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# CT-guided internal fixation of a hangman's fracture

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**Abstract** Most hangman's fractures are treated conservatively. If surgery is indicated, an anterior approach using a C2/C3 graft and plate fusion is usually preferred. Another surgical method according to Judet is direct transpedicular osteosynthesis by the dorsal approach. This surgery is frequently rejected because of the high risk of spinal cord damage or vertebral artery tear. Direct transpedicular osteosynthesis of hangman's fracture according to Judet is a "physiological operation" that does not cause fusion and creates anatomical conditions. This procedure enables appropriate reduction, compression of fragments and immediate stabilization of the C2 segment. A new aspect of Judet's method of internal fixation of a hangman's fracture is now proposed. Computed tomographic (CT) guidance is used to ensure safe and exact introduction of two screws from the posterior approach. This method of CT-guided internal fixation of hangman's fracture allows, preoperatively, for an accurate assessment of the pattern and course of fracture line, selection of the anatomically safest screw path and determination of an appropriate screw length. The procedure also allows for accurate intraoperative control of instrument and implant placement, screw tightening, fracture reduction and anchoring of the screw tip in the contralateral cortex, using repeated CT scans. The procedure is performed in a CT unit under sterile conditions. This method was used in the treatment of eight male and two female patients aged 21–71 years. All treated patients were without neurological deficit. Follow-up ranged from 12 to 57 months (mean 33.3 months). No intraoperative or early or late postoperative complications were apparent. This new aspect of the surgical procedure ensures highly accurate screw placement and minimal risks, and fully achieves the "physiological" internal fixation.

**Key words** Axis pedicle · Hangman's fracture · CT-guided surgery · Internal fixation

## Introduction

Some hangman's fractures require surgical treatment (Fig. 1). Most of these injuries are treated conservatively. If surgery is chosen, an anterior approach using a C2/C3 graft and plate fusion is usually preferred [8, 11, 18, 20]. Another surgical method is direct transpedicular osteosynthesis according to Judet [9] by the dorsal approach. This surgery is frequently rejected because of the high risk of spinal cord damage or vertebral artery tear.

The authors propose and elaborate on a new aspect of this surgical procedure that is safe and exact. The procedure is based on guidance using computed tomography (CT).

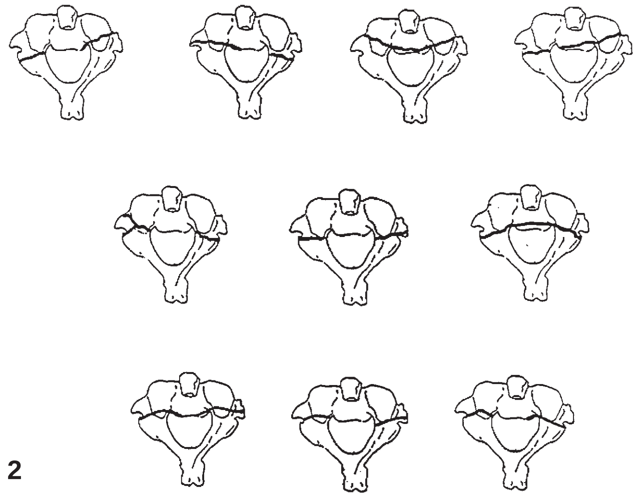

**Fig. 1** Hangman's fracture: typical lateral view

**Fig. 2** Axis vertebrae showing fracture lines from our patient collection

## Materials and methods

Sixty-three patients with cervical spine fractures of C2 were surgically treated between January 1994 and September 1998. Hangman's fracture was evident in 22 of the cases. During the same period, transpedicular osteosynthesis of the second cervical vertebra using CT-guided screws was performed in ten subjects. The group consisted of eight men and two women, aged between 21 and 71 years. Follow-up ranged from 12 to 57 months (mean 33.3 months). Five of the patients had sustained a fall injury, the other five injuries resulted from traffic accidents. All treated patients were without neurological deficits (Table 1). Asymmetrical courses of fracture lines were most often apparent. The symmetric hangman's fracture described by Wood-Jones [22] occurred only once. The mean distance between fracture lines was 5 mm, with a range of 3–8 mm (Fig. 2). The other 12 patients were treated with anterior interbody fusion. In the same time period seven patients with hangman's fracture were conservatively treated with halo-cast or halo-vest fixations.

An anterior approach was indicated in cases with a C2/C3 dislocation larger than 3 mm initially or on flexion/extension radiographs. A posterior approach was chosen in cases of lesser C2/C3 displacement on lateral radiographic view, but with the fracture gap larger than 3 mm on CT scan. A halo-cast or halo-vest was used in fractures without dislocation or with a very small (1–2 mm) dislocation of the fracture lines. The clear consent of each patient after receiving an explanation of the conservative and surgical treatment possibilities was mandatory.

### Surgical procedure

The procedure is performed under endotracheal anesthesia in a CT unit at the department of radiology, specially adapted for surgical use. A Symtex 3000 GE CT scanner is used. An experienced radiologist is present during the procedure. All necessary operating room sterile conditions are maintained in the CT unit. Prophylactic antibiotics are used in every case.

After a halo-ring is positioned, the patient is placed prone on the CT table and the patient's head is gradually flexed forward during repeated CT scanning to ensure the vertical position of the vertebra ring. In the final position, the endplate of C2 and the gantry of CT should be in the same plane. The patient's head is then firmly fixed to the CT table using the halo-ring (Fig. 3).

The most suitable plane for introduction of the screws is chosen using 2-mm CT axial scans through C2. At the same time, the vertebral artery foramen and the spinal canal are clearly identified. In the event that a fracture line passes through the vertebral artery foramen, a bolus of a contrast medium (80 ml i.v., 1 ml/s) is administered using an angiographic injector prior to surgery to visualize the course of the vertebral artery. This enables identification

**Table 1** Clinical details and follow-up (*Surg. delay* interval between trauma injury and surgery, *Proc.* procedure, *ROM* range of motion, *MVA* motor vehicle accident, *Osteoph.* osteophyte of lower edge of C2, *Calcif.* small calcification of anterior part of disc C2/C3)

| Case no. | Sex | Age | Injury | Surg. delay (days) | Proc. duration (min) | Hosp. stay (days) | Follow-up (months) | X-ray | ROM |
|---|---|---|---|---|---|---|---|---|---|
| 1 | M | 71 | Fall | 8 | 100 | 14 | 39 | Normal | Not full |
| 2 | F | 28 | Fall | 2 | 120 | 8 | 54 | Osteoph. | Full |
| 3 | M | 50 | Fall | 7 | 160 | 12 | 52 | Normal | Full |
| 4 | M | 30 | MVA | 7 | 90 | 13 | 16 | Normal | Full |
| 5 | M | 21 | MVA | 11 | 70 | 18 | 57 | Calcif. | Full |
| 6 | M | 55 | Fall | 9 | 100 | 14 | 23 | Normal | Full |
| 7 | M | 49 | MVA | 8 | 90 | 17 | 42 | Normal | Full |
| 8 | F | 34 | Fall | 29 | 60 | 39 | 18 | Normal | Full |
| 9 | M | 56 | MVA | 5 | 100 | 10 | 20 | Normal | Full |
| 10 | M | 54 | MVA | 11 | 90 | 15 | 12 | Normal | Full |

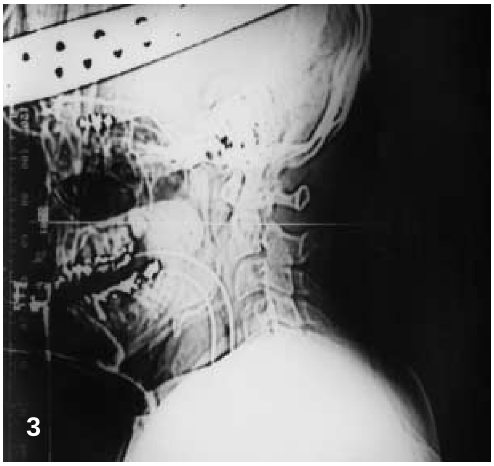

**Fig. 3** Patient's head position on the lateral computed tomographic (CT) scout view

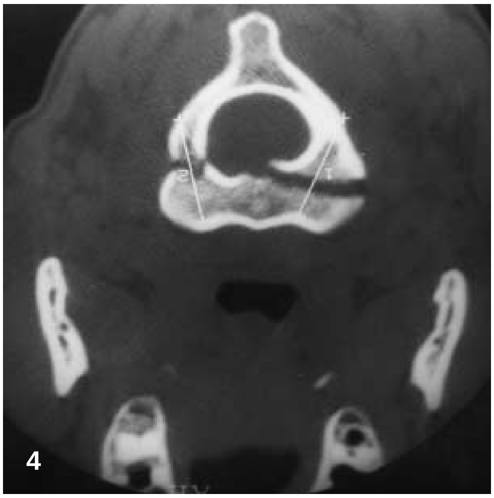

**Fig. 4** CT scan of C2 fracture with guiding lines

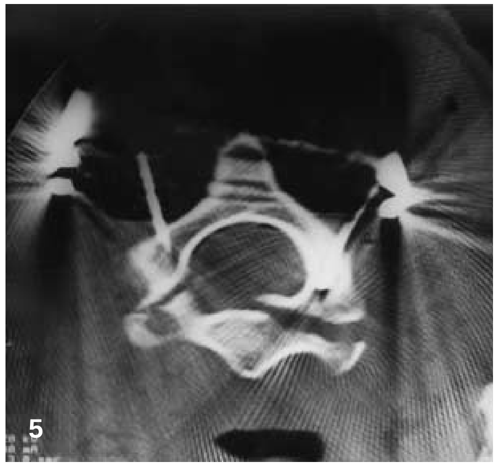

**Fig. 5** CT scan of C2 vertebra with introduced drill

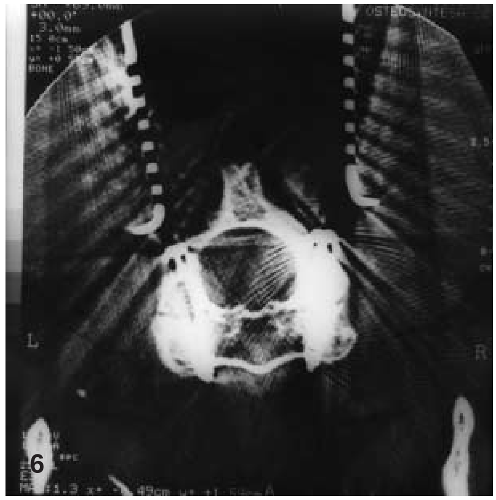

**Fig. 6** CT scan of C2 vertebra with two screws

of whether the artery encroachment is in a fracture gap, which could cause injury as a result of compression during repositioning or direct damage through the use of instruments and implants.

A CT cursor is used to mark the best screw position in the chosen plane after assessing the course of fracture lines and determining the extent of the fracture gap. A radiologist chooses the length of the screw and the angle of screw placement in the sagittal plane. The entry point distance from the spinous process can be measured preoperatively directly on a CT screen (Fig. 4).

An approximately 10-cm midline incision is made from the occipital bone distally. After detaching the neck muscles, only the dorsal part of the C2 arch is exposed, approximately 2 cm laterally, on the both sides of the C2 spinous process.

The osteosynthesis procedure starts with drilling into the posterior cortex of the C2 lamina to a depth of approximately 3 mm. Metallic markers (short K-wire pieces) are placed into these canals. The drilling site is identified by CT and the entry point and the direction of the screws is again assessed (Fig. 5). A drill is used to complete the canal, which is then tapped. Partially threaded (6- or 12-mm thread) 3.5-mm diameter AO cancellous screws are used for fixation (Fig. 6). A shorter thread (6 mm) is required when a fracture line passes through the C2 body. During drilling, the position of the drill should be repeatedly examined by CT. The exact location and depth of the instruments and implants are also controlled. This step-by-step surgery ensures a high level of safety for the procedure. If the patient's head is properly fixed and the surgery performed carefully, a single CT cut is sufficient for proper control. If a vertebra moves slightly in relation to a preoperative position, a correct axial scan is rapidly obtained from the lateral CT scout view. At the end of the procedure it is possible to assess the degree of reduction and the position of the screw tip in relation to the vertebral body. Protrusion by one or two threads (1–2 mm) in front of the anterior cortex is tolerated.

Between 9 and 14 scans were required during the surgery. The mean duration of the procedure was 98 min (range 70–160 min). Total radiation dose received by the patient was not measured. We estimate that the total radiation exposure did not exceed that of the radiation dose used for a craniocerebral trauma CT examination. During scanning, surgeons and staff were in an adjacent room.

Two days after the procedure, the patients were allowed to walk with a Philadelphia collar only. They were discharged from hospital between the 5th and 9th day. The duration of immobilization with a Philadelphia collar ranged from 2 to 3 months. Isometric contraction of the neck muscles started on the 3rd day after surgery, and active rehabilitation in the 9th postoperative week.

## Follow-up evaluation

The same surgeons checked all patients at regular periods: 3, 6, 12 and 24 months after surgery. Every clinical check-up included subjective evaluation, functional and neurological examinations, and antero-posterior, lateral and dynamic (flexion/extension) radiographic views.

**Fig. 7** Osteosynthesis of C2 fracture: lateral view

**Fig. 8** Osteosynthesis of C2 fracture: antero-posterior view

## Results

Two screws were used for fixation in all cases. We achieved satisfactory reduction with closure of the fracture gap in six patients. In all the other patients the fracture was fixed with a slight gap, not exceeding 2 mm. There were no intraoperative complications and in no case was the procedure discontinued.

Subjective complaints came from one patient. She reported mild or moderate pain in the cervical region after greater physical activity or weather changes. She used analgesics on an irregular basis only. All other patients were satisfied.

Clinical examination showed a full range of motion in the neck in nine patients. In one patient, a 71-year-old man, only slight limitation (according to his own opinion) of the rotational movement of the cervical spine was found 39 months after surgery, with other movements not being affected. No early or late postoperative complications were evident.

Radiographs did not show signs of nonunion, displacement of fragments, C2/C3 instability or implant failure (loosening, bending, or fracture of the screws) in any of the patients. In one case an osteophyte of the lower edge of C2, and in another case a small calcification of the anterior part of the disc, was seen. No anterior bony bridge at the level C2/C3 occurred (Figs. 7, 8).

## Discussion

The classical "hangman's fracture" occurred during legal hangings, when the knot of the noose was situated below the chin. In 1913 Wood-Jones [22] examined five executed prisoners and concluded that death was due to hyperextension and distraction of the cervical spine, which caused a bilateral symmetrical fracture of the arch of the second vertebra, and the tearing of the intervertebral ligaments and C2/C3 disc. The loosened odontoid process of the axis crushed the cord and caused instant death.

Fractures of the C2 arch are usually caused by a deceleration force – traffic accidents, jumps into water, falls etc. Usually, hyperextension is combined with axial loading, often accompanied by lateral flexion. Hyperflexion followed by hyperextension is a rare mechanism of injury, but causes the most severe fracture-dislocation [5]. It results in asymmetrical fractures of the arch that often extend into a vertebral body or even pass through a body in the sagittal plane [4]. Several reports, and classifications, of hangman's fractures acknowledge a variability of fracture patterns [1, 4, 5, 6, 9,13]. The term "traumatic spondylolisthesis" [6], or fracture of the ring of the axis [5,21], can also be used to describe these fractures; however, most surgeons refer to this injury as "hangman's fracture" as well, even though it doesn't look like the fracture described by Wood-Jones [14].

When assessing the type of fracture, and the extent of discoligamentous injuries that accompany these fractures, we must bear in mind the possibility of spontaneous repositioning of the fracture after the accident, or its repositioning during first aid. Radiographs and CT scans upon admission only show the resulting state and not the apical phase of the process [3]. The value of post-traumatic dynamic radiographs [5] depends on the patient's cooperation and the physician's courage to demonstrate the "apical" phase of the injury.

The ideal fixation system for the spine helps to achieve anatomical reduction, a return to painless function, and the reparation of possible nerve injury. Optimal stabilization of C2 makes the patient's early mobilization and rehabilitation possible. Instrumentation and fusion of uninjured motion segments should be avoided [2]. This is particularly important since the region of the upper cervical spine (C1, C2) is the most mobile part of the spine [19]. One of the "physiological operations" that does not cause fusion and creates anatomical conditions is direct transpedicular osteosynthesis of hangman's fractures, according to Judet, through the dorsal approach. This procedure provides for appropriate reduction, compression of fragments and immediate stabilization of the C2 segment. The important anatomical structures around C2 make this a potentially high-risk procedure. The screw passes through a narrowed part of the vertebra, which is laterally lined by the vertebral artery, and medially by the spinal cord. The diameter of the screw is 3.5 mm and the space through which it has to pass is 5–7 mm. The classic procedure introduces a screw at an angle of 25° to the sagittal plane [2]. The procedure does not respect the variability of vertebrae [10], nor does it exclude the possibility of injury to the vertebral artery [13] or the spinal cord. It has been shown that the alignment of the vertebral artery through the body of C2 is variable in 4% of cases [12, 15,16].

Since this is a high-risk procedure, most surgeons prefer the anterior approach, and achieve interbody fusion of C2/C3 using graft and a splint [8, 11, 18, 20].

The CT-guided internal fixation procedure ensures highly accurate screw placement and minimal risks, and fully achieves "physiological" internal fixation [17].

It is questionable whether an injured C2/C3 disc is capable of spontaneous recovery. We assume that the posterior part of the C2 arch usually remains tightly connected to its surroundings. This assumption can be verified during the procedure. Screwing the pathologically mobile anterior part of the arch to the body of C2 makes a stable construct, reliably renewing the stability of a fractured segment, and, at the same time, making impossible any shift of the body of C2 in relation to C3. Under these conditions, later discoligamentous instability is improbable [7].

Currently, any shift between C2 and C3 of more than 3 mm on the first radiographic view after admission or during dynamic views should not be automatically taken as an indication for an anterior approach, as posterior osteosynthesis could also be considered.

In the near future, the whole procedure will be supported by interactive guidance, and could probably also be performed percutaneously.

## Conclusions

Our new method of CT-guided internal fixation of a hangman's fracture allows, preoperatively, for an accurate assessment of the pattern and course of a fracture line, selection of the anatomically safest screw path and determination of an appropriate screw length.

This procedure also allows for accurate intraoperative implant and instrument placement, control of screw tightening and fracture reduction, as well as anchoring of a screw tip in the contralateral cortex using repeated CT scans.

A high level of accuracy, combined with minimal risk and the restoration of anatomical conditions, are the principal advantages of this method.

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