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Review Article

Perspective: Transthoracic, posterolateral, or transpedicular approaches to thoracic disks, not laminectomy

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ABSTRACT

Background: Anterior transthoracic, posterolateral (i.e., costotransversectomy/lateral extracavitary), and transpedicular approaches are now utilized to address anterior, anterolateral, or lateral thoracic disk herniations (TDH). Notably, laminectomy has not been a viable option for treating TDH for decades due to the much lower rate of acceptable outcomes (i.e., 57% for decompressive laminectomy vs. over 80% for the posterolateral, lateral, and transthoracic procedures), and a higher risk of neurological morbidity/paralysis.

Methods: Patients with TDH averaged 48-56.3 years of age, and presented with pain (76%), myelopathy (61%-99%), radiculopathy (30%-33%), and/or sphincter loss (16.7%-24%). Those with anterior/anterolateral TDH (30-74%) were usually myelopathic while those with more lateral disease (50-70%) exhibited radiculopathy. Magnetic resonance (MR) studies best defined soft-tissue/disk/cord pathology, CAT scan (CT)/Myelo-CT studies identified attendant discal calcification (i.e. fully calcified 38.9% -65% vs. partial calcification 27.8%), while both exams documented giant TDH filling > 30 to 40% of the canal (i.e., in 43% to 77% of cases).

Results: Surgical options for anterior/anterolateral TDH largely included transthoracic or posterolateral approaches (i.e. costotransversectomy, lateral extracavitary procedures) with the occasional use of transfacet/transpedicular procedures mostly applied to lateral disks. Notably, patients undergoing transthoracic, lateral extracavitary/costotransversectomy/transpedicular approaches may additionally warrant fusions. Good/excellent outcomes were quoted in from 45.5% to 87% of different series, with early postoperative adverse events reported in from 14 to 14.6% of patients.

Conclusion: Anterior/anterolateral TDH are largely addressed with transthoracic or posterolateral procedures (i.e. costotransversectomy/extracavitary), with a subset also utilizing transfacet/transpedicular approaches typically adopted for lateral TDH. Laminectomy is essentially no longer considered a viable option for treating TDH.

Keywords: Thoracic disk herniation, Anterior surgery, Transthoracic: posterolateral surgery, Costotransversectomy/lateral extracavitary, Posterior surgery, Transfacet/transpedicular

INTRODUCTION

For many decades, laminectomy has no longer been considered a viable option for treating TDH due to its' high risk of paralysis/increased morbidity [Table 1].[1,4,5,7] Rather, transthoracic, posterolateral (i.e., costotransversectomy/lateral extracavitary) and occasionally transfacet/transpedicular approaches are utilized to manage anterior/anterolateral TDH. More calcified and/or more midline lesions may warrant bilateral approaches and fusions. Those with

Table 1: Largely transpedicular surgery for anterior/antero-lateral thoracic disk herniations.

Author [Reference] Journal Year	Study Design	#Patients in Series Other	Results	Results	Conclusions
LeRoux[9] Neurosurgery 1993	TP 20 Pts MR -MCT 3-2 Level	6 Central 14 Lateral 6 Calcified	Radiology Not Correlate with Deficits	1 yr. Postop 20 Sig. Imp 8 Asym	Excellent TDH TP Safe/EFF
Currier[6] Spine 1994	TDH -Fusion Trans -thoracic + Fusion	19 Pts Central Central-lateral TDH	14 Myelop, 5 BB 13 Pain,3 Prior Lam "Compromised results of latera anterior decompression"	+MS 2 Pts Atypical Postop Course	Results TDH No Prior Lam/No MS Excellent 6, Good 6, Fair 1, Poor 1 Safe/Effective
Stillerman[13] J Neurosurg 1998	82 TDH 71 Pts 1971-1995 34 M 37 F 19-75 yo Avg. 48	T8-T11 Trauma 37% Pain 76% Radic Myelop 61%	Spastic 58% Sensory Loss 61% Bladder Loss 24% MR/ MCT 94% Central6% Lat Calcified 65%/7% ID	4 OR 60% TT 28% TF Lateral Intracavit -ary 10% TP 2%	Improved 87%, Spasticity 39% Sensory 84%, BB 76%, Motor 58% AE 14.6% 3 Major-1 Death, 1 CAD, 1 Reop/Para
Bilsky[3] Neurosurg Focus 2000	TP OR TDH 20 Pts 6 Radic 14 Myelop	Lam Proc Choice THD But High Rate Neuro Morbidity	TP-No Pt with Myelop Worse 4 Rad Pain Resolved 2 Pain Unchanged AE 15% Minor	No Postop Instability-Kyphosis CAL/Soft	CAL Central Disks May Use More TT or TS (Anterior) vs. Lateral (CT/LEC)
Chen[4] Neurosurg Focus 2000	TDH Post Lam Era Series 1-Few Lam	Safe Effective TT, LEC, TP Endoscopic	Preop SX Pain, Radic, Myelop Improved Postop	Studied OR Time EBL, LOS, Report AE	Need to Show Better Outcomes - Evaluate Future Advances
Chiu[5] Surg Technol Int 2002	Surgeon Choices for TDH	Lam Poor Outcomes	Alternatives CS, TT, TPP, PL, TP and, TS	Surgery Cord Compression	Lam Risks Neuro Deficits
Arts[2] Spine J 2014	Antero-Lateral MITT vs. TP TDH	100 TDH 56 MITT 44 TP	Diagnosis CT + MR 2 mos. F/O ASIA C/D 64% ASIA E 36% 58% CAL 77% > 1/3 Canal	Long Term Outcomes 72% Good MITT vs. 76% TP	Outcomes Improved 1 ASIA Grade 50% MITT 37% TP MITT > Longer OR, > EBL, > LOS
Kapoor[8] Eur Spine J 2018	Giant GHTD 33 Patients 1 Center Occupy > 40% Canal 2006-14 16 M 17 F 22 Thor, 9 CS 2 TP	Neural Monitoring Improved 1 Frankel Grade 13 pts Improved 2 Grades 1 Pt 45.5% Better 45.5% Same 45.5% 9% Worse	MJOA Favored Outcomes 84.4% 3 Intraop AE 9% 2 Dural Tears 1 Massie Blood Loss Delayed AE 12/(39%) Pts-Included Intercostal neuralgia Mechanic pain around CS	Progressive Paraplegia Cord Herniation Residual Disks Pleural Effusion CSF Fistula, Infective Diskitis	Favored outcome 91% Sig. Approach Complications for Thoracotomy Paracentral disks CS (< stenosis)
Nakhla *et al.*[10] Eur Spine J 2018	CAL Paracen TDH MI TP	2011-2016 5 Cases O-Arm Intraop	Assisted Tubular Retractor Success Anterior Decompressed Around Cord	MI TP Approach	Refined MI TP Approach with O-Arm Stereotactic Navigation Safe Effective

(Contd...)

Table 1: *(Continued).*

Author [Reference] Journal Year	Study Design	#Patients in Series Other	Results	Results	Conclusions
Sivakumaran[12] World Neurosurg 2018	TF or TP Approach TDH 24 Ptd 25 Disks Avg Age 56.3 Range 23-79	Myelopathy 99% Radiculopathy 33% Sphincter Loss 16.67% Axial Back Pain 43%	7 Central (30%) 14 (61%) Calcified 10 (43%) Large disks Mean F/O 6 mos (Rg 2-36 mos) 18 Unilateral (5 TF, 13 TF/TP) 7 Bilateral Lam 4 Unilateral Lam 3 Bilateral Diskectomy	1 Unplanned Reop for Residual Disk Avg OR Time 95 min Mean Los 4.9 Days (Rg 2-35) No major AE	Postop Frankel Grades Same/Improved TDH Including Large Calcified Lesions Safe TF/TP Approaches vs. "More Invasive Anterior Approaches" Microsurgical Technique
Wessell[14] Oper Neurosurg 2019	TDH Intraop US Guidance Uni TP/CS Approach	5 Patients TP 5 CS for TDH 6M, 4 F Avg Age 54 Rg 33-74	Single Level 5 Cen 5 Paracen 6 CAL (CT/Intraop)	Outcomes 9 of 10 Patients 8 Normal No WLS Followed Avg 20.4 wk (Rg 4-48 wk)	Uni TP/CS to TDH Safe Effective Cen/Paracen Even with CAL
Saway[11] J Neurosurg Spine 2021	Ultrasonic Spine Surgery PTD 43 Case Series	Partial TP Approach Spinal Cord Decompress 36 Giant TDH 66.7% (>40% Canal Compromise)	43 pts 54 PTD Myelopathy 86% Weakness 72% Sensory 65% Symptoms 10.4 mos 38.9% Full Calcification 27.8% Partial Calcification	Mean OR Time 197.2 Min EBL 238.8 cc LOS 44 days 65.1% Increase 1 Frankel Grade 6 (14%) Reop	Same Results +/- Calcified Disks Improved IONM Better Outcomes Posterior OR Intraoperative Ultrasonic Aspiration and Ultrasound Appropriate for TDH

TDH=Thoracic Disk Herniation, TP=Transpedicular (Approach), CS=Costotransversectomy, Uni=Unilateral, M=Males, F=Females Avg=Average, Rg=Range, Cen=Central, Lat=Lateral, Paracen=Paracentral, CT =Cat Scan, Intraop=Intraoperative, CAL=Calcified, WLS=Wrong Level surgery, SX=Symptomatic, Radic=Radiculopathy, Myelop=Myelopathy, SC=Spinal Cord, Manip=Manipulating, PTs=Patients, TT=Transthoracic, TS=Thoracscopic, LEC=Lateral Extracavitary (Approaches). MI=Minimally Invasive, MITT=Minimally Invasive Transthoracic (Approach), mos=Months, f/o=Follow-Up, ASIA=American Spinal Injury Association (Impairment Scale), EBL=Estimated Blood Loss, LOS=Length of Stay, TF=Trans Facet, GHTD=Giant Herniated Thoracic Disease, IMP=Improved, Asym=Asymptomatic, EFF=Effective, MCT=Myelo-CT, OR=Operations, AE=Adverse Events, CAD=Coronary Artery Disease, para=Paraparesis, ID=Intradural, Neuro=Neurological, TPP=Transpleural, Pts=Patients, PL=Posterolateral, Thor=Thoracotomy, PTD=Partial Thoracic Diskectomy, IONM=Intraoperative Neural Monitoring, F/O=Follow-Up, Stereo=Stereotactic, MR -MCT=Myelogram-CT Scan, yo=Year old, yr.=Year, Sig.=Significant, BB=Bowel and Bladder, MS=Multiple Sclerosis, CSF=Cerebrospinal Fluid, US=Ultrasound, MR=Magnetic Resonance

predominantly lateral TDH, however, can often undergo unilateral transfacet/transpedicular surgery with an occasional subset of patients also necessitating fusions [Table 1].[2,3,6,8-14] Interestingly, the overall percentages of good/excellent outcomes for TDH are lower than for lumbar disk herniation (LDH) due to the frequently encountered delays in diagnosis, prolonged cord microtrauma, and decreased blood supply to critical areas of the thoracic cord.

Series Citing Abandonment of Laminectomy for TDH Due to Risk of Paralysis

Several studies emphasized that performing laminectomy for TDH has been abandoned for decades [Table 1].[1,4,5,7] In 1985, Arce and Dohrmann studied 129 patients undergoing surgery for thoracic disk herniations and noted; "Regarding the results of surgical treatment, there was a success rate ranging from 57% for decompressive laminectomy to over 80% for the posterolateral, lateral, and transthoracic approaches." They concluded; "Consider that laminectomy was the operation of choice for patients with thoracic disk disease; when evidence began to mount that neurological worsening was a laminectomy-related complication, the procedure ceased to be used in the treatment of thoracic disk lesions".[1] Chen (2000) subsequently discussed the efficacy, safety, and surgical outcomes for TDH utilizing transthoracic, lateral extracavitary, transpedicular, and/or endoscopic procedures".[4] Chen noted that utilizing these newer approaches; "The vast majority of patients with thoracic disk lesions did not experience worsened (*neurological*) status postoperatively; this is keenly apparent

now that laminectomies are not being performed". Further, Chen advised; "A surgeon who is inexperienced in this field should consider referring these patients to more experienced surgeons." Chiu *et al*. (2002) also emphasized that; "The threat of cord injury has stimulated many attempted approaches including posterior laminectomy (abandoned currently as too likely to result in neurological loss)" in favor of "costotransversectomy, trans-thoracic trans-pleural, postero-lateral, transpedicular, and more recently transthoracic endoscopic approaches". [5] Further, Fessler and Sturgill (1998) observed; "Thoracic diskectomy has evolved over the last 60 years from resection through standard laminectomy, to posterolateral procedures to open thoracotomy and finally thoracoscopy".[7] They further observed that; "Morbidity seems relatively similar between most procedures other than laminectomy", and concluded that; "...laminectomy does not provide adequate access for the safe removal of these lesions".

Analysis of Subset of 345 Patients with TDH in 10 of 14 Studies

This review yielded 345 patients treated for TDH from 10 studies [Table 1].[2,3,6,8-14] The number of patients in 5 studies ranged from 5-10 cases/study,[3,6,9,10,14] 3 studies involved 24-33 cases each,[8,11,12] while 2 studies respectively included 71 and 100[2,13] patients.

Average Age for Patients with TDH

Patients with TDH usually averaged between 48-56.3 years of age [Table 1].[12-14] In Stillerman *et al*. (1998) for 71 patients with 82 TDH, the average age was 48.[13] In Sivakumaran *et al*. (2018) the 24 patients (with 25 disks) averaged 56.3 years of age (range 23-79).[12] In Wessell *et al*. (2019) the 10 patients with TDH averaged 54 years of age (range 33-74).[14]

THD: Clinical Presentations Included Pain, Myelopathy, Radiculopathy, and Sphincter Dysfunction

Patients in these 10 series of TDH[2,3,6,8-14] presented with varying frequencies of pain (76%), myelopathy (61%-99%) and/or radiculopathy (30%-33%), plus sphincter loss (16.7%-24%)[Table 1].[3,11-13] In Stillerman *et al*. (1998) 82 TDH, 76% of patients had pain, 61% had myeloradiculopathy, 61% had sensory deficits, 58% had spasticity, and 24% exhibited bladder dysfunction.[13] For Bilsky *et al*. (2000) 20 patients, 14 (70%) had myelopathy, while 6 (30%) had radiculopathy.[3] In the 24 patients with TDH from Sivakumaran *et al*. (2018), 43% complained of axial back pain, 99% exhibited myelopathy, 33% showed radiculopathy, with 16.7% demonstrating sphincter loss.[12] Of the 43 patients with TDH in Saway *et al*. (2021) series, 86% had myelopathy (i.e., including 72% with weakness), while 66% showed sensory deficits.[11]

MR Studies Best Documented TDH Location and Spinal Cord Pathology

For TDH, most typically found between the T8-T11 levels, MR studies best documented the soft tissues (i.e., disks, ligaments, stenosis etc.), spinal cord pathology (i.e., intrinsic high cord signals, edema, extent of cord compression), and location of TDH (i.e. central/anterior (30%), central/anterolateral (50%-100%), or lateral (6%-70%)) [Table 1].[6,9,10,12-14] Notably, the MR scans typically underestimate the incidence of calcification in thoracic disks making it essential to obtain additional CT-based studies. Further, the chronic intrinsic cord signal changes seen on preoperative MR scans, more indicative of myelomalacia than edema, may indicate a less optimistic outcome. In Le Roux *et al*. 20 TDH (1993), 6 (30%) of disks were central, and 14 (70%) were lateral.[9] In Currier *et al*. series (1994), all 19 TDH were central or central-lateral (100%)[6] For Stillerman *et al*. (1998) 71 patients with 82 TDH, MR/Myelo-CT studies documented 94% of TDH were central/lateral, with just 6% only lateral in location.[13] In Nakhla *et al*. (2018) series, all 5 patients had paracentral TDH.[10] Notably in Sivakumaran *et al*. (2018) 24 patients with 25 disks, 7 (30%) disks were central.[12] Finally, for Wessell *et al*. (2019), 5 TDH were central and 5 were paracentral.[14]

CT/Myelo-CT Studies Best Documented Calcification of TDH

CT and Myelo-CT exams best showed whether TDH were fully calcified (i.e., range 38.9% to 65%) vs. partially calcified (up to 27.8*); the extent of calcification of these TDH was critical in determining optimal surgical approaches [Table 1].[2,9,11,12-14] In Le Roux *et al*. 20 TDH (1993), 6 (30%) TDH were calcified.[9] For Stillerman *et al*. (1998) 65% of the 82 TDH were calcified; interestingly, a subset of 7% were intradural.[13] For Arts *et al*. (2014) 100 TDH, 58% of disks were calcified.[2] Of the 24 patients with 25 TDH in Sivakumaran *et al*. (2018), 14 (61%) disks were calcified.[12] Notably, for Wessell *et al*. (2019), 6 (60%) of 10 TDH disks were calcified.[14] Additionally, in Saway *et al*. (2021) 43 TDH, 38.9% of disks were fully calcified, while 27.8% were partially calcified.[11] Further, Myelo-CT was also an extremely valuable tool for marking pedicles preoperatively to decrease the incidence of wrong level surgery.

Incidence of Giant TDH Defined as Occupying > 30 to > 40% of the Spinal Canal

Several studies documented varying frequencies (i.e., 43%-100%) of large to giant TDH occupying > 30 to > 40% of the spinal canal [Table 1].[2,8,11,12] For Arts *et al*. (2014) study of 100 TDH, 77% were giant lesions occupying more than 1/3 of the spinal canal.[2] In Kapoor *et al*. (2018) study,

all 33 patients had giant TDH occupying over 40% of the spinal canal.[8] In Sivakumaran *et al.* (2018) 24 patients with 25 disks, 43% (10 disks) were "large."[12] Of the 43 patients with TDH in Saway *et al.* (2021) series, 36 (84%) of 43 TDH were giant lesions exhibiting > 40% canal compromise.[11]

Outcomes for the Different Operative Approaches to TDH

Thoracic disk surgery is usually more complex with often poorer outcomes when compared to lumbar or cervical disk herniations. In the thoracic spine, exposure of thoracic disks, typically requiring working anterior and/or anterolateral to the cord, limits midline access which is compounded by the high incidence of calcified disks. Further, limited corridors of access make addressing cerebrospinal fluid (CSF) leaks/dural repairs more difficult.

Transpedicular (TP), and Partial Transpedicular (PTP) Approaches For Addressing Central, Paracentral, and Lateral TDH

Three studies effectively utilized transpedicular (TP), minimally invasive TP (MI TP), and partial TP (PTP) approaches to TDH [Table 1].[9-11] One year after Le Roux *et al.* (1993) utilized TP surgery to address 6 central, and 14 lateral TDH, all 20 patients demonstrated significant improvement with 8 patients showing no residual deficits.[9] Utilizing MI TP procedures including the O-Arm (i.e. with stereotactic navigation) in all 5 of Nakhla *et al.* (2018) paracentral TDH, facilitated safe/effective dissection around these lesions.[10] In Saway *et al.* (2021) series, 43 patients with TDH (i.e. 36 giant disks) underwent partial transpedicular approaches; 65.1% improved by 1 Frankel Grade, but 6 (14%) required additional surgery.[11] Their average operative time was 197.2 minutes, average estimated blood loss (EBL) was 238.8 cc, the average length of stay was 44 days, and the reoperation rate was 14% (6 reoperations).[11]

Transpedicular and Costotransversectomy Approaches to Central/Paracentral TDH

Wessell *et al.* (2019) 10 patients with single level disease underwent 5 transpedicular vs. 5 costotransversectomy approaches to 5 central and 5 paracentral TDH [Table 1].[14] Outcomes for 8 of 9 patients were "normal" an average of 20.4 weeks postoperatively, and results were not impacted by whether or not the TDH were calcified.

Transfacet (TF)/Transfacet-Transpedicular (TF-TP) Approaches

Sivakumaran *et al.* (2018) 25 TDH were managed with 18 unilateral approaches (i.e. 5 transfacet (TF) and 13 transfacet/transpedicular procedures) vs. 7 laminectomies; all patients' preoperative Frankel grades were the same or better [Table 1].[12] Notably, they found that TF/TP procedures were safe even for central and/or large calcified TDH.

Outcomes and Adverse Events Following Transthoracic, Transfacet, Costotransversectomy, Intracavitary, and Transpedicular Surgery for TDH

Multiple studies cited the safety/efficacy of transthoracic, transfacet, costotransversectomy, intracavitary and transpedicular surgical approaches for TDH [Table 1].[2,6,8,13] In Currier *et al.* (1994) all patients with anterior/anterolateral disks underwent transthoracic procedures that resulted in 6 excellent, 6 good, 1 fair and 1 poor outcome (i.e. results confounded by the presence of Multiple Sclerosis in 2 patients and other factors in 1 patient).[6] Operative procedures for the 82 TDH in Stillerman *et al.* (1998) series in which 94% of TDH were central, and only 6% were lateral, included 60% transthoracic (TT) vs. 28% transfacet (TF), 10% intracavitary (IC), and 2% transpedicular (TP) approaches; they observed that 87% were improved postoperatively (i.e., motor improvement (58%), sensory improvement (84%), sphincter improvement (76%)).[13] However, 14.6% experienced perioperative adverse events that included 1 death, 1 major cardiovascular event, and 1 reoperation to address postoperative paraparesis. Arts *et al.* (2014) studied the results of 56 minimally invasive transthoracic (MITT) vs. 44 transpedicular (TP) procedures for TDH.[2] Long term outcomes were good in 72% of patients undergoing MITT vs. 76% having TP surgery; 50% of MITT patients improved 1 ASIA grade vs. 37% of TP patients, but MITT procedures required longer operative times, greater blood loss, and longer lengths of stay. In Kapoor *et al.* (2018) series of 33 giant TDH occupying > 40% of canal, patients underwent 22 thoracotomies, 9 costotransversectomies and 2 TP approaches; 45.5% of patients improved, but 45.5% remained the same, while 9% were worse.[8] Additionally, there were 3 major postoperative adverse events that included 2 dural tears, and 1 patient sustaining massive intraoperative blood loss. Furthermore, an additional 12 patients (39%) developed delayed postoperative adverse events that included paraplegia, cord herniation, pleural effusion, CSF fistula, and infectious diskitis [Table 1].

CONCLUSION

Anterior/anterolateral TDH are typically addressed with transthoracic or posterolateral procedures (i.e. costotransversectomy/extracavitary), with occasional patients also undergoing transfacet/transpedicular approaches; with any of these approaches, subsequent fusion may be warranted.[2,3,6,8-14] More typically, transfacet/transpedicular approaches are reserved for the more lateral TDH, and selective fusions may become necessary. Notably,

laminectomy has not been considered a viable option for treating TDH for decades due to their high morbidity/significant risk of paralysis.[1,4,5,7]

Declaration of patient consent

Patients' consent not required as patients' identities were not disclosed or compromised.

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Conflicts of interest

There are no conflict of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The author(s) confirms that there was no use of Artificial Intelligence (AI)-Assisted Technology for assisting in the writing or editing of the manuscript and no images were manipulated using the AI.

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