Original article

Occurrence and patterns of extralaryngeal branching of the recurrent laryngeal nerve in Thai cadavers

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Background and objective The recurrent laryngeal nerve (RLN) supplies motor control to the intrinsic laryngeal muscles, which is crucial for phonation and upper airway regulation, and receiving sensation from the vocal cord and subglottic region. Due to its proximity to the thyroid gland, this nerve is injured frequently during thyroidectomy, which leads to vocal cord paralysis. Despite anatomical landmarks provided for identifying the RLN during surgery, postoperative damage to this nerve still occurs. Past studies suggest that the RLN might have extralaryngeal branches that were unidentified and subsequently damaged. This study aimed to identify and classify the pattern of extralaryngeal branching of the RLN in the Thai population.

Method Seventy five neck specimens were used to identify the RLN and its extralaryngeal branches within the inferoposterior area to the thyroid gland. The branching pattern was then classified according to the number of branches leading to the larynx, and the difference between the left and right side were calculated by the chi-square test.

Result and conclusion Branching of the RLN can be classified into three major types and ten subtypes. An RLN with at least one branch seen outside the laryngeal area was found in 52 sides (69.33%) of specimens. Among this variation, about 30% had an RLN with two or three branches entering the larynx. No statistically significant difference in the number of each variation was found between the left and right side. These data should be useful for minimizing RLN injury and complications from thyroid surgery. **Chiang Mai Medical Journal 2014;53(3):119-126.**

Keywords: recurrent laryngeal nerve, thyroidectomy, larynx, anatomical variation

Introduction

The recurrent laryngeal nerve (RLN) is a branch from the vagus nerve, which is located within the visceral compartment of the anterior triangle of the neck. Upon its ascent from the thoracic cavity into the visceral compartment of the neck, the RLN is commonly found close to the tracheo-esophageal groove and located posterior to the lobes of the thyroid gland, before piercing the lower border of the inferior pharyngeal constrictor muscle in order to enter the laryngeal cavity. The RLN is known to innervate the intrinsic laryngeal muscles (except the cricothyroid muscle) and cricopharyngeus muscle, which are crucial for proper phonation and important

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for deglutition control, respectively. Additionally, this nerve provides sensory innervation from the laryngeal mucosa of the vocal cord and subglottic region, and parasympathetic secretomotor fibers to the mucous glands embedded within the laryngeal mucous membrane[1]. The RLN within the laryngeal cavity is probably connected to branches from the internal laryngeal nerve, as the laryngeal nerve plexus[2]. The course of the RLN before it enters the larynx makes it susceptible to iatrogenic damage during thyroidectomy procedures or surgical intervention of the nearby structures, such as the parathyroid gland. Postoperative complications of thyroidectomy due to RLN injury include vocal cord paralysis, hoarseness, stridor, dysphagia and partial airway obstruction. The gold standard for intraoperative nerve preservation is still direct identification by using the anatomical relationships with adjacent structures. Recently, research has attempted to find appropriate landmarks, such as the inferior thyroid artery[3-6], palpable landmarks on the thyroid and cricoid cartilages[7] and Berry's ligament[8,9], and their anatomical relationship with the RLN in order to develop a more precise identification method. Despite identification and preservation of the RLN posterior to the thyroid gland during a surgical procedure, postoperative permanent vocal cord paralysis still can be found in up to 0.7% of patients[10,11].

The recurrent laryngeal nerve is commonly known to possess a highly variable course, especially in the upper extralaryngeal part. Modern anatomical textbooks describe the RLN as having a diverse relationship with the inferior thyroid artery, tracheo-esophageal groove, and lateral ligament of the thyroid gland[1]. Branching patterns of the extralaryngeal portion of the RLN, superior to the inferior thyroid artery, are subjected exceptionally to variation, and many studies have reported the existence of extralaryngeal branches of this nerve[3,6] that are most commonly bifurcated into anterior and posterior branches. Intraoperative findings by Kandil and colleagues[12] and Serpell, Yeung and Grodski [13] revealed that extralaryngeal branching of the RLN was far more common than previously described. Therefore, recognition of extralaryngeal branches of the RLN is essential for surgical intervention of the thyroid gland and neighbouring structures. It has been proven from this anatomical evidence that variations in the extralaryngeal part of the RLN might lead to unintentional nerve damage and subsequent postoperative complications. This study aimed to assess and classify the occurrence of extralaryngeal branches of the RLN from Thai cadavers in order to provide applicable anatomical data for surgeons and otolaryngologists.

Method

This method was approved by the Institutional Ethical Review Board and informed consent was waived. Dissection and data collection were performed from August 2012 to July 2013 in the Surgical and Cadaveric Workshop, Faculty of Medicine, Chiang Mai University. Detailed dissection of the anterior region of the neck was conducted in 40 fresh Thai cadavers (29 males and 11 females), with age at death being between 38 to 91 years old. All cadavers were obtained through the departmental body donation procedure, and donation forms were signed by donors prior to their death. Among 80 sides of neck for dissection, five were excluded due to pathological features in the anterior neck or thyroid gland; therefore 75 sides of neck were investigated. The dissection procedure was started by removing the skin and subcutaneous tissue anterior to the sternocleidomastoid muscle and below the inferior border of the mandible. Then, the platysma muscle and infrahyoid strap muscles were cut subsequently and flapped superiorly to fully expose the thyroid gland. The recurrent laryngeal nerve and available extralaryngeal branches were exposed and identified around the inferior pole of the thyroid gland just lateral to the trachea or tracheo-esophageal groove. Branches to the larynx were identified by their penetration through the inferior border of the inferior pharyngeal constrictor muscle, while the tracheal and esophageal branches were identified by their terminal branches attached to the outer surface of these structures. Numbers of branches were recorded and photographed. Statistical differences between left and right sides were analysed by the chi-square test, with $p < 0.05$ considered to have statistical difference.

Results

From 75 sides of dissected necks, the recurrent laryngeal nerve was identified and its anatomical variations could be classified into three

types (Types I, II and III) by the authors according to the number of branch(es) penetrating into the larynx. Then each type was subdivided into subtypes by its occurrence of tracheal and/or esophageal branches, with a total of ten subtypes. The number of specimens found in each subtype and schematic diagrams are shown in Table 1 and Figure 1, respectively. Type Ia, which was identified as the RLN with no extralaryngeal branches, was found in 23 sides (13 left sides, 10 right sides) and accounted for 30.67% of the RLN studied (Figure 2). Nine subtypes, apart from Type Ia, were found in 52 sides (25 left sides, 27 right sides) and identified as variants of the RLN with extralaryngeal branches, which accounted for 69.33% of the RLN studied. Type Ib, which had a single laryngeal branch with tracheal branches, was found in eight sides (10.66%). Type Ic, which had a single laryngeal branch with esophageal branches, was found in nine sides (12.01%). The variants that had a single laryngeal branch with both tracheal and esophageal branches were classified as Type Id, which was found in 11 sides (14.67%). Interestingly, this study also identified two sides of the neck (2.67%) that had an RLN with a single laryngeal branch, with esophageal branches and small branches, which were associated with the common carotid artery and assigned to Type Ie.

Bifurcation of the RLN laryngeal branch also was a common variation, classified into Type II and divided further into three subtypes: Type IIa, IIc and IId, with only bifurcation of the laryngeal branch in 11 sides (14.67%); two laryngeal branches, with one esophageal branch, in five sides (6.67%) (Figure 3); and two laryngeal branches, with both tracheal and esophageal branches, in one side (1.33%), respectively. Trifurcation was an uncommon variant, but could be found in five sides of the necks studied; of which four (5.33%) had only three laryngeal branches, and were classified as Type IIIa (Figure 4). Only one side (1.33%) had three laryngeal branches with one tracheal branch and was assigned as Type IIIb. The occurrence between the left and right side of each variation type was not significant (p >0.05) in all types, as calculated by the chi-square test.

Discussion and conclusion

Identification and preservation of the recurrent laryngeal nerve during surgery is essential, since the rate of RLN injury was significantly reduced when a surgeon fully exposed this nerve [14]. Extensive anatomical data of the RLN is therefore required to help surgeons avoid post-

Table 1. Classification of extralaryngeal branches of the recurrent laryngeal nerve.

Type	Left		Right		Total	
	Numbers of specimen(s)	Percentage	Numbers of specimen(s)	Percentage	Numbers of specimen(s)	Percentage
Ia	13	34.21	10	27.03	23	30.67
Ib	2	5.26	6	16.22	8	10.67
Ic	7	18.42	2	5.41	9	12.00
Id	7	18.42	4	10.81	11	14.67
Ie	1	2.63	1	2.70	2	2.67
IIa	4	10.53	7	18.92	11	14.67
IIc	3	8.11	2	5.41	5	6.67
IId	0	0.00	1	2.70	1	1.33
IIIa	1	2.63	3	8.11	4	5.33
IIIb	0	0.00	1	2.70	1	1.33
Total	38	100.00	37	100.00	75	100.00

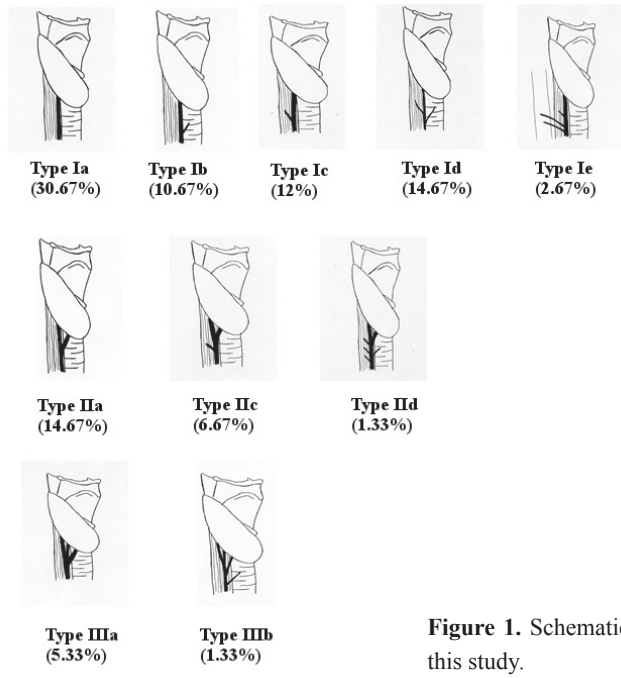

Figure 1. Schematic diagrams of extralaryngeal branching patterns found in this study.

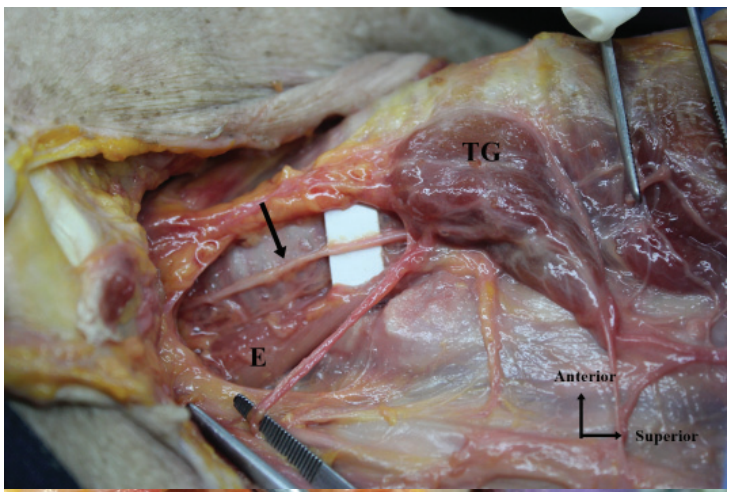

Figure 2. Recurrent laryngeal nerve with single laryngeal branch (type Ia). E: esophagus, TG: thyroid gland.

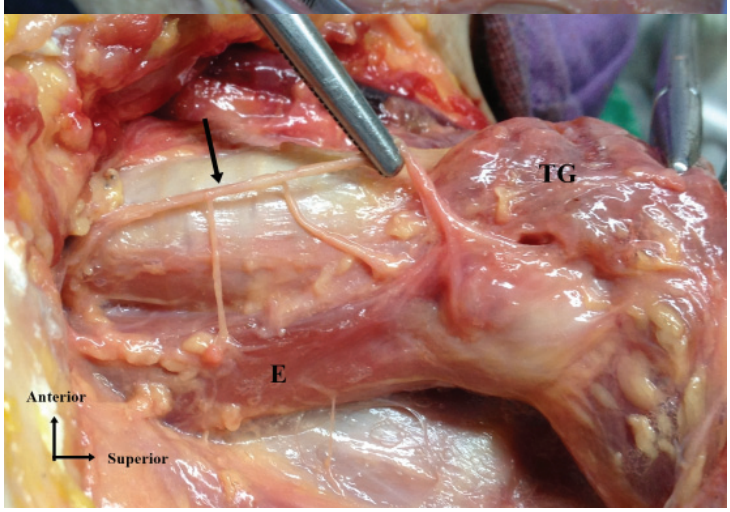

Figure 3. Recurrent laryngeal nerve with two laryngeal branches and one esophageal branch (type IIc). E: esophagus, TG: thyroid gland.

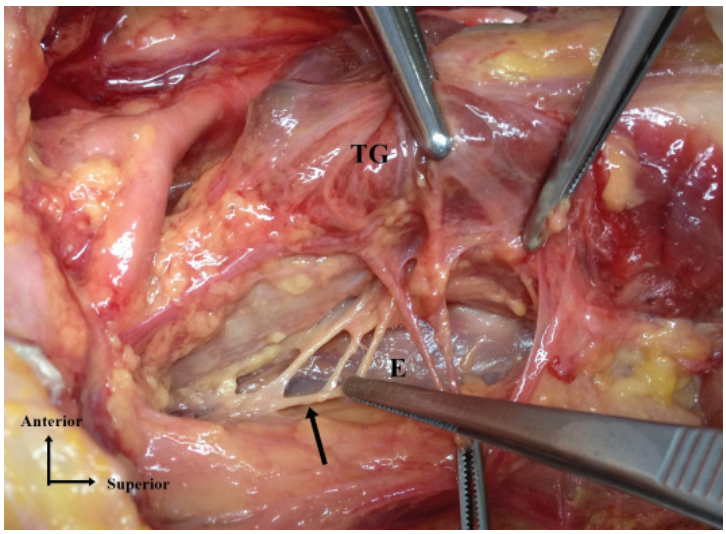

Figure 4. Recurrent laryngeal nerve with three branches entering larynx (type IIIa). E: esophagus, TG: thyroid gland.

operative vocal cord paresis. This study revealed that the majority of the RLN had branching outside the larynx, which occurred in 70% of the specimens dissected. Among the RLN with extralaryngeal branches, 17 had bifurcation and five had trifurcation of branches penetrating the larynx. The observation of RLN bifurcation before entry into the larynx was mentioned frequently in many studies, and described as anterior and posterior branches. Katz and Nemiroff showed that about 58% of the RLN branched at a distance of more than five mm below the cricothyroid joint[15]. Hisham and Lukman described that 33.4% of the RLN identified during thyroid surgery had two extralaryngeal branches [16]. Casella and colleagues found that 18.5% of the nerve dissected had one or more branches less than five mm from the cricothyroid muscle[17]. Ardito and colleagues claimed finding a higher rate of RLN branching of up to 72% when the nerve was explored, regardless of the distance from the cricothyroid joint[18], which indicated that branching of the RLN still can be found near the entry level of the larynx. A detailed examination of the RLN from the posterior approach by Yalcin and coworkers found that bifurcation of the RLN into two laryngeal branches, with one to three branches to the trachea, esophagus or thyroid gland, could be seen in 86.8% of the dissected specimens[19]. A recent study by Gurleyik found that bifurcation of the RLN accounted for 27.0% of dissected cases, and most of them were bifurcated near the course of the inferior thyroid artery[20]. Despite different measurement parameters of RLN branching, there is firm evidence that bifurcation of the RLN is a common anatomical finding. It was revealed recently that in each branch function the anterior branch of the RLN is the motor branch, while the posterior branch is the sensory one, as detected by nerve stimulation[12] and electromyography[13]. Beneragama and Serpell[11] suggested that the anterior branch might be jeopardized if the surgeon only identified the posterior branch, without knowing that the RLN is commonly bifurcated, which might lead to postoperative paralysis of the laryngeal muscles. Nevertheless, this study recommends that both laryngeal branches, if possible, should be identified to ensure minimal injury to the RLN. Trifurcation of the RLN laryngeal branch was reported in the literature as being from 1.0% to 7.3%[11,17,20,21], which is comparable to this study (6.66%). It had been suggested that the third branch innervated either laryngeal mucosa or the cricopharyngeal part of the inferior pharyngeal constrictor muscle, or both of these structures[21]. No statistical differences were found in the number of specimens between the left and right sides, as classified in all types of variation. This correlated with a

study of 100 cases by Gurleyik[20] and one in 220 patients by Kandil and co-workers[22], in which nearly equal numbers of RLN bifurcation were found in the left and right sides. However, other studies conducted with more than 100 patients revealed that bifurcation and trifurcation of the RLN were more common statistically in the right side than the left one[11,16,23]. The result of this study found RLN trifurcation in the right side of four specimens, while only one could be found in the left one, which suggested that trifurcation of the RLN in the right side might be significant in a larger number of subjects. This study recommends that surgeons should be aware of the frequent occurrence of extralaryngeal branches of the RLN when performing operations on the right side of patients.

In conclusion, this study revealed that most of the RLNs in the anterior cervical region have one or more extralaryngeal branches, and almost 30% of specimens have two or three branches penetrating the larynx. It is highly possible that the anterior laryngeal branch of the RLN is the motor branch supplying the laryngeal muscles, and must be identified and preserved during surgery. Furthermore, surgeons should be alert to identifying multiple branches of the RLN during surgery on the right side of the neck, since a higher frequency of bifurcation and trifurcation of the RLN was found there. These anatomical data should provide guidance in order to minimize postoperative complications in thyroidectomy.

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Conflict of interest

None

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การปรากฏและรูปแบบของแขนงนอกกล่องเสียงของเส้นประสาท recurrent laryngeal ในร่างชำแหละของชาวไทย

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วัตถุประสงค์ เส้นประสาท recurrent laryngeal (RLN) มีหน้าที่สั่งการกล้ามเนื้อภายในกล่องเสียง ที่ควบคุมการออกเสียงและทางเดินอากาศส่วนต้น และรับความรู้สึกจากเส้นเสียงและเยื่อเมือกของกล่องเสียงที่อยู่ด้านล่างต่อเส้นเสียง เส้นประสาทนี้อยู่ใกล้กับต่อมไทรอยด์และมีโอกาสเสียหายได้บ่อยในการผ่าตัดต่อมไทรอยด์ ซึ่งทำให้ผู้ป่วยมีภาวะอัมพาตของกล้ามเนื้อกล่องเสียง ถึงแม้ว่าจะมีโครงสร้างทางกายวิภาคศาสตร์ที่ช่วยบ่งชี้ตำแหน่งของเส้นประสาทนี้ก็ตาม การศึกษาในอดีตชี้ว่าเส้นประสาทนี้มีการแตกแขนงนอกกล่องเสียงบ่อยครั้ง และแขนงเหล่านี้อาจไม่ได้ถูกระบุระหว่างการผ่าตัดและเสียหายได้ การศึกษานี้จึงมีจุดประสงค์เพื่อประเมินและจัดจำแนกรูปแบบของการแตกแขนงนอกกล่องเสียงของเส้นประสาท recurrent laryngeal ในกลุ่มประชากรไทย

วิธีการ ผู้วิจัยศึกษาเส้นประสาท recurrent laryngeal และแขนงนอกกล่องเสียงในบริเวณด้านหลังและด้านล่างต่อต่อมไทรอยด์ในคอจำนวน 75 ข้างจากผู้อุทิศร่างกายเพื่อการศึกษา จากนั้นจึงจำแนกรูปแบบของการแตกแขนงตามจำนวนของแขนงที่ผ่านขึ้นไปยังกล่องเสียง ความแตกต่างทางสถิติของรูปแบบการแตกแขนงนอกกล่องเสียงระหว่างข้างซ้ายและขวาคำนวณโดยการทดสอบ chi-square

ผลการศึกษาและสรุปผลการวิจัย ผู้วิจัยสามารถจัดจำแนกรูปแบบการแตกแขนงนอกกล่องเสียงของเส้นประสาท recurrent laryngeal ได้เป็นสามกลุ่มใหญ่ และจำแนกเพิ่มเติมได้เป็น 10 กลุ่มย่อย โดยพบเส้นประสาท recurrent laryngeal ที่มีแขนงนอกกล่องเสียงอย่างน้อยหนึ่งแขนง จำนวน 52 ข้าง คิดเป็นร้อยละ 69.33 ของข้างที่ศึกษา ในกลุ่มนี้พบว่าประมาณร้อยละ 30 มีแขนงที่ผ่านขึ้นไปที่กล่องเสียงจำนวน 2 และ 3 แขนง ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างจำนวนที่พบในข้างซ้ายและขวาในทุกรูปแบบ ข้อมูลทางกายวิภาคศาสตร์นี้จะเป็นประโยชน์ต่อศัลยแพทย์เพื่อหลีกเลี่ยงความเสียหายต่อเส้นประสาท recurrent laryngeal และอาการแทรกซ้อนที่เกิดขึ้นหลังการผ่าตัดต่อมไทรอยด์ **เชียงใหม่เวชสาร 2557; 53(3):119-126.**

คำสำคัญ: เส้นประสาท recurrent laryngeal การผ่าตัดต่อมไทรอยด์ กล่องเสียง ความแปรปรวนทางกายวิภาคศาสตร์