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Distribution and Variability of the Abdominal Vagus Nerve: An Anatomical Study in Uganda

Distribución y Variabilidad del Nervio Vago Abdominal: Un Estudio Anatómico en Uganda

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SUMMARY: Iatrogenic injury to the vagus nerve during gastrointestinal surgery may result in postoperative complications due to disruption of its anti-inflammatory and neuromodulatory functions. Although anatomical variations of the abdominal vagus nerve have been described, data from African populations, particularly Uganda, remain limited. This study aimed to describe the distribution and anatomical variations of the abdominal vagus nerve. This analytical cross-sectional study was conducted on 67 unclaimed post-mortem human bodies. Dissections were performed using a standardized protocol, and anatomical findings were recorded using a pre-tested data collection form. Statistical analysis was performed using STATA version 13.0. The principal nerve of Latarjet was identified in 83.6 % of specimens, and a crow's foot pattern was observed in 80 %. A single hepatic branch was present in all specimens, while an anterior vagal plexus was identified in 32.8 %. The number of anterior gastric branches varied among specimens. A principal posterior nerve of the lesser curvature was present in 4.5 % of cases, and a single celiac branch was observed in all specimens. The first branch of the posterior trunk (criminal nerve of Grassi) was identified in 9 % of specimens. The number of posterior gastric branches ranged from three to eight, and the distance between the esophageal hiatus and the first gastric branch showed considerable variability. No statistically significant differences in vagal branching patterns were observed between individuals or between sexes. The abdominal vagus nerve demonstrates considerable variability in its distribution and branching pattern. Recognition of these variations is important during intra-abdominal surgical procedures to minimize inadvertent vagal injury.

KEY WORDS: Vagus nerve; Distribution; Variation; Abdomen; Uganda.

INTRODUCTION

The vagus nerve, also known as cranial nerve X or the "wandering nerve", is the longest cranial nerve and comprises both sensory and motor fibres. It provides the principal parasympathetic innervation to the gastrointestinal (GI) tract and abdominal organs, extending to the level of the proximal two-thirds of the transverse colon (Snell, 2010). Considerable inter-individual variation exists in the abdominal distribution of the vagus nerve (Skandalakis *et al*., 1980). Current descriptions of this distribution are often inconsistent, with most available data derived from studies conducted outside Africa, including populations in Argentina (Baccaro *et al*., 2013), and the United States of America (Boyd, 1949; Jackson, 1949; Skandalakis *et al*., 1980).

Vagal fibres are distributed throughout the GI tract, where they play a critical role in regulating food intake, digestion, epithelial barrier maintenance, and immune function (Stakenborg *et al*., 2013). Vagus nerve stimulation (VNS) enhances the secretion of gastric acid, insulin, glucagon, and pancreatic polypeptide, and strengthens intestinal barrier integrity through activation of enteric glial cells (EGCs). This activation promotes the release of S-nitrosoglutathione (GSNO), which up regulates tight-junction expression and preserves mucosal integrity (Rothschild *et al*., 1991). In addition, VNS inhibits mast-cell activation and stimulates the cholinergic anti-inflammatory pathway (CAP), mechanisms that facilitate

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resolution of innate immune responses by suppressing excessive production of gastrointestinal inflammatory cytokines(Kevin, 2016; Rothschild *et al*., 1991).

Consequently, accidental injury to the vagus nerve during intra-abdominal surgery may result in a wide range of postoperative complications, some of which can be life-threatening. These include recurrent peptic ulcer disease, post-vagotomy diarrhea, delayed gastric emptying, paralytic ileus, offensive belching, postprandial discomfort, cholelithiasis, and dumping syndrome, among others (Norman *et al*., 2008; Baccaro *et al*., 2013; Yolsuriyanwong *et al*., 2019). Furthermore, inadvertent vagotomy may impair the CAP, leading to persistent inflammation, which has been implicated in the pathogenesis of inflammatory bowel disease, sepsis, atherosclerosis, obesity, cancer, and other systemic conditions (Borovikova *et al*., 2000; Buijs *et al*., 2008; Andersson & Tracey, 2012; Wu *et al*., 2014; Tracey, 2015). In contrast, highly selective vagotomy, in which all potential abdominal vagal branches are carefully identified and preserved, has been associated with optimal outcomes and minimal postoperative morbidity (Johnston *et al*., 1975; David & Terrence, 2003; Philip, 2003).

Therefore, comprehensive knowledge of the abdominal distribution and anatomical variations of the vagus nerve within specific populations is essential for safe and effective abdominal surgery, with the aim of minimizing iatrogenic nerve injury and postoperative complications (Yamada *et al*., 2003). However, in Africa, and Uganda in particular, data on the distribution and variability of the abdominal vagus nerve remain scarce. This study therefore sought to provide a detailed and population-specific description of the anatomical distribution and variations of the abdominal vagus nerve in an African population. Such information may assist surgeons in reducing the incidence of accidental vagal nerve injury and associated postoperative complications following abdominal surgical procedures.

MATERIAL AND METHOD

Study design and setting

This was an analytical cross-sectional study. Data were collected from unclaimed bodies at the Kampala City Council Authority (KCCA) Mortuary in Kampala, the capital city of Uganda, and at the Mbarara Regional Referral Hospital/Mbarara University of Science and Technology (MRRH/MUST) Mortuary in Mbarara City, southwestern Uganda, located approximately 266 km from Kampala. The study was conducted between March and June 2017.

Study population, sample size and sampling

The study conveniently recruited all unclaimed bodies that met the inclusion criteria at the participating mortuary units during the data-collection period. The sample size was determined using Yamane's simplified formula for proportions (Yamane, 1967), and was estimated at 67 bodies, assuming a population size (N) of 80, representing the total number of unclaimed bodies expected during the study period based on mortuary records. A level of precision (e) of 0.05 was applied at a 95 % confidence interval

In this study, unclaimed bodies were defined as bodies at the mortuary for which no relatives had come forward to claim them within four weeks, after which such bodies were typically disposed of or donated to medical schools for anatomical teaching and research. However, in certain circumstances—such as limited storage space or malfunctioning mortuary freezers leading to accelerated decomposition—disposal could occur before two weeks had elapsed. Bodies that were grossly distorted due to decomposition were therefore excluded from the study.

The MRRH mortuary is administered by the referral hospital, whereas the KCCA mortuary is managed by the Uganda Police Force. The KCCA mortuary serves as the principal mortuary for the Kampala metropolitan area, with an estimated catchment population of approximately 4.3 million (World Population Review, 2025). Most unclaimed bodies were delivered by the police, commonly involving individuals who died during criminal activities, mob justice, or roadside incidents without identification. Additional cases included unclaimed hospital deaths. During the data-collection period, the KCCA mortuary also received bodies from Mulago National Referral Hospital (MNRH) due to the temporary closure of the MNRH mortuary for renovation.

Data collection procedure

The data collection procedure has been previous described (Ronald *et al*., 2021). A data collection form was developed based on previous related research (Boyd, 1949; Baccaro *et al*., 2013), and was pretested on two unclaimed bodies. In case of disagreements, a 3rd person was called as a tie-breaker. The data collection tool captured information on age, sex, and height of the bodies. The judgment of the age category of each body was done by the first author as a qualitative outcome (that is, child/ adult). The abdominal vagus nerve distribution and variation across gender was traced and documented from the esophageal hiatus, and the data collection tool captured information related to distribution of the vagus nerve namely: number of gastric posterior and anterior trunks; distance between esophageal hiatus and the first branch of the posterior and anterior vagal trunks ; presence/ absence of gastric vagal plexuses, criminal nerve of Grassi, principal posterior nerve of lesser curvature, and the principal nerve of Latarjet; number of gastric branches of the posterior and anterior vagal trunks; number of celiac branches of the posterior vagus trunk ; distance between first gastric branch and the hepatic branch as well as the most distal branch of the anterior vagus nerve; and the number of hepatic branches of the anterior vagus trunk.

Data was collected during the postmortem of bodies that fulfilled inclusion criteria in a previously published procedure (Ronald *et al*., 2021). A midline incision was made extending cranially from the symphysis pubis through to the xiphoid process, and the sternum up to the suprasternal notch. This was followed by stripping the diaphragm from its attachments to the thoracic and abdominal wall, the pericardium and pleural membranes. The esophagus was cut approximately 2 cm superior to the esophageal opening. 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 lobe of the liver laterally. We visually identified, examined, traced and documented the distribution of the anterior and posterior vagal trunks in the abdomen, noting variations. Distances were measured using a Vernier caliper (Vernier Caliper, DVLR-0605 0-6 INCH/150mm. Mitutoyo, Tokyo, Japan). Data was collected by the first author with an experienced mortuary assistant as a research assistant and a senior pathologist who opened the bodies to expose the abdominal viscera in accordance with specific mortuary dissection guidelines. Every 5th body (about 10 % of the bodies) was dissected in the presence of a senior anatomist for quality control. A high-resolution camera was used to take photographs to capture distribution pattern of the vagus nerve through the esophageal hiatus for possible future reference.

Data management and analysis

All data capture forms were checked for completeness prior to data entry. The data was entered in a database developed in Epi-Info version 6.0 and appropriate cleaning of data was done. The data base was imported in STATA software 13.0 for analysis. The characteristics of postmortem bodies were described using appropriate summary statistics including means for continuous variables (e.g. height, distances) and proportions for categorical variables (e.g. age category and gender). Proportions were used to describe the various types of vagal nerve distributions through the diaphragmatic opening, on the stomach, spleen, and liver. Univariate analysis using chi-square test was conducted to establish the overall variation of the vagus nerve distribution in the abdomen and entry through the diaphragm and across gender. Other variables especially age category and height were also included in this analysis. A significance level of 5 % was used.

Ethical considerations

The authors hereby confirm that every effort was made to comply with all local and international ethical guidelines and laws concerning the use of human cadaveric donors in anatomical research. Ethical approval was obtained from the Mbarara University of Science and Technology Research Ethics Committee (MUREC1/7) and the Uganda National Council for Science and Technology (HS2223). Administrative clearance was obtained from the Uganda Police Force prior to study initiation. The study was conducted in accordance with the Declaration of Helsinki and national guidelines (Shrestha & Dunn, 2020) , with strict respect for the dignity and confidentiality of the deceased. All bodies were returned to the respective mortuaries for disposition in line with standard operating procedures for unclaimed bodies.

RESULTS

Sociodemographic characteristics of study participants

The study included 67 unclaimed post-mortem cases, predominantly male (76.1 %), with an estimated age range of 14–80 years (Table I). Most cases were from KCCA City Mortuary (95.5 %), with a small proportion from MRRH/MUST Mortuary (4.5 %). The mean height of participants was 165.8 ± 8.6 cm. Variations across gender were not statistically significant but generally, females had fewer branches (Table II).

Vagus nerve distribution to the liver and spleen.

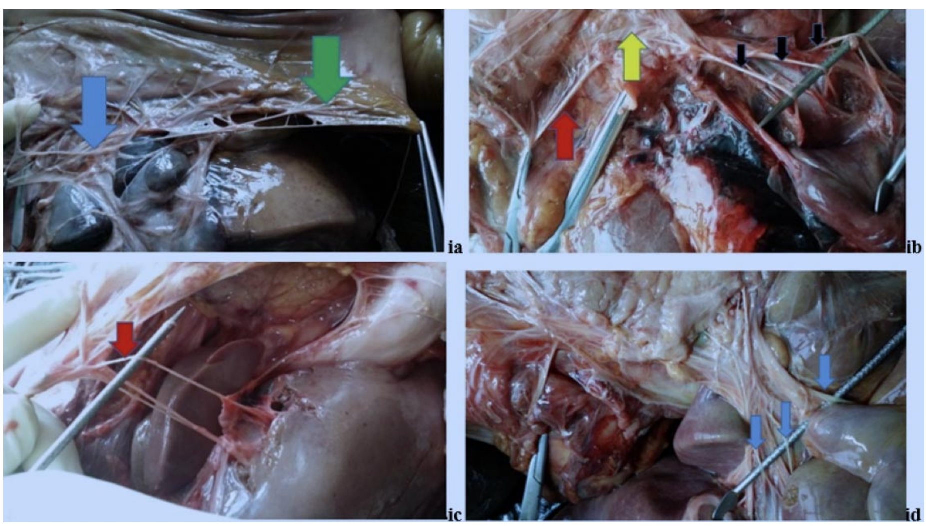
The hepatic plexus divided into multiple small branches ranging from 2 to 6, with four branches being most common (35.9 %) and six branches least frequent (7.7 %). In the majority of cases (91 %), the hepatic branch of the anterior vagus nerve entered the liver without giving off any divisions. The number of splenic plexus divisions ranged from 3 to 7, with three and four divisions being the most frequently observed patterns. Figs. 1a,b.

Table I. Demographic characteristics and distribution of vagal part of autonomic division on the stomach among partipants (N= 67).

Posterior vagal trunk distribution		**Overall N (%)**	**Sex Male n (%)**	**Female n (%)**	**p-value**
Number of gastric posterior trunk					1.000
	1	63 (94.0)	48 (94.1)	15 (93.7)	
	2	**1 (1.5)**	**1 (2.0)**	**0 (0.0)**	
	3	3 (4.5)	2 (3.9)	1 (6.3)	
Distance (cm) between esophageal hiatus and first branch of posterior vagal trunk, mean (SD)		1.2 (0.7)	1.18 (0.66)	1.29 (0.73)	0.567
Distance(in cm) between first gastric branch and celiac branch of posterior vagal trunk, mean (SD)		O.6 (0.45)	0.61 (0.46)	0.55 (0.46)	0.674
Presence of the first branch of the posterior vagal trunk					1.000
(criminal nerve of Grassi), n (%)		61 (91.0)	46 (90.2)	15 (93.8)	
Absent		6 (9.0)	5 (9.8)	1 (6.2)	
Present					
Number of gastric branches of the posterior vagal trunk, n (%)					0.491
	2	3 (4.5)	2 (3.92)	1 (6.25)	
	3	15 (22.4)	11 (21.57)	4 (25.00)	
	4	26 (38.8)	21 (41.18)	5 (31.25)	
	5	16 (23.8)	10 (19.61)	6 (37.50)	
	6	**6 (9.0)**	**6 (11.76)**	**0 (0.00)**	
	7	**1 (1.5)**	**1 (2)**	**0 (0.00)**	
Number of celiac branches of the posterior vagal trunk, n (%)					
	1	67 (100)	51(100)	16(100)	
Presence of principal posterior nerve of lesser curvature, n (%)					0.139
Absent		64 (95.5)	50 (98.0)	14 (87.5)	
Present		3 (4.5)	1 (2)	2 (12.5)	
Anterior vagal trunk		**Overall**	**Sex Male**	**Female**	**p-value**
Number of gastric anterior vagal trunk, n (%)					0.741
	1	53 (80.3)	40 (80.0)	13 (81.3)	
	2	10 (15.2)	7 (14.0)	3 (18.7)	
	3	**3 (4.5)**	**3 (6.0)**	**0 (0.0)**	
Distance (in cm) between esophageal hiatus and first branch of anterior vagal trunk, mean (SD)		1.2 (0.7)	1.16 (0.66)	1.23 (0.74)	0.751
Distance (in cm) between first gastric branch and hepatic branch of anterior vagal trunk, mean (SD)		0.5 (0.6)	0.61 (0.64)	0.28 (0.25)	0.052
Presence of anterior nerve of lesser curvature (principal nerve					0.716
of Latarjet), n (%)		**11 (16.4)**	**8 (15.7)**	**3 (18.8)**	
Absent		56 (83.6)	43 (84.3)	13 (81.2)	
Present					
Distance between the first gastric branch and the most distal point of the anterior nerve of lesser curvature (principal nerve of Latarjet), mean (SD)		15.5 (2.3)	15.8 (2.35)	14.5 (2.04)	0.0743
Presence of crow of foot, n (%)					0.720
Absent		13 (20.0)	9 (18.4)	4 (25.0)	
Present		**52 (80.0)**	**40 (81.6)**	**12 (75.0)**	
Number of gastric anterior branches, n (%)					0.544
	2	2 (3)	2 (3.92)	1 (6.25)	
	3	12 (17.9)	10 (19.61)	2 (12.50)	
	4	13 (19.4)	10 (19.61)	3 (18.75)	
	5	22 (32.8)	16 (31.37)	5 (31.25)	
	6	13 (19.4)	8 (15.69)	5 (31.25)	
	7	**4 (6)**	**4 (7.84)**	**0 (0.00)**	
	11	**1 (1.5)**	**1 (2)**	**0 (0.00)**	
Number of hepatic branches of anterior vagal trunk, n (%)					
	1	1 (100)	51 (100)	16 (100)	0.239
Presence of anterior gastric vagal plexus, n (%)					1.000
Absent		45 (67.2)	34 (66.7)	11 (68.8)	
Present		22 (32.8)	17 (33.3)	5 (31.2)	

Table II. showing gender variation and distribution of the vagus nerve to the liver and spleen.

Characteristic			**Sex**		**p-value**
		Overall n (%)	**Male n (%)**	**Female n (%)**	
Hepatic plexus branches along the hepatic artery and bile duct, n (%)					0.384
	2	5 (12.8)	3 (9.7)	2 (25.0)	
	3	9 (23.1)	7 (22.6)	2 (25.0)	
	4	14 (35.9)	11 (35.5)	3 (37.5)	
	5	8 (20.5)	8 (25.8)	0 (0.0)	
	6	3 (7.7)	2 (6.4)	1 (12.5)	
Number of hepatic branch divisions before entry into the liver, n (%)					
	0	61 (91.0)	47 (92.2)	14 (87.5)	0.323
	2	3 (4.5)	2 (3.9)	1 (6.3)	
	3	2 (3)	2 (3.9)	0 (0.0)	
	6	1 (1.5)	0 (0.0)	1 (6.2)	
Number of splenic plexus branches to spleen, n (%)					
	3				0.436
	4	13 (41.9)	10 (41.7)	3 (42.9)	
	5	12 (38.7)	9 (37.5)	3 (42.9)	
	6	4 (12.9)	4 (16.7)	0 (0.0)	
	7	1 (3.2)	0 (0.0)	1 (14.2)	
		1 (3.2)	1 (4.1)	0 (0.0)	



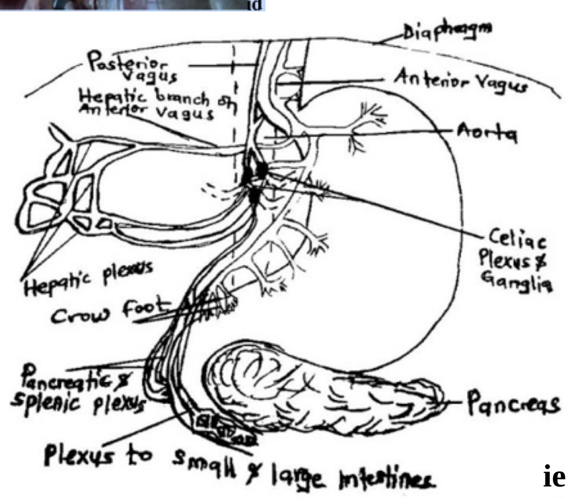


Fig. 1. Schematic diagram showing distribution vagal part of autonomic division. (**ia**) Anterior gastric branches showing the anterior nerve of lesser curvatura (principal nerve of Latarjet (blue arrow) and the crow's foot pattern (green arrow). (**ib**) Posterior vagal trunk (red arrow) terminating in the celiac plexus (yellow arrow), with hepatic, pancreatic, and splenic plexuses arising from the celiac plexus. (**ic**) Hepatic branch arising from the anterior vagal trunk (red arrow). (**id**) Divisions of the hepatic plexus within the portal hepatis prior to entry into the liver (blue). (**ie**) Schematic representation of the abdominal distribution of the nerves of the vagal part of autonomic division.

DISCUSSION

This study provides detailed morphological data on the abdominal distribution of the vagus nerve in a Ugandan population, addressing a notable gap in African anatomical literature. The findings reinforce the concept that vagal anatomy in the abdomen is highly variable, with important implications for surgical anatomy, neuromodulation, and visceral organ function.

The anterior vagus trunk demonstrated considerable variability in branching pattern and spatial relationships. The principal nerve of Latarjet was present in 83.6 % of participants, and the characteristic crow's foot pattern was observed in 80 %, proportions comparable to those reported by Sukumar *et al*. (2013) and Jackson (1949) , though lower than the 100 % prevalence reported by Shukla & Gohiya (2014). These differences underscore population-level morphological variability and emphasize that textbook descriptions may not reliably predict individual anatomy. The number of anterior gastric branches ranged from 3 to 12, with 4–7 branches accounting for nearly 90 % of cases, consistent with observations by Baccaro *et al*. (2013) and Jackson (1949). Such variability is of particular importance during selective gastric vagotomy and anti-reflux procedures, where inadvertent division of accessory gastric branches may lead to incomplete denervation or postoperative complications (Donahue, 2000; Okafor, 2015). Furthermore, a single hepatic branch was present in all specimens, contrasting with Jackson's report (Jackson, 1949) of its absence in 14 % of cases. Preservation of this branch is critical, as it contributes to hepatobiliary function and pyloric regulation (Donahue, 2000; Okafor, 2015). Additionally, the study revealed variable distance between the first gastric branch and the hepatic branch of anterior vagus variable across gender whereby it was less than 1 cm in all females (100 %) and only less than 1 cm in 82.3 % of male participants. The absence of comparable published data on the distance between the first gastric branch and the hepatic branch highlights the novelty of this study and its contribution to surgical topographic anatomy.

The posterior vagus trunk also exhibited marked variability. Posterior gastric branches ranged from 3 to 8, with 4–6 branches predominating. The criminal nerve of Grassi was identified in only 9 % of participants, a substantially lower prevalence than the 38 % reported among European populations (Jackson, 1949), suggesting possible ethnic or population-based anatomical differences. Failure to identify and divide this nerve during vagotomy has been implicated in recurrent peptic ulcer disease, underscoring its clinical relevance. The distance between the esophageal hiatus and the first posterior gastric branch was less than 2 cm in most cases, a finding that differs slightly from earlier reports by Boyd (1949). Such variations are clinically significant during esophageal and gastric surgeries, where misidentification of branching points can result in incomplete vagal interruption or unintended nerve damage.

With regard to the distribution of the vagus nerve to the liver and the spleen, this study found a hepatic plexus, in all participants , with variable branches between 2 and 6, the highest being 4 (35.9 %), followed by 3 and 5 (23.1 % and 20.5 % respectively). The hepatic branch divided into 2 to 6 branches just before entry into the liver in 9 % of participants. Some of the terminal hepatic branches occasionally anastomosed with hepatic plexus branches and appeared to extend up to the pyloric and duodenal regions, and to anastomose with branches from the celiac plexus. The spleen was supplied by branches of the splenic plexus along the course of distribution of the splenic artery up to the hilar region. No comparative studies on distribution of vagus nerve to spleen and liver were identified. This information is critical to avoid injury of vagus nerve supply to the liver and spleen which may be related with cholelithiasis in the former and failure of the Cholnergic Anti-inflammatory Pathway (CAP) , leading to non-resolution of inflammation which is implicated in the pathogenesis of inflammatory bowel disease, sepsis, atherosclerosis, obesity, cancer and many other conditions (Borovikova *et al*., 2000; Buijs *et al*., 2008; Andersson & Tracey, 2012; Wu *et al*., 2014; Tracey, 2015).

CONCLUSION

Collectively, these findings highlight that vagal anatomy cannot be assumed to follow a uniform pattern. The absence of statistically significant gender differences suggests that variability is more likely attributable to individual or population-level morphological factors rather than sex. For surgeons, gastroenterologists, and internationalists, awareness of these variations is essential to reduce iatrogenic nerve injury, avoid incomplete vagotomies, and optimize outcomes in upper gastrointestinal and hepatobiliary surgery.

Study limitations. The study was limited by incomplete demographic data due to the use of unclaimed postmortem bodies, restricting ethnic or geographical generalization without caution. Additionally, the cross-sectional nature and rapid specimen processing limited opportunities for re-examination. This was minimized by taking pictures for future reference. Difficulty in tracing fine neural branches to the pancreas and intestines due to limited magnification may have resulted in underestimation of minor branches.

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Conflict of interest. The authors declare that they have no conflict of interest.

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RESUMEN: La lesión iatrogénica del nervio vago durante la cirugía gastrointestinal puede provocar complicaciones postoperatorias debido a la alteración de sus funciones antiinflamatorias y neuromoduladoras. Si bien se han descrito variaciones anatómicas de la división autonómica vagal, los datos de poblaciones africanas, en particular de Uganda, son limitados. Este estudio tuvo como objetivo describir la distribución y las variaciones anatómicas del nervio vago abdominal. Este estudio transversal analítico se realizó en 67 cadáveres humanos no reclamados. Las disecciones se llevaron a cabo siguiendo un protocolo estandarizado y los hallazgos anatómicos se registraron mediante un formulario de recolección de datos previamente validado. El análisis estadístico se realizó con STATA versión 13.0. El nervio principal de la curvatura menor se identificó en el 83,6 % de los especímenes y se observó un patrón en pie de gallo en el 80 %. En todos los especímenes se encontró una rama hepática única, mientras que en el 32,8 % se identificó un plexo vagal anterior. El número de ramas gástricas anteriores varió entre los especímenes. Se observó un nervio posterior principal de la curvatura menor en el 4,5 % de los casos, y un único ramo celíaca en todos los especímenes. El primer ramo del tronco vagal posterior se identificó en el 9 % de los especímenes. El número de ramos gástricos posteriores osciló entre tres y ocho, y la distancia entre el hiato esofágico y el primer ramo gástrico mostró una variabilidad considerable. No se observaron diferencias estadísticamente significativas en los patrones de ramificación vagal entre individuos ni entre sexos. El nervio vago abdominal presenta una variabilidad considerable en su distribución y patrón de ramificación. El reconocimiento de estas variaciones es importante durante los procedimientos quirúrgicos intraabdominales para minimizar las lesiones vagales inadvertidas.

PALABRAS CLAVE: Nervio vago; Distribución; Variación; Abdomen; Uganda.

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