DISCUSSION

This new system for internal skeletal fixation of the spine not only permits stabilization of the spine over a short distance, but also reduction of the injured spine with the same instrumentation. It is no longer necessary to include more than one healthy segment of the spine in the fixation or fusion. The application of this stable fixation is possible not only in fracture treatment, regardless of the type of fracture, but also in many other disorders of the spine. The complication rate is low, provided the system is used correctly and the landmarks for insertion of the pedicle screws are respected. The two instrumentation failures occurred because of insufficient tightening of the system. It must be stressed that no neurologic deterioration or root problems due to the implant were encountered. The correction is better than that obtained with the classical Harrington system and its modifications, and it is achieved easily and reproducibly with ISFS. Postoperative management no longer requires a full plaster body jacket. The patient can be mobilized during the first postoperative week with a light, prefabricated three-point support.

Experience with this new instrumentation, after treatment of more than 90 patients with spinal trauma or other pathologic spinal disorders, has convinced the authors that Harrington, Jacobs, and Luque rods are no longer necessary as standard posterior instrumentation for the treatment of fractures of the lower thoracic and lumbar spine and other localized spinal disorders. This new instrumentation, however, does not change the indications for surgical treatment of spinal trauma or other spinal disorders, but it reveals the successful application of short segmental spinal fixation.

ACKNOWLEDGMENT

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Update—1987

Therapeutic Concept and Results of Operative Treatment in Acute Trauma of the Thoracic and Lumbar Spine: The Hannover Experience

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Summary: A therapeutic concept for the treatment of acute thoracolumbar spinal injury includes an early closed reduction as the first step. In cases with a surgical indication in the lower thoracic area as well as in the lumbar spine, the posterior approach is preferred. Following decompression of the spinal cord, a transpedicular lifting of the upper endplate is done and the fractured vertebra is filled with corticocancellous bone chips. Stabilization is achieved with an internal fixator usually over two motion segments only. Subsequently, autologous corticocancellous bone is added between lamina and between the transverse processes. In the thoracic spine proper, the anterior approach is more advantageous. Following spondylectomy (removal of the vertebral body whole or in part), an intercorporal spinal arthrodesis is performed utilizing a solid bone graft and plates. Seventy-six patients with 78 fractures and subluxations of the thoracolumbar spine were reexamined for an average of 3 years and 4 months after their operation. Of the patients with an incomplete cord injury (Frankel B–D) 60% improved at least one Frankel grade and an additional nine patients improved within their group. Clinical deterioration did not occur. Irrespective of the localization, the radiologically determined loss of correction following an anterior approach was an average of 7° whereas the settling after posterior approach averaged 9°. The sagittal index of the affected vertebra improved from 0.59 preoperatively to 0.80 postoperatively. All spinal arthrodeses healed with osseous reorganization. Twelve postoperative computer tomographies were analyzed (11 after a posterior decompression), and showed a decrease of the spinal canal compromise from 65% preoperatively to 11% following surgery. Key Words: Acute trauma—Lumbar spine—Thoracic spine.

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Acute spinal trauma with neurologic involvement and/or relevant bony deformity is being treated operatively more frequently in recent years. Considerations other than the rapid development of new fixation procedures are responsible for this. First, the nonoperative management of unstable osteoligamentous injuries does not always result in a stable restoration; subsequent, increasing bony deformity can often lead to persistent pain and/or later neurologic deterioration (2,6,7,12,15,19,21, 25). Second, early operative treatment lessens the amount and intensity of patient care and can shorten the duration of hospitalization and immobilization significantly (1,5,8,22). Third, although uncertainty persists as to whether neurologic deficits have a better prognosis with operative intervention,

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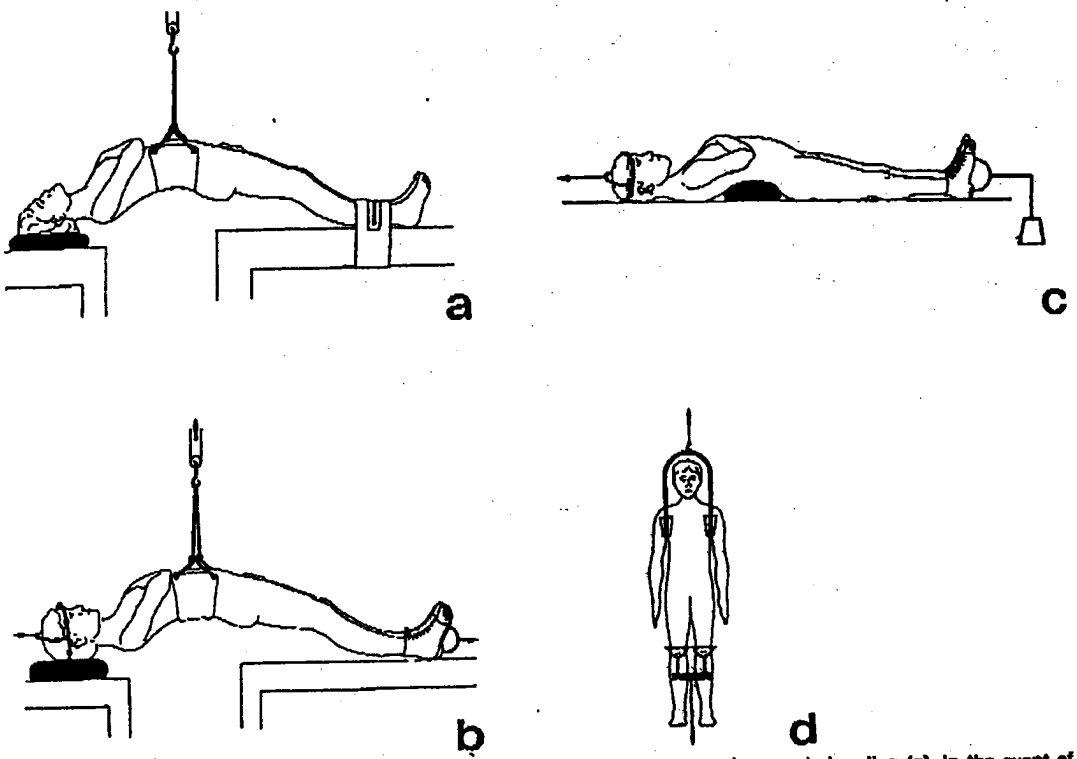


FIG. 1. Reduction of a lumbar spine fracture with a wedge deformity of a vertebra in a posterior sling (a). In the event of shortening or lateral displacement, additional traction must be used (b). Immobilization with the aid of either an Halo-apparatus with extension shoes (c) or by use of axillary slings and a supracondylar extension with Steinmann (d) for the time before surgery.

many indications point in this direction, especially when the anterior approach is used (13,17,21,23).

In the past years, we have used different approaches and devices. First we describe our present method used for unstable lesions of the thoracolumbar spine; we then report our follow-up results.

PRESENT THERAPEUTIC CONCEPT

After the initial clinical-neurologic and radiologic examinations, fractures and luxations should be reduced closed as soon as possible. A short acting anesthesia is often necessary (Fig. 1). Conventional radiograph and computed tomography (CT) scan help determine the position of the spine as well as the type of injury (Fig. 2).

Posterior Approach

If possible, our choice is the less traumatic posterior approach. Until 2 years ago, we used plates modified after Roy-Camille and Yosipovitch et al. for the paraspinal spinal arthrodesis (26,27; Fig. 3A). A major disadvantage of the system was the insufficient angular stability of the plate-screw connection as well as its fixed length (Fig. 3B). Therefore, we now prefer the spinal fixator system by Kluger (16) which allows distraction through an outrigging device and helps reduce the vertebra using extendable Schanz-screws (Fig. 4). These Schanz screws are connected to each other with telescopic bars. The device can be used for all varieties of injury: compression, distraction, and translation.

In both systems, the screws are positioned





FIG. 2. Closed reposition (performed with the patient under anesthesia) of an unstable L2 burst fracture with longitudinal traction and hyperlordosis. With the help of silicone pillows, the reduction can be maintained up to the time of surgery (a and b). Preoperative computed tomography scan of the same patient (c).

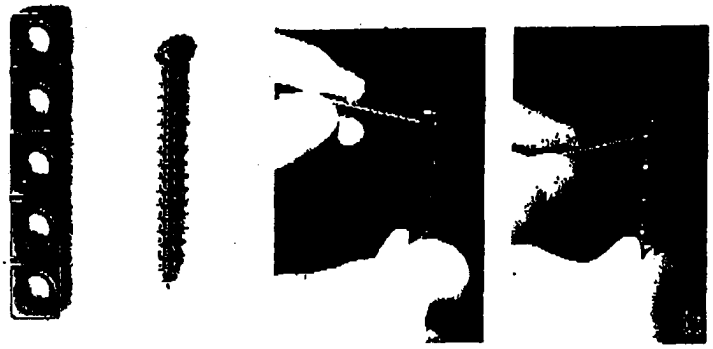


FIG. 3. The notched plate for the spine with a 6.5 mm cancellous screw for posterior spinal arthrodesis (Synthes, Paoli, PA) (a). Angular instability of the plate-screw connection with a pivoting area of ±15° (b).

a

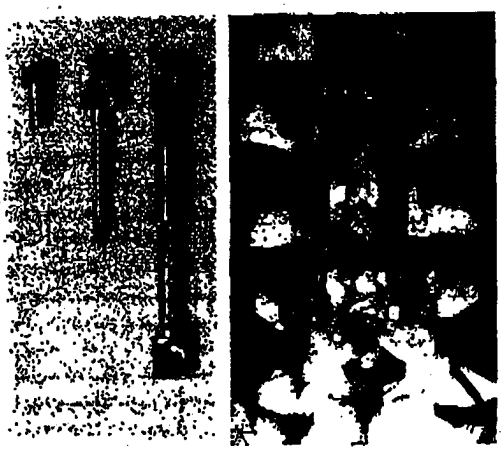


FIG. 4. Spinal fixator (Kluger (16); Tornier, Saint Ismier, France, marketing in Endotec GmbH, Leverkusen, F.R.G.).

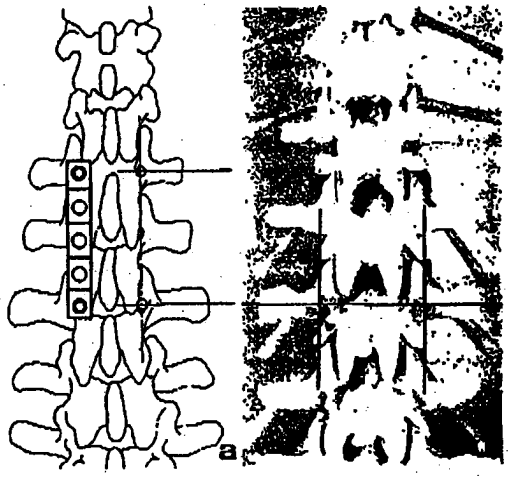


FIG. 5. Area of screw insertion at the point of intersection of two anatomic lines: one through the middle of the transverse processes, the other through the lateral edges of the articular processes (a). When an internal fixator is used, the vertical line must be drawn more laterally (b). The canal for the screw should be drilled with 15° of convergence and slightly in a caudal direction.

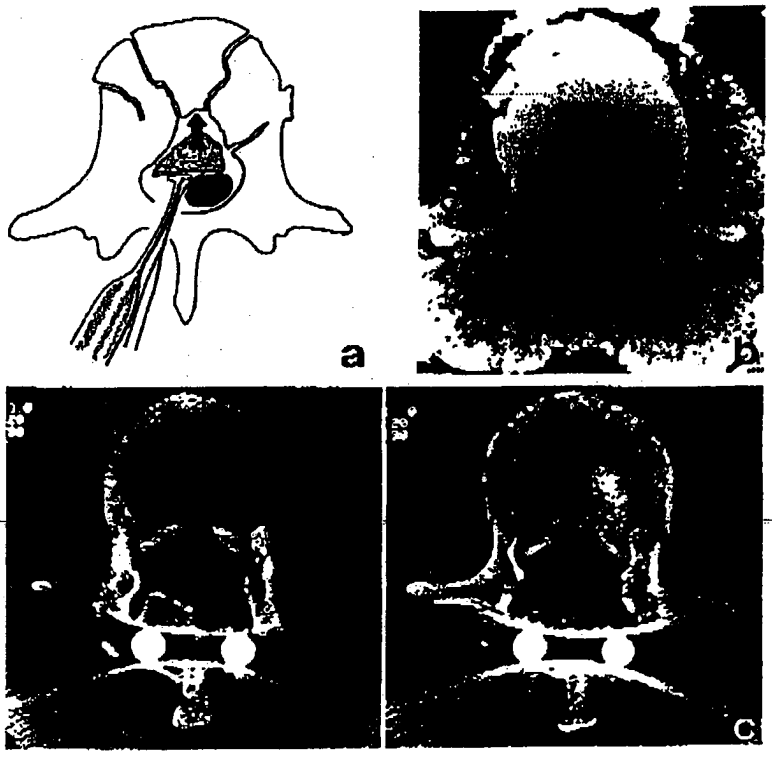


FIG. 6. Posterior decompression of the spinal cord. Following extended flavectomy, the penetrating fragment is reduced with the aid of a punch in an anterior direction (a). Clinical example of an L1 burst fracture; preoperative computed tomography scan (b). Considerable decompression of the spinal canal (c).

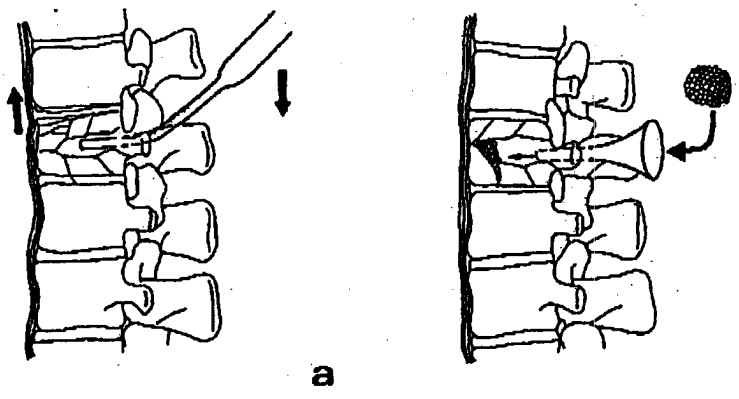


FIG. 7. Transpedicular lifting of a fractured vertebral body according to Danlaux (4) (a). The defect evolving from this procedure is filled with corticocancellous bone (b).

through the pedicles. The points of insertion are marked exactly with the help of landmarks (Fig. 5). The tip of the screws should not penetrate the anterior cortical surface of the vertebra.

Should a compression of the spinal cord persist after closed reduction, an extended flavectomy can be performed. Then, with a punch, the fragments can be knocked anteriorly far enough to relieve the spinal cord or the cauda equina (Fig. 6). If there is doubt as to the result, a myelography can be used intraoperatively for verification. In addition, the upper endplate of the vertebra can be lifted back transpedicularly. The defect evolving from this procedure can be filled through a funnel with corticocancellous bone chips (4; Fig. 7).

Anterior Approach

The anterior approach appears to be indicated in the following three situations: (a) if a decompression through a posterior approach seems futile, (b) if a bony deformation persists after a reduction attempt, and (c) if an osteosynthesis with the posterior approach is impossible due to destruction of the pedicle and the osseous neural arc of several adjacent vertebrae. In such cases, the spinal cord is decompressed anteriorly with a partial or subtotal spondylectomy and the defect is fused with a solid allo- or autogenous bone graft. The intercorporal spinal arthrodesis in the thoracic spine is then secured with a anterolateral plate (Fig. 8). In the lower thoracic and the lumbar spine an additional anterior plate is used (19). Usually, only two segments are bridged (Fig. 9).

Postoperative Treatment

All patients are treated postoperatively in a functional manner irrespective of the operative technique used and can be mobilized within a few days,

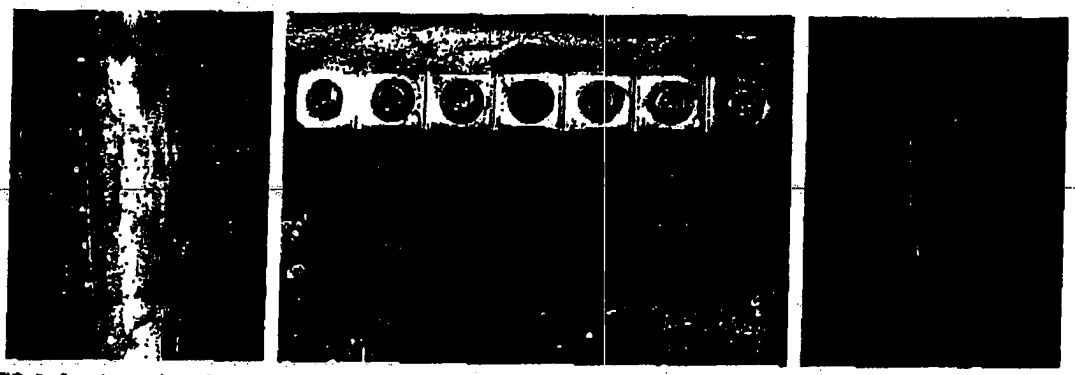


FIG. 8. Specimen of an 18-year-old polytraumatized woman who died of lung failure after an anterior stabilization. Anterior view shows the anterolaterally placed plate (a). Arrows in lateral view point to implanted solid bone block after removal of destroyed vertebra T5 and T6. The additionally implanted corticocancellous bone has been removed (b). Radiograph of same case (c).

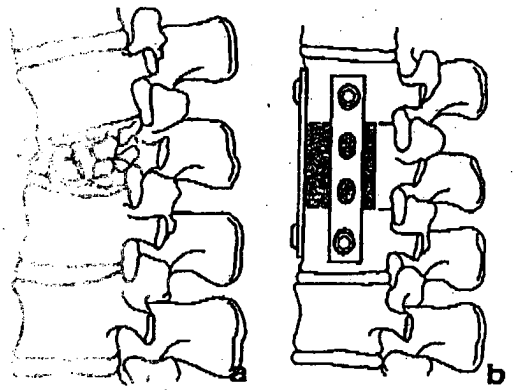


FIG. 9. Anterior spine arthrodesis of the lumbar spine with a bone block and two plates.

provided that neurologic recovery is adequate. In many cases, a three-point fixation brace must be worn (Fig. 10).

MATERIALS AND METHODS

Between 1979 and January 1, 1987, we treated 78 patients with 80 acute thoracic or lumbar spine injuries.

Causes of Injury

Thirty-one patients were injured in a fall, about the same number were involved in a car accident, and an additional nine patients sustained a direct blow with a heavy object (Fig. 11).

Type of Injury and Localization

We used the McAfee et al. classification (22). According to this schema, 51 patients were diagnosed as having a burst fracture, 3 as having a Chance fracture, 10 a flexion-distraction injury, and 16 a translational injury. Information on the distribution is shown in Table 1; data on additional injuries is given in Fig. 12.

Time of Operation

The delay between trauma and operation was only 6 h for 27 patients; 49 fractures (63%) were treated within the first 24 h. All patients who were operated on >3 weeks posttrauma were excluded from this study.

Operative Technique

Of the 50 patients operated on with a posterior approach, 2) received a paraspinal plate osteosynthesis. At the beginning of our follow-up period, interspinal wiring was used exclusively in six patients (Fig. 13A). The last 12 patients operated on received a spinal fixator (Fig. 14). The anterior spinal arthrodeses are shown in Fig. 13B; depending on their location, they were secured with one or two plates (Fig. 15). The number of fused segments is shown in Fig. 16.

RESULTS

In this retrospective study, the data from 76 patients with 78 lesions of the thoracolumbar spine were analyzed. Of the entire group of patients, 35 are female and 41 are male, with a mean age of 27 years (14–51 years). The average follow-up period was 3 years and 4 months (5 months to 5 years and 4 months).



FIG. 10. Mobilization of a patient with a three-point fixation brace 4 days following surgery for a lumbar spine burst fracture.

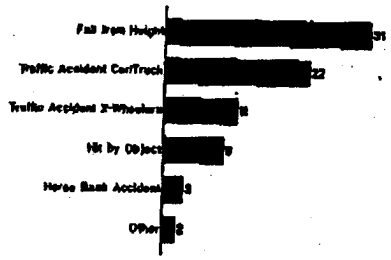
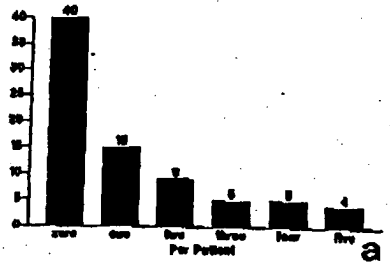


FIG. 11. Causes of fractures in 78 patients.



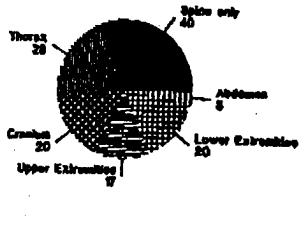


FIG. 12. Additional injuries. Number per patient (a) and type of additional injury (b).

Neurologic Course

According to the Frankel scale, 20 patients were categorized into group A, 12 into group B, 16 into group C, and 20 into group D. Only 10 patients had no neurologic deficit.

At the time of reexamination, neurologic status was unchanged in 37 patients, whereas improvement by one group was noted in 21 patients and improvement by 2 groups was noted in 9 other patients. In 9 additional patients, the decrease of neurologic deficits was not significant enough to elevate their group status. Of the 48 patients with an incomplete lesion (Frankel B–D), 29, or 60%, had improved by at least one group (Fig. 17). A comparison of the neurologic course of patients operated on with an anterior rather than a posterior approach does not show a significant difference in our group of patients: In both groups, about ⅔ of all patients with an incomplete lesion had improved.

Radiologic Course

Lateral radiographic views were used for determination of the sagittal index and the angle between the adjacent vertebral endplates. An assessment of the amount of neural compromise as a percentage of the midsagittal diameter of the spinal canal was possible with horizontal CT scans (Fig. 18).

The average preoperative kyphosis in the 27 patients with thoracic spinal injury operated on amounted to 25°, initially decreasing postoperatively to 6°, and then increasing to 16° of kyphosis at the last visit. An average of 10° of loss of correction was noted. Thirty-one patients were operated on in the area of the thoracolumbar transition with a preoperative angle of kyphosis of 16° with improvement to 4° of lordosis following surgical intervention. At follow-up visit, a loss of 10° to 6° of kyphosis could be measured. Surgery of the lumbar spine resulted in the largest amount of correction (Fig. 19). The preoperative angulation averaged 19° of kyphosis, improving to 11° of lordosis after surgery and finally settling to 5° of lordosis at last visit. The loss in this group amounted to 6° (Fig. 20).

In the patients who had anterior surgery, the loss of correction totaled 7° irrespective of location (20° preoperative kyphosis, 2° postoperative kyphosis, and 9° kyphosis at last visit), while the angulation following posterior surgery averaged 9° (15° preoperative kyphosis, 11° postoperative lordosis and 9° lordosis at last visit; Fig. 20). The sagittal index improved from 0.59 preoperatively to 0.80 postoperatively irrespective of location.

All the spinal arthrodeses were radiologically bridged by solid bony structures. In 21 patients, a breakage of an instrumentation screw occurred, but

TABLE 1. *Types of injury and their anatomic location*

	Th6-11	Th12-L1	L2-5	total
Stable Burstfractures	7	4	4	15
Unstable Burstfractures	6	18	12	36
Chance-Fractures	0	2	1	3
Flexion-Distraction	7	2	1	10
Translational Injuries	7	5	4	16
Total	27	31	22	80

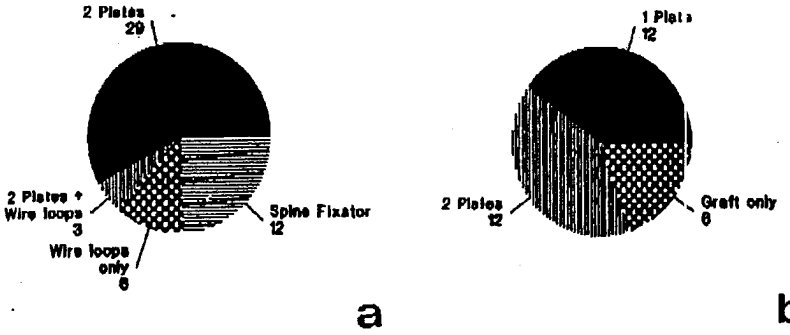


FIG. 13. Fusion technique employed in 50 operations with posterior approach (a) and 30 operations with anterior approach (b).

with the exception of one case, none of these incidences had an influence on outcome. In most cases, small fragment screws were involved and these are no longer used in our department.

Of the 12 postoperative CT scans, 11 were ordered after posterior decompression and one was ordered after anterior decompression. An average reduction of the sagittal spinal canal diameter from 65 to 11% was achieved. In two of the cases with a posterior approach, only a small improvement was noted. One patient improved by one Frankel grade; the other had an unchanged neurologic deficit.

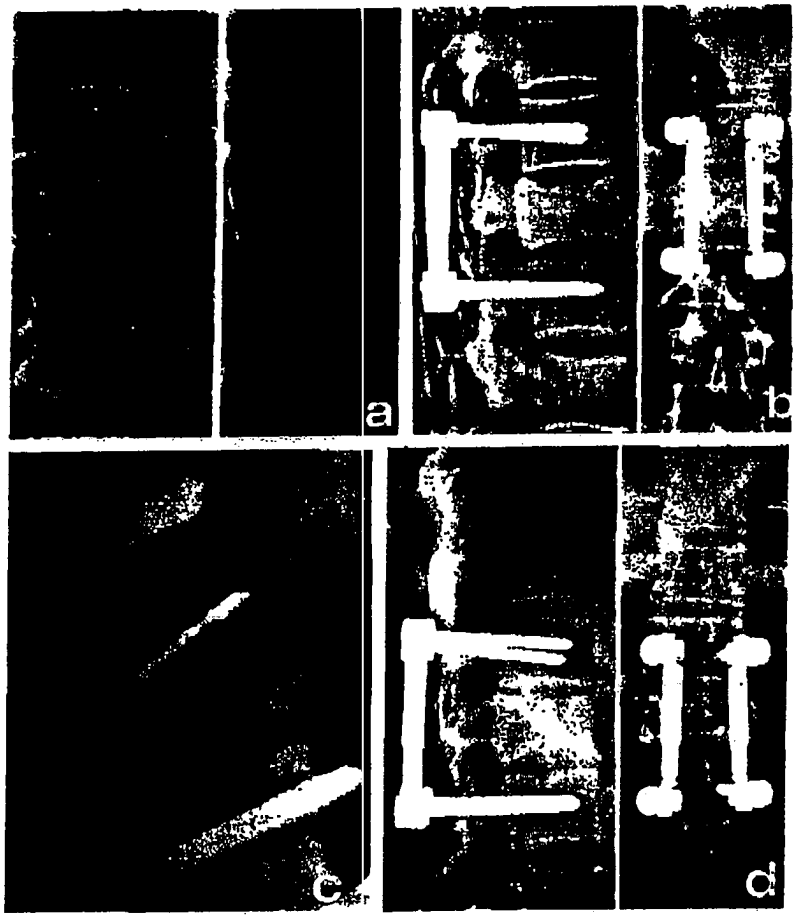


FIG. 14. W. M., 38 years old. Burst fracture L 1; preoperative radiograph and result following closed reduction (a). Postoperative radiograph (b). Transpedicular lifting of the upper vertebral plate (c). One and a half years later, only a small loss of correction remained (d). Neurologic recovery from Frankel D to E.



FIG. 15. S.T., 18 years old. Translational injury T ½ (a). Preoperative computed tomography scan (b) and postoperative result (c). Frankel A.

Complications

One postoperative deep wound infection occurred in a patient with an L1-translational fracture. The infection resolved after removal of the implants and installment of through-wound drainage. A bony fusion developed between L1 and L2. Unfortunately, the loss of correction at last visit amounted to 30°.

In two patients with complete paraplegia, the posteriorly implanted plates tore out shortly after an operation in the midthoracic spine. In both cases, unstable burst fractures of three adjacent vertebral bodies were present, which may account for the insufficient anchorage. Today, we would prefer the anterior approach. One of the patients fused following an right-sided thoracotomy; in the other, the osteoligamentous injury resolved after 4 months of bed rest. In an additional case (T10 compression fracture) a kyphosis reappeared shortly after the operation; this patient required a new posterior plate instrumentation.

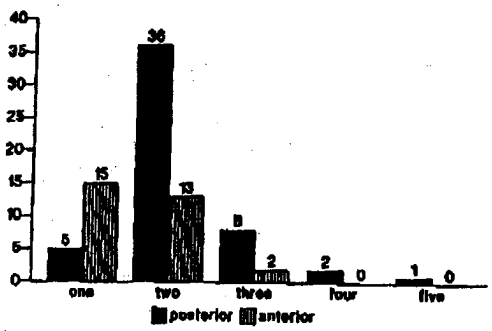


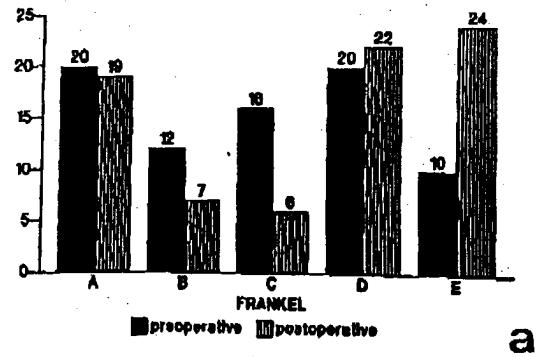
FIG. 16. Number of fused segments using anterior and posterior approach.

DISCUSSION

Neurology

Currently, the future of the neurologic outcome after an incomplete cord injury is not predictable. Indications, however, point toward a connection between effective fracture reduction and neurologic recovery. Bohlman and Eismont (3) produced by pressure an incomplete transverse spinal lesion in dogs and were able to show a distinct recovery several weeks later after the compression had been alleviated. Apparently, the nerve tissue had been compromised in its function but was not irreversibly damaged. Aebi et al. (1) reported an often positive correlation between early nonsurgical reduction within 6–12 h posttrauma and a later improvement of the neurologic status. We were able to confirm this observation with our own patients. We therefore consider an immediate nonsurgical reduction of dislocated fractures and luxations an important first step in minimizing the sequelae of the injury.

Significant neurologic improvement has been reported following anterior decompression (17,21,23). Nevertheless, the posterior approach can also be effective for decompression of a compromised spinal cord. Bony fragments can be removed with forceps or repositioned into the fractured vertebra following extended flavectomy. Garfin et al. (10) reported nine patients with burst fractures in the thoracolumbar zone. In all cases, a considerable



a

AA 19	AB 1	AC 0	AD 0	AE 0
BA 0	BB 6	BC 2	BD 4	BE 0
CA 0	CB 0	CC 4	CD 9	CE 3
DA 0	DB 0	DC 0	DD 9	DE 11
EA 0	EB 0	EC 0	ED 0	EE 10

b

FIG. 17. Neurologic course. Grading according to Frankel et al. (9).

spinal canal compromise persisted after closed reduction of the fracture. At surgery, it was possible to remove the block in eight cases with a posterolateral approach. Altogether, seven patients improved neurologically at least one Frankel grade in his series.

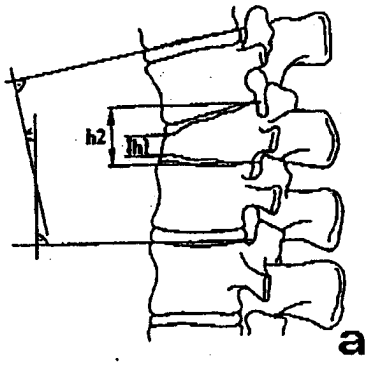
At follow-up in 48 patients with incomplete neurologic deficit, 30 showed an improvement of at least one grade. In nine patients, (all but 2 of whom were grouped into Frankel D), an improvement of their symptoms was noticed but was not sufficient to regroup them into Frankel E. The percentage of neurologically improved patients was about equal in the group with anterior and posterior approach.

Operative Technique and Radiologic Results

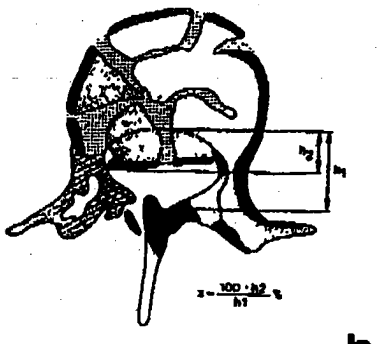
The spine is stabilized primarily to prevent further spinal cord injury. In addition, a high degree of restoration of the spinal anatomic axis and curvature is of equal significance. We believe that it is also important to fuse permanently as few vertebrae as possible, yet continue to utilize functional therapy postoperatively. Paraplegics particularly benefit from residual mobility of their spine. Kahanovitz et al. (14) reported micro- and macroscopical signs of degenerative disease in bridged but unfused spinal joints.

In the past, reported operative results utilizing Harrington rod instrumentation have not always been satisfactory. An insufficient postoperative correction, frequent reexplorations due to pain, dislocation of a hook or rod, and an unsatisfactory position with often 20° of kyphosis were the main reasons for unsatisfactory results (1,6,11,24,27). The fusion area in most cases was five to seven segments.

Better results can be achieved with posterior spinal arthrodesis using paraspinal plates. Roy-Camille et al. and Yosipovitch et al. (26,27) reported 44 patients with wedge-compression of >20° preoperatively. Following an "excellent reduction and stabilization" over five segments with two plates and screws, the follow-up examination revealed only three patients with correctional loss of >10°. Daniaux (4) treated 44 burst and compression fractures with transpedicular lifting of the upper end-



a



b

FIG. 18. Angle between the adjacent endplates of a fractured vertebra (alpha) and sagittal index h1/h2 (a). Percentage of compromise of spinal canal in a computed tomography scan (b).

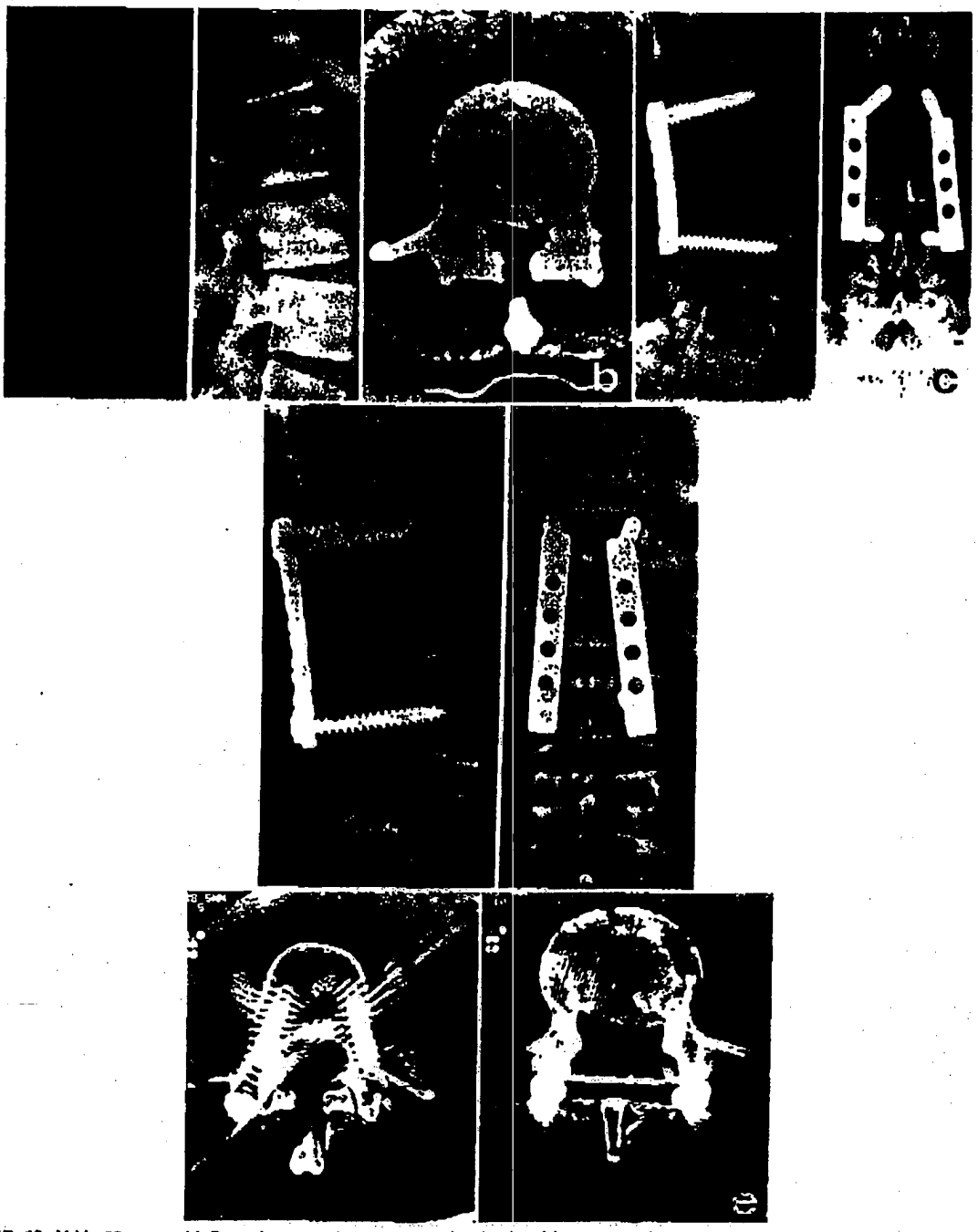


FIG. 19. M.M., 32 years old. Burst fracture of L1 and closed reduction (a). Preoperative computed tomography (CT) scan (b). Control radiograph in postoperative period (c) and 15 months later (d). Postoperative CT scan showing correct position of screws (left) and almost complete decompression of spinal canal (e). Neurologic recovery from Frankel C to E.

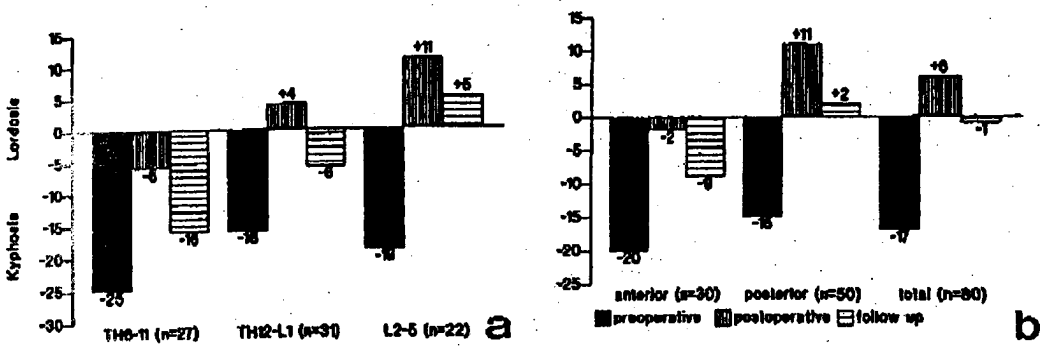


FIG. 20. Radiologic course, listed either by location of injury (a) or method of approach (b).

plate and a cancellous grafting as well as a short, only two segment bridging plate spinal arthrodesis. When compared to the early postoperative result, he found an average decrease of 10.4 degrees at followup.

In our patients, the settling between the immediate postoperative status and the status at followup was 9° following posterior surgery and 7° following anterior surgery. We were able to achieve this result despite two segment fusion in ~80% of all our operations. One restriction must be mentioned: Only a small percentage of all patients have had the implanted devices removed.

CONCLUSIONS

We suggest a short posterior paraspinal spinal arthrodesis with plates or an internal fixator for the lower thoracic spine as well as for the lumbar spine. It is possible to decompress the spinal cord with a posterior approach after flavectomy. In some cases with residual spinal stenosis, an end functional impairment is not predictable. When plates are used, a loss of correction of between 8 and 10° appears inevitable. Due to the stable connection between the Schanz screws and the longitudinal rods, we believe the internal spinal fixator can give us better results. The anterior approach is advantageous for the upper thoracic spine except for locked subluxations dislocations.

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Phillip G. Spiegel, M.D.
Editor-in-Chief

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