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Anatomical Assessment of Variations in Kambin's Triangle: A surgical and cadaver study

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Running head: Endoscopic extraforaminal approach, Kambin's triangle

Abstract

Background. The relationship of exiting root and Kambin's triangle is discussed in this article.

Objective. Transforaminal endoscopic surgery as the gold standard of less invasive lumbar disc surgeries is performed through Kambin's triangle. Existing root damage is one of the most important complication for this type of surgery. Anatomical variations in Kambin's triangle may be the main reason for nerve root damage during endoscopic lumbar disc surgery.

Method. Kambin's triangle was investigated with surgical views and cadaver studies.

34 patients with farlateral disc herniation were treated via extraforaminal approach under the microscope. On the other hand, 48 Kambin's triangles were dissected on 8 cadavers. Three main types of triangle were identified, and patients were grouped according to these three types of the triangle.

Results. Only 6 of the 34 patients had type 3 triangles, which is the wide classical triangle described by Kambin, however 17 patients had type 2, with a narrow space in the triangle, and 11 patients had type 1, with no space inside the triangle. Cadaver results were similar; only 10 of the 48 specimens had the type 3 classical triangle while 23 had type 2, and 15 had type 1 triangles. Our results disclosed narrowed or no space in 82,4% of the patients and 79,2% of the cadavers.

Conclusion. We observed that, a wide and safe room of the triangle may not be exist in some patients. Therefore, more care must be taken during endoscopic lumbar disc surgery to avoid nerve damage.

Key Words. Endoscopic discectomy, Extraforaminal approach, Kambin's triangle

INTRODUCTION

Endoscopic surgery has been accepted as a less invasive procedure for lumbar disc herniation and was introduced by Kambin and Hijikata in the 1970's.¹ For this purpose, Kambin described a safe area called Kambin's triangle: the exiting root is its hypotenuse, the inferior border of the lower vertebral body creates the base, and the height is formed by the articular process and superior articulating facet of the caudal vertebra. Using this path, there is a safe pathway near the upper part of the root for passing the cannulas and endoscopic instruments for nucleotomy or endoscopic fragment resection.^{2,3}

The major advantage of this type of surgery is that the ligaments, muscles, and bones are better preserved, limiting instability, facet arthropathy and disc space narrowing.⁴⁻¹⁰ Further, less manipulation of the epidural venous system may prevent scarring, edema and chronic neural fibrosis formation.^{11,12} This technique also allows a better view based on magnification and light. However, there are some complications that have reduced the popularity of this type of surgery during recent years. The most important complication is an existing nerve root damage, which adds a new symptom to the symptoms that the patient experienced before surgery.¹³⁻¹⁶ Damage to radicular arteries is another complication, which could cause epidural hematoma or cord ischemia if the Adamkiewicz artery has been damaged.^{17,18} Sairyo et al reported 2% nerve irritation, 1% epidural hemotoma in 100 cases of patient series.¹⁹ These types of damage may be caused by problems with the path of approach, the cannula diameter, the maneuvers used during endoscopy or normal variations in the Kambin's triangle.

The objective of this study was to evaluate the normal anatomy and the variations of the Kambin's triangle. The shape and size of the area was investigated with microsurgical findings as well as cadaver study findings.

METHODS

Subjects

An anatomical assay was conducted from to assess the normal variations in Kambin's triangle in vivo in lumbar disc herniation patients scheduled for a microsurgical lateral extraforaminal approach. Patients included in the assay are lumbar radiculopathy cases who did not respond to conservative treatment, showing lateral intra- or extraforaminal protrusion or extrusion. Patients with degenerative facet disease and facet hypertrophy have been excluded. The variables compiled by the surgeon include the patient's age, gender, date of surgery, level of involvement and the anatomical variation of Kambin's triangle. The video recordings of the patient's operation was reviewed by the surgeon after surgery for typing the triangle.

The variability of the results due to different observers is an important concern for this kind of investigations. The measurements were performed by same author to prevent this problem.

An ethics committee approval or patient consent for operative recording have not been necessary, because all the operations were routine spinal procedures and video recording of the operations is done in all operations.

Operative technique

The operation was performed under microscopic visualization by two neurosurgeons specializing in spine surgery. After applying general anesthesia, the patient was positioned in a prone posture. Fluoroscopy was used to determine the correct level. After preparation and draping of the skin, a lateral skin incision was performed 2 cm from the midline. After undermining the subcutaneous tissue, the fascia was incised, and a blunt longitudinal dissection of the paraspinal muscles was used to find the facet joint and the transverse process of the desired level. After exposure of the "U"-shaped connection of the superior and inferior transverse processes and the facet joint, the intertransverse ligament was removed. Under the ligament, we can follow path of the root, which usually begins at the junction of the superior transverse process and the lateral surface of facet joint and extends inferiorly, laterally and anteriorly.

Kambin's triangle is defined anteriorly by the exiting root, medially by the facet joint and inferiorly by the superior border of the inferior vertebral body and the inferior pedicle. After assessment of triangle variations and anatomy, extraforaminal discectomy was performed.

We used one dose of prophylactic antibiotic during surgery. An anti-hemorrhagic agent and drain were used to prevent hematoma formation. We used one dose of prophylactic antibiotic during surgery. An anti-hemorrhagic agent and drain were used to prevent hematoma formation from bleeding of muscles, and drain was removed in the first morning after surgery.

Cadaver study

On the other hand anatomy of Kambin's triangle was also studied in cadavers. Eight cadavers were dissected and Kambin's triangles were found and photographed. L5-S1 levels were excluded and L2-3, L3-4 and L4-5 levels were studied bilaterally. The shape and size of a total number of 48 triangles were investigated. It is very important to make a correct evaluation of the triangle in the cadaveric specimens, thus the processing of the cadavers were performed by same investigator with maximum attention to prevent any mistake.

Classification of Kambin's triangle

In order to provide standardization for the Kambin triangle the angle between the edge of facet joints and existing root were measured in all patients. In this way, standardization was achieved in the image captured from different sizes. This angle is an important indicator that provides information about what type of triangle will be formed. We found the mean degree of angles type 1: 5,6°, type 2: 13,5° and type 3: 39,3°. Cadaver results were similar type 1: 5,1°, type 2: 13,2°, type 3: 38,6°.

Consequently we classified Kambin's triangle into three types according to the surgical view appearances and cadaver study findings (Figure 1). The first type is a closed triangle without any available space between the triangle elements, the second type is a narrowed triangle and the third type is the normal triangle as described by Kambin.

RESULTS

Operative Results:

The summary of the patients' data and the type of the triangle which determined during surgery were summarized in Table 1. There were 34 patients of lumbar lateral discopathy (23 male, 11 female) in this study that met our inclusion criteria between 1999 and 2015. The patients' age range was 17-71 years old, with a mean age of 49,4 years.

Among all the cases, only 6 (17,6%) had the type 3 triangle, which is the normal triangle described by Kambin, with a wide area between the sides of the triangle. However, 17 cases (50%) had type 2 triangles, with a narrow space in the triangle, and 11 (32,3%) cases had type 1 triangles, with no space in the triangle (Figures 2-4). These data showed that 82,4% of the patients had a narrow space or there is no space in this triangle.

Cadavers Results:

There were 8 cadavers (6 male, 2 female) selected at random. The age range was 20- 57 years old with a mean age of 43,2 years.

A total number of 48 triangles between L2-5 were studied. Among all the cadavers, only 10 (20.8%) had a type 3 triangle, which is the normal triangle described by Kambin, with a wide area between the sides of the triangle. However, we found 23 (48%) type 2 triangles with a narrow space in the triangle, and 15 (31,2%) type 1 triangles, with no space in the triangle (Figures 5-7). As a result, we found abnormal space in the triangle in 79.2% of the cadavers similar with operative results.

DISCUSSION

Lumbar radiculopathy is a common cause of disability, occurring in 13-40% of people.²⁰ The main cause of pain in these patients is root compression or chemical irritation due to disc material extrusion, making open decompression surgery a reasonable solution. For a less invasive technique, Lyman and Smith invented chemonucleolysis in 1964.²¹

Kambin described a safe area called Kambin's triangle: the exiting root is its hypotenuse, the inferior border of the lower vertebral body creates the base, and the height is formed by the articular process and superior articulating facet of the caudal vertebra. Considering this triangle, the exiting nerve root goes inferiorly, anteriorly and laterally, so there is a safe pathway near the

upper part of the root for passing the cannulas and endoscopic instruments for nucleotomy or endoscopic fragment resection.^{2,3}

The major advantage of this type of surgery is that the ligaments, muscles, and bones are better preserved, limiting instability, facet arthropathy and disc space narrowing.⁸⁻¹⁰ Further, less manipulation of the epidural venous system may prevent scarring, edema and chronic neural fibrosis formation.^{13,14} This technique also allows a better view based on magnification and light. We have been performing endoscopic disc surgery since 1998. During this period, we have encountered a few cases of root damage or post-surgical long-term paresthesia (in 4 cases out of 66),²² and other research shows similar results.¹⁶ Further, there are some reports of damage to the radicular artery during endoscopic surgery followed by in situ hematoma formation or cord ischemia.^{17,18}

To assess the cause of these complications, we evaluated the normal anatomy and variations of the root in Kambin's triangle in in-vivo cases that are candidates for a lateral extraforaminal surgical approach. In this approach, after removal of the intertransverse ligament, the root pathway and the pattern of Kambin's triangle were clearly visible. All of the patients who underwent surgery had obvious nerve root compression. We performed microsurgical disc removal and video recording, and evaluated the anatomy of the triangle. This investigation showed that the type 3 classical Kambin's triangle was present in only 6 of the 34 patients (17,6%). However, the space was too narrow or absent in 28 patients (82,4%). Therefore, we aimed to investigate the anatomy of Kambin's triangle in normal spine on a cadaver study. This evaluation also disclosed that the space of triangle was too narrow or absent in 38 of the 48 specimens (79,2%), while the type 3 normal triangle was determined only in 10 cadaver specimens (20,8%).

Cadaver results were compared with the findings of the operation. Surprisingly cadaver and patient outcomes were overlapping. In patients out of the 34 cases 32,3% had type 1 triangles, which are completely closed triangles, 50% had type 2 triangles, which have narrow openings, and only 17,6% had type 3 triangles, which are the triangles previously described by Kambin.^{2,5,6,23,24} Cadaver results were similar; 15 (31,2%) had type 1 triangles, which are completely closed triangles, 23 (48%) had type 2 triangles, which have narrow openings, and only 10 (20,8%) had type 3 triangles.

Even the nerve root may be compressed and pushed from the bottom due to herniated disc, root will slide laterally and normal triangle would be expected to be seen in greater proportion but the results did not show that in both surgical and cadaver groups.

We know that the medial border of the triangle is composed of bone tissue (articular process and superior articulating facet of the caudal vertebra) and nervous tissue (traversing root and dura) under the bone. However, in most cases, even in young people without facet hypertrophy, the real working area is small and the bone tissue covers the triangle. It is necessary to remove a part of articular process to create enough space for endoscopic discectomy (Figure 8). This bone removal can be easily performed through the working channel and it is not necessary to use a different tubular system. This could be accompanied by the risk of damaging the nerve root, the radicular artery, dura and traversing root during surgery.

Consequently, although endoscopic disc surgery is a popular type of disc surgery today, we suggest more caution during surgery. This operation may be performed under local anesthesia so that the patient can communicate when the surgeon is working just close the nerve root. Neural monitoring would also be a useful addition. Further, we recommend fewer maneuvers during disc removal, bearing in mind the proximity of the root to the instruments during surgery.

We believe that it is necessary to expand this study with more cases and cadaver studies to be able to evaluate the frequency of each type of triangle at different levels, ages, and primary disorders such as disc space narrowing and degenerative disease. This may allow the identification of risk factors and the improvement of guidelines for this type of surgery.

Figure Legends

Figure 1: Types of extraforaminal triangle.

Figure 2: Type 1, no apparent triangle in operative view.

Figure 3: Type 2, small triangle in operative view.

Figure 4: Type 3, Kambin's original triangle, operative view.

Figure 5: Type 1, no apparent triangle in cadaver study.

Figure 6: Type 2, small triangle in cadaver study.

Figure 7: Type 3, normal triangle in cadaver study.

Figure 8: After facet joint removal (yellow oval line), a wide area can be created between two nerve roots. The original Kambin's triangle (blue triangle) is obviously smaller than the created wide area after bone removal (green line).

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Table 1: A summary of three Types of Kambin's Triangle in 34 Patients.

	Age	Gender	Type	Level
1	48	M	2	L3-4
2	17	F	2	L3-4
3	62	M	3	L3-4
4	46	F	1	L4-5
5	37	F	2	L5-S1
6	37	M	2	L5-S1
7	70	M	1	L3-4
8	64	F	1	L4-5
9	50	M	3	L4-5
10	50	M	2	L4-5
11	52	M	2	L3-4
12	63	M	1	L4-5
13	32	F	1	L4-5
14	54	F	3	L3-4
15	43	M	2	L4-5
16	64	F	1	L4-5
17	60	F	3	L4-5
18	70	M	2	L4-5
19	45	M	2	L4-5
20	58	M	2	L5-S1
21	38	M	1	L5-S1
22	49	M	2	L1-2
23	55	F	2	L4-5
24	44	M	1	L3-4
25	39	F	2	L4-5
26	71	M	2	L4-5
27	40	F	3	L4-5
28	41	M	2	L3-4
29	60	M	1	L2-3
30	45	M	1	L5-S1
31	35	M	2	L3-4
32	40	M	3	L4-5
33	65	M	1	L5-S1
34	37	M	2	L4-5

Type 1: no apparent triangle

Type 2: small triangle

Type 3- normal triangle (Kambin's original triangle)

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Type 1: no apparent triangle

Type 2: small triangle

Type 3- normal triangle (Kambin's original triangle)

Highlights

- Transforaminal endoscopic surgery is the gold standard.
- It is performed through Kambin's triangle.
- Every patient has not a wide Kambin's triangle as described.
- Only 20% of the patients have enough safe space in the triangle.
- To be aware of anatomical variations is important for successful endoscopic surgery.