Experimental

ELECTRICAL PROPERTIES IN THE EXTREMITIES ALONG MERIDIANS IN PATIENTS WITH UNILATERAL PULMONARY TUBERCULOSIS

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ABSTRACT

Objectives: Electrical properties along meridians may reflect the flow of Ki energy, a type of subtle energy. The objectives of this study were to characterize the laterality (disease versus non-disease side) of electrical properties along lung (LU) meridian in patients with unilateral pulmonary tuberculosis, and to examine the changes of the electrical properties over time along liver (LV) meridian during chemotherapy in patients with hepatitis induced by anti-tuberculosis chemotherapy.

Design and methods: Square wave pulses (3 V x 256 μsec) were applied between indifferent electrodes placed on the extensor surface of each forearm and active electrodes placed on the Well points of each meridian located near the root of finger- and toe-nails. The response electric current was characterized by 3 parameters: before polarization (BP; initial maximum) current, after polarization (AP; final stationary) current, and integrated coulomb (IQ; total electrical charge). Measurements was made before and at months 1, 2, 3, 4 and 5 or 6 months after starting anti-tuberculosis chemotherapy. Analysis was done by classifying patients into 3 groups according to liver function.

Results: The IQ value along the LU meridian was excessive on the tuberculosis-uneffected (or less severely affected) side compared to the tuberculosis-effected (or more severely affected) side before chemotherapy, and the IQ of the unaffected side decreased to the same level as the affected side two months after start of chemotherapy. The IQ and BP currents of LV meridian decreased coinciding with the onset of drug-induced hepatitis due to anti-tuberculosis drugs.

Conclusions: The electrical properties along the LU meridian demonstrated laterality in patients with unilateral pulmonary tuberculosis, and the electric properties along the LV meridian changed in response to the onset of drug-induced hepatitis. These findings suggest that Ki energy flow along some meridians is altered by diseases of the corresponding organ.

KEYWORDS: Pulmonary Tuberculosis, Drug-Induced Hepatitis, Electricity, Meridian, Subtle Energy

INTRODUCTION

In Eastern medicine, especially in acupuncture medicine, it has been empirically recognized that Ki energy, a type of subtle energy, always flows through meridians in the human body, and that diseases occur when the Ki energy flow is interrupted or vice versa. However, the existence of Ki energy and meridians has not been verified by Western medicine. It is only in recent years that the existence of meridian points has begun to be proven by experimental methods acceptable for Western medicine.[1]

According to acupuncture medicine, it has been believed empirically that there are 12 regular and 8 extra meridians in the human body, and that some meridians are intimately related to some organs.[2] For example, the lung (LU) meridian and liver (LV) meridian have been considered to be intimately related to the lung and liver, respectively. This also has started to be proven experimentally quite recently.[3]

The nature of Ki energy is not yet known. However, recent studies have shown that electrical properties along meridians are altered by stimulation of the corresponding organs, and that the electrical properties along meridians change as diseases of the corresponding organs progress.[3] For example, the average electrical resistance along meridians is higher in patients with liver failure and/or liver cancer than that in patients with fatty liver or acute or chronic hepatitis.[4,5] These observations indicate that Ki energy has an electrical characteristic. Therefore it is significant to study the electrical properties along meridians in order to understand the Ki energy flow.

In acupuncture medicine, the right-left balance of Ki energy flow is said to be important to maintain a healthy state. Then a question arises as to whether or not Ki energy flow is symmetric when disease occurs on one side of the body.

An objective of our study is to examine the changes in electrical properties along meridians with time during the course of disease. Another objective is to examine the right-left balance of electrical properties along meridians when disease occurs unilaterally. To achieve these objectives, we studied the electrical properties along meridians in patients with unilateral pulmonary tuberculosis before and after starting anti-tuberculosis chemotherapy. We also anticipated that some of the patients might develop liver dysfunction (i.e., drug-induced hepatitis) due to anti-tuberculosis drugs during the treatment period.

PATIENTS AND METHODS

Patients

All patients had active pulmonary tuberculosis diagnosed by positive sputum cultures. Only patients who had unilateral pulmonary tuberculosis on chest radiographs were selected for this study. Unilateral tuberculosis was defined as either having tuberculous lesions completely confined to one lung or the area of tuberculous lesions in one lung was at least three times more extensive than that in the other lung on chest

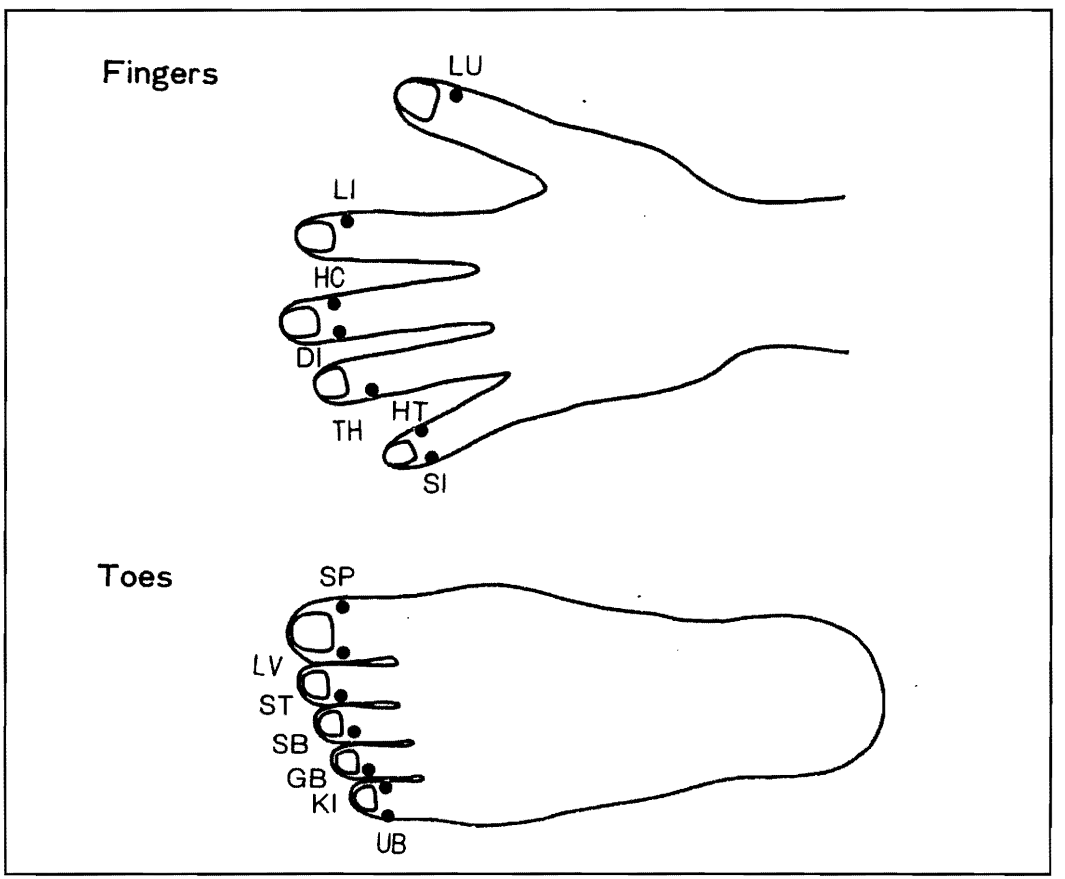
radiograph. From September 1996 through March 1998, 32 patients were enrolled in the study. All patients gave their informed consent to participate in the study. The study was approved by the local hospital Ethical Committee.

AMI Measurements

We used an AMI instrument (an apparatus for measuring the functioning of the Meridians and their corresponding internal organs) to study the electric properties along meridians. Details of this instrument are described elsewhere.[6] The principles and the measuring system of this instrument will be described briefly below.

Near the roots of finger and toe nails (some 3 mm proximal to the base of the nail) are the Well (Jing in Chinese and Sei in Japanese) points, where the meridians either begin or end, depending on the direction of Ki flow (Figure 1). These Well points are traditionally known to sensitively reflect the

Figure 1. Well points of fourteen meridians.
Upper extremities: LU; Lung, LI; Large Intestine, HC; Heart Constrictor, DI; Diaphragm, TH; Triple Heater, HT; Heart, SI ; Small Intestine
Lower extremities: SP; Spleen, LV; Liver, ST; Stomach, SB; Stomach Branch, GB; Gall Bladder, KI; Kidney, UB; Urinary Bladder



condition of the meridians to which they belong. Figure 1 illustrates the 14 Well points of the 14 meridians (12 are regular and 2 [Stomach Branch (SB) and Diaphragm (DI)] are extra meridians). The meridians are biologically symmetrical. Prior to measurement, two indifferent electrodes (Ag/AgCl; 2 cm x 3 cm) are attached to the extensor surface of each forearm about 5 cm above both wrists, and plate electrodes (Ag/AgCl; 4 mm square) coated with non-polarizing electrode paste are attached to the right and left Well points of all meridians (28 points in all). Square wave pulses (3 V x 256 μsec) are then sequentially applied between each active Well electrode and the indifferent electrode pair, through an external electric resistance of 100 **Ω**.

Then a response electrical current flows in the circuit.

The peak current that flows immediately after the application of the external potential to the skin is called the before polarization (BP) current. This current is thought to penetrate through all the cells and intercellular spaces with electrical capacity, including those layers possessing dielectric membranes such as the stratum corneum and basal membranes of the epidermis. The BP current is followed by an exponentially decreasing current, which reflects the polarization process (charging of capacitive elements) in the tissue. The steady-state current that flows after completion of all polarization is called the after polarization (AP) current. The steady state is normally reached within approximately 200 μsec. The total electric charge that is mobilized during the polarization process is called integrated coulomb (IQ), or total electrical charge. This is supposed to reflect the electrical capacity of basal cells and other dielectric tissues of the epidermis just beneath the plate electrodes at the Well points. The above mentioned electrical stimulus is so weak that the subject feels nothing at all during measurements (no response from the nervous system).

Measurement of three above-mentioned parameters (BP, AP and IQ) was performed from September 1996 through June 1998. The first measurement was made just before starting anti-tuberculosis chemotherapy including rifampicin, hydrazide and ethambutol. In many cases the measurements were done successively every month after starting anti-tuberculosis chemotherapy, but in some cases they were done only once during chemotherapy.

Mean values of the parameters measured before and 1, 2, 3, 4 and 5 (or 6) months after starting chemotherapy were calculated, and the changes of these parameters over time for each meridian was examined, giving special attention to laterality [the difference between the tuberculosis-affected (or more severely affected) side and the tuberculosis-unaffected (or less severely affected) side].

Some patients had alcoholic liver disease (diagnosed by a history of alcohol intake and elevation of serum γ glutamyltransferase (γ-GTP) to higher more than 45u/l) before chemotherapy, and some patients developed liver dysfunction due to anti-tuberculosis

Table 1
Characteristics of the study patients.

Male/Female	25/7
Mean age (yr)*	48.3 ± 19.6
Body Heaight (cm)*	164.0 ± 8.7
Body Weight (kg)*	54.6 ± 8.5
No.	32
Left-sided TB	19
Confined to left side	13
Predominantly left-sided	6
Right-sided TB	13
Confined to right side	5
Predominantly right-sided	8

* Mean ± SD (Standard Deviation)
TB : tuberculosis

drugs during chemotherapy. Therefore, cases in which serum hepatic enzymes were measured every month during chemotherapy were divided into the following three groups. In the first group, although the liver function was normal before chemotherapy, liver dysfunction [diagnosed by serum alanine aminotransferase (ALT) >40 u/l or γ-GTP >45 u/l] occurred during chemotherapy (group A). In the second group, hepatic function was normal before and during chemotherapy (group B). In the third group, the patients had alcoholic liver disease before chemotherapy, but their liver function did not worsen during chemotherapy (group C). BP and IQ values of these three groups were examined and compared to assess the effect of hepatic function on these parameters.

Statistical Analysis

Student's paired or unpaired t test (two-sided) was used to compare variables as appropriate, and *p*-values less than 0.05 were taken as significant.

Results

Patients

The characteristics of the study patients are shown in Table 1. The mean age was 48 years (range, 21 to 85). None had diagnosed HIV infection. Nineteen patients had left-sided and 13 had right-sided pulmonary tuberculosis. Eighteen patients had pulmonnry lesions completely confined to one lung, and 14 patients had pulmonary lesions predominantly in one lung. Areas of tuberculous lesions were assessed by inspection of chest radiographs, and the mean area ratio of tuberculous lesions of more severely affected to less severely affected sides was calculated to be 5.3:1 in these 14 cases.

Treatment and Clinical Course

All the patients were treated with 3 or 4 anti-tuberculosis drugs including rifampicin and isoniazid for more than 6 months without discontinuation. In 26 of 32 patients (81%), sputum culture for tubercle bacilli became negative two months after start of chemotherapy (Table 2).

Table 2
Increase of sputum culture negativity in 32 study patients during chemotherapy

Period of Treatment (months)	NO. of Negative Sputum Culture	
0 (before treatment)	0/32	(0 %)
1	11/32	(34%)
2	26/32	(81%)
3	31/32	(97%)
4	31/32	(97%)
5	32/32	(100%)

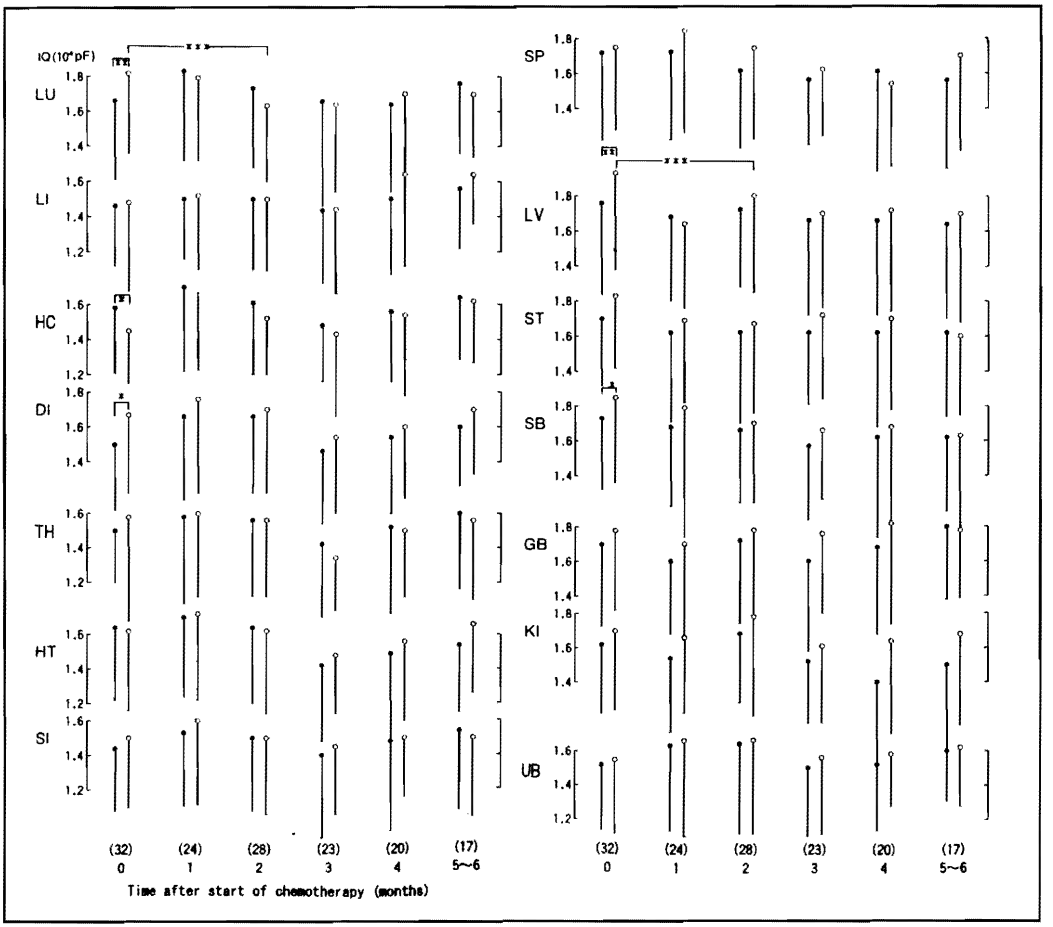


*Figure 2. Fig. 2. Changes in IQ values along 14 meridians over time during chemotherapy in 32 pulmonary tuberculosis patients. Solid circles denote mean values of affected or more severely affected side, and open circles those of unaffected or less severely affected side. The bars show - 1 standard deviation. Numbers in parentheses show number of cases. OM means just before treatment. M: Month(e), *: p <0.05 (paired Student's t-test), **: p < 0.01 (paired Student's t-test), ***: p <0.05 (unpaired Student's t-test)*

AMI Measurement

The IQ and BP values along 14 meridians were shown in Figures 2 and 3, respectively. IQ values at 0 month (just before chemotherapy) were significantly different (p <0.05 or p <0.01) between the affected (closed circle) and unaffected (open circle) sides along LU (Lung), HC (Heart Constrictor), DI (Diaphragm), LV (Liver) and SB (Stomach Branch) meridians

Before treatment the IQ values of the unaffected side along LU, DI, LV and SB meridians were excessive compared to those of the affected side, while the IQ value of the unaffected side along HC meridian was

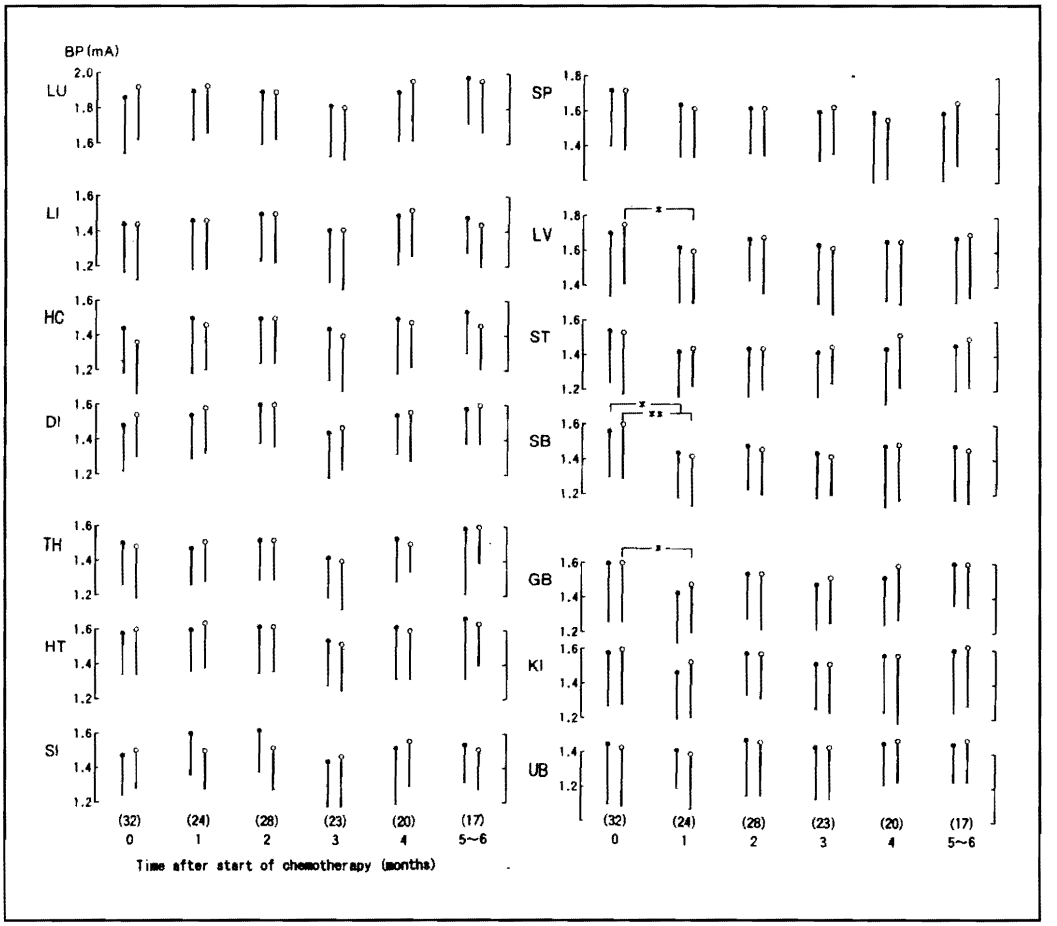


*Figure 3. Changes in BP values along 14 meridians over time during chemotherapy in 32 pulmonary tuberculosis patients. For details and abbreviations, see the legend in Figure 2. *: $p < 0.05$ (unpaired Student's t-test), **: $p < 0.01$ (unpaired Student's t-test)*

lower than that of the affected side. The IQ values of unaffected side along LU and LV meridians at 2 months after start of anti-tuberculosis chemotherapy decreased significantly ($p < 0.05$) compared to those at 0 month (Figure 2). The affected to unaffected side differences at 0 month along HC and DI meridians were not related to the presence of pericarditis and pleuritis, respectively (data not shown).

The BP values at 0 month were not different between the affected and unaffected sides. The BP values of the unaffected side along LV, SB, and GB meridians, and the BP value of the affected side along SB meridian at 1 month after start of anti-tuberculosis chemotherapy decreased significantly ($p < 0.05$ or $p < 0.0l$) compared to those at 0 month (Figure 3). The AP values showed no significant

changes in all the measurements (data not shown).

In 29 of 32 patients, serum ALT and γ-GTP were monitored every month during the treatment periods. These 29 patients were divided into the following three groups as described above. In group A (n = 10), liver dysfunction due to anti-tuberculosis chemotherapy appeared during treatment. Five cases of ALT elevation and another 5 cases of γ-GTP elevation were observed (Figure 4A). In group B (n = 11), no liver dysfunction was found before and during chemotherapy (Figure 4B). In group C (alcoholic liver disease; n = 8), elevation of γ-GTP before chemotherapy improved during chemotherapy (Figure 4C),

The mean - 1 standard deviation (SD) IQ values along LV meridian of these three groups are shown on the right side of Figure 4. In group A, the IQ values along LV meridian decreased significantly (p <0.05) between 0 to 2 months after start of chemotherapy. IQ values

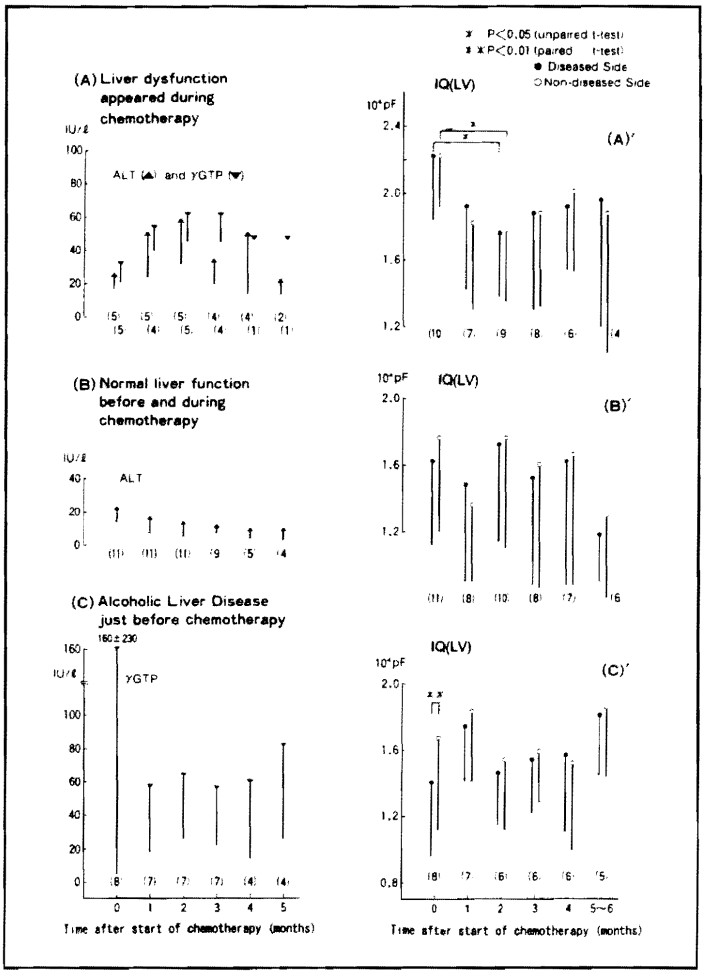


Figure 4. Relationship between liver function and IQ value of liver (LV) meridian.

(A), (B) and (C): Changes in serum alanine aminotransferase (ALT) and/or γ-glutamyltransferase (γ-GTP) levels of three groups classified by liver function are illustrated by mean (▲ and/or ▼) - 1 standard deviation (bar). (A') (B') and (C'):

*The corresponding changes of Liver (LV) IQ values in each group are also illustrated by the mean (solid and open circles) -1 standard deviation (bar). Solid circles denote mean liver (LV) IQ values of the affected or more severely affected side, and open circles denote the values of the unaffected or less severely affected side. Numbers of cases are shown in parentheses. *: p <0.05 (unpaired Student's t-test), **: p <0.01 (paired Student's t-test).*

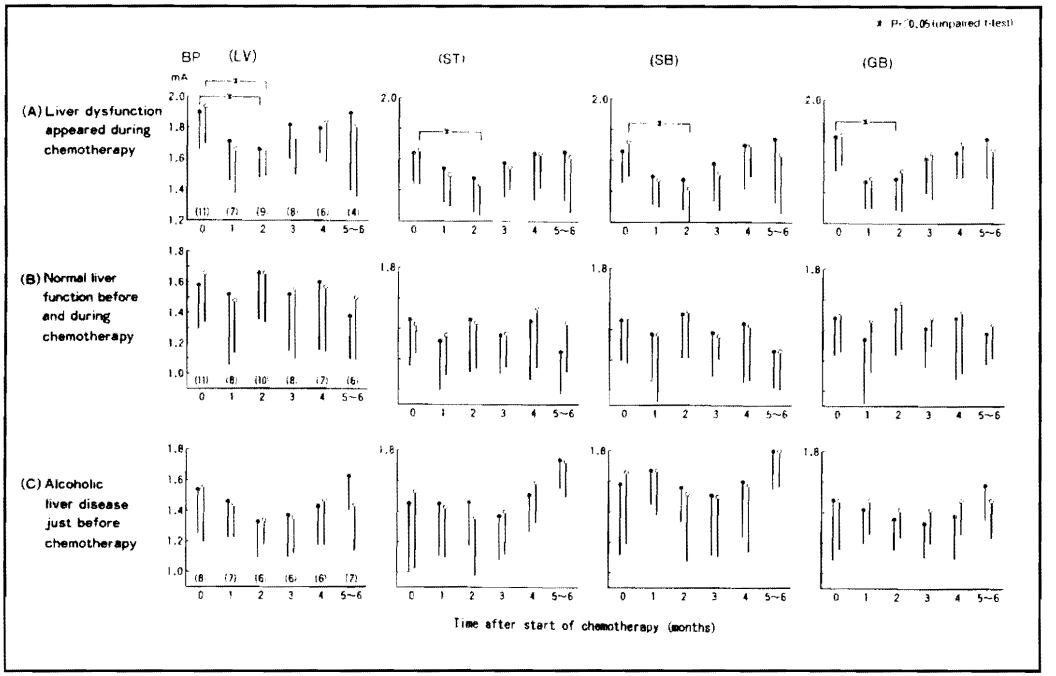


Figure 5. BP values of liver (LV), stomach (ST), stomach branch (SB) and gall bladder (GB) meridians during chemotherapy periods in 3 groups.

along GB meridian also showed a similar pattern, although the difference did not reach statistical significance (data not shown). In group B, the IQ values along LV meridian did not show any significant change during the treatment period. In group C a significant difference in IQ value along LV meridian was found between the affected and unaffected sides at 0 month.

In group A, The BP values along the LV, ST, SB and GB meridians decreased significantly from 0 to 2 months after chemotherapy. In Groups B and C, no significant changes in BP values were detected (Figure 5).

For meridians other than LV, ST, SB and GB, the IQ and BP values showed no significant changes over time during chemotherapy in all three groups (data not shown). The AP values along all meridians also did not change significantly over time in three groups (data not shown).

Discussion

In patients with unilateral pulmonary tuberculosis, the BP and AP values of all 14 meridians did not show any statistically significant differences between the tuberculosis-affected and -unaffected sides before start of anti-tuberculosis chemotherapy, while the IQ values of LU. HC, DI, LV and SB meridians showed differences between the affected and unaffected sides. The IQ value along LU meridian was higher on the unaffected side compared to the affected side.

Considering that the IQ value along LU meridian on the unaffected side decreased over time after start of anti-tuberculosis chemotherapy, the IQ value along LU meridian on the unaffected side was excessive compared to the affected side before start of chemotherapy. As the IQ value represents electric capacitance just beneath a Well point, the above result indicates that the electric capacitance of LU meridian on the unaffected side was elevated compared to the affected side before start of anti-tuberculosis chemotherapy.

We speculate that some signals from the lung, which we call Ki energy or a kind of subtle energy, regulate or alter the ionic condition along LU meridian, and change its electric capacitance. Therefore, the above-mentioned observations suggest that Ki energy along LU meridian on the unaffected side was increased above the usual level, perhaps in order to help the affected side by supplying Ki energy to that region.

DI meridian is related to diaphragm and lung, and so the increased IQ values on the unaffected side observed before chemotherapy may be also considered to be due to the same reason as in the case of LU meridian.

Differences in IQ values between the affected and unaffected side was also observed along LV meridian in patients with alcoholic liver disease. Although the reason for this finding is not clear, we postulate that the right-left balance of Ki energy along LV meridian is unstable in patients with alcoholic liver disease, and is easily affected by the flow of Ki energy along LU meridian.

Two months after start of anti-tuberculosis chemotherapy, the IQ values of both LU and LV meridians decreased on the unaffected side. The decrease in IQ value of LU meridian on the unaffected side was related to treatment with anti-tuberculosis drugs. A high rate of sputum culture negative conversion rate (81%) was achieved 2 months after start of chemotherapy, and patients felt well at that time. The finding may reflect that it is no longer necessary for the unaffected lung to support the affected one via Ki flow.

During anti-tuberculosis chemotherapy, transient IQ liver dysfunction (drug-induced hepatitis) appears in some patients. In most cases, the transient liver dysfunction improves spontaneously without discontinuation of chemotherapy. In our patients who developed liver dysfunction due to anti-tuberculosis drugs, both IQ and BP values of LV meridian decreased with elevation of serum hepatic enzymes (ALT or γ-GTP) and recovered as the liver function improved. This study clearly shows a relationship between acute liver injury and IQ or BP value of LV meridian.

These results indicate that during mild liver dysfunction due to anti-tuberculosis chemotherapy, ionic conditions along LV meridian were altered specifically, perhaps due to Ki energy flowing from the liver along LV meridian to its Well point. This may be interpreted that the amount of Ki energy flow from the liver through LV meridian to its Well point decreases during the acute phase and increases during the recovery phase of liver injury.

A study of a small number of patients with moderate and severe acute liver injury reported increase of the IQ value during the recovery phase (5), However, the behavior of IQ values during acute phase of liver injury has not been studied in detail. Our results showed that the IQ and BP values decreased during acute phase of liver injury in cases of mild liver injury.

Liver dysfunction also influenced the meridians (such as ST, SB and GB) that reflect function of digestive organs (such as stomach and gall bladder) adjacent to the liver. Especially, LV and GB meridians are known to share a Yin-Yang relationship (negativity-positivity relationship) in acupuncture medicine. It is reasonable to consider that these meridians are influenced to some degree in cases of liver dysfunction.

In conclusion, in patients with unilateral pulmonary tuberculosis, the IQ value of LU meridian reflects the laterality of the disease, and IQ and BP values of LV meridian reflect liver dysfunction in patients with hepatitis induced by anti-tuberculosis drugs.

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