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BIOMECHANICAL PROPERTIES OF THE THORACIC SPINE AFTER ANTEROLATERAL MINIMALLY INVASIVE DISCECTOMY

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ABSTRACT:
An understanding of the biomechanical properties of the thoracic spine and its osteoligamentous structures is important for the surgeon to avoid the potential destructive and destabilizing effects of surgery. Biomechanical consequences after anterolateral discectomy for thoracic disk herniation utilizing modified anterolateral extrapleural approach are briefly reviewed in this paper, in light of the biomechanical spine models of Denis and Benzel.
Keywords:
biomechanics, anterolateral extrapleural approach, thoracic disc herniation, thoracic spine, discectomy

Introduction

The major objectives of surgery for thoracic disk herniation (TDH) are adequate choice of approach, possibly minimal osteoligamentous resection, decompression of neural structures and, if necessary, stabilization of the operated spinal segment. An understanding of the biomechanical properties of the thoracic spine and its osteoligamentous structures is important for the surgeon to avoid the potential destructive and destabilizing effects of surgery [2, 8, 9]. Anterolateral approaches [4] and thoracoscopy [6] has become the golden standard in surgical management of TDH. Both of them, despite obvious advantages over posterolateral [1] and lateral approaches [4], have certain limitations. In order to excel our clinical results, we combined the advantages of traditional anterolateral extra/transpleural approach and thoracoscopy, yielding modified anterolateral extrapleural approach (MALEA) for the surgical treatment of TDH [7]. The employed approach is minimally invasive, implies the use of an endoscope and requires no fusion and bone drafting. The biomechanical properties of the thoracic spine after anterior discectomy for TDH utilizing MALEA are briefly reviewed in this paper, in light of the biomechanical spine models of Denis [5] and Benzel [2].

Anatomy and Biomechanics of the thoracic spine

The thoracic spine consists of a unique osteoligamentous complex. The costovertebral joints connect the vertebral bodies (VB) to the rib cage and to adjacent VBs. Articulations of the transverse process with the rib and the rib head to the VB provide spinal stability. The associated ligaments involved with these articulations are the costotransverse, superior costotransverse, radiate, and intraarticular ligaments. This complex provides significant stability compared with the cervical or lumbar spine. The normal range of motion in the thoracic spine is 2 to 20° for flexion-extension, 12 to 18° for lateral bending, and 4 to 16° for axial rotation. The facet joints change their orientation from the coronal plane in the cervicothoracic region to a more sagittal plane in the thoracolumbar region, that affects spinal motion – limited flexion-extension in the upper, and increased flexion-extension in the lower thoracic spine [2, 8, 9].

In 1983 Denis introduced a three-column model: the anterior column consists of the anterior longitudinal ligament (ALL) and the anterior half of the VB; the middle column is composed of the posterior half of the VB and the posterior longitudinal ligament (PLL), and the posterior column is composed of the posterior elements (facet joints and associated ligamentous structures) [5]. Although the three-column theory is clinically attractive, it is not absolutely valid biomechanically. Studies of kinematics during spinal loading and fracture have shown significant variability in injuries produced with similar forces. Yoganandan proposed that instability should be considered as a continuum, in which partial injuries to different structures of the spine may allow pathologic amounts of motion, even if gross failure is not evident initially [10].

This concept was used in another model, proposed by Benzel [2], where he visualized vertebral body within anterior and middle columns as 27 cubes (3 x 3 x 3), however this model does not evaluate the posterior column. Despite this, Benzels model is useful in accessing the biomechanical effects of anterolateral surgical approaches through the vertebral body.

The biomechanical properties of the thoracic spine are unique. In the cervical and lumbar spine, the smallest functional unit consists of two VBs and the interconnecting soft tissue. In the thoracic spine, this functional unit is not as straightforward. There are connections between VBs and the rib cage. These consist of the costovertebral and costotransverse joints. Thoracic VBs are connected to adjacent vertebrae via bilateral costovertebral joints [2, 8, 9].

The rib cage is the additional stabilizing component present in the thoracic spine. This sternal-rib complex has been described by Berg as the fourth column [3]. Oda and Tacheuchi, have performed sequential sectioning of the costovertebral joints and observed a large increase in the neutral zone, lateral bending, and axial rotation. The disruption of the rib cage resulted in further increase in lateral bending and axial rotation. Also they concluded that the intervertebral disc regulates the stability of the thoracic spine in flexion-extension, lateral bending, and axial rotation. Feiertag, after a series of experiments, found that the combination of rib head resection and radical discectomy provided significant increases in thoracic spine motion. A thoracic discectomy, complete unilateral rib head resection, or a unilateral total facet excision, however, did not cause a significant increase in motion if performed individually [8, 9].

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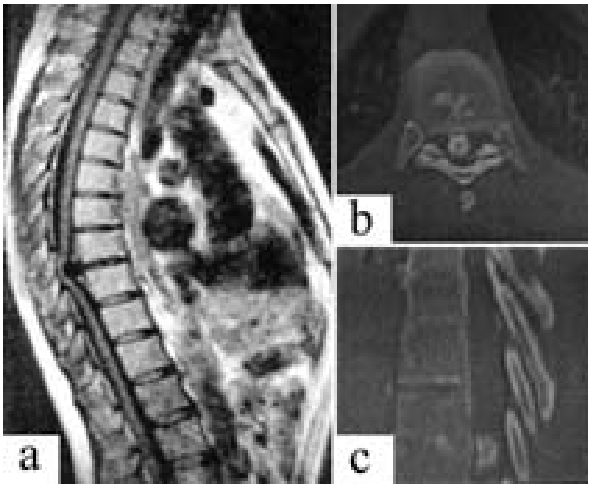

Fig. 1. *MRI and CT of the thoracic spine.*
***a** – Preoperative sagittal MRI shows massive central TDH at T8-9; Preoperative axial (**b**) and sagittal (**c**) CT shows massive central TDH at T8-9.*

Biomechanical consequences of modified anterolateral extrapleural approach (MALEA)

MALEA, as a modified variant of the transthoracic approach provides excellent exposure of the anterolateral thoracic spine and is particularly useful for centrally located calcified disc herniations or for multilevel exposure (Fig. 1 a,b,c). MALEA is accomplished without entrance into the pleural cavity and involves resection of the rib head, costovertebral joint, the posterior one third of the disk and the posterior one third of the vertebral body and a part of the PLL adjacent to the disk [7]. Unlike its prototypes, MALEA preserves pedicle, costotransverse ligament and transverse process. As a result, the middle column by Denis is interrupted, but anterior and posterior elements are preserved, as is the anterior and posterior load-bearing capability, thus fusion and bone grafting are not re-quired. Benzel’s 27-cube model is particularly useful to determine the anterior load-bearing capacity under these circumstances (Fig. 2 a, b).

The ventral ligamentous structures such as the ALL and PLL and the annulus fibrosis provide significant stability to the spine. The ALL is a strong ligament attached to the VB edges at each segmental level of the spine. It provides a moment arm that resists extension by it's ventral position and a tension band–like effect, which is an especially important contributor to postoperative spinal stability. ALL is always intact after MALEA. The PLL has far less biomechanical strength than its anterior counterpart in all areas of the spine. The position of the PLL provides a short moment arm and, in combination with its weak intrinsic mechanical properties, provides far less resistance to flexion than the dorsal elements [2, 8, 9]. The contribution of the PLL to resist flexion and distraction (albeit less than other ligaments) is impaired after MALEA in which the intention is to decompress the spinal cord. The contribution of the annulus fibrosis to spinal stability parallels that of the immediately adjacent ALL and the PLL. MALEA, although affects the dorsal one third of annulus, does not significantly disrupt the overall stability.

The bone removal during MALEA clearly affects stability. The degree of the spinal stability that remains is determined by the portion of the bone remaining in the ventral component of the VB and by the location and extent of the vertebrectomy. This is best demonstrated by the Benzels model considering the VB to be a cube composed of 27 equal-sized cubical segments. Resection of the dorsal portion (the posterior 9 cubes) in the coronal plane, does not result in loss of stability if the ventral section of cubes is intact, the ALL remains intact, and dorsal column osseous and ligamentous integrity remains (Fig. 2 a,b,c). Further minimizing of bone removal within posterior 9 cubes, as performed with MALEA, contributes even more to spinal stability.

Whereas the VBs provide ventral support and resistance to axial loads, the major biomechanical functions of uncovertebral joints include regulation of extension and lateral bending motion and torsion resistance. Destruction of the uncovertebral joints can result in loss of those resistive forces. This structure is left intact after MALEA as well.

Conclusion

The thoracic spine unique anatomical and biomechanical properties have to be considered when using MALEA or any other approach on this region. The spine with the weakened anterior column, as happens after traditional anterolateral approaches, tend to increase the kyphosis, due to kyphotic curvature having a natural-occurring moment arm anterior to the spine. MALEA, in our opinion, is devoid of this pitfall. However, despite it's minimal invasiveness the proposed approach inevitably affects the stability of the thoracic spine that requires postoperative follow-up and physical therapy, to maintain the adequate supportive properties of the spine at early postoperative period.

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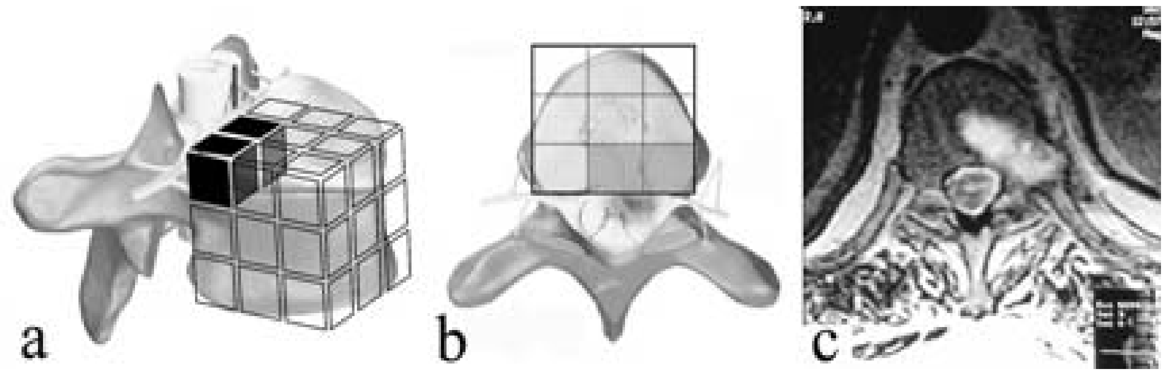

Fig. 2. Illustration of the MALEA and MRI of the thoracic spine.
a, b – Illustration of the MALEA using Benzel's model (shaded cubes show extent of resection); **c** – postoperative MRI shows a channel created by excision of the TDH, disc and vertebral bodies at T8-9.

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БИОМЕХАНИЧЕСКИЕ СВОЙСТВА ГРУДНОГО ОТДЕЛА ПОЗВОНОЧНИКА ПОСЛЕ ПЕРЕДНЕБОКОВОЙ МИНИМАЛЬНО ИНВАЗИВНОЙ ДИСКЭКТОМИИ

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АБСТРАКТ:

Понимание биомеханических свойств грудного отдела позвоночника и его костно-связочного аппарата важно для предупреждения потенциально деструктивного и дестабилизирующего эффекта оперативного вмешательства. В данной работе кратко рассмотрены биомеханические последствия переднебоковой дискэктомии при грыже грудного межпозвонкового диска, посредством модифицированного переднебокового экстраплеврального доступа, в свете биомеханических моделей позвоночника по Denis и Benzel.

Ключевые слова:

биомеханика, грыжа грудного межпозвонкового диска, переднебоковой экстраплевральный доступ, грудной отдел позвоночника, дискэктомия.

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MICROSURGICAL EVALUATION OF MODIFIED ANTEROLATERAL EXTRAPLEURAL APPROACH FOR THORACIC DISK HERNIATION

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ABSRTACT:

The management of thoracic disc herniation (TDH) has historically been prob-lematic, contradictory and technically demanding. We have modified the anterolateral extrapleural approach for the surgical treatment of TDH. The employed approach is minimally invasive, implies the use of an endoscope and requires no fusion and bone drafting. We used it for the treatment of 8 patients with symptomatic TDH. Postoperative results were favorable, and were accessed using ASIA/IMSOP classification. Our results suggest that modified anterolateral extrapleural approach (MALEA) may be a valuable option in the management of TDH.

Keywords:

anterolateral extrapleural approach, thoracic disc herniation, thoracic spine

Introduction

The incidence of thoracic disc herniation (TDH) is being estimated at around 1 in 1 million. TDH is associated with significant morbidity and disability and its management has historically been prob-lematic and technically demanding [1-9]. Although some authors have shown conservative treatment of TDH to be effective, myelopathy is an absolute indication for the surgical treatment [5, 9]. Nowadays the standard surgical management of TDH is an anterolateral transpleural approach [2] or thoracoscopy [9], both of which, despite obvious advantages over posterolateral [1] and lateral approaches [3], have certain limitations. In order to excel our clinical results, we combined the advantages of traditional anterolateral transpleural approach and thoracoscopy, yielding modified anterolateral extrapleural approach

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