Original Communication

THORAX-ABDOMINAL VAGUS NERVES IN FETUSES

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RESUMEN

Los nervios vagos han sido exhaustivamente estudiados en los adultos pero no en los niños, y mayormente en el trayecto intracraneal, más que en la periferia. El objetivo de este estudio fue proveer información más específica sobre los nervios vagos toraco-abdominales, describirlos en fetos y asociarlos con la rotación gástrica, de modo que pueda ser aplicada a procedimientos clínicos, reduciendo la morbilidad. Se disecaron treinta fetos entre 12 y 23 semanas de gestación, mayormente varones (87%), desde la parte inferior del cuello hasta el cardias, identificando los troncos y ramas de los nervios vagos. Los nervios fueron descriptos en su ingreso en el tórax en relación con las arterias carótidas, en su posición en el tercio superior del esófago asociados con el origen de las ramas cardíacas y pulmonares, en el tercio inferior del esófago con muchas variaciones en su distribución, a nivel diafragmático en el hiato esofágico y, finalmente, en relación con la posición gástrica. La discusión involucró descripciones hechas por diferentes autores incluyendo algunos estudios recientes que proporcionan resultados electrofisiológicos y consideraciones de aspectos clínicos, principalmente representados por procedimientos quirúrgicos y su morbilidad, ambos asociados con la lesión de los nervios vagos.

***Palabras clave**: Nervios vago, inervación del esófago, esófago torácico, anatomía, anatomía quirúrgica.*

ABSTRACT

Vagus nerves have been extensively studied in adults but not in fetuses, and mostly in the intracranial pathway than the peripheral one. The objective of this study was to provide more specific information on the thorax-abdominal vagus nerves, to describe them in fetuses and to associate them with the gastric rotation, so it could be applied to clinical procedures, reducing morbidity. Thirty fetuses between 12 to 23 weeks of gestation, mainly male (87%), were dissected from the lower neck to the cardias, identifying vagus nerve trunks and braches. Vagus nerves were described at the entrance in the thorax in relation with the carotid arteries, in their position at the upper third of the esophagus associated with the origin of cardiac and pulmonary branches, in the lower third of the esophagus with many variations in their distribution, at the diaphragmatic level in the esophageal hiatus and, finally, in relation with the gastric position. The discussion involved descriptions made by different authors including some recent studies providing electrophysiological results and considerations on clinical aspects, mainly represented by surgical procedures and their morbidity associated, both to vagus nerve injury.

***Key words**: Vagus nerves, esophageal innervation, thoracic esophagus, anatomy, surgical anatomy*

INTRODUCTION

Vagus nerves have been extensively studied in adults but not in fetuses, and mostly in the intracranial pathway than the peripheral one. (Testut and Latarjet, 1973; Williams and Warwick, 1992; Sadler and Langman, 2007; Takassi et al, 2013).

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Even if we could assume these nerves should not significantly vary from fetal to adult life, knowledge of anatomical details may be particularly important at the moment of certain clinical procedures (mainly surgical ones) in children. Combination of data of adult and fetal specimens may provide comprehensive information at the time of clinical decisions.

In the literature, vagus nerves final position at diaphragmatic level has been associated to the gastric rotation occurred between the 4th and 7th week of gestation (Prives, 1985; Zuidema, 1999; Sadler and Langman, 2007). Based on this concept, vagus nerves may vary their location in the lower third of the thorax and the abdominal part of the esophagus, following the stomach changes.

The objective of this study was to provide more specific information on the thoraco-abdominal vagus nerves, to describe them in fetuses and associate them with the gastric rotation, so it could be applied to clinical procedures, reducing morbidity.

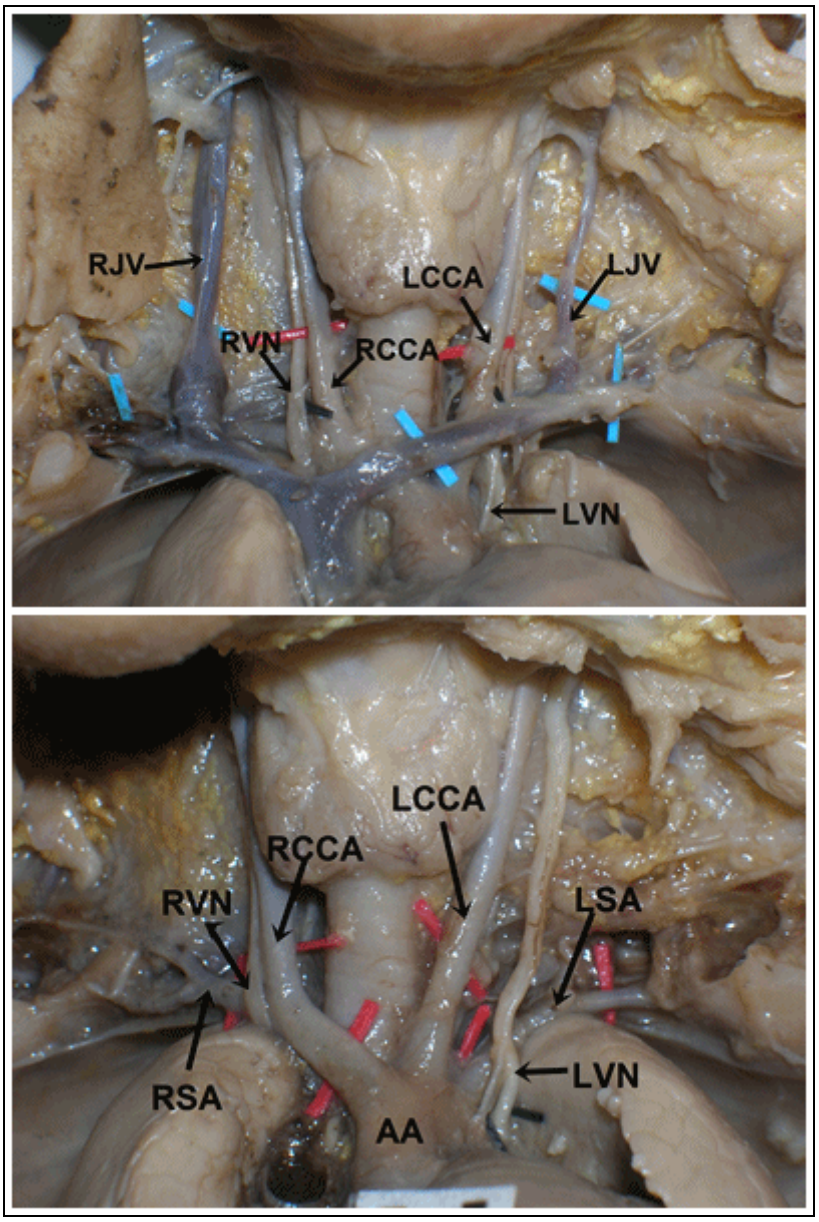

Figure 1.- Dissection of the neck and upper thorax. Vagus nerves at the entrance in the thorax. **RVN**-Right vagus nerve. **LVN**-Left vagus nerve. **RCCA**-Right common carotid artery. **LCCA**-Left common carotid artery. **RJV**-Right internal jugular vein. **LJV**-Left internal jugular vein. **AA**-Aortic arch. **RSA**-Right subclavia artery. **LSA**-Left subclavia artery.

MATERIAL AND METHODS

Thirty fetuses from the University Hospital of Maternity (provided after approval of the Hospital Ethical Committee), between 12 to 23 weeks of gestation (mean age: 17.31 weeks), were dissected from the lower neck to the cardias. Age was determined by crown-pump length. Most of them (87%) were male and only four were female. Instead we tried to keep the relations with the neighbouring anatomical structures as far as possible, cardiac branches always and pulmonary branches sometimes had to be cut to allow the nerve dissection around the esophagus under the level of the hilum of lung. The trachea was partially removed in its lower half and the heart was displaced laterally, usually to the right side. The diaphragm was opened to allow to complete the dissection and to let us the observation of the stomach position. Trunk and braches of the vagus nerves were carefully dissected to identify their location and relations among themselves and to the esophagus and cardias.

RESULTS

Vagus nerves entered the thorax laterally to the common carotid arteries and included in the same sheath. Internal jugular veins were laterally but significantly separated from each side nerve and artery in younger fetuses (Fig. 1). At this level nerve thickness compared to the artery was bigger than in adults; the diameter of the nerves was approximately half of the diameter of the arteries. They introduced into the mediastinum by passing in front of the subclavia artery and the arch of Aorta, and giving the inferior laryngeal nerve (recurrent). In one case, the right subclavia artery came from the left pulmonary artery and it was the only opportunity the right vagus nerve passed behind the aberrant vessel (Fig. 2). The left nerve is flexuous and longer than the right one in this upper region (Fig.1).

Pulmonary and cardiac branches had their origin a little over the hiium level. In this study we only found one right pulmonary branch given by the right nerve, while the left nerve provided the cardiac and left pulmornary branches (Fig. 3).

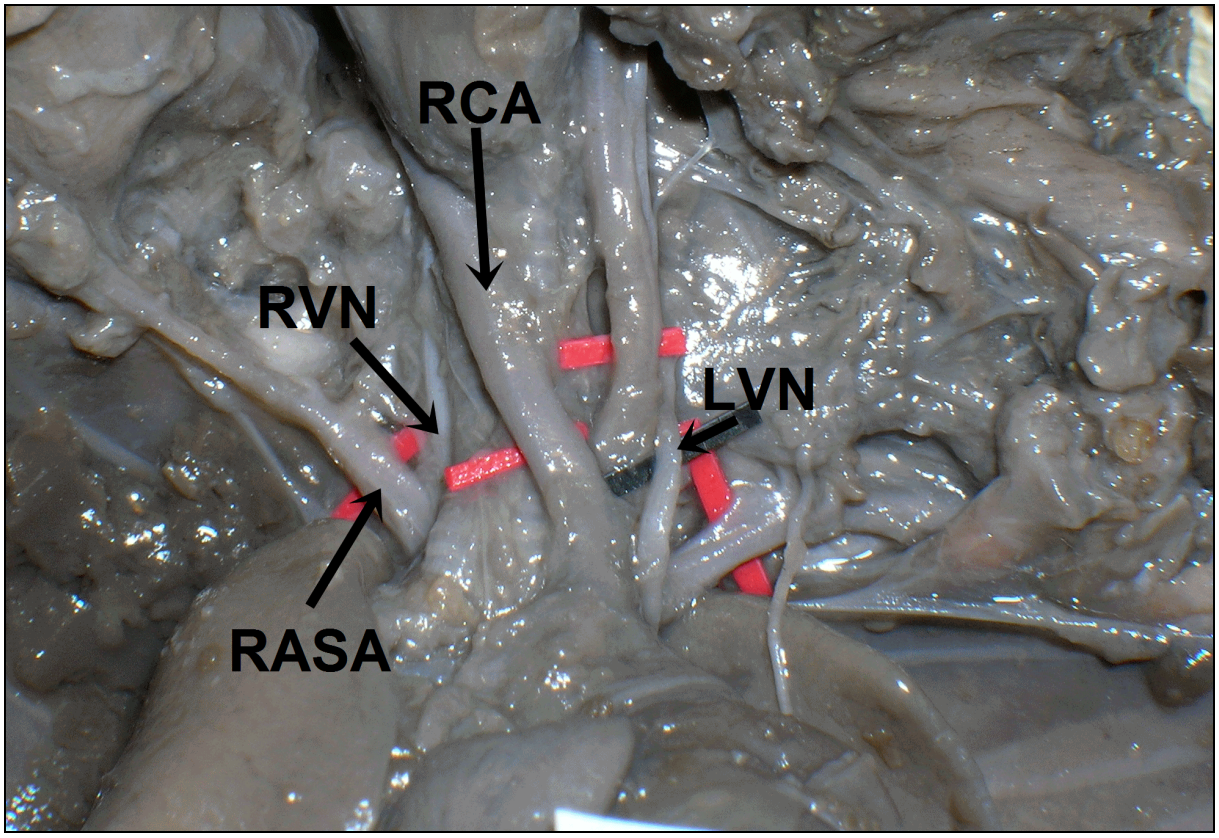

Figure 2.- Relation between the aberrant right subclavia artery and the right vagus nerve. **RASA**-Right aberrant subclavia artery. **RVN**-Right vagus nerve. **RCA**- Right common carotid artery. **LVN**-Left vagus nerve.

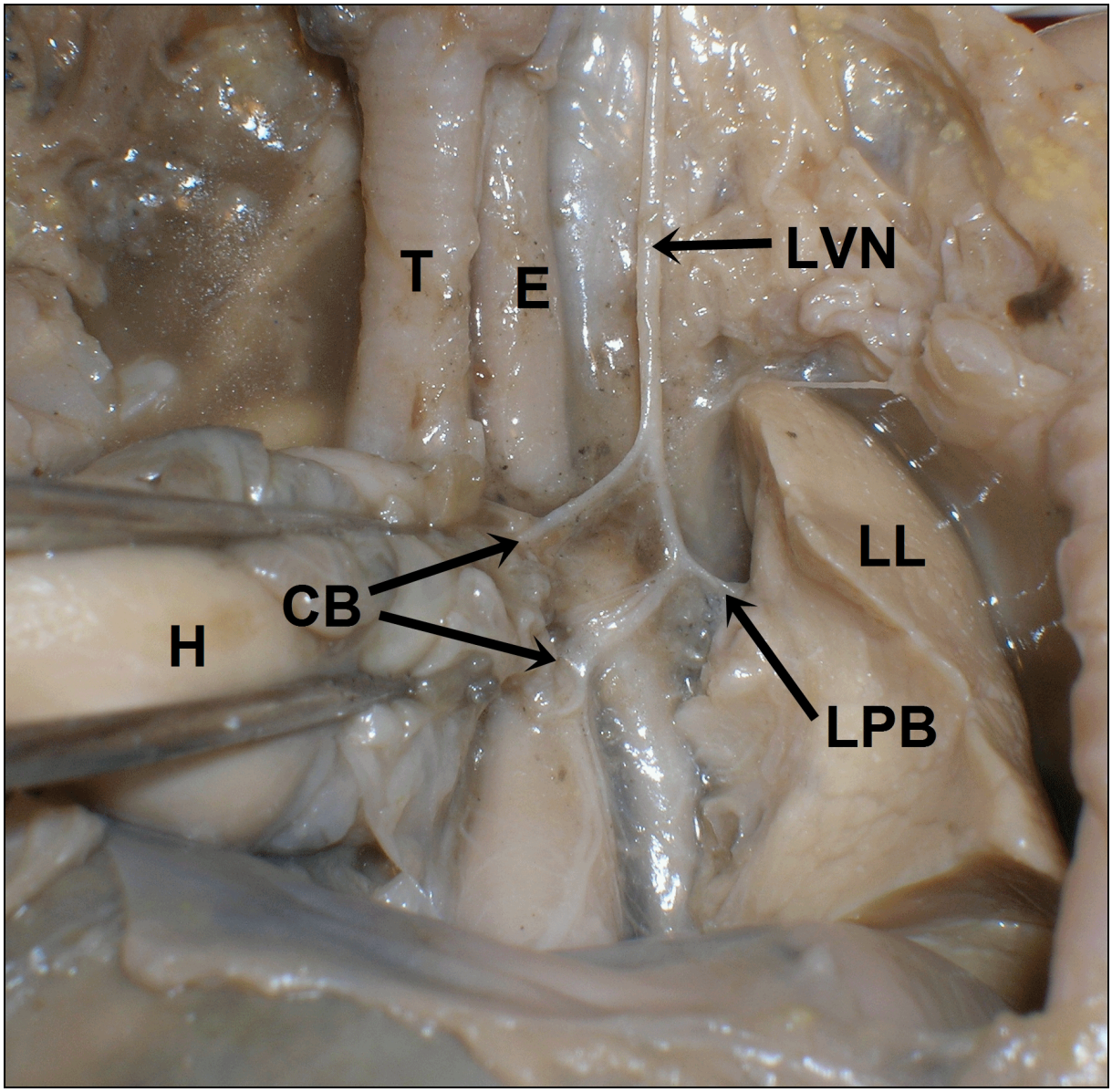

Figure 3.- Cardiac and pulmonar branches of the left vagus nerve. **E**-Esophagus. **T**-Trachea. **H**- Heart, **LL**-Left lung, **LVN**-Left vagus nerve. **CB**-Cardiac brances. **LPB**-Left pulmonary branch.

Cardiac branches found in this study were usually one, except 2 cases where we found two branches, both coming from the left vagus nerve. Left pulmonary branches were 2 in only three cases and only 1 in the rest. Pulmonar braches entered the hilum of the lung anteriorly respect to the bronchi.

According to our observations, the distribution and position of vagus nerves under the hilum level is variable and complex. They are right in contact with the esophagus but their position is not constant. In 26.66% of the cases the right nerve was posterior to the esophagus, in 16.66% it was anterior, in 13.33% it was passing from anterior to posterior next to the hiatus, in 16.66% it was lateral, in 10% it was coming from the lateral to the frontal position, in 10% it was lateral passing to posterior and in 10% of the cases it was lateral going backward. In 2 specimens there were 2 right branches: one (3.33%) with anterior and posterior branches and another (3.33%) with one branch coming from anterior to lateral and the other passing from posterior to lateral side of the esophagus. (Fig. 4)

The left vagus nerve was lateral moving to the anterior side of the oesophagus in 46.66% of the total cases, in 23.33% it was anterior all along the infrahilliar section, in 20% it was lateral and in 10% it was anterior passing to the posterior side. (Fig. 4)

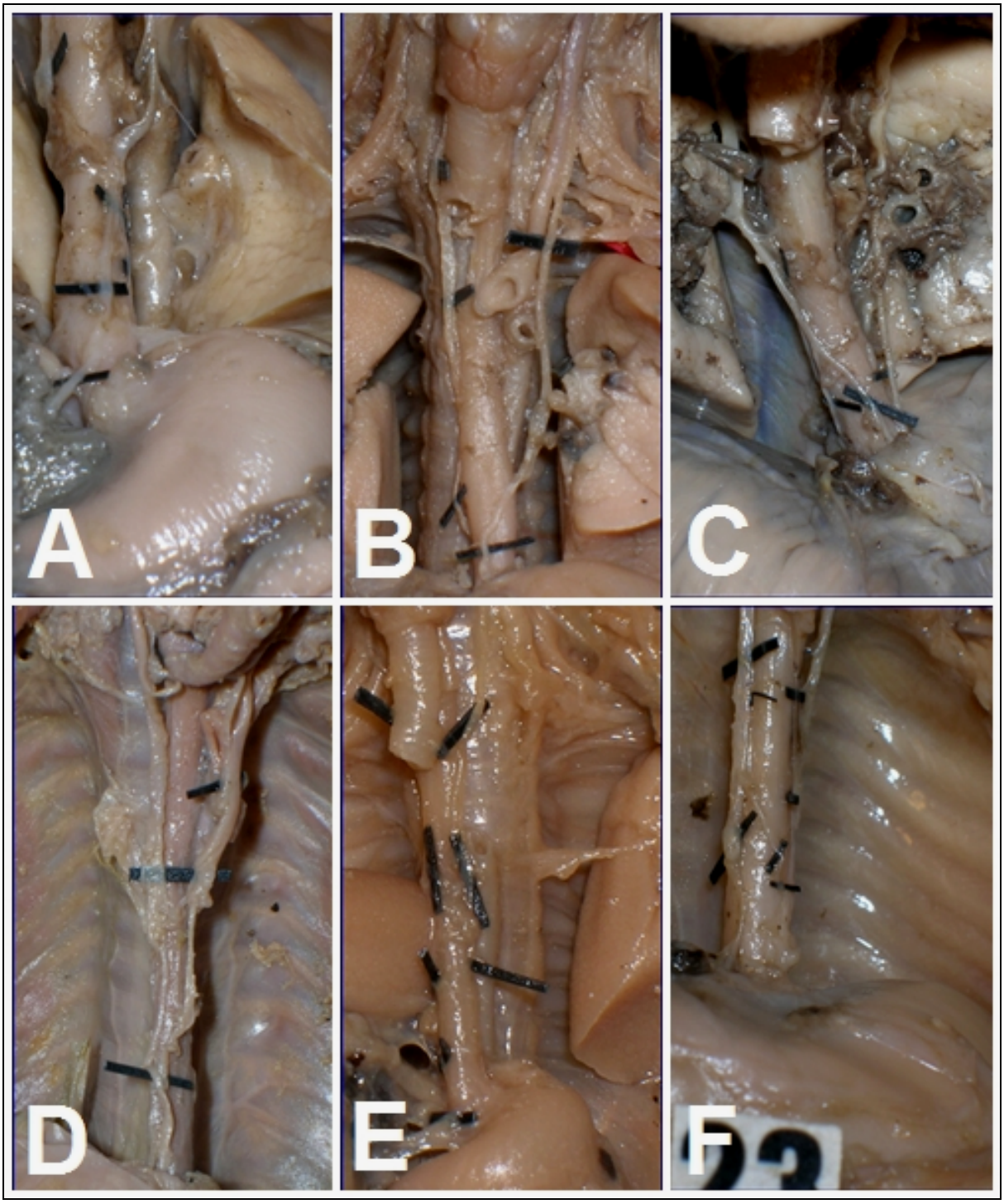

Figure 4.- Different position of the vagus nerves in the lower third of the esophagus. **A**-Most common position (right nerve posterior and left nerve anterior). **B**-Right nerve lateral. **C**-Two branches (anterior and posterior) on the right side. **D**-Both nerves anteriorly. **E**-Both nerves lateral. **F**-Esophageal plexus.

Instead of the described positions of the main nervous trunks, in 36.66% of the cases both nerves had multiple anastomosis around the oesophagus, forming an esophageal plexus. (Fig. 4)

Only in 30% of the total dissections, both nerves occupied the usually described location at the hiatus (left nerve anterior and right nerve posterior to the esophagus (Fig. 4).

In 2 cases we found a still unrotated stomach. In those fetuses the left nerve passed by the anterior side of the stomach and the right nerve passed posteriorly, even if in one case it was divided in multiple branches (Fig. 5).

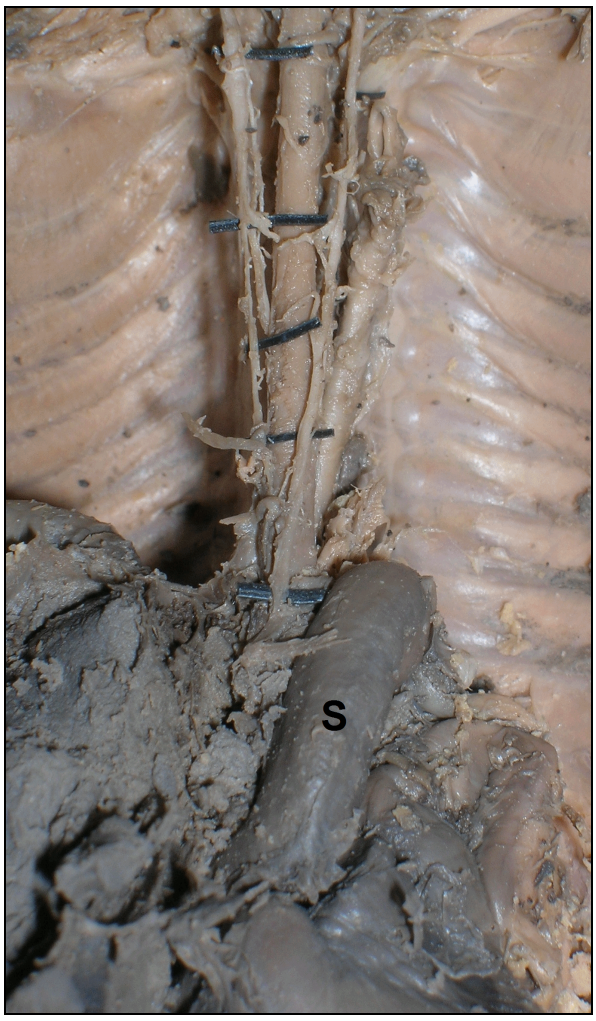

Figure 5.- Unrotated stomach with the right vagus nerve posterior and the left vagus nerve anteriorly located at the level of the esophageal hiatus. Nerves are shown overlying on black ribbons. **S**-Stomach

DISCUSSION

Miyake et al (2010) studied 15 fetuses from 9 to 25 weeks of gestation and considered vagus nerves had high propensity to change their topographical relation to the common carotid artery "from a primitive ventral course to a final dorsal course" in fetuses from 9 to 20 weeks of gestation. Even if our study did not include the nerves cervical pathway, these results differed from our findings and the lateral position of vagus nerves informed at lower part of the neck and upper of the thorax. Same authors (Miyake et al, 2010) considered the common carotid sheath appeared at or after the 20 weeks, but we found it in all our specimens and including the homolateral vagus nerve.

Cardiac innervation depends on autonomic branches including vagus and cervical sympathetic nerves. Instead usual descriptions indicated cardiac parasympathetic innervation was provided by vagus trunks and inferior laryngeal nerves, and sympathetic innervation came from the cervical level as independent branches (Testut and Latarjet, 1973; Williams and Warwick, 1992), recent studies have demonstrated vagus nerves contain both, parasympathetic and sympathetic fibers, by cervical anastomosing and hitchhiking (Seki et al, 2014; Verlinden et al, 2015). Nerve morphology has not shown significant differences in relation to the percentage of sympathetic fibers, demonstrated by nerve stimulation (Seki et al, 2014).

Lung branches were described as forming two plexus, anterior and posterior (Williams and Warwick, 1992), just one plexus or by three braches on each side (superior, middle and inferior). We found independent branches on both sides entering the hilum of lungs instead we did not find all the described branches in adults (Testut and Latarjet, 1973; Weijs et al, 2015). We could never identify a pulmonary plexus.

Traditional descriptions locate vagus nerves laterally to the oesophagus but moving from to anterior and posterior, following the rotation of the stomach from left to right (Prives, 1985; Zuidema, 1999; Sadler and Langman, 2007). However, for other authors (Nebot-Cegarra et al, 1999; Gratacós et al, 2007) "the stomach of human embryo undergoes heterogeneous and multifactorial rotation". They considered 2 different theories for stomach rotation: the real rotation and the apparent rotation. In the second case, the morphological gastric changes (represented by the growth of left gastric wall over the right and the enlargement of the gastric mesenteries) and unequal visceral growth (mainly the liver) may explain the cause of our findings with non rotated stomach and vagus nerves located anterior and posterior (left and right respectively) to the esophagus.

Preservation of vagus nerves during esophagectomy is a challenge for surgeons as most of the post-operative morbidity is related to vagus injuries (Takassi et al, 2013; Weijs et al, 2015). Studies carried on by dissection of fresh cadavers and evaluating surgical cases informed preservation of the nerve trunks after vagal-sparing esophagectomy with cervical anastom-

osis (Takassi et al, 2013). However, the conservation of the main branch does not guarantee the innervation of all the anatomical structures. Separating vagus nerves when they form a real plexus around the esophagus (with multiple anastomosis) keeping intact innervation is nearly impossible in the 36.66% of cases we found esophageal plexus. Weijs et al (2015) studied the involvement of pulmonary nervous supply during trans-thoracic esophagectomy with "en bloc" lymphadenectomy and transection of the vagus trunks at the level of the azygos vein. Without special care, during this surgical procedure they demonstrated between 68 to 100% denervation of both lungs. That percentage was significantly reduced (0 to 13%) by performing the vagotomy distally to the last pulmonary branch; they have dissected to be three branches for each lung.

Involvement of vagus nerves during fundoplication for the treatment of gastroesophageal reflux in children or adults is rare. However, the identification of the nerve trunks is necessary and the anatomical distribution in the distal part of the esophagus is determinant for the results and to avoid post-operative morbidity (Miyano et al, 2015; Razumosky et al, 2015).

Segmental resection of the esophagus (Gopal et al, 2015) is not a frequent operation but the surgical results depend on the location and extension of the damaged segment, and the possibility to save the nerve trunks and branches. Esophageal replacement (with colon) for the treatment of congenital or acquired atresia in children or adults, with or without fistula, and unavoidable sacrifice of vagus nerves is the most extended procedure with higher morbidity and mortality (Spitz, 2014; Ezemba, 2014; Fragoso et al, 2015; Ortiz et al, 2015).

Anatomical relationship among the esophagus and the left atrium is the responsible of periesophageal vagus nerve injuries during catheter ablation of atrial fibrillation causing gastric hypomotility, pyloric spasm and acalculous cholecystitis (Kuwahara, 2013; Tsuboi et al, 2014).

Vagus nerve stimulation (VNS) is a minimally invasive surgical procedure implanting an electronic device to stimulate the nerve. Recently VNS therapy has been used for chronic heart failure and may improve imbalance of autonomic control by increasing parasympathetic activity (Seki et al, 2014). The presence of sympathetic and parasympathetic fibers permits to consider VNS as an effective option for the treatment of depression, epilepsy, cardiovascular and neurodegenerative diseases. This procedure has been used in children mainly for the treatment of medically refractory epilepsy (Yu et al, 2014).

In conclusion, the knowledge of vagus nerves associated to the esophagus, in the thorax and the upper abdomen provide important information to decide, evaluate and interpret complications after different surgical procedures. Our study pretended to provide additional information to the not always consistent literature and link it to the clinical aspects.

Conflict of interest
None

Funding
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Ethical Approval
From the University Hospital of Maternity

Informed Consent
Not necessary

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