LARYNX ULTRASONOGRAPHY: An alternative technique in the evaluation of the aero-digestive crossroad.

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Abstract-

The larynx is a high complexity organ, crossroad of the airway and digestive tract which has a small size and mobility in different planes; all this makes the study very difficult.

Computed tomography (CT) and magnetic resonance (MR) are used for larynx evaluation, both have limitations.

Ultrasonography (US) is an innocuous accessible and non-expensive study, which can be performed in the patient bed. Because its high spatial resolution it constitutes nowadays the study of election in most of neck soft tissue pathology.

In addition, US, allows evaluation in real time of the different structures, which is relevant on those that present movement.

The aim of this study was to determine the role of US in the evaluation of the larynx and structures functional and anatomically related to it.

40 patients, (randomly selected from the population of the Pasteur hospital) were studied with high resolution US, using a high frequency linear probe (up to 10 MHz) attached to Simmens Acusson equipment. Previously an objective system for evaluation of those larynx components that in authors opinion had more relevance was designed. These components were selected because of their anatomic, physiologic and pathologic importance (i.e. thyroid, cricoid, larynoid cartilages; hyoid bone, pre-epiglottic space, true and false vocal cords, etc).

US evaluation of those components of the larynx is possible. US is a relatively innocuous method that has the best spatial resolution, which can be useful in the study of different larynx pathologies. This is why we suggest US as an alternative and complementary technique.

Keywords- Larynx ultrasonography, neck ultrasonography, high resolution ultrasonography.
I) OBJECTIVES-

General-
To determine the use of US in the evaluation of the larynx as well as the structures anatomical and functionally related to it.

Specific-
Determine the role of US in:

I) Visualization of: thyroid, cricoid, arytenoid cartilages, as well as ultrasonographic characteristics of each one of these cartilages.

II) Visualization of vocal cords and ventricular bands, as well as their US characteristics.

III) Evaluation of hiotiroepiglotic space and its US characteristics.

IV) Evaluation of some of the intrinsic and extrinsic larynx muscles and their characteristics.

II) MATERIAL AND METHODS-

We studied 40 patients randomly selected from the population of the Pasteur Hospital with high resolution US using a high frequency linear probe (up to 10 MHz) attached to Simmends Acusson equipment. We used a high resolution setup (testicle), a 10 Mhz frequency, two superficial focuses and we adapted this settings to the findings. Patients were studied laid down in supine position, with their neck hyperextended (achieved with a pillow under their shoulders). They were asked to breathe normally.

We initiated the study of the larynx in the axial plane identifying the thyroid cartilage, which we used as a landmark for the rest of the study. Then we used coronal, sagittal and oblique planes. After this we asked the patient to perform Valsalva maneuvers and phonation of a long vowel “a” with the intention of evaluating the vocal cord motion and vibration.

Previously an objective system for the evaluation of those larynx components that in the authors’ opinion had more relevance was designed. These components were selected because of their anatomic, physiologic and pathologic importance.

III) RESULTS-

A) The sample selected was composed by 50% males and 50% females. There were 37,5% between 21 and 49 years, 27,5% between 50 and 69 years, 25% above 70 years and only 10% below 20 years of age. The percentages of structures visualized by the authors are shown in table 1 and graphic 1.

<table>
<thead>
<tr>
<th>Structures</th>
<th>% Visualization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyroid (TC)</td>
<td>100</td>
</tr>
<tr>
<td>Cricoid (CC)</td>
<td>100</td>
</tr>
<tr>
<td>Arytenoid (AC)</td>
<td>75</td>
</tr>
<tr>
<td>Vocal cords (VC)</td>
<td>75</td>
</tr>
<tr>
<td>Ventricular bands (VB)</td>
<td>75</td>
</tr>
<tr>
<td>Cricothyroid mass. CTM</td>
<td>100</td>
</tr>
<tr>
<td>Thyrato-arytenoid musc. TAM</td>
<td>100</td>
</tr>
<tr>
<td>Cricothyroid space GTS</td>
<td>100</td>
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<tr>
<td>HTE Space</td>
<td>100</td>
</tr>
</tbody>
</table>

Thyroid and cricoid cartilages were visualized in 100% of patients, whereas arytenoids were seen in only 75% of cases. In 100% of the population we were able to identify the hiotiroepiglottic and inter- cricothyroid spaces. The anterior commissure was identified in 67,5% and the peri-cricoid space in a 65%.

Another objective was to define the percentage of visualization of the vocal cords and the ventricular bands, which were visualized in 72,5% of the patients. The thyro-hyoid and crico-thyroid membranes were visualised in all patients.
The crico-thyroid and thyro-hioid muscles were seen in 100% of the cases whereas the thyro-aritenoid muscle was seen in 80%.

We always identified the hyoid bone.

The presence of calcifications in the thyroid and cricoïd cartilages was responsible for not identifying the aritenoid cartilages, the vocal cords, ventricular bands, the thyro-aritenoid muscle and the movements and vibration of the cords. In table and graphic 2 and 3 we represent these findings.

B) ANATOMIC BACKGROUND-

The larynx is part of the airway and the phonation organ. It is composed by multiple mobile cartilages; articulations and ligaments bond to each other and to the structures that surround them. It's also composed by muscles and a mucosa.

CARTILAGES-

There are normally eleven cartilages, three odd midline cartilages: thyroid, cricoid and epiglottic and four paired lateral cartilages: aritenoid, Santorini’s, Morgagni’s and sesamoids. We will describe only the thyroid, cricoids, aritenoid and epiglottic cartilages.

The cricoid cartilage is located in the inferior portion of the larynx; it has a ring shape, composed by an anterior segment named the cricoïd arch and a posterior segment or the cricoïd plaque. (Fig. 1)

The thyroid cartilage is situated above the cricoid arch. It is composed by two quadrilateral plates binded at the anterior edge, forming a dihedral angle that points backwards. Its posterior edge continues up and downwards with the mayor and minor apophysis respectively. (Fig. 1)

The epiglottic cartilage is located in the antero-superior portion of the larynx, behind the thyroid cartilage, which exceeds. It forms the skeletal frame of the epiglottis. (Fig. 1)

The aritenoid cartilages are two small cartilage pieces with pyramid shape, located above the lateral portion of the cricoid ring. Two of the angles of the base of this pyramids, give origin to the vocal and muscular apophysis. The first one gives insertion to the posterior and lateral crico-aritenoid muscles and the second one gives insertion to the vocal ligament. (Fig. 1)
ARTICULATIONS AND LIGAMENTS-

We will analyze only the ligaments that are relevant to this article.

The crico-thyroid membrane also known as the middle crico-thyroid ligament, extends from the middle part of the inferior edge of the thyroid cartilage to the superior edge of the cricoid arch. (FIG1).

The larynx mucosa is reinforced in all its extension by an elastic membrane that has two thickenings called the superior and inferior thyro-artenoid ligaments. The superior ligaments are continued by the ariteno-epiglottic ligaments. All of these structures form the fibrous frame of the larynx vestibule. The inferior ligaments constitute the elastic cone of the larynx whose free edge forms the vocal ligament. (Fig1)

MUSCLES-

There are two types of muscles in the larynx, extrinsic and intrinsic. The first group has an insertion in the larynx and in the structures that surround it. The second group has both insertions in the larynx. (Fig. 3)

INTERNAL CONFIGURATION-

The inner surface of the larynx presents on each side in its middle portion, two superposed folds, which are oriented in the antero-posterior axis. They are called the vocal cords and the ventricular bands (FIG. 4 y 5). Between them we found the Morgagni ventricles, two diverticula of the larynx lumen. The vocal cords divide the larynx lumen in three levels; superior or supra-glotic also known as the larynx vestibule, middle or glotic level, and inferior or sub-glotic level. (Fig. 1 and 4)
FUNCTIONALITY-

The larynx is the entrance into the inferior airway and the organ of phonation. When swallowing the larynx lumen closes as it opens into the pharynx protecting the airway. This mechanism is accomplished by the epiglottis that occludes the upper opening of the larynx assisted by the ventricular bands, which ensures a complementary occlusion and the airway protection. That is why the superior level functions as the protection apparatus of the airway.

The larynx cartilages, the vocal cords, the elastic cone, their articulations and muscles, constitute the sound producing apparatus. This sound is modified by the resonance in the superior levels, at the larynx, pharynx, mouth and nose, were the voice takes character.

C) US CHARACTERISTICS OF THE SELECTED STRUCTURES-

When the thyroid cartilage was not calcified it presented a characteristic appearance, homogeneous with a central portion slightly hiperchogenic related to a peripheral hipoechoic band (FIG. ). In the axial plane we could see the characteristic morphology of the cartilage, as an ‘open book’. The quadrilateral plates were homogeneous with a thick posterior zone that gradually thins toward the anterior angle. As we sweep the transducer in this plane we could watch the continuity of the posterior edge with the superior and inferior apophysis. We could also identify how the inferior ones articulated with the cricoid ring, and how the distance between this structures and the mucosa at this level was very thin.

In an important percentage (80%) of the patients the cartilage was calcified, which was related to the age and with different pathologies. These calcifications could be partial (65%) or total (15%) refer to tables and graphics 2 and 3. Partial calcifications localize more often in the posterior segments of the quadrilateral plates and in the inferior apophysis. The maximum thickness of the plates was, in our population; 4,7mm average on the right side and 4,6mm average on the left.

The cricoid cartilage was homogeneously hiperechoic related to the thyroid cartilage. When there were no complications it could be correctly studied by us. In an axial plane, the circular configuration of the ring of the cartilage was characteristic. Many times the cricoid plaque remained hidden or was confused with the aritenoid carilages and the muscles and its insertions between them. The thickness of the anterior portion of the ring was, in our population, 2,5mm, whereas its lateral portion measured 4,8mm and 4,9mm average on the right and left sides respectively. The calcifications in this cartilage also were, partial or total, they were present in 52, 5% of the cases; being partial in 40% of the population, and total calcification represented 12, 5%.

The aritenoids, when they were visualized, looked hiperechoic and homogeneous. Generally they were explored better during Valsalva manoeuvers; this causes an adduccion of the vocal cords which eliminates the air between the cords. The aritenoids appeared then one next to the other, symmetric and hiperechogenic. (FIG. 2)

As for the intrinsic muscles selected, they could be studied in all patients. They were hipoechoic related to the cartilages and the extrinsic muscles. Generally they did not have the fibrilar appearance that is characteristic of the skeletal muscles, instead they appeared more like the the abdominal viscera muscles. For their identification we used axial, sagital, coronal and oblique planes. The crico-thyroid muscle was identified covering the cricoid ring. The vocal muscle or the thyro-aritenoid muscle was better depicted in the longitudinal planes, in which we could even...
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differentiate the two portions internal and external, this one with a more fibrillar appearance. (Fig.3 and 4) The thicknesses of the muscle as well as the vocal cord or ventricular bands were very variable because they depend of the moment during the respiratory cycle or even phonation. The vocal cords were seen characteristically with a pyramid shape in the axial plane. In its anterior portion we
could appreciate two zones, one exterior hiperechogenic, which corresponds to cellular tissue between the cartilage and the muscle. The interior zone, hipoechoic, represents the thyro-aritenoid muscle. We could neither identify the vocal ligament nor the elastic cone during passive examination. The posterior portion of the vocal cords is occupied by the aritenoid cartilages which have already been described. (Fig. 3) During Valsalva manoeuvers, the vocal cord closed one to each other, making contact by its medial edge. In that moment
they form a characteristic image that resembles a smiling face. (Fig. 6)

During phonation of a long vowel “a” we could visualize, in some cases, the vibration of the free edge of the elastic cone; the vocal ligament, which is characteristic and reminds the vibration of a guitar string. The ventricular bands had in the axial plane a similar shape compared to the vocal cords, but they were hypechochogenic related to them. We could identify an external hypechoic zone that we think represents the external and superior fascicles of the thyro-artinoid muscle. We could also identify a hypechoic external zone (as seen in vocal cords) that represents the cellular tissue between the muscle and the cartilage.

During Valsalva manoeuvres, the ventricular bands also had an adduction movement, but they did not contact as perfectly as the vocal cords, the remaining air between them creates an air-artefact image.

Studying the larynx in longitudinal (coronal) planes, in some patients, we could clearly identify the vocal cord and the ventricular band, with their differences previously mentioned. In this plane, between them, we could see an air-artefact image that corresponded to the Morgagni ventricle. (Fig. 4)

We measured the vocal cords and ventricular bands obtaining this average results: right vocal cord medial hipoechoic segment 5.1mm, lateral hiperechoic segment 1.2mm; left vocal cord: medial hipoechoic segment 4.9mm, lateral hiperechoic segment 1.3mm; right and left ventricular bands averaged 5.2mm.

The hiothyroepiglottic space, in our study, was hypechoic and homogeneous, which is probably due to its fat constitution. In both axial and sagittal planes we identified four levels; in the surface the level of thyro-hyoid muscle, just below the level of the thyro-hyoid membrane, further down the level of the fatty tissue and in the deepest level the epiglottic cartilage. (Fig 5) The size of this space was variable; in average we obtained the following measures: cephalo-caudal diameter 14mm, transversal diameter 18mm, and antero-posterior diameter 10mm. The crico-thyroid space is constituted by the homonym muscle and membrane both
previously described. In its lateral portion the thickness of the space decreases towards the crico-thyroid articulation. In the midline we measured an average distance of 8.6mm in the sagittal plane.

The calcifications often seen in the cricoid and thyroid cartilages made difficult the identification of the structures previously described although it did not turn it impossible. Because in our series the calcifications more often were partial and localized in the posterior zone of the cartilages (quadrilateral plates and cricoid ring) they allowed the study of the region of interest. Even in the cases of partial anterior calcifications, these were discontinuous; the zones between the calcifications presented a sufficient window to assess the areas of interest. In those patients with total calcifications we obtained a very poor evaluation, although in a few of them, using lower frequency and harmonic technology, we could evaluate the cartilages but not the structures behind them.

The hyoid bone was identified in all patients; meanwhile, in other bones we could only assess the surface.

DISCUSSION AND CONCLUSIONS-

Larynx is a high complexity organ, both functionally and anatomically. The evaluation of this organ requires a profound anatomic, histological and functional knowledge.

To perform this evaluation the clinician has at its disposal direct clinical and laryngoscopic examination, and various imaging methods. Although Magnetic resonance (MR) and computed tomography (CT) are nowadays the imaging methods of choice, but in the evaluation of the larynx they have limitations. These are related to spatial resolution capability and the fact that they perform only a static evaluation.

In our study it is shown how US is a valid method in the evaluation of the most important anatomic and functional elements of the larynx.

The most important advantages of US are to complement the areas where MR and CT have limitations. If we add the universal advantages of US: accessibility, economy, and superior spatial resolution, we could suggest US as an alternative and complementary imaging method in the evaluation of the larynx.

The limitations of US depend on the presence and degree of calcifications in the cricoid and thyroid cartilages (present in 80% of the population in our study). These cartilages are the windows used for the visualization of deeper structures. However, patients with partial calcifications, (65% had partial calcifications) allowed us to obtain important information.

From our study we were able to confirm that these calcifications are more frequently seen in older patients who are the population in which cancer is more prevalent. We could conclude then that there would be a limitation in the evaluation of laryngeal cancer, more prevalent in elderly patients. Nevertheless, we should consider the value of US in the evaluation of the hiothyroepiglottic space and the limitations that MR and CT have in assessing the compromise of the thyroid and cricoid cartilages, which is of critical importance in the estimation of laryngeal cancer.

We must also consider that there are other laryngeal pathologies that are more prevalent in a younger population which could be assessed by US since in these patients calcifications would not be present. Furthermore, we could add the value of US in the evaluation of larynx functionality; this is of great importance in some patients (i.e. singers, actors, etc). In these cases US becomes a non invasive method able to give information that invasive ones cannot (information of sub mucosal alterations).

Because of all these considerations we conclude that US is a useful method in the evaluation of the larynx, and could have a
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complementary role in the algorithm of laryngeal study.

Links to videos-

- [http://www.youtube.com/watch?v=oiap5H-91O4](http://www.youtube.com/watch?v=oiap5H-91O4)
- [http://www.youtube.com/watch?v=SB09S6S_SWw](http://www.youtube.com/watch?v=SB09S6S_SWw)
- [http://www.youtube.com/watch?v=K0a6z_SPD7k](http://www.youtube.com/watch?v=K0a6z_SPD7k)

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