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ORIGINAL ARTICLE

Hangman's fracture: a clinical review based on surgical treatment of 15 cases

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Abstract

This is a retrospective analysis of cases with hangman's fracture. The subject of 'hangman's fracture' has been elaborately evaluated in the literature. The authors propose an alternative format of surgical treatment that is based on modification of existing classification schemes. During the period 2015 to March 2020, 15 patients having hangman's fracture were identified and were surgically treated. The clinical condition was classified on the basis of American Spinal Injury Association scale (ASIA scale) and VAS parameters. The patients were classified into 4 groups depending on the presence (or absence) of atlantoaxial and/or C2–3 instability. Surgical decisions were guided by the proposed classification. Clinical evaluation and dynamic CT scan were done at follow-up visits. During the average follow-up of 26 months, all patients are essentially asymptomatic. There was marginal restriction of extent of neck movements in all cases. There was solid bone fusion in all cases. The proposed novel classification scheme based on the presence of atlantoaxial and C2–3 instability assisted in directing the treatment strategy of hangman's fracture.

Keywords Hangman's fracture · Spondylolisthesis · Atlantoaxial instability

Introduction

The historical issues about naming of C2 pars fracture as 'hangman's fracture' and its consequences and associations have been elaborately discussed in the literature [14]. The nomenclature of posttraumatic C2 over C3 spondylolisthesis is frequently used. The wide range of non-surgical conservative options and surgical procedures recommended and conducted for the treatment of hangman's fracture are a testimony of incomplete or inadequate understanding of the subject [1, 2, 4, 6, 12, 13]. The classification system proposed by Effendi [3] and subsequently modified by Levine and Edwards [10, 11] has been followed to identify patients suitable for conservative non-surgical treatment and to design treatment strategy in those where surgery is indicated. On the basis of our experience with successful treatment of 15 cases, we describe our treatment strategy. We propose an alternative classification of hangman's fracture, particularly taking into additional consideration the presence of evidences of atlantoaxial instability. The classification scheme was essentially formulated on the basis of retrospective analysis of surgically treated cases. Incorporation of atlantoaxial instability has not been done in previously described classification schemes. Our experience suggests that the classification can be used to analyse the extent of fracture and its effects and to guide the surgical strategy. It was identified that 'high' vertebral artery loop in relationship with the C2 pars was present in all cases and the fracture line passed through the vertebral artery foramen in each case. Such vertebral artery correlation has not been described in association with hangman's fracture.

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Material and methods

During the period January 2015 to March 2020, 15 patients were identified to have hangman's fracture as per classically described parameters and were surgically treated. The cases are retrospectively analysed. Retrospective data collection was approved by the local ethics committee. Due consent of the patients was taken to include their data in the analysis. All the patients provided written informed consent before surgery, and all clinical tests and surgical procedures were conducted according to the principles of Declaration of Helsinki. Patients treated conservatively and without surgery were excluded from the analysis. Exact clinical details and radiographic data of these cases were not available for review.

The clinical condition was classified on the basis of American Spinal Injury Association scale (ASIA scale) and VAS parameters.

On the basis of retrospective analysis of radiographic images and the strategy of surgical treatment adopted, the patients were classified into 4 types depending on the presence (or absence) of indicators of atlantoaxial and C2–3 instability. Atlantoaxial instability was identified when the fracture line involved the C2 facet or when on neutral profile imaging the atlantoaxial instability as identified by the distance between the anterior border of facet of axis and anterior border of facet of atlas was more than 2 mm. C2–3 instability was identified when there were clear evidences of disruption of the C2–3 disc; on neutral profile imaging, the body of C3 was more than 5 mm anterior to the body of C3 and when there was an abnormal angulation of the C2 vertebra over C3 vertebra.

The proposed classification divided the Hangman's fracture into the following types (Figs. 1, 2, 3, 4, 5, 6, 7):

Type 1: No atlantoaxial or C2–3 instability (1 case)
Type 2: Presence of C2–3 instability and no atlantoaxial instability (6 cases)
Type 3: Presence of atlantoaxial instability and no C2–3 instability (2 cases)
Type 4: Presence of both atlantoaxial and C2–3 instability (6 cases)

Table 1 shows the clinical status, nature of the injury and the distribution of the patients according to the proposed classification.

All the patients were operated after placing them in cervical traction. The patients were placed in prone position with the head end of the operation table elevated by about 30°. The traction assisted in realigning the fractured segments and helped keeping the head and face away from the headrest and avoided their direct pressure contact [7, 8]. Atlantoaxial fixation was carried out with the technique described by the senior author in 1994 [7, 8]. The atlantoaxial joint was widely opened after elevating the C2 ganglion. The articular cartilage was denuded using sharp instruments or drill and bone graft was inserted and packed into the joint space. Plate/rod and screw fixation was then carried out. Bone graft (harvested from the iliac crest) was additionally placed in the midline after appropriately preparing the host bone.

In addition to difficulties related to distraction and separation of the fractured segments of C2 pedicle and relatively thin pedicle size, high vertebral artery loop in the pedicle-superior facet of C2 made screw insertion particularly tricky. Venous bleeding in the region also makes conduct of the surgery a formidable procedure. After appropriately preparing the region and protecting the vertebral artery, a screw guide hole was made into the C2 pedicle across the fractured segments using a power drill. Wherever necessary, the vertebral artery was mobilised out of its groove after its appropriate and wide exposure by drilling off the pedicular bone shell that covered the vertebral artery loop by our recently described technique [9]. A strong screw purchase of both sides of fractured segments was a key surgical issue and forms a primary stabilising foundation. The position of the patient under cervical traction that reduced the extent of deformation and the process of tightening the C2 screw were the factors that were seen to bring the two fractured segments closer without the need for any further manipulation. Whenever C2 pars screw insertion was not possible due to any anatomical or technical reason, the rostral screw was inserted into facet of atlas and the caudal screw was inserted in a transarticular fashion in C2–3 articulation (1 case) [5]. The two screws were then stabilised with a plate. C2–3 fixation was done by the transarticular technique described earlier by Camille and Saillant in 1972 [15].

After surgery, the patients were mobilised with a firm cervical collar and were advised to restrict neck movements for a period of about 2 months. The patients were reviewed at 6 weeks and 6 months after surgery and at subsequent hospital visits. Bone fusion was considered successful when at the end of 6 months there were no significant pain and other neurological symptoms, there was no evidence of implant malfunction, there was evidence of fusion across the articular surfaces of the atlantoaxial joint, and when there were no relative movements of the spinal bone components on dynamic neck movements.

Results

There were 12 males and 3 females in the series and their ages ranged from 7 to 65 years, the average being 38 years. The nature of injury and the primary symptoms at the time of admission, and the time elapsed after the injury and when surgical treatment was conducted are elaborated in Table 1. Table 1 also summarises the clinical condition before operation and at the time of last follow-up visit and also shows the spinal segments that were fixated.

In one case (case no. 1) (Fig. 1), atlantoaxial fixation was done as discussed. In 3 cases (case nos. 4, 12, 14, 15)

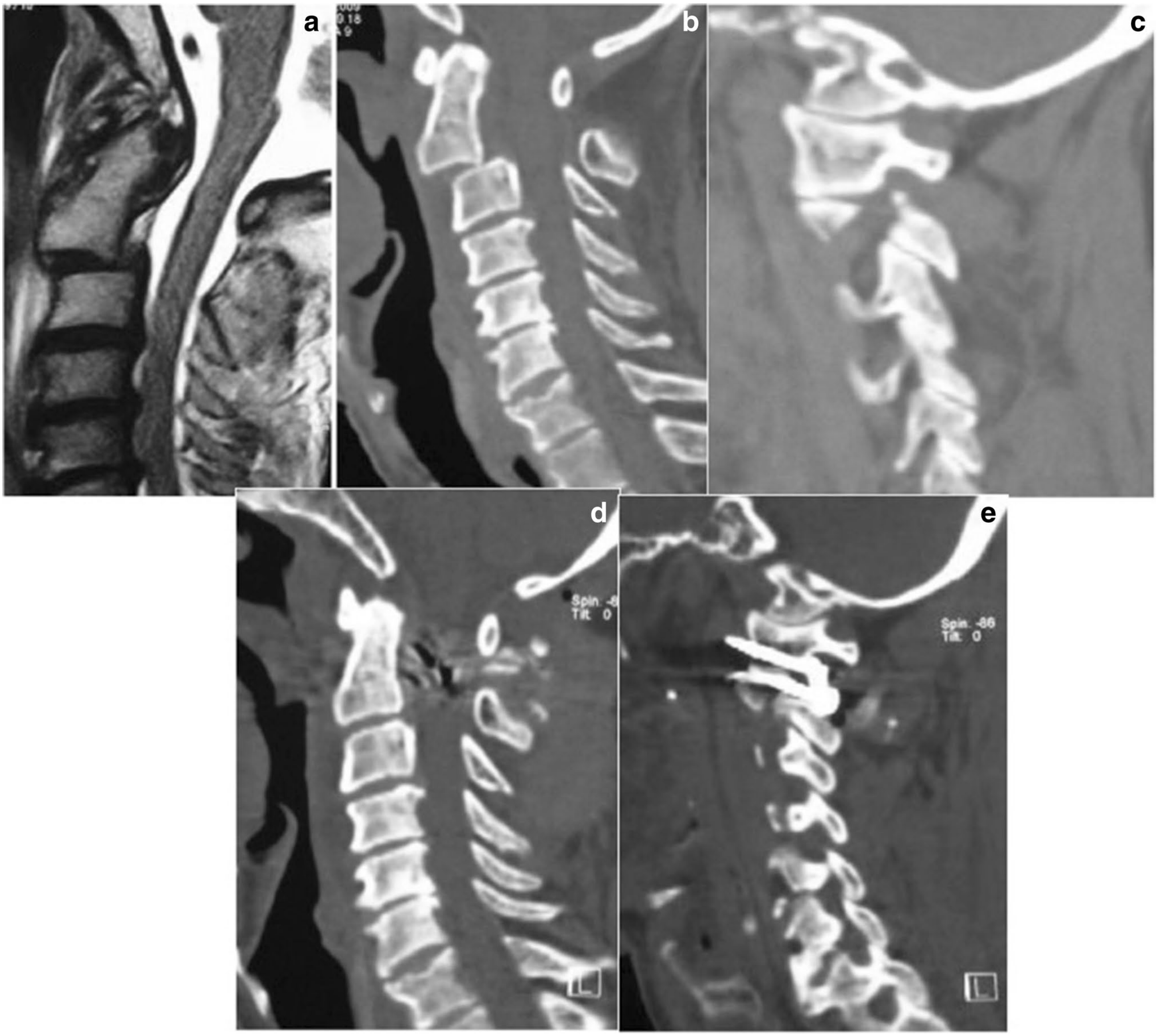

Fig. 1 (Case no. 1) Images of a 64-year-old male patient. A: T2-weighted MRI showing C2 over C3 listhesis. B: CT scan showing listhesis. C: CT scan shows the fracture line and distraction of the fractured segments. The fracture line passes through the facet of C2. C2–3 articulation is unaffected (type 4). D: Postoperative (after 2 days of surgery) CT scan showing reduction of C2–3 listhesis. E: Postoperative CT scan showing the implant. The C2 screw is seen to realign the fractured segments

(Figs. 4 and 7), only C2 pedicular fixation was done, the screw traversing across the fractured segments. To fix the C1–2–3 spinal segments, a number of permutations and combinations were deployed. In 4 cases (cases 2, 5, 10, and 11) (Figs. 2 and 5), the plate used for C1–2 fixation was extended to include the C3 facet. In 1 case (case 3) (Fig. 3), the C1 screw was inserted into its facet and the caudal screw was inserted into the inferior facet of C2 [5]. In 2 cases, C2–3 fixation (cases 8 and 13) was done using the transarticular fixation technique. In 1 case, C1–2 fixation (case 7) was done as described and additionally C2–3 fixation was done. In one case, C1–2–3–4 fixation (case 6) (Fig. 6) was done as C3–4 instability was additionally identified by manual manipulation of the bones of the region. In 1 case (case 9), C1–C2 fixation as described was done on one side and a C2 pedicular screw insertion was done on the other side.

The follow-up ranged from 6 to 62 months (average 26 months). The preoperative neck pain was entirely relieved after surgery. All patients recovered satisfactorily following the surgical treatment (Table 1). Two patients did not follow-up personally after 6 months of surgery, but on telephonic conversation were well and functional and had only marginal complaints. There was no evidence of recurrent symptoms or evidence of instability of any spinal segments. There was no

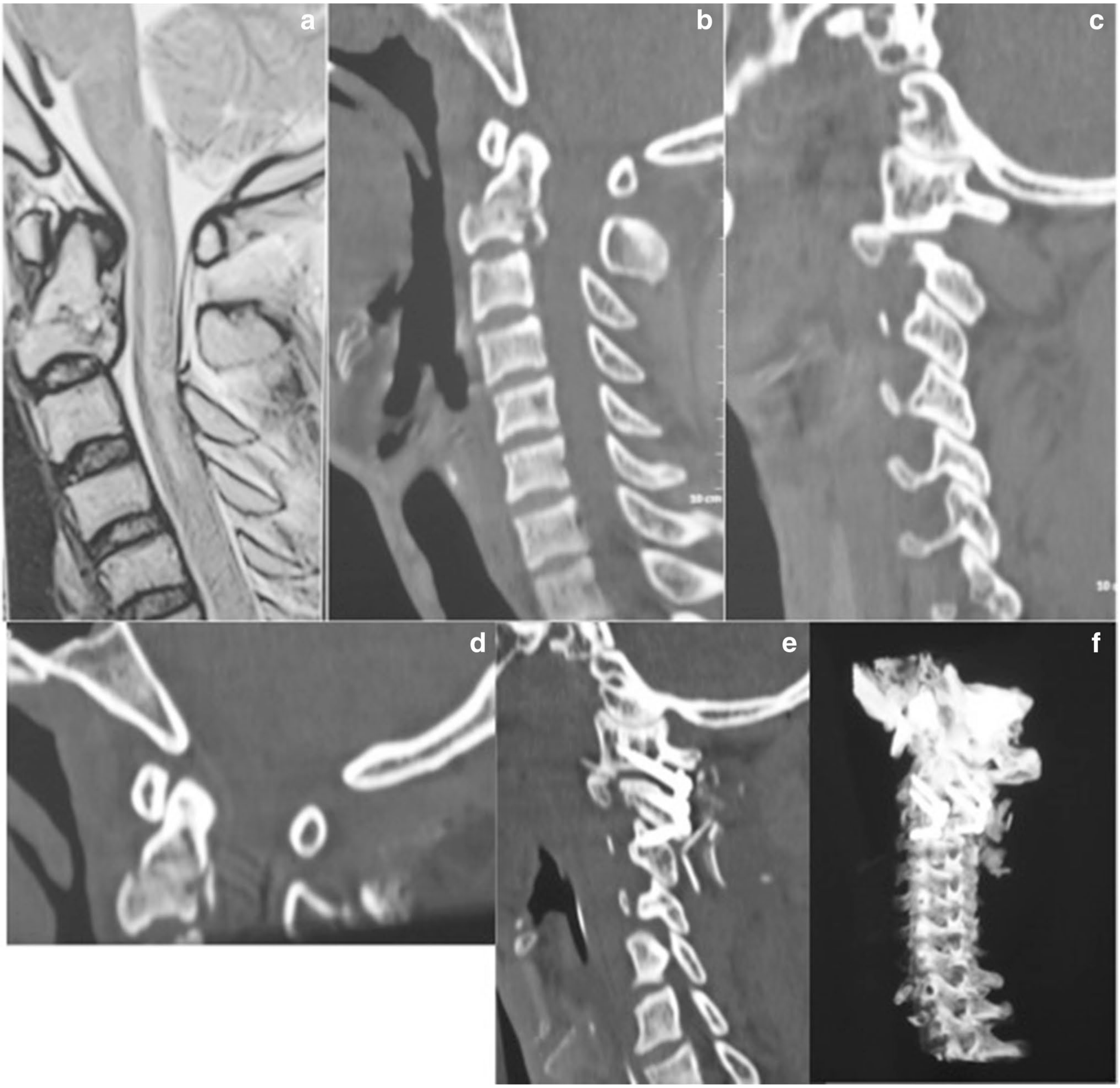

Fig. 2 (Case no. 2) Images of a 28-year-old male patient. A: T2-weighted MRI showing fracture of body of C2 vertebra. B: CT scan showing the C2 body fracture. C: CT scan showing the pedicular fracture involving the facetal surface. Distraction of the fractured bones can be seen (type 3). D: Postoperative CT scan. E: Postoperative CT scan showing the implant. C1–2–3 fixation is done. C2–3 screw is transarticular. F: 3-D CT scan showing the implant

evidence of non-union in any case. The restriction of neck movements was insignificant in all cases and did not affect their routine life function.

Discussion

Fracture of the pedicle of the C2 vertebra as a result of 'hyperextension' cervical injury has been commonly referred to as Hangman's fracture [14]. In spinal injury cohort, Hangman's fracture is a relatively common clinical entity. The fact that a number of classifications schemes have been described is suggestive that controversies are rife in the understanding of the exact nature of injuries and the treatment protocol has not yet been standardised [12, 14].

Similarities of Hangman's fracture with the more commonly identified clinical entity of lumbosacral spondylolisthesis are stark. The fracture of pedicles of axis vertebra on both sides divides the entire bone column into two parts: the

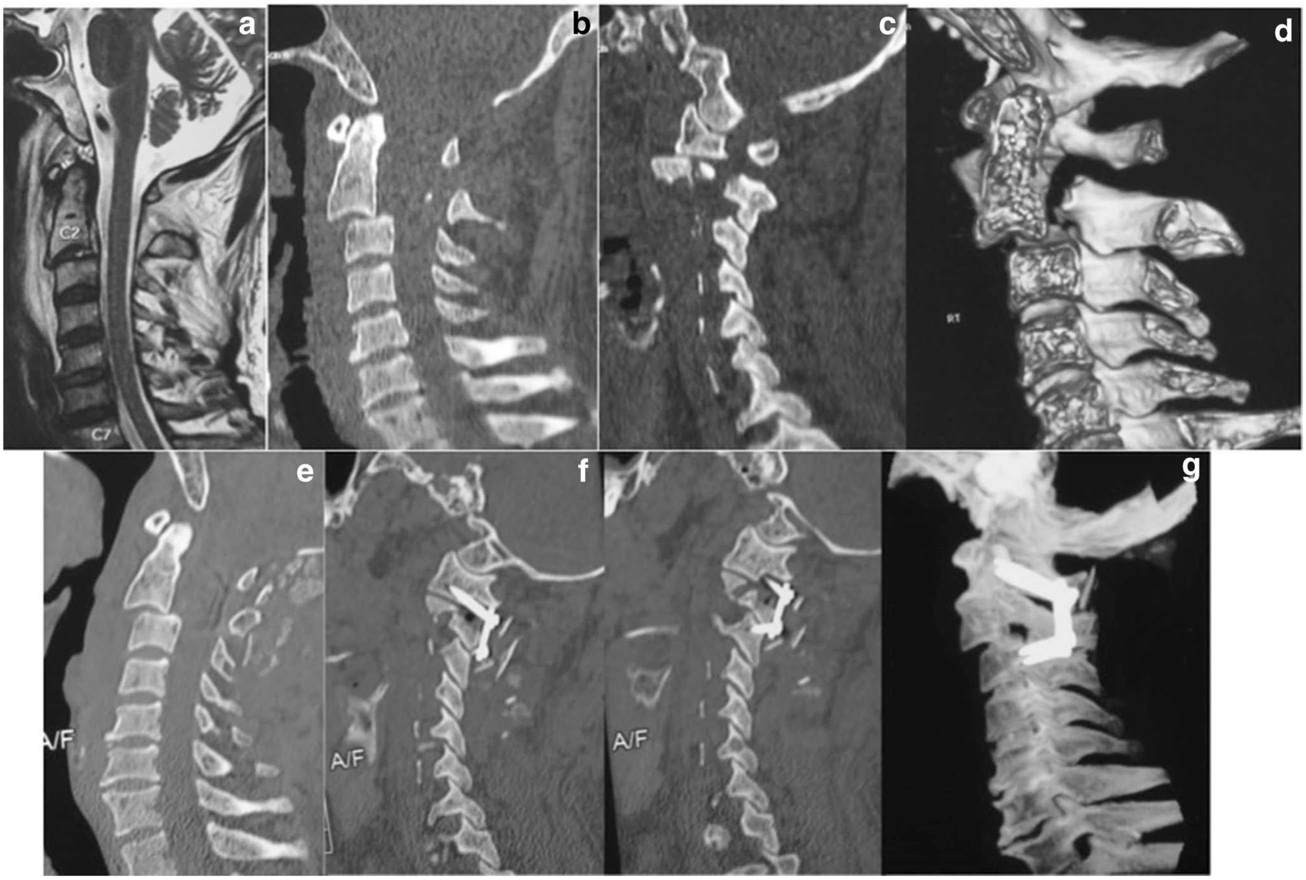

Fig. 3 (Case no. 3) Images of a 48-year-old male patient. A: T2-weighted MRI showing listhesis of C2 over C3 vertebra. B: CT scan showing the listhesis. C: CT scan showing distraction of the fractured segments. Fracture involves the C2 articular surface (type 4). D: 3-D CT scan showing the fracture line and the C2–3 listhesis. E: Postoperative CT scan. F: Postoperative CT scan showing the implant. Fixation involves C2 facetal screw and C2–3 screw in a transarticular fashion. The screws are held by plate. G: 3-D CT scan showing the implants

anterior column comprising the skull, atlas, body and the odontoid process and superior facets of axis (partly or completely) and the posterior column comprising the laminae, spinous process and the inferior facets of axis that articulate with the superior facet of the C3 vertebra and the entire spine below this level. The fracture line separates the superior facet of the axis from the inferior facet. The disconnection can lead to atlantoaxial instability and disruption of the C2–3 intervertebral disc complex and listhesis of the body of axis over the body of the C3 vertebra. Muscles and soft tissues now support the entire region and the process results in 'severe' muscle spasm and neck pain. Although identified by others, disruption or locking of C2–3 facetal articulation was not seen in any case. It is clear that unless there is spontaneous bone fusion, the region complex is unstable. This can be observed by reported cases of neglected Hangman's fracture presenting with delayed neurological deficits and worsening of C2 over C3 listhesis [17, 19]. Displacement of bone segments anterior to the fracture line is away from the neural structures. This is probably the reason that neurological deficits are not the early hallmarks of Hangman's fracture.

Apart from severity of injury, due to more frequent identification in the 'older' population, osteoporosis has been identified to be an important predisposing factor [12]. Four of our patients were above the age of 50 years. On the basis of genetic analysis, one 7-year-old patient (case 9) was identified to have 'osteopetrosis' [16]. Apart from injury, poor nutritional status, deficiency of vitamins and calcium in the general population seeking treatment in authors' charitable public institution could be a predisposing factor. The inclusion of C1–2 in 9 cases, C2–3 in 9 cases and C3–4 in 1 case is suggestive that the severity of injury was more severe than that addressed by Effendi's and Levine/Edwards classifications. In all cases, we identified the presence of 'high' vertebral artery loop in relationship to the pedicle of the C2 vertebra. In all these cases, the fracture line was in continuity with the vertebral artery foramen. It is obvious that the presence of vertebral arterial loop reduced the thickness of the pedicle and makes it susceptible to fracture.

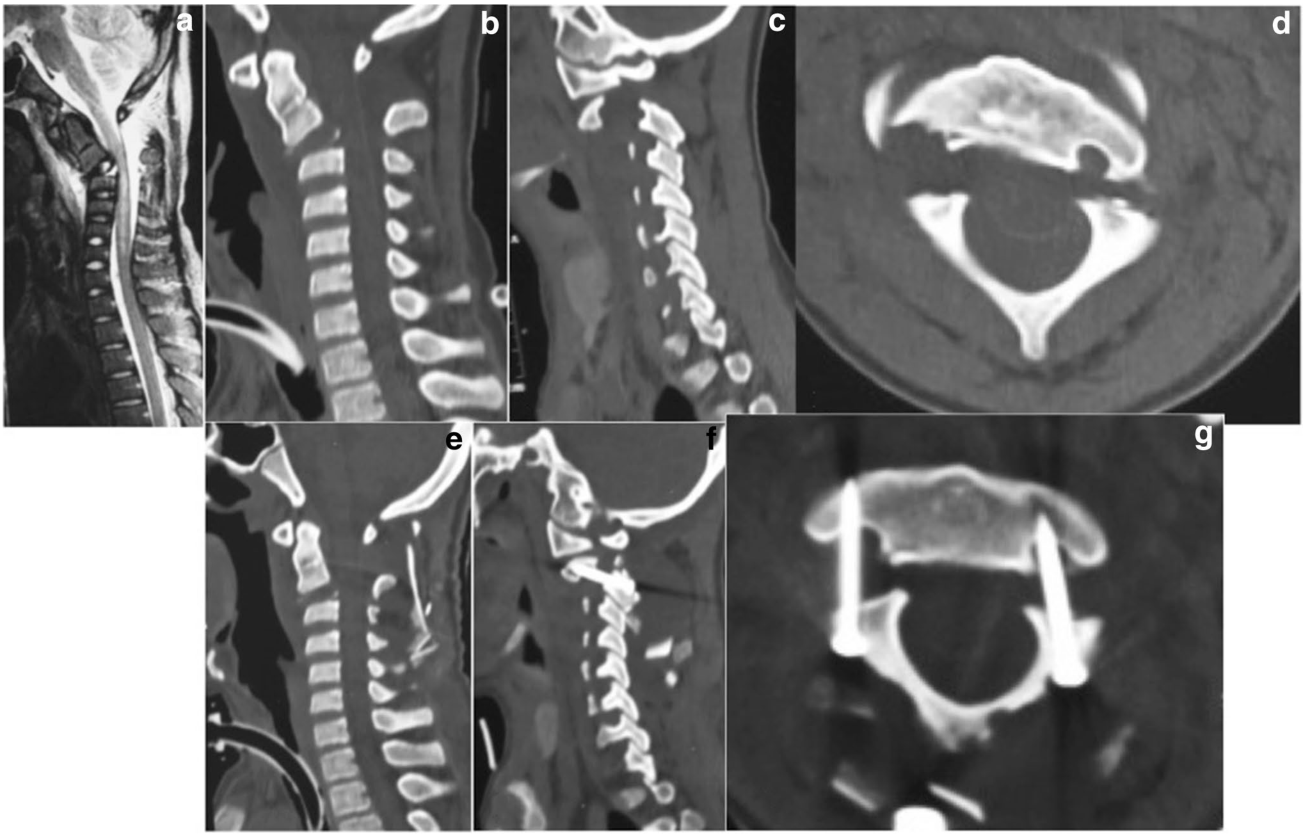

Fig. 4 Images of a 14-year-old male patient. A: MRI showing the disruption of C2–3 disc space. B: CT scan showing the angulation of C2 vertebra and the disc space disruption. C: CT scan showing the fracture line and distraction of the fractured segments. The fracture line involves the articular surface of C2 facet (type 4). D: Axial view of C2 vertebra showing the fracture and distraction of the fractured segments. Vertebral artery foramina are seen. E: Postoperative CT scan. F: Postoperative CT scan showing the screws traversing across the fractured segment. Realignment of the C2 facetal bone is seen. G: Postoperative CT scan showing the screws across the fractured segments

Our literature search did not identify the mention of high vertebral artery loop as a predisposing factor for Hangman's fracture. The risk of vertebral artery injury during pedicular screw insertion has been alluded to in cases with Hangman's fracture [4]. The most crucial surgical issue was to insert C2 screw that traversed across the fracture line and engaged the fractured segments of C2 posterior elements [6]. In select cases, drilling of posterior bone dome of the high-riding artery, exposure of the arterial loop and its inferior and lateral mobilisation with the technique described by us earlier are useful [9]. It was observed that power-driven drill was a useful tool to make a guide hole for screw insertion in such cases. Screw insertion across the fracture line and subsequent tightening of screws without any other manoeuvring were observed to bring the distracted segments closer to each other and in alignment. Compression screws or lag screws with bicortical purchase can be helpful to affect realignment in such cases.

Considering the relatively complex anatomical terrain and the possibility of severe neurological complications in an otherwise preserved clinical state has made conservative and non-surgical observation a popular option. More aggressive surgical techniques have only recently become popular. Various patterns of stabilisation have been described for the surgical treatment for Hangman's fracture [1–4, 6, 10–13, 20]. However, scanning through the literature on the subject does not identify a specific strategy of surgical treatment. Both anterior and posterior and also combined anterior and posterior approaches have been successfully deployed [1–4, 6, 10–13, 20]. Our literature survey identifies that satisfactory surgical outcome was reported despite the wide variation in the surgical approaches adopted by anterior, posterior or anterior–posterior surgical routes [1–4, 6, 10–13]. Probably due to our long-term familiarity with surgery in the region, surgery was a preferred mode of treatment over conservative approach. Posterior surgical approach was preferred in all cases, probably due to the satisfactory surgical experience by using our technique of fixation for over 3 decades. We found posterior approach suitable as it allowed deployment of screw fixation in the firm components of the

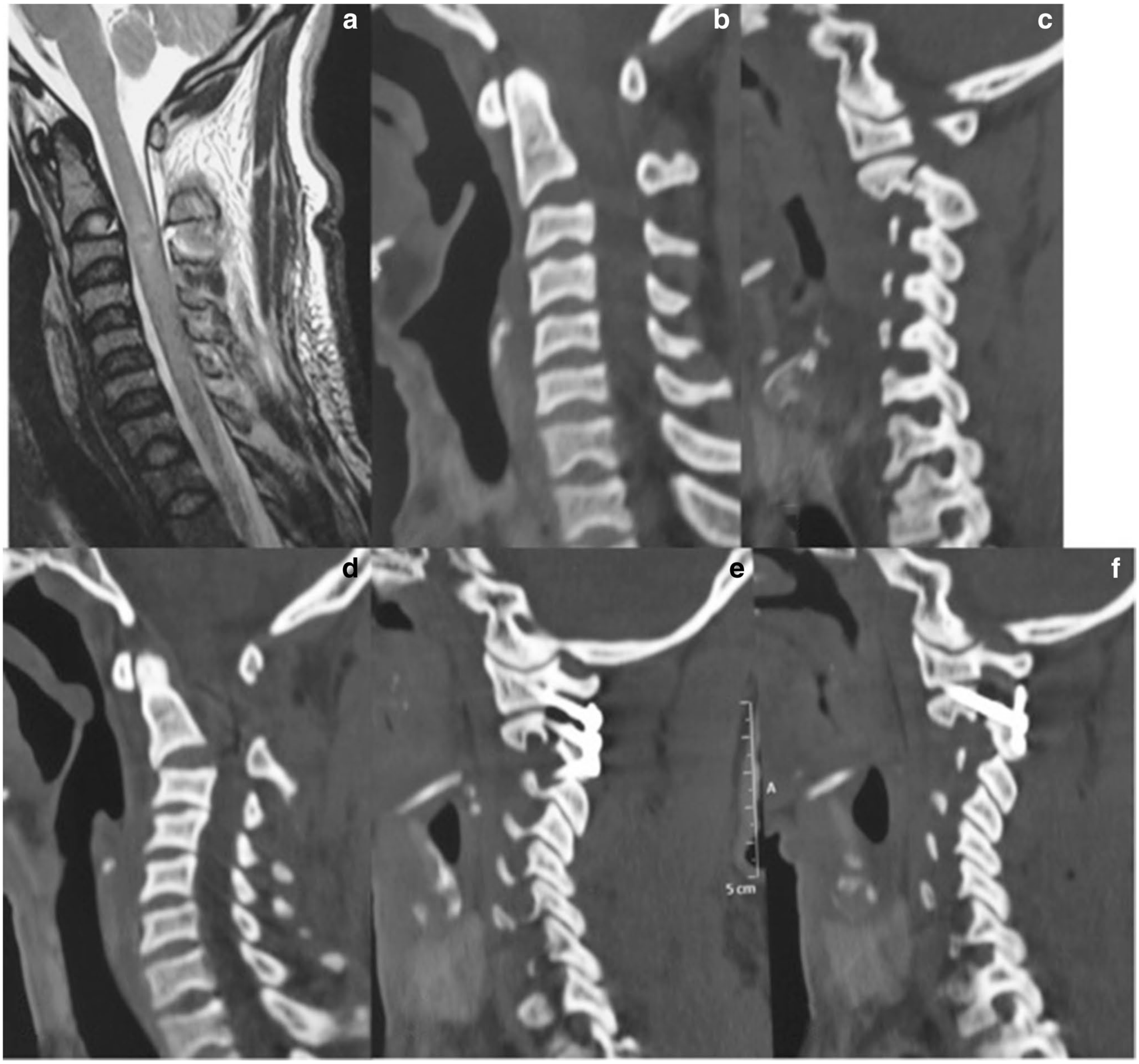

Fig. 5 (Case no. 5) Images of a 24-year-old male patient. A: MRI showing disruption of C2–3 disc space. B: CT scan showing the angulation of the C2 body and odontoid process. C: CT scan showing the C2 pedicular fracture (type 2). D: Postoperative CT scan. E: Postoperative CT scan showing the C1–2–3 fixation. C2–3 fixation is transarticular

vertebra namely the facets and pedicles. Moreover, extension of fixation both superiorly and inferiorly was possible after manual handling of bones and visual observation of stability of the region. The large extensor muscles attached to the posterior spinal elements, particularly to the C2, spinous process could be sharply sectioned. It appears that the strength of these muscles can possibly disrupt the implants placed through the anterior cervical route. The proponents of anterior approach identify easier surgical access and possibility of direct manual reduction and stabilisation of C2–C3 listhesis.

The proposed classification was essentially based on the type of surgical treatment adopted in the series. Inclusion of the C1–2 instability formed a distinct feature of the classification scheme. The more popular classification proposed by Effendi and subsequently modified by Levine and Edwards [3, 10, 11] does not include the parameter of atlantoaxial instability. The criteria of diagnosing atlantoaxial instability by the parameter of listhesis of facet of atlas over the facet of axis of more than 2 mm and C2–3 instability by listhesis of body of C2 over body of C3 by more than 5 mm in the presence of fracture of the pedicle of axis were

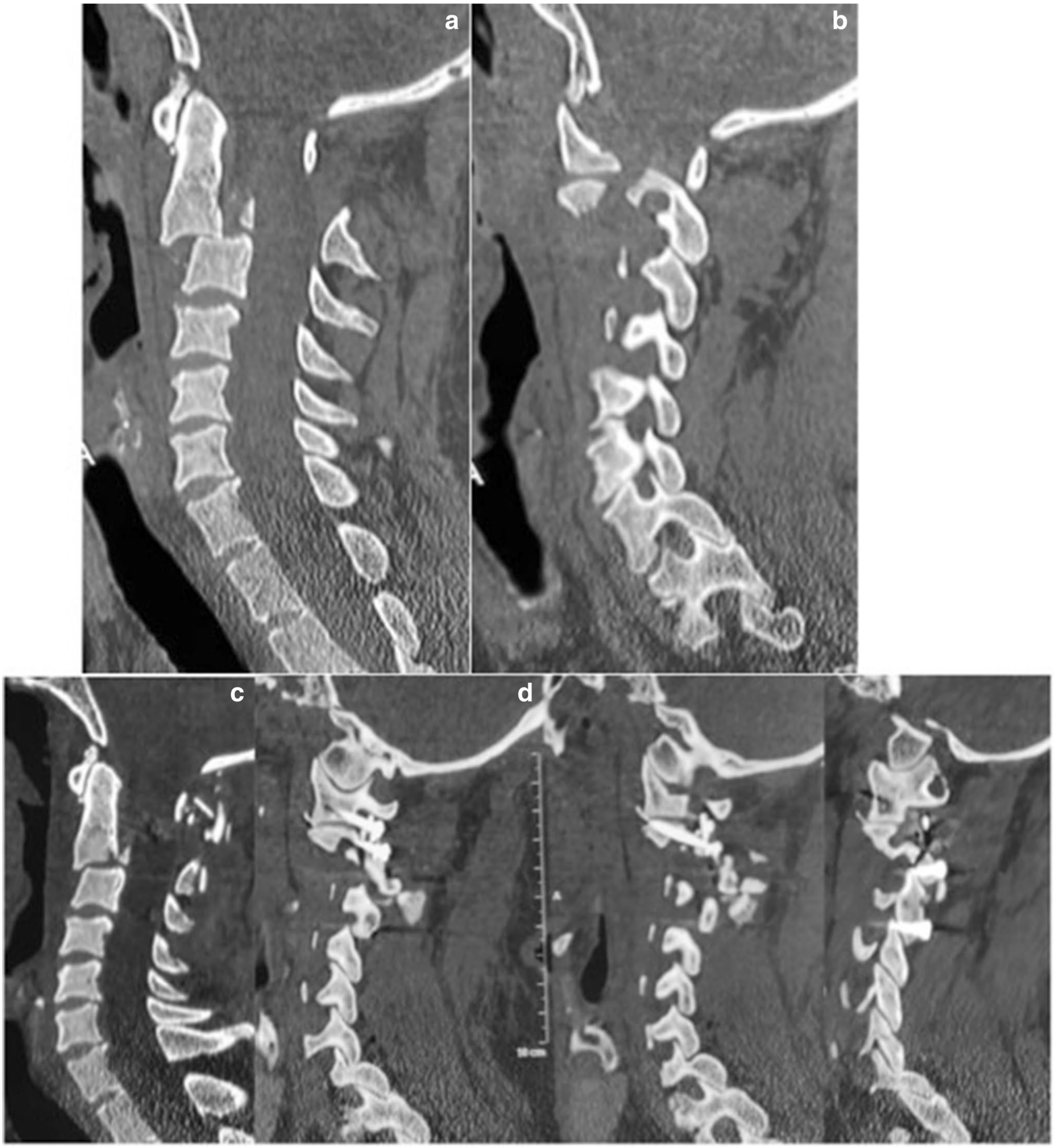

Fig. 6 (Case no. 6) Images of a 25-year-old male patient. A: CT scan showing the C2–3 listhesis (type 4). B: CT scan showing the fracture and the distraction of fractured segments. Note the high vertebral artery groove. C: Postoperative CT scan showing the realigned bones. D: Postoperative CT scan showing the implant and the realigned facet. C2–3 screw is placed independently in a transarticular fashion

arbitrary and based on approximately 4 decades of experience of the senior author in the subject. Such parameters of identification of atlantoaxial and C2–3 instability have not been described earlier. Although it is only an assumption, whenever the fracture line passed through the facet of the axis, the atlantoaxial joint was considered to be unstable and in such situation it seems impossible to save the function of the joint. Consequently, atlantoaxial fixation aiming at arthrodesis may be the optimal form of surgical treatment. On a similar line, when listhesis of C2 vertebral body over

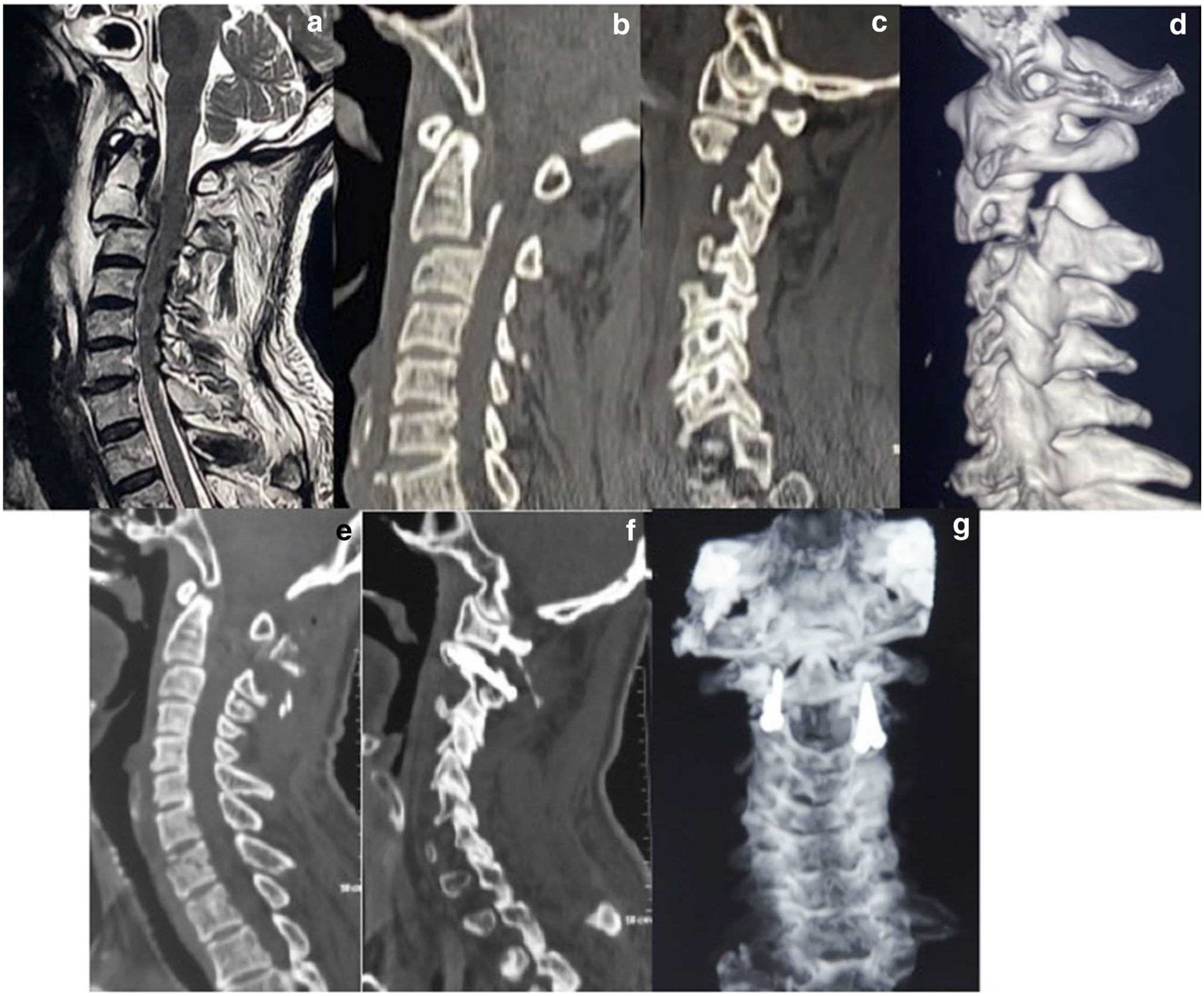

Fig. 7 (Case no. 15) Images of a 50-year-old male patient. A: T2-weighted sagittal MRI shows listhesis of C2 over C3 vertebral bodies. B: CT scan shows listhesis of C2 over C3 vertebral bodies. C: CT scan cut passing through the facets showing fracture and displacement of pedicle of C2 vertebra. D: 3-D CT scan showing bilateral fractures of the C2 pedicles. E: Postoperative CT scan showing alignment of the C2–3 vertebral bodies. F: CT scan showing the passage of screws across the fracture line and realignment of bone of the region. G: Anteroposterior view of plain radiograph showing two screws in each fractured pedicle

C3 vertebral body was more than 5 mm, there were clear evidences of disc disruption and when the angulation of the C2 over C3 vertebra was visibly abnormal it was impossible to save the C2–3 disc function and movements. C2–3 fusion appeared to be ideal in such a situation. C1–2–3 fixation appears to be mandatory when the insertion of screw across the fractured segments is not possible. More than realignment, the aim of the surgical procedure was to achieve firm stabilisation of the affected spinal segments and to provide an environment for bony arthrodesis.

The proposed classification scheme can guide the selection of surgical approach. The fact that several different combinations of surgical treatment were used to treat the relative small number of patients in the series reflects the complexity often encountered in traumatic lesions of the axis. Type 1 cases (like in the classification proposed by Effendi) [11] may be suitable for conservative and non-surgical treatment. Surgical treatment in such cases can involve only C2 pedicular screw fixation that traverses across the fracture line. In general, type 2 cases are suitable for C2–3 fixation and type 3 cases are suitable for atlantoaxial fixation. Type 4 cases will need C1–2–3 fixation. It appears that whenever in doubt, it is better to perform C1–2–3 fixation, particularly in cases of significant deformation. Apart from radiological guides, inclusion of C3–4 in the fixation construct will depend on the assessment of stability by direct visual and manual assessments. More that realignment, it seems that strong stabilisation of all the affected bone segments is

Table 1 Table showing the clinical data

Case no	Sex/age	Clinical features/nature of injury	Mode of injury	VAS score		ASIA score		Radiological features – fracture type – current classification/Levine and Edwards modification of Effendi classification	Time between injury and surgery in days	Fixation performed
				Pre op	Post op	Pre op	Post op			
1	M/64	Neck pain, spastic quadriparesis	Road traffic accident	8	0	C	E	Type 4/type III	2	C1-2 fixation (Fig. 1)
2	M/28	Neck pain, quadriplegia	Road traffic accident	9	0.5	B	D	Type 3/type 1	4	C1–2–3 fixation (Fig. 2)
3	M/48	Neck pain, restriction of neck movements, spastic quadriparesis	Road traffic accident	9	1	D	E	Type 4/type III	7	C1–2–3 fixation (Fig. 3)
4	M/14	Neck pain, spastic quadriparesis	Road traffic accident	7	0.5	D	E	Type 4/type IIa	10	C2 pedicular screws (Fig. 4)
5	M/24	Neck pain, quadriplegia	Road traffic accident	8	0	B	C	Type 2/type IIa	9	C1–2–3 fixation (Fig. 5)
6	M/25	Neck pain, restriction of neck movements	Fall of ceiling on neck	9	0.5	C	E	Type 4/type III	2	C1–2–3–4 fixation (Fig. 6)
7	F/55	Neck pain, spastic quadriparesis	Road traffic accident	8	0	D	E	Type 3/type III	14	C1–2–3 fixation
8	M/21	Neck pain, spastic quadriparesis	Road traffic accident	9	0.5	D	E	Type 2/type IIa	5	C2–3 fixation
9	M/7	Neck pain, spastic quadriparesis	Case of osteoporosis with fall from bed	7	0	C	E	Type 1/type I	26	C1–2 fixation on one side and C2 screws on the other side
10	F/60	Neck pain, spastic quadriparesis	Road traffic accident	9	0	D	E	Type 4/type III	5	C1–2–3 fixation
11	M/65	Neck pain, spastic quadriparesis	Road traffic accident	8	0	C	E	Type 4/type III	3	C1–2–3 fixation C1–2–3 plate and screw fixation
12	F/37	Severe neck pain with restriction of neck movements	Road traffic accident	9	0.5	E	E	Type 2/type II	180	C2 pedicular screws
13	M/37	Neck pain, spastic quadriparesis	Road traffic accident	7	0	D	E	Type 2/type IIa	5	C2–3 fixation
14	M/34	Severe neck pain with restriction of neck movements	Road traffic accident	9	1	E	E	Type 2/type II	25	C2 pedicular screws
15	M/50	Neck pain, restricted neck movements, spastic quadriparesis	Road traffic accident	9	1	C	E	Type 2/type II	5 days	C2 pedicular (Fig. 7)

crucial. The treatment ultimately aims at arthrodesis of the region. The restriction of neck movements will be dependent on the number of spinal segments that are stabilised and if atlantoaxial joint is included in the fixation construct.

The very fact that 8 different combinations were used to treat 15 patients involved in this retrospective review reflects the complexity often encountered in traumatic lesions of the axis. In this respect, to comprehensibly classify the injury pattern and to propose a uniformly applicable surgical strategy may not be possible. Limitations of small sample size due to relative rarity of such injuries can affect the conclusions. Surgical decisions can be observer dependent and may not be objective and reproducible. It is obvious from the positive outcomes despite the variability in treatment pattern that patients with Hangman's fracture fare well after reasonably strong stabilisation procedures. The role of external immobilisation in ultimate bone fusion of the affected spinal segments needs to be stressed.

Conclusions

Our satisfactory results in 100% of cases following a number of types of fixation indicate the validity of surgical treatment. The clinical usefulness of the proposed classification system will have to be evaluated further.

Author contribution Atul Goel: conceptualisation, methodology, validation, formal analysis, writing – original draft, writing – review and editing, supervision, project administration.

Akshay Hawaldar: methodology, data collection, writing – review and editing.

Abhidha Shah: conceptualisation, methodology, validation, formal analysis, writing – original draft, writing – review and editing.

Sagar Bhambere: methodology, data collection, writing – review and editing.

Malwinder Singh: methodology, data collection, writing – review and editing.

Aditya Lunawat: methodology, data collection, writing – review and editing.

Mehul Baldha: methodology, data collection, writing – review and editing.

Nishchith Sudarshan: methodology, data collection, writing – review and editing.

Data availability N/A

Code availability N/A

Declarations

Ethics approval Retrospective data collection was approved by the local ethics committee. Due consent of the patients was taken to include their data in the analysis. All the patients provided written informed consent before surgery, and all clinical tests and surgical procedures were conducted according to principles of Declaration of Helsinki.

Consent to participate As above

Consent for publication As above

Conflict of interest The authors declare no competing interests

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