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ORIGINAL ARTICLE

Anatomical variation and distribution of the vagus nerve in the esophageal hiatus: a cross-sectional study of post-mortem cases in Uganda

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Abstract

Purpose Vagus nerve injuries during gastroesophageal surgery may cause significant symptoms due to loss of vagal anti-inflammatory and neuromodulator function. Many previous studies have shown high anatomical variability of the vagus nerve at the esophageal hiatus, but information on its variability in Uganda specifically and Africa in general is scanty. This study provides a reliable and detailed description of the anatomical variation and distribution of the vagus nerve in the esophageal hiatus region of post-mortem cases in Uganda.

Methods This was an analytical cross-sectional survey of 67 unclaimed post-mortem cases. Data collection used a pretested data collection form. Data were entered into Epi-Info version 6.0 data base then exported into STATA software 13.0 for analysis.

Results The pattern of the anterior vagal trunk structures at the esophageal hiatus was: single trunk [65.7%]; biplexus [20.9%]; triplexus [8.9%] and double-but-not-connected trunks [4.5%]. The pattern of the posterior trunk structures were: single trunk [85.1%]; biplexus 10.4% and triplexus [4.5%]. There was no statistically significant gender difference in the pattern of vagal fibres. There was no major differences in the pattern from comparable British studies.

Conclusion The study confirmed high variability in the distribution of the vagus nerve at the esophageal hiatus, unrelated to gender differences. Surgeons must consider and identify variants of vagal innervation when carrying out surgery at the gastroesophageal junction to avoid accidental vagal injuries. Published surgical techniques for preserving vagal function are valid in Uganda.

Keywords Vagus nerve · Uganda · Distribution · Variation · Esophageal hiatus

Introduction

Integrity of the vagus nerve is of great importance for normal gastrointestinal neuromodulatory and anti-inflammatory functions. Many previous studies have demonstrated high anatomical variability of the vagus nerve at the esophageal hiatus and in the abdomen [2, 18]. These variations are highly significant for surgeons to consider during operative procedures at the gastroesophageal junction. Injury to the vagus nerve is known to be a significant risk during gastrothoracic surgery, particularly commonly performed procedures such as antireflux surgery (ARS) and hiatal hernia repairs. Complication rates have been shown to be common after surgery affecting between 20 and 67% of patients. Inadvertent vagotomy causes significant delayed gastric emptying (gastroparesis) and may cause gastroesophageal reflux. These symptoms may be sufficiently severe to require reoperation, and the reoperation rate is significant [2, 7, 15, 17, 19]. Damage to the hepatic branch of the anterior vagus nerve during Laparoscopic Nissen Fundoplication has been reported to prolong the gallbladder emptying time (GET) increasing the risk of gallstones [5, 12]. In addition, the increasingly valuable technique of vagal nerve stimulation

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(VNS) relies on having an intact vagal nerve, and patients who have had vagal nerve damage cannot be treated by VNS. VNS is currently approved for management of intractable epilepsy, severe depression, inflammatory arthritis, and Crohn's disease [8, 13, 14]. Hundreds of clinical trials are currently underway, to examine the potential use of VNS to manage heart failure, stroke, Alzheimer's disease, traumatic brain injuries, asthma, diabetes, obesity, post-operative ileus and septic shock among others [3, 4, 6, 13, 20–22]. This study sought to validate and provide a reliable and detailed description and statistical analysis of the anatomical variation and distribution of the vagus nerve in the esophageal hiatus region in Uganda. Study findings could provide confirmation of the pattern of vagal innervation, and inform surgeons of anatomical variations to avoid accidental injury to the vagus nerve.

Materials and method

This was an analytical cross-sectional survey using 67 post-mortems on frozen bodies at Mbarara Regional Referral Hospital, the teaching hospital for Mbarara University of Science and Technology, and Mulago City Mortuary which is the main mortuary for Mulago National Referral hospital located in Kampala, the capital city of Uganda. The bodies were of patients who were unclaimed by relatives, the Ugandan legal position being that the bodies become property of the institution after a fixed period, and available for anatomical teaching and research. The routine post-mortem pathological dissection technique of the participating hospitals was used. A midline incision was made extending from the xiphoid process to the symphysis pubis. The incision was extended cranially through the sternum up to the suprasternal notch. Next, the diaphragm was stripped from the thoracic and abdominal wall attachments and its attachments to the pericardium and pleural membranes. The esophagus was cut approximately 2 cm superior to the esophageal hiatus. Then, all the abdominal visceral including the diaphragm were stripped and placed on the dissection table. The esophageal hiatus and the stomach were exposed by reflecting the lesser omentum and the left liver lobe laterally. We visually identified, examined and traced the distribution of the anterior and posterior vagus nerves noting variations. We used the diaphragmatic constriction (Inferior esophageal "sphincter") located approximately 2 cm superior to the gastroesophageal junction as a landmark [11] to identify patterns and variations by careful dissections and visual identification at this point. Data were collected using a pretested data collection form. Specimens were organized and labeled; and data obtained from each were registered on individualized charts. Data collection was done by the first author KR with an experienced mortuary assistant as a research assistant. Every 5th body was dissected by KR together with MG, an experienced anatomist to ensure external quality control. A high-resolution camera (4.3 megapixels) was used to take photographs to capture the entry and exit and the distribution pattern of the vagus nerve through the esophageal hiatus for possible future reference. Data were entered in a database developed in Epi-Info version6.0 and then exported into STATA software 13.0 for analysis.

Results

General information

In this study, 67 adult post-mortem cases (16 females and 52 males) were included (Table 1).

Distribution of anterior vagal trunk in esophageal hiatus

The most common pattern was single anterior trunk (65.7%) followed by biplexus (20.9%); triplexus (8.9%) and the least common was double-but-not connected (4.5%), (Figs. 1, 2, 3).

Distribution of posterior vagal trunk in esophageal hiatus

The most common pattern was single posterior trunk (85.1%) followed by biplexus (10.4%) and triplexus

Table 1 Distribution of vagus nerve through the diaphragmatic opening; double-but-not-connected means two separate trunks; biplexus means two interconnected trunks and triplexus means three interconnected trunks

Diaphragmatic opening distribution		
Characteristic	*N*	*n* (%)
Structure in hiatus of anterior trunk, *n* (%)	67	
Single		44 (65.7)
Double-but-not-connected		3 (4.5)
Biplexus		14 (20.9)
Triplexus		6 (8.9)
Structure in hiatus of posterior trunk, *n* (%)	67	
Single		57 (85.1)
Biplexus		7 (10.4)
Triplexus		3 (4.5)
Vagal overall trunks through diaphragm, *n* (%)	67	
2		41 (61.2)
3		14 (20.9)
4		8 (11.9)
5		4 (6.0)

Fig. 1 2 vagal trunks through diaphragm; A single anterior trunk marked with single arrow pointing to the left and a single posterior trunk marked by double arrows pointing to the left

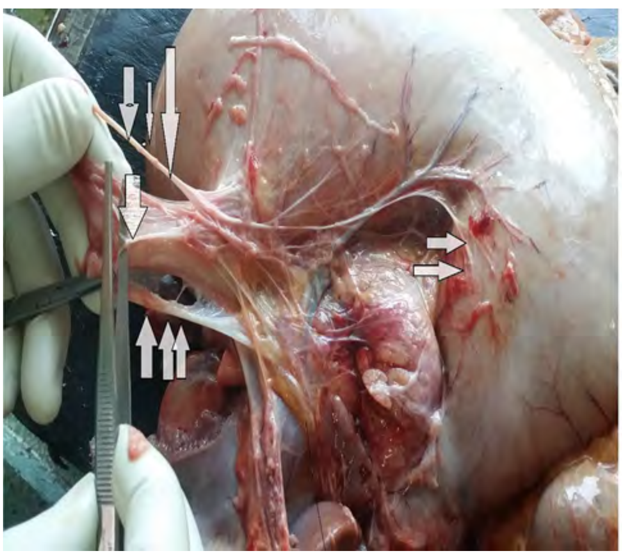

Fig. 2 3 vagal trunks through esophageal hiatus: an anterior biplexus marked by arrows pointing downward and a single posterior trunk marked by arrows pointing upwards

(4.5%). Generally, 34.3% and 14.9% of anterior and posterior trunks respectively were observed to go through esophageal hiatus as one of the many varieties of multiple trunk structures such as double trunks not connected, biplexus and triplexus. The number of trunks through the diaphragm ranged between 2 and 5 with 2 occurring most frequently (61.2%) and 5 least frequent (6%), (Fig. 4).

Distribution of the vagus nerve in the esophageal region across gender

There was no statistically significant ($p > 0.05$) variation across gender. The observed difference was absence of posterior vagus biplexus among all female participants (Table 2).

Discussion and conclusion

The study found a single posterior and a single anterior trunk as the most common pattern through the esophageal hiatus. The proportion of participants with single anterior trunk was 65.7%, with gender-specific proportions of 66.7% males and 62.5% females. The proportion of participants with single posterior trunks was 85.1%, with gender-specific percentages of 82.4% males and 93% females. Multiple trunks were also observed: 34.3% of cadavers had multiple anterior trunks, and 14.9% of the cadavers had multiple posterior trunks. The study did not find statistically significant ($P > 0.05$) difference of the vagus nerve in the esophageal region when analyzed by gender.

Our study result of 65.7% single anterior trunk was close to the 67% reported by Mitchell [10] in the United Kingdom; 67% by Ruckley et al. [16] in Scotland and 58% by Mackay and Andrews [9] in the United States of America (USA). However, it was considerably higher than 13% reported by Baccaro et al. [2] in Argentina. The latter study had a very small sample size of 15 specimens compared to 67 specimens utilized in our study which may explain their very different result.

Similarly, in our study, 85.1% of cases cadavers had a single posterior trunk through the esophageal hiatus. This finding was close to the 95% reported by Ruckley et al. [16] in Scotland, but higher than 60% observed by Alden [1] and 53% by Mitchell [10] elsewhere in the United Kingdom.

Multiple structures (double unconnected trunks, biplexuses and triplexuses) through the diaphragm were identified in this study, 34.3% in the anterior trunk, and 14.9% in the posterior trunk. Baccaro et al. [2] in Argentina reported 87% presence of multiple structures of the anterior trunk, while Alden [1] in the USA reported 78% multiple structures in the anterior trunk, and 20% multiple structures in the posterior trunk. These studies and our findings confirm findings that multiple structures are commoner in the anterior trunk than the posterior trunk. We noted that multiple vagal trunks were rarer in the female group in our study and a triplexus structure totally absent, although the numbers were too small to allow valid statistical sub analysis. There was a difference between the proportion of multiple structures between our study (34.3%) and the studies by Baccaro et al. [2] and Alden [1]. Our study and the two studies had very different sample

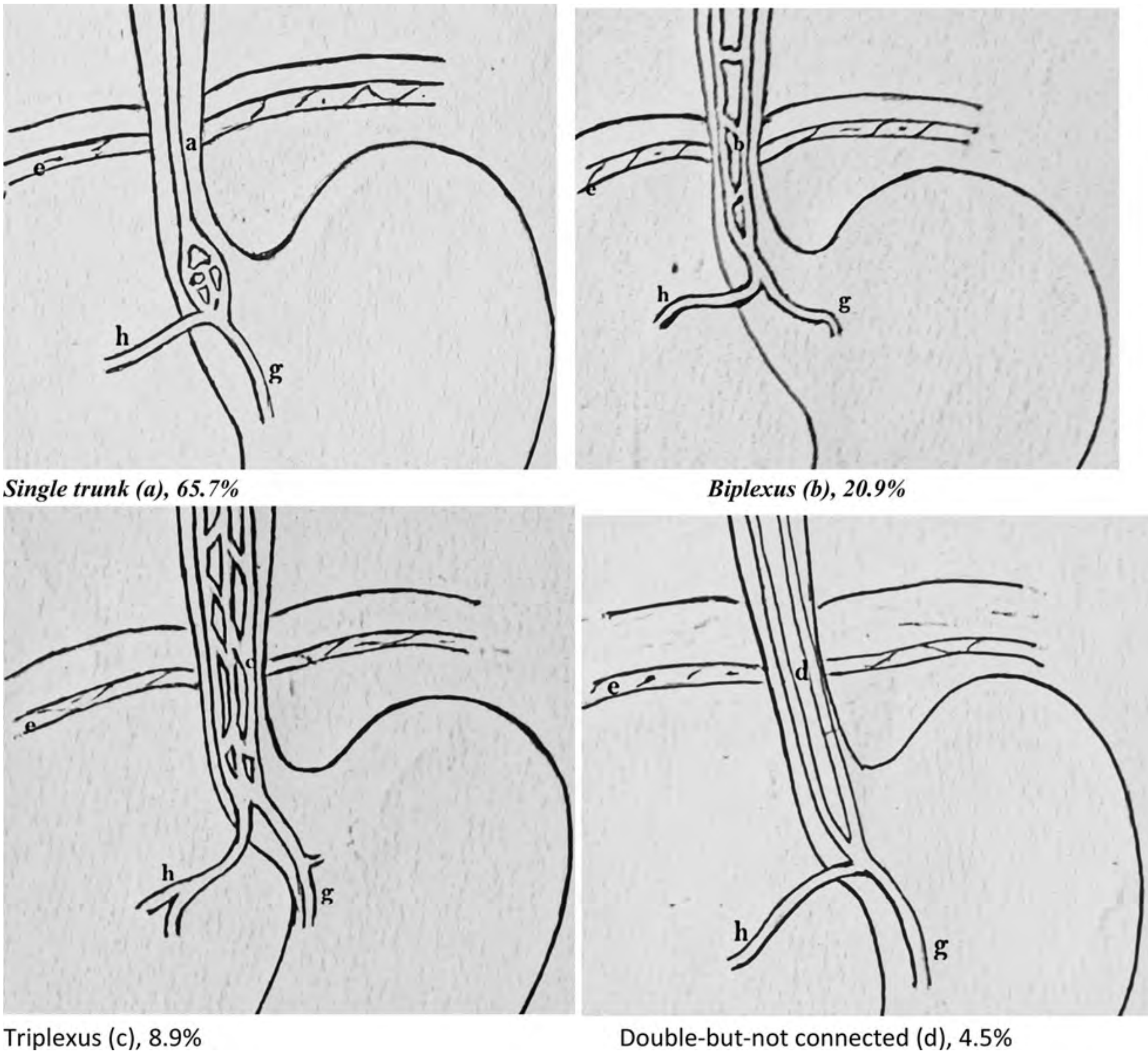

Fig. 3 Structural varieties of the anterior vagus nerve through the esophageal hiatus; (i) Single trunk (**a**), 65.7%; (ii) Biplexus (**b**), 20.9%; (iii) Triplexus (**c**), 8.9% and (iv) Double-but-not connected; (**d**), 4.5%; **h** is the hepatic branch of the anterior vagus nerve; **g** is the gastric branch of anterior vagus (of Laterjet); **e** is the diaphragm

sizes. The sample size was 67 in our study, while it was 15 for Baccaro et al. and 50 for Alden. The other possible explanation for the difference in the incidence of multiple vagal trunks could be differences in dissection and observation skills. The current study did not find statistically significant gender variations, and we were unable to find any previous studies that compared vagus nerve variations in esophageal hiatus across gender.

In summary, we would comment that, it is crucial for antireflux; hiatal hernia repair and surgical peptic Ulcer Disease (PUD) surgeons to have consideration for variations. It is particularly important for surgeons to recognize that, multiple vagal structures may exist in the hiatal area. Identification of single anterior and posterior trunks at operation is insufficient to avoid the possibility of producing injuries to vagal fibres, with possible life threatening complications resulting from the parasympathetic denervation of many vital organs distal to the esophageal hiatus [12, 17].

Conclusions

There is high variability in the distribution of the vagus nerve in the esophageal hiatus that is not related to gender differences. Surgeons must consider and identify variants of vagal innervation when carrying out surgery at the

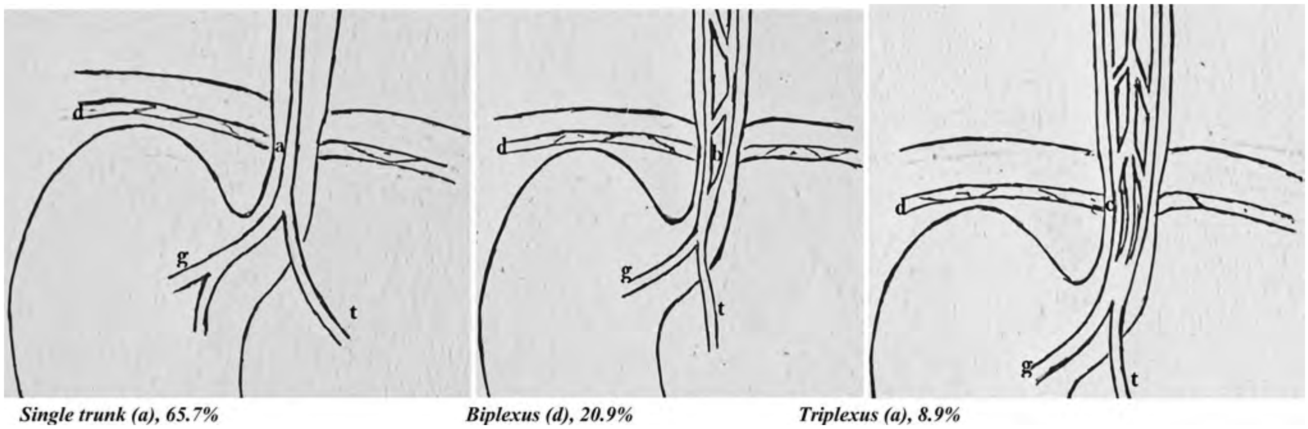

Fig. 4 Structural varieties of the posterior vagus nerve through esophageal hiatus: (i) Single trunk (**a**), 65.7%; (ii) Biplexus (**b**), 20.9%; (iii) Triplexus (**c**), 8.9%; **g** is the gastric branch of posterior vagus; and **t** is celiac branch of posterior vagus; **d** is the diaphragm

Table 2 Distribution of the vagus nerve in the esophageal hiatus across gender; Double-but-not-connected means two separate trunks; biplexus means two interconnected trunks and triplexus means three interconnected trunks

Characteristic	*N*	Overall *n* (%)	Gender		*p* value
			Male *n* (%)	Female *n* (%)	
Structure in hiatus of anterior trunk, *n* (%)	67				0.873
Single		44 (65.7)	34 (66.7)	10 (62.5)	
Double-but-not-connected		3 (4.5)	2 (3.9)	1 (6.2)	
Biplexus		14 (20.9)	10 (19.6)	4 (25.0)	
Triplexus		6 (8.9)	5 (9.8)	1 (6.3)	
Structure in hiatus of posterior trunk, *n* (%)	67				0.295
Single		57 (85.1)	42 (82.4)	15 (93.7)	
Biplexus		7 (10.4)	7 (13.7)	0 (0.00)	
Triplexus		3 (4.5)	2 (3.9)	1 (6.3)	
Overall vagal trunks through diaphragm, *n* (%)	67				0.942
2		41 (61.2)	31 (60.8)	10 (62.5)	
3		14 (20.9)	10 (19.6)	4 (25.0)	
4		8 (11.9)	7 (13.7)	1 (6.2)	
5		4 (6.0)	3 (5.9)	1 (6.2)	

gastroesophageal junction to avoid accidental vagal injuries. Published surgical techniques for preserving vagal function are valid in any part of the world.

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Author contributions RK: Project development, data collection or management, data analysis, manuscript writing/editing. GN: project development, data collection or management, manuscript writing/editing. MK: manuscript writing/editing. GM: project development, data collection, manuscript writing/editing. IOA: data analysis, manuscript writing/editing.

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Availability of data and materials The full dataset generated and analyzed during the current study are not publicly available for ethical reasons. However, deidentified data can be made available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Consent to participate Informed consent was waived because researchers only accessed unclaimed bodies that had no identified living relative(s) or legal representatives. Administrative permission was received from the Uganda police authorities, the custodians of all unclaimed bodies, before data collection.

Ethical approval Approval of this study was obtained from the Research Ethics Committee of Mbarara University of Science and Technology (Ref.No. MUREC1/7) and the Uganda National Council for Science and Technology (Ref. No. HS2223). The procedures used in this study adhered to the tenets of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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