



Surgical Approaches in Management of Spinal Tuberculosis

Vishal Kumar¹ Amit Kumar Salaria¹ Aditya Aggarwal¹ Sarvdeep Singh Dhatt¹

¹Department of Orthopaedics, Post Graduate Institute of Medical Education & Research, Chandigarh, India

Address for correspondence Amit Kumar Salaria, MS, DNB, MBBS, Department of Orthopaedics, Post Graduate Institute of Medical Education & Research, Sector 12, Chandigarh 160012, India (e-mail: meetamit20salaria@gmail.com).

Ann Natl Acad Med Sci (India)

Abstract

Keywords

- ▶ tuberculosis
- ▶ approaches to control spinal TB
- ▶ anti-tubercular treatment
- ▶ functional outcome

Although the management of spinal tuberculosis (TB) is mainly medical, there are select surgical interventions for the same, especially in the event of complications. However, with multiple choices with regard to approaches and surgical techniques, one is often left with too many options. We, therefore, performed a literature review on the subject with respect to the surgical approaches to control spinal TB. Our aim is to enable the reader to understand the rationale behind various surgical approaches and techniques involved in managing spinal TB.

Introduction

Tuberculosis (TB) has been observed since 6000 BC, from the time of mummies in Egypt to the oldest Indian medical treatises dating back to 1000 BC.¹ Skeletal TB constitutes approximately 10% of extrapulmonary TB, and spinal TB forms half of that chunk.² Increasing frequency of TB and global migration phenomenon have led to it being a health problem not only in developing but also in developed countries.² Recent emergence of multidrug-resistant (MDR) strains and increasing burden of chronic medical conditions and HIV have catapulted it to the level of a menace.³

Usual presentation of spinal TB is an innocuous back pain. The classical TB symptoms of fever, loss of appetite, and weight loss are often missing. Thoracolumbar back pain not usually of mechanical type, more prominent at night, and paraspinal muscle spasm on examination may arouse the suspicion of spinal TB in endemic countries. In non-endemic countries, this presentation is often missed, and MRI scans may be delayed till many more clinical features and more advanced damage to vertebral column become apparent. This is an important reason why more cases of spinal TB

are surgically treated in Western countries, whereas a large number of cases are managed conservatively in India.

In cases of suspected spinal TB, X-ray of the spine is usually the first investigation. However, X-rays may miss early lesions, and noticeable bony destruction may not be apparent for up to 3 months from the time the disease sets-in. Therefore, in a robust clinical suspicion, MRI remains the main investigation of choice, as it detects the earliest changes and outlines extent of soft-tissue involvement, and helps assessing response to the treatment.⁴ The gold standard for diagnosis, however, is the growth of *Mycobacterium* from the infected tissue.

Multidrug antitubercular treatment (ATT) is the mainstay of treatment of spinal TB, whether simple or complicated. Studies have demonstrated that chemotherapy alone had similar functional outcome when compared with debridement and fusion.^{5,6} Tuli's middle path regime is based on similar findings where multidrug ATT is the main focus of therapy. However, there remain certain select indications for surgery such as lack of response to ATT, progressive deficit despite treatment, severe weakness, instability, severe pain and deformities. With the advent of newer surgical

DOI <https://doi.org/10.1055/s-0041-1731596>
ISSN 0379-038X

© 2021. National Academy of Medical Sciences (India).

This is an open access article published by Thieme under the terms of the Creative Commons Attribution-NonDerivative-NonCommercial-License, permitting copying and reproduction so long as the original work is given appropriate credit. Contents may not be used for commercial purposes, or adapted, remixed, transformed or built upon. (<https://creativecommons.org/licenses/by-nc-nd/4.0/>).

Thieme Medical and Scientific Publishers Pvt. Ltd. A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

approaches and techniques, it is increasingly more difficult to select a suitable one for the same, especially for the trainee surgeon, as some of them have a considerable learning curve. This review focuses on the surgical management of spinal TB with special regard to surgical approaches and techniques. However, we emphasize that the management of spinal TB is multidrug ATT, and we do not want the reader to understand that surgery is needed in every case.

Newer ultrafast modalities of diagnosis of TB, consisting of rapid molecular tests and including Gene X-pert and line probe assay (LPA), have revolutionized the utility of nonoperative treatment in spinal TB.^{7,8}

The Xpert Mycobacterium tuberculosis (MTB) rifampicin (RIF) assay is a fully automated diagnostic test for the TB. The Xpert MTB/RIF is a cartridge-based nucleic acid amplification test (NAAT) for simultaneous rapid TB diagnosis and rapid antibiotic sensitivity test. It is diagnostic test that can identify MTB DNA and resistance to RIF. The GeneXpert test showed a sensitivity of 95.6% and specificity of 96.2% for spinal TB.⁹ It is a molecular test which detects DNA of MTB and helps in the detection of mycobacteria as well as rifampicin resistance in just 2 hours. LPA is a similar molecular test detecting resistance not only to rifampicin but also to isoniazid, quinolones, and second-line injectables, thus diagnosing not just MDR but also extremely drug resistant (XDR) TB in just 48 hours.¹⁰ Therefore, these tests must be asked for on every biopsy specimen in addition to TB Mycobacterium growth indicator tube (MGIT) culture and histopathology. MGIT is a system that determines whether TB bacteria will grow in the presence of ATT drugs. If the bacteria grow, then they are resistant to the drugs, because the drugs could not stop their growth.

Surgical Management

Rationale

The TB lesion itself, cold abscess, paraplegia, instability, and deformity, all can be addressed by surgery if indicated; moreover, it provides infected tissue for culture and histopathological examination. Tissue culture still remains the only confirmatory diagnostic modality to date. Additional advantages of surgery include removal of infected focus, possible shortening of chemotherapy, early effective neurological recovery, reduction of recurrence, and meeting patients' functional demands. The basis of surgery is adequate debridement or decompression, maintenance of stability, and correction of deformity.

Surgical Approaches and Techniques

Currently, the surgical management of spinal TB is focused on the anterior-only approach, all posterior approach, and the combined anterior and posterior approach, with each of having distinct advantages, disadvantages, and limitations (→ **Table 1**). Further, various minimally invasive approaches like thoracoscopic approaches are also evolving. Moreover, there is also a recent trend in combining the various minimally invasive procedures with the traditional anterior and posterior approaches.

Anterior-Only Approach

As TB of the spine is mainly an anterior disease, anterior approach was classically more widely used, due to the larger exposure that it provides.¹¹ Indeed, the classic teaching has been that anterior cord decompression is necessary in cases of spinal TB, and that laminectomy fails to relieve pressure even after the removal of the only stabilizing structures that the patient had, that is, the posterior arch and the ligament complex. Furthermore, the concept was that any surgery on the diseased spine should preserve the intact structures as much as possible to ensure residual stability. Also, early studies that attempted posterior-only fusion reportedly failed due to the presence of anterior disease.¹¹

In general, anterior approaches to spine are indicated for decompression when anterior neural compression is radiologically proven. They are reserved for experienced

Table 1 Depicting indications, merits and demerits of various approaches

Indications of surgery	
Failure of antituberculosis therapy	
Progressive deficit despite treatment	
Severe weakness	
Instability	
Severe pain and deformity	
Additional advantages of surgery	
Provides tissue for diagnosis	
Removal of infected focus	
Shortening of chemotherapy	
Early recovery, reduced recurrence	
Basis of surgery	
Adequate debridement/decompression	
Maintenance of stability	
Correction of deformity	
Anterior approaches	
Advantages	Disadvantages
Access to anterior cord	Steep learning curve
Possibility of radical debridement	Pulmonary complications
Preserves the only intact bony structure left	Iatrogenic neurovascular injury
	Result in progression of deformity
	Anterior bony insufficiency may need additional grafting
Posterior approaches	
Advantages	Disadvantages
Easy to learn	May take away the only intact bony structure
Avoids anesthesia and pulmonary complications	Radical debridement may not be possible in some cases
Three-column fixation	
Safer deformity correction	

spinal surgeons and not recommended for new or in-training surgeons because of the steep learning curve. Many centers mandate a multidisciplinary approach for such interventions, employing the skill of neurosurgeons, head and neck surgeons, gastrosurgeons apart from orthopedic spinal surgeons. However, this approach is rife with problems such as pulmonary complications and possible iatrogenic injury to vascular, visceral, or neural structures. These cannot be used in the setting of significant deformity and result in significant progression of kyphosis when used without instrumentation, as shown by Rajasekaran and Soundarapandian.¹² Further, there occurs a significant anterior bony insufficiency, which surgeons attempt to combat with fibular strut grafts that failed without additional fixation.

Posterior Approach

There are several recent studies published in the literature advocating the posterior-only approach (► **Table 2**). The basis of all posterior approach is to reach the diseased part of the vertebrae either through transpedicular, transfacet, or costotransversectomy route, and simultaneously fix all the three columns with modern pedicle screws. Posterior approach through a midline longitudinal incision provides the most direct access to posterior elements of spine at all levels. Conventional teaching is that posterior approach should be avoided in anterior pathologies, as the removal of the only intact bony structure would lead to instability, subluxation, or dislocation. However, posterior approach has the advantage of three-column fixation, resulting in a safer deformity correction, which is shown to suppress infection perhaps by providing stability^{19,21-23}. Indeed, it is the most commonly performed approach nowadays due to its easier and relatively simpler nature. The advent of pedicle screws and segmental posterior fixation has given a new life to posterior approaches. It gives adequate cord exposure for

decompression and excellent deformity correction. It also reduces the risk of anesthesia and avoids complications associated with the anterior approach. Transpedicular approach provides good circumferential decompression and a stable fixation at the same time.^{24,25} In the real sense, much of the work in posterior approach has been on the back of ATT, as debridement is no longer the main focus of treatment. Many previous studies show that posterior fixation with proper ATT has good cure rate even without debridement.²⁶⁻²⁸ The anterior disease which is left without debridement is taken care of by the ATT. So, fewer invasive procedures are gaining popularity.²⁹ It may have more to do with detecting the disease in its early stages, where it is amenable to less gruesome procedures, which begs the question that would such a stage might even be responsive to ATT alone?

According to a meta-analysis performed by Muheremu et al, there were no significant differences in the operative time, blood loss, hospital stay, fusion rates, or loss of Cobb angle at follow-up when anterior and posterior approaches were compared.¹⁶ On the contrary, many authors have reported that posterior approaches may be better at some of the above parameters than anterior or even combined approaches.^{13,30,31} One of these had disproportionately more thoracic spinal TB cases in anterior group than the posterior group, which may have influenced the aforementioned outcome.^{32,33}

Theoretically, either of them have their own advantages, with anterior providing better debridement, while posterior giving more stability and less loss of correction of deformity; hence, the rationale of combining them for select cases. However, to avoid the complications arising from the increased operative time and violation of thoracic and abdominal space, newer extrapleural approaches have been described, with the aim of not only giving good results but also providing access to both anterior and posterior structures with the same approach.^{34,35}

Combined Approach

The rationale behind this approach is combining the benefits of both the anterior and posterior approaches. If the patient's physiology allows, it can be performed as a single procedure; otherwise, a staged procedure is preferred. It is especially useful in failed anterior surgeries and in cases of severe destruction and deformities.

Minimally Invasive Procedures

All of the posterior approaches can be made into minimally invasive ones if only a small area needs to be exposed. It basically involves dilating the thoracolumbar fascia by insertion of a tubular retractor. The location of incision is most important in having the adequate exposure, which should be planned as per preoperative radiology and intraoperative fluoroscopic images.³⁶ The procedure has the advantage of early recovery and minimizes morbidity of the patient. Recent studies have demonstrated good functional outcome of such approaches in spinal TB.³⁷ Also, surgeons have successfully demonstrated video-assisted thoracoscopic surgery in spinal TB for anterior

Table 2 Recent studies advocating posterior only approaches

Author	Conclusion
Zheng et al ¹³	Posterior approach better for lumbosacral TB, especially with regards to Cobb angle at last follow-up
Zhou et al ¹⁴	No difference in outcome when compared for thoracic and thoracolumbar spinal TB. However, surgery time and blood loss less for posterior approaches.
Zhao et al ¹⁵	Microbiological outcome study showing equal effectiveness of debridement by anterior versus posterior approaches
Muheremu et al ¹⁶	Meta-analysis: No significant differences except correction of Cobb angle, which is better in posterior approach
Liu et al ¹⁷	Meta-analysis: Posterior approach had same results when compared with combined approach but with less surgical time and complications
Yang et al ¹⁸	Meta-analysis: Posterior approach had better clinical outcome than anterior or combined approaches

debridement and fusion.³⁸ We think that more prospective studies are required before these approaches become popular for this indication. They do not seem feasible in the setting of severe deformity. Patient selection will be key to their success, as extensive destruction or deficit would be difficult to deal with the limited exposure they provide.

Combined Open and Minimally Invasive Procedures

With the advent of minimally invasive percutaneous pedicle screw insertion techniques, now increasing number of surgeons are combining the anterior procedures with this to decrease the morbidity of the combined approaches and better patient rehabilitation. ► **Table 3** briefly describes the various surgical approaches and the levels which can be addressed.

Specific Circumstances

Cold Abscess

Abscess drainage is no longer recommended unless complications arise due to the same. In most cases, these resolve with chemotherapy alone. So, drainage is not performed nowadays even for large cold abscesses. However, if complications such as dysphagia or respiratory distress arise, the same may need to be drained. The palpable ones can be drained from routine surgical approaches. Further, iliopsoas abscess can be drained via the anterior approach by making an incision on the iliac crest just behind the anterior superior iliac spine, from where after cutting the external and internal obliquus muscle, one can reach the iliac bone and drain the abscess extraperitoneally, unless it points more posterior from where it can be drained through the floor of the Petit's triangle. Surgical drainage is only indicated when percutaneous technique fails.³⁹ If required, percutaneous is the norm.⁴⁰ Psoas abscess may even present as pseudoflexion deformity of the hip. For cervical spine, incision can be made either anterior or posterior to the sternocleidomastoid, depending upon the position of the abscess. We recommend proper evaluation

before draining any abscess, if indicated, as it is quite possible that one may be dealing with other pathology, which may result in disastrous outcomes. It is not unheard of to drain an abscess only to find blood.

Role of Debridement

Debridement alone does not improve healing or halt the progression of kyphosis. It may even damage growth plates in children. On the other hand, some researchers have shown that decompression alone can be performed using transpedicular approach without radical debridement with good functional results.⁴¹ Debridement has to be combined with fusion or instrumentation. The shift from debridement alone to fixation with or without debridement is perhaps due to the success of ATT, as various surgical treatment options have evolved from before the time of antituberculosis drug era. However, various controversies exist regarding timing and type of surgery, with most surgeon's preferring an individualized treatment program.

Classification Systems: No role yet?

Various classification systems have attempted to stage the disease, in order to improve universality in management. Mehta and Bhojraj described one such system based on the surgical strategy they used for their respective patients which, in turn, was based on extent of lesion and patient-related risk factors. Kumar et al, Oguz et al and Moon et al have described other such systems.⁴²⁻⁴⁵ Teegala et al gave a clinicoradiological grading system for craniocervical junction tuberculosis.⁴⁶ However, none is widely accepted at the moment, perhaps highlighting the need for a better system in the future, which could possibly direct the choice of technique or the approach as well.

Deformity Correction

Many of the patients treated conservatively end up with a deformity greater than 60 degrees, which can cause serious cardiorespiratory medical complications, not to mention the psychological effects the cosmetic problems cause. Authors

Table 3 Various approaches and levels that can be addressed

Anterior approaches	Cervical	1. Transoral 2. Retropharyngeal 3. Southwick/Robinson	Occiput-C3 Occiput-C3 C2-T1
	Cervicothoracic	1. Low anterior cervical 2. High transthoracic 3. Transsternal	C1-T1 C6-T4 T3/T4
	Thoracic	Transthoracic VATS	T2-L2
	Thoracolumbar	Retroperitoneal	L1-L5
	Lumbosacral junction	Transperitoneal	L5-S1
Posterior approaches	1. Transpedicular 2. Transfacet 3. Transforaminal		T2-S1 Both limited debridement ± Instrumented fusion
	4. Costotransversectomy		Debridement only

Abbreviation: VATS, video-assisted thoracic surgery.

have described “at risk signs” to identify children who are at risk of developing severe deformity, a type which is termed “buckling collapse.”^{47,48} This kyphosis may even result in compression of spinal cord, leading to paraplegia years after onset of disease.⁴⁹ A prudent approach would be to identify patients who might develop such sequelae early. The rate of progression depends upon number of vertebrae involvement, amount of height loss, and part of the spine involved. Patients with posterior involvement along with vertebral body loss may require fixation to prevent progression of deformity early. There are formulas described to predict the final deformity.¹²

Twenty to thirty degrees of single-level deformity can be addressed with pedicle subtraction osteotomy.^{50,51} Severe rigid deformities require techniques such as vertebral column resection.⁵² Minor deformities can be dealt with simpler Ponte’s osteotomies at single or multiple levels.

Conclusion

Spinal TB remains a medical disease with ATT as its main management. However, in the setting of complications and specific case scenarios, there remains the role of surgical management. With multiple surgical options available, there also remains confusion regarding appropriate choice when surgery is indeed needed. Anterior approaches have been the gold standard due to the exposure they provide and the possibility of adequate debridement. However, they have a high learning curve and complication rate. Also, these may not be a good choice in the setting of significant deformity. Posterior approaches are easier to perform and provide safer deformity correction. We cannot recommend new minimally invasive procedures for spinal TB till more data is available for them. Instead of following one particular algorithm, we should focus on individualizing the treatment for the spinal TB patient with regard to the stage of disease and functional demand.

Conflict of Interest

None declared.

References

- 1 Taylor GM, Murphy E, Hopkins R, Rutland P, Chistov Y. First report of *Mycobacterium bovis* DNA in human remains from the Iron Age. *Microbiology (Reading)* 2007;153(Pt 4): 1243–1249
- 2 Pareek M, Greenaway C, Noori T, Munoz J, Zenner D. The impact of migration on tuberculosis epidemiology and control in high-income countries: a review. *BMC Med* 2016;14(1):48
- 3 Barnes PF, Bloch AB, Davidson PT, Snider DE Jr. Tuberculosis in patients with human immunodeficiency virus infection. *N Engl J Med* 1991;324(23):1644–1650
- 4 Sinan T, Al-Khawari H, Ismail M, Ben-Nakhi A, Sheikh M. Spinal tuberculosis: CT and MRI feature. *Ann Saudi Med* 2004;24(6):437–441
- 5 Darbyshire J. Five-year assessment of controlled trials of short-course chemotherapy regimens of 6, 9 or 18 months’ duration for spinal tuberculosis in patients ambulatory from the start or undergoing radical surgery. Fourteenth report of the Medical Research Council Working Party on Tuberculosis of the Spine. *Int Orthop* 1999;23(2):73–81

- 6 A controlled trial of six-month and nine-month regimens of chemotherapy in patients undergoing radical surgery for tuberculosis of the spine in Hong Kong. Tenth report of the Medical Research Council Working Party on Tuberculosis of the Spine. *Tubercle* 1986;67(4):243–259
- 7 Kim SJ. Drug-susceptibility testing in tuberculosis: methods and reliability of results. *Eur Respir J* 2005;25(3):564–569
- 8 Caminero JA; World Health Organization. American Thoracic Society/British Thoracic Society. Treatment of multidrug-resistant tuberculosis: evidence and controversies. *Int J Tuberc Lung Dis* 2006;10(8):829–837
- 9 Gurbanova E, Mehdiyev R, Blondal K, et al. Mitigation of discordant rifampicin-susceptibility results obtained by Xpert *Mycobacterium tuberculosis*/Rifampicin and *Mycobacterium* growth indicator tube. *Microb Drug Resist* 2017;23(8):1045–1052
- 10 Yadav RN, Singh BK, Sharma SK, et al. Comparative evaluation of GenoType MTBDRplus line probe assay with solid culture method in early diagnosis of multidrug resistant tuberculosis (MDR-TB) at a tertiary care centre in India. *PLoS One* 2013;8(9):e72036
- 11 Hodgson A-R, Stock FE, Fang HSY, Ong GB. Anterior spinal fusion. The operative approach and pathological findings in 412 patients with Pott’s disease of the spine. *Br J Surg* 1960;48:172–178
- 12 Rajasekaran S, Soundarapandian S. Progression of kyphosis in tuberculosis of the spine treated by anterior arthrodesis. *J Bone Joint Surg Am* 1989;71(9):1314–1323
- 13 Zheng B, Hao D, Guo H, He B. Anterior versus posterior surgical approach for lumbosacral tuberculosis. *J Int Med Res* 2018;46(7):2569–2577
- 14 Zhou Y, Li W, Liu J, Gong L, Luo J. Comparison of single posterior debridement, bone grafting and instrumentation with single-stage anterior debridement, bone grafting and posterior instrumentation in the treatment of thoracic and thoracolumbar spinal tuberculosis. *BMC Surg* 2018;18(1):71
- 15 Zhao C, Pu X, Zhou Q, et al. Can a posterior approach effectively heal thoracic and lumbar tuberculosis? Microbiology outcomes of the operative area. *J Orthop Surg Res* 2019;14(1):24
- 16 Muheremu A, Niu X, Wu Z, Tian W. Study on anterior and posterior approaches for spinal tuberculosis: a meta-analysis. *Eur J Orthop Surg Traumatol* 2015;25(Suppl 1):S69–S76
- 17 Liu J, Wan L, Long X, Huang S, Dai M, Liu Z. Efficacy and safety of posterior versus combined posterior and anterior approach for the treatment of spinal tuberculosis: a meta-analysis. *World Neurosurg* 2015;83(6):1157–1165
- 18 Yang P, Zang Q, Kang J, Li H, He X. Comparison of clinical efficacy and safety among three surgical approaches for the treatment of spinal tuberculosis: a meta-analysis. *Eur Spine J* 2016;25(12):3862–3874
- 19 Chen YC, Chang MC, Wang ST, Yu WK, Liu CL, Chen TH. One-stage posterior surgery for treatment of advanced spinal tuberculosis. *J Chin Med Assoc* 2003;66(7):411–417
- 20 Zindrick MR, Wiltse LL, Widell EH, et al. A biomechanical study of intrapeduncular screw fixation in the lumbosacral spine. *Clin Orthop Relat Res* 1986;(203):99–112
- 21 Sundararaj GD, Behera S, Ravi V, Venkatesh K, Cherian VM, Lee V. Role of posterior stabilisation in the management of tuberculosis of the dorsal and lumbar spine. *J Bone Joint Surg Br* 2003;85(1):100–106
- 22 Broner FA, Garland DE, Zigler JE. Spinal infections in the immunocompromised host. *Orthop Clin North Am* 1996;27(1):37–46
- 23 Weisz RD, Errico TJ. Spinal infections. Diagnosis and treatment. *Bull Hosp Jt Dis* 2000;59(1):40–46
- 24 Lee TC, Lu K, Yang LC, Huang HY, Liang CL. Transpedicular instrumentation as an adjunct in the treatment of thoracolumbar and lumbar spine tuberculosis with early stage bone destruction. *J Neurosurg* 1999;91(2(Suppl)):163–169

- 25 Zaveri G. The role of posterior surgery in spinal tuberculosis. *ArgoSpine News J* 2011;23:112–119
- 26 Medical Research Council Working Party on TB of the Spine. A 15-years assessment of controlled trial of management of TB of the spine in Korea and Hong Kong. Thirteenth report of the Medical Research Council Working Party on TB of the Spine. *J Bone Joint Surg Br* 1998;80B:456–462
- 27 Medical Research Council Working Party on TB of the Spine. Five-year assessment of controlled trials of short-course chemotherapy regimens of 6, 9 or 18 months' duration for spinal tuberculosis in patients ambulatory from the start or undergoing radical surgery. Fourteenth report of the Medical Research Council Working Party on Tuberculosis of the Spine. *Int Orthop* 1999;23(2):73–81
- 28 Medical Research Council Working Party on TB of the Spine. Controlled trial of short-course regimens of chemotherapy in the ambulatory treatment of spinal TB. Results at three years of a study in Korea. *J Bone Joint Surg Br* 1993;75:240–248
- 29 Pu X, Zhou Q, He Q, et al. A posterior versus anterior surgical approach in combination with debridement, interbody auto-grafting and instrumentation for thoracic and lumbar tuberculosis. *Int Orthop* 2012;36(2):307–313
- 30 Garg B, Kandwal P, Nagaraja UB, Goswami A, Jayaswal A. Anterior versus posterior procedure for surgical treatment of thoracolumbar tuberculosis: a retrospective analysis. *Indian J Orthop* 2012;46(2):165–170
- 31 Zeng H, Wang X, Pang X, et al. Posterior only versus combined posterior and anterior approaches in surgical management of lumbosacral tuberculosis with paraspinal abscess in adults. *Eur J Trauma Emerg Surg* 2014;40(5):607–616
- 32 Cui X, Ma YZ, Chen X, Cai XJ, Li HW, Bai YB. Outcomes of different surgical procedures in the treatment of spinal tuberculosis in adults. *Med Princ Pract* 2013;22(4):346–350
- 33 Meena S, Mittal S, Chowdhary B. Spinal tuberculosis: which is the best surgical approach? *Med Princ Pract* 2014;23(1):96–97
- 34 Jain AK, Dhammi IK, Jain S, Kumar J. Simultaneously anterior decompression and posterior instrumentation by extrapleural retroperitoneal approach in thoracolumbar lesions. *Indian J Orthop* 2010;44(4):409–416
- 35 Miriam K, X Paul V, Joel AF. Evaluation of 11th rib extrapleural- retroperitoneal approach to the thoraco lumbar junction. *J Neurol* 2000;93:168–174
- 36 Canale ST, Azar FM, Beaty JH, Campbell WC, Campbell's Operative Orthopaedics. 13th ed. Philadelphia, PA: Elsevier, Inc; 2017 1603–1604
- 37 Garg N, Vohra R. Minimally invasive surgical approaches in the management of tuberculosis of the thoracic and lumbar spine. *Clin Orthop Relat Res* 2014;472(6):1855–1867
- 38 Kandwal P, Garg B, Upendra B, Chowdhury B, Jayaswal A. Outcome of minimally invasive surgery in the management of tuberculous spondylitis. *Indian J Orthop* 2012;46(2):159–164
- 39 Elnaim AL. Bilateral psoas abscess and extensive soft tissue involvement due to late presentation of Pott's disease of the spine. *Indian J Surg* 2011;73(2):161–162
- 40 Dave BR, Kurupati RB, Shah D, Degulamadi D, Borgohain N, Krishnan A. Outcome of percutaneous continuous drainage of psoas abscess: a clinically guided technique. *Indian J Orthop* 2014;48(1):67–73
- 41 Chacko AG, Moorthy RK, Chandy MJ. The transpedicular approach in the management of thoracic spine tuberculosis: a short-term follow up study. *Spine* 2004;29(17):E363–E367
- 42 Mehta JS, Bhojraj SY. Tuberculosis of the thoracic spine. A classification based on the selection of surgical strategies. *J Bone Joint Surg Br* 2001;83(6):859–863
- 43 Kumar K. A clinical study and classification of posterior spinal tuberculosis. *Int Orthop* 1985;9(3):147–152
- 44 Oguz E, Sehirlioglu A, Altinmakas M, et al. A new classification and guide for surgical treatment of spinal tuberculosis. *Int Orthop* 2008;32(1):127–133
- 45 Moon MS. Tuberculosis of spine: contemporary thoughts on current issues and perspective views. *Curr Orthop* 2007;21:364–379
- 46 Teegala R, Kumar P, Kale SS, Sharma BS. Craniovertebral junction tuberculosis: a new comprehensive therapeutic strategy. *Neurosurgery* 2008;63(5):946–955
- 47 Rajasekaran S. The natural history of post-tubercular kyphosis in children. Radiological signs which predict late increase in deformity. *J Bone Joint Surg Br* 2001;83(7):954–962
- 48 Rajasekaran S. Buckling collapse of the spine in childhood spinal tuberculosis. *Clin Orthop Relat Res* 2007;460(460):86–92
- 49 Tuli SM. Severe kyphotic deformity in tuberculosis of the spine. *Int Orthop* 1995;19(5):327–331
- 50 Bradford DS, Tribus CB. Vertebral column resection for the treatment of rigid coronal decompensation. *Spine* 1997;22(14):1590–1599
- 51 Bridwell KH, Lewis SJ, Lenke LG, Baldus C, Blanke K. Pedicle subtraction osteotomy for the treatment of fixed sagittal imbalance. *J Bone Joint Surg Am* 2003;85(3):454–463
- 52 Wang Y, Zhang Y, Zhang X, et al. Posterior-only multilevel modified vertebral column resection for extremely severe Pott's kyphotic deformity. *Eur Spine J* 2009;18(10):1436–1441