Anatomical anomalies of the laryngeal branches of the vagus nerve in pigs (Sus scrofa)

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Abstract
To delineate the anomaly and frequency of their occurrence in a pig model, we reported the topography of the vagus laryngeal branches and compared the differences with humans. Thirty sides of cervical vagus nerve in 15 fresh cadavers (Sus scrofa) were microdissected. We measured the branch diameters and lengths of the laryngeal branches using a Vernier caliper with a resolution of 0.01 mm. Two patterns of the vagus laryngeal branches were shown: 56.7% with the cranial laryngeal nerve (CLN) and 43.3% without the CLN. The diameters and the length of the CLN were not affected by the side of the neck (P > 0.05), but the diameters of the recurrent laryngeal nerve (RLN) and the nodose ganglion were significantly different between left and right sides (P < 0.05). The left RLN was thinner than the right side in diameter (P < 0.05). Four of the 30 sides had anastomoses between the vagus and the cervical sympathetic chain. There were some differences between the pig anatomy and human anatomy, but the patterns were largely similar. The similarities support the utility of this model, which is closer in size to humans than the standard rodent models.

Keywords: Vagus nerve, Sus scrofa, abnormalities, cranial laryngeal nerve, recurrent laryngeal nerve


The cranial laryngeal nerve (CLN), and its two branches the internal laryngeal nerve (ILN) and the external laryngeal nerve (ELN), together with the recurrent laryngeal nerve (RLN) are critical for swallowing, speech and respiration.1 Due to their anatomical positions, these nerves are vulnerable to iatrogenic injury during various surgeries, such as thyroidectomy,2,3 spine surgery4 and endarterectomy.5 Therefore, a thorough understanding of the laryngeal anatomy and the possible variations of these nerves in pigs is important for successful outcomes of studies using this animal model.

The sample in this study included 15 healthy fresh cadavers of female Yorkshire pigs (Sus scrofa) (Tom Morris Farms, Reisterstown, MD, USA) with the age of 1–3 weeks. The pigs weighed 3–5 kg with the length from the base of the ear to the base of the tail of 34.5 mm (SD = 6.7 mm). An anterior approach was performed to dissect the laryngeal branches of the cervical vagus. The laryngeal nerves (CLN, ILN, ELN and RLN) on both sides (30 sides) were dissected under a surgical microscope (Carl Zeiss OPMI CS-NC, JHOC 6253, Ross Building, Johns Hopkins University, Baltimore, MD, USA). The cervical vagus was carefully dissected from the nodose ganglion to the entrance of the thoracic cavity using microsurgical forceps. Subsequently, the ILN and the ELN were traced to their entrance into the larynx. We also documented the course of the RLN to the point where it pierced into the larynx. Branch diameter and length were measured using a Vernier caliper, with a resolution of 0.01 mm. These measurements are listed in Table 1. Because the nerve course was sometimes twisted or curved, all nerve lengths were the true length of the nerve itself, and not the distance between the two endpoints. We tested for left–right differences using a paired t-test (SYSTAT12).

There were two patterns of laryngeal branches of the vagus: with CLN and without CLN as shown in Figure 1. In all, 56.7% (17 of 30 cases) showed the CLN trunk arising from the nodose ganglion of the cervical vagus, just caudal to the jugular foramen within the carotid sheath. In the other 13 cases, the ILN and the ELN branched from the cervical vagus nerve directly without the CLN truck. The bifurcation of the CLN into the ILN and the ELN from its origin of the nodose ganglion was diverse in distance. The distance of the CLN from the origination to the upper point of the bifurcation of the common carotid artery was 4.84 ± 0.52 mm. All of the ILNs originated from the nodose ganglion directly. In some cases the
ELN branched from the cervical vagus nerve directly without the CLN truck and the external laryngeal nerve (ELN); (b) without CLN: the ILN and the cranial laryngeal nerve (CLN): the CLN trunk arising from the nodose ganglion before reaching the larynx. The ILNs were all dorsal to the cranial cervical ganglion, extending caudally to pierce the lateral aspect of the thyrohyoid membrane. No anastomosis was found with the RLN outside the larynx.

The lengths and diameters of these nerves are shown in Table 2. The diameters of the CLN and the cervical vagus and the length of the CLN were not affected by the side of the neck \((P > 0.05)\), but the diameters of the RLN and the nodose ganglion were significantly different between left and right sides \((P < 0.05)\). The mean left RLN was thinner than the mean right side in diameter with \(0.66–0.76\) mm \((P = 0.046)\). The mean diameter of left nodose ganglion was thicker than the mean right side with \(2.77–2.57\) mm \((P = 0.022)\). The ELN, on average, was longer and thinner than the ILN \((P < 0.05)\). The correlation was found between the body length and the diameters of the NG, CV, CLN and ILN \((\text{Pearson correlation } r > 0.75)\).

The classic description of the superior laryngeal nerve in humans is of a constant and short trunk that divides into the internal and external branches. This is also true of some animals, such as dogs, cats, rats and pigs.\(^6\) However, in our study, less than 57% of cases had this normal CLN configuration. This pattern has not previously been reported in pigs, although it has been in humans. Kambic \textit{et al.}\(^7\)
reported that in 5% of their dissections the ILN and the ELN arose from the lower pole of the nodose ganglion of the cervical vagus. Another report documented 6% of cases missing the trunk of the superior laryngeal nerve in 40 fresh cadavers, with the bifurcation occurring just below the nodose ganglion. In humans the bifurcation of the superior laryngeal nerve into internal and external branches usually occurs with the bifurcation of the common carotid into the internal and external carotid arteries (75%), but sometimes the superior laryngeal nerve divides alongside the bifurcation of the carotid artery (15%) or more caudally (10%). In pigs the bifurcation of the CLN in the pig model was outside the bifurcation of the common carotid artery caudally and medially. In humans, the ILN was largely observed in a parallel and medial position to the superior laryngeal artery (89%), and in 11% of the dissections it was located inferiorly and medially to that artery. Then both went downwards and medially piercing into the thyrohyoid membrane in humans. In pigs, the ILN is always located dorsal to the cranial laryngeal artery parallelly or caudally. In humans the ELN runs either superficially or deeply to the inferior pharyngeal constrictor muscle, after which the terminal branches of the ELN penetrate the horizontal and the oblique bellies of the cricothyroid muscle and the inferior pharyngeal constrictor muscle. In our study, all the ELNs except one innervated the cricothyroid muscle and the causal pharyngeal constrictor muscle. Most of the ELNs (73.3%) only had one branch arriving in the cricothyroid muscle. In humans 17.3% of the RLNs had a communicating branch with a similar diameter to the RLN connecting with the sympathetic trunk. We did not find any variations in pigs. An anastomosis connecting the cervical sympathetic chain with the CLN and its branches is called the CLN loop (in humans it is called the superior laryngeal nerve loop) with the incidence of 98.3% in humans, which is significantly higher than our findings in pigs.

Our sample provided statistical details as to the pattern of the laryngeal branches of the cervical vagus nerve in the pig, with details on the topography and anatomical variations. There were some differences between the pig anatomy and human anatomy, but the patterns were largely similar. These results should be useful to researchers who are carrying out accurate experiments and studies on laryngeal function and surgery in a pig model. The similarities support the utility of this model, which is closer in size to humans than the standard rodent models.

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REFERENCES


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