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Safe management of acute cervical spine injuries

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- Cervical spine injuries are frequent and often caused by a blunt trauma mechanism. They can have severe consequences, with a high mortality rate and a high rate of neurological lesions.
- Diagnosis is a three-step process: 1) risk assessment according to the history and clinical features, guided by a clinical decision rule such as the Canadian C-Spine rule; 2) imaging if needed; 3) classification of the injury according to different classification systems in the different regions of the cervical spine.
- The urgency of treatment is dependent on the presence of a neurological lesion and/or instability. The treatment strategy depends on the morphological criteria as defined by the classification.

Keywords: cervical spine; trauma

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Introduction

Epidemiology, injury mechanisms and patho-biomechanics

Cervical spine injuries are found in about 2% to 3% of all blunt trauma victims.[1-3] Between 19% and 51% of all spinal injuries are located in the cervical spine.[4,5] Cervical spine injuries have the highest reported mortality rate of all spinal injuries, as these injuries have a high incidence of spinal cord injury, may complicate intubation and are often associated with traumatic brain injury.[6] The age distribution shows two peaks between the ages of 20 to 45 years and 70 to 80 years,[7] and the incidence rate per blunt injury shows an increasing risk for cervical spine injury with increasing age.[7] Risk factors include male gender and age older than 64 years.[7]

Motor vehicle accidents are the most common mechanism of injury and account for about half of the injuries.[1] Falls from less than 2 m still account for about 20% of all injuries. Sports injuries also play a significant role.[1]

From the biomechanical point of view, indirect, blunt trauma to the cervical spine is the major mechanism. The direction and magnitude of the experienced forces and moments will result in specific injury patterns along the upper and lower cervical spine. For instance, an axial load onto the head might create either an impression fracture of the occipital condyles, an atlas ‘ring’ burst fracture or a compression fracture of a subaxial vertebral body.[8-10] In contrast, sagittal acceleration and deceleration (whiplash mechanism) is likely to cause a subaxial facet joint subluxation along with a disruption of the posterior tension band.[11] Hyperextension or hyperflexion of the upper cervical spine might create an axis ‘ring’ fracture or an odontoid fracture.[12-14]

Diagnostic work-up of cervical spine trauma

General considerations

Even severe cervical spine injuries can occur in everyday life events, so a typical emergency department physician will face a patient with possible c-spine injury in nearly every shift. Due to the frequency of possible trauma mechanisms, radiographic evaluation and associated radiation exposure should be weighed against the possible fatal consequences of an overlooked injury.

The recommended approach is to utilize diagnostic modalities with high availability and high sensitivity but moderate specificity as a primary screening tool as a first step.

In a second and maybe third step, suspected injuries can then be further clarified by using modalities of lower availability but higher diagnostic value. In the cervical spine, a clinical algorithm is recommended to sort out patients with a very low probability of cervical spine injury and then imaging should be performed on the remaining patients. This approach has shown to reduce imaging efforts while still providing a high level of diagnostic security, without missing significant injuries.

Table 1. NEXUS low-risk criteria[3]

NEXUS low-risk criteria
Cervical spine radiography is indicated for patients with neck trauma unless they meet all of the following criteria:
No posterior midline cervical spine tenderness
No evidence of intoxication
A normal level of alertness (score 15 on the Glasgow Coma Scale)
No focal neurological deficit
No painful distracting injuries

Clinical algorithms

The NEXUS Criteria[3,15] define five anamnestic (based on history) and clinical examination low-risk criteria, which allow imaging to be minimized after blunt cervical trauma (Table 1). The Canadian C-Spine rule[16] consists of a three-step process, checking for: 1) a list of three high-risk criteria that directly mandate imaging; then 2) checking for a list of five low-risk criteria, which allow for a safe clinical examination; and 3) as a last step, focused clinical examination.

Both of these clinical decision rules have shown a good sensitivity in the range of 90% to 100% in several large prospective cross-sectional studies. In a direct comparison, the Canadian C-Spine rule showed slightly higher diagnostic values, which should be weighed against the (slightly) higher complexity of its application.[17]

CT

When it comes to imaging, as indicated by the aforementioned clinical decision rules, we recommend a CT scan of the whole cervical spine as a primary option. CT is available in the majority of trauma centres around the clock, and has a proven high diagnostic value for bony as well as for most of the disco-ligamentous injuries. Sensitivity for any cervical spine lesion is around 87.5% and sensitivity for any unstable lesion reaches 100% (compared with MRI as the gold standard).[18] It provides good visualization, especially of the transitional zones (cranio-cervical and cervico-thoracic), which often cause problems with conventional radiographs. Compared with MRI, there are fewer contraindications such as heart pacemakers or claustrophobia, and the evaluation of unstable, unconscious and ventilated patients is easier due to shorter examination times; in addition, there is no need for the use of special MRI-compatible equipment.

MRI

MRI in the c-spine trauma patient is a good option in very specific situations: for instance, when a bony lesion is suggestive of an additional ligamentous injury, which might alter the treatment strategy. Examples are the evaluation of integrity of the transverse atlanto-axial ligament in a Jefferson fracture of the atlas or the C2/C3 disc in axis 'ring' fractures. Another frequent indication is screening for an exaggerated myelopathy in a patient with a neurological deficit which does not show any signs of injury in the CT scan (so-called SCIWORET; spinal cord injury without radiographic evidence of trauma).[18] In children and adolescent patients, MRI is a good option to screen for any lesion without exposing the vulnerable patient to the radiation of a CT scan. Recent studies and meta-analyses have shown there is very little further benefit of MRI compared with CT in the detection of cervical spine injuries in the unconscious or awake patient,[19,20] although a missed injury rate of up to 5% of significant lesions has been reported for CT against MRI.[21] In addition, MRI is a good diagnostic tool to detect minor injuries such as vertebral bone bruise in adjacent levels.

Conventional radiography

Although the benchmark for c-spine screening for many years, conventional radiography has been shown to have a low sensitivity, especially in the transitional regions.[22,23] With the development and validation of the aforementioned clinical decision rules, the importance of conventional radiography for the detection of cervical spine injuries has decreased significantly.

Physician-guided fluoroscopy

In the neurologically intact patient who shows suspicious findings for segmental instability on CT or MRI, a dynamic fluoroscopy in flexion and extension might add diagnostic value. This examination should be performed by an experienced physician only.

A static flexion/extension radiograph without passive guidance by a physician is not recommended due to proven lack of therapeutic consequences.[24]

Vascular imaging including CT- and MR-angiography

The anatomical proximity of the cervical spine and the vertebral artery in the transverse foramen and above pose a unique situation with specific needs for vascular imaging in certain injury patterns.

Although the specific risk factors for vertebral artery injury in the c-spine have not been finally determined yet, we recommend performing vascular imaging in the following conditions:

- a fracture line running through the transverse foramen
- a severe facet joint fracture
- a facet joint subluxation or dislocation
- prior to posterior surgical stabilization of the occipital-atlanto-axial joint complex
- presence of any neurological deficit, which might be caused by cerebral hypoperfusion.

The diagnostic value of CT-angiography and MR-angiography seem to be quite similar, so there is no preference for either of the modalities.[25,26]

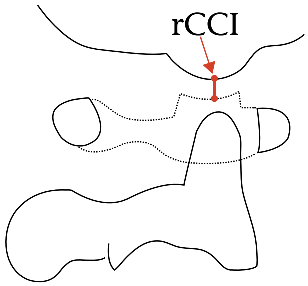

Fig. 1 Measurement of the revised cranio-cervical interval (rCCI), which is the most sensitive parameter for the diagnosis of atlanto-occipital instability available.[26]

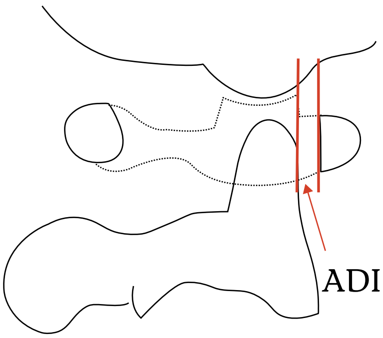

Fig. 2 The anterior atlanto-dental-interval (aADI) is the distance between the anterior cortex of odontoid peg and the posterior cortex of the anterior atlas arch.

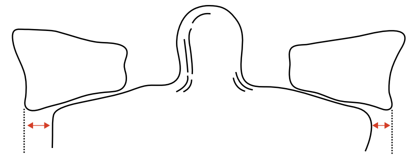

Fig. 3 Rule of Spence. Measurement of the atlas lateral mass overlap in mm.

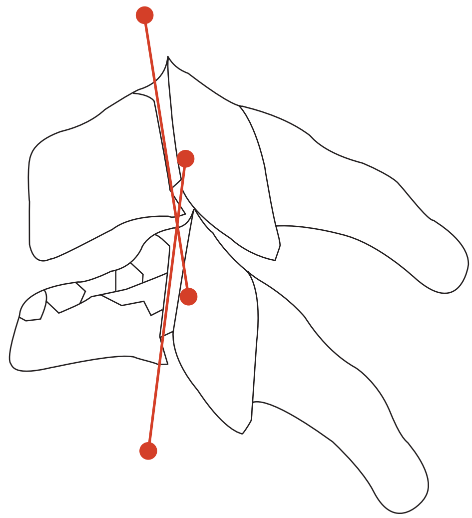

Fig. 4 The posterior tangent method to estimate the angle between two vertebral bodies in a compression type injury of the lower cervical spine.

Some important radiographic measures

Cranio-cervical interval (CCI)

For any occipital-cervical instability, several radiographic parameters have been proposed.

The best sensitivity and specificity has been shown for the revised CCI (rCCI), developed by Pang et al.[27] In the sagittal plane, the distance between the occipital condyle and the facet joint surface of the atlas lateral mass is measured (Fig. 1).[28] If the value exceeds 2.5 mm, an unstable lesion is likely.

The anterior atlanto-dental-interval (aADI)

The aADI is used to detect translatory unstable lesions of the transverse atlanto-axial ligament. It is measured between the anterior cortex of the odontoid peg and the posterior cortex of the anterior ring of the atlas. In the adult, values more than 3 mm are regarded as abnormal (Fig. 2).

Lateral overlap (rule of Spence)

In atlas ring fractures, the lateral overlap of the atlas lateral masses against the lateral borders of the axis joint surface in the anteroposterior view have been regarded as an indicator for transverse ligament rupture (Fig. 3). Spence et al[29] determined a lateral overlap of more than 6.9 mm as a predictor for transverse ligament insufficiency in a cadaveric biomechanical study. In a recent biomechanical study, this value was reduced to a value of around 3.8 mm,[30] but the clinical significance of an absolute value was questioned, since unstable lesions can also appear with lower values.

Endplate angle

The endplate angle, also known as the Cobb angle, is the angle between the endplates of two adjacent or distant vertebrae. In traumatic disorders, it is mainly used to decide upon the need for surgical intervention due to a kyphotic deformity in compression fractures of the vertebral body.

A slightly higher reproducibility has been shown for the posterior tangent method, which uses the angle between the posterior walls of adjacent vertebral bodies (Fig. 4).[31]

Facet joint overlap

In the lower cervical spine, the percentage of overlap of the facet joint surfaces of two neighbouring articular

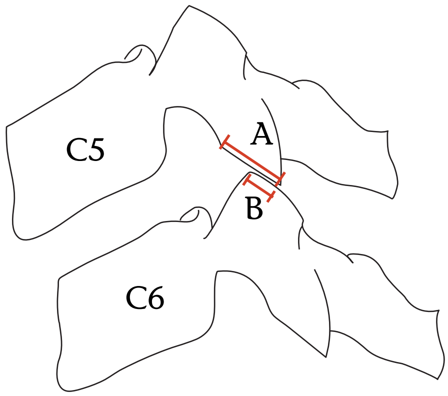

Fig. 5 Facet joint overlap. If the ratio B:A is less than 0.5, the joint is considered to be unstable.

processes can indicate an unstable lesion of the facet joint. If the articulating surfaces overlap less than 50% of their length, the joint is considered to be unstable (Fig. 5).

Pre-vertebral soft tissue

The pre-vertebral soft-tissue swelling was considered an indirect sign for cervical spine injury. As a rule of thumb, the mnemonic 'six at two, twenty-two at six' describes the assumed normal values for pre-vertebral soft-tissue thickness at the second and sixth cervical vertebra in mm. In contrast, a recent diagnostic study proved that measurement of the pre-vertebral soft-tissue thickness has a very low sensitivity, but good specificity, especially for the soft tissue at C6.[32]

Upper cervical spine

Classification of upper cervical spine injuries

Fractures of the occipital condyles can be classified according to Anderson and Montesano.[8] They differentiated three types of injuries:

1. Impression fractures of the occipital condyle (usually stable);
2. A skull base fracture radiating into the occipital condyle (usually stable);
3. An avulsion fracture of the occipital attachment of the Alar ligament (potentially unstable).

Types 1 and 2 are regarded as stable and can be treated in a cervical collar. Type 3 should cause suspicion of an unstable injury of the occipito-cervical junction. If there are any other signs of an instability of the cranio-cervical junction (i.e. soft-tissue oedema in the MRI or increased CCI in the sagittal CT-scans), a surgical stabilization is advised.

For atlas fractures, there are several classification systems available. The three most commonly used are the Jefferson classification,[9] the Gehweiler classification[33] and the Dickman sub-classification of the latter.[34]

The Jefferson classification differentiates between five different fracture types (anterior arch, posterior arch, 'burst', lateral mass and lateral mass plus posterior arch). However, several authors have added numbers to this description, defining posterior alone and anterior alone fractures as Jefferson type I. A fracture of both arches (four-part 'burst' fracture) was described as type II and a lateral mass fracture with or without a posterior arch fracture as type III. Type I is the most common followed by type III and type II.

The Gehweiler classification differentiates five subgroups of atlas fractures (Fig. 6).[33] A type 1 atlas fracture is an isolated fracture of the anterior arch, whereas a type 2 atlas fracture is an isolated, usually bilateral, fracture of the posterior atlas ring. A fracture of the anterior and posterior arch of the atlas, the 'Jefferson-fracture' is classified as Gehweiler 3. Gehweiler 3 fractures may be further subdivided into stable and unstable injuries. In stable injuries, the transverse atlantal ligament is intact (so-called type 3a). A fracture of both the anterior and posterior atlas ring and a lesion of the ligamentum transversum atlantis, is regarded as unstable (so-called type 3b). The type 4 fractures are fractures of the lateral mass. Type 5 fractures are isolated fractures of the C1 transverse process.

To further describe the morphology of a lesion of the transverse atlanto-axial ligament in Jefferson burst or Gehweiler Type 3 fractures, Dickman sub-divided these lesions in four different categories (Table 2).[34]

Odontoid fractures are commonly classified according to Anderson/D'Alonzo (Fig. 7).[35] They distinguished three types of injuries: type 1 is the rare fracture of the tip of the odontoid peg, which is equivalent to an avulsion fracture of the alar ligament; type 2 is a fracture running through the base of the odontoid peg and is usually regarded as unstable; type 3 involves the base of the odontoid peg and runs in a u- or v-shape through the body of the axis, which creates a large surface with possible interdigitations. They have a good healing capability and are usually regarded as stable.

Grauer et al[36] further subdivided the type 2 injuries regarding the orientation of the fracture plane or presence of comminution, which has implications for the choice of treatment (Fig. 8).

Axis ring fractures are defined as fractures resulting in a separation of the C2-vertebral body and the posterior elements. They are also called 'traumatic spondylolisthesis of the axis' or 'hangman's' fracture. There are several classifications available for axis ring fractures. The most common are the classification according to Effendi

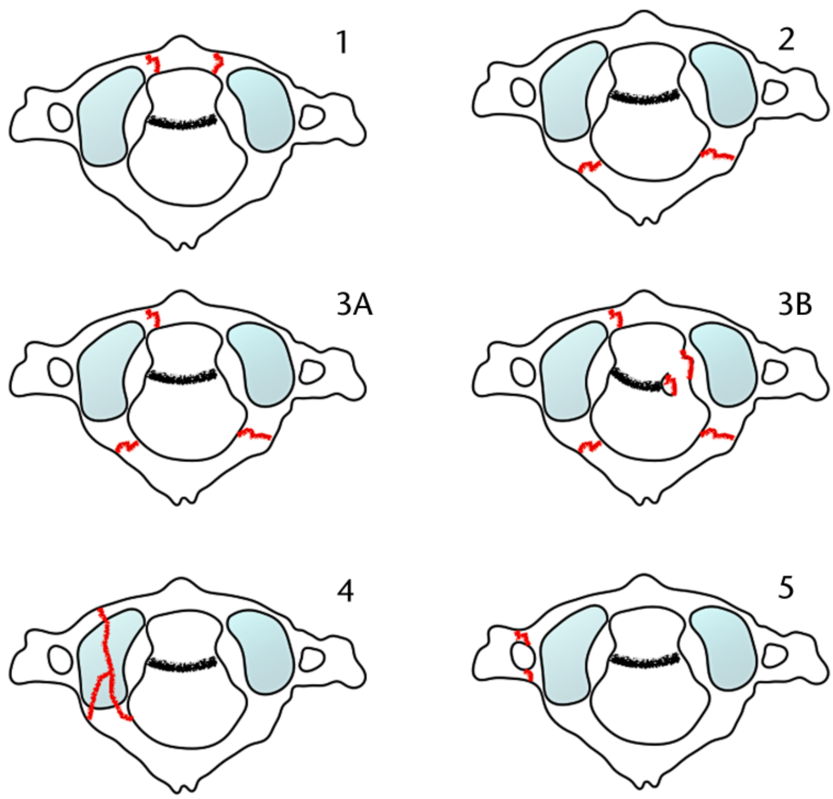

Fig. 6 Gehweiler classification of atlas ring fractures.[31]

Table 2. Dickman's subdivision of Gehweiler type 3 fractures[34]

I. **Intraligamentous lesion**
   A. mid-substance tear
   B. near insertion tear
II. **Bony avulsion**
   A. isolated bony avulsion
   B. combination with lateral mass fracture

et al,[37] its modification according to Levine and Edwards[38] and the classification according to Francis and colleagues.[39] Since they were introduced in the 1980s, they are based on static radiograph and therefore do not further examine any functional instability or the presence of a lesion to the disco-ligamentous structures, although this topic is directly related to the decision-making process regarding treatment. It is important to realize that the critical step is to comprehend the pathology at the C2-C3 disk.

The Effendi classification is based on radiographic signs in the lateral view.[37] Levine and Edwards published their classification system, based on the previous work of Effendi, in 1985.[38] Both take into account the amount of displacement and angulation of the C2-vertebral body against the C3 vertebral body as well as the position of the

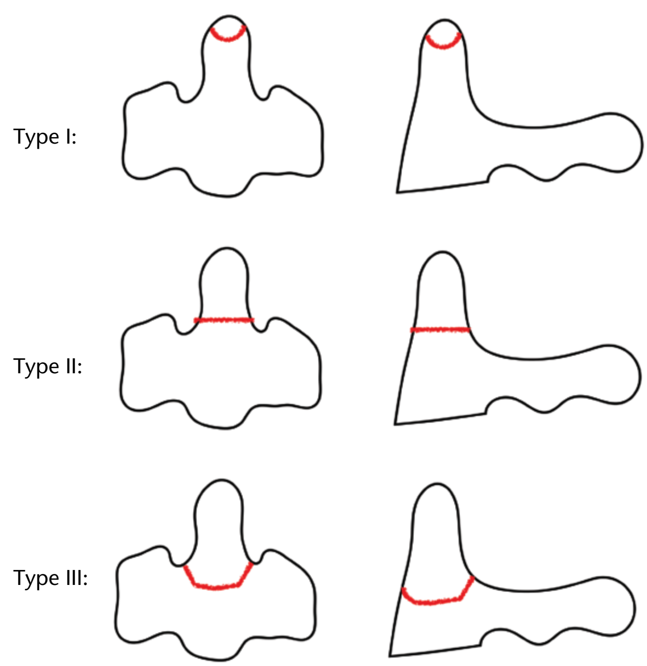

Fig. 7 Classification of odontoid fractures by Anderson and D'Alonzo.[33]

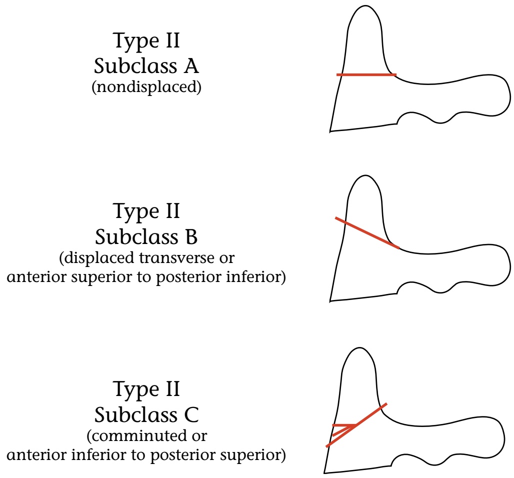

Fig. 8 Grauer subclassification of Anderson/D'Alonzo Type II injuries regarding the orientation of the fracture plane.[34]

C2-C3 facet joint. Although the Effendi classification is rather imprecise in setting the borders between the type I and II lesions ('minimal displacement' and 'normal disk space' *versus* 'displacement' and 'abnormal disk'), Levine and Edwards do quantify the cut edge between the two types at least for anteroposterior translation (3 mm), but neither do that for angulation ('no angulation' *versus* 'significant angulation').

A locked C2-C3 facet joint constitutes a type III lesion in both classification systems.

Although these classification systems were developed more than 30 years ago, before the CT and MRI era, they still are widely used in the everyday clinical setting.

The atlanto-occipital dissociation is a severe injury with a high rate of fatal outcomes. The occipito-atlantic joint complex is usually a very tight joint. Any dislocation is indicative of a severe and life-threatening instability, so the major diagnostic goal is to detect such an injury at all rather than to classify its sub-groups. The most cited classification is that proposed by Traynelis et al[40] and it divides the injuries based on the direction of the dislocation as seen on the radiograph (anterior, posterior, longitudinal). However, due to the high rate of instability of the injuries, the direction of the dislocation is only a snapshot of the moment and usually has no prognostic or therapeutic consequences.

Another classification proposed by Horn et al[41] uses a different approach, taking into account different grades of abnormal findings in the CT and MRI and helping to determine the appropriate therapy. The authors differentiate two grades of atlanto-occipital dislocation. Grade I lesions have normal findings on CT and only moderately abnormal findings on MRI. These injuries are regarded as stable and can be treated conservatively in a hard cervical collar. Grade II lesions have abnormal findings on CT and grossly abnormal findings on MRI.

Lesions of the transverse atlanto-axial ligament may lead to a translatory instability in the anteroposterior direction. They are classified according to De La Caffinière et al,[42] depending on the radiographic aADI. Type 1 shows an aADI of 4 mm to 5 mm, Type 2 of 6 mm to 10 mm and Type 3 of 11 mm to 15 mm.

A rotatory atlanto-axial instability is very rare. They are classified according to Fielding and Hawkins[43] into four types: 1) rotatory subluxation without any anteroposterior translation; 2) rotatory subluxation with an anterior shift of 3 mm to 5 mm; 3) rotatory subluxation with an anterior shift of more than 5 mm; 4) rotatory subluxation with a posterior shift.

Treatment options: surgical

Occipito-cervical stabilization/fusion is performed by mounting a plate on the occipital skull, preferentially in the midline region, where skull bone is thickest, and connecting it in a screw-rod construct to any lateral mass or pedicle screws below. It is indicated in any severe instability of the occipital-atlantal joint complex (Horn grade II/ Anderson/Montesano type 3). If an unstable atlas ring fracture with the need for surgical fixation shows a destroyed lateral mass, which makes screw insertion impossible (combination of Gehweiler 3b and 4), extension to the occiput might be necessary as well.

Another indication for occipital-cervical fixation is seen in dislocating sagittal split fractures of the lateral mass of the atlas (Gehweiler 4), which tend to dislocate laterally and therefore lead to joint surface incongruence in the occipital-atlantal joint.

Inclusion of the occiput into a cervical instrumentation will cause significant soft-tissue disturbance as well as loss of motion especially in the flexion/extension movement, so the decision has to be made carefully.

The instrumented fusion or stabilization of the atlanto-axial joint complex is indicated in any severe instability of this segment. Possible options are a trans-articular screw fixation according to Grob and Magerl[44] using two parallel-oriented cortical bone screws crossing the atlanto-axial joints plus a posterior fusion and tension band according to Gallie, or an angle stable internal fixator construct with lateral mass screws in C1 and pedicle screws in C2, as described by Goel[45] or Harms and Melcher.[46]

Typical indications include: unstable/dislocated odontoid fractures, which are not suitable for anterior odontoid screw fixation (Anderson/D'Alonzo type 2/Grauer type C injuries); pseudarthroses or locked dislocations of older odontoid fractures after conservative treatment; unstable atlas ring fractures (Gehweiler 3b), which are not suitable for isolated osteosynthesis of the atlas.

In Jefferson 'burst' fractures/Gehweiler 3b fractures, the integrity of the atlas ring has to be reconstructed to prevent lateral dislocation of the lateral masses and consequent joint

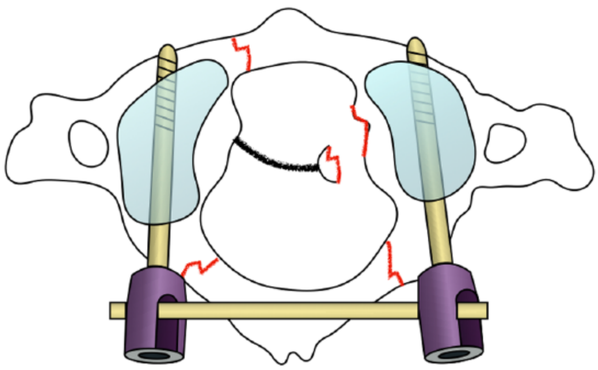

Fig. 9 The isolated osteosynthesis of the atlas is technically demanding, but motion-preserving. This advantage justifies its increasing application in unstable atlas injuries.

incongruence. The benchmark for surgical treatment for many years was atlanto-axial fusion, which sacrificed more than half of the axial rotation motion of the cervical spine. To prevent the detrimental result of this procedure, direct osteosynthesis of the atlas ring gained more and more favour (Fig. 9). Although technically difficult, it preserves the rotational capabilities of the Atlanto-axial joint complex. It is suitable in unstable isolated fractures of the atlas ring (Gehweiler 3b), which do not show any involvement of the facet joint surface. Until now, clinical data are unclear about the significance of the type of lesion to the transverse atlanto-axial ligament according to the Dickman classification.[47]

The anterior odontoid screw fixation is a minimally-invasive, motion-preserving therapy for unstable fractures of the odontoid peg. It can be applied, when several conditions are met: healthy bone stock at the site of screw insertion; the approach in the direction of the screw trajectory should be checked prior to surgery, hyperkyphotic deformity might obviate the access; the fracture plane should be almost perpendicular to the screw trajectory (Grauer type IIA or B); there should be no comminution.

Treatment options: conservative

Conservative treatment is indicated in all fractures which are not dislocated and show no other signs of instability. This is valid for Anderson/Montesano type 1 and 2 injuries, Gehweiler type 1, 2, 3a, 4 (with exceptions) and 5 as well as Effendi/Levine I and II injuries. Conservative treatment includes a cervical spine immobilization in a cervical collar for around six weeks, analgaesic medication and physical measures, such as fango or kryotherapy.

Lower cervical spine

Classification of lower cervical spine injuries

Injuries of the lower cervical spine (i.e. from C3 to C7) can be classified according to the Arbeitsgemeinschaft für Osteosynthesefragen (AO) Magerl, Sub-axial Injury Classification or the recently developed AOSpine Classification for Sub-axial Cervical Spine Injuries.[48-50]

Due to the proven reliability and the combination of morphological and clinical parameters, we recommend the use of the AOSpine classification for sub-axial cervical spine injuries.[50]

According to this classification, the main injury type is classified either as a compression injury (Type A), disruption of either the anterior OR the posterior tension band (Type B), or disruption of both the anterior AND the posterior tension band with translatory instability (Type C).

Further relevant parameters are the type of facet joint injury (coded by the letter F), a concomitant neurological injury (N) as well as general comorbidities (M), which have significant impact on therapeutic decisions.

Type A injuries are subdivided into five sub-types: A0: isolated spinous or transverse process fracture without any effect on stability or a bone bruise in the MRI without any deformation of the vertebral body; A1: single endplate impression without posterior wall involvement; A2: fracture running through both endplates without posterior wall involvement (coronary split fracture); A3: posterior wall involvement, one endplate remains intact (superior or inferior burst fracture); A4: posterior wall involvement, both endplates are affected (complete burst or burst-split fracture).

Type B injuries are further divided into three sub-types: B1: pure osseous injury of the posterior tension band (‘chance-fracture’); B2: osteo-ligamentous or ligamentous disruption of the posterior tension band; B3: disruption of the anterior tension band (hyperextension injury).

Type C injuries are not further divided into sub-types. The neurological status is grouped into five different classes: N0: no neurological impairment; N1: transient neurological impairment, which has already resolved at the time of examination; N2: persisting radicular symptoms, either motor or sensory; N3: incomplete spinal cord injury (ASIA B-D); N4: complete spinal cord injury (ASIA A).

Facet joint injuries are divided into four sub-groups: F1: non-displaced fractures which do not affect more than 1 cm or more than 40% of the facet joint dimension; F2: displaced fractures or fractures affecting more than 1 cm or more than 40% of facet joint dimension; F3: fracture of the pedicle and the lamina of the same vertebral body, which separates the lateral mass from the rest of the vertebra (‘floating lateral mass’); F4: subluxation of more than 50% or perched luxation. These injuries are a sign of severe disruption of the posterior tension band and therefore an indicator for at least a B-type or even C-type injury.

In case of a bilateral injury of the identical severity, the letters ‘BL’ are added after the code.

Some specific comorbidities have influence on the therapeutic regime and are coded as so-called ‘modifiers’ with the letter 'M': M1: this is a posterior capsulo-ligamentous injury without complete disruption, mainly seen on the MRI, it usually shows focal mid-line tenderness; M2: this is a critical disc herniation behind the posterior wall of the affected vertebral bodies; M3: stiffening/metabolic disease (for example, ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis); M4: injury of the vertebral artery.

Further information on the classification systems may be obtained from the original publications.[50]

Treatment options

Possible therapeutic options include early functional conservative management with external immobilization using a cervical collar with different degrees of rigidity, Halo vest immobilization as well as anterior and/or posterior stabilization with decompression if indicated.

In general, the therapeutic strategy, which should be closely re-evaluated over the course of treatment, depends on two main criteria: first on the injury morphology; and second, on individual patient criteria such as age, general health, bone quality and biomechanically important bony changes such as diffuse idiopathic skeletal hyperostosis or ankylosing spondylitis.

The assessment and classification of the injury according to the AOSpine classification for sub-axial injuries facilitates therapeutic decision-making. Further, the risk of progressive kyphotic angulation and consequent deterioration of the sagittal profile should be taken into account.

The urgency for surgical management mainly depends on existent or imminent neurological deficits and on the degree of instability.

A0-Fractures are stable and are treated with early functional conservative therapy with adequate pain medication. A soft cervical collar may be used for pain relief for a short period (maximum six weeks).

A1-Fractures are stable and are in most cases managed with early functional conservative therapy, as described for A0-Fractures, with excellent results.

In rare cases, a significant kyphotic deformity is present or may develop in the course of treatment; thus the monosegmental kyphotic angulation should be measured initially, during the course of treatment and after six weeks. An increase in kyphotic angulation, > 15° difference to the adjacent segments, may be an indication for anterior monosegmental (rarely bisegmental) fusion in view of preservation of the sagittal cervical profile.

A2-Fractures are stable and are usually managed with early functional conservative therapy similarly to A1-Fractures. Also in A2-Fractures an increase in kyphotic angulation, > 15° difference to the adjacent segments, may be an indication for anterior fusion in view of preservation of the sagittal cervical profile; however, in contrast to A1-Fractures a bisegmental fusion should always be performed.

A3-Fractures include the risk of posterior wall dislocation and of concomitant neurological impairment. Further, the risk of secondary kyphotic angulation is considerably higher as compared with A1- and A2-Fractures. Therefore, anterior fusion is recommended either in a mono- or bisegmental manner, depending on the degree of vertebral destruction.

Oligo-symptomatic patients with a kyphotic angle of less than 15° and no relevant narrowing of the spinal canal with preservation of the liquor spare space may be treated conservatively with a rigid cervical collar for six weeks. In these cases, the bi-segmental kyphotic angulation should be measured initially, during the course of treatment and after six weeks closely.

A4-Fractures show a high degree of vertebral destruction with involvement of both endplates and both adjacent discs and should be recognized as unstable injuries. The risk of posterior wall dislocation and of concomitant neurological impairment as well as the risk of secondary kyphotic angulation is higher as compared with A3-Fractures. Therefore, bi-segmental anterior fusion is recommended.

B1-Injuries are unstable and posterior bi-segmental instrumentation in terms of a tension-band fixation is recommended. Fusion may not be performed in order to allow re-mobilization of the two motion segments after implant removal following bony healing.

Despite their instability, these injuries exhibit a tendency for good bony healing and may be suitable for conservative treatment in a hyperextended cervical orthosis in individual cases. However, this requires immediate radiological control following reduction in the hyperextended cervical orthosis and short-term follow-up in the course of treatment.

B2-Injuries are unstable and surgical stabilization is recommended. The surgical approach (anterior, posterior or combined) as well as the decision for fusion length (mono- or bi-segmental) mainly depends on the A-component (degree of vertebral body destruction) of this injury.

B3-Injuries are unstable and anterior mono-segmental fusion is recommended. In cases of ankylosing spondylitis (M3) different principles should be applied; due to the severe rigidity of the whole spine, a short segment anterior instrumentation is subject to huge lever moments, which poses the risk for implant failure. Additionally, severe kyphotic deformity might obviate an anterior approach to the cervical spine. In the majority of ankylosing spondylitis cases, the best option is a posterior long-segment instrumentation.

C-Injuries are highly unstable and urgent surgical stabilization is recommended. Due to the high variability of C-Injuries an individual therapeutic strategy is indicated. However, the surgical approach (anterior, posterior, combined) as well as the decision for fusion length (mono-, bi- or multi-segmental) is highly influenced by the A-component (degree of vertebral body destruction) of this injury.

F1-Injuries are stable and are treated with early functional conservative therapy with adequate pain medication. A cervical collar may be used for pain relief for a short period (maximum six weeks). Radiological follow-up in the course of treatment and after six weeks is recommended to recognize secondary dislocation.

F2-Injuries are usually components of unstable B- or C-Injuries, which dictate the surgical strategy. Possible nerve root compression by the facet fragment may therefore require an additional posterior approach in case of an anterior stabilization.

F3-Injuries are components of unstable B- or C-Injuries, which dictate the surgical strategy. Possible nerve root compression by the facet fragment may therefore require an additional posterior approach in case of anterior stabilization. Because the underlying instability usually involves the cranial and caudal adjacent segments, they both should be included in the stabilization. This requires a bi-segmental instrumentation in every case.

F4-Injuries are components of unstable B- or C-Injuries, which dictate the surgical strategy. Possible nerve root compression by the facet fragment may therefore require an additional posterior approach in case of an anterior stabilization.

Unilateral or bilateral locked facets require a differentiated concept in order to ensure a safe reduction without neurological compromise.

In general, closed reduction should be performed under fluoroscopy by an experienced spine surgeon under OR standby or directly in the OR.[51] To ease closed reduction patient relaxation is recommended. Because there is an inverse correlation between time since luxation and reduction success, closed reduction should be performed as early as is safely possible.

In neurologically-intact patients, it is recommended to perform closed reduction in the anaesthetized patient in the OR directly prior to surgery. In case a closed reduction is not possible, immediate anterior decompression is performed, followed by an open reduction attempt with a distractor (e.g. Caspar-distractor). Usually, reduction should be achieved with this algorithm in over 95% of locked facets.[52,53] In the rare case that an anterior open reduction may not be achieved, the reduction must be performed by an open posterior approach following the anterior decompression.

In cases where the surgeon prefers primary open posterior reduction, a pre-operative MRI is mandatory to exclude herniated disc material which may constrain the spinal canal following reduction without anterior decompression.

Patients with neurological compromise should undergo reduction as soon as possible; however, the benefits and risks of immediate reduction should be thoroughly assessed.

Conclusions

Cervical spine injuries are a common entity in major trauma patients but can also occur in minor trauma cases. Safe diagnosis mainly relies on screening for particular risk factors and clinical examination as well as CT imaging.

Classification and treatment should be applied specifically for the different regions of the cervical spine (craniocervical junction, upper cervical spine and lower cervical spine) due to their different anatomy and biomechanics. The major goal of classification is differentiating stable from unstable injuries. Treatment options include conservative treatment for stable injuries and stabilization and fusion for unstable injuries, often combined with surgical decompression. Except in the case of a severe neurological injury, the prognosis is usually quite good.

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