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CLINICAL STUDY

Relationship between Renying pulse augmentation index and Cunkou pulse condition in different blood pressure groups

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Abstract

OBJECTIVE: To explore the relationship between Renying pulse (carotid) augmentation index (AI) and Cunkou pulse condition in different blood pressure groups, and the clinical significance of Renying and Cunkou pulse parameters to reflect vascular function.

METHODS: Eighty-six patients with essential hypertension (EH) and 52 individuals with normal blood pressure (control group) between September 2010 and January 2012 were included in this study. Renying pulse AI was examined by a new diagnostic tool (ALOKA ProSound Alpha 10) — wave intensity (WI) that is calculated as the product of the derivatives of the simultaneously recorded blood pressure changes (dP/dt) and blood-flow-velocity changes (dU/dt), while Cunkou pulse condition was detected by DDMX-100 Pulse Apparatus in both EH and control groups. A multifactorial correlation analysis was performed for data analysis.

RESULTS: After adjusting for potential confounding variables, in the EH group, AI was positively correlated with t_5, $w_{2/t}$ (r_{t5}=0.225, P<0.05; $r_{w2/t}$=0.230, P<0.05) and negatively correlated with h_5, h_5/h_1 and w_2 (r_{h5}= - 0.393, P<0.01; $r_{h5/h1}$= - 0.444, P<0.01; r_{w2}= - 0.389, P<0.01). In the control group, AI was positively correlated with t_3, t_4, t_5 and w_1 (r_{t3}=0.595, P<0.01; r_{t4}=0.292, P<0.05; r_{t5}=0.318, P<0.05; r_{w1}=0.541, P<0.01) and negatively correlated with h_1, h_2, h_3, Ad and A (r_{h1}= - 0.368, P<0.05; r_{h2}= - 0.330, P<0.05; r_{h3}= - 0.327, P<0.05; r_{Ad}= - 0.322, P<0.05; r_A= - 0.410, P<0.01). In the total sample group (EH plus control group, n=138), AI was positively correlated with t, t_5, w_1 and $w_{2/t}$ (r_t=0.257, P<0.01; r_{t5}=0.266, P<0.01; r_{w1}=0.184, P<0.05; $r_{w2/t}$=0.210, P<0.05) and negatively correlated with h_5, h_5/h_1, w_2 and Ad (r_{h5}= - 0.230, P<0.01; $r_{h5/h1}$= - 0.218, P<0.05; r_{w2}= - 0.267, P<0.01; r_{Ad}= - 0.246, P<0.01). Multiple linear regression analysis was carried out to model the relationship (F=7.887, P<0.001).

CONCLUSION: Renying pulse AI can effectively predict arterial stiffness in synchrony with the manifestations of Cunkou pulse in elderly patients with hypertension. Cunkou pulse apparatus is a valuable tool for evaluating AI in clinical practice. The close correlations reported above reflect the holistic concept of Traditional Chinese Medicine.

Key words: Ultrasonography; Hypertension, essential; Cunkou pulse diagnosis; Renying pulse; Augmentation index; Wave intensity

INTRODUCTION

The objective quantifiable study on the Traditional Chinese Medicine pulse condition study might further contribute to future research on pulse manifestation, one of the four pillars underpinning the pattern differentiation for treatment in Traditional Chinese Medicine (TCM). Together, these two new ultrasonic diagnostic tools — eTRACKING (ET) and Wave Intensity (WI) — provide powerful methods for understanding the changes in pulse condition. Cunkou and Renying pulse diagnostic methods are important parts of the "three portions and nine pulse-feelings" theory, which is a term used in holistic TCM.

Augmentation index (AI) is a measure obtained from the arterial pressure curve (AI_p), and is proposed as a predictor of arterial stiffness. WI is a novel technique of the Aloka Company based on Alpha10 ET, and is a new hemodynamic index that is potentially useful for analyzing interaction with the cardiovascular system. AI_{et} is defined as the AI value resulting from a change in the arterial diameter curve.[1] Both of them contribute equally to arterial stiffness evaluation. In this study, we aimed to establish potential Cunkou pulse condition parameters to reflect arterial stiffness.

MATERIALS AND METHODS

Patients

From September 2010 to January 2012, 86 patients with essential hypertension (EH) [48 men and 38 women, mean age (62 ± 10) years] from the Department of Traditional Chinese Medicine and Physical Examination Center of Fujian Provincial Hospital were included in this study. In the EH group, there were 23 patients with Grade 1 EH (five patients with well-controlled blood pressure), 35 with Grade 2 EH (29 patients with well-controlled blood pressure), and 28 with Grade 3 EH (25 patients with well-controlled blood pressure). The control group consisted of 52 healthy individuals [22 men and 30 women, mean age (59±11) years] with normal blood pressure from the Physical Examination Center of Fujian Provincial Hospital. This study was approved by the Medical Ethics Committee of Fujian Provincial Hospital. All participants gave signed informed consent, and were handled according to the Ethics Committee Regulatory Guidance. There were no significant differences in sex and age between the EH and control groups (P>0.05) (Table 1).

Hypertension was diagnosed according to the criteria of the Chinese Hypertension Prevention and Treatment Guidelines, 2005.[2] The exclusion criteria were as follows: secondary hypertension, severe anemia, hyperthyroidism, heart failure, rheumatic heart disease, congenital heart disease, cardiomyopathy, arteriovenous fistula, constrictive pericarditis, pericardial effusion, hepatocirrhosis, asthma, malignant tumor, autoimmune diseases and other systemic diseases.

Table 1 General characteristics in EH and control groups

Item	Control	EH	Statistics	*P* value
Age (years)	58.9±11.4	62.2±10.2	-1.802	0.074
SBP (mm Hg)	119.7±9.4	138.6±13.8	-9.082	0.000
DBP (mm Hg)	71.7±8.5	79.2±8.8	-5.017	0.000
PP (mm Hg)	48.0±10.2	58.0±14.7	-4.398	0.000
BMI (Kg/l^2)	23.7±2.4	23.8±2.5	0.010	0.992
AST (IU/L)	24.1±9.1	24.1±7.8	0.003	0.997
TG (mmol/L)	1.5±0. 8	2.0±0.6	-4.606	0.000
CHOL (mmol/L)	4.9±1.1	5.9±1.0	-5.591	0.000
HDL-C (mmol/L)	1.2±0.3	1.3±0.3	-1.104	0.272
LDL-C (mmol/L)	2.9±0.9	3.7±0.9	-5.063	0.000
FPG (mmol/L)	5.3±0.6	5.3±0.7	-1.944	0.054
LDH (IU/L)	179 (154-199)	194 (175-206)	-2.143	0.032
α-HBDH (IU/L)	140 (121-167)	146 (131-156)	-1.259	0.208
CK (IU/L)	88 (63-113)	107 (71-132)	-1.677	0.094
CK-MB (IU/L)	13.7±4.0	13.0±4.4	0.923	0.358
BUN (mmol/L)	5.5 (4.6-5.8)	4.7 (4.0-5.5)	-2.277	0.023
Creatinine (μmol/L)	69.4±10.5	76.0±16.8	-2.579	0.011
UA (μmol/L)	315.0±73.1	367.6±76.2	-4.074	0.000

Notes: EH: essential hypertension group; control: normal blood pressure group; SBP: systolic blood pressure; DBP: diastolic blood pressure; PP: pulse pressure; BMI: body mass index; AST: serum glutamic-oxaloacetic transaminase; TG: serum triglycerides; CHOL: serum cholesterol; HDL-C: serum hyperdensity lipoprotein cholesterol; LDL-C: serum low density lipoprotein cholesterol; FPG: serum fasting blood glucose; LDH: serum lactate dehydrogenase; α-HBDH : serum α-hydroxybutyric dehydrogenase; CK: serum creatine kinase; CK-MB: creatine kinase isoenzyme; BUN: blood urea nitrogen; UA: uric acid.

Experimental equipment

In this study, ALOKA ProSound Alpha 10 (SN 200N8431) Color Doppler Ultrasonic Diagnostic Apparatus (Hitachi Aloka Medical, Ltd., Tokyo, Japan) equipped with a 1-5-MHz heart broadband probe and a 5-13-MHz vascular probe, and DDMX-100 Pulse Apparatus (Shangxin Medical Technology of Shanghai University of TCM, Shanghai, China) were adopted. All participants were tested at ≥1 h after meals at room temperature of 20℃-24℃.

WI definition

WI offers a novel method for evaluating cardiovascular function by recording hemodynamic parameters. WI is defined as (dP/dt) (dU/dt), where dP/dt and dU/dt are the derivatives of P and U with respect to time. AI, an artery elastic parameter, is defined as the ratio $\Delta P/PP$ (ΔP: pressure from shoulder to late peak; PP: pulse pressure).[3,4] In all patients, there was a linear relationship between pressure and vessel diameter.

WI examination

Participants received WI examination after sitting or lying down for 10 min at a room temperature of 20℃-24℃. Coffee or strong tea was not allowed before examination. Blood pressure in the left brachial artery was measured twice and then standard electrocardiography leads were connected. WI analysis was setup as follows: Beam Steer (B) as 15°, Beam Steer (Flow) as - 15° and Angle Correct as 60°. The detector was placed 2.0 cm lower than the sinus part of the right common carotid artery (Renying pulse). The forearm of the examiner remained supported to avoid detector instability. The head and tail ends of the detector were adjusted along the longitudinal axis of the target vessel to ensure that the angle between the blood flow and Doppler beam emission direction was ≤60°, with a vertical linkage between the 2D sampling gate (width: 2.5 mm) and artery wall. A "double line" echo revealed the anterior and posterior artery walls by pressing one-key optimization. WI mode was started by clicking WI on the liquid crystal display. The 2D sampling gate was placed in the middle/external membrane between the anterior and posterior artery walls to guarantee a vertical linkage between the sampling gate and artery wall. The pulse repetition frequency of color Doppler was modified to the minimum without color mixture of blood flow. A stable deflection angle of <20° was recommended. Both participant and examiner were required to hold their breath during image collection. Images and data were collected after pressing the Select button. At least six and five waves were needed for description and analysis, respectively. When WI image collection was completed, the Lock button was clicked. The trackball was moved to reply and we chose several images of cardiac cycles with a uniform curve of vessel diameter. The Select button was clicked to move the trackball, replay 2D images, and choose those images with clear middle and external membranes of the vessel wall, and favorable perfusion of color Doppler images. The Store button was clicked to store the first image. Blood pressure was measured twice to obtain the mean value. Four images were recorded for further analysis.

Pulse condition parameter collection

Participants underwent examination at rest, with the wrist straight and palm upward on a pillow. The detector probe was fixed on the left Cunkou pulse (radial artery pulse on the inside of the radial styloid). According to the optimal pulse pressure, the vertical compression screw of the sensor was rotated to record 5-7 waves (pressure 50-225 g). A set of pulse images with a mean pulse difference of 25 g was recorded. Various pulse condition parameters were automatically collected and analyzed by computer.

Definition of main electropulsograph indices[5]

Time: t was defined for both the pulse and cardiac cycles, covering the period from the beginning to the end of the pulse diagram. t_1 increased between the beginning of the pulse diagram and the principal wave peak, which implied a rapid ejection period. t_4 was the systolic time between the beginning of the pulse diagram and the dicrotic notch, which implied systole. t_5 was the slowly decreasing time between the end of the pulse diagram and dicrotic notch, which implied diastole.

Wave amplitude: h_1 was the principal wave height between the principal wave peak and pulse diagram baseline. It represented the artery wall volume and pressure at systole, reflecting cardiac ejection function and main arterial compliance. h_3 was the tide wave height between the baseline and wave peak, which implied peripheral resistance and vascular tension. h_4 was the dicrotic notch height between baseline and the bottom of the dicrotic notch, which implied vascular peripheral resistance. h_5 was the repulse wave height between the dicrotic notch baseline and the repulse wave peak, which implied main artery compliance.

W_2 was the pulse diagram width above $1/5h_1$, while w_1 was above $1/3h_1$, suggesting the period when arterial pressure remained high. w/t was the duration during which the aortic pressure remained high. It was related to the start of h_3 and peripheral resistance. As was systolic area. Pulse diagram area was related to cardiac output. Ad was diastolic area. A was the sum of systolic and diastolic pulse diagram areas.

Ratio: h_1/t_1 was the ascending branch slope, h_3/h_1 was the tension coefficient, h_4/h_1 was the resistance coefficient, and h_5/h_1 was the elastic coefficient.

Statistical analysis

The data were analyzed by SPSS version 15.0 (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed as mean ± *SD*. The *t* test was used for comparison of means. Median (M, 25%-75%) was used to analyze quantitative but non-normal distribution. Mann-

Whitney U test or Pearson χ^2 test of fourfold tables was used for comparison of two means. Multiple linear regression was performed for multivariate correlation analysis. $P<0.05$ was considered statistically significant.

RESULTS

General characteristics

Age, systolic blood pressure (SBP), diastolic blood pressure (DBP), PP, serum triglyceride (TG), serum cholesterol (CHOL), serum low-density lipoprotein cholesterol (LDL-C), serum lactate dehydrogenase (LDH), blood urea nitrogen (BUN), serum creatinine (SC) and uric acid (UA) were significantly different between EH and groups ($P<0.05$) (Table 1). AI, t, t_1, t_2, t_5, h_1, h_3, h_4, h_5, h_3/h_1, w_2, As and A were significantly different between the EH and groups ($P<0.05$) (Table 2).

Multivariate correlation between AI and pulse condition parameters

After adjusting for potential confounding variables including sex, age, SBP, DBP and body mass index (BMI), in the control group, AI was positively correlated with t_3, t_4, t_5 and w_1 (r_{t3}=0.595, $P<0.01$; r_{t4}=0.292, $P<0.05$; r_{t5}=0.318, $P<0.05$; r_{w1}=0.541, $P<0.01$) and negatively correlated with h_1, h_2, h_3, Ad and A (r_{h1}= - 0.368, $P<0.05$; r_{h2}= - 0.330, $P<0.05$; r_{h3}= - 0.327, $P<$ 0.05; r_{Ad}= - 0.322, $P<0.05$; r_A= - 0.410, $P<0.01$) (Table 3).

After adjusting for potential confounding variables including sex, age, SBP, PP, DBP and BMI, in the EH group, AI was positively correlated with t_5 and $w_{2/t}$ (r_{t5}= 0.225, $P<0.05$; $r_{w2/t}$=0.230, $P<0.05$) and negatively correlated with h_5, h_5/h_1 and w_2 (r_{h5}= - 0.393, $P<0.01$; $r_{h5/h1}$= - 0.444, $P<0.01$; r_{w2}= - 0.389, $P<0.01$) (Table 3).

After adjusting for potential confounding variables including sex, age, SBP, PP, DBP and BMI, in the total sample group (EH plus control group, n=138), AI was positively correlated with t, t_5, w_1 and $w_{2/t}$ (r_t=0.257, $P<$ 0.01; r_{t5}=0.266, $P<0.01$; r_{w1}=0.184, $P<0.05$; $r_{w2/t}$= 0.210, $P<0.05$) and negatively correlated with h_5, h_5/h_1 and w_2, Ad (r_{h5}= - 0.230, $P<0.01$; $r_{h5/h1}$= - 0.218, $P<$ 0.05; r_{w2}= - 0.267, $P<0.01$; r_{Ad}= - 0.246, $P<0.01$) (Table 3).

Multiple linear regression analysis in total sample group (method: enter)

In multiple linear regression, we established a set of in-

Table 2 Comparison of AI and pulse condition parameters between EH and control groups

Item	Control	EH	Statistics	*P* value
AI	18.05±10.41	22.98±11.10	- 2.576	0.011
t (s)	0.80±0.09	0.84±0.09	- 2.817	0.006
t_1 (s)	0.16±0.04	0.13±0.02	4.025	0.000
t_2 (s)	0.24±0.03	0.21±0.02	5.426	0.000
t_3 (s)	0.28±0.03	0.29±0.13	- 0.494	0.622
t_4 (s)	0.36±0.03	0.35±0.03	- 0.052	0.959
t_5 (s)	0.48±0.10	0.53±0.10	- 3.078	0.003
h_1 (mm)	16.12±5.65	20.36±8.20	- 3.285	0.001
h_2 (mm)	14.22±3.96	16.05±6.40	- 1.775	0.078
h_3 (mm)	12.38±5.30	14.22±3.96	- 2.158	0.034
h_4 (mm)	6.84±2.39	7.74±2.59	- 2.037	0.044
h_5 (mm)	0.48 (0.40-0.54)	0.2 (- 0.4-0.6)	- 2.606	0.009
h_3/h_1	0.67±0.21	0.94±1.07	- 2.208	0.030
h_4/h_1	0.44±0.12	0.45±0.21	- 0.278	0.781
h_5/h_1	- 0.01 (- 0.05-0.02)	0.005 (- 0.03-0.02)	- 1.159	0.246
t_5/t_4	1.51±0.59	1.46±0.44	0.439	0.661
w_1 (s)	0.21±0.02	0.21±0.08	-0.378	0.706
w_2 (s)	0.16±0.02	0.19±0.13	- 1.904	0.060
w_1/t	0.24±0.03	0.24±0.09	0.168	0.867
w_2/t	0.18±0.02	0.18±0.09	0.407	0.685
As (mm^2)	3.70±1.61	4.60±1.58	- 2.948	0.004
Ad (mm^2)	1.58±0.76	1.59±0.62	- 0.068	0.946
A (mm^2)	5.28±2.16	6.00±1.98	- 2.006	0.047

Notes: EH: essential hypertension group; control: normal blood pressure group; AI: augmentation index; t: pulse cycle; t_1: ascending time; t_4: corresponding left ventricular systolic; t_5: corresponding left ventricular diastolic; h_1: principal wave height; h_3: tide wave height; h_4: dicrotic nothch height; h_5: repulse wave height; w_2: pulse diagram width above $1/5h_1$; w_1: pulse diagram width above $1/3h_1$; As: systole area; Ad: diastole area; A: the sum of systole and diastole pulse diagram area.

Table 3 Multifactorial correlation analyses between AI and pulse condition parameters in both EH and control groups

Pulse condition parameter	Control (n=52)		EH (n=86)		Total sample (n=138)	
	r	P value	r	P value	r	P value
t	0.210	0.156	0.211	0.064	0.257	0.003
t_1	- 0.067	0.657	0.143	0.210	- 0.007	0.939
t_2	0.172	0.247	- 0.067	0.562	- 0.03	0.731
t_3	0.595	0.000	- 0.022	0.846	0.055	0.535
t_4	0.292	0.047	- 0.103	0.369	0.144	0.103
t_5	0.318	0.029	0.225	0.048	0.266	0.002
h_1	- 0.368	0.011	- 0.04	0.728	- 0.124	0.160
h_2	- 0.330	0.023	0.094	0.413	- 0.048	0.585
h_3	- 0.327	0.025	0.137	0.230	- 0.043	0.629
h_4	- 0.233	0.115	- 0.046	0.690	- 0.075	0.395
h_5	- 0.032	0.829	- 0.393	0.000	- 0.230	0.009
h_3/h_1	- 0.095	0.524	0.022	0.846	0.078	0.379
h_4/h_1	- 0.115	0.440	0.031	0.789	0.029	0.744
h_5/h_1	- 0.196	0.186	- 0.444	0.000	- 0.218	0.013
t_5/t_4	0.065	0.664	- 0.077	0.503	- 0.087	0.327
w_1	0.541	0.000	0.074	0.521	0.184	0.036
w_2	0.298	0.042	- 0.389	0.000	- 0.267	0.002
w_1/t	0.213	0.150	0.111	0.334	0.151	0.087
w_2/t	- 0.044	0.771	0.230	0.043	0.210	0.017
As	- 0.196	0.188	0.000	0.998	- 0.021	0.813
Ad	- 0.322	0.027	- 0.198	0.082	- 0.246	0.005
A	- 0.410	0.004	- 0.096	0.403	- 0.172	0.050

Notes: EH: essential hypertension group; control: normal blood pressure group; AI: augmentation index; t: pulse cycle; t_1: ascending time; t_4: corresponding left ventricular systolic; t_5: corresponding left ventricular diastolic; h_1: principal wave height; h_3: tide wave height; h_4: dicrotic nothch height; h_5: repulse wave height; w_2: pulse diagram width above $1/5h_1$; w_1: pulse diagram width above $1/3h_1$; As: systole area; Ad: diastole area; A: the sum of systole and diastole pulse diagram area.

dependent variables (t, t_5, h_5, h_5/h_1, w_2, $w_{2/t}$ and Ad) and a dependent variable (AI). The results were shown as below: the multiple correlation coefficient (R= 0.549), the coefficient of determination (R^2=0.301), and adjusted coefficient of determination (R^2_a=0.263). A significant correlation was reported by analysis of variance (F=7.887, P<0.001). The model for multiple linear regression was AI= - 4.418 + 12.177 × t + 31.36 × t_5-0.704 × h_5-5.461 × h_5/h_1-34.281 × w_2 + 44.215 × w_2/t-1.391×Ad+e_i.

DISCUSSION

Many studies in TCM have focused on blood vessels. Pulse Feeling of Renying Cunkou is an old pulse-taking method, which was used for establishing the diagnosis of a meridian disease according to differentiation of the feeling of the Renying and Cunkou pulses. *Huang Di Nei Jing* indicates that pulse feeling is widely used and characterized as Renying, Cunkou and Fuyang pulses.[5] *Nan Jing* states that 12 meridians have arteries, and among these, Cunkou is critical to determine the prognosis and modality. Cunkou, the pulse of lung meridian, is also the center of the pulses. During the day, all pulses throughout the body will return to Cunkou, which is also the origin and end of all meridians.[6] Cunkou is a traditional pulse to evaluate healthy conditions in humans; however, modern western clinicians pay more attention to Renying (carotid) pulse, because Renying pulse is closer to heart than Cunkou, which can reflect the interaction of heart and arterial system and is more suitable for evaluate the comprehensive function of heart and arterial system.

ΔP/PP BP augmentation was first described in 1980[7] and officially defined in 1989.[8] An increasing number of studies have confirmed the efficacy of artery function indices such as reflected wave AI, artery pulse wave velocity, SBP, ankle brachial index, and PP.[9] Artery elasticity indicates endothelial function and affects PP, SBP and DBP.[10] AI refers to general elasticity of the arterial system to display sensitive pressure feedback caused by large and small changes in blood vessel elasticity. AI covers the levels of the intensity of the pressure wave, reflection, and conduction velocity changes. A smaller AI indicates a smaller increase in SBP and DBP resulting from the pressure reflected wave. The higher the AI, the higher the SBP and PP. Despite similar clinical significance, AI is superior to PP for evaluation of artery elasticity. AI of the reflected wave is commonly accepted as a measure of the arterial reflected wave. Furthermore, it is an indirect measure of arterial stiffness.[11] Previous studies have found that AI is an independent risk factor and predictor of morbidity and mortality in cardiovascular disease.[12,13] Recently, AI has been used in drug assessment for artery elasticity improvement, such as statins, nitrates and sildenafil.[14]

The AI of the reflected wave is defined as the proportion of central pulse pressure due to the late systolic peak, which is in turn attributed to the reflected pulse wave. After ventricular ejection, blood pressure is conducted to the peripheral vessels as waveforms. When it reaches resistant small vessels, because of differences in vascular structure pressure waves, it generates reverse reflected waves immediately. The antegrade pressure wave and reflected wave form the actual pressure wave measurement. Usually, the antegrade pressure wave and reflected wave overlap during diastole if the conduction velocity of the pressure wave is normal. If the reflected wave returns earlier, the antegrade pressure wave and reflected wave overlap during systole, resulting in higher SBP and lower DBP. The overlap can also occur during late systole when a higher conduction velocity of the pressure wave or earlier reflection occurs. AI is calculated by pulse wave as follows AI=ΔP/PP, where ΔP is the difference between P2 and P1, respectively, the pressures at times t_2 and t_1, and PP (SBP-DBP). There are four subtypes of AI characterized by different reflection sites.[15] AI is thought to be valuable as a risk factor for cardiovascular disease in clinical practice. The velocity of the reflected wave increases if the arterial elasticity deteriorates. Thus, a larger interval between overlap site and pressure wave peak at systole accounts for a large ΔP.[16]

As to pulse condition parameters, h_5/h_1 represents the ratio between amplitude repulse wave amplitude and principal wave amplitude, which indicate artery compliance and aortic function. When artery compliance decreases, h_5/h_1 is ≤0. In contrast, h_5/h_1 increases if there is normal artery compliance and aortic valve function.

There are many factors involved in the overlap between antegrade wave and reflected wave.[17-21] (a) Vessel stiffness. The overlap occurs during systole when the pressure wave is conducted faster along the blood vessels with higher stiffness. In addition, the overlap amplitude increases during systole when the reflected wave has a larger amplitude along the vessels with higher stiffness. The results of this study indicated that, in the total sample group, AI was negatively correlated with pulse condition parameters (h_5, h_5/h_1, w_2 and Ad), which characterized peripheral resistance. (b) Interval between reflection site and heart. The closer the interval, the earlier the reflection occurs. The reflection site is close to the heart when the resistance of the small arteries is high. People with shorter stature are inclined to have a high PP and hypertension during systole for the same reasons. (c) Cardiac cycle and left ventricular ejection time are longer if the heart rate is slower. Thus, central SBP increases when the reflected wave overlaps with the antegrade wave at systole. AI, the ratio of aortic reflected wave, actually represents central artery pressure and PP. A higher central artery pressure affects left ventricular pressure loading and negative coronary factors, and subsequently increases cardiovascular events. In the present study, AI of the total sample group was positively correlated with t, t_5, w_1 and $w_{2/t}$, and negatively correlated with w_2. As for pulse condition parameters, h_1, t, t_4 and As mainly represent systole, while t_5, h_5 and Ad mainly represent diastole. This further elucidates that AI is closely related to cardiac cycle time and heart rate. Thus, certain pulse condition parameters are useful for assessment of artery elasticity. (d) Blood pressure level. In a study of 120 healthy control and 120 EH patients, Ma *et al*[22] found that radial AI increased when blood pressure was elevated (control group <EH Grade 1 group <EH Grade 2 group < EH Grade 3 group, $P<0.05$).

As mentioned above, the pulse of elderly hypertensive patients is mainly manifested as a "wiry pulse", which feels like putting your fingers on the string that typically presents as taut and forceful, as though pressing on the string of a drawn bow. It often occurs when there is insufficiency of *Yin* and hyperactivity of *Yang* in the liver. Recent studies have suggested that the mechanism of formation of wiry pulse is complex, which is relevant to atherosclerosis, elevated blood pressure, increased PP, decreased vascular compliance, increased peripheral resistance, accelerated pulse wave velocity, and other factors that result in increased vasoconstriction or effective changes in blood circulation. Wiry pulse graphs are characterized as follows:[5] (a) the tidal wave is significantly higher; (b) $h_3/h_1 \geq 0.7$, $w/t>0.2$; (c) increased dicrotic notch, $h_4/h_1>0.5$; (d) flat dicrotic wave, $h_5/h_1 \leq 0.05$. The results of Renying pulse AI were consistent with some characteristics of wiry pulse in hypertension patients.

Applying the technology of WI AI_{et} for prediction of one of the classic indicators of arterial stiffness, we found that AI_{et} and pulse manifestation were obviously correlated. In addition, two modes of operation were established in this study to discuss how to detect the degree of vascular stiffness using a pulse manifestation model.

The small sample size in this study limits its clinical utility to understand fully the relationship between reflected wave AI of the carotid artery and pulse condition parameters. At present, there is insufficient evidence to explain the relationship between reflected wave AI of the carotid artery (Renying pulse) and Cunkou pulse condition parameters in humans. A further study with a larger number of participants is needed in the future.

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