ORIGINAL ARTICLE
Tele-ultrasound in community with limited resources: The association of hypertension on reduced carotid artery circumferential strain
Tele-ultrassom em comunidade com recursos limitados: associação da hipertensão com a redução da tensão circunferencial da artéria carótida

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How to cite

Abstract

Background: Stroke is one of the leading causes of death worldwide, in majority triggered by modifiable risk factors such as hypertension. Aim: To assess relations between hypertension and carotid arteries radial and circumferential deformation, assessing a population of participants after a first ischemic stroke and healthy controls. Methods: Retrospective study, from 2016 to 2017, with a sample of the PAI project control group, an urban population of the São Francisco Valley in the Northeast of Brazil, 105 people 40 to 80 years-old, including patients after a first episode of ischemic stroke in the absence of known cardiovascular disease; and a control group of healthy volunteers, matched by age, sex, and presence of hypertension. Asynchronous analysis was performed by tele-ultrasonography of carotid artery ultrasound with images acquisition of EKG-synchronized videos in cross-section of the common carotid artery bilaterally and then strain values were acquired by Speckle Tracking technique, computing the mean circumferential and radial peaks of both carotids. Univariate and multivariable analyses
assessed the association between carotid strain and hypertension. Results: 84 participants had analyzable images (29 patients after a first episode of stroke). The mean age was 60.5 ± 11.6 years, 46.5% were women, 70.2% had hypertension. Radial deformation was lower but non-significant in participants with hypertension compared to those without hypertension (-3.13% vs. -3.35%, respectively, p = 0.54). There was significantly less circumferential deformation among participants who had hypertension compared to those without hypertension (4.16% vs. 5.3%, respectively, p = 0.003). Hypertension maintained association with lower circumferential strain in multivariate analysis (coef = -1.13; p = 0.019). Conclusion: hypertension was independently associated with the decrease in the carotid artery circumferential deformation. Tele-ultrasound associated with carotid strain analysis shows promising results for the evaluation of subclinical changes in carotid arteries in populations with limited resources in remote regions such as the Northeast of Brazil.

Keywords: circumferential strain; stroke; subclinical cardiovascular disease; hypertension; Tele-ultrasound; urbanization.

Resumo

Introdução: O AVC é uma das principais causas de morte no mundo, em sua maioria desencadeado por fatores de risco modificáveis, como a hipertensão. Objetivo: Avaliar as relações entre hipertensão e deformação radial e circunferencial das artérias carótidas, em uma população de participantes após um primeiro acidente vascular cerebral isquêmico e controles saudáveis. Métodos: Estudo retrospectivo, de 2016 a 2017, com amostra do grupo controle do projeto PAI (Projeto de Aterosclerose em Indígenas), população urbana do Vale do São Francisco, Nordeste do Brasil, com 105 pessoas entre 40 e 80 anos, incluindo pacientes após primeiro episódio de acidente vascular cerebral isquêmico na ausência de doença cardiovascular conhecida; e um grupo controle de voluntários saudáveis, pareados por idade, sexo e presença de hipertensão. A análise assíncrona foi realizada por tele-ultrassonografia da artéria carótida com aquisição de imagens de vídeos sincronizados com EKG em corte transversal da artéria carótida comum bilateralmente e em seguida os valores de strain foram adquiridos pela técnica de Speckle Tracking, computando os picos médios circunferenciais e radiais de ambas carótidas. Análises univariadas e multivariadas avaliaram a associação entre distensão carotídea e hipertensão. Resultados: 84 participantes tinham imagens analisáveis (29 pacientes após um primeiro episódio de acidente vascular cerebral). A média de idade foi de 60,5 ± 11,6 anos, 46,5% eram mulheres, 70,2% tinham hipertensão. A deformação radial foi menor, mas não significativa, nos participantes com hipertensão em comparação com aqueles sem
hipertensão (-3,13% vs. -3,35%, respectivamente, p = 0,54). Houve significativamente menos deformação circunferencial entre os participantes que tinham hipertensão em comparação com aqueles sem hipertensão (4,16% vs. 5,3%, respectivamente, p = 0,003). A hipertensão manteve associação com menor deformação circunferencial na análise multivariada (coef = -1,13; p = 0,019). **Conclusão:** a hipertensão esteve independentemente associada à diminuição da deformação circunferencial da artéria carótida. A tele-ultrassonografia associada à análise da deformação carotídea apresenta resultados promissores para avaliação de alterações subclínicas nas artérias carótidas em populações com recursos limitados em regiões remotas como o Nordeste do Brasil.

**Palavras-chave:** deformação circunferencial; acidente vascular cerebral; doença cardiovascular subclínica; hipertensão; tele-ultrassom; urbanização.

**Introduction**

Stroke is one of the leading causes of disability and death worldwide [1,2], with 10.3 million new cases and 113 million disability-adjusted life years annually [3]. Stroke incidence varies between countries based on their degree of development. Stroke incidence has seen a 42% decrease in developed countries and a 100% increase in underdeveloped and developing countries over the past 4 decades [3]. The Global Burden of Disease study [3] showed that 90% of stroke cases were triggered by modifiable risk factors, such as hypertension, diabetes, tobacco, and others, and more than 75% of these cases could have been prevented if risk factors had been controlled. For this reason, it is necessary to discuss new ways to predict stroke in order to prevent it, given that its morbidity and mortality directly impact individuals’ quality of life and social conditions, as well as financial and healthcare systems; an example may be seen in Europe, where annual spending exceeds 38 billion euros [4].

About 87% of strokes are of ischemic etiology [5], and the leading cause of ischemic stroke in the carotid territory is thromboembolism of the internal carotid artery or the middle cerebral artery due to atherosclerotic plaque, corresponding to 25% of cases [4,5,6]. In carotid arteries, increased stiffness is associated with hypertension, diabetes mellitus, age, and body mass index (BMI) [7]. It is, thus, of the utmost importance to develop non-invasive techniques for detecting early atherosclerotic processes in carotid arteries [5].

Carotid artery strain, a new method based on speckle tracking, has been shown to be promising for assessing tissue stress and strain rate [5,7,8,9]. This method was originally developed to analyze regional myocardial function on echocardiography,
assessing the lengthening or shortening of a region of interest [7]. Previous studies have showed that carotid artery strain could be an important marker of arterial aging, particularly in patients with different vascular diseases [10,11]. In following with these, other studies have gone on to correlate carotid artery strain with stroke, providing evidence of a decrease in carotid artery expansion during diastole in patients with stroke, in comparison with age-matched healthy volunteers. It has, thus, been shown that analysis of carotid artery strain may provide better risk stratification for stroke [5].

Teleultrasound (TUS) allows remote medical care for populations with limited access to specialized health services [12]. TUS may be used as a screening tool for patients living in areas with limited medical resources, reducing the demand for travel to faraway health care centers, thus positively impacting on the reduction of costs for the Brazilian National Health System, as well as providing improved access to health services in vulnerable communities [13].

For this reason, the aim of this study was to retrospectively assess, in an exploratory manner, the relationship between hypertension and radial and circumferential deformation of the carotid arteries, in an urban population, control group sample of the PAI project, of the São Francisco Valley in the Northeast of Brazil, after a first ischemic stroke and healthy controls, through asynchronous analysis by tele-ultrasound images.

**Methods**

This is a unicentric, case-control study with retrospective analysis, from 2016 to 2017, with a sample of the PAI (Projeto de Aterosclerose em Indígenas) project control group, an urban population of the São Francisco Valley in the Northeast of Brazil. The main objective was to assess the association between stroke and subclinical cardiovascular changes, through asynchronous tele-ultrasound image analysis in an urban population with limited medical resources. The study was approved by institutional local and national ethics committees.

**Study population**

A sample of the PAI project control group, 105 people 40 to 80 years-old, an urban population of the São Francisco Valley were separated into 2 groups: study group (SG) and healthy control group (HCG), at a 1:2 proportion, respectively, totaling 35 patients in SG and 70 in HCG. Ischemic Stroke was defined by the National Institutes of Health (NIH) Scale [13] and confirmed by non-contrast skull computed tomography.
The SG included participants of both sexes, between 40 and 80 years old, diagnosed with first episode of ischemic stroke, with no known cardiovascular disease (myocardial infarction, angina pectoris, heart failure, pulmonary hypertension, congenital heart disease, atrial fibrillation or flutter, heart tumors, cardiorespiratory arrest due to any cause, or myocarditis) at the moment of data collection.

The HCG included participants without stroke and with no known cardiovascular disease, preferably relatives of SG participants. Participants were age-matched (respecting the age group from 40 to 80 years old), sex, and hypertension, given that this is a recognized stroke risk factor [14].

Exclusion criteria were: patients whose physical or conscious state did not allow them to provide informed consent or patients who did not wish to participate in the study. Participants whose carotid duplex ultrasound (CDU) imaging was not satisfactory for analysis were also excluded from this study.

Clinical parameters

Hypertension was defined as self-reported, by the use of antihypertensive medication, or as 2 measurements of systolic blood pressure \( \geq 140 \) mmHg or diastolic blood pressure \( \geq 90 \) mmHg. Diabetes mellitus was defined as self-reported, by the use of hypoglycemic drugs, or as 2 rapid glucose tests \( \geq 126 \) mg/dL or glycated hemoglobin (HbA1c) > 6.5%. Dyslipidemia was defined as self-reported, by the use of hypolipidemic drugs, or as total cholesterol > 200 mg/dL. Patients who had used tobacco for more than 6 months were considered smokers. Body mass index (BMI) was calculated as body weight divided by height squared.

Tele-ultrasound of carotid artery and strain analyses

Asynchronous analysis was performed by tele-ultrasonography (TUS) of carotid artery of all participants with images acquisition of EKG-synchronized videos in cross-section of the common carotid artery bilaterally. Images were collected using a Vivid S6 scanner (General Electric Health) 2 to 14 days after the ischemic stroke episode, in order to avoid the acute phase. Then strain values were acquired by Speckle Tracking technique, computing the mean circumferential and radial peaks of both carotids. Subsequently, a single reader blindly analyzed the images.

Carotid artery strain analysis was performed via 2-dimensional cross-sectional ultrasound images, using Wall Motion Tissue Tracking software, developed to assess cardiac strain by the speckle tracking technique. We created the following internal
protocol for semi-automatic analysis: we manually fixed 6 points along the medial-adventitial layer of the carotid artery; the software automatically identified the tissue for point tracking and divided the carotid into 6 segments (left ventricular short-axis modeling as defined by American Heart Association [15], generating videos that demonstrated the point tracking and strain curves for each segment; segments whose point tracking was visually considered inappropriate were excluded; peak circumferential and radial strain values of the properly screened segments were computed to average the peaks (used for statistical analysis). The procedure was repeated in both carotids, and then the mean for each patient was computed.

**Statistical analysis**

Continuous variables were described as means and standard deviations. Categorical variables were described as percentages. Univariate analysis utilized unpaired Student’s t-test. Linear regression was used for multivariate analysis, with strain values as dependent variables. Univariate and multivariable analyses assessed the association between carotid strain and hypertension. STATA version 10.0 software was used for statistical analysis.

**Results**

The study included 105 participants, 34% of which diagnosed with stroke. Of these 105 patients, 21 had no analyzable carotid images, due to motion artifacts. Therefore, in this study, we assessed a total of 84 participants, 29 with stroke and 59 without stroke. Of the total participants, the mean age was 60.5 ± 11.6 years, 46.5% were women, 70.2% had hypertension, mean radial strain was −1.88 ± 1.68 %, and mean circumferential strain was 3.92 ± 1.96 %. Other clinical characteristics of the participants are detailed in Table I.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (59) Average (± SD)</th>
<th>Study (25) Average (± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>51 (23)</td>
<td>60 (1.4)</td>
</tr>
<tr>
<td>Male, %</td>
<td>52.5</td>
<td>53</td>
</tr>
<tr>
<td>Hypertension, %</td>
<td>69</td>
<td>72</td>
</tr>
<tr>
<td>Diabetes mellitus, %</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>Dyslipidemia, %</td>
<td>37</td>
<td>52</td>
</tr>
<tr>
<td>Tobacco, %</td>
<td>8</td>
<td>32</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>21.5 (5)</td>
<td>28.5 (5)</td>
</tr>
</tbody>
</table>
There was statistical significance for circumferential strain between participants who had hypertension and those who did not. However, there was no significance when comparing circumferential deformation between stroke groups. For radial strain, neither comparisons regarding the presence of hypertension nor the presence of stroke were significant (Table II).

<table>
<thead>
<tr>
<th>Strain</th>
<th>Hypertension average (SD)</th>
<th>Stroke average (SD)</th>
<th>p-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumferential</td>
<td>Yes 4.16 (1.4) No 5.30 (1.5)</td>
<td>Yes 4.47 (1.6) No 4.52 (1.4)</td>
<td>0.003</td>
<td>0.897</td>
</tr>
<tr>
<td>Radial</td>
<td>−3.13 (1.4) No −3.35 (1.4)</td>
<td>−3.37 (1.6) No −3.12 (1.3)</td>
<td>0.545</td>
<td>0.510</td>
</tr>
</tbody>
</table>

In multivariate analysis, using stroke and hypertension as parameters for circumferential strain, there was statistical significance for hypertension. When the same parameters were used to analyze radial strain, there was no statistical significance (Table III).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Circumferential strain</th>
<th>Radial strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>Coef. −.1908578 p-value 0.691</td>
<td>Coef. −.0636015 p-value 0.913</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Coef. −1.132466 p-value 0.019</td>
<td>Coef. .4507601 p-value 0.435</td>
</tr>
</tbody>
</table>

Discussion

In this exploratory analysis, we have demonstrated that hypertension, an important risk factor for stroke [14], is related to the reduction of carotid artery circumferential strain. Circumferential strain, when compared to radial strain, has shown to be a more robust marker of early carotid disease.

Cardiovascular function deteriorates with aging in all organisms, but some processes accelerate this deterioration, such as hypertension [16,17], which increases vascular resistance, resulting in remodeling and in endothelial dysfunction in low-resistance arteries. Hypertension, thus, represents the most important predictor of cardiovascular events [17]. The occurrence of hypertension may represent an acceleration of the initial development of age-related vascular changes [16,18]. For this reason, clinical guidelines for the prevention of cardiovascular events show how patient lifestyles and behaviors may contribute to the acceleration of vascular deterioration [16,18].
It is of great importance to discuss new ways for predicting stroke, as it is one of the leading causes of disability and death worldwide [1,2], with reports of approximately 10.3 million new cases annually [3]. Carotid ultrasound is a noninvasive, inexpensive and widely available method, and it is a recommended method for assessing overall cardiovascular risk [19]. In a manner similar to that already validated for myocardial strain [7], carotid strain can also be incorporated into ultrasound, and it has demonstrated the potential to be used as an early subclinical marker of vascular changes typically implicated in genesis and progression of cerebrovascular disease. Both the aging process and known risk factors for cardiovascular disease alter the elastic properties of the carotid artery wall. These changes have been validated for carotid strain evaluation using the speckle tracking method [8,20,21,22].

In accordance with data from the literature [7,8], circumferential strain seems to be a more robust parameter than radial strain for analysis of deformation of the medial-adventitial layer of the carotid artery. Corroborating our findings, other studies have shown that stroke patients have less carotid artery circumferential strain than healthy, age-matched patients [5,8,22,23]. This decrease in circumferential strain was also seen in the univariate analysis of known risk factors for stroke, such as hypertension, diabetes mellitus, dyslipidemia, and tobacco [5,7].

Importantly, our findings highlight the influence of hypertension on carotid deformation, regardless of the presence of ischemic stroke. Hypertension is an important risk factor for cerebrovascular disease [3]. Furthermore, it is closely related to changes in vascular properties. These findings differ from the previously described findings. When performing multivariate analysis of stroke risk factors, stroke was found to be the only factor independently associated with reduced carotid artery circumferential strain, with risk factors being confounding elements [5].

Although radial deformation showed a non-significant tendency to be reduced in participants with known hypertension when compared to those without hypertension, we found a greater carotid artery radial strain in participants after ischemic stroke, in comparison with healthy control participants. This data may be related to atherosclerotic plaque rupture, leading to mechanical weakening and excessive plaque strain under the blood pressure load [23,24,25]. Furthermore, some studies using magnetic resonance imaging (MRI) have shown that an increase in strain can be found in carotid artery bifurcation regions, and it is related to sites with early atherosclerotic inflammation [24,25,26,27]. However, further studies are needed to assess whether the same findings of carotid artery strain calculated by MRI are similar to those used in CDU.

Our study had several limitations; the performance of CDU was difficult in obese patients, patients with reduced neck height, and patients with enlarged thyroid glands. In
addition, the software used had been designed for cardiac strain evaluation, and it presented errors when reading some carotid images, even when they were initially considered adequate. There was, thus, a reduction in the number of participants for analysis. This may have led to there being no statistical significance of stroke in relation to reduced circumferential strain in the carotid artery, although there was a tendency. Taking this into consideration, further studies with larger numbers of participants should be performed to confirm our results.

Conclusion

In this exploratory study, hypertension was independently associated with the decrease in the carotid artery circumferential deformation. Circumferential strain seems to be more robust than radial strain for analyzing changes in the carotid artery wall. Tele-ultrasound associated with carotid strain analysis shows promising results for the evaluation of subclinical changes in carotid arteries in populations with limited resources in remote regions such as the Northeast of Brazil.

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Conflicts of interest
The Author(s) declare(s) that there is no conflict of interest.

References


