Role of ultrasonography in the evaluation of correlation between strain and elasticity of common carotid artery in patients with diabetic nephropathy

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Received July 13, 2015; Accepted October 14, 2015; Epub October 15, 2015; Published October 30, 2015

Abstract: Objective: This study aimed to investigate the correlation between strain and elasticity of the common carotid artery (CCA) by ultrasonography and evaluate its clinical significance in patients with diabetic nephropathy (DN). Methods: A total of 68 DN patients and 54 healthy subjects were randomly recruited from the Ultrasound Department from April 2014 to March 2015. The maximum of circumferential strain (CSmax), maximum of circumferential strain rate (CSRmax), compliance coefficient (CC) and stiffness index (β) of the CCA were determined by ultrasonography in all the patients, and correlation analysis was performed. Results: The CC, CSmax and CSRmax in DN group were significantly lower than in healthy controls (P<0.05), but β was markedly higher than in control group (P<0.05). There was a significantly positive correlation of CSmax and CSRmax with CC and a negative correlation with β in both control group and DN group. Conclusion: There is significant correlation between strain and elastic of the CCA. CSmax and CSRmax may be used to reflect the mechanical characteristics of CCA.

Keywords: Diabetic nephropathy, vascular complications, common carotid artery, strain, elasticity

Introduction

The elasticity related parameters such as compliance coefficient (CC) and stiffness index (β) can objectively reflect the stiffness of arteries [1, 2] and may be used to clinically evaluate the arterial elasticity in the early stage of a disease. Thus, increasing studies pay attention to the arterial elasticity in humans [3-5]. In recent years, with the application of ultrasonography and the up-dating of corresponding software, clinicians are easy and accurately acquire these elasticity related parameters via instruments [6, 7]. However, studies on the arterial strain are still in their infant stage. There is evidence showing that arterial strain can be used to reflect the arterial deformation and then to evaluate the arterial movement [8]. Since elasticity and strain may reflect the mechanical and motion characteristics of arteries, whether there is correlation between them is still unclear. This study was undertaken to investigate the correlation between elasticity and strain of the common carotid artery in patients with diabetic nephropathy (DN).

Materials and methods

A total of 68 patients with DN were recruited from the Ultrasound Department of our hospital between April 2014 and March 2015. DN was diagnosed according to the Tervaert criteria [9]. There were 26 males and 42 females and the median age was 45.26±12.89 years (range: 34-60 years). Vascular diseases secondary to hypertension, cardiac dysfunction and other endocrine diseases were excluded. In the same period, healthy subjects (n=54) were recruited...
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Instruments and methods

Mylab90 ultrasound scanner (Esaote, Italy) was used in this study with LA523 probe and its frequency of 4-13 MHz. There is supporting software used to measure the elasticity and strain of CCA.

The blood pressure and heart rate were measured routinely, and the patients’ characteristics (gender, birth date and blood pressure) were input into the ultrasound scanner. Patients were asked to lie in supine position and the neck was completely exposed. The electrocardiogram was measured during the whole ultrasonography. The CCA was scanner transversally and longitudinally to identify the arterial plaques. Once arterial plaques were present, patients were excluded from this study. The arterial plaques were determined according to the criteria of Salcumi et al [10]: The increase in the thickness of the intima-media thickness (IMT) of focal CCA by >1.2 mm is used to define the arterial plaque. The target artery was from 1.5 cm above the beginning part of CCA to 1.5 cm below the bifurcation of CCA.

Figure 1. Elasticity related parameters of right CCA. The width of sampling frame was 1.4-1.5 cm, the location and height of sampling frame were adjusted, the probe was fixed, and patients were asked to hold the breath. When 6 stable vascular dilations were present on the screen (standard deviation ≤15), the images were frozen.

Table 1. Basic information of DN patients and healthy subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (year)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>HR (bpm)</th>
<th>BMI (kg/m²)</th>
<th>LVEF (%)</th>
<th>SV (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>54</td>
<td>45.98±13.02</td>
<td>116.81±12.98</td>
<td>70.82±9.77</td>
<td>68.14±11.03</td>
<td>65.46±8.72</td>
<td>73.02±9.68</td>
<td></td>
</tr>
<tr>
<td>DN</td>
<td>68</td>
<td>45.26±12.89</td>
<td>113.47±12.65</td>
<td>72.34±9.86</td>
<td>70.21±11.92</td>
<td>63.23±8.63</td>
<td>70.35±9.46</td>
<td></td>
</tr>
</tbody>
</table>

Note: SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; HR: Heart Rate; BMI: Body MassIndex; LVEF: Left Ventricular Ejection Fraction; SV: Stroke Volume.

as controls. There were 24 males and 30 females and the median age was 45.98±13.02 years (range: 30-62 years) (Table 1). Coffee and alcohol were not administered within 24 h before examination.
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Figure 2. Elasticity related parameters (CC and \( \beta \)) of right CCA.

Figure 3. Semi-automatic tracing method was used. Twelve spots were marked on the intima of CCA which was divided into 12 segments. The reference spot was marked at the lumen center.
was 1.4-1.5 cm and the location and height of sampling frame were adjusted. Then, the probe was fixed, and patients were asked to hold the breath. When 6 vascular dilations with favorable stability were present and observed (the standard deviation ≤15), the image was frozen and data were input to acquire the elasticity related parameters such as CC and β (Figures 1 and 2).

Table 2. Strain and elasticity related parameters in DN patients and healthy subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>CSmax (%)</th>
<th>CSRmax (s⁻¹)</th>
<th>CC (mm²/kPa)</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>54</td>
<td>6.50±0.99</td>
<td>0.65±0.08</td>
<td>1.35±0.31</td>
<td>3.72±1.01</td>
</tr>
<tr>
<td>DN</td>
<td>68</td>
<td>4.19±0.78</td>
<td>0.42±0.10</td>
<td>0.78±0.26</td>
<td>7.00±1.36</td>
</tr>
<tr>
<td>F</td>
<td>2.368</td>
<td>2.273</td>
<td>3.009</td>
<td>2.971</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>14.075</td>
<td>14.230</td>
<td>10.867</td>
<td>14.791</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

Note: CSmax: maximum of Circumferential Strain; CSRmax: maximum of Circumferential Strain Rate; CC: Compliance Coefficient; β: stiffness index.

*P<0.05 when compared with Control group.

Measurement of stain related parameters of right CCA: The transverse section of CCA was obtained at 5 cm above the beginning part of CCA, and the probe was vertical to the skin. The intima was clearly indicated, and images of the transverse section of CCA were captured in 3 consecutive cardiac cycle. The videos were replayed, and the automatic analysis software was used to detect the strain related parameters. The image was fixed when the T wave was present in the EEG, and semi-automatic tracing method was used. Twelve spots were marked on the intima of CCA which was divided into 12 segments. The reference spot was localized at the lumen center, and automatic analysis was performed. The mean maximum of circumferential strain (CSmax) of different segments and the mean maximum of circumferential strain rate (CSRmax) of differ-

Figure 4. Automatic analysis with the supporting software of the ultrasound scanner. The mean CSmax was obtained from each segment. (CSmax=3.43).
ent segments were determined for further analysis (Figures 3 and 4).

Statistical analysis

Data are expressed as mean ± standard deviation. Statistical analysis was performed with SPSS version 18.0. Pearson correlation analysis was employed to evaluate the correlation between elasticity and strain of the CCA. A value of P<0.05 was considered statistically significant.

Results

Of 54 healthy subjects the CSmax was 6.50%±0.99%, the CSRmax was 0.65±0.08 s⁻¹, and the CC was 1.35±0.31 mm²/kPa. Of 68 patients with DN, the CSmax was 4.19%±0.78%, the CSRmax was 0.42±0.10 s⁻¹ and CC was 0.78±0.26 mm²/kPa. The CSmax, CSRmax and CC in healthy controls were significantly higher than those in DN groups (P=0.000). The β was 3.72±1.01 in 54 healthy controls and 7.00±1.36 in 68 patients with DM, showing markedly difference between them (P=0.000) (Table 2).

In healthy controls and DN patients, the correlation between elasticity and strain of the CCA was further evaluated. Results showed significant linear correlation between CSmax and CC, between CSmax and β, between CSRmax and CC and between CSRmax and β. The correlation coefficient between CSmax and CC was 0.859 (P=0.000), and the regression equation was Y=1.969+3.140X. The correlation coefficient between CSmax and β was -0.898 (P=0.000), and the regression equation was Y=9.794-0.644X. The correlation coefficient between CSRmax and CC was 0.848 (P=0.000), and the regression equation was Y=0.205+0.308X. The correlation coefficient between CSRmax and β was -0.898 (P=0.000), and the regression equation was Y=0.877-0.064X (Figure 5).

Discussion

Studies have revealed that atherosclerosis is closely related to the cardiovascular events [11]. Atherosclerosis is one of chronic complications of diabetes mellitus (DM) and signifi-

Figure 5. Correlation analysis of CSmax and CC (A), CSmax and β (B), CSRmax and CC (C) and CSRmax and β (D) of CCA in 68 DN patients and 54 healthy controls.
cell hyperplasia is present in the intima, extracellular matrix including collagen and proteoglycans accumulate and intimal hyperplasia causes the formation of connective tissues. However, the elasticity and deformation capability of connective tissues are lower than those of smooth muscle cells, and thus the elasticity and strain of arterial wall reduce [28].

Taken together, the elasticity and strain related parameters of CCA may reflect the mechanical characteristics of arteries and there is a significant correlation between them in patients with DN. Elasticity related parameters are classic indicators used to evaluate the mechanical movement, and strain and strain rate provide new indicators for the evaluation of mechanical movement of arteries. In our study, correlation analysis demonstrates the correlation between elasticity and stain of CCA in DN patients and healthy population. Our findings provide evidence for future investigations on the mechanisms underlying the movement of middle to large arteries in different populations, and broaden the exploration.

Acknowledgements

This study was supported by the National Natural Science Foundation of China (NSFC) (No.81200630), Health and Family Planning Commission of Zhejiang Province, China (No.2015KYA159, No.2015ZDA028, No.2012KYB-130).

Disclosure of conflict of interest

None.

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