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Prevalence and Clinical Outcome of Sympathetic Chain Injury after Anterior Approach to Upper Lumbar Fractures

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ABSTRACT

Background data: The sympathetic chain is a vulnerable structure in anterior reconstructive surgeries to upper lumbar fractures.

Purpose: To explore the prevalence of sympathetic chain injuries following the anterior surgical approach to treat upper lumbar fractures and their impact on clinical outcomes.

Study design: A nonrandomized prospective cohort study.

Patients and Methods: Consecutive cases with upper lumbar fractures that undergone surgery by either anterior or posterior approaches were preoperatively and postoperatively evaluated for sympathetic chain injury and followed up six months after surgery to explore outcomes. Two simple, valid, and reliable bedside tests were used to assess sympathetic functions: the skin wrinkling test (SWT) and the skin temperature difference (STD). Outcomes were assessed using the Oswestry Disability Index (ODI) and the 12-Item Short Form Survey (SF-12) at six months in both positive and negative groups with sympathetic injury.

Results: The 2 approach groups (32 cases each) showed comparable demographic and clinical criteria. The SWT showed high interrater reliability with agreement in 92% of cases. The positive group with confirmed sympathetic injury included 29 cases, all of which belonged to the anterior approach group. The negative group with equivocal or confirmed intact sympathetic function included 35 cases; 3 of them belonged to the anterior group. The ODI and SF-12 scores were found to be comparable between positive and negative groups 6 months after surgery.

Conclusion: Sympathetic chain injury is a frequent complication (90.6% of cases) following the anterior approach to upper lumbar fractures. The cases are unilateral, relatively silent, and related to the side of approach with no clinical impact on quality of life on 6-month outcome assessment. (2020ESJ201)

Keywords: Sympathetic; Lumbar; Fractures; Anterior approach

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INTRODUCTION

Fractures are considered the most common pathological entities affecting the thoracolumbar junction.[19] The posterior surgical approach is the most accepted and widely practiced surgical choice for this pathology. However, the anterior approach, including instrumentation and reconstruction, proved effective with satisfactory results in terms of neurological decompression, kyphosis correction, and stable arthrodesis even in some types of unstable three-column thoracolumbar injuries.[9, 23, 27] In spite of higher complications associated with the anterior approach,[20] others report no differences in the incidence of complications between the two approaches.[10, 16, 28, 30] However, to the best of our knowledge, none of the studies conducted on anterior approaches to upper lumbar fractures evaluated the prevalence of sympathetic chain injury during anterior surgery. This study aimed to explore the prevalence of sympathetic chain injury during anterior lumbar spine reconstruction and its effects on the clinical outcome compared to posterior fixation and fusion.

PATIENTS AND METHODS

We report a nonrandomized prospective cohort study. The study was approved by our local institutional review board (IRB) with written informed consent taken from each patient. Between June 2015 and December 2018, patients were recruited according to the eligibility criteria (Table 1).

Initial Assessment of Cases

Following admission and resuscitative measures, complete history-taking, detailed neurological examination, and full radiologic evaluation were performed. Radiographic and computed tomographic (CT) images were routinely performed and assessed by the senior resident. Cases with Thoraco-Lumbar Injury Classification and Severity (TLICS) scores of 4 or more indicated an immediate second opinion by the certified neurosurgeon on duty. Candidates considered appropriate for surgical intervention were further evaluated using the load sharing classification (LSC) score to select the surgical approach. Cases with LSC scores < 7 were managed by posterior fixation/fusion, whereas those greater than 7 were selected for anterior reconstructive surgeries. Cases were categorized into either anterior or posterior groups. Eligible cases were added consecutively to the anterior group over the prespecified period, with an equal number of consecutive cases included in the posterior group for final analysis. Magnetic resonance (MR) imaging was not indicated for any of our cases as all selected patients were neurologically intact.

Preoperative sympathetic function assessment was performed using skin wrinkling test (SWT) and skin temperature difference (STD). Skin wrinkling in hot water produced by the underlying vasoconstriction[40] was considered a useful assessment tool for the integrity of the limb sympathetic supply.[6,39] It was also considered a reliable test of sympathetic function and can adequately evaluate sympathetic blockade.[37] Both feet were immersed in a bucket containing warm (40 C°) water for 30 minutes as described by Bull and Henry[6]; then, the degree of wrinkling was assessed by direct visual evaluation in adequate indirect daylight using a 5-point clinical scale[7] for each toe (Table 2). Patients were instructed to avoid using any cream or lotion on their feet on the day of testing and avoid drinking tea or coffee 2 hours before the test.[36] Maintaining the temperature at 40°C over the entire test period was done by regular addition of hot water to the bucket and monitoring by a thermometer. The allowable maximum temperature deviation was 2°C.[36] The scores of the five toes for each limb were used to obtain the mean limb score. Scores less than 3 (i.e., 0–2) were considered indicators for sympathetic dysfunction, whereas scores of 3 or 4 indicated normal sympathetic function (Figure 1). This test was evaluated for both limbs in every case by two trained residents independent of the

study. Cutaneous temperature measurement is a commonly used method for lumbar sympathetic block monitoring.[13, 21, 38] The lower limbs skin temperature was measured after keeping the limbs uncovered for 10 minutes in a fixed and neutral AC-controlled room temperature (24–26°C). The skin temperature for each limb was calculated as the mean of 3 measurements taken, namely, i) the outer shin of the leg and ii) the dorsal and iii) plantar surfaces of the foot in specified standardized locations for all patients (Figure 2). Measurements were done using a handheld Equinox International® Non-Contact Infrared Thermometer adjusted to surface temperature mood in Celsius. Readings were taken at about 5 cm away from the skin surface and skin temperatures were compared between both limbs in each patient. A skin temperature difference (STD) equal to or more than 2°C was considered suggestive of sympathetic injury. Only cases with assumed intact sympathetic function, SWT ≥3 in both limbs and STD <2°C, were included in the study.

Postoperative Assessment

Postoperative sympathetic integrity and functional assessments were compared between the two groups. STD and SWT were assessed on the second to fifth days postoperatively. The postoperative SWT was assessed twice on each case by 2 raters by estimating the test score for each limb. In case of a SWT discrepancy between the two raters, then, the mean rater score was calculated. The interrater reliability for SWT scoring was evaluated using Cohen's kappa (k). During assessments, cases showing abnormal limb SWT (score <3) and STD ≥2°C were considered as confirmed sympathetic injury cases and were grouped in the positive group. Those with normal SWT scores and STD <2°C were considered as excluded sympathetic injury cases. Other cases were considered equivocal cases and were grouped with the excluded cases in the negative group.

The effect of sympathetic injury on clinical outcome was assessed between approach groups by comparing the patient-related outcome scores using translated versions of the Oswestry disability index (ODI) [2, 15] and 12-Item Short Form Survey (SF-12).[4, 14, 41] These assessment questionnaires were filled at 6 months in the outpatient clinic or during telephone calls performed by independent physicians. An online SF-12 score calculator was used to create the SF-12 based physical (PCS-12) and mental (MCS-12) scores. [29]

Statistical Analysis

The Shapiro–Wilk test was used for testing the normality of data distribution. Analytic statistics included a comparison of outcome assessment scores between the two groups using the independent *t*-test or Mann–Whitney test. Categorical variables were analyzed using the chi-square test. All statistical procedures were done using the Statistical Package for the Social Sciences (SPSS Statistics) for Microsoft Windows (Version 17.0, 2008; SPSS Inc., Chicago, IL, USA). The statistical significance level (alpha) was a p value ≤ 0.05 based on a two-sided hypothesis test. Our null hypothesis was "comparable prevalence of sympathetic chain injuries in anterior and posterior approach groups, with no impact of sympathetic dysfunction on final clinical outcome."

RESULTS

The demographic and preoperative clinical characteristics of patients are presented in (Table 3). The distribution of age and BMI was found to be the same across positive and negative groups of sympathetic injury ($p = 0.316$ and 0.671, respectively). Similarly, no significant difference in sex or level of fracture was found between the two groups ($p = 0.344$ and 0.628, respectively). Postoperative SWT was abnormal (score <3) in 31 cases and normal in 33 cases (Table 4). The agreement between the raters (in about 92% of cases) was found to be almost perfect using Cohen's kappa with bootstrap resampling (Table 5).

In the anterior group, measured ipsilateral limb skin temperatures ranged from 28.2 to 35.7°C

(mean 31.9 ± 1.8°C), where the contralateral limb ranged from 28.1 to 32.9 C° (mean of 30.5 ± 1.4°C). However, in the posterior group, skin temperatures were 28.3–32.8°C (mean 30.3 ± 1.5°C) and 30.6 ± 1.4°C in left and right lower limbs, respectively. The recorded STDs ranged from 0.1–3.2°C (mean 1.46 ± 1.02°C).

Sympathetic chain injury is shown to be statistically higher in the anterior compared to the posterior approach (29 cases or 90.6%) with statistical significance, X^2 (1, N = 64) = 53.029 (p < 0.001). Coming across the sympathetic chain during psoas muscle elevation was documented in 19 cases at the extreme anterior border of L2 (in 10 cases) and L1 (in 9 cases). In 8 cases, unintentional exposure of the sympathetic chain was suspected, and all of them belonged to the positive group. The subjective symptoms related to sympathetic injury (e.g., warmth and soreness) were reported in patients of positive and negative groups with similar frequencies (p = 0.112 and 0.193, respectively). The mean ODI and SF-12 scores in both positive and negative groups with sympathetic chain injury are presented in (Table 6).

Table 1. Eligibility criteria for the study population.

Selection criteria	Exclusion criteria
Traumatic upper lumbar (L1–L3) fractures with TLICS scores > or = 4	Posttraumatic neurological deficits
	Associated significant lower limb injuries
	Patients not assessed for sympathetic function preoperatively
	Confirmed or equivocal preoperative sympathetic injury
	Missed assessment of sympathetic function 2–5 days postoperatively

Table 2. The 5-point clinical scale based on Clark et al.[7]

Grade	Description
0	No evidence of any skin wrinkling at the tip of the toe
1	The tip of toe is not completely smooth
2	≤ 2 lines of wrinkling on the tip of the toe
3	≥ 3 lines of wrinkling on the tip of the toe
4	Wrinkling completely distorting the pulp of toe tip

Table 3. Demographic and preoperative clinical findings in patients.

Parameters	Values	Differences between approach groups (p value)
Age/years	36.2 ± 9.4	p = 0.126, Student's t-test
Sex (female/male)	28/36	p = 0.512, chi-square test
BMI[1]	27.4 ± 5.4	p = 0.098, Student's t-test
Fracture level (L1/L2/L3)	49/12/3	p = 0.103, chi-square test
Preoperative SWT[2] score	18 cases: score 3 46 cases: score 4	p = 0.410, chi-square test
Preoperative STD[3]	1.2 ± 0.3	p = 0.374, Student's t-test

[1]Body mass index.

[2]Skin wrinkling test.

[3]Skin temperature difference.

Table 4. Results of sympathetic chain assessment in approach groups.

Parameters		Anterior group (32 cases)	Posterior group (32 cases)
SWT[1]	Abnormal score (score < 3)	29 cases (26 with rater agreement; 3 with mean rater score)	2 cases (with rater agreement)
	Normal score (score ≥3)	3 cases (2 with rater agreement; 1 with mean rater score)	30 cases (29 with rater agreement; 1 with mean score)
STD[2]	Abnormal: ≥2 degrees	29 cases	No case
	Normal: <2 degrees	3 cases	32 cases
Sympathetic chain injury	Negative	3 cases (confirmed[3])	32 cases (30 cases confirmed[3]; 2 cases equivocal[4])
	Positive	29 cases (confirmed[3])	No case

[1]Skin wrinkling test.

[2]Skin temperature difference.

[3]Confirmed = both the SWT and STD were normal or were abnormal.

[4]Equivocal = SWT and STD have different results; one is normal, while the other is abnormal.

Table 5. Postoperative SWT scores and degree of agreement between raters.

Parameters	Rater 1	Rater 2	Overall agreement
Score 0	5 cases (7.8%)	5 cases (7.8%)	Kappa = 0.844, SE = 0.070, 95% CI = 0.688–0.968, $p < 0.001$
Score 1	12 cases (18.8%)	12 cases (18.8%)	
Score 2	12 cases (18.8%)	15 cases (23.4%)	
Score 3	27 cases (42.2%)	18 cases (28.1%)	
Score 4	8 cases (12.5%)	14 cases (21.9%)	
Injured chain	29 cases (45.3%)	32 cases (50.0%)	
Intact chain	35 cases (54.7%)	32 cases (50.0%)	

Table 6. Comparison of ODI and SF-12 scores between positive and negative groups.

Parameters		Positive group	Negative group	*p* value
ODI score[1]		24 ± 3.6	24 ± 4.4	0.746
SF-12:[2]	PCS-12	39.4 ± 6.9	39.7 ± 6.8	0.858
	MCS-12	52.5 (11.5)	49.2 (12.1)	0.032

[1]Oswestry Disability Index.

[2]12-Item Short Form Survey.

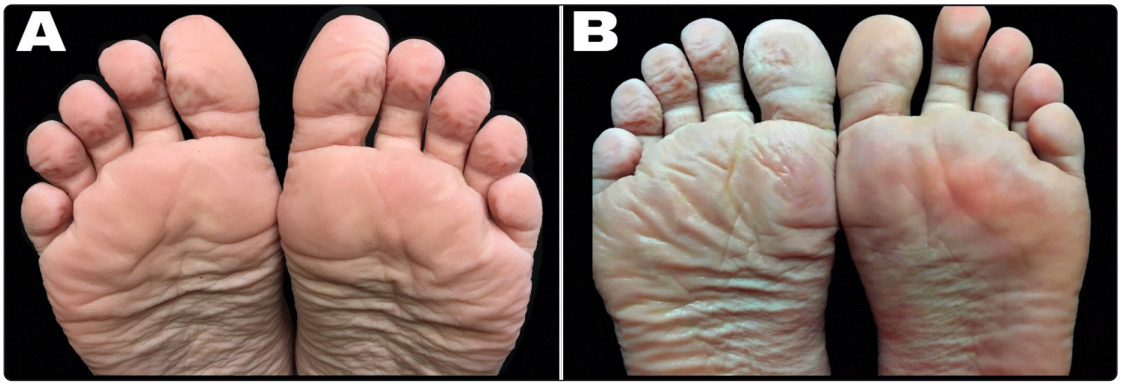

Figure 1. Two Postoperative cases: the left case underwent posterior fixation/fusion resulting in intact postoperative sympathetic functions. The SWT score was 4 on both feet. The right case underwent a left-sided anterior approach, which resulted in postoperative ipsilateral sympathetic dysfunction. The SWT score was 4 on the right contralateral and 0 on the ipsilateral (left) foot.

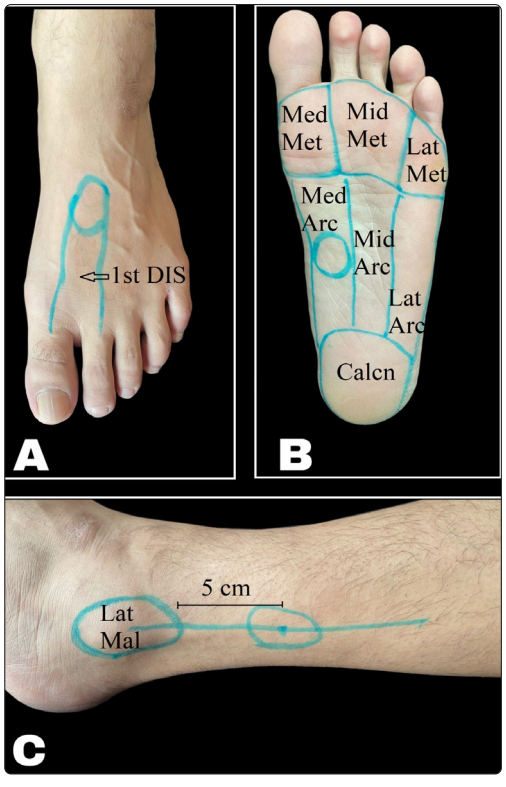

Figure 2. The locations specified for temperature measurement. (A) The dorsum of the foot at the most proximal part of the first interosseous space; (B) the middle region of the medial arch of the sole; (C) the lateral aspect of the leg 5 cm above the lateral malleolus. DIS: dorsal interosseous space; Med Met, Mid Met, and Lat Met: medial, middle, and lateral metatarsals, respectively; Med Arc, Mid Arc, and Lat Arc: medial, middle, and lateral arch, respectively; Calcn: calcaneus; Lat Mal: lateral malleolus.

DISCUSSION

Anterior approach to upper lumbar fractures was found to be significantly associated with sympathetic chain injury (>90%), even when sympathetic chain was not encountered intraoperatively. The technique used to expose the lateral aspect of vertebrae may be the factor causing sympathetic interruption. Incising the psoas muscle near its anterior border and posterior retraction of the main bulk of the muscle may interrupt the rami communicantes connecting the spinal cord to the sympathetic chain. Therefore, it may be more reasonable to mobilize the whole muscle with the underlying tissue, including the sympathetic trunk, in an en bloc fashion subperiosteally to expose the bone and subsequent implant placement.

Our study population included cases with upper lumbar fractures (L1–L3) due to the relevance of L2 ganglion at these levels and its significance in the sympathetic function of the lower limb. Although the site and number of ganglia in the lumbar sympathetic chain are variable,[22, 25] the ganglia associated with the L2 vertebra were reported to be the largest and the most constant. [33] Moreover, in contrast to the grey rami found at all levels of the sympathetic trunk, the white rami are found only at the thoracic and the upper two lumbar levels. [26] This implies that the L2 ganglion is the last station in the sympathetic chain receiving information from the spinal cord and transmitting it to the subsequent ganglia in the chain. Thus, injury of this ganglion or its connections may interrupt the sympathetic flow to the sympathetic ganglia of the ipsilateral limb. For this reason, L2 ganglion is customarily targeted by resection or injection to achieve ipsilateral lower limb sympathetic deprivation during sympathectomies or sympathetic blockade.[5, 8, 12]

Symptoms associated with sympathetic dysfunction, like warmth and soreness, were found to be subtle and nonspecific. The skin wrinkling test (SWT) was conducted due to the role played by sweat gland myoepithelial cells and the absence of sebum in palms and soles.[37] SWT is considered an easy, inexpensive, and reliable test for sympathetic function, which achieves improved sensitivity and specificity when compared to the starch-iodine sweat test, correlates well with intraepidermal nerve fiber density (IENFD), and it is better than the sympathetic skin response (SSR) test.[32, 37] Moreover, it is an easy bedside test to detect nerve injuries in traumatized limbs among uncooperative patients. [34] Visual evaluation of SWT is considered superior to the digital analysis of photographs.[36] Temperature differences between limbs exceeding one standard deviation from the mean temperature of corresponding control areas, i.e., between homologous regions in opposite limbs, are considered pathological.[35] In this study, the standard deviations from the mean skin temperatures of homologous control regions in contralateral limbs in anterior group and both limbs in the posterior groups were 1.4, 1.5, and 1.4°C, respectively. Therefore, STD with a cutoff of 2°C in this study was considered reasonable to indicate sympathetic dysfunction.

Sympathetic chain injury was diagnosed in 90.6% in the anterior group. These values are a little bit optimistic and the true frequency of chain injury may be higher because, in the current study, we considered both abnormal SWT and STD $\geq$ 2°C to confirm the diagnosis of the sympathetic injury. Cases with one prerequisite were considered equivocal and were added to the negative group. This may put the actual frequency of sympathetic chain injury somewhere between 90% and 100% in upper lumbar fractures managed via anterior approaches.

Although the sympathetic injury was found to be an almost inevitable complication in anterior surgery, it is considered insignificant because of the lack of discerning disability at six months postoperatively. The ODI and the physical component score (PCS-12) of SF-12 did not significantly differ between the two groups. Surprisingly, MCS-12 scores were found to be significantly higher in the sympathetic injury group indicating better mental performance. The underlying etiology and clinical importance of this result is unclear. Endoscopic thoracic sympathectomy performed bilaterally was found to improve social phobias[24] and social anxiety disorders.[18] Moreover, a single stellate ganglion block was found to alleviate anxiety and depression.[3] Whether these positive emotional effects can be elicited after lumbar sympathectomy is unknown and may need further clarification in future studies. Although 13–54% of cases with bilateral lumbar sympathectomy can develop ejaculatory disturbances,[17] this is very rarely reported with unilateral sympathectomy. In our study, no case with ejaculatory disturbances was reported, and all of those with resulting sympathetic chain injury were unilateral cases.

One of the limitations of this study is its observational nature; therefore, randomization of cases did not occur. We tried to overcome this

by including all consecutive cases with upper lumbar fractures that undergone surgery via the anterior approach during the specified period and an equal number of consecutive cases that undergone surgery via the posterior approach. Both the surgeons in both approach groups and the independent physicians performing the SWT were blinded to the main aim of the study. Another limitation was the use of SWT in lower limbs, which is a relatively subjective test for sympathetic function. However, the SWT was found to be a reproducible test with a high interrater agreement in the current study.

CONCLUSION

Although the sympathetic chain injury is commonly encountered in anterior approaches (90.6% of cases) used to treat upper lumbar fractures, injuries are unilateral, and therefore, the clinical impact was subtle. Our study shows no significant difference in clinical outcomes and quality of life at six months following surgery.

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الملخص العربي

التواتر و الحصيلة السريرية لإصابات سلسلة العصب الودي التالية للجراحات الأمامية لعلاج كسور الفقرات القطنية العليا

البيانات الخلفية: تعتبر سلسلة العصب الودي من الأنسجة المعرضة للإصابة أثناء الجراحات البنائية الأمامية لكسور الفقرات القطنية العليا

الغرض: استكشاف تواتر حدوث إصابة سلسلة العصب الودي بعد الجراحات المذكورة و الحصيلة السريرية لها

تصميم الدراسة: دراسة استباقية اترابية

المرضى و الطرق: تم ضم حالات متتابعة من كسور الفقرات القطنية العليا في مجموعتين متساويتين من انواع الجراحات ؛ أمامية و خلفية مع تقييم وظيفة العصب الودي قبل و بعد الجراحة بالإضافة إلى تقييم الحصيلة السريرية بعد ستة أشهر. تم استخدام اختباري تغضن الجلد بالقدمين و اختلاف حرارة الجلد لتقييم وظيفة العصب الودي. تم استخدام منسب عجز أسوستري و المسح القصير ذو الاثني عشرة بند لقياس الفرق بالحصيلة السريرية بعد ستة أشهر بين الحالات ذات الإصابة للعصب الودي و الحالات السليمة

النتائج: لم يوجد اختلافات ديموغرافية أو سريرية بين مجموعتي الجراحات؛ الأمامية و الخلفية. أظهر اختبار تغضن الجلد اتفاقا كبيرا بين الراصدين، و بلغ الاتفاق بينهما ٩٢٪ من الحالات. تم تأكيد إصابة العصب الودي في ٢٩ حالة انتمت جميعها لمجموعة الجراحة الأمامية. بلغت الحالات السليمة أو ذات الإصابة غير المؤكدة ٣٥ حالة منها ٣ حالات بالمجموعة الأمامية. لم تظهر قياسات الحصيلة السريرية فوارق تذكر بين الحالات ذات الإصابات المؤكدة و غيرها بعد ٦ أشهر من الجراحة

الخلاصه: تعتبر إصابات سلسلة العصب الودي إصابات شديدة التواتر بعد الجراحات الأمامية لكسور الفقرات القطنية العليا. وهذه الإصابات تكون أحادية الجانب و غير مؤثرة في الحصيلة السريرية و جودة المعيشة على المدى القصير.