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Anterior versus Posterior Approach in Surgical Treatment of Dorsolumber Spondylodiscitis

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Abstract

Background: Spinal infections exhibit a wide range of clinical signs. The clinical effects can encompass the vertebral bodies, spinal canal, intervertebral discs, and adjacent paravertebral structures. Surgical treatment becomes necessary when there's a presence of neurological deficits, epidural abscess, or the development of kyphotic deformity. The approach involving anterior debridement and fusion has demonstrated its efficacy in managing pyogenic spondylodiscitis. This method facilitates direct reach to the infected disc, allowing thorough debridement and proper placement of bone graft to ensure adequate stabilization. On the other hand, the posterior approach is more proficient in correcting kyphosis. **Aim:** The aim of this thesis is to conduct a comprehensive comparison of the clinical, radiological, and functional outcomes between the surgical approaches of anterior and posterior methods in the treatment of spondylodiscitis. **Patients and methods:** A prospective cohort study was conducted in Benha university hospital including thirty patients with dorsolumber spondylodiscitis were admitted and managed operatively between May 2020 and June 2023. Patients were divided into two groups. Group (A): 15 patients (50%) were operated via anterior approach and group (B): 15 patients (50%) were operated via posterior approach. The diagnosis was confirmed through a combination of clinical presentation, laboratory analyses, and radiological evaluations. The study involved a 12-week follow-up period to assess the progression and outcomes of the condition. **Results:** The mean age of patients of group A was 52 ±8 and group B was 52 ±7. The most frequent site in group A was lumbar (46.7%), followed by thoracolumbar (40%) and thoracic (13.3%), while in group B, the most frequent was lumbar (40%), followed by thoracic (33.35) and thoracolumbar (26.7%). Functional outcome (regarding Oswestry disability index) was improved from 84% and 82% preoperatively to 28% and 30% postoperatively in Group A and Group B respectively. Regarding Local Kyphotic Angle, group B demonstrated significantly higher correction degrees than the anterior approach group A. Regarding hospital stay in our study, Group B demonstrated significantly higher hospital stay than group A. Also, Posterior group exhibited significantly higher operative time and blood loss. **Conclusion:** Both the anterior and posterior approaches are effective in accomplishing the objectives of surgical intervention for thoracic and lumbar Spondylodiscitis. However, the posterior approach provides notably superior correction of the kyphotic angle, albeit at the cost of increased operative time, prolonged hospital stay, and greater blood loss.

Keywords: Spine infection, Spondylodiscitis, approach to spine.

Introduction

Spinal infection holds historical significance, with some accounts tracing back to the Iron Age (1). In 1779, Pott provided the initial comprehensive depiction of tuberculosis infection within the spine, while Lanneloung, a century later, introduced the term "pyogenic osteomyelitis of the spine" in medical literature (2).

Spondylodiscitis encompasses a spectrum of disorders affecting bones, discs, and ligaments (3). It encompasses various clinical conditions, such as discitis, osteomyelitis, and epidural abscess. Pyogenic spondylodiscitis constitutes around 2-7% of all musculoskeletal infection cases (4,5). The majority (approximately 95%) of pyogenic spinal infections involve the vertebral bodies or intervertebral discs, with the remaining 5% affecting the spine's posterior elements. The lumbar spine is the most common site of infection (45-50%), followed by the thoracic (35%), cervical (3-20%), and sacral regions (6,7). Typically, pyogenic spondylodiscitis involves two adjacent vertebrae and the intervening disc due to the segmental artery's supply to the disc and lower part of the upper vertebra and upper part of the lower vertebra (8).

Contamination primarily occurs through hematogenous spread or from adjacent tissues. Spontaneous pyogenic spondylodiscitis is primarily associated with Staphylococcus aureus and streptococcus as the prevailing pathogens (9). Symptoms usually appear gradually, with back or neck pain (90% of cases), limb weakness, numbness, and sphincteric dysfunction. Additional indicators encompass fever, nausea, vomiting, weight loss, and confusion (10). The diagnostic process involves laboratory tests, radiological assessments including magnetic resonance imaging (MRI) and computed tomography (CT) scans, as well as thorough tissue sampling for microbiological analysis (11).

In the early stages, non-operative treatment like intravenous antibiotic therapy and external immobilization can be considered for spontaneous pyogenic discitis, particularly when neurological signs, instability, deformity, or spinal cord compression are absent. This approach may also be combined with surgical methods. Surgical management, involving debridement and/or stabilization through instrumentation, is typically employed for symptomatic cases involving neural compression, instability, failure of medical treatment, or uncertain diagnosis (12,13).

Patients and methods

Pre-operative Evaluation:

thirty patients with dorsolumber spondylodiscitis were admitted and managed operatively between May 2020 and June 2023. Patients were divided into two groups. Group (A): 15 patients (50%) were operated via anterior approach and group (B): 15 patients (50%) were operated via posterior approach. The diagnosis was established on basis of clinical presentation as well as laboratory and radiological investigations with follow up period of 12 weeks.

Inclusion criteria: A- A root, spinal cord, or cauda equina compression on MRI (epidural abscess). B- Spinal instability due to bone destruction or severe deformity such as kyphosis more than 15 degrees. C- An anterior abscess larger than 2.5 cm in dorsal or lumber spine. D- Postoperative Spondylodiscitis. E- Unsuccessful medical treatment of cases initially treated conservatively. F- Severe pain as an indication for surgery. G- Pyogenic, Tubercular or Brucellar spondylodiscitis were included. H- Cooperative patients and medically fit for operations. I- Informed consent to patient treatment and inclusion in our study.

Exclusion criteria: A- Spondylodiscitis not indicated in the inclusion criteria. B- Concomitant infections, hepatic and/or renal failure and malignant tumors. C- Cervical spondylodiscitis. D- Patients who are unfit for surgery.

Patient Evaluation: All patients underwent thorough medical history collection, which included information like age, gender, time of arrival, concurrent medical conditions (such as diabetes mellitus, chronic immune suppression), systemic symptoms (weight loss), fever presence, localized axial pain, mechanical pain, radicular pain, night pain, and comprehensive neurological assessment (including motor function, sensory examination, reflex evaluation, and autonomic dysfunction assessment). Laboratory tests were conducted at the time of admission, including complete blood count (CBC), erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), blood culture, Widal test, and Brucella test. Results were documented upon presentation and during follow-up. Thorough radiological evaluations were performed on all patients, encompassing spinal X-rays, CT scans with 3D and sagittal views to assess bone integrity, as well as MRI scans to evaluate spinal cord condition and extent of cord compression.

Surgical Procedure: Surgery was considered for patients facing spondylodiscitis with neural compression, instability, unsuccessful medical treatment, or inconclusive diagnosis. The surgical approach comprised two main methods: (a) removal of infected disc material, drainage of pus, and elimination of infected bone until healthy, well-vascularized bone was reached; (b) posterior stabilization using instrumentation in cases of instability and/or deformity. This research encompassed two distinct patient groups: Group A (consisting of 15 patients) underwent an anterior approach, while Group B (also containing 15 patients) underwent a posterior approach.

Anterior Approach (Group A): Patients allocated to Group A underwent a single-stage anterolateral approach, employing variations such as transthoracic, thoracoabdominal, and retroperitoneal techniques. Following induction of general anesthesia and endotracheal intubation, patients were positioned on their right side. The affected spinal level was aligned with the articulated section of the operating table. In a precise manner, infected material was excised until exposing healthy, well-vascularized bone. When addressing kyphosis correction, a tricortical iliac autograft was positioned in the resulting intervertebral space. Moreover, among these patients, eleven with kyphosis and/or instability received additional minimally invasive percutaneous pedicular screw fixation.

Posterior Approach (Group B): In Group B, the posterior approach encompassed a one-stage posterolateral procedure. Patients were placed in a prone position on a specialized table designed for spinal fractures. Pedicle screws were meticulously placed two levels above and two levels below the affected region. A system for temporary fixation and controlled distraction employing a single rod was employed to sustain spinal stability during decompression and bone resection. Initially, the side more affected within the spinal canal underwent procedures such as hemilaminectomy and facetectomy. With utmost care, the spinal cord, cauda equina, and nerve roots were delicately retracted to establish a conducive working space. Removal of necrotic tissue and intervertebral discs was followed by drainage of paraspinal abscesses. For the purpose of fusion, the end plates of the superior and inferior vertebrae were prepared through curettage. Subsequently, a tricortical autograft sourced from the posterior superior iliac spine was inserted to bridge the gap between the vertebrae above and below. Dual rods were meticulously positioned and adjusted to achieve proper compression. The surgery duration and blood loss were meticulously documented to facilitate subsequent evaluation.

Following debridement and tissue sampling, empirical intravenous antibiotics were initiated. These antibiotics covered common pathogens like Staphylococcus aureus and streptococcus. The selection of antibiotics was adjusted based on the identified pathogens and their sensitivities. This targeted antibiotic therapy continued for an average of six weeks, with the administration regimen being tailored to the patient's clinical progress, laboratory results, and pathogen identification.

Post-Surgical Care: The antibiotic treatment was guided by specific isolated agents and persisted for approximately six weeks. For instances involving Staphylococcus aureus infection, intravenous administration of oxacillin was maintained for two weeks. After discharge, a transition to oral ciprofloxacin for four weeks followed. In cases of MRSA (Methicillin-resistant Staphylococcus aureus) infection, meropenem or alternative treatment approaches were considered. Upon discharge, the continuation of oral ciprofloxacin was extended to an eight-week duration

Post-Operative Evaluation:

Clinical Evaluation: Patients were assessed early after surgery, at discharge, and in 3-week intervals. Clinical parameters, including back pain evaluated using the visual analog scale (VAS) (14) and neurological impairment using the Frankel scale (15), were evaluated.

Radiological Evaluation: Postoperative X-rays and CT scans were conducted on the second day after surgery to confirm screw placement and detect instability. Follow-up assessments occurred at 3 months to document fusion or deformity. Fusion and local kyphotic angle (LKA) were evaluated using Brantigan criteria (16) and Cobb technique (17), respectively. Functional results were assessed using the Oswestry disability index (ODI) (18).

Statistical methods:

Data management and statistical analysis were carried out utilizing SPSS version 28 (IBM, Armonk, New York, United States). The assessment of the normality of quantitative data involved employing the Shapiro-Wilk test in conjunction with direct data visualization techniques. Based on the assessment of normality, quantitative data were succinctly summarized using either means and standard deviations or medians and ranges, as appropriate. For categorical data, the summarization approach utilized encompassed numbers and corresponding percentages.

A comparative analysis of quantitative data between the groups under study was executed through the utilization of either the independent t-test or the Mann-Whitney U test, contingent on the normal or non-normal distribution of the respective quantitative variables. Correspondingly, the comparison of categorical data was facilitated through the application of either the Chi-square test or Fisher's exact test, as appropriate. The statistical tests employed were all two-sided.

Significance levels were determined by evaluating p-values, with values less than 0.05 being considered statistically significant.
(19)

Results

Patient Characteristics

The mean age of patients of group A was 52 ±8 and group B was 52 ±7. Males were 9 (60%) in group A and 10 (66.7%) in group B. The most frequent site in group A was lumbar (46.7%), followed by thoracolumbar (40%) and thoracic (13.3%), while in group B, the most frequent was lumbar (40%), followed by thoracic (33.35) and thoracolumbar (26.7%). Chronic disease was the most frequent risk factor in groups A and B (80% in each). No significant difference was observed between the studied groups regarding risk factors (P = 1.0). The most frequent predominant pathogen in groups A and B was Staph aureus (40% and 33.3%, respectively), followed by staph epidermidus (13.3 for each), pseudomonas aeruginosa (6.7% for each), mycobacterium tuberculosis (6.7% and 20%, respectively), and brucella (6.7% for each). No significant difference was observed between the studied groups (p = 0.970).

Clinical Results

the median VAS score improved from 8 in groups A and B preoperatively to 3 postoperatively in both groups. No significant differences were observed between the studied groups regarding the pre and postoperative VAS scores (P = 0.806 and 0.325, respectively). Regarding Frankel score (202) for neurological impairment, good outcomes (score D & E) were the most frequently reported (33.3%), while in group B, score D was the most frequent (46.7%) with no significant difference observed (P = 0.708).

Functional Results

regarding Oswestry disability index (ODI) (18), functional outcome was improved from 84% and 82% preoperatively to 28% and 30% postoperatively in Group A and Group B respectively, with no significant difference between both groups.

Radiological Results

Local Kyphotic Angle in group B (Posterior approach) demonstrated significantly higher correction degrees than the anterior approach group A (P-value = 0.024). According to Brantigan criteria, most patients in group A (80%) demonstrated fused criteria compared to 66.7% in group B. Probably fused criteria was reported in 20% of group A compared to 26.7% in group B, with no significant difference (P = 0.682).

Posterior group exhibited significantly higher **operative time** (194 ±25 vs. 169 ±22, P = 0.008) and **blood loss** (882 ±132 vs. 661 ±108, P < 0.001) than Anterior group.

Results of Complications

In our study only one patient in group A had complicated wound healing compared to three patients in group B, with no significant difference (P = 0.598). And one patient in group A had infection recurrence compared to two patients in group B, with no significant difference (P = 1.0).

Table (1) Demographics of the studied groups

		Group A (n = 15)	Group B (n = 15)	P-value
Age (years)	Mean ±SD	52 ±8	52 ±7	0.905
Sex				
Males	n (%)	9 (60)	10 (66.7)	0.705
Females	n (%)	6 (40)	5 (33.3)	

Table (2) Affected site in the studied groups

		Group A (n = 15)	Group B (n = 15)	P-value
Site				
Thoracic	n (%)	2 (13.3)	5 (33.3)	0.520
Thoracolumbar	n (%)	6 (40)	4 (26.7)	
Lumbar	n (%)	7 (46.7)	6 (40)	

Table (3) Risk factors in the studied groups

		Group A (n = 15)	Group B (n = 15)	P-value
Risk factor				
Chronic disease	n (%)	12 (80)	12 (80)	1.0
Previous surgery	n (%)	3 (20)	2 (13.3)	
Both	n (%)	0 (0)	1 (6.7)	

Table (4) Predominant pathogen in the studied groups

		Group A (n = 15)	Group B (n = 15)	P-value
Predominant pathogen				
Staph aureus	n (%)	6 (40)	5 (33.3)	0.970
Staph epidermidus	n (%)	2 (13.3)	2 (13.3)	
Pseudomonas aeruginosa	n (%)	1 (6.7)	1 (6.7)	
Mycobacterium tuberculosis	n (%)	1 (6.7)	3 (20)	
Brucella	n (%)	1 (6.7)	1 (6.7)	

No agent identified	n (%)	4 (26.7)	3 (20)

Table (5) Pre and postoperative VAS scores in the studied groups

VAS score		Group A (n = 15)	Group B (n = 15)	P-value
Preoperative	Median (range)	8 (7 - 10)	8 (6 - 10)	0.806
Postoperative	Median (range)	3 (1 - 5)	3 (1 - 6)	0.325

VAS: Visual analogue scale

Table (6) Pre and postoperative Frankel scale in the studied groups

Frankel scale		Group A (n = 15)	Group B (n = 15)	P-value
Preoperative				
A	n (%)	1 (6.7)	1 (6.7)	0.745
B	n (%)	5 (33.3)	2 (13.3)	
C	n (%)	5 (33.3)	7 (46.7)	
D	n (%)	4 (26.7)	5 (33.3)	
E	n (%)	0 (0)	0 (0)	
Preoperative				
A	n (%)	0 (0)	1 (6.7)	0.708
B	n (%)	1 (6.7)	0 (0)	
C	n (%)	4 (26.7)	2 (13.3)	
D	n (%)	5 (33.3)	7 (46.7)	
E	n (%)	5 (33.3)	5 (33.3)	

Table (7) Pre and postoperative ODI in the studied groups

ODI		Group A (n = 15)	Group B (n = 15)	P-value
Preoperative (%)	Median (range)	84 (76 - 94)	82 (70 - 98)	0.512
Postoperative (%)	Median (range)	28 (22 - 82)	30 (18 - 92)	0.935

ODI: Oswestry Disability Index

Table (8) Pre and postoperative LKA and correction in the studied groups

LKA		Group A (n = 15)	Group B (n = 15)	P-value
Preoperative (degrees)	Median (range)	31 (24 - 36)	33 (29 - 41)	0.149
Postoperative (degrees)	Median (range)	11 (4 - 15)	9 (7 - 14)	0.961
Correction (degrees)	Median (range)	21 (18 - 23)	24 (0 - 30)	0.024*

*** Significant P-value; LKA: Local Kyphotic Angle**

Table (9) Hospital stay in the studied groups

		Group A (n = 15)	Group B (n = 15)	P-value
Hospital stay (days)	Median (range)	8 (6 – 15)	12 (10 – 21)	0.001*

*Significant

Table (10) Operative time and blood loss in the studied groups

		Group A (n = 15)	Group B (n = 15)	P-value
Operation time (min.)	Mean ±SD	169 ±22	194 ±25	0.008*
Blood loss (ml)	Mean ±SD	661 ±108	882 ±132	<0.001*

***Significant P-value**

Table (11) Brantigan criteria in the studied groups

		Group A (n = 15)	Group B (n = 15)	P-value
Brantigan criteria				
Unfused	n (%)	0 (0)	1 (6.7)	0.682
Probably unfused	n (%)	0 (0)	0 (0)	
Uncertain	n (%)	0 (0)	0 (0)	
Probably fused	n (%)	3 (20)	4 (26.7)	
Fused	n (%)	12 (80)	10 (66.7)	

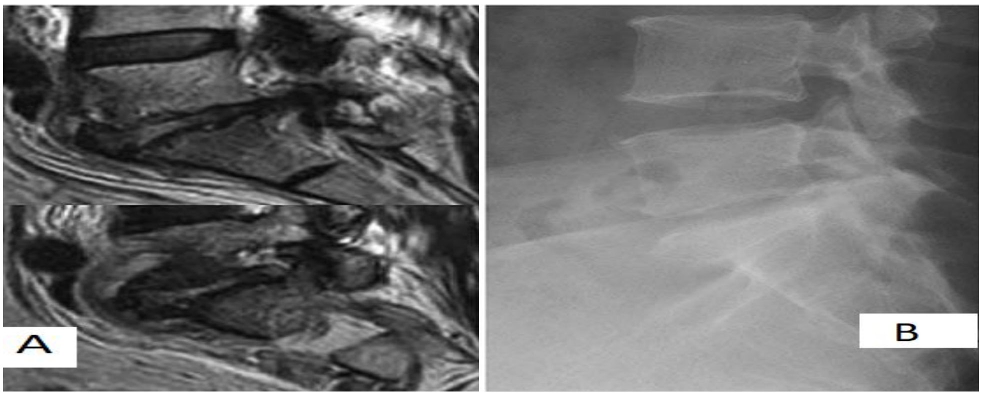

Fig. (1) Preoperative **A:** MRI, **B:** X-ray of female patient 56 years old with L5-S1 Spondylodiscitis. Her VAS score on admission was 7. Frankle scale was C preoperatively. And ODI was 84%.

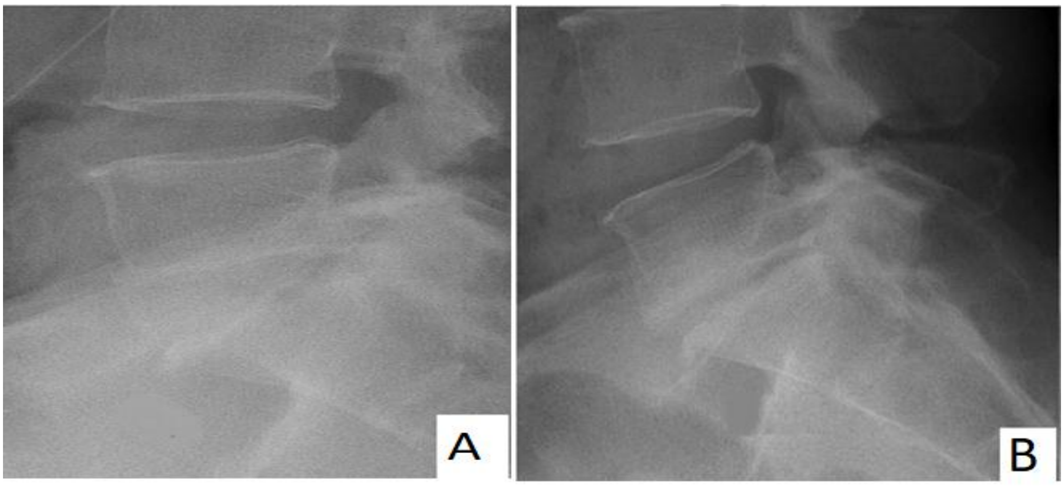

Fig.(2) A One month follow up X-ray, **B:** follow up x-ray after 3 months. VAS score = 3. Frankle scale was improved from C to D.

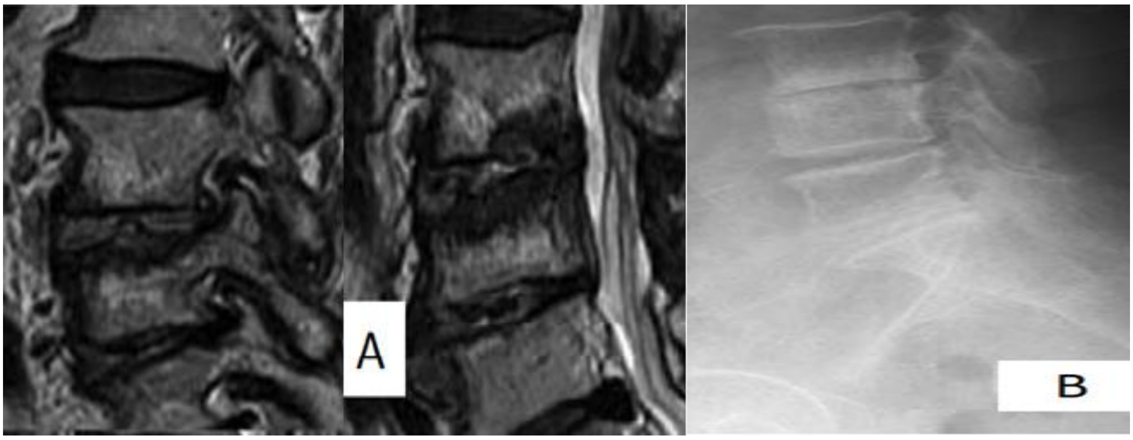

Fig. (3) Preoperative **A:** MRI, **B:** X-ray of male patient 52 years old with L4-L5 Spondylodiscitis. VAS score on admission was 8. Frankle scale was C preoperatively. And ODI was 82%.

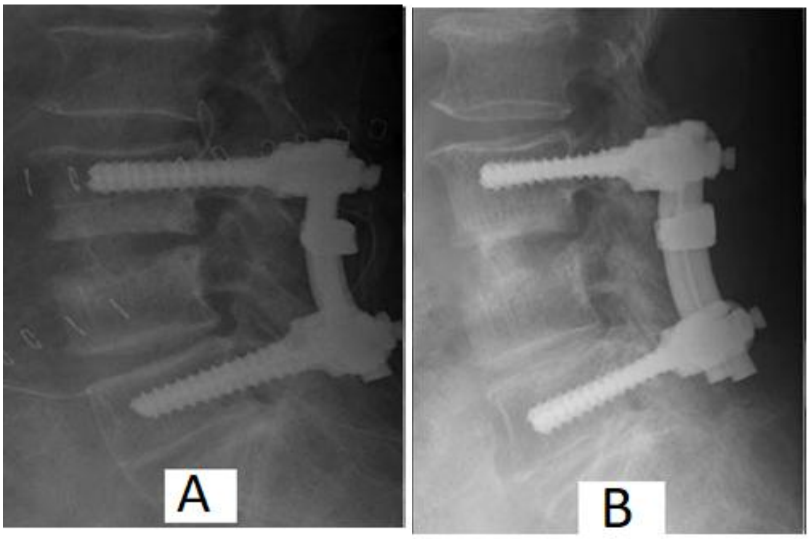

Fig. (4) A Immediate postoperative x-ray, **B:** Follow up X-ray after 3 months. Showing pedicle screws fixation with correction of kyphosis. VAS score = 4. Frankle scale was improved from C to D.

Discussion

A diverse range of clinical manifestations characterizes spinal infections, involving vertebral bodies, intervertebral discs, the spinal canal, and paravertebral structures. Etiologically, these infections can be classified into pyogenic (bacterial), granulomatous (tuberculous or fungal), and parasitic (Echinococcosis) categories (20).

Surgical intervention becomes imperative when neurological deficits, epidural abscesses, or kyphotic deformities develop. The efficacy of anterior debridement and fusion has been substantiated in treating pyogenic spondylodiscitis. This technique offers a direct pathway to the infected disc, enabling thorough debridement, effective bone graft placement, and reliable stabilization. Additionally, it facilitates tissue biopsy for precise microbiological diagnosis. However, it's important to note that solely relying on the anterior approach might not consistently restore spinal stability or correct kyphotic deformities as effectively as the posterior approach, which has shown better results in these aspects (21).

The primary objective of this study is to conduct a comprehensive comparison of clinical, radiological, and functional outcomes between the anterior approach (Group A) and the posterior approach (Group B) for surgical management of patients with dorsal or lumbar non-specific spondylodiscitis.

Our study revealed that the mean age of patients in Group A was 52 ± 8 and in Group B was 52 ± 7, with no significant difference (P-value = 0.905). These findings align with previous studies such as Korovessis et al. in 2006 (22) and Pee et al. in 2008 (23) who reported similar mean ages of 55 and 58 years, respectively.

In our study, the most frequent affected site in Group A was the lumbar region (46.7%), followed by thoracolumbar (40%) and thoracic (13.3%). For Group B, the order was lumbar (40%), thoracic (33.3%), and thoracolumbar

(26.7%). However, no significant difference was observed between the two groups (P = 0.520). Comparable observations were made in the studies by Korovessis et al. in 2006 (22) and Včelák et al. in 2014 (24), where the distribution of affected sites displayed similar patterns.

Regarding risk factors, chronic disease was the most frequent in both Group A and Group B (80% in each). There was no significant difference between the two groups (P = 1.0). This aligns with the findings of Korovessis et al. in 2006 (22) and Pee et al. in 2008 (23), where chronic disease also stood out as the predominant risk factor.

The most prevalent pathogen in both Group A and Group B was Staph aureus (40% and 33.3% respectively), followed by Staph epidermidis (13.3% for each), Pseudomonas aeruginosa (6.7% for each), Mycobacterium tuberculosis (6.7% and 20% respectively), and Brucella (6.7% for each). However, no significant difference was noted between the two groups (P = 0.970). Similar pathogen prevalence was seen in the studies by Korovessis et al. in 2006 (22), Včelák et al. in 2014 (24), and Endres et al. in 2012 (25). Pee et al. in 2008 (23) showed Staph epidermidis as the predominant pathogen.

In terms of the Visual Analog Scale (VAS) score, our study demonstrated a median improvement from 8 in both preoperative groups to 3 postoperatively in both groups. No significant differences were observed between the groups for pre and postoperative VAS scores (P = 0.806 and 0.325 respectively). However, Hassan K. et al. in 2016 (26) reported significantly better VAS scores for back pain in the posterior group compared to the anterior group

In our study, regarding Frankel score (15) for neurological impairment, good outcomes (score D & E) were the most frequently reported (33.3%), while in group B, score D was the most frequent (46.7%) with no significant difference observed (P = 0.708). Similarly, there was no significant difference in neurological improvement in the study of Hassan K. et al., 2016 (26). However, Bhavuk et al. (27) noted a relatively superior neurological recovery rate in the anterior group (76%) compared to the posterior group (72.2%). They proposed that the posterolateral approach posed greater challenges in effectively removing anterior debris and decompressing neural elements, leading to an increased incidence of neurological injuries in contrast to the anterior approach.

In our study, concerning the Oswestry Disability Index (ODI) (18), the functional outcomes displayed improvement from preoperative rates of 84% and 82% to postoperative rates of 28% and 30% in Group A and Group B, respectively. No statistically significant difference in functional outcomes regarding the Oswestry Disability Index (ODI) was observed between the two groups. This finding was consistent with the study conducted by Hassan K. et al. in 2016 (26), where a significant difference was not found (P=0.05) in functional outcomes with respect to the Oswestry Disability Index (ODI).

In our study, with respect to the Local Kyphotic Angle, Group B (Posterior approach) exhibited a significantly greater degree of correction compared to the anterior approach Group A (P-value = 0.024). Comparable outcomes were reported by Bhavuk et al. (27), who demonstrated more substantial postoperative angle correction in the posterior group (54.3°) than in the anterior group (23.3°), along with relatively less angle loss during the latest follow-up (2.2° and 2.8°, respectively). Likewise, Quershi et al. (28) found that the anterior approach was less effective in correcting deformities, while the posterior approach led to superior deformity correction. This disparity might be attributed to the pedicular system's capacity to facilitate enhanced kyphotic angle correction compared to the anterior system. Additionally, the degree of angle loss during the latest follow-up was notably lower in the posterior group than in the anterior group. In terms of hospital stay, our study found that Group B had significantly longer hospital stays than Group A (median = 12 vs. 8 days, P = 0.001).

Furthermore, our study revealed that the posterior group experienced significantly longer operative times (194 ± 25 vs. 169 ± 22, P = 0.008) and higher blood loss (882 ± 132 vs. 661 ± 108, P < 0.001) compared to the anterior group. These findings were consistent with those reported by Hassan K. et al. in 2016 (26), where the average operative time for the anterior group was notably shorter than that of the posterior group (P = 0.05). Additionally, blood loss and blood transfusion requirements were significantly lower in the anterior group compared to the posterior group (P = 0.05) in their study.

According to the Brantigan criteria, the majority of patients in Group A (80%) fulfilled the fused criteria, whereas 66.7% of patients in Group B met the same criteria. The presence of fused criteria was observed in 20% of Group A and 26.7% of Group B, with no significant difference (P = 0.682). Correspondingly, in the study by Hassan K. et al. in 2016 (26), certainty of fusion was achieved in all 20 patients of the anterior group (100%) and in 21 patients of the posterior group (95.4%).

Examining complications, our study recorded only one case of complicated wound healing in Group A, compared to three cases in Group B, without a significant difference (P = 0.598). Similarly, infection recurrence was noted in one patient in Group A and two patients in Group B, with no significant difference (P = 1.0).
In conclusion, both anterior and posterior approaches effectively achieve the objectives of surgical intervention for thoracic and lumbar spondylodiscitis. However, the posterior approach notably excels in correcting the kyphotic angle, although this advantage is counterbalanced by longer operative times, extended hospital stays, and increased blood loss.

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