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ORIGINAL ARTICLE

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Functional outcome in patients with thoracolumbar burst fractures treated with dorsal instrumentation and transpedicular cancellous bone grafting

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Abstract The aim of the study was to develop an insight into the impairments in spinal fracture patients, operatively treated with an internal fixator, and also into their ability to participate in daily living, return to work and quality of life as defined by the World Health Organization. Nineteen patients operated for a type A fracture of the thoracolumbar spine (T9–L4) between 1993 and 1998 in the University Hospital Groningen, the Netherlands, aged between 18 and 60 years, without neurological deficit were included in the study. Operative treatment consisted of fracture reduction and internal fixation using the Universal Spine System, combined with transpedicular cancellous bone grafting and dorsal spondylodesis. No ventral fusion operations, laminectomies or discectomies were done. Restrictions in body function and structure were measured on radiographs and in functional capacity tests, such as lifting tests and ergometry. Restrictions in activities were studied with the Visual Analogue Scale (VAS) Spine Score and the Roland Morris Disability Questionnaire (RMDQ). Restrictions in participation/quality of life were analysed with the Short Form 36 (SF36) and described in the return to work status. The radiological results are comparable to the literature. The reduction of the anterior wedge angle was followed by a gradual partial loss of intervertebral angle and regional angle. The maximum oxygen uptake (VO_2-max) was reduced in only 8.3% of the patients. Arm and trunk lift was within the normal range in 87% and 80% of the patients respectively, but only 53% of the patients were able to perform a leg lift within the normal range. A mean RMDQ score of 4.0 positive items (SD 6.0) was found, and the mean VAS Spinal Score was 79.4 (SD 25.0), both better than in other series. No significant differences compared to the values of a comparable (healthy) age group could be identified in any variable of the SF36. A high correlation was seen between RMDQ, VAS Spine Score and the SF36 categories. No correlation was found between the anterior wedge angle and the regional angle on the one hand, and functional capacity tests or questionnaire scores on the other. Of the patients in paid employment before the trauma, 87% had returned to work at follow-up. About 50% of the patients had been obliged to change the intensity of their work or the kind of work they performed after the injury and treatment. In this matter, leg (muscle) performance seems a more important factor than overall condition (VO_2-max). The results of the study indicate that patients with thoracolumbar spinal fractures without neurological deficit, treated with dorsal instrumentation, perform like healthy people 3–8 years after injury, according to the RMDQ, VAS Spine Score and SF36 results. Physical capacity tests reveal that leg (muscle) performance seems a more important factor in impairment than arm lift or overall condition.

Keywords Spinal fracture · Operative treatment · Internal fixator · Outcome assessment · Exercise test · Questionnaires

Introduction

Clinical studies on the functional outcome of the treatment of trauma patients are relatively scarce. As a consequence, little is known about the degree of disability after trauma in general and after spinal fractures in particular [37]. Outcome after thoracolumbar spinal fractures is generally seen in terms of the radiological result of the treatment, referred to by some authors as "surrogate" outcome [18]. Functional outcome after operative therapy is seldom investigated. The present study describes the functional outcome of patients with a thoracolumbar burst fracture, operatively treated with pedicle screw internal fixation, transpedicular cancellous bone grafting, and dorsal spondylodesis [3, 4, 5]. Ventral fusion was not pursued. The aim of the study is to develop insight into the impairments in these patients, and also into their ability to participate in daily living, return to work and quality of life as defined by the World Health Organization (WHO) in the International Classification of Function, Disability and Health (ICF) [2, 36].

Materials and methods

Patients operated for a type A fracture (Comprehensive Classification [23]) of the thoracolumbar spine (T10–L4) between 1993 and 1998 in the University Hospital Groningen, the Netherlands, aged between 18 and 60 years, without neurological deficit were included in the study. Exclusion criteria were spinal disorders in their medical history (including low back pain previously treated by a medical specialist), pathological fractures and insufficient command of the Dutch language. The Medical Ethics Committee of the University Hospital Groningen approved the study protocol (no. 99/12/206).

Within these criteria, a group of 35 patients were identified. Eleven patients did not respond, four refused to join the study, and one patient agreed to participate in the study, but did not show up at several appointments. Eventually, 19 patients joined the study. The mean age of the respondents was 40.5 (range 24–57, SD 10.3) years; ten patients were male and nine were female. Aetiologic factors were: traffic accidents (n=3), accidental fall from a height (n=10) and sports accidents (horse riding, motor sports and parachute jumping) (n=6). Fracture levels were mainly T12 and L1 (Table 1), and the Comprehensive Classification of the type A fractures showed 68% A3 fractures (Table 2). Three patients had multiple fractures at other locations. In all patients the Injury Severity Score (ISS) was derived from the codes of the Ninth version of the International Classification of Diseases (ICD-9) [12]. Mean ISS was 10.6 (range 9–22). One patient suffered from diabetes mellitus, two from cardiovascular ischaemic disease and two from chronic obstructive pulmonary disease. Respondents did not differ in fracture severity, co-morbidity, age or gender from non-respondents.

Table 1 Level of spinal fracture in 19 patients

Level	n
T10	1
T11	0
T12	8
L1	8
L2	0
L3	2
L4	0

Table 2 Comprehensive classification in 19 patients [23]

Class		Subclass	n
A1	2	A1.1	0
		A1.2	1
		A1.3	0
A2	4	A2.1	0
		A2.2	0
		A2.3	4
A3	13	A3.1	9
		A3.2	4
		A3.3	1

Operative treatment consisted of fracture reduction and internal fixation using the Universal Spine System (USS, Synthes) within 8 days, combined with transpedicular cancellous bone grafting of the fractured vertebral body. Dorsal spondylodesis was performed only in A3-type fractures, at the level of the injured endplate. No ventral fusion operations, discectomies or laminectomies were performed. Early postoperative complications were seen in three patients—one deep wound infection, one temporary bladder dysfunction, and one superficial decubital ulcer.

Within a week after surgery all patients were transferred to a rehabilitation centre, where they were mobilised with a simple thoracolumbar support orthesis (reclination brace) within 2 weeks after operation. In 18 patients the implants were removed at 9 months after the primary operation. In one patient (A3.3 fracture) the implants were left in place, because both segments had been stabilised additionally by dorsal spondylodesis.

Functional outcome in this study is defined by using the concepts described in the ICF of the WHO. The ICF recognizes *restrictions in body function and structure, restrictions in activities*, and *restrictions in participation/quality of life*.

Restrictions in body function and structure

In this study restrictions in body function and structure are described by objective findings in radiographical analysis in the course of follow-up, using the anterior wedge angle (AWA) and regional angle (RA), and by testing the physical capacity of the respondents after 3–8 years (static and dynamic lifting tests, and an ergometric exercise test).

The anterior wedge angle (AWA) and regional angle (RA) were measured at 0, 1, 9, and 24 months on plain transverse radiographs. The change in the angles was calculated for the following periods: the perioperative period (period I: t=0–1 months), the period until implant removal (period II: t=1–9 months) and the period after implant removal (period III: t=9–24 months) [22].

Physical tests

Dynamic lifting test

The patient is asked to lift a box with a weight from the floor to a 75-cm-high table and back to the floor again four times in 20 s. The starting weight for men is 5.85 kg, and for women 3.6 kg. After 20 s of lifting exercises the patient rests for 20 s. After each rest, the patient decides whether they will stop or go on to a heavier weight (men 4.5 kg more, women 2.5 kg more) [24]. The personal maximum weight is calculated with the formula:

$$\text{Wmax} = 0.6 \times \text{Body mass}$$

The test is stopped when the cardiac frequency rises above the personal maximum value, when the personal maximum lifting weight is achieved, when the patient cannot perform the exercise within 20 s or when the patient wants to stop for other reasons. The personal maximum cardiac frequency (MaxCF) is 85% of the age-related maximum cardiac frequency [MaxCf=(220–age)x0.85]. The highest lifted weight according to the dynamic lifting test is called the maximum lifted load. The maximum lifted load is then compared to the Dutch National Institute for Occupational Safety and Health (NIOSH) norm, according to which norm a person is allowed to lift a maximum load of 14.8 kg over an 8-h working day [24, 25, 40]. The loading degree is calculated as follows:

$$\text{Loading} - \text{degree} = \frac{\text{max lifted load}}{14.8\ \text{kg}} \times 100\%$$

Static lifting test

The static lifting test consists of three tests. In a leg lift test (NIOSH norm 23 kg), a trunk lift test (NIOSH norm 14 kg) and an arm lift test (NIOSH norm 15 kg), the patient is asked to lift an "acceptable maximum effort" (AME) in three positions [11]. Between the tests, 1 min of rest is allowed. The test is repeated with either the NIOSH norm, in case the patient lifted a higher weight than the NIOSH norm at the first attempt, or with 50% of the lifted weight in case the NIOSH norm was not reached. The loading degree in the leg, trunk and arm lift was calculated as follows:

$$\text{Loading degree} = \frac{\text{AME}}{\text{Second lift (NIOSH} - \text{norm or 50\% AME)}}$$

Ergometric test

The VO_2-max (maximum oxygen uptake in litres per minute) was calculated after a sub-maximal bicycle ergometry, in which the cardiac frequency, measured in beats per minute (bpm), the working load (Watts) and the number of revolutions (per minute) were measured [40]. The formula is:

$$VO_2 - \text{max(male)} = \frac{174.2 \times \text{max working load} + 4020}{103.2 \times \text{cardiac frequency} - 6299}$$

and:

$$VO_2 - \text{max(female)} = \frac{163.8 \times \text{max working load} + 3780}{104.4 \times \text{cardiac frequency} - 7514}$$

The starting load at 60 revolutions per minute is 50% of the Lean Body Mass (LBM) for 2 min. The load is raised to 150%, 200% and 250% of the LBM until the cardiac rate is 120 bpm or more. The highest load is performed for 6 min. The lifting test and ergometric test findings were compared to normal values.

Restrictions in activity and/or degree of disablement

Restrictions in activity and/or the degree of disablement were assessed by the Dutch versions of two disease-specific questionnaires, the Visual Analogue Scale VAS Spine Score and the Roland Morris Disability Questionnaire (RMDQ) [15, 30, 31].

The VAS Spine Score, developed to be used in spinal fracture patients, asks the patient to rate the functional outcome in 19 items on an analogue 10-cm visual scale. The patient's perception of pain and restriction in activities, related to problems of the back, is measured [15]. Higher scores represent better results, recalculated to percentages of the maximum score (0–100%).

The RMDQ was developed to measure and register changes over time during the treatment of low back pain. The form consists of 24 statements concerning certain (restrictions of) activities, qualified as positive (restricted) or negative (not restricted) [30, 31]. Lower scores on the scale of 0–24 represent better results.

Restrictions in participation and aspects of quality of life

Finally, restrictions in participation and aspects of quality of life were described in the Short Form 36 and in the return to work status.

Short Form 36

The Dutch version of the Medical Outcome Study MOS 36 item Health Survey or Short Form 36 (SF36) scale contains nine subscales: physical functioning, social functioning, role limitation due to physical problems, role limitation due to emotional problems, mental health, energy and vitality, pain, general perception of health and change in health over the past year [26, 39]. Higher scores represent better results.

Return to work status

The respondents were asked about their former and actual employment status.

Statistical analysis

The RMDQ result, VAS Spine Score, and SF36 score were compared to reference data with the Student *t*-test [15, 18, 20, 41]. Regression analysis was used to determine the correlation between changes in radiological angles and RMDQ, VAS Spine Score, and SF36, respectively.

Results

Restrictions in body function and structure

Radiographic evaluation showed that the preoperative mean AWA was 16.2°, which was reduced to 7.2° postoperatively. Until the end of follow-up, the AWA gradually increased to 8.5°. The RA was reduced from 13.2° to 5.0° in period I. The RA increases, mostly after implant removal, to 12.9° at 24 months (Table 3). The main loss in AWA and RA occurred in period III (after implant removal) (Table 4).

Physical capacity, measured as static and dynamic lifting strength, VO_2-max, and loading degree in the bicycle ergometric test show large ranges in all categories (Table 5). Comparison with normal values of healthy probands in comparable age groups shows that arm and trunk lift was within the normal range in 87% and 80% of the patients respectively, and 53% of the patients were able to perform a leg lift load within the normal range (Table 5).

Table 3 Radiographic measurements of anterior wedge angle (AWA) and regional angle (RA) in 19 patients in the course of treatment

t (months)	0 (preop)	1 (postop)	9	24
AWA	16.2°	7.2°	7.5°	8.5°
RA	13.2°	5.0°	6.1°	12.9°

Table 4 Changes in AWA and RA in periods I, II, and III

	I	II	III
AWA difference	8.9°	0.1°	–1.2°
RA difference	8.2°	–1.1°	–6.8°

Restrictions in activities (disablements)

In the RMDQ a mean score of 4.0 positive items (SD 6.0, median 1.0, range 0–20) was found (Table 6). Two out of 19 patients had an unexpectedly high score (18 and 20).

The VAS Spine Score revealed a mean score of 79.4 (median 90.5, SD 25.0, range 17.4–100) (Table 7). The mean value does show a difference compared to uninjured people (P=0.042). The distribution of scores is skew because of two very low scores.

Restrictions in participation/quality of life

SF36 analysis revealed no significant differences compared to the values of a comparable (healthy) age group in any subscale [10].

The return to work status shows that 13 of the 15 patients (87%) who had been in paid employment before injury had returned to work at follow-up. Seven of them (47%) had arranged changes in the kind of work or in the intensity or duration of the work they were doing. One patient (7%) changed his job. Two of fifteen patients in paid employment before the injury stopped working post injury and received social security benefits.

A high correlation was seen between RMDQ, VAS Spinal Score and the SF36 subscales (Table 8). No correlation was found between preoperative AWA and RA, or AWA and RA at 24 months, or AWA differences on the one hand, and functional capacity test scores, RMDQ, VAS Spinal Score, or SF36 on the other.

Discussion

Functional outcome in patients with an operatively treated thoracolumbar burst fracture is a relatively infrequent topic

Table 5 Functional capacity measured by bicycle ergometric test and static and dynamic lifting test in 12–15 patients

	N	Mean	SD	Range		% under norm	*P*-value (*t*-test)
VO_2-max (ml/min.kg)	12	34.0	6.5	20.8	45.5	8.3	0.239
Max leg lift (kg)	15	41.7	21.1	5.0	80.0	46.7	<0.001
Max arm lift (kg)	15	36.6	21.1	5.0	82.5	20.0	0.668
Max trunk lift (kg)	15	26.0	11.9	2.5	45.0	13.3	0.221

Table 6 Comparison of Roland Morris Disability Questionnaire(RMDQ) values in patients with low back pain (mean score, SD) and operatively treated spinal fractures

Author	Group	*N*	Follow-up (years)	Positive items	
				Mean	SD
Leclair et al. [20]	Simple low back pain (mean duration 2.3 weeks)	99	–	10.9	4.7
	Low back pain with radiculopathy (mean duration 28.1 weeks)	97	–	14.2	5.2
Weinstein et al. [41]	Conservatively treated thoracolumbar burst fractures	42	20.2 (11–55)	13.2	–
Kraemer et al. [18]	Thoracolumbar burst fractures (operative and non-operative)	24	3.8 (2.2–7.1)	15.6	6.5
Our study	Thoracolumbar burst fractures after USS	19	4.5 (2.6–7.9)	4.0	6.0

Table 7 Visual Analogue Scale Spine Score

	Values in uninjured people [15] (*n*=136)	Hannover study[a] [15]			Our study[b] at follow-up (54 months) (*n*=19)
		Before trauma (*n*=53)	At implant removal (7–13 months) (*n*=51)	At follow-up (23 months) (*n*=53)	
Mean	92.0	89.6	58.3	66.1	79.4
Median	94	95	59.0	70	90.5
SD	7.5	14.9	22.2	25.0	25.0
Range	58–100	21–100	13–97	15–100	17.3–100

[a] Trauma levels T10–L2
[b] Trauma levels T9–L4

Table 8 Correlation between RMDQ, VAS Spine Score and SF36

	VAS	RMDQ	SF36 Physical functioning	SF36 Social functioning	SF36 Role restriction physical problem	SF36 Vitality	SF36 Pain	SF36 General health
VAS	1.00	–0.72**	0.54*	0.51	0.69**	0.71**	0.66*	0.60*
RMDQ	–0.72**	1.00	–0.69**	–0.76**	–0.83**	–0.56*	–0.60*	–0.68*
SF36 Physical functioning	0.54*	–0.69**	1.00	0.57*	0.42	0.51	0.30	0.55*
SF36 Social functioning	0.51	–0.76**	0.57*	1.00	0.71**	0.56*	0.81**	0.85**
SF36 Role restriction, physical problem	0.69**	–0.83**	0.42	0.71**	1.00	0.63*	0.64*	0.71**
SF36 Vitality	0.71**	–0.56*	0.51	0.56*	0.63*	1.00	0.75**	0.82**
SF36 Pain	0.66*	–0.60*	0.30	0.81**	0.64*	0.75**	1.00	0.87**
SF36 General health	0.60*	–0.68*	0.55*	0.85**	0.71**	0.82**	0.87**	1.00

*P<0.05; **P<0.01

of research. In this study we tried to develop an insight not only into the radiological and functional impairments in these patients, as defined by the ICF of the WHO, but also into patients' ability to participate in daily living, such as return to work and quality of life [2, 36].

Restrictions in body function and structure

The radiographic findings were compared to those in the literature [13, 22]. Previous studies have shown that the AWA and RA can be restored by indirect instrumental manipulation via pedicle screws. The AWA remains almost the same in the course of follow-up, even after implant removal. The RA decreases to the preoperative value in 24 months. The main part of the decrease is due to loss of intervertebral angle [22]. The effect of the segmental dorsal spondylodesis is a complete loss of range of motion of this segment [21]. At the adjacent segments a loss of 50% of normal range of motion occurs without spondylodesis. This is believed to be the effect of trauma, operative treatment and immobilisation [21].

Three to eight years after operation, the functional capacity in our study population remains decreased compared with uninjured people. In testing the maximum leg lift, almost 50% of the patients perform less well than the lowest normal value. In the arm and trunk lift tests, the VO_2-max, and the ergometric test, the patients show better scores, but variable percentages of patients score below the lowest normal values (Table 5). Although no patients with neurological deficit were included in the study and no neurological complications occurred, the test results show a decrease in performance and functional capacity, especially in leg lift and bicycle load, suggesting a major effect in leg muscle performance. In the future, more intensive leg muscle training in the rehabilitation programme may help to overcome this effect.

Restrictions in activity (disablement)

In our series the mean RMDQ score is better than previous reported RMDQ scores in patients with low back pain, radiculopathy or thoracolumbar fractures at 3.8 years and at 20.2 years of follow up (P<0.001) (Table 6).

Questionnaire data analysis of conservatively treated patients after a follow up of 11–55 years (mean 20 years) in 42 patients with burst fractures in 1987 showed that 88% had returned to their former job, some time after their injury [41]. Other findings in these patients were: 57% never became pain free, 90% reported some pain at follow-up, and 62% rated their pain as very minor. The RMDQ score in this conservatively treated group of patients was 13.2 (range 4.6–17.3 items, i.e. 55%, range 19–72%); this was considered by the author of that study to represent a *low disability of the mean patient* [41]. In our opinion, a mean number of 13.2 positive items in the RMDQ represents a *high* level of disability. This is in contrast with the low number of positive items in our study.

Another study showed that only 33% of patients with burst fractures returned to their previous employment [18]. This miscellaneous group of patients revealed a mean RMDQ score of 15.6 positive items (SD 6.5 items) after a follow-up of 3.8 years. Findings in the return to work status will be influenced by the injury and its treatment, but also by the intensity and availability of social security in the country and in the studied era.

Our RMDQ results of 4.0 positive items and 87% return to work are favourable compared to findings in the literature. The RMDQ scores are much better than previous reported RMDQ scores in patients with low back pain, radiculopathy or thoracolumbar fractures at 3.8 years and 20.2 years of follow-up (P<0.001).

Comparison of our results of the VAS Spinal Score with the results of the patients described by Knop et al. [15] (the Hannover study) show higher values in our series. The difference in mean (79.4 vs 66.1) and median

(90.5 vs 70) scores at follow-up are relatively large and significant ($P<0.05$). Our longer follow-up period may be an explanation for this difference, and there may also be a difference in injury factors (for example neurological deficit), which are not specified in the Hannover series [15].

No correlation could be identified between radiological outcome and functional capacity tests. This suggests that there is no relation between the quality of reduction and fixation, and the functional outcome. A possible relation may be unrecognised because of the relative uniformity of the AWA and RA values, and of changes in those values, over the course of follow-up. Unexplained is the lack of correlation between reduced functional capacity and restriction in activities.

In our opinion the results suggest that the operative treatment of thoracolumbar fractures without anterior fusion can lead to a good functional result.

Choice of Questionnaire

We chose to use the RMDQ as a specific back pain measure. Specific questionnaires for (low) back pain evaluation are numerous; for example, the Dallas Pain Questionnaire [19], Back Pain Functional Scale [35], Low Back Outcome Score [8, 32], Quebec Back Pain Disability Scale [16, 17], Million Questionnaire [27], Waddel Questionnaire [38], Oswestry Disability Questionnaire [6] and Roland Morris Disability Questionnaire (RMDQ), derived from the Sickness Impact Profile (SIP) [7, 30, 31].

These questionnaires measure the complaints in patients with low back pain, but are rarely used for the evaluation of trauma patients [14, 18, 28, 32]. The Sickness Impact Profile and the SF36 [10] have seldom been used for spinal fracture treatment evaluation, but the latter shows correlation with low back pain scores after spinal surgery [9]. In a literature review in 1995, it was found that Oswestry and RMDQ had an equal validity with the Million and Waddel questionnaires in low back pain research; however, the former have been used and evaluated more frequently [1].

The RMDQ was developed to measure and register changes over time during the treatment of low back pain [30, 31]. Changes in the RMDQ-score are dependent on the initial RMDQ score of the individual patient. So the initial score should be taken into account [29, 34]. Comparison with the Oswestry Disability Scale showed us that the RMDQ is more reliable than the Oswestry, because Oswestry is associated with a higher frequency of items being left blank and of more than one option being ticked in multiple response items [33]. It was because of these findings that we decided to use the RMDQ as the back pain specific questionnaire.

Restrictions in participation/quality of life

Grevitt et al. showed that the validity of the SF36 in operative spinal procedures is good [9]. In our series, VAS Spinal Scores correlate with RMDQ and all but one of the SF36 subscales, while the RMDQ correlates with all SF36 subscales (Table 8).

In our study the limited number of patients cause an increased risk of bias, although the non-respondents did not differ from the respondents in fracture severity, co-morbidity, age or gender.

Conclusions

Evaluation of disease-specific and non-disease-specific health status items and clinical tests show that patients with thoracolumbar spinal burst fractures (type A) without neurological deficit, who were operatively treated with dorsal transpedicular internal fixation, transpedicular cancellous bone grafting and dorsal spondylodesis, perform like healthy people 3–8 years after injury, according to RMDQ results, VAS Spine Score and SF36 score. These favourable results are obtained without anterior fusion. Only 2 of 15 patients stopped working. About 50% of the patients had to change the intensity of their work or the kind of work after the injury and treatment. In this matter leg (muscle) performance seems a more important factor than arm lift or overall condition (VO_2-max). These impairments do not necessarily imply restrictions in activities and participation, but paying more attention to leg muscle strength in training programmes seems logical.

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