An open access thyroid ultrasound-image Database

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An open access thyroid ultrasound-image Database

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ABSTRACT

Computer aided diagnosis systems (CAD) have been developed to assist radiologists in the detection and diagnosis of abnormalities and a large number of pattern recognition techniques have been proposed to obtain a second opinion. Most of these strategies have been evaluated using different datasets making their performance incomparable. In this work, an open access database of thyroid ultrasound images is presented. The dataset consists of a set of B-mode Ultrasound images, including a complete annotation and diagnostic description of suspicious thyroid lesions by expert radiologists. Several types of lesions as thyroiditis, cystic nodules, adenomas and thyroid cancers were included while an accurate lesion delineation is provided in XML format. The diagnostic description of malignant lesions was confirmed by biopsy.The proposed new database is expected to be a resource for the community to assess different CAD systems.

1. INTRODUCTION

Thyroid disorders are the most common endocrine pathologies, among which thyroid cancer is the more frequent. According to the American Cancer Society, 62.980 new cases and 1.890 deaths will take place in the United States[1] in 2014. The incidence of palpable thyroid nodules on the adult population is about 67% and 10% of them can be malign[2].[3] Modern imaging techniques such as the computer tomography (CT) and Ultrasound (US) image modalities, are used to detect, diagnose and manage thyroid nodules. B-mode Ultrasound image is the best cost-effective method and less invasive technique. However, interpretation of ultrasound images requires a high degree of expertise and training while the reading performance is affected in any case by the noise and speckle of the ultrasound images as well as the ability of the operator to properly acquire the image.[4] An inaccurate US capture of a nodule might result in unnecesary fine-needle aspiration (biopsy).

Usually, a thyroid nodule is described as hypo-echoic, iso-echoic, or hyper-echoic, being the echogenicity its brightness when compared to the normal parenchyma surrounding this. Hypoechogenicity has been associated to thyroid malignancy.[5] Most of the thyroid nodules tend to have various internal echogenicities, making the final diagnosis very complicated. For instance, the follicular adenoma can be either iso-echoic or hyper-echoic.[6] Several ultrasound features have been found to be associated with an increased risk of thyroid cancer, including hypoechogenicity, predominantly solid composition and calcifications.[7] Usually, thyroid nodules are heterogeneous, composed of various internal echo patterns that confuse radiologists and physicians at the moment of identifying the thyroid nodule. In order to standardize the ultrasound report that describes and evaluates thyroid lesions, an agreement, still under evaluation, is the Thyroid Imaging Reporting and Data System (TIRADS) that categorizes the nodules as benign, probably benign, borderline, suspicious for malignancy and malignant.[8]

On the other hand, computer aided diagnosis of thyroid ultrasound, systems aimed to support the diagnosis process, are clasically composed of two main stages, feature extraction and classification (between benign or malignant) stages. These systemas attempt to eliminate the weaknesses of operator dependency and to improve the diagnostic accuracy. However, an actual limitation for these systems to develop is the necessity of enlarginkg the scientific community interested in this kind of problems. Thyroid ultrasound-image databases play then a central role in developing algorithms devoted at detecting and diagnosing lesions. Such datasets facilitate comparison of results from different studies. Different opinions from the scientific community agree about the urgency of building a benchmark database of US images,[2] accessible publicly that supports the comparison

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and evaluation of different algorithms and CAD systems. To the best of our knowledge, there are no available ultrasound-image databases with the associated diagnostic description and report of main findings.

In this work, an image database of thyroid ultrasound images is presented and made public (available in www.cimalab.unal.edu.co). The proposed database contains a set of B-mode Ultrasound images, corresponding a 389 cases of study that include a complete annotation and diagnostic description of suspicious thyroid lesions, using the TI-RADS lexicon description performed by at least two expert radiologists. Several types of lesions such as thyroiditis, cystic nodules, adenomas and thyroid cancers are included and their accurate contours are provided in XML format. The diagnostic description of malignant lesions was confirmed by a biopsy procedure. Furthermore, additional annotation of training radiology students was compare with the expert's , helping them to used this data set as a tool in the training process for the new radiologists.

2. MATERIALS AND METHODS

A set of cases with relevant thyroid disorders were selected from the IDIME Ultrasound Departament (Institute with over ten years of experience), one of the largest diagnostic imaging centers in Colombia and who performs more than 2000 thyroid ultrasounds associated to Fine Needle Aspiration per year. The selection of patients was based on TI-RADS description.[7] These selected patients signed the informed consent agreeing about using this information exclusively with scientific purposes and they underwent both the ultrasound and the biopsy in the same session. Thus, the staff of head and neck experts of IDIME collected a total number of 299 patients, 270 women and 29 men whose ages varied as 57.35 ± 16.2 years. The experts evaluated the patient individually and described the specific features filling the TIRADS requirements. They were separated in different consulting rooms, none of them knew the outcome of the evaluation. The second observer performed the biopsy following the ATA (American Thyroid Association) recommendations. The images were extracted from thyroid ultrasound video sequences captured with a TOSHIBA Nemio 30 and a TOSHIBA Nemio MX Ultrasound devices, both set to 12 MHz convex and linear transductors, containing the most relevant pathological features seen such as size, shape, margin, composition, calcifications and echogenicity for a given view, i.e. sagital or transverse, which were selected by the radiologists and their pathologies confirmed by biopsy using the BETHSEDA system.

Once, the images were acquired and saved in an uncompressed JPEG format, an image annotation tool was developed, which is designed to allows segmented nodules and annotated labels to be instantly shared via the web and to grow over time. For this, we designed an online Javascript drawing interface that works on many platforms, is easy to use, and allows to make a TI-RADS description of nodules over collected data. Figure 1, shows a snapshot of the proposed online annotation tool. The tool provides a simple drawing interface that allows users to outline the silhouettes of the nodule present in each image. When the user opens the application, a new image is displayed. The user provides an annotation by clicking along the boundary of an nodule to form a polygon. The user closes the polygon by clicking on the initial point or with a right click. After the polygon is closed, a pop-up dialog box appears querying for the nodule description according to TI-RADS category such as (1) Normal thyroid, (2) Benign, (3) No suspicious US feature, (4a) One suspicious US feature, (4b) Two suspicious US features, (4c) Three or four suspicious US features and (5) Five suspicious features.The experts and the radiology resident had an individual interface to perform the annotation, this interface allowed them evaluate different images from the same nodule. The annotation was performed without additional information.After this procedure, ultrasound properties were include as well as the location, examination date and frequency (MHz) in an alone XML file. These annotations are added to the database and becomes available for immediate download for research.

On the other hand, the whole cases were categorized by the experts radiologists among thyroiditis, cystic nodules, malignant or benign nodules. The initial diagnosis based on the ultrasound features was confirmed by the pathological report. These pathologic description, as well as the BETHESDA (System for Reporting Thyroid Cytopathology)[9] results, were also included in XML file. The expert's evaluations were compared to analize the accuracy of both radiologist as well as the variability inter observers with the BETHESDA report, the Gold Standard for thyroid cancer. The table 3, shows these results. The XML files provide discriminant information such as malignant and benign cases, each contains the number case, following of patient's information as age and sex. The nodule's information was separed into composition,size, echogenicity, margin characteristics,

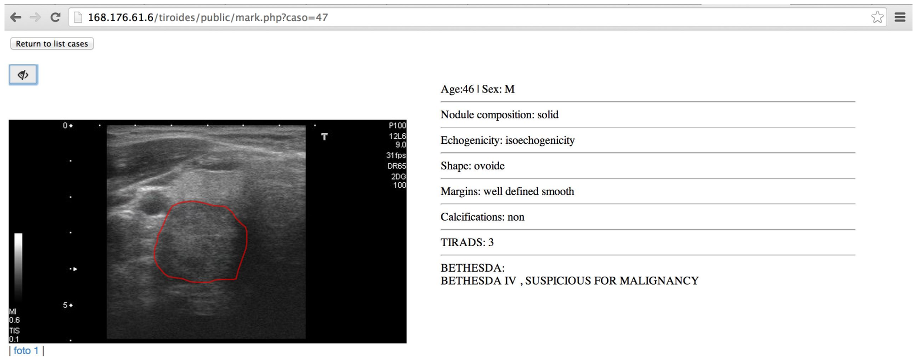

Figure 1. Screenshot of the online annotation-tool

calcification presence and TIRADS score. Finally, the free hand annotation nodule coordinates are described as a code-point. Figure 2 illustrate a manual nodule segmentation by the radiologist.

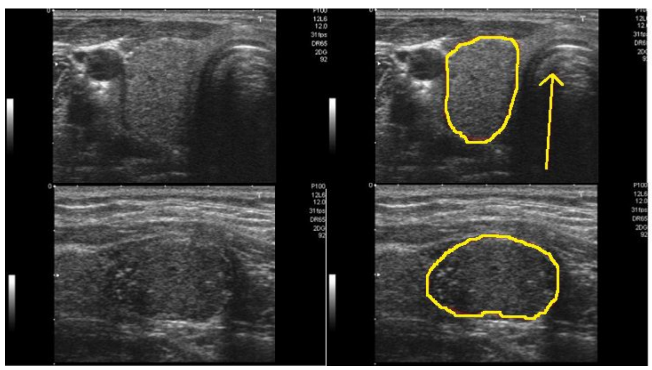

Figure 2. a) original image, b) segmented image by radiologist

Table 1. BETHESDA SYSTEM

SCORE[9]	DESCRIPTION[9]
1	Nondiagnostic or Unsatisfactory
2	Benign Consistent with a benign follicular nodule
3	Atypia of Undetermined Significance or Follicular Lesion of Undetermined Significance
4	Follicular Neoplasm or Suspicious for a Follicular Neoplasm
5	Suspicious for Malignancy
6	Malignant

3. RESULTS

The DDTI (Digital Database Thyroind Image) is a public open access dataset. It contains the analysis of 347 thyroid ultrasound images, performed by two experts in 299 patients with thyroid disorders. The patients were classified by the experts using the TIRADS system.Table 2, shows how many cases of each category the dataset contains per observer. The BETHESDA system confirmed 200 cases. Thyroiditis and goiter cases were 137 . Spongiform nodules were 18 cases. The papillar and follicular cancer was confirmed in 21 patients. 24 samples were unsatisfactory for the pathology study.

A discrepancy among the TIRADS score and the Bethesda system was analyzed for each observer. The TIRADS system has been validated to correlate the image features with the pathological diagnosis. This classification pretends avoid the unnecessary FNA and performs an accuracy diagnostic related with the thyroid disorder. One of the most interesting aspect was the behavior of the thyroid disorders in the male population. The majority of the nodules in men are related with cancer, this aspect was known by the observers and became in a bias, almost all male cases were classified with a TIRADS over 4a. Nevertheless, the Bethesda system confirmed only 4 malignant cases.

The most prevalent nodule composition in the 299 patients was solid, in multiples studies this characteristic is related with malignancy but in our dataset benign and malignant nodules presented it.

Another important feature for malignancy was the presence of calcifications, most of the nodules have micro and macro calcifications that can only be seen during the ultrasound process and after the image capture these lost,in our data set the experts performed the annotation not only of the boundaries of the nodules also of some specific features as the calcifications,veins, arteries, muscles and trachea.

On the other hand, the dataset contains 38 images without clinical information, only the definition of the boundaries is available. These images were used for training. The radiology students had the opportunity to evaluated the images and performed the annotation following the TIRADS requirments. After this process the annotation was compared with the expert's.

Figure 3. Screenshot of the online training annotation-tool

The original uncompressed JPEG images and XML files have been uploaded to the http://www.cimalab.unal.edu.co web site. The access to the dataset is open and the user can download the cases divided in benign and malign following the TIRADS score, as well the images for training.

TIRADS	Observer 1 No. Diagnosed Cases			Observer 2 No. Diagnosed Cases		
	Male	Female	Total	Male	Female	Total
2	3	35	38	2	18	20
3	2	12	14	3	30	33
4a	9	76	85	11	79	90
4b	5	70	75	8	93	101
4c	6	50	56	1	34	35
5	4	26	30	4	16	20

Table 2. Distribution of the TIRADS classification for each observer

BETHESDA	CASES
1	24
2	137
3	18
4	8
5	13
6	0

Table 3. PATOLOGIC DIAGNOSIS

4. DISCUSSION

The analysis of thyroid ultrasound images is a wide field in continuous expansion due to the difficulty in the ultrasound nodule detection. The clinical aspects of this study allowed us to find the most relevant features of the images defined by neck and head experts. The wealth of this database is given by the variety of diagnoses and cases, among thyroiditis, goiter, nodules and cancer. The complexity of the images and their interpretation reflect the need to develop strategies to support the diagnosis and the following.On the other hand, is relevant the possibility of having multiple datasets for the radiology community to validate retrospectively the TIRADS classification.

The DDTI main interest is based on the use of the images to apply CAD (Computer Aid Diagnosis) systems through the extraction of features from the nodule image. Each malignant feature can be detected using specific image analysis in the thyroid ultrasound to minimize the operator-dependent nature inherent in US images and make the diagnostic process reproducible.

The use of CAD systems in the ultrasound analysis, is related with the reduction of the inter-observer variability and the extraction of nodule features that can not to be obtain just with the visual component. The main objective of CAD in thyroid ultrasound is give a support to the expert to help him to improve the accuracy diagnosis and decrease the unnecessary thyroid biopsies. Nowadays, there are no available open access thyroid ultrasound-image databases with the associated diagnostic description and report of main findings.

5. FUTURE WORK

The Digital Database of Thyroid Ultrasound Images (DDTI) is a resource for the scientific community. Its open access will allow the use of multiple thyroid ultrasound images for their analysis, the application of CAD systems and algorithms.

Currently, DDTI contains 299 cases with 347 images. Each month a set of new cases will be downloaded with the expert annotation, pathological diagnosis and clinical description.More observers will be added. Currently , we have two head and neck experts from the same institution. In order to support the radiologist's diagnosis, more institutios will be added too as well some patohology laboratories to perform the correlation among the histological and ultrasound components.

The main objective of the DDTI is developed an algorithm to support the diagnosis, pretending identify the main nodule features to reduce the variability inter-intra observer. This database will allowed to compare other CAD systems used in thyroid ultrasound images.

The DDTI will be use as a training tool for the radiology students of the Universidad Nacional de Colombia.

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