Optimized quantification of thyroid nodular vascularization from 3-D contrast-enhanced ultrasound images
Thyroid nodules occur in 50% of the worldwide population.

< 5% of Thyroid Nodules are Cancers

**Incidence:** 2.1% (Globocan, 2012)

**Mortality:** 0.5% (Globocan, 2012)
Thyroid Nodules: Diagnostic Procedure

**Common Approach in Differential Diagnosis**

Conventional B-Mode Ultrasound Imaging + Fine Needle Aspiration

Inconclusive diagnosis

25% of all cases

Overtreatment and unneeded surgery
Aim of this work

To represent the complete 3-D vascular network of thyroid nodules
To objectively characterize tumoral vascular pattern
To ease and support differential diagnosis
Volume Preprocessing and Filtering

Malignant Nodule

Benign Nodule

Original central Slide

Thresholding

Vessel Enhancement

Methods

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Vascular Skeleton and Centerline Extraction

Morphological information  Flow intensity information

Malignant Nodule

Benign Nodule

Skeleton  Centerlines

Guide

3-D Rendering

Methods

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Vascular Features Extraction

Tortuosity Measurements

Distance Metric (DM)

\[ DM = \frac{L}{d} \]

Inflection Count Metric (ICM)

\[ ICM = (\text{number of IP}) \times DM + 1 \]

Sum Of Angles Metric (SOAM)

Architectural Parameters

Number of Trees (NT)

Number of Branches (NB)

Vascular Volume Density (VVD)

Spatial Vascular Pattern (SVP) Perilesional/Intranodular

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Computation of Spatial Vascular Pattern

**Perilesional Benign Tumor**

**Intranodular Malignant Tumor**

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**Methods**
20 patients with solid solitary thyroid nodules

- 3 Males, age 43 ± 10 years
- 17 Females, age 46 ± 13 years

- 10 benign tumors (cytology)
- 10 malignant tumors (histopathology)

Analysis of Tumor Vasculature
Tortuosity Measurements: DM, ICM, SOAM
Architectural Parameters: NT, NB, VVD, SVP
## Results

### Statistical Analysis

<table>
<thead>
<tr>
<th>CEUS</th>
<th>Benign Tumors</th>
<th>Malignant Tumors</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (a.u.)</td>
<td>13.91 ± 8.31</td>
<td>82.93 ± 49.38</td>
<td>&lt;&lt; 0.05</td>
</tr>
<tr>
<td>ICM (a.u.)</td>
<td>35.78 ± 18.63</td>
<td>227.62 ± 93.97</td>
<td>&lt;&lt; 0.05</td>
</tr>
<tr>
<td>SOAM (a.u.)</td>
<td>4.28 ± 3.19</td>
<td>26.51 ± 21.19</td>
<td>&lt;&lt; 0.05</td>
</tr>
<tr>
<td>VVD (%)</td>
<td>30.30 ± 11.40</td>
<td>60.30 ± 7.11</td>
<td>&lt;&lt; 0.05</td>
</tr>
<tr>
<td>NT (a.u.)</td>
<td>5.30 ± 1.34</td>
<td>8.40 ± 2.79</td>
<td>&lt;&lt; 0.05</td>
</tr>
<tr>
<td>NB (a.u.)</td>
<td>18.30 ± 5.83</td>
<td>53.70 ± 17.72</td>
<td>&lt;&lt; 0.05</td>
</tr>
<tr>
<td>SVP (a.u.)</td>
<td>6/10</td>
<td>10/10</td>
<td>&lt;&lt; 0.05</td>
</tr>
<tr>
<td>Age (y)</td>
<td>46 ± 11</td>
<td>45 ± 14</td>
<td>&gt; 0.05</td>
</tr>
</tbody>
</table>

Values expressed as mean ± SD

**All vascular parameters are significantly higher for malignant tumors**

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Conclusion and Future Developments

Tumor vasculature can be extracted from 3-D CEUS Volume

A minimum set of Vascular Parameters can differentiate benign from malignant nodules

Vasculature from 3-D CEUS images can be used in early differential diagnosis

Prostate Tumor Localization and Characterization

- CEUS
- Vessellness Filtering
- Histological Label
- ICM map
- NT map
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