaging in patients with possible TLS trauma include the mechanism of injury and other factors, in addition to examination findings.

**Clinical Clearance of the Thoracolumbar Spine – Adult (≥16y)**

Clinical evaluation is unreliable for TLS clearance, except for the lowest risk blunt trauma patients (e.g. young, low-energy mechanism).[5] Unlike cervical spine clearance, algorithms that guide thoracolumbar spine clearance have not been rigorously tested or validated.[77] Clinical clearance of the TLS is not well described and the studies that support the utility of clinical clearance are based on a small number of retrospective studies.[78] Because of the lack of rigorous data, there is no NEXUS or CCR counterpart as yet that is applicable to evaluating the TLS, but it is generally accepted practice that for the patient who is alert, stable, and without neurological injury or deficit on exam may be considered for clinical clearance.[79] Patients who were ambulating after the injury are also considered lower risk for significant TLS injury. Due to the lack of clear protocols and validated data, application of clinical clearance should be highly selective.

Suggested algorithms are largely similar to those used in cervical clearance, with the added considerations of high risk features and any evidence of new cervical fracture because of the known association with simultaneous thoracolumbar fractures.[79]

There are 4 steps to the clinical clearance process for the thoracolumbar spine, all of which require some degree of clinical judgement:

1. Can this patient be evaluated?
2. Are there high risk historical features or mechanisms?
3. Is there a neurological deficit?
4. Are there positive clinical findings?

*See Figure 9 for Adult TLS flowchart*

**Step 1 – Can this patient be evaluated?**

Patients who meet ANY of these three criteria require radiographic imaging:

i. GCS < 15
ii. evidence of intoxication
iii. unreliable or uncooperative with examination

⇨ If no criteria are met, proceed to step 2.

**Step 2 – Historical risk factor assessment**

Are there any high risk factors favouring imaging? [3,71,79,80,81,82]

- Age ≥ 60y
- Dangerous mechanism:
  - Fall ≥ 3m
  - Ejection / vehicle rollover
  - MBA
  - Pedestrian v car ≥60kph
  - Forceful direct blow

⇨ If high risk factors are present then the patient will require TLS imaging
⇨ If unsure then consult senior clinician (clinical judgment required if dangerous mechanism is the only risk factor in a young adult who has mobilized)
⇨ If no high risk factors are identified and particularly if low risk factors are also present, then proceed to step 3.

**Step 3 – Is there a neurological deficit?**

The presence of neurological deficit consistent with TLS injury mandates urgent imaging.
Further log rolling to examine the spine is unnecessary and potentially harmful and should be deferred until after imaging results are obtained.

⇨ If no neurological deficit is present, proceed to step 4.

**Step 4 – Are there any positive clinical findings?**

The presence of certain clinical signs along the TLS indicates the need for imaging:

- Focal pain/tenderness
- Bruising
- Haematoma
- Palpable step-off

The presence of a fracture elsewhere in the spine mandates imaging of the entire spine, as the risk of a second, non-contiguous fracture may be as high as 20%.[83]

⇨ If there are no positive clinical findings, the TLS can be considered CLINICALLY CLEARED. Unlike C-spine clearance, no further functional assessment is necessary, however those patients who continue to have persistent severe pain will need to be re-evaluated for injury.

Pearls and Pitfalls of Clinical Clearance of the Thoracolumbar Spine

**Distracting injuries**

Results from a recent large prospective trial suggest that the presence of distracting injuries is not a relevant factor in the clinical assessment of blunt TLS trauma in awake and alert patients.[84] 95% of 321 patients with distracting injuries were correctly cleared of TLS injury and none of the 17 missed injuries were surgically significant.

**Adult thoracolumbar spine clinical clearance summary - Awake Asymptomatic Patient**

| |
|---|
| In the awake, asymptomatic adult patient who is neurologically intact, and who is able to complete a thoracolumbar examination, radiographic evaluation of the thoracolumbar spine is not recommended.[3] Discontinuing thoracolumbar immobilization in this patient population is recommended. |

**Radiographic Clearance of the Thoracolumbar Spine – Adult (≥16y)**

In the 2012 EAST guidelines for screening for TLS injuries after blunt trauma, the authors point out that all but the most clear-headed, neurologically intact, and asymptomatic patients should be considered for clinical clearance.3 And even in these patients, a high-risk mechanism of injury alone should lead to serious consideration for radiographic clearance before spinal precautions are lifted. Cervical spine fracture is a risk factor for injury elsewhere in the spine and should result in thoracolumbar screening with CT. Reformatted images from standard CT studies of the chest and abdomen are preferred in multi-trauma.

**Imaging Modalities available at Bendigo Health**

**Computed Tomography**

Multi detector helical CT (≥64 slice) is the standard of care for immediate evaluation of the blunt trauma with suspected TLS injury.

**X-ray (plain films)**

There is no role for plain films of the TLS in trauma (unless CT is unavailable).

**CT versus X-ray**
*Accuracy* **-** CT is superior when compared to plain radiographs in patients with suspected thoracolumbar spine injury. At least eight separate studies have described the inferiority of plain films as compared to CT in screening the thoracolumbar spine after blunt trauma (See table x). Compared to plain films of the thoracolumbar spine, CT is significantly more sensitive.

*Radiation dose* **-** in contrast to the higher relative radiation exposure with cervical CT compared with plain radiograph, CT of the TL spine involves lower levels of radiation exposure compared with plain films (13 milliSieverts [mSv] versus 26 mSv).[85]

*Efficiency* - the ability to use the images from CT chest, abdomen and pelvis to screen for spinal fractures decreases the time, cost, patient transportation, and radiation exposure involved in spinal injury evaluation. Reformatted images are 100% sensitive for thoracolumbar fractures.[85,86,87]

*Selective imaging* - there is no available literature on the selective imaging of potentially injured parts of the TL spine. The TL spine should be considered as one unit.

| Author | Year | Class of Data | No. Patients | Sensitivity of CT, % | Sensitivity of X-Ray Study, % | Sensitivity of CT for Unstable Fractures, % | Sensitivity of X-Ray Study for Unstable Fractures, % |
|---|---|---|---|---|---|---|---|
| Hauser CJ | 2004 | II | 215 | 97 | 58 | 100 | 100 |
| Wintermark M | 2003 | II | 100 | 78 | 32 | 97.2 | 33.3 |
| Sheridan R | 2003 | II | 78 | 95–97 | 62–86 | 100 | — |
| Herzog | 2004 | II | 70 | 100 | 57–75 | 100 | 57–77 |
| Mejia V | 2004 | II | 1,576 | 94–98 | 58–59 | 100 | — |
| Berry GE | 2005 | III | 103 | 100 | 73 | 100 | 93 |
| Antevil JL | 2006 | III | 573 | 100 | 71 | — | — |
| Smith R | 2009 | II | 59 | 89 | 37 | 100 | 63–75 |

Table 6: Sensitivity of CT and plain Xray for TLS fractures. Reproduced from Sixta et al.[3]

**Magnetic Resonance Imaging**
MRI's role in thoracolumbar spine is only pertinent after a spine injury has been found, usually by CT. MRI is excellent for soft tissue, ligamentous, and spinal cord evaluation, but is inferior for bony structure injury when compared to CT. Because CT is more accurate and more efficient at detecting bony fractures and unstable spinal injuries, MRI has no role in the initial screening or radiographic clearance of the thoracolumbar spine - CT is still first line

In the presence of neurologic injury or suspected injury, MRI is the gold standard because of its unique ability to evaluate the spinal cord, intervertebral discs, and the ligaments. Selective use of MRI to evaluate high-risk injuries, such as burst fractures, even in the absence of neurologic deficits is reasonable but not well studied.

**Adult TLS radiological clearance summary - Awake Symptomatic Patient**

| |
|---|
| High quality CT imaging of the thoracolumbar spine in the symptomatic trauma patient has been proven to be more accurate than plain films, with higher sensitivity and specificity for injury following blunt trauma. If high quality CT is available, plain films are not necessary. If high quality CT is not available, anterior and lateral thoracolumbar spine xrays are required. |

**Awake patient, persistent symptoms, negative CT**

Any neurological deficit requires urgent referral to a neurosurgical/spinal service. The vast majority of patients with neurological deficits secondary to trauma will be transferred out +/- MRI prior to transport.

Those with no neurological symptoms but with persistent pain on functional assessment despite negative CT are appropriate for local initial management. The senior clinician may choose to discontinue the spinal precautions.

**Adult TLS radiological clearance summary - Obtunded or Unevaluable Patient**

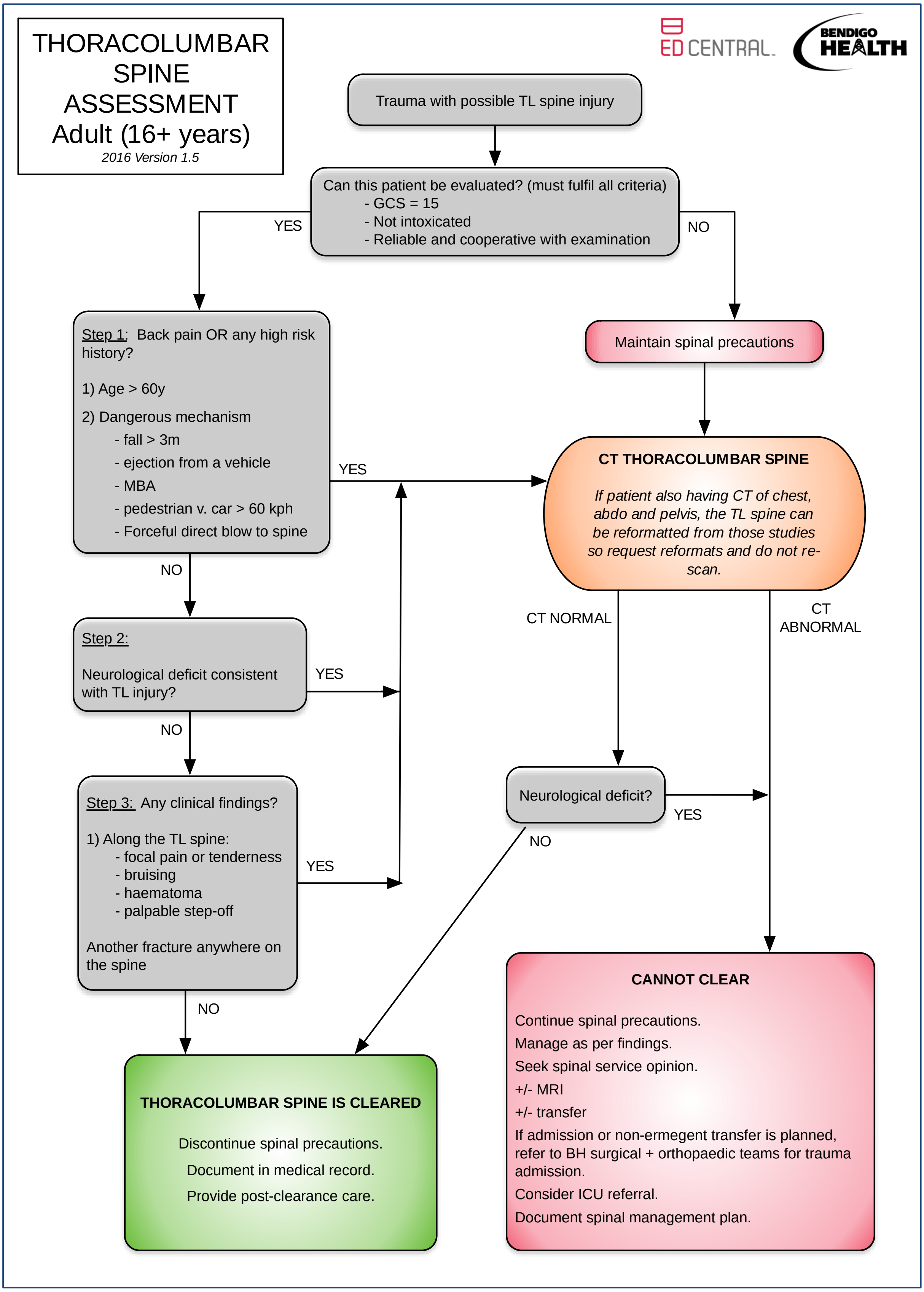
| |
|---|
| High-quality CT imaging is recommended as the initial imaging study of choice. In the case of high-risk mechanisms this will ideally be obtained by reformatting of the images from CT chest/abdo/pelvis. |

Any neurological deficit should prompt urgent spinal referral, as above.

**Negative CT, obtunded/unevaluable patient**

For those with negative CT and no neurological deficit, the senior clinician may choose to discontinue the spinal precautions

## Figure 9: Adult Thoracolumbar spine assessment flowchart (≥16years)



## THORACOLUMBAR SPINE ASSESSMENT AND CLEARANCE – PAEDS <16y

### Introduction

Fractures of the thoracic spine account for 25-30% of all spine injuries in children, while lumbar fractures account for 20-25%. Injuries to the thoracic spine and the thoracolumbar junction have a higher incidence of spinal cord injury, with neurologic deficit seen in up to 40% of cases. Multiple-level injuries are seen in 30-40% of children with thoracic or lumbar spine fractures. Fractures of the lower thoracic and upper lumbar spine have associated small bowel and visceral injury in up to 50% of cases.

Mechanism of injury is important in identifying the risk of thoracic or lumbar spine injury. In Victoria, MVCs and falls account for most of the injuries, but non-accidental injuries to these regions do occur. 47% of patients with thoracolumbar spine injuries have an injury to one or more other body regions. A significant number of these have abdominal injuries with or without further injuries, usually as seat-belt injury in a motor vehicle accident.

### Clinical examination

Examination should focus on the presence of tenderness and signs of bruising or deformity over the spine. This is assessed by log-rolling the patient while spinal immobilisation is still in place. A search for abnormal neurological signs, particularly signs of spinal cord or cauda equina lesions should also be made.

The presence of pain in the back makes injury more likely; however absence of pain does not exclude injury. Any patient who has pain or tenderness over the spine should have the spine evaluated by radiography.

Patients at risk of having thoracic or lumbar spine (and cervical spine) injuries missed are those with:

- altered conscious state
- other significant injuries.
- multi-level injuries

A thorough assessment and investigation of the abdomen and chest is mandatory for all patients with significant thoracic and upper lumbar spine injuries. Associated injuries to the pelvis must not be forgotten with lumbar spine injuries.

### Clearance of the paediatric thoracolumbar spine

There are currently no validated evidence-based guidelines for clearance of the paediatric thoracolumbar spine in the literature. Information presented here is taken from the RCH paediatric trauma manual. [88]

Indications for thoracolumbar spine imaging:

- Pain in the thoracic or lumbar region.
- Tenderness of the spine in the thoracic or lumbar region.
- Significant bruising or deformity of the spine.
- Altered conscious state.
- Proven fracture in another region of the spine.

Children poorly localise the level of the injury, therefore imaging the full length of thoraco-lumbar spine may be necessary (discuss with treating consultant).

**Radiographic Evaluation**

The standard views for both areas are the AP and lateral Xrays. A swimmer's view may be needed to visualise the first two thoracic vertebrae, as the shoulders often obscure the upper thoracic spine.

On lateral view:

1. Follow the anterior and posterior vertebral body lines and the spinolaminar line on the lateral view. These three lines should have a parallel course.
2. The height of each vertebral body should be assessed anteriorly and posteriorly. A difference of more than about 3mm should be treated as pathologic.

On AP view:

3. The para-spinal lines should be closely inspected to detect evidence of paraspinal haematoma.
4. The posterior elements should be visible through the vertebral body and should be in alignment. Look at gap between the spinious processes.

**Indications of an unstable fracture:**

- Vertebral body collapse with widening of the pedicles
- Greater than 33% compromise of the spinal canal by retropulsed fragments
- Translocation of more than 2.5 mm between vertebral bodies in any direction
- Bilateral facet joint dislocation
- Greater than 50% anterior compression of the vertebral body associated with widening of the interspinous space.

While most thoracic and lumbar spine fractures are diagnosed on initial plain radiographs, these films often do not provide enough information on the extent of the injury and a CT scan of the region is usually obtained to elucidate the full extent of the injury. MRI will be needed to visualise all ligament and spinal cord involvement. If neurological signs are present do a CT or MRI scan after consultation with paediatric neurosurgery.

**Treatment**

Consultation with a paediatric orthopaedic surgeon or neurosurgeon should be sought for the definitive care of the injury.

## APPENDIX 1: Stability of Cervical Spine Fractures

### C1 and C2 fractures[89]

| Injury (mechanism) | Stable | Comment |
|---|---|---|
| **Atlanto-occipital dislocation** (flexion) | No | * Often instantly fatal<br>* More common in children because of small, horizontally-oriented occipital condyles<br>* Dislocation can be anterior (most common), superiorly distracted, or posterior |
| **Anterior atlantoaxial dislocation** (flexion) | No | * Associated with transverse ligament rupture<br>* Most commonly occurs in patients with rheumatoid arthritis and ankylosing spondylitis from ligament laxity<br>* Widening of predental space seen on lateral plain film |
| **Jefferson fracture = C1 burst fracture** (axial compress'n) | No | * 33% with associated C2 fracture<br>* Low incidence of neurologic injury because of wide C1 spinal canal<br>* Usually involves fractures of both the anterior and posterior C1 arches, often with 3 or 4 fracture fragments<br>* Complication: transverse ligament rupture, especially if C1 lateral masses are ≥7 mm wider than expected (MRI recommended)<br>* Complication: vertebral artery injury (CT angiography recommended) |
| **C1 posterior arch fracture** (extension) | Yes | * An associated C2 fracture (occurs 50% of time) makes the posterior arch fracture unstable<br>* On plain films, no displacement of lateral masses on the odontoid view and no prevertebral soft tissue swelling, unlike Jefferson burst fracture |
| **C2 dens fracture** (flexion) | +/- | * *Type I (stable)*: Avulsion of dens with intact transverse ligament<br>* *Type II (unstable)*: Fracture at base of dens; 10% have an associated rupture of the transverse ligament— MRI provides definitive diagnosis of ligament rupture<br>* *Type III (stable or unstable)*: Fracture of dens extending into vertebral body |
| **Hangman's fracture = C2 spondylolisthesis** (extension) | No | * Bilateral C2 pedicle fractures<br>* At risk for disruption of the posterior longitudinal ligament (PLL), C2 anterior subluxation, and C2-C3 disk rupture.<br>* Low risk for spinal cord injury because of C2 anterior subluxation, which widens spinal canal |
| **Extension teardrop fracture** (extension) | No | * Small triangular avulsion of anteroinferior vertebral body, at insertion point of anterior longitudinal ligament<br>* Occurs most frequently at C2 level, but can occur in lower cervical spine<br>* Complication: central cord syndrome due to ligamentum flavum buckling during hyperextension<br>* Requires CT differentiation from very unstable *flexion* teardrop fracture |

## C3 to C7 fractures[89]

| Injury (mech) | Stable | Comment |
|---|---|---|
| **Articular mass fx** (flex-rotation) | Yes | * Associated with transverse process and vertebral body fractures<br>* Uncommon |
| **Burst fx** (axial compress'n) | Yes/ No | * Compressive fracture of the anterior and posterior vertebral body<br>* Complication: spinal cord injury because of retropulsed vertebral body fragment (especially anterior cord syndrome) |
| **Spinous process fx** (flexion) | Yes | * A.K.A "Clay Shoveler's Fracture"<br>* Spinous process fracture from forceful neck flexion<br>* Most commonly occurs in lower cervical levels (C7)<br>* Not associated with neurologic injury |
| **Extension teardrop fx** (extension) | No | * See *C1 and C2 fracture* PV card<br>* Most commonly occurs at C2 |
| **Facet dislocation, bilateral** (flexion) | No | * Significant anterior displacement (>50%) of spine when bilateral inferior facets displace anterior to the superior facets below<br>* At risk for injuring anterior and posterior longitudinal ligament, disk, vertebral arteries, and spinal cord |
| **Facet dislocation, unilateral** (flex-rotation) | Yes | * Usually causes 25-50% anterior displacement of spine<br>* Complication: vertebral artery injury (CT angiography recommended) |
| **Flexion teardrop fx** (flexion and axial load) | No | * Fracture and anterior displacement of anteroinferior vertebral body (appears similar to extension teardrop fracture, except much more unstable)<br>* Rupture of both ant & post ligamentous complexes<br>* Unique findings for flexion (versus extension) teardrop fx: Same-level fxs, displacement of posterior structures<br>* Regarded as one of the most unstable fx in the lower cervical spine, because involves both columns<br>* Usually occurs at C5 or C6 |
| **Subluxat'n, anterior** (flexion) | No | * Ruptured posterior ligamentous complex, such that anterior and posterior vertebral lines are disrupted<br>* Complication: vertebral A. dissection (CT angio rec)<br>* May only be evident during flexion views by conventional xray --> the interspinous distance widens and the vertebral body subluxes anteriorly |
| **Transverse process fx** (lateral flexion) | Yes | * Complication: vertebral A. injury, because travels within the transverse foramina (CT angio rec)<br>* Complication: Cervical radiculopathy and brachial plexus injuries associated in 10% of cases |
| **Wedge fx** (flexion) | Yes | * Compression fracture of only the anterosuperior vertebral body endplate<br>* Disruption of anterior vertebral line |

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