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Frequency Analysis of First Heart Sound for the Elderly

T. ISHIZUKA, M.D.,* A. ISHIZUKA, M.D.†

*Department of First Pathology, Dokkyo University School of Medicine; †Department of Internal Medicine, Tochigi City, Tochigi, Japan

Summary: Frequency analysis of first heart sound in elderly and expired cases was performed to reveal changes of the cardiovascular system accompanying aging. The vibration was analyzed for isometric contraction phase or 0.06 seconds following the main vibration of first sound by means of fast Fourier transform technique, and main frequency was compared. Mean main frequencies were 43.0 ± 15.4 cps (mean $\pm$ SD) in 21 cases from 54 years to 69 years, 41.4 ± 12.6 cps in 34 cases from 70 years to 79 years, 40.0 ± 14.4 cps in 19 cases from 80 years to 89 years, and 44.2 ± 4.5 cps in 4 cases from 90 years to 94 years. It was 44.4 ± 8.0 cps in 6 cases with left ventricular hypertrophy (LVH) on ECG, and 37.2 ± 7.5 cps in 18 cases without LVH. It was 35.7 ± 6.5 cps in 9 cases who expired and 32.6 ± 5.8 cps in cases of those who died within a year. Though mean main frequencies were almost equal in these groups, it is higher than that of younger subjects, which suggests stiffness of the cardiovascular system of the aged. It was suggested that the stiffness of the cardiovascular system is greater than the increase in cardiac weight of elderly subjects with LVH. Mean main frequency was low in subjects who dies within a year, which may be due to cardiomegaly.

Key words: frequency of first sound, fast Fourier transform, aging, cardiovascular system, left ventricular hypertrophy, degeneration of myocardium

Address for reprints:

Takehiko Ishizuka, M.D.
Department of First Pathology
Dokkyo University School of Medicine
Kitakobayashi 880
Mibu Machi
Azusa-Cho, Tochigi City
Tochigi, Japan

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Introduction

First heart sound is derived from vibrations of the cardiovascular system.[1] As valves and myocardium degenerate with aging,[2] frequencies of vibration of first sound may change as well.

Frequency analysis of first sound using fast Fourier transform algorithm (FFT) has been performed on patients with various diseases,[3-5] and younger volunteers.[6,7] But a comprehensive study of the frequency analysis in the elderly or deceased cases is lacking.

In this study, first sounds of the elderly were analyzed by means of computer technique for FFT to reveal changes of the cardiovascular system associated with aging, especially in cases with left ventricular hypertrophy (LVH) on ECG and in expired subjects.

Materials and Methods

Subjects were 78 volunteers ranging in age from 54 to 97 years who were accommodated in facilities for the elderly. They included 39 cases of essential hypertension, 2 cases of heart valvular diseases, 1 case of old myocardial infarction, 1 case of postapoplectic state, and 35 healthy cases.

Frequency spectra of first heart sound during isovolumic contraction time (ICT), which was assumed to be 0.06 s, were analyzed according to the method of Adolp et al.[3] and compared: (a) between four groups consisting of all cases classified according to age, (b) between two groups consisting of 24 cases with or without left ventricular hypertrophy (LVH) on ECG, and (c) between a group consisting of 9 subjects (all of whom died later), and another group consisting of 69 survivors.

Phonocardiograms of all subjects were recorded at the fourth intercostal space close to the left sternal border during quiet respiration with the subjects supine. Heart sounds were recorded with a Fukuda MIC-8800 T polygraph and a MA-280 sound microphone. The microphone was held in position on the chest wall. The phonocardiogram and lead II of the ECG were recorded on an TEAC R-410 data

recorder. The sound signals were filtered below 50 cps and above 800 cps.

The frequency response of the sound amplifier and microphone combination was flat between 100 cps and 500 cps. In the lower frequency range, there was an 18 db attenuation per octave. In the higher frequency range, there was a 12 db attenuation per octave. The tape recorder was operated at a speed of 15.2 cm/s and had a passband frequency of 0 to 1000 cps.

The frequency content of heart sounds was determined using a digital signal processor (Sanei Signal Processor 7 T 17) from the data on a magnetic tape recorder. After transient capture of the portion of the four consecutive cardiac cycles on an oscillograph, a cursor was moved on the first high-pitched component of each first sound, from which the duration of 0.06 s was considered to be ICT. A FFT was performed during ICT, and displayed on recording paper as the amplitude spectra for each frequency for 1 to 300 Hz.

The dominant frequency was defined as the frequency with the highest amplitude shown in the sound spectrum. The dominant frequencies of first sounds of each case were the average of 4 beats. Frequencies below 20 cps were disregarded because they could have been precordial movements.[6]

ECG was recorded in 24 cases, and blood pressures of all cases were measured in a supine position at the time of the recording of phonocardiograms.

Probabilities of statistical differences were based upon an unpaired Student's *t*-test.

Results

In the group below 70 years of age (21 cases; 10 males and 11 females) (Table I) the average age was 65.6±3.7 years (mean±SD), mean blood pressure was 115.3±7.9 mmHg, and dominant frequency was 43.0±15.4 cps.

In the group from 70 years to 79 years (34 cases; 21 males and 13 females) (Table I) the average age was 74.9±2.5 years, mean blood pressure was 116.4±17.3 mmHg, and dominant frequency was 41.4±12.6 cps.

In the group from 80 years to 89 years (19 cases; 6 males and 13 females) (Table I) the average age was 83.2±2.4 years, mean blood pressure was 115.6±14.4 mmHg, and dominant frequency was 40.0±10.5 cps.

In the group 90 years or more (4 cases; 1 male and 3 females) (Table I) the average age was 92.3±2.8 years, mean blood pressure was 110.3±14.7 mmHg, and dominant frequency was 44.2±4.5 cps.

In 6 cases with LVH on ECG which was judged by amplitudes of R waves and ST-T pattern in leads V_5 and V_6 (2 males and 4 females) (Table II), the average age was 79.3±7.1 years, mean blood pressure was 115.3±11.3 mmHg, total amplitude of R waves in leads V_5 and V_6 was 5.0±1.1 mV, and the dominant frequency was 44.4±7.9 cps.

In 18 cases without LVH on ECG (6 males and 12 females) (Table III) the average age was 74.8±10.7 years, mean blood pressure was 115.4±15.7 mmHg, total amplitude of R waves in leads V_5 and V_6 was 2.8±1.0 mV, and dominant frequency was 37.2±7.5 cps.

In 9 subjects, who died of diseases (4 males and 5 females) (Table IV), the average age was 77.2±5.1 years, and the dominant frequency was 35.7±6.5 cps. In 5 cases, who died within one year, the average age was 77.4±3.4 years, and the dominant frequency was 32.6±5.8 cps. The duration from the date of the study to the date of death ranged from 99 days to 365 days. In 4 cases, who died beyond one year, the average age was 77.0±6.7 years, and the dominant frequency was 39.6±5.2 cps. The duration range was 466 days to 727 days.

In 69 survivors (34 males and 35 females) the average age was 75.1±8.2 years, and the dominant frequency was 42.6±13.3 cps.

Discussion

Both acceleration and abrupt deceleration of myocardium and blood mass in ventricles cause vibration of the cardiovascular system.[1] The frequency of vibration is almost proportional to the stiffness of the system and inversely proportional to its weight.[3,5]

The dominant frequency of first heart sound was 95±11 cps in patients with degenerated porcine bioprosthetic valves in mitral position, and 51.3±3 cps in patients with normal porcine bioprosthetic valves when the sound signal was filtered below 50 cps and above 500 cps.[5]

The dominant frequency of first heart sound for 74 normal subjects averaged 48 cps when a high-pass filter of 20 cps and a low-pass filter of 1500 cps were used.[6] The

TABLE I Relationship between dominant frequency of first sound and age

Group (yr)[a]	No. of cases	Age (yr)	Sex (M:F)	Mean blood pressure (mmHg)	Dominant frequency (cps)
54≤ <70	21	65.6±3.7	10:11	115.3±7.9	43.0±15.4
70≤ <80	34	74.9±2.5	21:13	116.4±17.3	41.4±12.6
80≤ <90	19	83.2±2.4	6:3	115.6±14.4	40.0±14.4
90≤	4	92.3±2.8	1:3	110.3±14.7	44.2±4.5

[a]Group classified according to age.

TABLE II Frequency analysis in the cases with left ventricular hypertrophy

Case	Age (yr)	Sex	Mean blood pressure (mmHg)	R waves (mV)[a]	ECG findings	Dominant frequency (cps)
1	75	F	103	5.3	LVH	38.1
2	79	F	121	5.2	LVH, ST-T change	46.9
3	75	M	137	6.2	LVH, ST-T change	32.3
4	76	M	106	5.3	LVH	45.9
5	90	F	110	2.6	LVH, ST-T change	45.9
6	54	F	115	5.4	LVH	57.6
Mean±SD	79.3±7.1		115.3±11.3	5.0±1.1		44.4±8.0

R waves=total amplitude of R waves in leads V_5 and V_6.

TABLE III Frequency analysis in the cases with no left ventricular hypertrophy

Case	Age (yr)	Sex	Mean blood pressure (mmHg)	R waves (mV)[a]	Dominant frequency (cps)
1	81	F	116	1.1	50.8
2	82	F	100	1.6	43.9
3	85	F	129	1.6	33.2
4	81	F	93	1.8	29.3
5	73	F	157	2.3	34.2
6	78	M	117	2.0	33.2
7	70	M	126	2.2	41.0
8	80	F	110	2.8	29.3
9	84	M	123	2.4	29.3
10	78	F	107	2.5	26.4
11	80	M	129	3.0	40.0
12	84	F	110	3.8	39.1
13	91	F	87	3.9	41.0
14	64	F	120	3.5	43.9
15	84	M	97	3.3	31.3
16	91	M	127	4.1	50.8
17	72	M	112	4.3	28.3
18	69	M	117	4.1	43.9
Mean±SD	74.8±10.7		115.4±15.7	2.8±1.0	37.2±7.5

[a]R waves, total amplitude of R waves in leads V_5 and V_6.

TABLE IV Frequency analysis in expired cases

Case	Age (yr)	Sex	Duration (day)[a]	Cause of death	Dominant frequency (Hz)
1	79	M	99	Rupture of abdominal aneurysm	43.9
2	81	F	115	Uremia, hypertension	29.3
3	75	M	206	Cerebral hemorrhage	32.2
4	80	F	245	Lung cancer	29.3
5	72	M	365	Liver cancer	28.3
6	80	M	466	Congestive heart failure	40.0
7	78	F	569	Intestinal obstruction	46.9
8	66	F	687	Epidural hematoma	32.2
9	84	F	727	Cerebral infarction	39.1
	77.2±5.1				35.7±6.5

[a]Duration=duration from the date of study to the date of death.

age range of their cases was 6 months to 70 years. The dominant frequency was 20 cps to 28 cps in 20 healthy volunteers in the age range of 17 years to 29 years.[4,7]

In this study, the dominant frequency of first sound was almost equal in subjects greater than 90 years or less than 70 years of age, but it was higher than the dominant frequency of healthy young volunteers.

Pathology could account for these findings. The thickening of valves increases with age until the seventh decade, and calcification of mitral valve ring was found in 11.6% of 2000 consecutive autopsies of elderly patients.[2] Left ventricular dimensions decrease with aging, while the thickness of myocardium in left ventricular outflow tract tends to thicken until the seventh decade.[2]

Accordingly, the cardiovascular system, including the valves will grow stiffer with age until the seventh decade, while mass of the cardiovascular system may become smaller, which results in the increase in the frequency of first sound.

The dominant frequency of first sound in this study was slightly lower than that for patients with normal porcine bioprosthetic valves, which suggests that such valves may be stiffer than the human mitral valve or may be derived from the different size of the cardiovascular system.

Usually, LVH means increased mass of the cardiac system, but the dominant frequency was slightly higher in cases with LVH than in cases with no LVH. Stiffness of the system may increase in elderly patients with LVH, and LVH may be caused not only by hypertension but also other factors such as ischemia or deposition of lipofucin or amyloid in myocardium.

The dominant frequency was lower in expired subjects, especially in those who died within one year, which may be because such cases suffering from uremia, arteriosclerosis, and so on, incline to suffer cardiomegaly or increased mass of the cardiovascular system.

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