Don't Forget The Bubbles

PAEDIATRIC CERVICAL SPINE INJURIES

Facilitators Guide

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Duration **up to 2 hours**
Equipment required **Computer with projector for imaging**

OUTLINE (USE THE SECTIONS THAT ARE RELEVANT FOR YOUR LEARNERS)

- Introduction and Basics: (10 mins) pre-reading, glossary of terms, anatomical considerations
- Main session: (2 x 15 minutes) case discussions covering the key points and evidence
- Advanced session: (2 x 20 minutes) case discussions covering diagnostic dilemmas; advanced management and escalation
- Sim scenario (30-60 mins)
- Quiz (10 mins)
- Infographic sharing (5 mins): 5 take home learning points

PRE-READING FOR LEARNERS

Expectation is for the learners to have read some of these links before the session.

https://pedemmorsels.com/pediatric-cervical-spine-injury/ Read it

https://pedemmorsels.com/airbag-injury-and-children/ Read it

https://dontforgetthebubbles.com/paediatric-c-spine-injuries/ Read it

https://dontforgetthebubbles.com/c-spine-x-ray-interpretation/ Read it

GLOSSARY OF TERMS

EMS – Emergency Medical Services
CSI – Cervical Spine Injury
SCIWORA – Spinal cord injury without radiological abnormality
XR – X-radiography
ED – Emergency Department
NEXUS – National Emergency X-radiography utilization study
PECARN – Paediatric Emergency Care Applied Research Network
GCS – Glasgow Coma Scale
MILS – Manual in line stabilization
MVC – Motor Vehicle Collision
ATV – All terrain vehicles
NPV - Negative Predictive Value
PEM – Paediatric Emergency Medicine
TBI – Traumatic Brain Injury
NICE – National Institute for Health and Care Excellence, United Kingdom
MRI- Magnetic Resonance Imaging

INTRODUCTION AND ANATOMICAL CONSIDERATIONS

The incidence of cervical spine injury is low and represents only 1-2% of all paediatric major trauma (1).

The Cervical spine is overrepresented as the region where more than half of all paediatric spinal injuries occur and the main reason for this is the relatively larger head size leading to the fulcrum of flexion being in the cervical column (2-4). Other features also make it susceptible to injury: ligamentous laxity, incompletely ossified vertebrae and more horizontally orientated facet joints (5).

The incidence of ligamentous injury is thought to be higher in younger, non-communicative children under 3 years of age (6).

The precise location of injury in the cervical spine can be variable across the age range (7-9).

Four injury patterns are common in children with cervical spine trauma:

Fracture	Subluxation with Fracture	Subluxation without Fracture	SCIWORA

Dislocations or subluxations are more common in upper cervical spine injuries and associated with greater morbidity (9). To compare with Adults, children are over twice as likely to suffer atlanto-axial injury (8).

Weaker musculature and underdeveloped interlocking bony processes contribute to the subluxation/dislocation and SCIWORA (spinal cord injury without radiological abnormality) type injury patterns we see in children (10). SCIWORA refers to CT and plain film. A lesion may be detected on MRI.

SCIWORA is the presence of myelopathy as a result of trauma with no evidence of fracture or ligamentous instability on imaging. The mechanism relates to the flexibility of the paediatric spine being greater than that of the spinal cord which becomes damaged as it is stretched beyond its limits. Neurological signs or symptoms even if transient must be elicited in the history to make this diagnosis (2).

Manage the cases below as you would in your own setting using local guidelines and procedures to make this whole exercise as realistic as possible and also to stimulate further analysis and discussion.

MAIN CASES

CASE SCENARIO 1 - C-SPINE INJURY IN THE OLDER CHILD

A 13 year old boy arrives in your ED. He came off his bicycle at speed whilst engaged in a downhill mountain racing contest. He was wearing a helmet and protective clothing but hit his head against a tree as he landed.

He did not lose consciousness. He describes immediate onset neck pain which now persists.
Volunteer ambulance services were supervising the event and treated his pain with paracetamol and ibuprofen whilst preparing him for transfer in full spinal precautions. He is brought into your ED strapped to a spinal stretcher with a hard cervical collar in place as well as head blocks and tape.

On handover it is noted that he felt a weird sensation in his right arm at the time of the event which lasted perhaps 3-5mins and has not returned. The crew found his neck to be diffusely tender on examination.

What features in history and on examination are we concerned about regarding the potential for cervical spine injury?

How do we take handover of these patients and protect them whilst we work up their injury?

WHO TO SUSPECT AND IMMOBILIZE

NEXUS

Validated by Vicellio

Prospective
<18yrs
3065 participants

Low risk for C spine injury with all of ...

- ☑ Absence of posterior midline cervical spine tenderness
- ☑ Absence of a neurological deficit.
- ☑ Absence of intoxication
- ☑ Normal level of alertness
- ☑ Absence of distracting pain

Sensitivity 100%
Specificity 19.9%

✕ Cannot be applied reliably to children <9yrs

Canadian C Spine

Prospective
>16yrs
8924 participants

Three clinical questions to detect clinically important CSI...

1 Is a high-risk factor present mandating XR?

- Age ≥ 65 years
- Paresthesias
- Dangerous mechanism

2 Is the scenario low risk allowing for assessment of neck range of motion?

- low-risk mechanism
- absence of midline neck pain
- ambulatory at any point
- ability to sit up

3 Are patients able to actively rotate their neck 45 to both sides?

Sensitivity 100%
Specificity 42.5%

✕ Cannot be applied reliably to children <16yrs

PECARN

Prospective
<18yrs
4091 participants

Any one of the following factors is associated with CSI in children...

- Altered Mental Status
- Focal Neurological Findings
- Report of neck pain
- Reported decreased neck mobility or on physical examination
- High risk MVC
- Significant torso injury
- Diving as the mechanism
- Predisposing factors such as T21

Sensitivity 90.5%
Specificity 45.6%

↓ Underpowered to establish definitive rule

Predisposing vulnerability to bony or ligamentous failure: Down Syndrome(T21), Rheumatoid Arthritis, Rickets, Osteogenesis Imperfecta, Ehlers-Danlos Syndrome, Achondroplasia, Marfans Syndrome, Renal osteodystrophy, Klippel Feil disease, Morquio Syndrome, Grisel syndrome.

^A high risk MVC is one of the following: Head on collision, rollover, patient ejected from the vehicle, death of another passenger occurred, speed of collision over 88kph (55mph).

~Distracting injury is vaguely defined by NEXUS to include burns and long bone fractures etc. It can be refined to mean any substantial injury of the upper torso due to proximity to the cervical spine (14).

As described above (11), the Viccelilo study (2001) looked at the performance of NEXUS in the paediatric subgroup. In 2017 however, Cochrane (2017) found there was conflicting evidence to support use of NEXUS in children and called for additional well designed studies with larger sample sizes to better evaluate this population (15).

Some points to consider regarding immobilization:

Where a cervical spine injury is suspected, appropriate immobilization must be achieved.

Ask the co-operative child to lie still. Apply gentle manual in line stabilisation (MILS) and give lots of encouragement (age appropriate) to minimise movement. The neck should reside neutrally or in a position of comfort for the child. Bear in mind that babies may require a pad or similar thoracic elevation device laid onto the trauma mattress to elevate the torso and preserve neutral alignment of spine due to their relatively larger heads. This will prevent any forced flexion occurring.

While providing MILS and reassurance, we must address pain as a matter of urgency. Immobilisation may increase leverage on the neck in a sore and struggling child. Once deemed safe to do so (and rapport has been established where applicable), radiolucent blocks and straps can be applied to free up that team member from the task of MILS. As well as helping limit movement, blocks

also serve as a communication tool / visual reminder to the team that we are worried about this spine and to handle with care.

If coming in by EMS, transfer using scoop from ambulance mattress to radiolucent ED trauma mattress. During transferring manoeuvres, the team leader should ensure that the minimal number of movements and gentle max 30 degree tilts are all that's needed to get them on and off a scoop stretcher.

The leader should also ensure that all team members understand their role and are given adequate prompts prior to any movements being performed "ready, steady, move". Use the opportunity allowed by tilting to complete your standard assessment of the spine (and the patients back for other injuries or relevant findings). Document appropriately.

Sometimes children 6 years old and above (not possible to put on below this age) may come in via EMS wearing cervical collars. These are removed to assess the cervical spine in ED while MILS is being applied and hard collars should not be placed back on as they can have a number of negative effects, particularly with prolonged use (16).

Two piece collars are different and are often recommended by spinal specialists as a treatment modality for stable fractures or as a bridge to definitive management.

CASE SCENARIO 2 - CHILDREN UNDER THE AGE OF 3

A 10 month old girl who was a back seat occupant in a rearward facing baby seat is involved in a head on RTC at 30kph (18mph).

The incident occurred in a housing estate. She presents with her Mother who was the restrained driver for review at a mixed Adult and Paediatric ED.

You have already assessed and cleared Mum from any serious injury.
You now examine her baby who is crawling away from you on the bed saying “mama”.

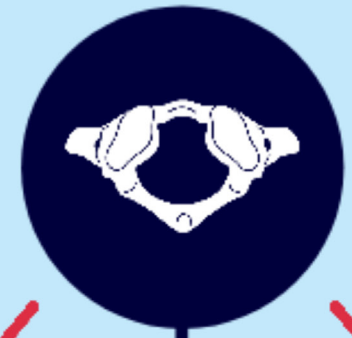
Discuss how we need to adapt our assessment to suit younger children.

Are we worried about this baby and do we want imaging?

Outside of the factors looked at in the large studies, are there any other items which we should consider important in history and on physical examination for all children?

The studies we have looked at so far don’t have many children **under the age of three years old.** We will now explore some which do:

CHILDREN < 3 YEARS



Not Suspicious for CSI

Anderson 2010

- Prospective cohort
- <3yrs old
- Hospitalized with blunt trauma

575 participants
28 with CSI

NEGATIVE XRAY

PLUS

- Low impact mechanism
- No focal pain
- No neurological deficit
- Sits up and moves their head without pain

Suspicious for CSI

Pieretti-Vanmarcke 2009

- Retrospective review
- <3yrs old
- 22 Trauma registries
- Blunt trauma

12, 537 participants
83 with CSI

WEIGHTED SCORING

- GCS < 14 (3 pts)
- Eye score on GCS = 1 (2 pts)
- MVC (2 pts)
- Age >2yo (1 pt)

SCORE < 2
Sensitivity - 92.9%
Specificity - 69.9%
for excluding CSI

Expert Consensus on factors which are suspicious for CSI (18-21)

History findings:

- persistent neck pain
- child or parent feeds like the child has an abnormal head position
- difficulty with neck movement
- fall >1m or 6 steps of stairs or fall from greater than body height
- hyperextension injury, acceleration-deceleration injury involving the head or clothes-lining (blunt trauma to the head/neck by a stationary object while the patient is in motion)
- bicycle collision, pedestrian versus bicycle, accidents involving motorized recreational vehicles, horse riding accidents.
- current or transient neurological symptoms (motor or sensory): weakness, paraesthesia, lightning or burning sensation down the spine or radiating to an extremity
- neurological symptoms related to neck movement.

Physical examination findings

- torticollis or abnormal head position
- posterior midline cervical tenderness
- substantial injury to the chest, abdomen or pelvis (one that is life-threatening, warrants inpatient observation or surgery)
- physical signs of neck trauma such as ecchymosis, abrasion, deformity, swelling, tenderness
- limited cervical range of motion
- significant trauma to head or face
- inconsolable child

Where the child does not have any concerning features on history or examination, we can look at some low risk factors which offer us some reassurance:

Low risk factors identified by NICE (20):

- simple rear end MVC
- comfortable in sitting position in ED
- ambulatory at any time since injury
- no midline cervical tenderness
- presenting with delayed onset neck pain

In the awake and alert patient with no neurological signs or symptoms who has neck pain or unspecified neck tenderness, NICE Clinical Guideline 176 permits the search for any one low risk factor from the above list.

If one is found, further clinical assessment of the neck, beyond the initial assessment and palpation is performed.

This comprises asking the patient to perform 45 degree bilateral active neck rotations. If this is tolerated the cervical spine can be cleared clinically. If not, the patient gets imaged.

Some further points

Persistent neck pain/tenderness in the posterior midline with normal clinical examination otherwise and normal conventional radiographs requires further evaluation. The same applies even if the patient presents sub acutely (18). This will vary between institutions but may take the form of a referral to the orthopaedic or spinal service followed by MRI or CT.

Beware the "trivial" injury, especially in younger children.
Correlate history with clinical examination. Remember these patients can be more difficult to assess and there exists limited evidence to guide their management. There are cases in children 9 months to 6 years of falls less than 5ft, out of bed, down steps, running, somersaulting which have led to C1-2 subluxations, rotatory subluxation, C2 pedicle fractures, odontoid fractures and neural arch C2 fractures.
Examination findings were torticollis, neck pain, limited range of motion neck, refusal to move neck any one or combination of the above on exam but never just neck pain (22).

Beware also of markings on the child's body from seatbelts or other age appropriate restraint systems. These may indicate extreme flexion of the cervical spine has occurred especially in head on collision (23).

As always, consider the potential for non-accidental injury in your differential.

Involve a senior early in the assessment and management of all suspected cervical spine injury children.

Interpretation of imaging (where it is necessary) and patient reassessment:

As we have discussed above, plain films are the main imaging tool used to assess the cervical spine in the ED. These must be interpreted by a senior physician due to the inherent challenges involved.

If imaging is adequate and shows no abnormality in an alert and cooperative patient (or if imaging was not required in the absence of concerning features), reassess for resolution of neck pain post analgesia.

Check 45 degrees of neck rotation either side of the midline.
If normal, ask if you are satisfied that there isn't any persisting clinical concern.
If they examine well and there is no residual concern, many institutions and the NICE guidelines declare that the spine is now clear.

This final clearance step should always be performed with a senior present.

CASE SCENARIO 3 - CHOICE OF IMAGING

An 11 year old boy is involved in a single vehicle RTA as a front seat passenger restrained in a booster seat. The vehicle slid at 120kph (75mph) and spun out of control demolishing a fence at the side of the dual carriageway and impacting a treeline before being propelled back onto the road.

There is extensive damage to the four door saloon and all airbags deployed.
The boy's father was driving at the time and they self extricated by kicking out a front door which was slightly wedged by the distorted frame.
They stood by the side of the road awaiting help to arrive.
The father states he is fine apart from a few scrapes from broken glass and declines further assessment by Paramedics.
The son complains that he now notices neck pain on moving his head backward and forward. EMS reviewed and decided to treat him with full spinal precautions.
He arrives in your ED and is assessed as having no evidence of bruising or deformity of the neck and no midline bony tenderness.
He has a normal neurological examination. His neck pain is persistent despite ibuprofen and paracetamol given by EMS en route. He is reluctant to move it much.

Do you want to image this child and if so, what imaging do you want to perform?

Imaging choices for those who cannot be cleared clinically

The sensitivity of two or more radiographic views for detecting cervical spine injury has been reported to be in the region of 85-94%, whereas CT ranges from 81-100%. These figures reflect the unique anatomical challenges inherent in interpreting images in this patient cohort, particularly those under the age of 8 years old. In adults, by comparison, CT sensitivity sits around 97-100%. This makes plain films a higher yield modality in the paediatric population, backed up by CT where plain film findings are abnormal or ambiguous (24).

To obtain the optimal sensitivity from plain film we need two or more views. The odontoid view is technically difficult to obtain in children less than 5 years old

and may not yield much diagnostic information which can't be obtained on antero-posterior and lateral.

Many paediatric radiologists do not routinely obtain odontoid views in children younger than 5 years and many more stop after the first attempt is unsuccessful. The fracture that can only be assessed on the odontoid view is the Jefferson fracture (an eponym for a burst fracture of C1) and this occurs with axial loading mechanisms (uncommon below this age). Usually there is an associated head injury which would require neuroimaging (including upper cervical spine in CT) (25).

In infants and young children, fractures of the dens tend to involve the subdental synchondrosis (naturally weak area of C2), from flexion mechanisms.
The resulting anterior tilt of the dens is normally visible on lateral views.

Adopting a pragmatic approach based on the child's age and clinical status allowing them to obey commands and open their mouth is the best course of action (26). Safety is paramount and this view can be dangerous as some movement is required of the patient (10).

It is common practice now to minimize the exposure of children, parents and staff to radiation. The neck is a radiosensitive anatomical area and the thyroid gland receives a 100-200 fold higher radiation dose with CT than with the standard three view plain film series. This extrapolates to a 2x higher mean excess risk of thyroid cancer for patients 0-4years (27).

To help put that into perspective, in the Republic of Ireland the incidence of thyroid cancer is 3.61/100,000 at baseline (28).

Ionizing radiation imparts a small but real risk of malignancy at the population level. This impact is greater on paediatric patients (29).

Where does the benefit outweigh the risk in obtaining a CT?

It takes time and a greater degree of patient cooperation to obtain plain films. As explored above, plain films can have lower sensitivity than CT so require a reliable history and physical examination to back them up as a diagnostic tool. CT has a superior ability to detect critical paediatric cervical spine injury in higher risk trauma patients because it provides more anatomical detail (30, 31).

indications for CT imaging (1, 13, 18, 20):

- peripheral focal neurological signs or symptoms including paraesthesia in upper / lower limb(s)
- patient is intubated / respiratory failure (severe TBI or C3/4/5 injury damaging phrenic nerve)
- GCS <13 on initial assessment, pointing to TBI
- head or multisystem trauma undergoing CT
- signs of substantial head injury (e.g. signs of base of skull fracture)
- where an urgent diagnosis is required e.g. for theatre
- plain films are technically difficult or inadequate
- strong clinical suspicion persists in spine of normal plain films e.g. symptomatic with head first axial loading as mechanism
- plain films demonstrate a bony injury

The use of MRI

This will vary between institutions.

In patients who have neurological signs on examination, MRI should be the primary modality wherever possible (26).
It is often used as a follow on investigation from CT in the intubated sick trauma patient who is unconscious and difficult to assess from a neurological perspective clinically. They are now stabilized enough either via Intensive Care or Surgical input to undergo an MRI.

Younger children with isolated neck injury who are difficult to assess and in whom we are concerned due history and physical examination may also be suitable candidates for MRI (32) post normal plain XR instead of going to CT. Bear in mind that many children will require a general anaesthetic to tolerate this imaging modality as it takes longer than CT or XR to perform.

CASE SCENARIO 4 - TORTICOLLIS

A 2 year old girl presents with her Father after landing awkwardly post a fall down the last two steps of stairs in her home yesterday evening.
She has been starting to walk up and down the stairs and is always supervised. Last night, she complained of some pain which responded to the paracetamol syrup given to her by Dad.
She slept well but since this morning, she has been holding her neck strangely and prefers to lie down. You are the senior registrar on duty and one of your colleagues asks for your review. She is lying in a position of comfort on her left side. When you go to examine her she sits up and clings to her Father crying and making it clear that she does not want to be examined, saying bye-bye.
She has a torticollis to the left and is moving all limbs. Analgesia was given and plain films were obtained. These looked normal to you and the patient was reviewed and looks more comfortable now, although the torticollis persists.

Should we be concerned? Outline your steps in this patient's management.

Torticollis in the setting of trauma, even in the absence of neurological signs or symptoms is concerning.

There is an association between torticollis and cervical spine injury, particularly rotatory subluxation of C1 on C2 (Atlanto axial rotatory subluxation or fixation as it is sometimes termed), however it can also be seen in other patterns of cervical spine injury too (34-38).

Typically, in trauma, the ipsilateral sternocleidomastoid muscle is in spasm. This differs from torticollis from other causes (benign paroxysmal torticollis, cervical lymphadenitis, cervical spine/cord tumours, posterior fossa tumours) where the contralateral sternocleidomastoid is in spasm (37).

Despite the fact this little girl's neurological assessment remained normal, it was decided to proceed to MRI under general anaesthesia.
This demonstrated atlanto-axial rotatory subluxation.

This case emphasises the concerning nature of traumatic torticollis, even in the absence of neurological signs or symptoms.

Discussion of injury patterns

Injuries sustained by mechanism (33):

Hyper-flexion	Hyper-extension	Axial Load
Flexion teardrop	Hyperextension dislocation	Burst fracture (If occurs to C1 the eponym of Jefferson applies)
Bilateral facet dislocation	Extension teardrop	
Unilateral facet dislocation	Hangman's fracture (C2 Pedicles)	
Anterior subluxation		
Wedge fracture		
Spinous process fracture		

Falls from elevation, MVCs, being stuck by motor vehicles while walking or riding and blunt blows to head and neck are more likely to result in axial (C2 and above) CSIs.

Sports related cervical spine injuries are more likely to result in injuries to the sub-axial (below C2) region or SCIWORA. Children involved in diving and motor sports (All-terrain-vehicles and motorcycles) are more likely to sustain sub-axial cervical spine injuries (8).

X-ray interpretation session

In addition to the links given at the start of this material, please see the companion document to this guide offering further coverage of cervical spine imaging.

QUIZ

Question 1.

What percentage of paediatric spinal injuries are located in the cervical region?

A - 12% **B - 40%** **C - 50% or more** **D - 2%**

The Cervical spine is overrepresented as the region where more than half of all paediatric spinal injuries occur and the main reason for this is the relatively larger head size leading to the fulcrum of flexion being in the cervical column.

Question 2.

Which of the following mechanisms in history are concerning for a cervical spine injury?

A - Motor Vehicle Collision at a speed of above 30kph (18mph)

B - Diving into a pool

C - Fall from greater than body height

D - Transient neurological symptoms

E - All of the above

Expert consensus on factors which are suspicious for a CSI include: persistent neck pain, child or parent feeds like the child has an abnormal head position, difficulty with neck movement, fall >1m or 6 steps of stairs or fall from greater than body height, hyperextension injury, acceleration-deceleration injury involving the head or clothes-lining (blunt trauma to the head/neck by a stationary object while the patient is in motion), bicycle collision, pedestrian versus bicycle, accidents involving motorized recreational vehicles, horse riding accidents, current or transient neurological symptoms (motor or sensory): weakness, paraesthesia, lightning or burning sensation down the spine or radiating to an extremity, neurological symptoms related to neck movement.

Question 3.

Plain films are not sensitive enough in children to be our first choice in most circumstances where imaging of the cervical spine is deemed necessary.

A - True

B - False

The sensitivity of two or more radiographic views for detecting cervical spine injury has been reported to be in the region of 85-94%, whereas CT ranges from 81-100%. These figures reflect the unique anatomical challenges inherent in interpreting images in this patient cohort, particularly those under the age of 8 years old.
In adults, by comparison, CT sensitivity sits around 97-100%.
This makes plain films a higher yield modality in the paediatric population, backed up by CT where plain film findings are abnormal or ambiguous.

Infographic of the take home tips

1. Cervical spine injury represents 1-2% of all paediatric trauma.
2. A good clinical assessment is paramount. Know the concerning history and examination features for cervical spine injuries.
3. Know how to handle the suspected spinal injury patient with care.
4. Be aware of your local pathways and protocols for this injury.
5. Always ask for senior help in selecting and interpreting cervical spine imaging and performing clinical clearance.

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