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Research Paper

Feasibility of total en-bloc spondylectomy on L5 by a posterior-only approach: An autopsy study

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ABSTRACT

Purpose: To obtain a better understanding of the structures around L5 vertebra and provide some anatomical evidence of the feasibility of total en-bloc spondylectomy (TES) on L5 in a posterior-only approach.

Methods: 12 simulated TESs on L5 by a posterior-only approach were conducted on human cadavers. The distance between the traction point of L4 nerve root and the dural sac (Da), the anterior-posterior diameter of the vertebral body,(Va), the distance between the start point of L4 nerve root and the traction point of L5 nerve root (Dh) and the height of the vertebral body (Vh) were measured. Paired *t*-test and liner regression were performed to determine the difference and correlation between Da and Va, and between Dh and Vh. The risk of nerve roots or blood vessels damages, and the obstruction caused by iliac wings were evaluated.

Results: Liner correlations were found between Da and Va, and between Dh and Vh. The regression equations were Da = 0.6673Va + 11.28 and Dh = 1.009Vh + 1.003. There are statistical significant differences between Dh and Vh, and between Da and Va in those whose Va < 34.96 mm. Nerve roots or blood vessels damages and the obstruction caused by iliac wing were able to be avoided.

Conclusions: If the patient has an anterior-posterior diameter of L5 vertebral body shorter than 34.96 mm, it is possible that the vertebral body can be taken out during TES in a posterior-only approach. Prevention of nerve roots or blood vessels damages, and the obstruction caused by iliac wings are difficulties of this procedure yet not insurmountable. TES on L5 by a posterior-only approach might a possible alternative in treating diseases like L5 vertebral body tumors.

1. Introduction

Tumors that occur on the vertebral body have always been a difficulty in the field of bone tumor [1]. The biological behavior of malignant spinal tumor are often aggressive, which includes eroding the surrounding bones and soft tissues, cause significant pain, pathological fracture and neurological deflects [2,3]. Surgical resections of the tumor combined with adjuvant therapies are considered ideal treating strategies of the disease [4–6]. However owing to the complex anatomical structure around the spine, a complete resection of the spinal tumor without any collateral damage was almost impossible until the late 20th century [7]. Today the procedure still holds remarkable challenge.

The ideal outcomes to obtain from surgical interventions are a complete resection of the tumor lesion, combined with spinal stability reconstruction and local recurrence prevention [8]. Although conventional piecemeal resection approach meets the demands, the recurrence rate is rather high due to the inevitable tumor cell contamination [9].

Roy-Camille et al. first brought up the conception of total en-bloc spondylectomy (TES) in the 1970s [10]. And the procedure was then perfected by Tomita et al. since 1994 [11]. By resecting the cancerous vertebra only in two main pieces, vertebral arch and vertebral body, the perioperative tumor contamination is avoided and in turn the recurrence rate is significantly minimized after surgery. Today the TES approach has become the most widely regard surgical procedure for treating spinal tumors [12].

TES proceeded in a posterior-only approach is considered suitable in treating vertebral body tumors on the thoracic or upper-lumbar (L1–L3) region [13]. Since the vertebral body need to be extracted aside from the dural sac in one piece, the nerve roots above and below will sometimes be severed to obtain a larger space for the procedure. Nerve roots in that region usually don't account for motion functions separately which means it's an acceptable sacrifice.

TES approach on the lower lumbar region, L5 in particular, due to

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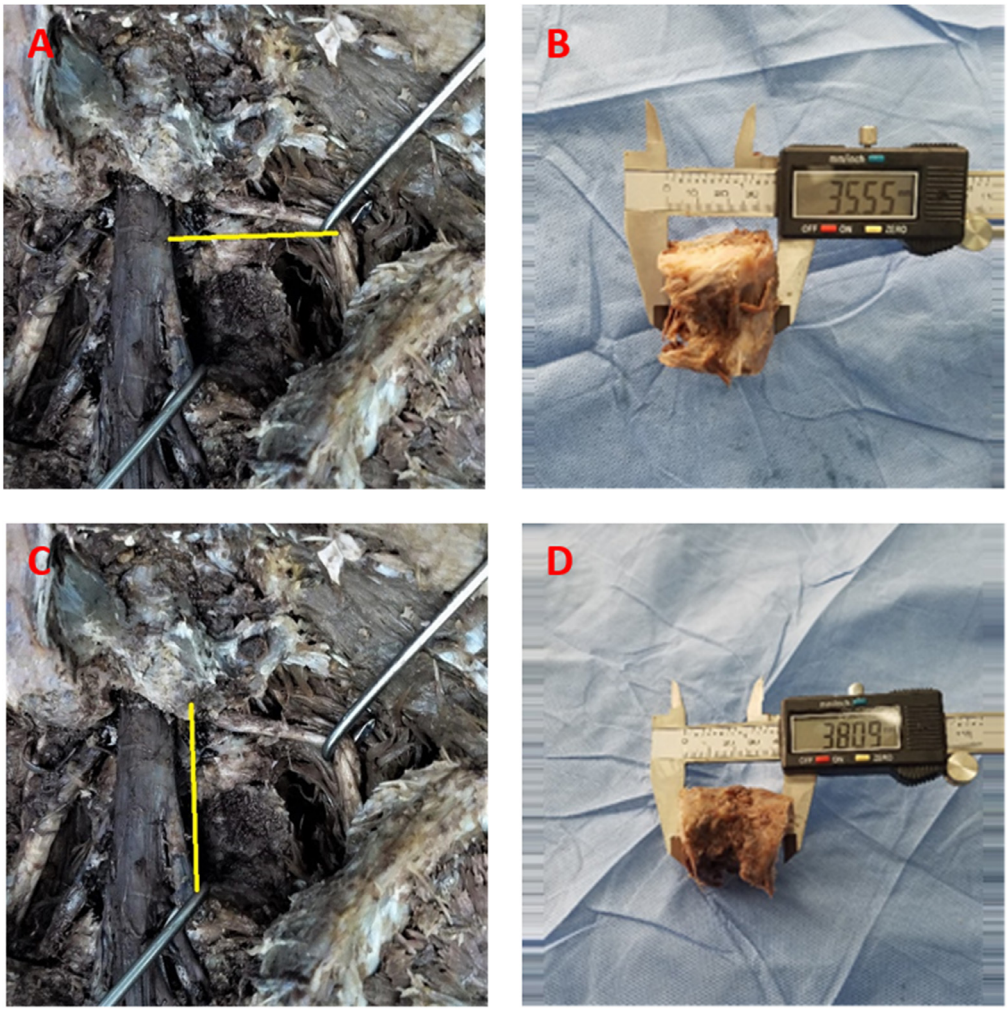

Fig. 1. Measurements of D_a(A), V_a(B), D_h(C) and V_h(D).

the larger vertebral body and the obstruction caused by the iliac wing, along with the critical functions of L4 and L5 nerve roots whose sacrifices are unacceptable, it's still under debate whether proceed in a posterior-only approach is operatable [14]. In common opinion, TES on the lower-lumbar region should be done by a combined anterior-posterior approach [15,16].

A combined anterior-posterior approach TES on L5 has its certain disadvantages. It takes more surgical time and cause heavier blood loss. Surgical wound on the lower abdomen can also cause unnecessary injuries to the peritoneum and further lead to abdominal infection or intestinal disabilities. Such complications, according to Tokuhashi's report, had taken place in about 10% of the patients who underwent this surgical intervention [17]. Whereas a posterior-only approach TES on L5 can perfectly avoid such problems. In light of this idea, we assume that TES on L5 by a posterior-only approach is a better alternative in treating L5 vertebral body tumor if the anatomical difficulties can be overcome.

Here we conducted this series of simulated surgeries on cadavers so as to obtain a better understanding of the structures around the L5 vertebra and provide some anatomical evidence of the feasibility of TES approach on L5 in a posterior-only approach.

2. Materials and methods

2.1. Subjects

12 adult cadavers (7 male, 5 female) embalmed by formalin beforehand were subjected in this research. All subjects revealed no spinal region deformation or surgical histories on the spine. The cadavers were provided by the Laboratory of Human Anatomy, Medical School of Nantong University.

2.2. Treatments

We performed simulated L5 TESs through a posterior-only approach on all subjects. The procedures were as follow.

1. The cadavers were placed in a prone position. A posterior midline incision at the length of about 25 cm was made from L3 level to lower sacrum. To give a full expose of the L5 vertebra, muscles were separated along the spinous process and the vertebral lamina of L3–L5; muscles posteriorly attached to the upper sacrum were severed as well.
2. Separate the interspinous ligament above and below the L5 spinous process. Remove the soft tissues on both L4/L5 facet joints. Dislocate the inferior articular processes of L4 on both sides with a rongeur, meanwhile remove the joint capsules of L5/S1 facet joints to uncover the L5 vertebral arch. The lower part of the L4 vertebral lamina, the L4 spinous process and the S1 spinous process were removed as well if a clearer view was needed.
3. Locate the L4/L5 intervertebral foramen on both sides and the L4 nerve roots that travel through. Remove nearby soft tissues and widen the foramens, allowing the nerve roots to be stretched freely. Osteotomies were then performed on both of the L5 pedicles so as to

separate the vertebral arch. The first two cadavers were treated with wire saw, and the remaining was done by an osteotome since we considered it handier.

4. After removing the vertebral arch in one piece, ligamentum flavum was then resected to detach the dural sac from bony structures. Carefully expose the L4/L5/S1 nerve roots on both sides. Gently pull the nerve roots sideways and dissect bluntly forward to the lateral side of L5 vertebral body. A curved blunt detacher was then applied to dissociate the anterior side of L5 vertebral body. Subsequently, sever the L4/L5 and L5/S1 intervertebral discs with scalpel to obtain a complete separation of L5 vertebral body. Afterwards, adjust its position mildly in preparation of extraction. The dural sac, L4 and L5 nerve roots of one side were pulled aside to form a rectangle-shaped gap for the vertebral body to be extracted. In particular, the L4 nerve root was pulled superior-laterally to its maximum degree while guaranteed not being damaged. Slowly rotate the vertebral body around the dural sac and out from the gap to complete the simulate surgery. Notably, if the iliac wing covered vertically above the extraction route of the vertebral body, a mild osteotomy around the posterior superior iliac spine can be performed to avoid this obstruction.

2.3. Measurements

A rectangle or diamond shaped gap was formed after stretch the nerve roots to a suitable position, which is crucial for the extraction of the vertebral body. We defined the distance between the traction point of L4 nerve root and the dural sac as the length of the gap (D_a), since it was the space where the longest distance of the vertebral body, the anterior-posterior diameter (V_a), needed to go through. Likewise, the distance between the start point of L4 nerve root and the traction point of L5 nerve root was named the height of the gap (D_h), which needed to fit for the height of the vertebral body (V_h) (Fig. 1). Each of the four parameters was measured during or after the surgery using a vernier caliper.

2.4. Statistical analyses

Paired *t*-test and liner regression were performed to determine the difference and correlation between D_a and V_a, and between D_h and V_h. A p value (two-sided) of < 0.05 was considered statistically significant. All analyses were carried out using SPSS for Windows, version 22.0.0 (SPSS, IBM corp., New York, USA).

3. Results

12 cadavers were submitted in our study, including 7 male and 5 female. 10 amongst them had gone through a successful simulated TES on L5 by a posterior-only approach, while another 2 (No.2/3), including 1 male and 1 female, failed to complete the surgeries ideally. The reasons were laceration of the L4 nerve root during traction in the female cadaver, and too large the volume of the vertebral body to be pulled out in the male cadaver.

The parameters of D_a, D_h, V_a and V_h were measured during or after the surgeries, detailed in Table 1. The mean value of D_a, D_h, V_a and V_h were 34.30 ± 2.02 mm, 37.79 ± 3.64 mm, 33.98 ± 2.53 mm and 36.46 ± 3.07 mm respectively.

Paired *t*-test was used to determine the differences between D_a and V_a, and between D_h and V_h. And the result showed a significant difference between D_h and V_h ($p = 0.034$). However no statistical significant difference was observed between D_a and V_a ($p = 0.433$) (Table 2). On the other hand, liner regression analysis revealed significant liner correlations between D_a and V_a, and between D_h and V_h (Fig. 2). The regression equations are as follow.

$D_a = 0.6673V_a + 11.28$ ($p = 0.005$), and $D_h = 1.009V_h + 1.003$ ($p = 0.004$).

By further analyze the regression equations, we predicted that D_h was mostly likely bigger than V_h since the coefficient in the equation was bigger than 1 and the constant bigger than 0. And when $V_a < 34.96$ mm, the tendency might suggest $D_a > V_a$. In light of this conclusion, we conducted another paired *t*-test between D_a and V_a only in subjects whose $V_a < 34.96$ mm (No.2/4/7/8/9/10/11). To our surprise, a statistical significant difference was observed ($p = 0.001$) (Table 3.)

4. Discussion

TES approach is well recognized as the most effective and efficient surgical method in both alleviating symptoms and preventing recurrence for patients with vertebral body tumors [12]. A thoracic vertebra TES can be simply done by a posterior-only approach, because surgeons are allowed to sacrifice the thoracic nerve roots if necessary [13]. However lower-lumber, especially L5, on the other hand, for reasons such as larger vertebral body, iliac wing obstruction and the crucial functions of L4/L5/S1 nerve root, are usually carried out in a combined anterior-posterior approach [15]. A posterior-only TES on L5, though might lead to slighter blood loss and avoid complications in the abdomen cavity, is still deemed hardly an alternative by many surgeons. To our knowledge, few research has focus on determine if this procedure possesses possibility. Huang W etc. published recently a report about a series of L4 vertebra TES in a posterior-only approach. According to them, TES in a posterior-only approach on L4 was a preferable choice in treating L4 vertebral body tumors [18].

In our study, we tried to obtain a profounder understanding on the anatomy of L5 region and in turn evaluate the feasibility of the posterior-only approach by conducting simulated surgeries on human cadavers. 10 of the total 12 simulated surgeries were conducted successfully. In our experience, the trickiest part of the surgery was rotating out the vertebral body through the gap formed by the dural sac, the L4 and L5 nerve roots, and the lateral muscles. The ideal scenario in completing this procedure was the subject having a $D_a > V_a$ and $D_h > V_h$ at the same time. In fact, such measurements were found in most of the cadavers we operated but 2 (No.1/3). The male cadaver that we failed to extract the vertebral body had the D_a of 37.06 mm and V_a of 39.26 mm, meanwhile D_h was 38.73 mm and V_h was 40.14 mm. Another male cadaver had the D_a of 33.82 mm and the V_a of 36.46 mm, we eventually pulled out the vertebral body by extra force which we considered maybe unacceptable in actual surgery.

We found significant liner correlations between D_a and V_a, and between D_h and V_h. According to the regression equations, D_h was mostly likely bigger than V_h, and when $V_a < 34.96$ mm, the tendency suggest $D_a > V_a$. Furthermore statistical significant differences were observed between D_h and V_h, and between D_a and V_a of those whose $V_a < 34.96$ mm. As conclusion, we predict that if the patient has an anterior-posterior diameter of L5 vertebral body shorter than 34.96 mm, it is possible that the vertebral body can be taken out during TES in a posterior-only approach.

The risk of nerve roots damage is a condition that cannot be ignored during the surgery [19]. Damages on L4 and L5 nerve roots may result in sense or motion losses on the lower limbs [20,21]. However even in Tokuhashi's report, where TES were done combined anterior-posteriorly and the vertebral bodies were extracted from the ventral side, 30% of the patients had experienced neurological defects on the lower limbs after surgery [13]. As for a posterior-only approach, in order to roll out the vertebral body, nearby nerve roots have to be pulled aside. To our observation, the size of the gap was critically affected by the traction extent of L4 nerve root. Thus, it is a step that need to be carefully dealt with to avoid potential nerve laceration or fracture.

Blood vessels that attached to the anterior side of the vertebral body is another risking factor during the approach because they are not able to be observed directly during the surgery. In conventional combined anterior-posterior approaches, the main blood vessels are separated

Table 1
Measurements of the 12 cadaveric specimens (mm).

No.	Gender (M/F)	D_a	D_h	V_a	V_h
1	M	33.82	42.21	36.46	40.16
2	F	33.52	33.01	32.36	32.67
3	M	37.06	38.73	39.26	40.14
4	F	33.76	38.22	33.17	37.01
5	M	37.26	42.38	35.55	38.09
6	M	36.43	38.17	35.41	37.23
7	F	31.38	36.48	30.87	35.37
8	M	33.69	40.89	33.48	35.24
9	F	32.45	32.64	31.49	32.15
10	F	31.64	31.94	30.89	31.87
11	M	34.43	40.74	33.27	40.41
12	M	36.10	38.02	35.56	37.12
Mean		34.30 ± 2.02	37.79 ± 3.64	33.98 ± 2.53	36.46 ± 3.07

Table 2
Paired *t*-test result between D_a and V_a and between D_h and V_h.

	t	95% CI	*p*
D_a/V_a	0.813	(−0.536,1.165)	0.433
D_h/V_h	2.414	(0.117,2.544)	0.034

Table 3
Paired *t*-test result between D_a and V_a in subjects with $V_a < 34.96$ mm.

	t	95% CI	*p*
D_a/V_a	5.694	(0.435,1.091)	0.001

from the ventral side with direct view. Previous anatomical researches had demonstrated that most of the abdominal aorta branched into the common iliac arteries at L4 level, while the iliac veins joined into the inferior vena cava at L5 level [22]. In fact during our surgeries, what we had observed about the blood vessels was consistent with the literature. No obvious blood vessel damage took place during our procedures. In our experience, vascular injuries could be avoided in posterior-only approach when operated with skills and caution.

The obstruction of the iliac wing is more critical a condition in male subjects other than females. Female subjects usually possess pelvis structures border than that in male subjects as we observed during the surgeries. The iliac wing, more specifically the inferior superior iliac spine, mostly causes inconvenience in exposing and separating the L5 nerve root. Furthermore, it may somehow block the route for extracting the vertebral body. Osteotomy of the inferior superior iliac spine can be carried out if necessary so as to avoid such obstruction.

There are certain limitations in our study that needed to be pointed out. The study was conducted on embalmed human cadavers. The embalming process may affect the tenacity of tissues [23], which means the toughness of nerve roots or blood vessels may not be the same compared with fresh samples or in actual surgeries. Additionally, it is the standard procedure that the pedicle screws and one side of the titanium rod to be implanted beforehand during the actual surgeries, which may limit the operation field and make procedures more difficult. Lastly, all the subjects we operated revealed only normal spinal structure. In many of the real cases, there may be large tumor mass formed around the vertebral body and therefore need to be evaluated more thoroughly to determine the possibility of the procedure. Further clinical studies are required to further demonstrate the feasibility of

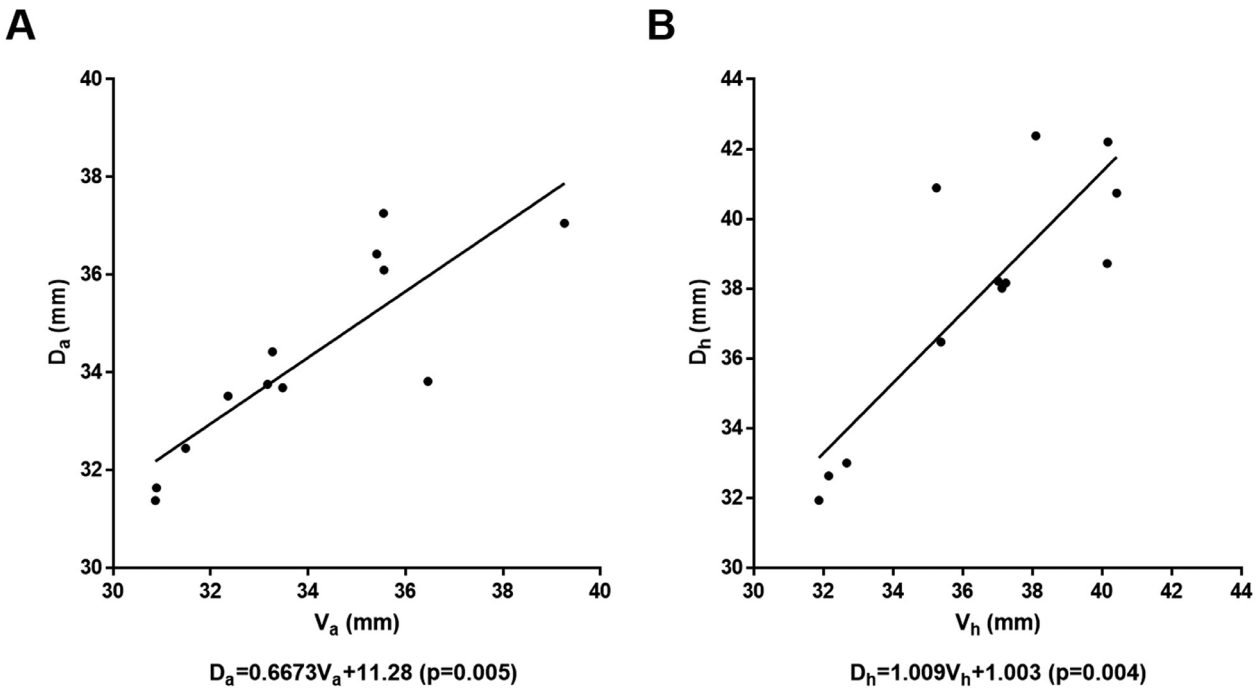

Fig. 2. Liner regression result between D_a and V_a(A) and between D_h and V_h(B).

TES on L5 by a posterior-only approach.

5. Conclusions

In this research we conducted 12 simulated TES on L5 by a posterior-only approach on human cadavers to explore the feasibility of this particular surgical method. Some liner correlations between D_a and V_a, and between D_h and V_h were found during the research. The regression equations were $D_a = 0.6673V_a + 11.28$ and $D_h = 1.009V_h + 1.003$ respectively, by which we predicted that if the patient has an anterior-posterior diameter of L5 vertebral body shorter than 34.96 mm, it is possible that the vertebral body can be taken out during TES in a posterior-only approach. Prevention of nerve roots or blood vessels damages, and the obstruction caused by iliac wing are difficulties of this procedure yet not insurmountable. As conclusion, TES on L5 by a posterior-only approach might a possible alternative in treating diseases like L5 vertebral body tumors.

Conflict of interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jbo.2018.10.003.

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