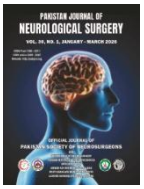

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Original Research

Dysautonomia as a Surgical Complication of Transdiaphragmatic Approach to Thoracolumbar Fractures

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ABSTRACT

Objective: A Quasi-experimental study was conducted to observe the effects of sympathetic chain resection or mobilization in patients with dorsolumbar fractures undergoing anterior decompression and stabilization.

Materials and Methods: Patients with thoracolumbar traumatic fractures who underwent anterior decompression and fixation were included. Autonomic sympathetic effects were studied by checking cutaneous temperature at the dorsum of the feet, plantar ninhydrin sweat test, and sympathetic skin response on the dorsum of the foot by electrical stimulation.

Results: 33 patients were operated on for thoracolumbar fractures. Sympathetic changes were more prominent at combined L1 and L2 fractures (18%) as compared to D11, D12 (90%) in the early postoperative period. Affected limb temperature increased in (57.5%), with positive ninhydrin test in 54.5% and Negative in 57.5%. Average difference in cutaneous temperature on the right side = 96.01°F and on the left side = 96.7°F. The average mean difference on both sides was 1.66°F. Sympathetic skin response was positive in 57.5% and Negative in 54.5% of cases. Nerve conduction studies revealed reduced amplitude and prolonged latencies, asymmetrical, L>R, of bilateral. Permanent sympathetic damage was observed in 9% and, temporary damage in 72%, and 18% were fail to follow up after six months.

Conclusion: Unilateral thoracolumbar sympathetic chain mobilization or resection (ramisectomy or ganglionectomy) leads to cutaneous temperature elevation, decreased sweating, decreased SPO2, and trophic changes on the operative side. Thus, the sympathetic chain should be handled with care to avoid sympathetic dysautonomia in the lower limbs.

Keywords: Spine, spinal injuries, autonomic nervous system, dysautonomia, thoracolumbar fractures, trans-diaphragmatic approach.

Abbreviations: ASIA = American Spinal Injury Association Impairment Scale. TLICS=Thoracolumbar Injury Classification and Severity Score. Parasympathetic nervous system (PNS). SLUDD=Salivation, Lacrimation, Urination, Digestion, and Defecation. CT scan= Computed tomography. MRI= Magnetic resonance imaging.

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INTRODUCTION

The sympathetic autonomic nervous system (SANS) is the branch of the autonomic nervous system(ANS). It arises from the TI thoracic vertebra to the L2 lumbar vertebra, and cell bodies are distributed bilaterally and symmetrically in the spinal gray matter. In contrast to the Parasympathetic nervous system (PANS), the preganglionic fibers of SANS are shorter than the postganglionic fibers. The preganglionic and postganglionic fibers of both SANS and PNS secrete the neurotransmitter acetylcholine, except the SANS postganglionic fibers to the sweat gland and arrector pili, which contain nicotinic receptors. SANS ganglia are distributed at four regions, which include cervical, thoracic, lumbar, and sacral regions, which extend from the base of the skull to the coccyx. SANS somatic (vasoconstrictor) fibers travel through 31 pairs of spinal nerves, visceral motor function for the salivary gland, and piloerector sensation for skin, and Splanchic supply to the thoracic and abdominal viscera.[1] The stress response is augmented with adrenal release of noradrenaline and adrenaline with activation of alpha or beta receptors.

The ANS modulates involuntary functions of the body, e.g., respiration, heart rate, digestion, and sexual activity. It constitutes the sympathetic, parasympathetic, and enteric nervous system. The thoracolumbar flow or the sympathetic nervous system elevates activity and attention, preparing the body for a fight or flight response by diverting blood flow to skeletal muscles and lungs.

The parasympathetic nervous system (parasympathetic nervous system) PNS has a role in salivation, lacrimation, urination, digestion, and defecation (SLUDD). It supplies the head, viscera, and sexual organs. The parasympathetic nervous system lacks control of skeletal muscles and skin. Its ganglia lie near the supplying organ. It conserves energy and works opposite to the sympathetic nervous system through feedback control.[2]

Imbalanced sympathetic discharge caused by autonomic dysreflexia may produce life-threatening complications if not treated. Strong stimuli from the bowel, bladder, or skin may cause excessive sympathetic discharge from the intact peripheral autonomic nervous system that results in intense vasoconstriction in the subphrenic splanchnic vascular bed. This is perceived by baroreceptors in the neck and conveyed to the brain through the 9th and 10th cranial nerves. The brain (Hypothalamus) regulates it by inhibiting descending sympathetic discharge and increasing vagal discharge. The parasympathetic effect is manifested by flushing of skin, sweating, nasal congestion, bradycardia, and pupillary constriction; these effects are observed in the upper part of the body above the level of spinal cord injury. The SANS overstimulation results in pale, cool, and goose skin (piloerection).[3,4]

Patients with dorsolumbar fractures may have paraparesis and loss of sphincter control. These injuries need decompression, fusion, and fixation with instrumentation. We prefer anterior cord decompression, which needs sympathetic chain resection or mobilization. The sympathetic dysreflexia is not so marked in thoracolumbar junction injuries. This study aimed to observe the sympathetic autonomic dysfunction and its effects on the operative site in the anterior thoracolumbar approach.

MATERIALS AND METHODS

Place and Duration of Study

A quasi-experimental study was conducted at the Department of Neurosurgery, Suleiman Roshan Medical College, Tando Adam, Sindh, Pakistan, over a period of 3 years from July 2022 to June 2024.

Inclusion Criteria

Patients with Traumatic thoracolumbar junction fractures at D11, D12, L1, and L2 were included.

Exclusion Criteria

Fractures of the spine above D11 and below L2 were excluded. Those managed conservatively and having severe co-morbidities were excluded. The anterior approach was not adopted for patients with severe obesity, lung contusions, and other pulmonary pathologies, and severe polytrauma cases. Patients were evaluated with a history and thorough examination.

Radiological Criteria, Clinical and Somatic Assessment

Imaging studies were performed with X-rays, computed tomography (CT) scan, and /or magnetic resonance imaging (MRI). Somatic neurological assessment was done with the ASIA (American Spinal Injury Association) scale, perianal sensation, and bulbocavernous reflex. The Thoracolumbar Injury Classification and Severity (TLICS) scoring was adapted for the decision of surgery.

Procedure

Anterior transthoracic and transdiaphragmatic decompression was performed by exposing the psoas muscle. retracting or resecting and mobilizing the sympathetic chain.

Postoperative Assessment

Check x-rays, CT (Computed Tomography) scan, and/or MRI (Magnetic resonance Imaging was performed. The ASIA (American Spinal Injury Association) scale was adopted to observe changes in somatic effects.

Findings of Sympathetic Response Assessment

On the second postoperative day, autonomic changes were measured by Cutaneous temperature, Oxygen saturation (SPO2), the Ninhydrin sweat test, trophic changes, and Sympathetic skin response.

a. Cutaneous temperature measurement

In all afebrile patients and at comfortable room temperature, skin temperature was measured at the dorsum of affected food on the left side (as we preferred to approach the decompression and sympathetic chain mobilization on the left side) by ordinary digital thermometer and infrared thermometer (Bing Zin Infrared Thermometer (Model: No. BZ-R6), it showed mean temperature on Right side = 96.01 degree Fahrenheit (°F) (and on left side =96.70°F. Mean difference on both sides was 1.660°F. A temperature difference of more than 1°F was considered pathological.

b. Ninhydrin sweat test

This standard and qualitative test is very easy to perform for the presence of amino acids in the sweat of the patient.

A simple white paper was pressed against the clean plantar side of the feet to print out sweat, then painted in Ninhydrin solution (0.5% of Ninhydrin plus 50 ml of acetone Secco solv dried and 1 pasteur pipette of acetic acid 100% anhydrous per analysis, was prepared by a chemist on special request of the department.

When paper is left dried in the sun for 15 minutes, it changes into a bluish to purplish color due to the reaction of ninhydrin with amino acids present in the sweat of the tested samples.

It was analysed by an operating surgeon, and results were categorized into no perspiration, mild or negligible (considered ve), moderate, and severe perspiration according to the richness and thickness of colour that was observed on white paper.

SPO2 was recorded with the monitor brand: N-Tech, model: NT7. Nerve conduction studies were measured with NCV (Nerve conduction velocity) and EMG (Electromyography) Machine.[3]

Data Analysis

The data was interpreted using the (statistical package for social services), SPSS version 26. The means and standard deviations were analysed for numerical data like age.

RESULTS

Clinical Background

A total of 33 patients were operated on for thoracolumbar fractures. There were n=27 (81.82%) males and n=6 females (18.18%) with a male to female ratio (4.5:1). Age varied from 10 to 45 years. The average age is (25.64 years).

Maximum cases were noted as L1 fractures n=15 (45.4.51%), L1 and L2 (6.06%), L2 in n=4 (12.12%), D12 n=5 (16.13%), and D11 n=2 (12.12%). Two vertebral fractures were seen in D11/ 12 n= 2(12.125) and D12/L1 n=3 (3.03%). Neurological assessment on ASIA reveals majority in ASIA A n=13(39.39%), B n=4(12.12%), C as n=3(12.12%), D as n=3 (3,03%) and E as n=5 (15.15%) (**Figure 1).**

Preoperative TLICS Scoring 4 to 10. The average score was 6.

Procedure and Approach

Left thoraco-phrenico-laparatomy was performed in the majority of cases, n=31 (93.94%). Bone fusion is achieved with an iliac crest strut graft or cage filled with cancellous bone. Fixation done with vertebral body screws. 2 screws were used in n=2 (6.06%), 3 screws in n=1 (3.03%), and 4 screws in n=30 (96. 77%) (**Figure 2).**

Immediate Postoperative Day

Postoperatively, these patients complained that the lower limb on the operative side remained warm, with raised temperature at L1-L2, which was recorded 97.8 degrees Fahrenheit, and at L2 it was 98.2 degrees Fahrenheit as compared to 96.8 degrees Fahrenheit on the non-operative site.

In our study, we did not observe trophic changes in the early postoperative Period only 9.09% patient developed trophic changes after six months, and 18% had decreased sweating and trophic changes. Cutaneous temperature at the dorsum of the foot was recorded by an ordinary digital thermometer and an infrared thermometer; it showed a mean temperature on the right side = 96.01°F and on the left side =96.7°F. Mean difference on each side was 1.66°F. Oxygen saturation measured on both big toes showed on the right 96% and on the left 97.7%, the average difference was 1.7%. Muscle bulk was not measured (**Figure 1)**.

Overall, a sympathetic response was observed on the second postoperative day in 51.5% at the L1 level, 15% at D12, 6% at D11-D12,6% at D11, and a dysfunctional sympathetic response was observed at L2 in 12% and L1-L2 in 6% of cases (**Table 1).**

Follow up

On follow-up, cutaneous response was observed in 54% of patients at weeks,57% of patients at 2 months,54% of patients at 6 months, and 54% of patients at 1 year, respectively. No response was

observed in 45% of cases at 2 weeks,45% at 2 months,27% at six months, and 9% of cases at 1 year of follow-up. Ninhydrin was negative in 45% cases and positive in 54%. In the early postoperative period, within 2 weeks. Out of 33 patients, 57% experienced sympathetic dysfunction. 9% patients developed permanent dysautonomia, and 90% of patients had temporary dysautonomia, which was observed within one year after surgery. About 27% patient fail to follow up after 6 months; they were contacted via phone call,9% even didn't even respond to the phone call (**Table 2**).

ASIA Score
A=Absent sensory and Motor Function
B=Sensory +Ve, Motor Non-Functional
C=Sensory+ve, Motor Subnormal
D= Sensory+Ve, Motor Power > 3
E=Both Sensory Plus Motor functional

A	13
B	4
C	4
D	3
E	5

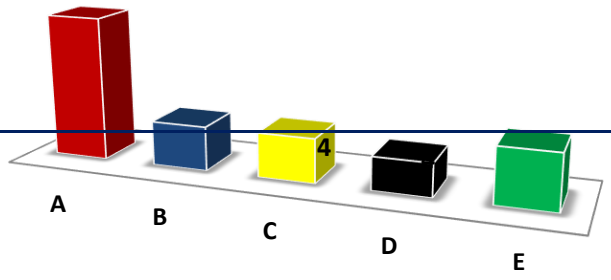

Figure 1: *Representative of the American Spinal Injury Association Scale for Neurological Assessment.*

Number of screw fixation	
4 Screw	22
3 Screw	01
2 Screw	02

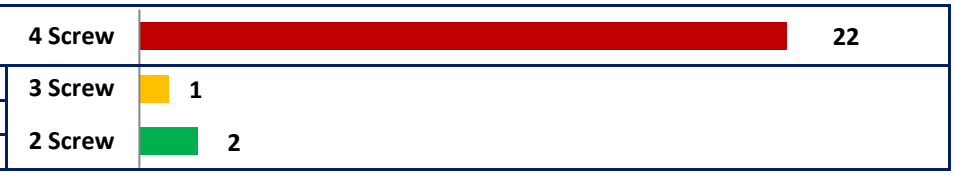

Figure 2: *Representative of the Number of Screw Fixations Done in Dorsolumbar Traumatic Fractures.*

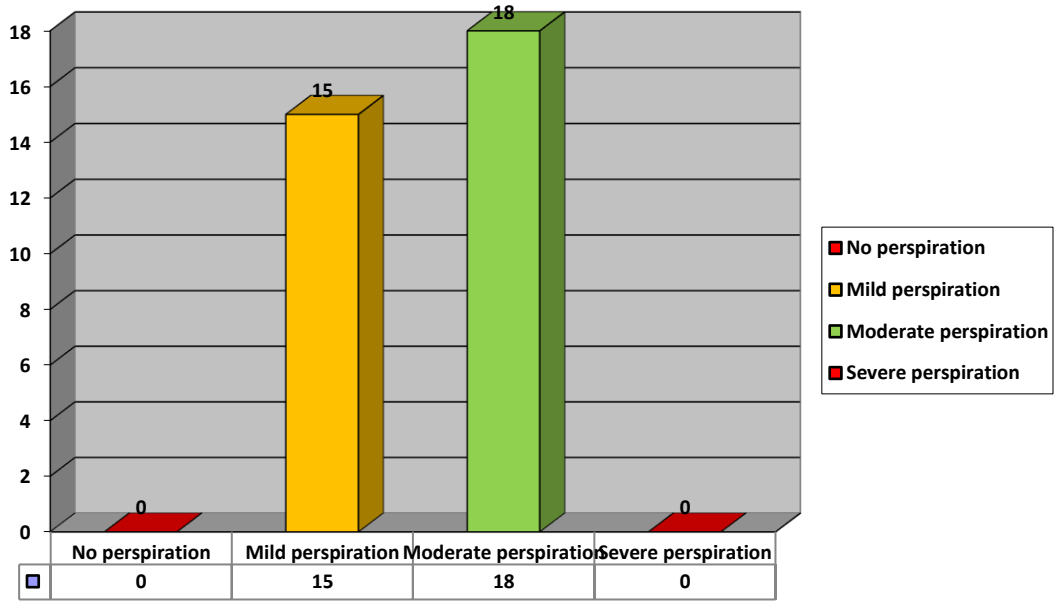

Figure 3: *Ninhydrin perspiration test Assessment result.*

Table 1: *Location of fractures and postoperative patients' sympathetic response and parameters assessed on the second postoperative day.*

		Sympathetic Response Assessment					
Fracture Location	**Number of Patients**	**Temperature Changes**	**Ninhydrin Sweat Test**	**O2 Saturation**	**Sympathetic Cutaneous Response**	**Postoperative Day**	**Limb (Operative Side)**
L1-L2	2	Increased 97.8\degf	Negative	Reduced	No Response	2nd day	Left
L2	4	Increased 98.2\degf	Negative	Reduced	No Response	Second day	Left
L1	17	Normal	Positive	Normal	Positive	2nd day	Left
D12	5	Normal	Positive	Normal	positive	2nd day	Left
D11	2	Normal	Positive	Normal	positive	2 nd day	Left
D11 and D12	2	Normal	Positive	Normal	positive	2nd day	Left

Table 2: *Sympathetic Response Parameters, Trophic Changes, Temperature, Cutaneous Response, and Ninhydrin Test Conducted At 2 Weeks,2 Months,6 Months, and 1 Year of Follow-up.*

Sympathetic Response Parameters			**2 Weeks**	**2 Months**	**6 Months**	**1 Year**
Trophic changes			0	0	0	3
Normal temperature			15	14	14	5
Increased Temperature			18	19	18	3
Sympathetic cutaneous response		+ve	18	18	18	18
		-ve	15	15	9	3
Ninhydrin perspiration test	Positive		18	18	18	9
	Negative		15	15	15	9

Temporary sympathetic chain dysfunction	Permanent sympathetic chain dysfunction
30	3

Table 3: *Comparison of our Study in light of the literature review.*

Literature review	**Level of surgery**	**Sympathetic dysfunction**	**Number/ percentage**	**Recovery**
Our study	Dorsolumbar, especially at L1/L2	yes	57%	90% yes, 9% no
Kang bu et al.	L4-L5,L5-S1(other levels not mentioned)	yes	6.6%	Yes 100%
Ikard MD et al.	Thorocolumbosacral	yes	Not mentioned	Yes
Tobias L.et al.	Dorsolumbar scolosis	yes	100% at L3 and below	Yes, almost in all cases

(Both preoperative (Figures 4A and 4B) and postoperative (Figures 5A and 5B) X-rays are included with consent from the patient's relatives.

DISCUSSION

In the Anterior transthoracic transdiaphragmatic approach, the sympathetic chain may be damaged by direct use of cautery, indirect mobilization of the sympathetic chain, or by bony fragment impingement, especially in traumatic fracture dislocation, destruction by tumor, or infective pathology that involves the vertebral body and paravertebral tissue.[5,6]

In lower limbs, preganglionic myelinated sympathetic fibers of the lower thoracic and upper

lumbar originated from the lateral horn of the spinal cord and travel via the preganglionic white ram, communicating to the sympathetic trunk that runs caudally to communicate with postganglionic sympathetic fibers at multiple levels. The location of the sympathetic ganglion is variable except for L2, which is considered to be a constant in position. Therefore, fractures and surgical manipulation at this level may produce temporary or permanent sympathetic dysfunction and no sympathetic outflow from L2 to caudally, because sympathetic preganglionic white rami fibers are only present in thoracic and lumbar up to L2.[7.8.9.10]

In our study, out of 33 patients, 18 developed sympathetic chain dysfunctions postoperatively, which were more evident after 2 weeks, and commonly observed at L1 and L2 fractures with total or near total dislocation that results in entrapment and avulsion of the sympathetic chain and ganglion.

Ikard et al, had also noticed sympathetic dysfunction in a variety of Thorocolumbosacral pathologies; however, they didn't mention the exact number of patients and the specific level where maximum damage had occurred, even though they experienced full recovery over time.[11]

We experienced that in 9% of cases, there was permanent damage to the sympathetic ganglion in distraction and translational injuries, impeding the total recovery time. 90% 0f patients recovered over 6 months.

Because the L2 ganglion was already damaged in L1 and L2 fracture dislocation, complicated fractures required maximum manipulation for cord decompression, along with 4-point fixation with screws and rods, which is the main reason for permanent damage to the sympathetic chain and ganglion (Figures 4 (A, B) and Figures 5(A, B)).

In contrast to that, research was conducted by Kang Bu et al, who observed 100% recovery over the period of six months, with no permanent damage to the sympathetic nerve because of

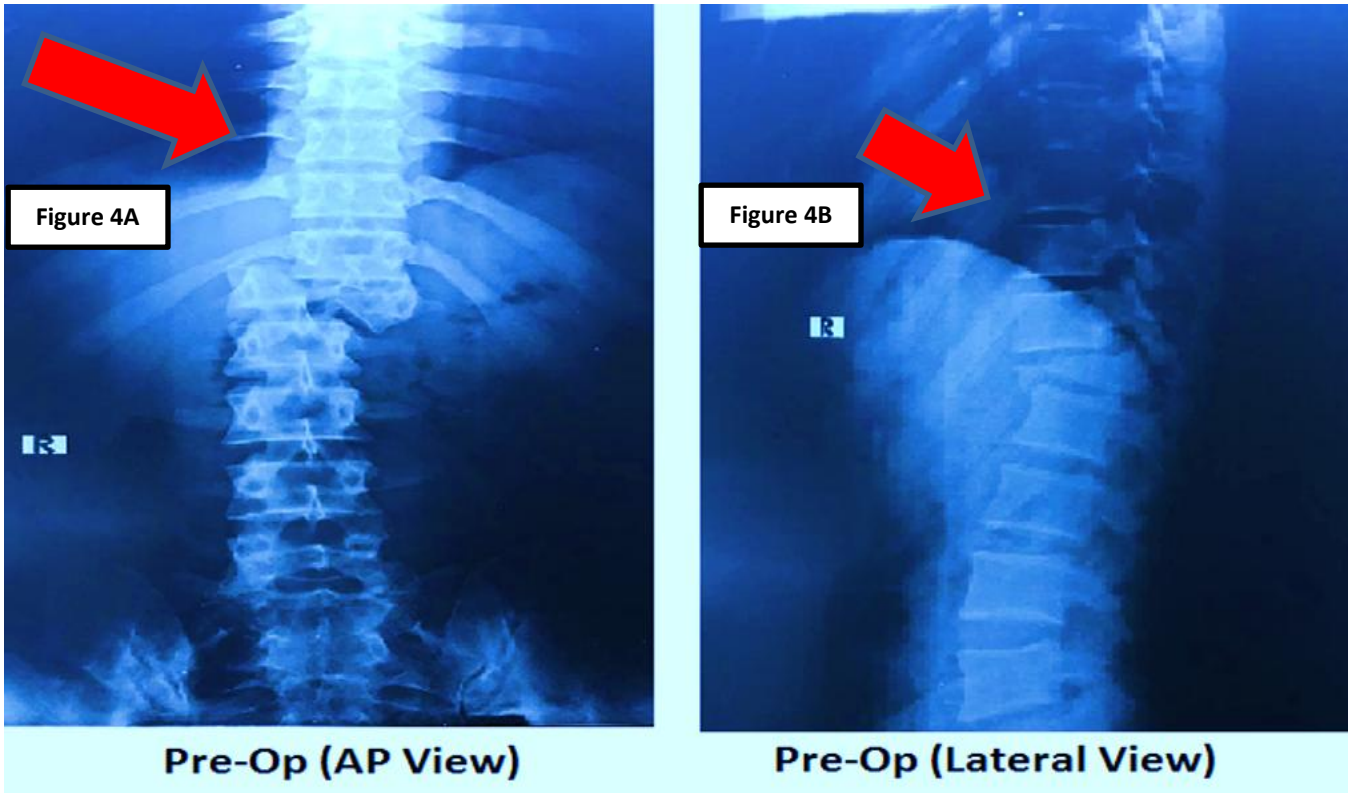

Figure (4A): *Pre operative Anterior-Posterior and figure.* **(4B)** *Lateral X-rays, Lumbosacral spine (arrow) pointing D-11 and D-12 Fracture dislocation.*

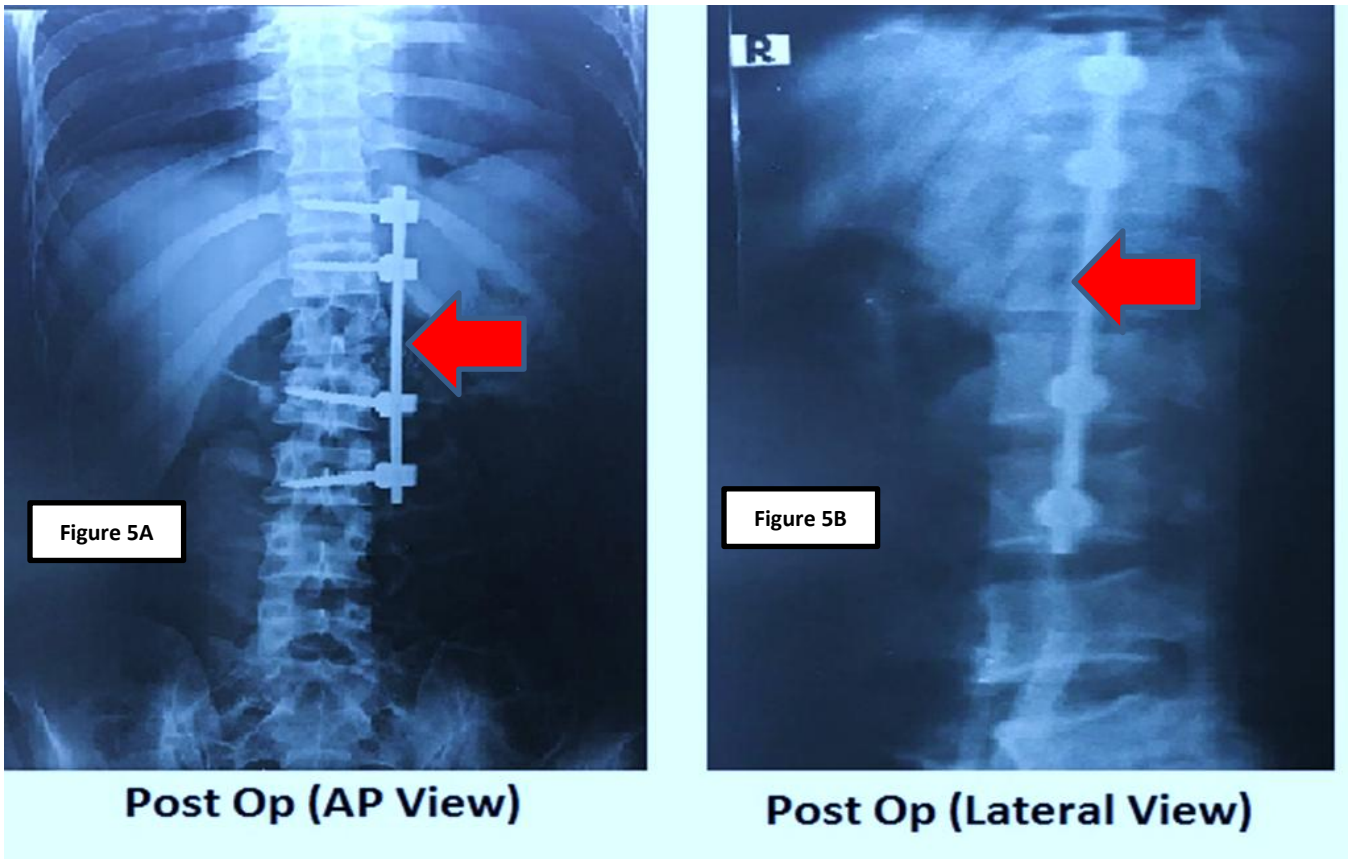

Figure 5 (A): *Post operative Anteroposterior (AP) and* **Figure (5B):** *Lateral X-Ray, (arrow) pointing to the complete reduction of D-11 and D-12 Fracture and 4 points screw fixations with rod.*

relatively simple pathology involving L4-L5 and S1 levels.[12]

However, retrograde ejaculation was observed in their study because of hypogastric plexus involvement at L5 and S1. In contrast, our study did not observe retrograde ejaculation due to higher lumbar level involvement, as well as mostly paraplegic patients with sensory impairment, so we could not assess it.

Our observation was almost similar to L, Tobias et al; likewise, the small sample size, L2 ganglion involvement, and its manipulation during scoliosis correction, decompression, and fixation of lower thoracic and upper lumbar vertebrae.[13]

However, in contrast, they also noticed 100% recovery **(Table 3).**

In our study, we noticed unilateral sympathetic chain dysfunction at the site of approach on the left side; therefore, we only mentioned the involved site findings, as the control side (Right) was unremarkable.

Most of our patients were bed-bound or required regular assistance; they were unaware of the rise in temperature, absence of sweating, and even trophic changes.

The variation in skin vascular response on the operated side could be assessed in a variety of ways, e.g., subjecting the patient to extreme cold by applying Ice packs or hot air to affected feet, or by vigorous physiotherapy and exercise.[14.15] Nerve conduction studies showed reduced amplitude and prolonged latencies asymetrically, L<R of

bilateral tibial and motor nerves, which consist of bilateral sciatic nerve neuropathy, more severe at the left side.

We have observed unilateral sympathetic. dysautonomia on the operative side. Such observation has been made in rabbits and other animals. Brown and Adson also observed a distinct rise in skin temperature in peripheral parts after lumbar sympathectomy.[16]

In contrast to humans, laboratory animals, with complete lumbar symapthetectomy still have the possibility of postganglionic control because of an intact sacral ganglion, even if it is also severed, local adrenaline released along the smooth muscle of denervated vessel can provide rapid and complete recovery.[17.18]

LIMITATION OF STUDY

Our study was limited to a single center, with a limited number of patients; only traumatic thoracic and lumbar fractures were included.

RECOMMENDATION OF THE STUDY

A multi-center study should be included. Multiple pathologies like tumors, Pott's disease/infectious, compressive disease of the spine, as well as degenerative disease, may be researched and observed for involvement of the Sympathetic chain. Levels other than the Dorsolumbar spine, like the cervical spine, may be observed for involvement of the sympathetic ganglion and chain, along with their somatic effects.

RECENT ADVANCES

Minimally invasive procedures like endoscopic thoracotomy and decompression of fractured spine with single or multiple ports should be tried and compared with open thoracotomy procedures.

CONCLUSION

Thoracolumbar fractures dealt with trans phrenic thoracolaparatomy cause sympathetic dysautonomia. It is manifested with a temperature and oxygen saturation difference between the operative and non-operative side. Cutaneous temperature is higher, and oxygen saturation is lower, with reduced cutaneous response and a negative Ninhydrin test on the operative side. Even though in most cases, sympathetic function might be recovered over the period of time. The Sympathetic chain should be handled with care and mobilized gently to avoid resection or destruction.

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Additional Information

Disclosures: The authors declared that there is no conflict of interest.
Ethical Review Board Approval: An approval was taken from the ethical review committee of Suleiman Roshan Medical College (reference # SRMC/Principal/318. Scans were added with the patients' permission.
Human Subjects: Written and informed consent was taken from all participants /patients of the study.
Conflict of Interest with compliance with the ICMJE uniform disclosure form, the authors of this study declare the following:
Financial Relationship: There is no financial or any other relationship or activities with any other organization at present or in the past years that might have an interest in the submitted research study.
Other Relationship: All authors of this study declared that there are no relationships or activities that might appear to bias or influence the submitted study work.
Data Availability Statement: The interested researchers can contact the corresponding authors for data sharing.
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AUTHORS CONTRIBUTIONS

Sr.#	Author's Full Name	Intellectual Contribution to Paper in Terms of:
1.	Professor shams Raza Brohi	1. Study design and methodology.
2.	Fahmida Arab Mallah	2. Paper writing.
3.	Muzammil Dilbar	3. Data collection and calculations.
4.	Abdul Raza Mari	4. Analysis of data and interpretation of results.
5.	Prof: Hamid Akbar Sheikh	5. Literature review and referencing.
6.	Syed Aamir Shah	6. Editing and quality insurer.