How to Approach into Dorsal Root Entry Zone of Brachial Plexus: Thai People Cadaveric Study

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Objective: *To describe the anatomy of dorsal root entry zone (DREZ) of brachial plexus for microsurgical DREZ lesioning in Thai population.*
Material and Method: *Two hundred DREZ of 20 formalin-fixed adult human cadaveric spinal cords from C5 to T1 were collected for study. Measured parameters at each spinal cord segment include number of dorsal rootlets, DREZ length, segmental length, distance from posterior median sulcus to posterolateral sulcus, and angle and depth of DREZ.*
Results: *Two hundred DREZ were evaluated. The average number of dorsal rootlets was 6.7±1.48 (4 to 11). The average DREZ length was 11.41±1.62 (6.9 to 16.2) mm. The average segmental length was 12.92±1.96 (8 to 18.4) mm. The average distance from posterior median sulcus to posterolateral sulcus was 3.64±1.29 (2.2 to 4.9) mm. The average angle of DREZ was 34.84±1.00 (32.2 to 37.7) degrees. The average depth of DREZ was 1.41±0.31 (0.6 to 2.2) mm.*
Conclusion: *The authors recommended the starting point for DREZ lesioning at the posterolateral sulcus, which is about 3.64 mm from the posterior median sulcus with the angle of about 34.8 degrees and depth of about 1.41 mm. However, there was rather high variation in term of distance from posterior median sulcus to posterolateral sulcus and depth of DREZ.*

Keywords: *Anatomy, Dorsal root entry zone, Brachial plexus, DREZ lesioning*

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Brachial plexus injury is a common injury that leads to functional impairment of upper extremity. The most common cause of brachial plexus injury is traffic accident. Songcharoen[1] showed that 82% of the brachial plexus injuries were caused by motorcycle accident, 9% by other traffic accidents, and 9% by gunshot, stabbing, and other means.

Neuropathic pain is one of the most common sequelae of brachial plexus injury. The prevalence is as high as 76%[2]. The mechanism of this type of pain is by increasing spontaneous dorsal horn potentials after brachial plexus avulsion[3]. Neuropathic pain following brachial plexus injury can lead to impaired quality of life and psychosocial problems. Treatment options include medication such as gabapentin, pregabalin, antidepressant, and surgical intervention. Berman et al[4] showed that successful nerve transfers to restore limb function can reduce pain from spinal root avulsions.

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Surgical intervention such as dorsal root entry zone (DREZ) lesioning is indicated for patients who are not responsive to pain medication. Effectiveness of DREZ lesioning for neuropathic pain following brachial plexus avulsion injuries has been reported in the literature[5-14]. Good or excellent pain relief after DREZ lesioning can be achieved in 50 to 95.3%[6-14]. However, there are only few anatomical studies of DREZ in the literature and none in Thai population. The purpose of the present study was to describe anatomy of DREZ of brachial plexus for microsurgical DREZ lesioning.

Material and Method

Twenty formalin-fixed adult human cadaveric spinal cords from Department of Anatomy, Faculty of Science, Mahidol University, Bangkok, Thailand, were included in the study. Cadavers that had history of spinal surgery, spinal trauma, and spinal congenital deformity were excluded.

Cadavers were placed in prone position. Skin incision was made in midline. Muscles of posterior part of neck and upper back were dissected from spinous processes, laminae, lateral masses, and transverse processes of cervical and upper thoracic

vertebrae. Laminectomy and bilateral facetectomy were performed to expose underneath dura and nerve root sleeves. Spinal cord from C4 to T2 along with surrounding dura was removed from spinal canal and collected for evaluation. Anatomy of DREZ at bilateral C5 to T1 spinal levels were evaluated.

Measured parameters were divided into two groups, longitudinal plane, and axial plane. Vernier Caliper (GHJB302 20pcs/lot Mini 150mm 6" Digital LCD Groove Vernier Caliper) was used for measurement of longitudinal plane parameters (Fig. 1). The longitudinal plane parameters included number of dorsal rootlets, DREZ length, and segmental length. DREZ length defined as length from the uppermost to the lowermost dorsal rootlets at each spinal level. Segmental length defined as length from the uppermost rootlet of that level to the uppermost rootlet of the next level below.

Cross section of spinal cord at each level from C5 to T1 was used for axial plane parameter measurement including distance from posterior median sulcus to posterolateral sulcus, angle, and depth of DREZ (Fig. 2). Distance from posterior median sulcus to posterolateral sulcus was measured by Vernier Caliper (GHJB302 20pcs/lot Mini 150mm 6" Digital LCD Groove Vernier Caliper). Angle of DREZ defined as angle between longitudinal axis of DREZ and mid-sagittal plane of spinal cord. This angle was measured by digital protractor (Wixey Digital Angle Rule Protractor 200mm/8" Gauge with Clear Plastic Rule WR41). Depth of DREZ defined as distance between dorsal surface of spinal cord at posterolateral sulcus and dorsal surface of dorsal horn of spinal cord. This last parameter was measured under microscopic view (InnoLife Portable 5MP 50X-500X Magnification 8-LED USB Digital Microscope) with magnification power of 20x. All collected data were analyzed with IBM SPSS Statistics version 24.

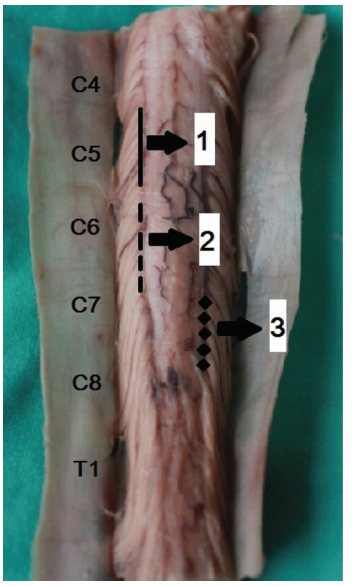

Fig. 1 Dorsal surface of spinal cord showed longitudinal plane parameters including 1) number of dorsal rootlets (black line), 2) DREZ length (dashed line), and 3) segmental length (dotted line).

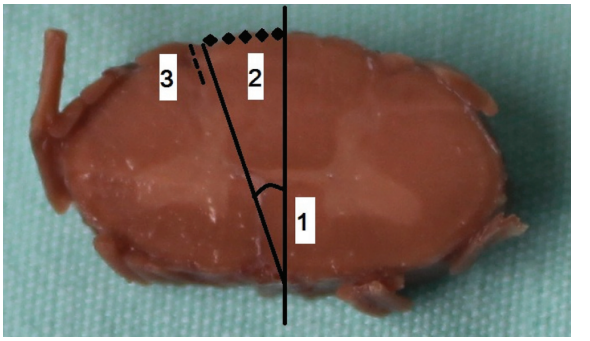

Fig. 2 Cross section of spinal cord at C6 level showed axial plane parameters including 1) angle of DREZ, 2) distance from posterior median sulcus to posterolateral sulcus (dotted line), and 3) depth of DREZ (dashed line).

Results

Two hundred DREZ were evaluated. Longitudinal plane parameters including number of dorsal rootlets, DREZ length, and segmental length were shown in Table 1. The average number of dorsal rootlets from C5 to T1 was 6.7±1.48 (4 to 11). C6 level had the largest number of dorsal rootlets (7.2±1.73). The average DREZ length from C5 to T1 was 11.41±1.62 (6.9 to 16.2) mm. C6 level had the longest DREZ length (12.0±1.84 mm). The average segmental length from C5 to T1 was 12.92±1.96 (8 to 18.4) mm. C5 level had the longest segmental (13.99±2.06 mm).

Axial plane parameters including distance from posterior median sulcus to posterolateral sulcus, angle, and depth of DREZ were shown in Table 2. The average distance from posterior median sulcus to posterolateral sulcus from C5 to T1 was 3.64±1.29 (2.2 to 4.9) mm. The longest distance was at C6 (3.76±0.38 mm). The average angle of DREZ was 34.84±1.00 (32.2 to 37.7) degrees. C7 level had the largest angle (35.10±1.03 degrees). The average depth of DREZ was 1.41±0.31 (0.6 to 2.2) mm. C5 level had the deepest distance of DREZ (1.52±0.32 mm).

Table 1. Longitudinal plane parameters in mean ± SD (range)

Spinal cord segment	Number of dorsal rootlets	DREZ length (mm)	Segmental length (mm)
C5	6.75±1.42 (4 to 9)	11.60±1.89 (7.4 to 15.2)	13.99±2.06 (9.9 to 18.3)
C6	7.20±1.73 (4 to 11)	12.00±1.84 (8.3 to 16.2)	13.70±2.10 (10.4 to 18.4)
C7	7.18±1.58 (4 to 10)	11.55±1.43 (8.8 to 15.6)	12.43±1.42 (10.8 to 17.0)
C8	6.70±1.38 (4 to 10)	10.86±1.32 (6.9 to 14.9)	11.79±1.44 (8.0 to 16.2)
T1	5.70±1.27 (4 to 9)	11.03±1.63 (8.6 to 14.8)	12.41±1.77 (9.2 to 15.7)
Total	6.70±1.48 (4 to 11)	11.41±1.62 (6.9 to 16.2)	12.92±1.96 (8.0 to 18.4)

DREZ = dorsal root entry zone

Table 2. Axial plane parameters in mean ± SD (range)

Spinal cord segment	Distance from posterior median sulcus to posterolateral sulcus (mm)	Angle of DREZ (degrees)	Depth of DREZ (mm)
C5	3.69±0.39 (2.8 to 4.5)	34.71±0.75 (33.1 to 36.6)	1.52±0.32 (0.8 to 2.2)
C6	3.76±0.38 (2.7 to 4.5)	34.77±1.12 (32.9 to 37.1)	1.45±0.33 (1.0 to 2.0)
C7	3.71±0.39 (2.9 to 4.9)	35.10±1.03 (33.0 to 36.9)	1.41±0.28 (0.7 to 1.8)
C8	3.40±0.46 (2.5 to 4.5)	35.06±1.14 (33.4 to 37.7)	1.42±0.35 (0.6 to 2.1)
T1	2.88±0.82 (2.2 to 3.6)	34.57±1.00 (32.2 to 36.9)	1.27±0.25 (0.6 to 1.8)
Total	3.64±1.29 (2.2 to 4.9)	34.84±1.00 (32.2 to 37.7)	1.41±0.31 (0.6 to 2.2)

Discussion

DREZ lesioning is a destructive procedure for various condition including neuropathic pain from brachial plexus injuries, caudal equina and/or spinal cord lesions, chronic cancer pain, spasticity, and neurogenic hyperactive bladder[5]. DREZ lesioning was first attempted in 1972 by Sindou by a technique of microscopic coagulation[5]. Other techniques of DREZ lesioning include radiofrequency thermocoagulation, ultrasonic technique, and suctioning of the dorsal horn. The target of DREZ lesioning is nucleus proprius (laminae IV and V) at dorsal horn of spinal cord. However, there are risks of injury to dorsal column medially and corticospinal tract laterally.

Although DREZ lesioning procedure has been performed for several decades, there are only few studies regarding anatomy of DREZ in the literature. Merten et al[15] used magnetic resonance imaging (MRI) 1.5 Tesla to investigate the radiologic anatomy of dorsal horn of spinal cord. The angle between the dorsal horn axis and the sagittal plane was measured as from 25.5 degrees at C2 to 40 degrees at C8 segments.

Karatas et al[16] conducted an anatomical study of DREZ in 15 human cadavers. The distance from the midline to the DREZ ranged from 1.1 to 4.7 mm and decreased in lower cervical spine. Longitudinal length of dorsal rootlets ranged from 4.3 to 17.7 mm. The longest longitudinal length of DREZ was at C5 level. The number of dorsal rootlets ranged from 2 to 13. The average number of dorsal rootlets tended to increase in the lower cervical spine.

Xiang et al[17] conducted another cadaveric study of DREZ of brachial plexus in 20 adult cadavers. The average number of rootlets was 7.76 and C6 has the most. The angle from the inferior rootlet to spinal cord diminished gradually from up to down. The average distance from posterior median sulcus to posterolateral sulcus was 2.95 mm. The average length, width, and angle of posterior horn were 3.47 mm, 1.346 mm, and 35.9 degrees, respectively. The authors concluded that the lesion-making apparatus should be inserted at an angle of 30 to 40 degrees, the width of lesion should be less than 1.2 mm and the lesion depth less than 3.1 mm.

In the present study, the average number of dorsal rootlets was 6.7±1.48 (4 to 11). The largest number was at C6 spinal segment. This was the same result as in the study of Xiang et al[17]. The average DREZ length in the present study was 11.41±1.62 (6.9 to 16.2) mm. The longest DREZ length was at C6, whereas the longest DREZ length was at C5 in the study of Karatas et al[16]. The average segmental length in the present study was 12.92±1.96 (8 to 18.4) mm. The longest segmental length was at C5. In the present study, the average distance from posterior median sulcus to posterolateral sulcus was 3.64±1.29 (2.2 to

4.9) mm. The largest distance was at C6 with the trend of decreasing distance in lower cervical spine as in the study of Karatas et al[16]. The average angle of DREZ was 34.84±1.00 (32.2 to 37.7) degrees. The largest angle was at C7. The average depth of DREZ was 1.41±0.31 (0.6 to 2.2) mm. The deepest distance was at C5.

Axial plane parameters are more important than longitudinal plane parameters for DREZ lesioning procedure to avoid complications from injury of dorsal column medially and corticospinal tract laterally. Regarding axial plane parameters in the present study, there was low variation of angle of DREZ (32.2 to 37.7 degrees). However, there was rather high variation in term of distance from posterior median sulcus to posterolateral sulcus (2.2 to 4.9 mm) and depth of DREZ (0.6 to 2.2 mm). Limitations of the present study are rather small sample size and including only Thai cadavers.

Conclusion

C6 spinal segment had the largest number of dorsal rootlets, the longest DREZ length and the longest distance from posterior median sulcus to posterolateral sulcus. However, the largest angle and the deepest distance of DREZ was at C7 and C5, respectively. The authors recommended the starting point for DREZ lesioning at the posterolateral sulcus which is about 3.64 mm from the posterior median sulcus with the angle of about 34.8 degrees and depth of about 1.41 mm in the undeformed spinal cord. However, there was rather high variation in term of distance from posterior median sulcus to posterolateral sulcus and depth of DREZ.

What is already known on this topic?

There are only few anatomical studies of DREZ in the literature. The largest study from Xiang et al[17] concluded that DREZ lesioning should be performed at an angle of 30 to 40 degrees, the width of lesion should be less than 1.2 mm and the lesion depth less than 3.1 mm. However, there is no anatomical studies in Thai population.

What this study adds?

This is another anatomical study for surgical approach to DREZ of brachial plexus focusing on Thai population.

Potential conflicts of interest

None.

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เราจะสามารถเข้าถึงตำแหน่งทางเข้ารากประสาทด้านหลังของข่ายประสาทของแขนได้อย่างไร: การศึกษาในศพชาวไทย

พิชญะ มหาทิพย์วิถี, พรจันทร์ สายทองดี, ฮาสือนะ บอซู, พณิช สถาพรธีระ, เกรียงศักดิ์ แซ่เตีย

วัตถุประสงค์: *เพื่อศึกษากายวิภาคของทางเข้ารากประสาทด้านหลังของข่ายประสาทของแขนสำหรับการผ่าตัดจุลศัลยกรรมเพื่อสร้างรอยโรคบริเวณทางเข้ารากประสาทด้านหลังในศพชาวไทย*

วัสดุและวิธีการ: *ทำการเก็บรวบรวมข้อมูลของทางเข้ารากประสาทด้านหลัง 200 จุด ในไขสันหลังตั้งแต่ระดับรากประสาทส่วนคอที่ 5 จนถึงรากประสาทส่วนอกที่ 1 ในศพผู้ใหญ่ที่แช่ฟอร์มาลีน 20 ศพ โดยข้อมูลที่เก็บรวบรวม ได้แก่ จำนวนรากประสาทด้านหลัง ความยาวของทางเข้ารากประสาทด้านหลัง ความยาวของไขสันหลังแต่ละปล้อง ระยะทางระหว่างร่องตรงกลางด้านหลังกับร่องด้านข้างด้านหลัง มุม และความลึกของทางเข้ารากประสาทด้านหลัง*

ผลการศึกษา: *ข้อมูลของทางเข้ารากประสาทด้านหลัง 200 จุด ได้นำมาวิเคราะห์พบว่า จำนวนเฉลี่ยของรากประสาทด้านหลัง คือ 6.7±1.48 (4-11) ความยาวเฉลี่ยของทางเข้ารากประสาทด้านหลัง คือ 11.41±1.62 (6.9-16.2) มิลลิเมตร ความยาวเฉลี่ยของไขสันหลังแต่ละปล้อง คือ 12.92±1.96 (8-18.4) มิลลิเมตร ระยะทางเฉลี่ยระหว่างร่องตรงกลางด้านหลังกับร่องด้านข้างด้านหลัง คือ 3.64±1.29 (2.2-4.9) มิลลิเมตร มุมเฉลี่ยของทางเข้ารากประสาทด้านหลัง คือ 34.84±1.00 (32.2-37.7) องศา ความลึกเฉลี่ยของทางเข้ารากประสาทด้านหลัง คือ 1.41±0.31 (0.6-2.2) มิลลิเมตร*

สรุป: *ผู้นิพนธ์พบว่าจุดตั้งต้นของการสร้างรอยโรคบริเวณทางเข้ารากประสาทด้านหลังที่ตำแหน่งร่องด้านข้างร่วมด้านหลัง ยาวประมาณ 3.64 มิลลิเมตร จากร่องตรงกลางร่วมด้านหลังโดยทำมุมประมาณ 34.8 องศา และความลึกประมาณ 1.41 มิลลิเมตร อย่างไรก็ตาม มีความแปรผันค่อนข้างมากในแง่ของระยะทางระหว่างร่องตรงกลางร่วมด้านหลังกับร่องด้านข้างร่วมด้านหลังและความลึกของทางเข้ารากประสาทด้านหลัง*