RESONANCE OF ORGANS WITH THE HEART

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INTRODUCTION

Traditional Chinese medicine consists essentially of three parts, acupuncture, herb medicine and pulse feeling [while looking (望), smelling (聞), and asking (問) are common in western medicine]. Due to its curing ability, acupuncture has brought attention to western civilization. However, the fundamental theory of Chinese medicine that pulse gives the resonance condition of internal organs has not been attended by any Western literature.

Since Harvey in 1628 (1) found that the blood is circulated in a closed system, there have been many important discoveries in the West, such as Windkessel model (2), the derivation of wave propagation in elastic artery tube (3), the frequencies dependence of arterial trees (4,5,6), and so on.

In the Orient, the written record of blood circulation theory was started no later than one thousand year B.C. in Chou-li (周禮). It stated that from the pulse feeling you may "feel the movement of the nine internal organs" which was the foundation of pulse feeling diagnosis in later years.

"From the pulse may we really feel the health condition of the internal organs?"

Our experiments were designed to investigate this very fundamental conjecture of Chinese medicine.

FLUID-DYNAMICS MODEL

A simple experimental model of circulation was built and the purpose of this experiment was to investigate the variation of "pulse shape" when the distribution of blood flow was changed.

In the cardiovascular system of human body, the heart is working like a pump to let blood flow through all parts of body. The main "internal organs" of Chinese medicine are

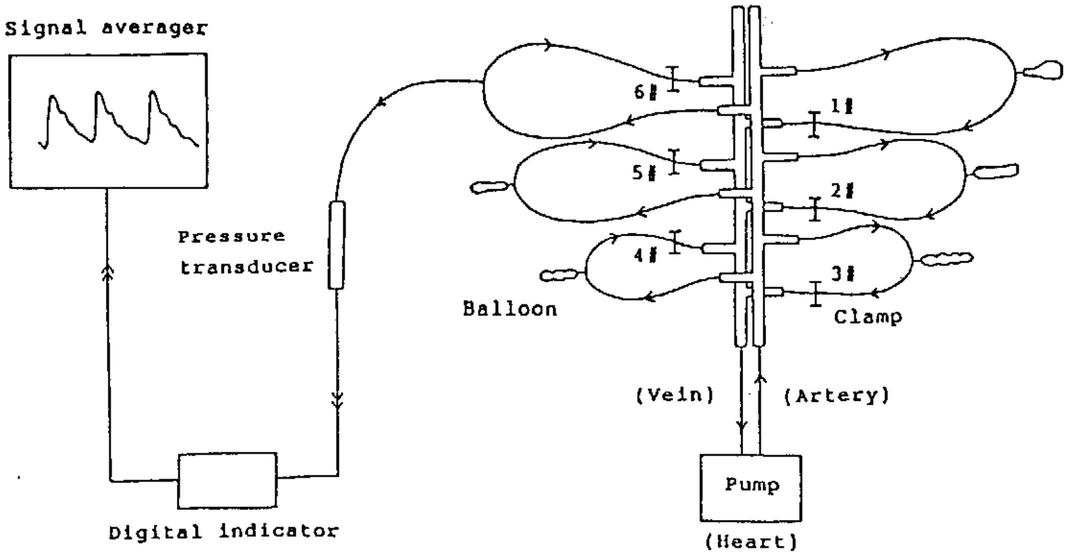

FIGURE 1. The modeling diagram of the circulatory system. The single arrow shows the fluid flow direction, the double arrow shows the direction of the electric signal.

the five Orbs ("wu tsang", the direct translation is the cardiac, hepatic, splentical, pulmonary and renal orbs or by the functional interpretation, the heart and aorta, liver, spleen, lung and kidney). If there is one organ in trouble, the blood flow through it, the blood pressure across it as well as blood volume in this organ will be changed. In the West, many papers have discussed about the relationships between blood flow and pressure change in the artery (7,8,9), however it seems that less research exists about the relationship between "pulse shape" and blood flow distribution in the whole body-which include arteries, veins and organs. Actually, blood is richly distributed in these five orbs under basal conditions (10,11).

The blood circulation system could be viewed as a connection of several closed loops (11). And the microcirculation of an organ might be replaced by an equivalent impedance (9), since we studied the wave form in the larger arteries. In this experiment, a similar closed system composed of some elastic distensible tubes, elastic balloons, clamps, electric pulse pump was connected, together with pressure transducer and the oscilloscope to detect the pulse shape as shown in Figure 1. There were five clamps, tied respectively on the different diameter tubes, opened or closed as needed to get a different flow pattern which simulated the change of impedance in the microcirculation within the organs, we named them as 1#, 2#, 3#, 4# and 5#, clamp respectively (see Figure 1). This circulation was divided into five loops which was controlled by the five clamps. A small balloon of different size and shape was tied in the middle of each loop. These five balloons which represented the main organs-five orbs, permitted the fluid to flow in and out at the outlets. Distilled water was used as fluid flows through all the tubes and other factors were neglected to simplify the model.

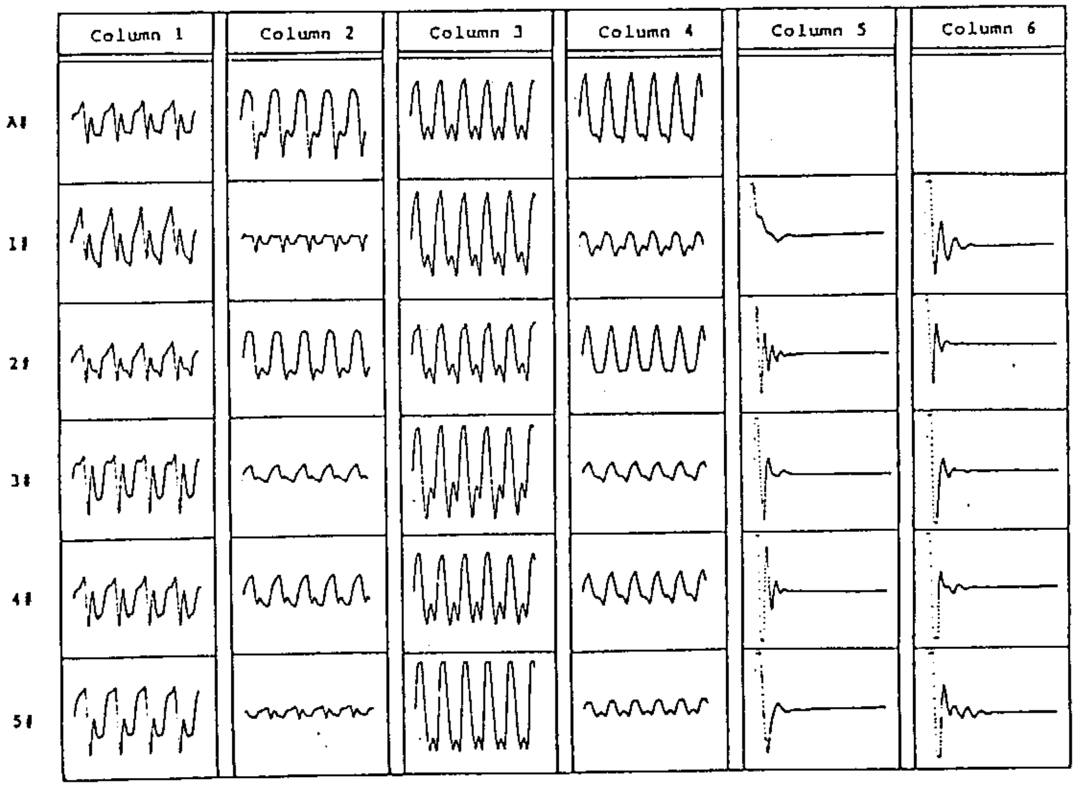

FIGURE 2. Records of pulse shape taken from the model of circulatory system in Figure 1 with the effect of changes in flow pattern.
A#: Represents the reference pulse shape before changing the flow pattern.
From the 1# to 5#: Represent the corresponding clamps which were opened or closed when needed to change the flow pattern.

We operated the pulse pump in a constant frequency at 0.6 Hz which also gave a constant shape for each pulse, the pressure, passed through the fixed point of the 6# loop, was measured by a linear pressure transducer (Validyne Model DP 103) and then converted into D.C. output signal by a digital indicator. The waveform was then clearly shown in an oscilloscope (The E.G.G. Signal Averager, Model 4202) or a chart recorder.

Firstly, we opened all of the clamps to obtain a normal pulse shape for reference. Next, we closed only one clamp in sequence from 1# to 5# to get a series of the changed pulse shape. Any time when we opened all of the clamps and waited for few seconds the pulse shape would return to the original contour, and the results were illustrated in Column 1, Figure 2. If we closed all the clamps, then opened only one clamp in sequence from 1# to 5#, the results were illustrated in Column 2, Figure 2. In Column 3 and Column 4, we repeated these experiments with a higher pumping frequency (about 1.2 Hz).

To further study the physical properties of this simulated circulatory system, we repeated the procedure as described before. That was to open all the clamps, and closed only one in sequence, but this time we stopped the pump and gave a gentle strike at the center of each ballon. The results were shown in Column 5, Figure 2. Then we closed all the clamps and opened only one in sequence, gave a gentle strike again, the results were shown in Column 6, Figure 2.

From these data, it was clear that each balloon (organ) had its own resonance frequency. It would resonate at some specific frequencies of the pump (heart and aorta cavity) which caused the different pulse shape when blood distribution was changed.

From this model we might also see that the blood flow had two components, one was equivalent to direct current in electrical current, which was from the diastole pressure (this amount is usually small); and the other was equivalent to alternating current in electrical current which was from the pulse (The difference between systolic pressure and diastolic pressure).

According to the hemodynamics (7,8,9), the impedance is a frequency dependent variable, it will change similarly to an L-C (inductance-capacitance) circuit in electrical alternating current. Therefore when a tissue in trouble, no matter how its elasticity, mass, volume, shape or resistance were changed, it would all be reflected in the impedance change. Since the impedance is controlling the blood flow rate, the blood flow into the organ would be changed, so would its resonance frequency, and the results would show up in the pulse shape.

ANIMAL MODEL

Sprague-Dawley rats (300 g-450 g) were anesthetized with urethan and -chloralose. Cannulation to the tail artery (A. candalis) was done by I. V. Cath (B-D). The rats were then dissect to find the renal artery (A. revalis) or the artery toward the spleen (lower part of A. lienogostrica that leads to spleen only).

A clamp was used to clamp the chosen artery. The shape of the pulse was recorded with pressure transducer RP-1500 Narco-Bio-System (Houston U.S.A.), which was connected to an preamplifier then to an oscilloscope and through A/D converter to an IBM PC. Pulse shapes were analyzed with Fourier Transform software using T (period) = 1 pulse.

We decided to use Fourier transform to analyze the pulse shape, because we found that the pulse shape faithfully reproduced itself, which guaranteed the spectrum to be concentrated in frequencies centered at integral multiplications of the heart rate. Actually many investigators had also reported that the spectrum of blood pressure is harmonics of the heart rate in many different animals (12,13) including rat (14). The intensity of the harmonics was monotonically decreased with increasing of harmonic number (this can be seen from the Figure 3 f.t.

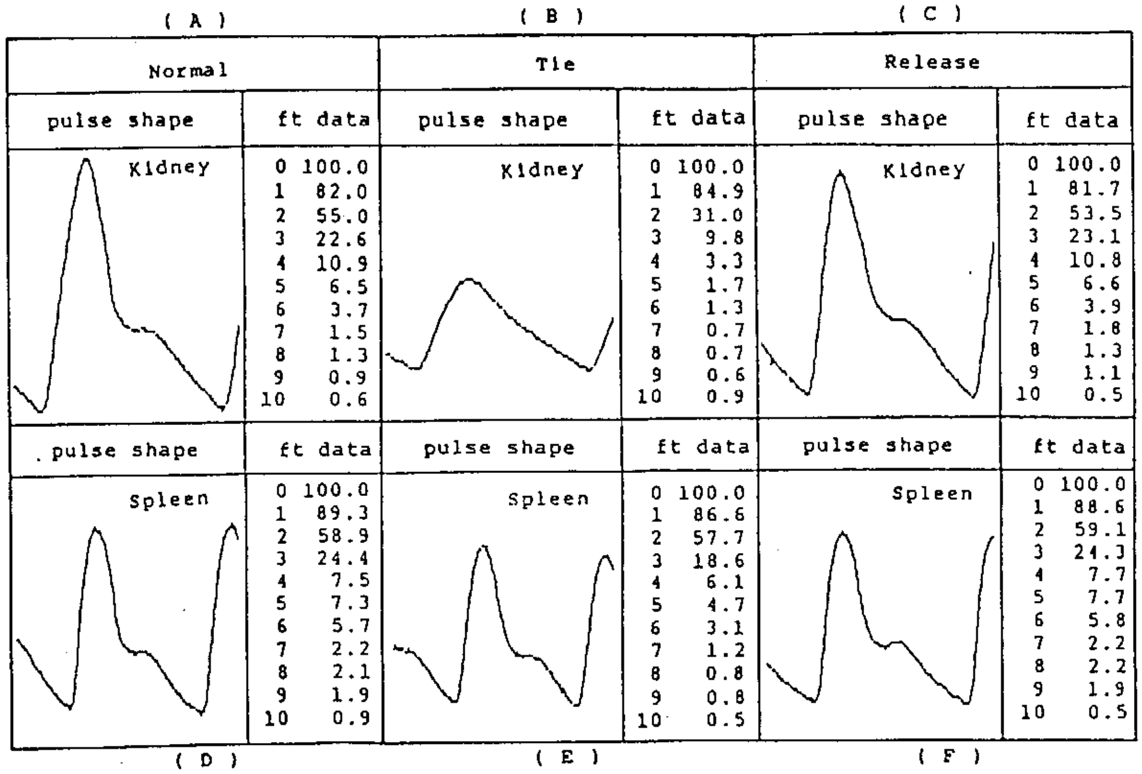

FIGURE 3. Shape of the pulse pressure as function of time with the nomalzied Fourier transfrom data on the right. The amplitude of the zero frequency term was used as 100% baseline. The data are presented as percentage of amplitude of each frequency compared with the amplitude of zero frequency.

data, the normalized intensity is decreasing with increasing harmonic number). This analytic method actually normalize the frequency with the heart rate of each individual. The typical pulse shape from tail artery of rat is shown in Figure 3 (A).

After clamping the renal artery the pulse shape changed to Figure 3 (B) right away. After recording for a few seconds we removed the clamp, and the pulse shape (Figure 3 (C)) returned to that shown in Figure 3 (A).

Results from five rats are shown in Table 1.

Figure 3 (D)-(F) shows the results of clamping the artery toward the spleen.

Table 2. Gives the results of five rats.

From the results it is clear that kidney is in resonance with the second harmonic and up. The spleen is in resonance with the third harmonic and up. Our data (not shown here) also suggests that the liver is in resonance with all of the harmonics. The first harmonic is the largest one, and the kidney is in resonance with the second harmonic and up. These leave the liver to share the second harmonic and up

TABLE 1. Present the difference of the amplitude of different harmonics before and after the clamp for kidney.

T/n	Rat 1			Rat 2			Rat 3			Rat 4			Rat 5		
	S.D.%		D.%	S.D.%		D.%	S.D.%		D.%	S.D.%		D.%	S.D.%		D.%
	(N)	(T)		(N)	(T)		(N)	(T)		(N)	(T)		(N)	(T)	
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	2.2	1.4	3.7	1.2	4.1	3.5	2.6	2.9	-4.5	1.8	2.2	0.5	2.3	2.2	0.9
2	2.1	3.7	-49.4	2.2	10.0	-43.5	4.0	3.3	-45.0	1.4	4.1	-36.8	2.7	5.8	-12.2
3	4.0	4.4	-64.9	7.0	10.1	-56.5	4.7	7.4	-52.5	4.2	11.2	-40.5	3.5	16.7	-21.1
4	1.4	5.7	-77.9	4.5	23.3	-70.1	6.1	19.6	-73.2	5.5	20.3	-56.9	3.1	4.7	-25.6
5	3.1	11.1	-82.2	9.7	24.5	-74.4	6.0	14.8	-73.9	3.4	21.7	-58.0	3.0	12.5	-22.7
6	2.0	14.0	-81.6	10.2	31.8	-63.8	6.9	22.4	-62.8	7.2	17.5	-42.1	6.7	21.7	-32.0
7	4.3	18.2	-80.9	17.6	44.1	-49.1	10.2	40.9	-55.7	8.9	27.5	-23.6	12.7	48.7	-5.7
8	8.6	41.1	-71.4	13.7	27.7	-45.3	19.0	21.1	-53.6	20.2	73.7	-58.5	20.9	79.2	13.5
9	7.5	10.2	-58.4	18.9	29.8	-32.7	18.9	47.3	-49.0	34.5	31.5	-42.5	32.4	66.7	0.5
10	14.3	52.9	-73.6	26.1	22.9	62.8	30.9	49.4	28.4	19.7	26.7	-31.9	40.8	42.3	96.3

Number of data = 6
SD: standard deviation
N: before clamp
T: after clamp
D: the difference between N and T

TABLE 2. Present the difference of the amplitude of different harmonics before and after the clamp for spleen.

T/n	Rat 1			Rat 2			Rat 3			Rat 4			Rat 5		
	S.D.%		D.%	S.D.%		D.%	S.D.%		D.%	S.D.%		D.%	S.D.%		D.%
	(N)	(T)		(N)	(T)		(N)	(T)		(N)	(T)		(N)	(T)	
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1.9	1.0	-2.2	1.5	1.3	-0.7	3.0	1.3	4.7	1.8	3.8	3.5	1.5	2.9	-4.3
2	1.1	2.0	-2.7	1.2	1.6	-1.9	3.4	2.8	3.8	2.0	2.0	-0.8	1.6	4.3	-1.6
3	3.0	7.1	-23.8	2.3	3.9	-14.8	3.6	5.4	-14.8	2.7	6.8	-14.4	1.4	4.9	-25.3
4	4.6	3.9	-18.4	1.5	3.6	-19.4	8.2	7.9	-17.7	5.2	9.3	-28.5	4.8	21.9	-38.8
5	5.4	4.8	-35.4	2.5	5.5	-26.2	10.3	10.1	-7.2	2.4	11.7	-5.4	6.7	25.4	-35.7
6	3.5	4.3	-46.8	2.1	4.1	-31.2	13.0	23.5	-22.6	10.7	10.9	-11.9	6.8	52.5	-31.4
7	7.5	14.4	-44.1	4.0	8.1	-37.1	20.3	49.6	-45.6	24.2	31.7	-34.5	23.7	57.5	-51.7
8	11.2	10.8	-57.0	7.1	12.4	-38.3	41.8	12.5	-12.2	26.1	35.0	-43.6	15.4	49.1	-46.4
9	9.6	21 2	-53.1	12.5	25.5	-41.3	30.7	30.7	-34.2	40.6	51.9	-14.3	16.7	46.8	-25.6
10	48.1	52.0	-29.6	21.1	40.0	-37.3	10.2	43.6	-24.3	10.0	63.4	-8.2	18.3	40.5	-7.6

Number of data = 6
SD: standard deviation
N: before clamp
T: after clamp
D: the difference between N and T

with the kidney, and to share the third harmonic and up with the kidney, spleen and so on. Therefore, the first harmonic is the major driving force for blood to flow into the liver. So is the second harmonic will be the major driving force for kidney. The third harmonic is the major driving force for spleen. From these results we may also deduce that blood flow to liver would be greater than blood flow to kidney which in turn would be greater than blood flow to spleen, if the organs had similar resistance.

According to these results the movement of the organ is mainly in resonance with the lowest harmonic of this specific organ. In other words the liver is in resonance with the fundamental harmonic of heart rate, the kidney is with the second harmonic and the spleen is with the third harmonic and so on.

From the fact that the impedance of the arterial tree is a frequency dependent quantity (4,5,6), we may deduce that the energy lost is minimum when the pressure wave has the resonance frequency. However, there could not be too many different frequencies in the pressure wave, it would be very difficult for the heart to generate it. And our experiments have proven the existence of resonance harmonics which are fixed frequencies in organs, this might explain why the heart is repeating its beat. From our experiments, the liver is in resonance mainly with the fundamental harmonic. However the liver may not be the only tissue in resonance with the fundamental harmonic, there may be other arterial trees in other tissues that are in resonance with this fundamental harmonic also. The liver is an isolated organ. Now the question is how these other arterial trees may be arranged to keep the energy lost to minimum. If these arterial trees with the same resonance frequency are arranged in a linear continous fashion, this becomes a series of forced vibrational lumped elements. Mathematically, it is equivalent to oscillations in a homogenous electric network. This system may behave like a band pass filter, and allows a certain range of frequencies to pass with minimal energy loss. (Actually the behavior of the organ is somewhat like a high pass filter. It suggests the basic resonance frequency of each element is the lowest one in the passing band).

This linear continous arrangement of resonant arterial trees may be called a Meridian, which may well be the same meridian in Chinese medicine. The blood will flow along it as one resonance unit.

CONCLUSION

We may thus say that the existence of harmonics in the pressure wave is the most effective way for the heart to perform. While the existence of the meridians is the way to distribute blood with least energy loss.

The shape or the spectrum of the pressure wave in the artery may also give information of the blood distribution to organs which are related to the resonance conditions of these organs. The blood distribution may in turn related to the health condition of these organs.

Our experiments attempted to bridge the three-thousand-year old pulse-feeling in the Orient with the three-hundred-year old hemodynamics in the West. It is hoped that we may develop this theory into not only a new theory in cardiovascular system which will solve many problems of heart diseases, hypertension, stroke, etc., but also a systematical approach to understand the traditional Chinese medicine.

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