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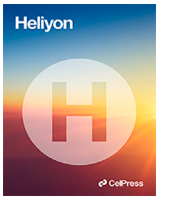

Research article

Pulse signal may be a key bridge connecting cardiology and pulse diagnosis of TCM

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ABSTRACT

Objective: This study extracts atherosclerosis indices from six channels of *Cunkou* and discusses the data distribution, aims to explore the connection between cardiology of modern medicine (MM) and traditional Chinese medicine (TCM) pulse diagnosis.

Methods: We use a device capable of simultaneously collecting the pulse signals of the *Cun*, *Guan* and *Chi* to test the population participating in routine physical examinations. Firstly, we collected pressure pulse waves from six channels of *Cunkou* of 1045 healthy subjects (578 men and 467 women, average age = 37.99±16.02 years). Secondly, we extracted the two most common arteriosclerosis indices pulse transit time (PTT) and Augmentation index (AIx) from six-channel pulse waves. Lastly, T-test and correlation test were taken to analyze the differences and relevance of the atherosclerosis indices extracted from six channels of *Cunkou*.

Results: When analyzing AIx and PTT at different wrist, it was found that AIx of left wrist is significantly higher than that of right wrist ($P < 0.001$), while the PTT of left wrist is significantly lower than that of right wrist ($P < 0.001$), a phenomenon that is common in both men and women. Furthermore, regardless of whether it is left or right wrist, the AIx at *Chi* channel is higher than that at *Cun* ($P < 0.05$) and *Guan* ($P < 0.05$). At the same time, the PTT at *Guan* is bigger than that at *Cun* in two wrists ($P < 0.05$). However, when the specific channel is not considered, there is no significant difference in AIx and PTT between each channel and the corresponding wrist ($P > 0.05$). In addition, regardless of gender, when the specific channel is not considered, AIx and PTT of each wrist are significantly correlated with age ($P < 0.001$).

Conclusions: The differences of the atherosclerosis indices AIx and PTT in six channels support that the method of *six-channel pulse diagnosis* is indispensable in TCM. Additionally, the pulse waves obtained from each channel can be utilized as a dependable foundation for diagnosing atherosclerotic conditions. This study is beneficial for promoting the integration of TCM and MM in diagnosing disease.

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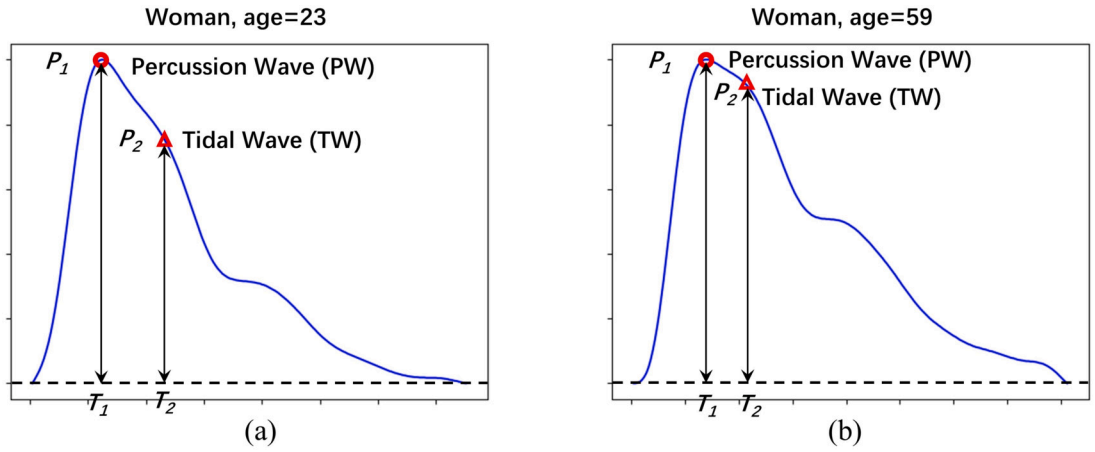

Fig. 1. Extracting AIx and PTT from the pulse signal. AIx = P2/P1, PTT = T2-T1. The data shown in panel (a) is for a 23 years old woman, and panel (b) is for a 59 years old woman. An increase in age indicates an increase in AIx, while a decrease in PTT.

1. Introduction

Cardiovascular disease (CVD) is the commonest diseases to threaten people's physical and mental health, and atherosclerosis is an important risk factor for CVD [1]. It is significant to assess atherosclerosis for the prevention of CVD. Meanwhile, it is a usual way to evaluate atherosclerosis by testing the shape characteristics of pulse signal [2]. Ferreira et al. discoursed that pulse signal analysis is a bridge between traditional Chinese medicine (TCM) pulse diagnosis and cardiology [3]. In fact, the researchers of different medical backgrounds all over the world have carried out a lot of contributions in this field. Assessing atherosclerosis by the feature parameters of pulse signals of radial artery is one of the most important research hotspots in modern medicine (MM). The pulse data from one stronger beating point of radial artery is usually collected [4].

Pulse transit time (PTT) and Augmentation index (AIx) are the most common atherosclerosis indices of pulse signal. Normally, one single cycle pulse data of healthy people includes three special peaks, sequentially referred to as Percussion Wave (PW), Tidal Wave (TW) and Dicrotic Wave (DW). AIx is equal to the ratio of TW value to PW value (AIx = P2/P1), and PTT is represented by the time difference of PW and TW (PTT = T2-T1), as given in Fig. 1(a, b). TW is formed as the result of the reflection of blood flow. The progression of arteriosclerosis with increasing age leads to an acceleration in blood flow velocity. This, in turn, results in a higher energy of the TW, indicated by an increase in AIx, and an earlier occurrence of the TW, indicated by a decrease in PTT [5]. AIx was proposed as an important index to access vascular stiffness [6]. The previous studies have shown that AIx is positively age-related. Moreover, AIx is a potential marker to CVD, Choi pointed out that AIx is closely related to Framingham risk score [7]. PTT was obtained to evaluate arteriosclerosis by one single pulse wave [5]. The study proposed by Tang et al. showed PTT was closely related to age [8].

Moreover, the analysis for pulse signal is an important part of quantitative research on pulse condition of TCM. The distribution differences of characteristic parameters extracted from pulse signal of the patients with arteriosclerosis were studied. Chen believed that the radial pulse wave of the subjects with different degree of arteriosclerosis is also different [9]. Liu found that partial features of pulse diagnosis information between Qi deficiency constitution and Yang deficiency constitution are significantly difference in northwest China [10]. Xu pointed out that the partial pulse parameters of hypertensive patients were significantly different from the normal control group [11]. Besides, many researches shown that the pulse waves at *Cun*, *Guan* and *Chi* are different [12,13].

However, *six channels of Cunkou respectively correspond to Zang fu* is an important theory of TCM diagnosis, which is disputed in MM:

(i)Taking the pulse at Cunkou alone has become a unique diagnostic method of pulse diagnosis in TCM [14]. TCM diagnosis has a history of nearly two thousand years. *Cunkou* represents radial artery at two wrists, which consists of *Cun*, *Guan* and *Chi*, as shown in Fig. 2. There are six channels in two wrists, *six-channel pulse diagnosis* is the important method of pulse diagnosis in TCM. The quantitative study on pulse condition of *Cunkou* is an essential part of modern research in TCM, it is also one of the main research directions to evaluate arteriosclerosis by analyzing the pulse signal of six channels [15].

(ii) MM hardly pays attention to the location of pulse detection in Cunkou. Cun, *Guan*, *Chi* has not been widely accepted in MM. MM mainly focuses on the point of *Cunkou* with strong pulse beats [4,8]. Therefore, it is a hot and difficult research topic in medical field to combine the research viewpoints of MM with TCM [16].

This study aims to contribute the integration between the research perspectives of cardiology in MM and the necessity of *six-channel pulse diagnosis* in TCM:

- In response to the difficulty in identifying TW of the pulse wave, we propose fourth-order derivative to estimate the location of TW, and further extract the two most common parameters (AIx and PTT) for evaluating arteriosclerosis.
- We analyze the differences of arteriosclerosis indices acquired from six channels of *Cunkou* to support the necessity of *six-channel pulse diagnosis* in TCM.

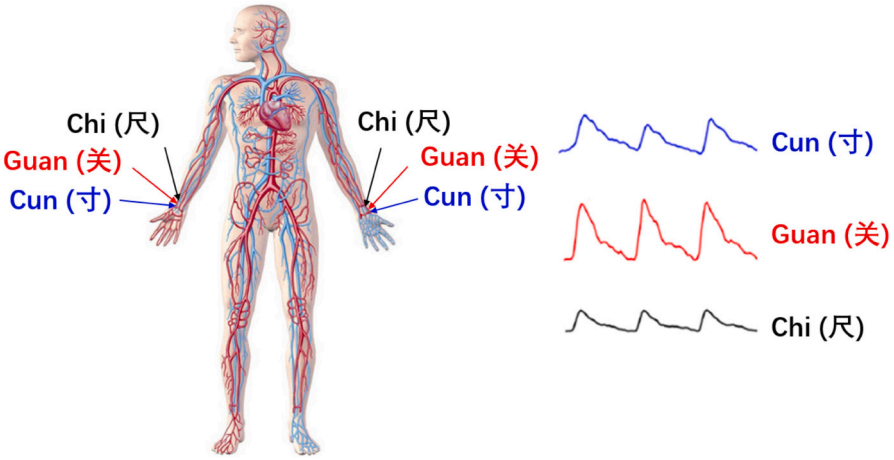

Fig. 2. The diagram for collecting pressure pulse signal of six channels at Cunkou. There are three pulse-taking channels of Cun, Guan and Chi in each wrist.

Table 1
Basic characteristic of the subjects.

	Male ($n=578$)	Female ($n=467$)	P value
Age (years)	40.33±15.73	35.09±14.72	$P<0.001$
Height (cm)	168.12±7.06	158.19±5.45	$P<0.001$
Weight (kg)	66.75±11.31	54.59±8.54	$P<0.001$
BMI (kg/m^2)	23.60±3.56	21.83±3.36	$P<0.001$
SBP (mmHg)	120.54±12.64	113.91±14.33	$P<0.001$
DBP (mmHg)	75.28±9.41	71.04±9.93	$P<0.001$
PP (mmHg)	45.26±10.14	42.87±10.59	$P<0.001$
HR (beats/min)	75.92±12.45	77.92±12.64	$P<0.05$

BMI: body mass index; DBP: diastolic blood pressure; HR: heart rate; PP: pulse pressure; SBP: systolic blood pressure. All values are given as mean ± std. The differences of 8 characteristics were significance ($P<0.05$).

• We analyze the correlation of arteriosclerosis indices between two wrists, as well as the correlation between arteriosclerosis indices and age, to verify the conclusions of MM, without considering *Cun*, *Guan* and *Chi*.

2. Methods

2.1. Study design

TCM believes that the pulse beat at six channels of *Cunkou* represents the health status of different *Zangfu* of the body, but the different channels of *Cun*, *Guan* and *Chi* are not distinguished in MM. In order to explore the connection between TCM and MM, we designed the research framework, as given in Fig. 3.

This work supports the necessity of the *six-channels pulse diagnosis*, a cornerstone of TCM, by conducting a comparative analysis of atherosclerosis indices across various channels and between the wrists. Furthermore, eschewing *Cun*, *Guan* and *Chi* of TCM, this work endeavors to elucidate the relevance between atherosclerosis indicators and age, as well as to assess the correlation of these parameters between two wrists. This comprehensive approach aims to corroborate the findings of MM research pertaining to atherosclerosis.

2.2. Subjects

We recruited 1045 healthy subjects (578 men and 467 women) who participated in health examination at Hunan Academy of Traditional Chinese Medicine Affiliated Hospital, The Fourth Hospital of Changsha and The First Hospital of Hunan University of Chinese Medicine. The characteristics of subjects were given in Table 1.

We included the subjects who passed the health examination, it mainly included heart rate, blood pressure and body temperature. We excluded the subjects who had a history of CVD, and the subjects with a history of dependence on drugs or alcohol were also excluded.

Data collection was mainly accomplished by the medical students, who had at least three years of experience. The process was supervised by the management department of the three hospitals.

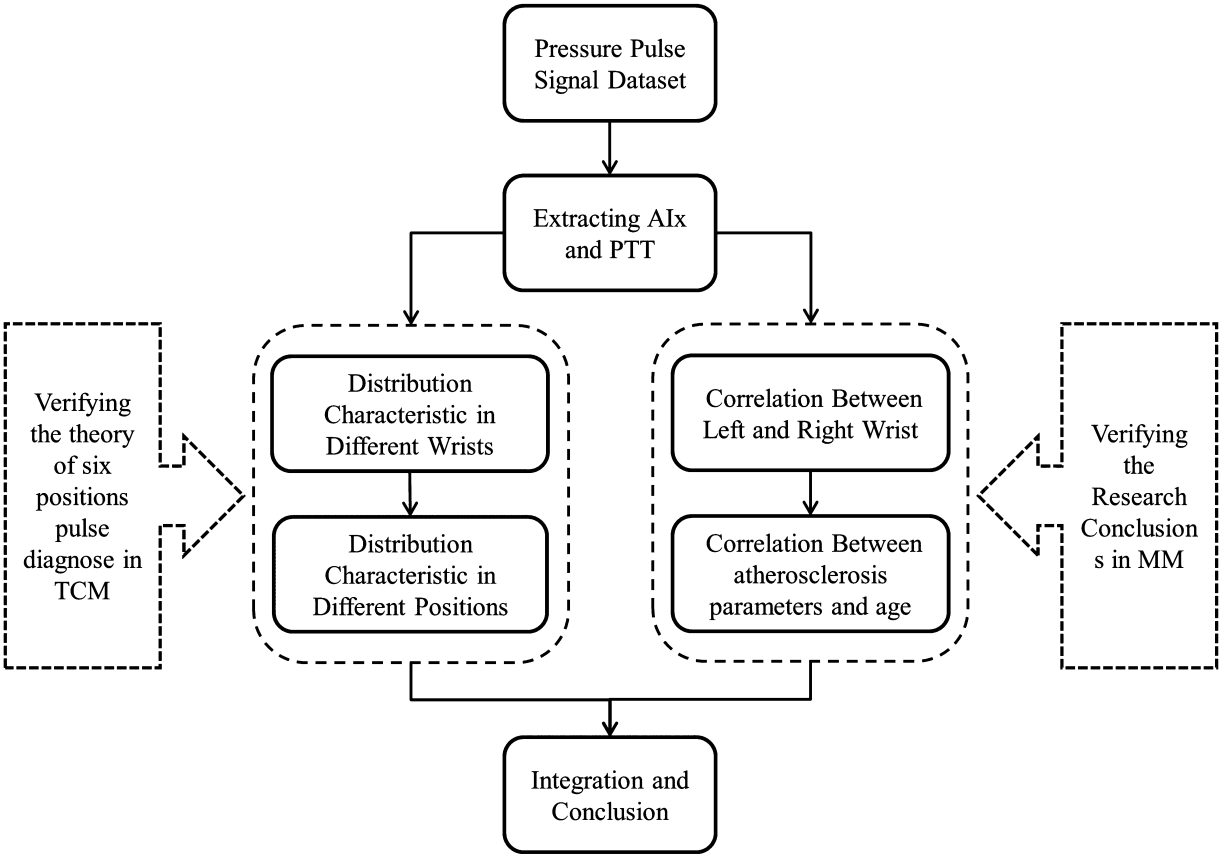

Fig. 3. The flowchart for the methodology of this work. This study analyzes the correlation of atherosclerosis indicators extracted from the pulse signals of the six channels and explores the connection between cardiology of MM and TCM pulse diagnosis.

2.3. Equipment and measurements

The pulse data acquisition equipment (Patent number: 200810225717.0) [17] was developed by China Academy of Chinese Medicine Sciences (CACMS), which adopted pressure sensors. The device can simultaneously collect pulse data from three channels of single wrist at 1000 Hz sampling frequency. Moreover, the device automatically converts the units of data collected by sensors into gram-force and saves the data on the local disk.

All participants had a rest at least 3 minutes before testing, and then pulse data of six channels was collected successively. Each time recorded approximately 30 s. During the testing, the subjects are instructed to sit upright while keeping their arms relaxed, ensuring that the heart and the position of data collection are essentially at the same horizontal level. Meanwhile, the device can adjust the contact pressure on the skin to obtain clear pulse data. *Maijing* records "Marked by the styloid process of radius, the inner side of the styloid process is *Guan*, the front of *Guan* is *Cun*, and the back of *Guan* is *Chi*". The details were shown in Fig. 4(a, b).

2.4. Extracting AIx and PTT

There is great difference in pulse signals among different people. In many cases, The TW is extremely faint and the location of the TW is not obvious. In view of this, the fourth derivative was used to recognize the location of TW [18], as shown in Fig. 5(a, b). Before extracting AIx and PTT, baseline correction is essential. The baseline is obtained by fitting the start and end points of the pulse signal with a linear model. The previous works had proposed that it is an effective approach [4,5,8]. AIx and PTT of all pulse data were extracted by this method in this work.

2.5. Verifying the potential necessity of six-channel pulse diagnose in TCM

In TCM, *Zangfu* actually includes heart, lung, liver, spleen, kidney and life gate. Six channels of *Cunkou* represent different *Zangfu*, and reflect the health status of different *Zangfu*. In details, Left-Cun, Right-Cun, Left-Guan, Right-Guan, Left-Chi and Right-Chi represent heart, lung, liver, spleen, kidney and life gate respectively. The TCM doctors diagnose disease by touching the pulse of six channels.

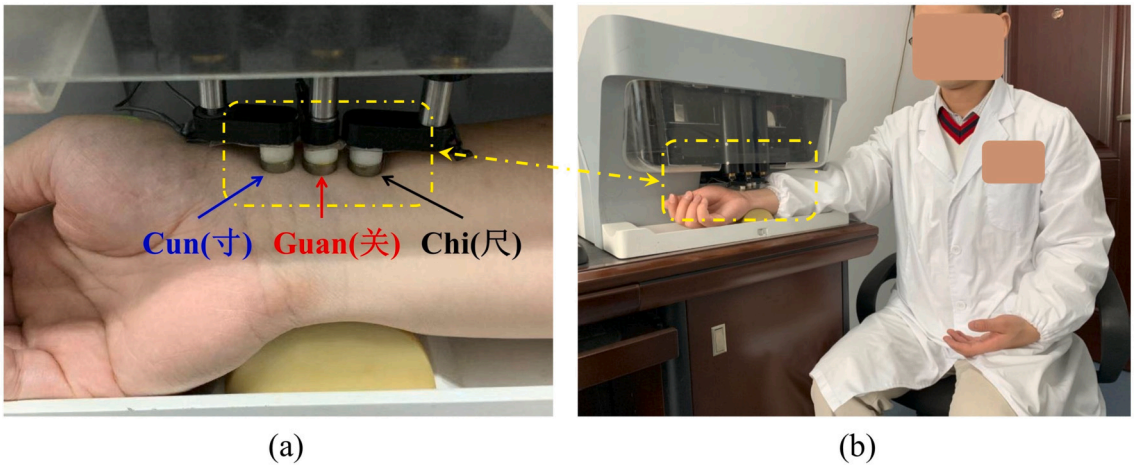

Fig. 4. The channels of *Cun*, *Guan* and *Chi* when collecting pulse data. Panel (a) illustrates the collection channels, and panel (b) shows the posture of the subject.

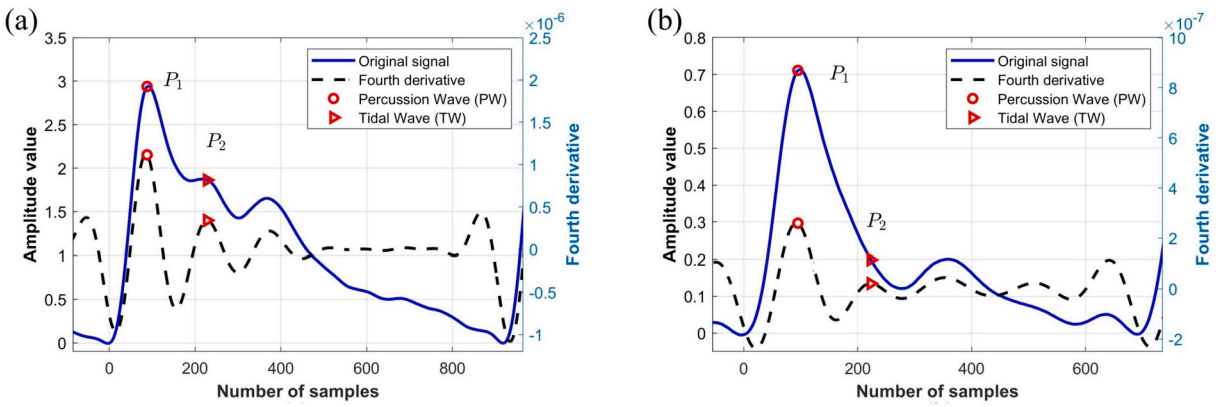

Fig. 5. In both panel (a) and panel (b), fourth derivative can effectively identify the position of TW. AIx is equal to the ration of P2 to P1, and PTT is expressed by the time difference of the PW and TW. The unit for the vertical axis is gram-force, and the unit of the horizontal axis is the sampling time point at a sampling frequency of 1000 Hz.

The pulse diagnosis based on six channels is an essential component of TCM pulse diagnosis. This work focuses on the necessity of this pulse diagnosis method. Thus, we demonstrate the potential value of *six-channel pulse diagnosis* by analyzing the differences in key parameters extracted from the pulse signals of six channels. Therefore, we should verify whether there is difference in the parameters of pulse data at six channels of *Cunkou*. This work not only analyzes the differences in different wrists, but also analyzes the differences between the three channels of *Cun*, *Guan* and *Chi*.

2.6. Verifying the research conclusions in MM

In MM, *six-channel pulse diagnose* has not been widely accepted. We want to verify whether the pulse wave of any channel can be used as the basis for evaluating atherosclerosis. So we analyze the difference of the parameters between each channel and the corresponding wrist. We also should analyze the data distribution of the atherosclerosis indices without considering three channels. In this study, we verify whether the atherosclerosis indices are age-related and analyze the correlation of atherosclerosis indices between left and right wrist.

2.7. Statistical methods

The values in this manuscript were expressed as mean±std. The difference of basic characteristic parameters between male and female were analyzed by variance analysis (ANOVA). The difference of two wrists was evaluated by paired sample T-test (PSTT). The difference of AIx and PTT among different channels was also evaluated based on PSTT. The difference of AIx and PTT between each channel and the corresponding wrist was calculated by independent sample T-test (ISTT). The relevance of age with AIx and PTT was calculated by unary linear regression (ULR). The relevance between left and right wrist was also calculated by ULR. $P < 0.05$ was considered to indicate statistical significance. All data works were processed in MATLAB.

Table 2
The difference of two parameters between left and right wrist.

	AIx			PTT		
	Left wrist	Right wrist	*P* value	Left wrist	Right wrist	*P* value
Male ($n=578$)	0.669±0.196	0.648±0.201	$P<0.001$	0.128±0.012	0.130±0.013	$P<0.001$
Female ($n=467$)	0.702±0.184	0.681±0.192	$P<0.001$	0.131±0.014	0.133±0.015	$P<0.001$

AIx: Augmentation index; PTT: pulse transit time. The values are given as mean±std. Paired sample T-test was used to analyze the differences of AIx and PTT between two wrists in male and female.

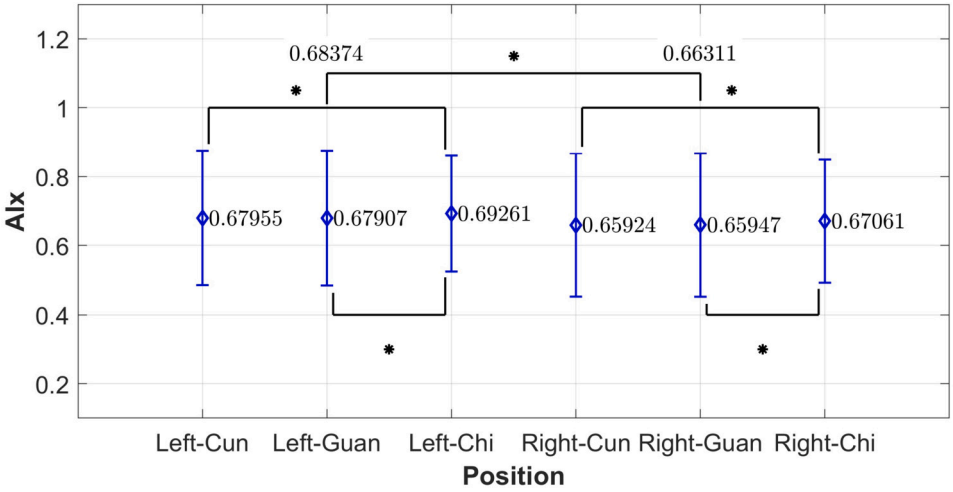

Fig. 6. The significance of difference of AIx at six channels of Cunkou, '*' represents $P<0.05$ based on paired sample T-test.

3. Results

3.1. AIx and PTT in different wrists

The differences of two arteriosclerosis indices between left and right wrist were compared in Table 2. In this part, the value of each wrist is the average value of the corresponding three channels of *Cun*, *Guan* and *Chi*. AIx was bigger in left wrist than right wrist both in men and women ($P<0.001$). Moreover, PTT was smaller in left wrist than right wrist both in men and women ($P<0.001$).

3.2. AIx and PTT at six channels of Cunkou

The differences of AIx at six channels of *Cunkou* we show in Fig. 6. The AIx of men and women are calculated together. AIx was bigger in left wrist than right wrist ($P<0.05$). In details, AIx at *Chi* was bigger than that of *Cun* ($P<0.05$), and AIx at *Chi* was bigger than that of *Guan* both in two wrists ($P<0.05$). The difference between *Cun* and *Guan* was not statistically significant both in two wrists ($P>0.05$).

Furthermore, we also analyzed the difference of AIx between each channel and the corresponding wrist, the results are given in Fig. 7(a-f). There were insignificant difference ($P>0.05$) in AIx between each channel and the corresponding wrist.

Fig. 8 illustrated the differences of PTT at six channels of *Cunkou*. The PTT data of men and women are calculated together. In details, PTT of right wrist was bigger than that of left wrist ($P<0.05$). Moreover, PTT at *Chi* was bigger than that at *Cun* in right wrist ($P<0.05$), and it was not statistically significant in left wrist ($P>0.05$). In additional, PTT at *Guan* was bigger than that at *Cun* both in left and right wrists ($P<0.05$), and the difference between *Guan* and *Chi* was not statistically significant both in left and right wrists ($P>0.05$). Moreover, difference of PTT between each channel and the corresponding wrist were given in Fig. 9(a-f). The results showed that the difference of PTT between each channel and the corresponding wrist was not statistically significant ($P>0.05$)

3.3. The relevance of AIx and PTT between left and right wrist

Fig. 10(a, b) illustrated the relevance of AIx between two wrists in different genders. The value of each wrist is the average value of the corresponding three channels. There was a statistically significant correlation between right and left wrist both in men and women ($P<0.001$). The correlation coefficients were both larger than 0.95.

The relevance of PTT between right and left wrist in different genders was given in Fig. 11(a, b). The value of each wrist is the average value of the corresponding three channels. There was also a statistically significant correlation between right and left wrist both in men and women ($P<0.001$), and the correlation coefficients were as high as 0.90 and 0.88, respectively.

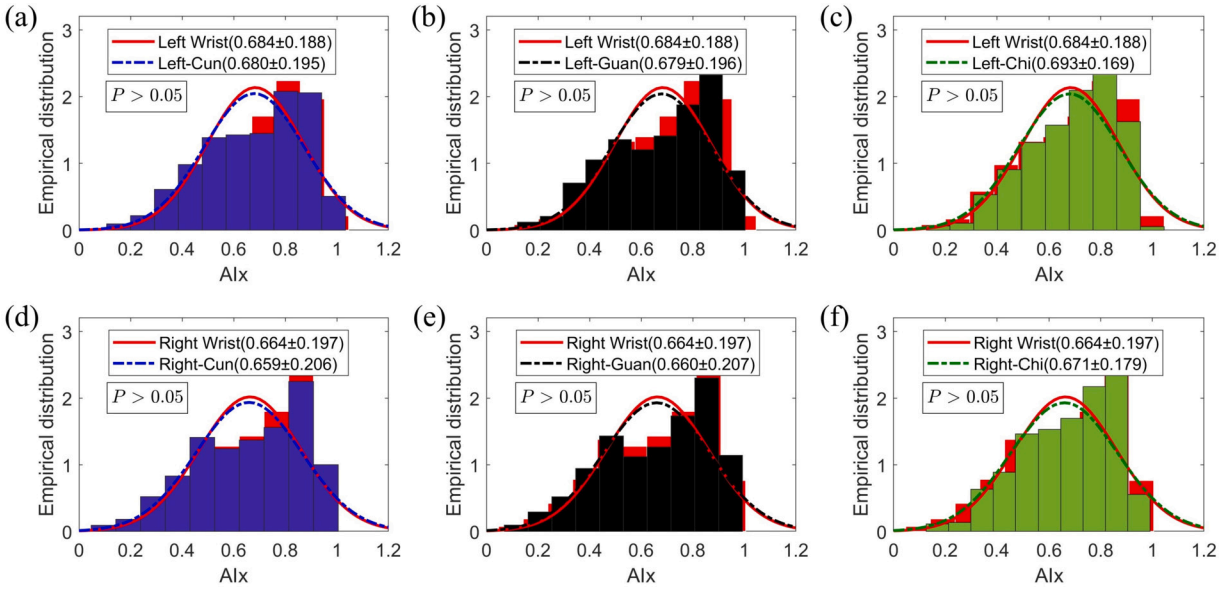

Fig. 7. The difference of AIx between each channel and the corresponding wrist. In panel (a), (b) and (c), the differences of AIx in Left-Cun, Left-Guan, Left-Chi, and left wrist are compared, respectively. In panel (d), (e) and (f), the differences of AIx in Right-Cun, Right-Guan, Right-Chi, and right wrist are compared, respectively.

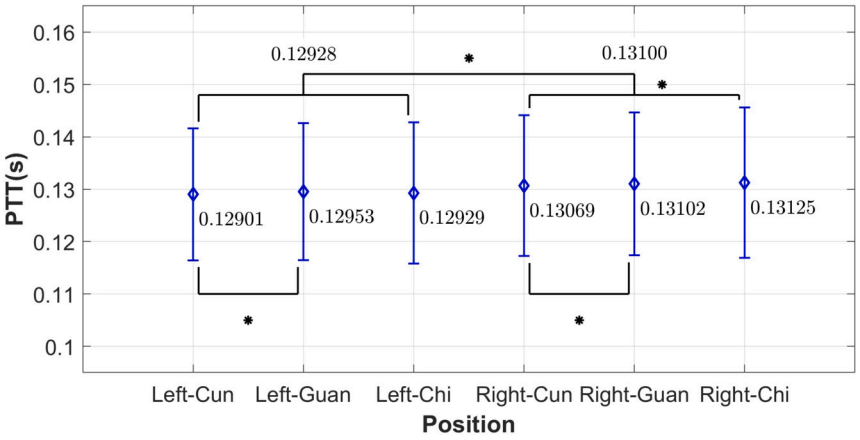

Fig. 8. The significance of difference of PTT at six channels of Cunkou, '*' represents $P < 0.05$ based on paired sample T-test.

3.4. The relevance of age with AIx and PTT

The relevance between age and AIx was given in Table 3. AIx of left wrist and AIx of right wrist were statistically significant to age ($P < 0.001$) both in men and women without considering three channels, the value of each wrist was not the average value of the corresponding three channels. Moreover, AIx was positively age-related ($P < 0.001$) in each channel.

Table 4 showed the relevance between age and PTT. PTT of left wrist and PTT of right wrist were statistically significant to age ($P < 0.05$) both in men and women in the condition of neglecting three channels, the value of each wrist was not the average value of the corresponding three channels. There was a statistically negative correlation ($P < 0.05$) between PTT and age in each channel.

4. Discussion

The research on pulse signal is not only a hot spot in MM, but also an important part of quantitative analysis for pulse diagnosis in TCM [7]. However, the viewpoint of *six-channel pulse diagnosis* in TCM has not been widely accepted in MM. Few studies simultaneously focus on the differences and connections between pulse diagnosis theory of TCM and cardiology of MM. Therefore, it is greatly significant to integrate TCM with MM by analyzing the difference and regularity of the pulse signals at six channels of *Cunkou*. Indeed, the researchers have pointed out that the analysis for pulse signal is a bridge between cardiology of MM and pulse diagnosis of TCM [3]. This study extracted AIx and PTT from pressure pulse waves of six channels at *Cunkou* and analyzed the distribution

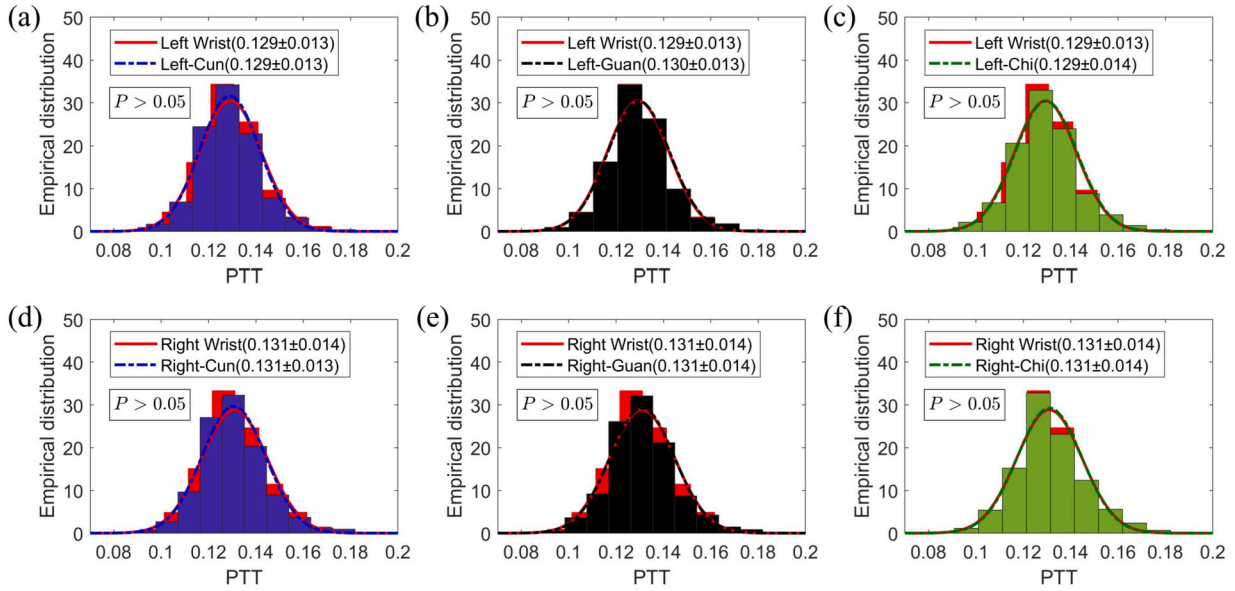

Fig. 9. The difference of PTT between each channel and the corresponding wrist. In panel (a), (b) and (c), the differences of PTT in Left-Cun, Left-Guan, Left-Chi, and left wrist are compared, respectively. In panel (d), (e) and (f), the differences of PTT in Right-Cun, Right-Guan, Right-Chi, and right wrist are compared, respectively.

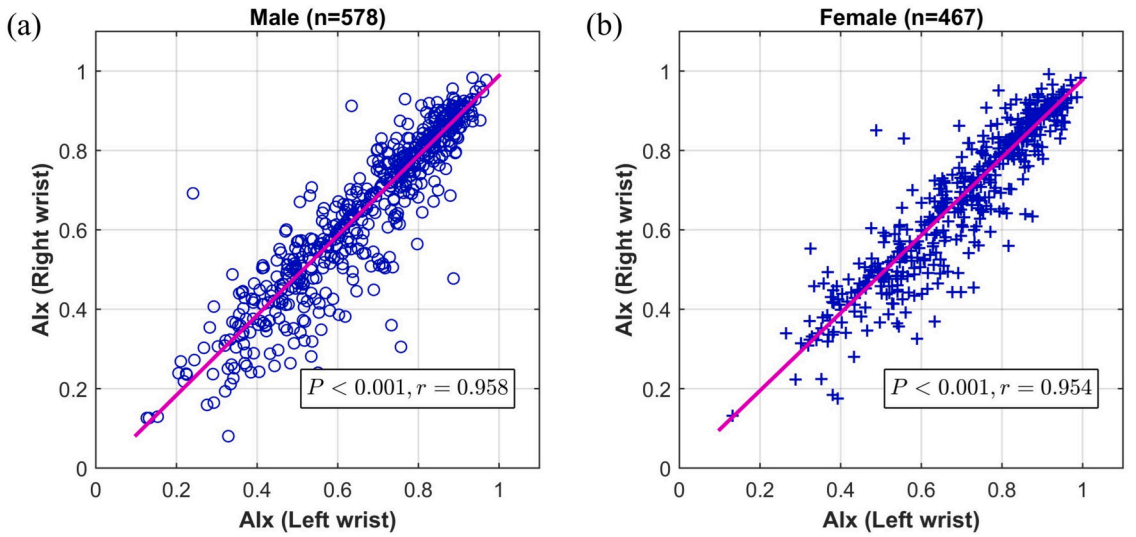

Fig. 10. Panel (a) shows the relevance of AIx between right and left wrist in man. Panel (b) gives the relevance of AIx between right and left wrist in woman.

characteristics of the atherosclerosis indices. We found that the research conclusions of pulse diagnosis in TCM and MM are both interpretable.

4.1. The differences of left and right distinguish Yin and Yang in TCM

Syndrome differentiation is the basic principle to recognize diseases in TCM. In fact, the differences between right and left hand have been also recorded in the ancient books of TCM. *Neijing* believes that left and right hands can be used to distinguish *Yin* and *Yang*, the left pulse is *Yang pulse* and the right pulse is *Yin pulse* [19]. *Yang* and *Yin* are not specific but relative in TCM, and they are used to describe the difference. The results of this study show that AIx and PTT are different between left and right wrist, given in Table 2. In both men and women, AIx of right wrist is smaller than that of left wrist ($P < 0.001$), and PTT of right wrist is bigger than that of left wrist ($P < 0.001$). It illustrates that the vascular elasticity of right hand is better than left hand. Some researchers believe that frequent use of right hand is one of the main reasons for better vascular elasticity of right hand [20].

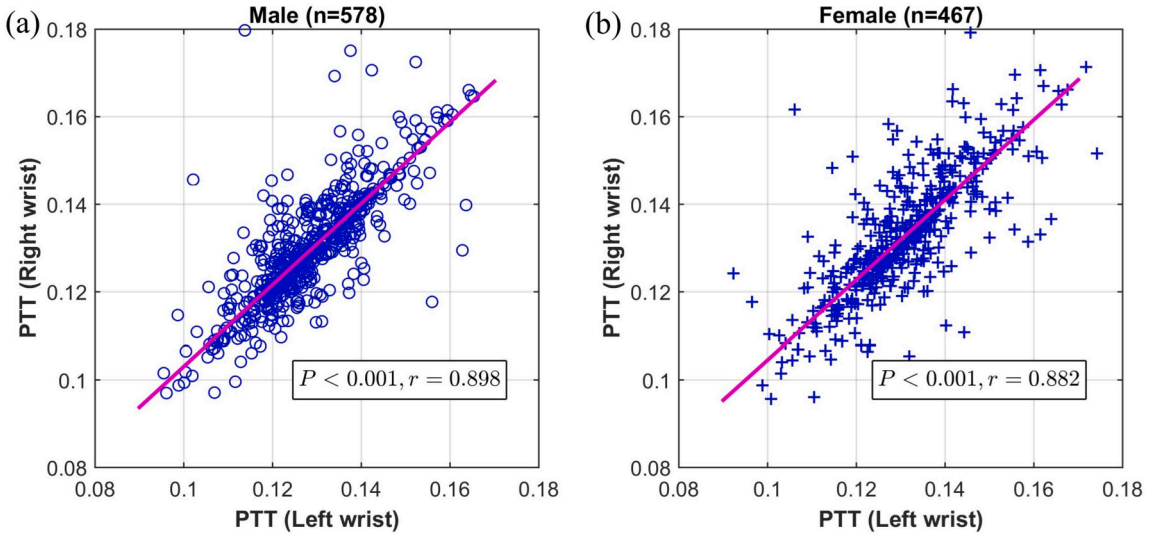

Fig. 11. Panel (a) shows the relevance of PTT between right and left wrist in man. Panel (b) gives the relevance of PTT between right and left wrist in woman.

Table 3
The relevance between age and AIx at different channels and different wrist.

Sex	Wrist	*P* value	*r*	Channel	*P* value	*r*
Male	Left wrist (*n* = 578×3)	*P* < 0.001	0.473	Cun (*n* = 578)	*P* < 0.001	0.472
				Guan (*n* = 578)	*P* < 0.001	0.486
				Chi (*n* = 578)	*P* < 0.001	0.464
	Right wrist (*n* = 578×3)	*P* < 0.001	0.520	Cun (*n* = 578)	*P* < 0.001	0.506
				Guan (*n* = 578)	*P* < 0.001	0.531
				Chi (*n* = 578)	*P* < 0.001	0.527
Female	Left wrist (*n* = 467×3)	*P* < 0.001	0.562	Cun (*n* = 467)	*P* < 0.001	0.557
				Guan (*n* = 467)	*P* < 0.001	0.590
				Chi (*n* = 467)	*P* < 0.001	0.541
	Right wrist (*n* = 467×3)	*P* < 0.001	0.614	Cun (*n* = 467)	*P* < 0.001	0.624
				Guan (*n* = 467)	*P* < 0.001	0.633
				Chi (*n* = 467)	*P* < 0.001	0.586

The results of the linear regression show that AIx at each location is significantly correlated with age. *r* and *P* value represent the results of the correlation coefficient and the linear correlation test, respectively. Additionally, when not distinguishing between the different pulse channels (Cun, Guan and Chi), AIx at each wrist is also significantly correlated with age.

Table 4
The relevance between age and PTT at different channels and different wrists.

Sex	Wrist	*P* value	*r*	Channel	*P* value	*r*
Male	Left wrist (*n* = 578×3)	*P* < 0.001	-0.125	Cun (*n* = 578)	*P* < 0.05	-0.106
				Guan (*n* = 578)	*P* < 0.005	-0.124
				Chi (*n* = 578)	*P* < 0.001	-0.144
	Right wrist (*n* = 578×3)	*P* < 0.001	-0.126	Cun (*n* = 578)	*P* < 0.005	-0.126
				Guan (*n* = 578)	*P* < 0.005	-0.118
				Chi (*n* = 578)	*P* < 0.001	-0.134
Female	Left wrist (*n* = 467×3)	*P* < 0.001	-0.197	Cun (*n* = 467)	*P* < 0.001	-0.171
				Guan (*n* = 467)	*P* < 0.001	-0.179
				Chi (*n* = 467)	*P* < 0.001	-0.240
	Right wrist (*n* = 467×3)	*P* < 0.001	-0.200	Cun (*n* = 467)	*P* < 0.001	-0.162
				Guan (*n* = 467)	*P* < 0.001	-0.214
				Chi (*n* = 467)	*P* < 0.001	-0.223

The results of the linear regression show that PTT at each location is significantly correlated with age. *r* and *P* value represent the results of the correlation coefficient and the linear correlation test, respectively. Additionally, when not distinguishing between the different pulse channels (Cun, Guan and Chi), PTT at each wrist is also significantly correlated with age.

4.2. The differences of Cun, Guan and Chi support six-channel pulse diagnosis in TCM

Meanwhile, *Six-channel pulsed diagnosis* is an important method of pulse diagnosis in TCM. The contents recorded in $Neijing$ indicate that the six channels of $Cunkou$ can reflect the health status of different $Zangfu$ [21]. In clinical practice, the doctors of TCM need to carefully check the pulse condition of six channels, then compare the pulse condition of six channels and diagnose on diseases [22]. This study shows that there are slight differences in the two arteriosclerosis indices of six channels. Specifically speaking, AIx at Chi is bigger than that of Cun ($P<0.05$) and $Guan$ ($P<0.05$), the difference of left wrist is identical to the right wrist (Fig. 6). Besides, PTT at Chi is bigger than that at Cun, it is statistically significant in right wrist ($P<0.05$) but not statistically significant in left wrist ($P>0.05$). PTT at $Guan$ is bigger than that of Cun, which is statistically significant in both wrists ($P<0.05$) (Fig. 8). Different channels of Cun, $Guan$ and Chi at two wrists represent heart, liver, kidney, lung, spleen and life gate [23]. The ancient book of TCM $Suwen$ records "The pulse of liver is $Xian$, the pulse of heart is Gou, the pulse of spleen is Dai, the pulse of lung is Mao, and the pulse of kidney is Shi". The differences of arteriosclerosis indices at six channels of $Cunkou$ verify the necessity of *six-channel pulse diagnosis* in TCM. TCM believes that the differences at six channels of $Cunkou$ are judged by a combination of various factors. AIx and PTT are components of these factors. This study explores the way to verify the differences of six channels by analyzing the distribution characteristics of AIx and PTT.

4.3. High correlations between two wrists indicate the effectiveness of any side

Moreover, the researchers of MM not only use the pulse wave from radial artery ($Cunkou$) but also the pulse wave from carotid artery to access atherosclerosis. Sugawara proposed that AIx obtained from carotid and radial artery is very similar, and they are both effective parameters for evaluating vascular function [24]. In this work, the correlation between the left and right wrist is extremely strong ($P<0.001$, $r>0.88$) whether AIx or PTT, shown in Fig. 10(a, b) and Fig. 11(a, b). The results in this work show that the two atherosclerosis indices of two wrists are consistent, which is a further perfection to the research viewpoint of Sugawara.

4.4. Any channel of Cun, Guan and Chi can serve as an effective basis for evaluating arteriosclerosis

In the other hand, six channels of $Cunkou$ are not considered in MM and the pulse data from one stronger beating point of radial artery ($Cunkou$) is usually collected. In this study, Fig. 7(a-f) and Fig. 9(a-f) analyzed the difference of AIx and PTT between each channel and the corresponding wrist, and the difference is not statistically significant ($P>0.05$). In addition, we discussed the relevance between age and the two atherosclerosis indices of each channel, we found that each relevance is statistically significant ($P<0.05$). Moreover, we also analyze the correlation between age and the two atherosclerosis indices of each wrist without considering *six-channel*. The results are given in Table 3 and Table 4, AIx of either wrist is positively correlated with age ($P<0.001$) and the PTT of either wrist is negatively correlated with age ($P<0.001$). The findings are consistent with the conclusions research on AIx and PTT in MM [5,7].

4.5. Limitations and future works

However, this study also has limitations. Three channels (Cun, $Guan$, Chi) and three depths (Fu, $Zhong$, $Chen$) called Three Channels and Nine Indicators (TPNI), which plays an irreplaceable role in TCM pulse diagnosis. Furthermore, this study did not focus on the impact of epidemiological characteristics such as age categories, active or sedentary on the results. Thus, these potential influence factors will be considered in our future works.

5. Conclusions

This study aimed to build the bridge between cardiology of MM and TCM pulse diagnosis by analyzing the data distribution of AIx and PTT extracted from pressure pulse wave of six channels at $Cunkou$. The results suggest the necessity of *six-channel pulse diagnosis* in TCM. Besides, In MM, pulse signals from any channel can serve as an effective basis for evaluating arteriosclerosis without considering Cun, $Guan$ and Chi. This study further expands the horizons for integrating the theories of TCM and MM in the diagnosis and treatment of diseases.

Ethics statement

A signed informed consent form was provided for each subject before testing. This study was approved by the ethics committee of Xiangyang Central Hospital under the registration number 2023-070, and complied with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of our institution.

CRediT authorship contribution statement

Qingfeng Tang: Writing – review & editing, Writing – original draft, Funding acquisition. **Yan-kun Chen:** Methodology, Data curation. **Shiping Liu:** Writing – original draft, Software. **Jue Wang:** Methodology. **Liangliang Zhang:** Funding acquisition, Formal analysis. **Haoyu Qu:** Supervision, Resources, Funding acquisition. **Hui An:** Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data associated with this study are not deposited into a publicly available repository, but the data will be made available from H.Y. Qu on reasonable request.

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