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The clinical and radiological outcomes of a transfacet pedicle-sparing approach for directly addressing the compression of unstable thoracolumbar burst fractures with retropulsion

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Abstract

Background The management of thoracolumbar burst fractures with retropulsion has been a matter of debate, the present study aimed to investigate the clinical and radiological outcomes of a transfacet pedicle-sparing approach for directly addressing the compression of unstable thoracolumbar burst fractures with retropulsion.

Methods We examined a cohort of 163 consecutive patients diagnosed with unstable thoracolumbar burst fractures that exhibited significant canal compromise. These patients underwent a transfacet pedicle-sparing procedure aimed at directly alleviating the compression caused by the retropulsed bone segment at our institution. Clinical outcomes were assessed using the Frankel scale and the Oswestry Disability Index (ODI), while radiological outcomes were evaluated based on the Cobb angle, percentage of anterior height compression (PAHC), vertebral body compression rate (VBCR), and canal compromise.

Results Among the 163 patients, 98 (59.8%) were male and 66 (40.2%) were female. The mean age of the participants was 45.42 ± 8.71 years, with an average follow-up period of 21.19 ± 4.42 months. Postoperative assessments revealed a significant reduction in canal compromise, decreasing to 9.72 ± 1.73 from a preoperative value of 61.21 ± 5.33 ($p < 0.001$). The Cobb angle also demonstrated a significant postoperative reduction ($p = 0.011$). Both VBCR and PAHC showed significant decreases postoperatively when compared to preoperative measurements ($p < 0.05$). Neurological outcomes improved significantly postoperatively, as indicated by the Frankel grade ($p < 0.05$). Furthermore, the ODI at the last follow-up was significantly lower than the preoperative ODI ($p < 0.001$), reflecting a marked enhancement in patient functionality.

Conclusions Our research has shown that the transfacet pedicle-sparing approach is an effective technique for directly managing the compression of unstable thoracolumbar burst fractures with retropulsion, resulting in favorable clinical and radiological outcomes.

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Introduction

Thoracolumbar fractures represent a significant proportion of spinal injuries, with burst fractures being among the most common and clinically challenging types. These fractures typically involve damage to both the anterior and middle columns of the spine, as described by the Denis three-column classification system, and account for approximately 20% of all thoracolumbar injuries [1–3]. Burst fractures are often caused by high-energy trauma, such as motor vehicle accidents or falls from height, and are characterized by the compression of the vertebral body, often accompanied by retropulsion of bone fragments into the spinal canal. This can lead to spinal canal stenosis, neurological deficits, and spinal instability, making their management complex and multifaceted.

The optimal treatment strategy for thoracolumbar burst fractures has long been a subject of debate within the medical community. Treatment options range from conservative management, which includes bracing and physical therapy, to surgical interventions such as anterior, posterior, or combined approaches [4, 5]. The choice of treatment depends on several factors, including the severity of the fracture, the degree of spinal canal compromise, the presence of neurological deficits, and the overall stability of the spine. In cases where vertebral collapse results in significant spinal canal encroachment, surgical intervention is often necessary to decompress the neural elements, stabilize the spine, and prevent further neurological deterioration [6, 7].

Surgical management of thoracolumbar burst fractures aims to achieve two primary objectives: decompression of the spinal canal to relieve pressure on the spinal cord and nerve roots, and stabilization of the spine to restore alignment and prevent further deformity. Various surgical techniques have been developed to address these goals, including direct anterior approaches, which allow for thorough decompression of the retropulsed bone fragments, and posterior approaches, which focus on indirect decompression through ligamentotaxis and stabilization with instrumentation [6, 8]. While anterior fixation has traditionally been favored for fractures with significant retropulsion due to its ability to provide direct decompression, recent studies have demonstrated that posterior approaches can achieve comparable outcomes, often with reduced surgical morbidity and shorter operative times [8–10].

In light of these findings, our study adopted a postero-lateral approach utilizing a novel transfacet pedicle-sparing technique at the fracture level. This technique was designed to achieve direct decompression of the retropulsed bone fragment while preserving the integrity of the pedicles, thereby minimizing disruption to the surrounding anatomical structures. The transfacet pedicle-sparing approach offers several potential advantages, including reduced blood loss, shorter operative times, and preservation of spinal stability, making it a promising alternative to traditional surgical methods.

The primary objective of this study was to evaluate the clinical and radiological outcomes of the transfacet pedicle-sparing approach for the treatment of unstable thoracolumbar burst fractures with retropulsion and severe spinal canal stenosis. By analyzing parameters such as spinal canal compromise, Cobb angle, vertebral body compression ratio (VBCR), percentage of anterior height compression (PAHC), and neurological function, we aimed to assess the efficacy of this technique in restoring spinal alignment, decompressing the spinal canal, and improving patient outcomes. Additionally, we sought to contribute to the growing body of evidence supporting the use of posterior approaches for the management of thoracolumbar burst fractures, particularly in cases where direct decompression is required. Through this study, we hope to provide valuable insights into the optimal surgical management of these complex injuries and to offer a viable alternative to traditional anterior approaches.

Methods

A total of 163 consecutive patients diagnosed with unstable thoracolumbar burst fractures accompanied by retropulsion were included in this study. These patients underwent a transfacet pedicle-sparing approach for direct decompression of the retropulsed bone fragment at our institution between June 2017 and June 2023. The inclusion criteria were strictly limited to patients with traumatic thoracolumbar burst fractures, while those with pathological fractures (e.g., due to tumors or infections), osteoporotic fractures, a history of prior spinal surgeries, or multiple vertebral fractures were excluded. Additionally, patients with complete neurological deficits (Frankel grade A) were also excluded to ensure a homogeneous study population. Ethical approval for the study was granted by the Scientific Research Board of Kermanshah University of Medical Sciences, and written informed consent was obtained from all participants prior to their inclusion in the study.

Upon arrival at the emergency department, all patients underwent a thorough clinical evaluation, including a detailed physical examination to assess neurological status, motor and sensory function, and any signs of spinal cord injury. To confirm the diagnosis and evaluate the extent of the injury, a series of imaging studies were performed. These included anteroposterior (AP) and lateral thoracolumbar radiographs, computed tomography (CT) scans of the thoracolumbar spine, and magnetic resonance imaging (MRI) with T1-weighted, T2-weighted, and short-tau inversion-recovery (STIR) sequences. These imaging modalities provided comprehensive information on the structural integrity of the spine, the degree of spinal canal compromise, and the presence of soft tissue or spinal cord injuries.

The severity of the thoracolumbar injury was assessed using the Thoracolumbar Injury Classification and Severity Score (TLICS). A TLICS score greater than 4 was considered an indication for surgical intervention, as this score reflects significant spinal instability and neurological involvement. Radiological parameters, including the Cobb angle, percentage of anterior height compression (PAHC), vertebral body compression ratio (VBCR), and the degree of spinal canal compromise, were meticulously evaluated by an experienced radiologist to ensure accuracy and consistency in measurements.

1. **Cobb angle measurement**: The Cobb angle was determined by measuring the angle formed between the upper endplate of the vertebra immediately above the fracture and the lower endplate of the vertebra immediately below the fracture. This measurement was used to quantify the degree of spinal deformity and kyphosis resulting from the injury [1, 2].
2. **Spinal canal compromise**: The extent of spinal canal compromise was assessed by comparing the anteroposterior (AP) diameter of the spinal canal at the level of the fractured vertebra to the average diameter of the spinal canal at the vertebrae immediately above and below the injury. This ratio provided insight into the degree of canal stenosis caused by the retropulsed bone fragment [1, 2].
3. **Vertebral body compression ratio (VBCR)**: The VBCR was calculated as the ratio of the anterior vertebral height to the posterior vertebral height of the fractured vertebra, multiplied by 100%. This metric was used to quantify the degree of vertebral body collapse and compression resulting from the injury [1, 2].
4. **Percentage anterior height compression (PAHC)**: The PAHC was determined by dividing the anterior vertebral height of the fractured vertebra by the average anterior vertebral height of the vertebrae immediately above and below the fracture, multiplied by 100%. This parameter provided a measure of the loss of anterior vertebral height due to the fracture [1, 2].

All radiological measurements were performed using standardized techniques and validated methods to ensure reliability and reproducibility. The data collected from these assessments were used to evaluate the effectiveness of the surgical intervention in restoring spinal alignment, decompressing the spinal canal, and improving patient outcomes. Preoperative and postoperative comparisons of these parameters were conducted to assess the impact of the surgical procedure on spinal stability, neurological function, and overall patient recovery.

To ensure the reliability of radiological measurements, all parameters (Cobb angle, spinal canal compromise, and VBCR) were independently assessed by two expert measurers blinded to patient outcomes. Inter-observer reliability was evaluated using the Kappa statistic (κ). The inter-observer agreement for all radiological measurements was excellent ($\kappa = 0.9$), indicating a high degree of consistency between the two measurers. In instances of minor discrepancies, a consensus was achieved through discussion.

Surgical technique

The surgical procedure began with the patient positioned prone on a Jackson table, utilizing chest and pelvic support posts to optimize spinal alignment and stability. This positioning often provided an initial reduction of the kyphotic deformity, monitored in real-time using a lateral image intensifier. A midline posterior approach was then employed, with meticulous dissection of the paraspinal muscles to expose the affected vertebrae. Pedicle screws were inserted two levels above and two levels *below* the fractured vertebra to provide multi-segmental stabilization. It's important to note that while pedicle screw fixation was used above and below the fracture, a pedicle-sparing technique was attempted at the *fractured vertebra* level itself, avoiding complete pediculectomy unless absolutely necessary.

A *limited* laminectomy was performed at the level of the fractured vertebra to allow for adequate visualization of the spinal canal and retropulsed fragments. The extent of the laminectomy was tailored to the individual patient's anatomy and the degree of spinal canal compromise. In some cases, a partial facetectomy was performed using a high-speed drill to further improve access. The nerve roots were carefully protected during this process using nerve root retractors. A microscope was *selectively* used to enhance visualization in cases with significant dural compression or when meticulous removal of small fragments was required. The retropulsed fragments were carefully compressed and repositioned by gently tapping

on their posterior aspect using specialized instruments, with real-time monitoring under image intensification to ensure accurate reduction. In cases where the dural sac was adherent to the fragments, meticulous dissection was performed to separate the dura from the bone. Any dural tears were primarily repaired with sutures or a dural substitute, depending on the size and location of the tear.

The length of the rods was measured and contoured to either a straight or slight lordotic angle to aid in further reduction and maintain sagittal alignment. The rods were securely attached to the pedicle screws, and additional controlled reduction was achieved through a combination of distraction and compression applied across the fracture site using the pedicle screws and rods. This step-by-step approach ensured precise reduction and stabilization of the fractured vertebra while minimizing the risk of neurological complications (Figs. 1 and 2).

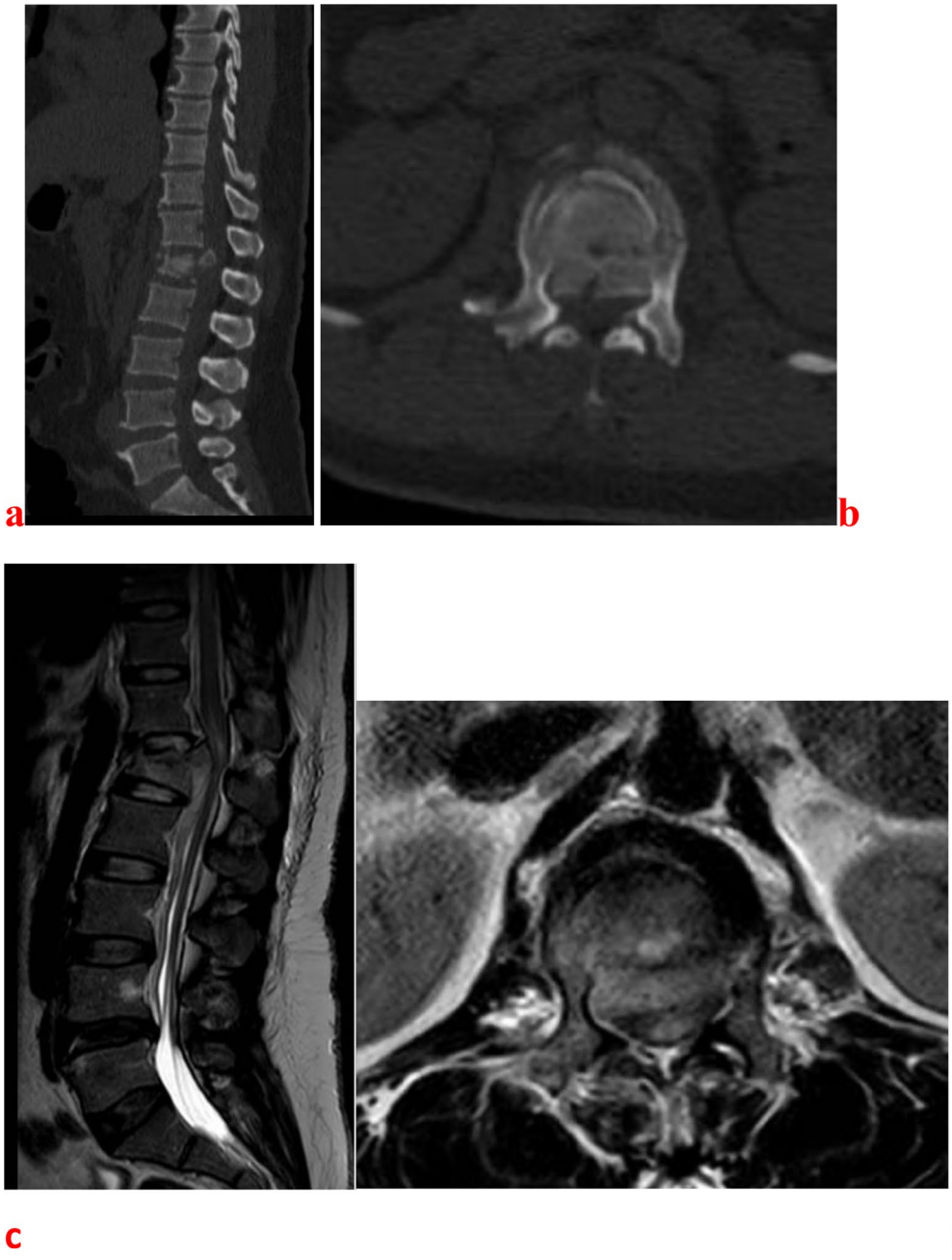

Fig. 1 Preoperative imaging of a patient with a traumatic L1 burst fracture and retropulsion causing spinal canal stenosis: (**a**) sagittal CT, (**b**) axial CT, (**c**) sagittal MRI, (**d**) axial MRI

Fig. 2 Postoperative CT (**a**, **b**) and MRI (**c**, **d**) demonstrate significant improvement in spinal canal compromise and restoration of vertebral height compared to preoperative imaging

Clinical outcome assessment

Neurological function was evaluated using the Frankel grading system, which was employed to compare the pre-operative neurological status with the findings from the latest follow-up evaluation. The Frankel scale, ranging from grade A (complete neurological deficit) to grade E (normal neurological function), is a widely recognized tool developed by the American Spine Injury Association (ASIA) to assess spinal cord injury and recovery.

In addition to the Frankel grading system, the Oswestry Disability Index (ODI) was utilized to assess lumbar function and the impact of the injury on the patient's daily

Table 1 Descriptive characteristics of the sample

Variable		*N* (%)
Sex	Male	98 (59.8)
	Female	66 (40.2)
Cause of Injury	Road Traffic crashes	103(62.8)
	Fall	54 (32.9)
	Assault/violence related	5 (3.0)
	Other	2 (1.2)
Level of Vertebra	T10	8 (4.9)
	T11	14 (8.5)
	T12	64 (39.0)
	L1	52 (31.7)
	L2	26 (15.9)
Smoking	Yes	30(18.3)
	No	134 (81.7)
Diabetes	Yes	27 (16.5)
	No	137(83.5)
Pre-operative Frankel grade	A	0 (0.00)
	B	36 (22.0)
	C	72 (43.9)
	D	56(34.1)
	E	0(0.00)
Last follow up Frankel grade	A	0 (0.00)
	B	0 (0.00)
	C	12 (7.3)
	D	55(33.5)
	E	97(59.1)

activities. The ODI was administered both at the time of admission and during the latest follow-up visit to evaluate improvements in functional outcomes and quality of life post-surgery [11–13]. These assessments provided a comprehensive understanding of the clinical outcomes, including neurological recovery and functional improvement, following the surgical intervention.

Statistical analysis

The SPSS 23 software (SPSS Inc., Chicago, Illinois) for data analysis was utelized. We presented the data as mean ± standard deviation. The Student's t-test and the Chi-square test were employed to compare continuous and categorical variables at admission and last follow up. Additionally, a binary logistic regression analysis was conducted to evaluate factors associated with treatment failure. The significance level for all analytical tests was set at < 0.05.

Results

The study analyzed a total of 163 cases, comprising 98 male patients (59.8%) and 66 female patients (40.2%). The average age of the patients was 45.42 years, with a standard deviation of 8.71 years. The follow-up period averaged 21.19 months, with a standard deviation of 4.42 months. The primary cause of injury was road traffic accidents, accounting for 103 cases (62.8%), followed by falls, which were responsible for 54 cases (32.9%). The most frequently affected vertebrae were T12, involved in 64 cases (39.0%), followed by L1 in 52 cases (31.7%), L2 in 26 cases (15.9%), T11 in 14 cases (8.5%), and T10 in 8 cases (4.9%). Among the patients, 30 were smokers (18.3%), and 27 had diabetes mellitus (Tables 1 and 2).

Table 2 Mean and standard deviation of quantitative variables

Variable	Mean	Standard deviation	Statistical analysis
Age	45.42	8.71	N/A
Follow Up	21.19	4.42	N/A
Body Mass Index	22.97	2.17	N/A
Pre- operative VBCR (%)	67.22	5.31	***P*=0.038**
Post- operative VBCR (%)	57.13	4.58	
Pre- operative PAHC (%)	69.34	5.07	***P*=0.031**
Post- operative PAHC (%)	60.28	4.97	
Pre- operative Cobb(°)	14.21	4.11	***P*=0.011**
Post- operative Cobb(°)	8.73	4.03	
Pre- operative Canal compromise (%)	61.21	5.33	***P*<0.001**
Post- operative Canal compromise (%)	9.72	1.73	
Pre- operative ODI	58.6	6.06	***P*<0.001**
Last follow up ODI	7.36	2.01	

VBCR: Vertebral body compression rate; PAHC: percentage of anterior height compression; ODI: Oswestry Disability Index

Postoperative results showed a significant reduction in the degree of canal compromise, decreasing from a preoperative value of 61.21% ± 5.33 to 9.72% ± 1.73 ($p < 0.001$). The Cobb angle also demonstrated a notable decrease following surgery ($p = 0.011$). Both the Vertebral Body Compression Ratio (VBCR) and the Posterior Arch Height Compression Ratio (PAHC) showed significant reductions postoperatively compared to their preoperative measurements ($p < 0.05$).

Neurological outcomes, as assessed by the Frankel grade, improved significantly after surgery compared to the preoperative status ($p < 0.05$). Furthermore, the Oswestry Disability Index (ODI) at the last follow-up was significantly lower than the preoperative ODI ($p < 0.001$), indicating a marked improvement in patient functionality (Tables 1 and 2). These findings suggest that the surgical intervention was effective in alleviating spinal canal compromise, correcting spinal alignment, and enhancing neurological function.

Discussions

In this study, we explored a transfacet pedicle-sparing approach for managing unstable thoracolumbar burst fractures with retropulsion. Our results indicated that this method was highly effective, as evidenced by both clinical outcomes and radiological evaluations. The optimal treatment for thoracolumbar burst fractures remains

a topic of debate [4, 14]. Some studies advocate for anterior vertebral body reconstruction combined with short-segment posterior instrumentation, citing advantages such as reduced re-kyphosis risk, fewer motion segments affected, and lower implant failure rates [15, 16]. Conversely, other research suggests that posterior-only instrumentation may yield superior functional and subjective outcomes compared to combined anterior-posterior procedures [8, 14, 17, 18]. Although the anterior approach is often recommended for decompressing retropulsed fragments in burst fractures with significant spinal canal compromise, it is associated with higher morbidity, increased bleeding, and longer recovery times [8, 16]. As an alternative, we evaluated the transfacet pedicle-sparing approach.

Performing a standard laminectomy at the fracture level can be technically demanding due to limited visibility and restricted instrumentation space. Therefore, it is crucial to expand the surgical field without jeopardizing spinal stability or causing harm to adjacent nerves or the spinal cord [6, 9, 10, 14]. In our approach, a microscope was utilized during the procedure, and a laminectomy was performed at the fracture site. A portion of the facet complex was carefully removed using a high-speed drill, with the nerve root protected using a nerve root retractor. This created space for a Carpenter's gauge to be positioned anterior to the thecal sac. This technique is considered safe because the spinal cord and nerve root are intentionally shielded as the instrument is maneuvered posterior-laterally to the spinal cord. Additionally, radiographic guidance was employed to assist in repositioning the displaced vertebra. Spinal stability was preserved by minimizing pedicle dissection. Realigning the displaced fragment also helps restore vertebral body mass, which can prevent further kyphosis [6, 10, 11]. By combining posterior decompression with this technique and posterior instrumentation, we observed immediate improvements in segmental kyphosis, significant spinal canal decompression, and enhanced vertebral body height in patients with thoracolumbar burst fractures and severe canal compromise [11, 17, 18].

Limitations

This study is limited by its retrospective design and a relatively small sample size. The single-center nature of the study reduces the ability to generalize the findings. Additionally, the lack of comparison with other approaches is a further constraint. It is suggested that future multicenter prospective trials be conducted to more thoroughly assess the outcomes of this approach.

The selection of a transfacet pedicle-sparing approach for the treatment of unstable thoracolumbar burst fractures with retropulsion warrants careful consideration. While traditionally employed for disc herniations where spinal stability is less compromised, our rationale for utilizing this technique in select burst fracture cases centered on minimizing iatrogenic instability and maximizing the potential for indirect reduction. By preserving a portion of the pedicle, we aimed to maintain some structural support and avoid exacerbating instability through complete pedicle removal. This approach allowed for direct visualization and decompression of the spinal canal via a partial facetectomy, while also facilitating indirect reduction and ligamentotaxis through pedicle screw placement and rod contouring. It is crucial to acknowledge that the pedicle-sparing approach was preferentially applied to burst fractures exhibiting specific characteristics, namely those without severe pedicle comminution. In cases of significant pedicle fracture or when extensive vertebral body reconstruction was necessary, a more traditional pediculectomy may have been warranted. Further research is needed to directly compare the clinical and biomechanical outcomes of pedicle-sparing versus pediculectomy approaches in the management of unstable thoracolumbar burst fractures.

Our study employed specific radiographic parameters to characterize thoracolumbar burst fractures, including Cobb angle, spinal canal compromise, and VBCR. While the Cobb angle served to quantify the degree of kyphotic or lordotic deformity, it's important to acknowledge that not all burst fractures present with measurable kyphosis. In such cases, a value of 0 degrees was recorded, and the absence of kyphosis did not preclude inclusion in the study, as our primary focus remained on spinal canal compromise and neurological status. Spinal canal compromise was assessed by measuring the anteroposterior diameter at the fracture level, compared to adjacent levels. While transverse encroachment was not directly quantified, its presence was qualitatively considered. Furthermore, recognizing the potential limitations of calculating VBCR based solely on the fractured vertebra, we propose to re-analyze our data using adjacent intact vertebrae as a reference standard. This methodological refinement will allow for a more accurate assessment of vertebral body compression and its potential impact on clinical outcomes. Further research is warranted to determine the optimal methods for radiographic assessment of thoracolumbar burst fractures and their correlation with clinical outcomes.

Conclusion

Our research has shown that the transfacet pedicle-sparing approach is an effective technique for directly managing the compression of unstable thoracolumbar burst fractures with retropulsion, resulting in favorable clinical and radiological outcomes.

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Author contributions
EA and SRB had the idea for this study. EA, MN and MA participated in outlining the concept and design. MN and MA did the data acquisition. EA and SRB did the statistical analysis and wrote the first draft of the manuscript. EA, SRB, and MA revised the final manuscript. All authors have read and approved the manuscript.

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Data availability
The datasets generated and/or analysed during the current study are not publicly available due them containing information that could compromise research participant privacy/consent but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study adhered to the Declaration of Helsinki and appropriate national guidelines. The study received ethics approval by the Kermanshah University of Medical Science Ethics Committee. Written informed consent to participate was obtained from all patients. All methods were carried out in accordance with relevant guidelines and regulations. The patient's data included in this manuscript has not been previously reported.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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