Clinical Studies on Arterial Blood Pressure Changes Caused by
Tilting from Horizontal to Head-up Position

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SUMMARY: In the realm of pediatrics particularly children of school age, those who complain of dizziness, lightheadedness of the like without any organic diseases are diagnosed as having orthostatic dysregulation (OD). With the subject in the supine position on a tilting table, the systolic pressure (SP), diastolic pressure (DP), heart rate (HR), stroke volume (SV), cardiac output (CO) and total peripheral resistance (TPR) were examined for the supine position (S) and tilting position at 20° (T) using the Korotkoff Sound Graph recorder. SP fell off significantly and an increase of HR was small when the posture has been changed from S to T in the OD group compared with the control group. The findings above suggest that these changes are due to the decrease of vagal activities being not predominant or to the increase of sympathetic activities not being so conspicuous in OD group.

Regarding complaints such as dizziness, lightheadedness and poor waking without any organic change in the realm of pediatrics, particularly children from higher classes of primary schools to junior high schools, we grasp them as a syndrome, diagnose it as orthostatic dysregulation (OD) and give guidance on the daily life and pharmacotherapy in accordance with symptoms. The criteria for diagnosis of OD are shown in Fig. 1. On the basis of the nature of complaint, OD was divided into major symptoms and minor symptoms. The major symptoms consist mainly of cardiovascular symptoms and the minor symptoms are made up of gastrointestinal symptoms. The mechanism by which major symptoms are produced was studied by a noninvasive method from the aspect of hemodynamics centering around the arterial blood pressure.

SUBJECTS

The subjects are boys and girls aged 8 to 16 years, broken down to 20 children who are free of organic diseases and have no complaint whatever at as the control group and 8 children with OD who complained of cardiovascular symptoms, the so-called major symptoms.

METHOD

After making the subject lie quietly in a supine position on a tilting table, the blood pressure is measured with Korotkoff Sound Graph (KSG, Parama Co., Tokyo), whereupon SV, CO, TPR are calculated by a built-in computer. A comparative study was made about the supine position, S and tilt (20°) position, T.
Criteria of orthostatic dysregulation

Major manifestations
A. Liability to syncope or dizziness
B. Sick on standing up, falling down at worst
C. Being sick when taking a bath or seeing or hearing unpleasant things
D. Palpitation or shortness of breath following slight physical exertion
E. Difficulty in getting up in the morning, feeling unwell in the noon

Minor manifestations
a. Pallid complexion
b. Loss of appetite
c. Occasional peri-umbilical colic
d. Lassitude of fatigability
e. Liability to motion sickness
f. Decrease in pulse pressure of more than 16 mmHg on standing in the postural test
g. Decrease in systolic pressure of more than 21 mmHg on standing in the postural test
h. Increase in pulse rate of more than 21/ min on standing in the postural test
i. Decrease in T₁, T₁₁ amplitude on ECG of more than 0.2 mV on standing in the postural test

The presence of either combined 1 major, and 3 minor, or of combined 2 major and 1 minor or of 3 major manifestations indicates a high probability of OD.

RESULTS

Values measured are as follows. The mean value was used in studying the results for both S and T. The range of errors was set at ± 3 mmHg.

1) Systolic pressure, SP mmHg (Fig. 2)
SP showed no change whatsoever in the control group, with 112 for S and likewise 112 for T. In the OD group, it fell off average 11 for T compared with S, with 110 for S and 99 for T. The difference was significant at p<0.05.

2) Diastolic pressure, DP mmHg (Fig. 3)
DP was 50 for S but increased at 57 for T in the control group. In the OD group, it was 49 for S but slightly increased at 54 for T. As for changes in the blood pressure with shifting of the posture from S to T, however, there was no significant elevation in both the control group and the OD group.

3) Heart rate, HR t/min (Fig. 4)
In the control group, HR was 73 for S but significantly increased at 80 for T with the posture changed to the tilt position (p<0.05). In the OD group, it was 70 for S and 74 for T, the increase for T being slight.
4) Stroke volume, SV ml (Fig. 5)

In control group, SV increased with the posture changed to the tilt position, with 70 for S and 75 for T. In the OD group, it was 76 for S but decreased at 73, slight as it was, for T. Regarding SV change with shifting of the posture, however, the change was not significant in both groups.

5) Cardiac output, CO 1/min (Fig. 6)

In the control group, CO increased with shifting of the posture, with 4.22 for S and 4.47 for T. In the OD group, it was 4.56 for S but decreased slightly at 4.40 for T. As with SV, no significant change was observed in both groups regarding CO changed with shifting of the posture.

6) Total peripheral resistance, TPR dyne·sec/cm (Fig. 7)

In the control group, TPR was 1350 for T against 1323 for S. A similar tendency was observed in the OD group; that is, TPR increased slightly for T compared to S, with 1212 for S and 1259 for T. As for the magnitude of change with shifting of the posture, no significant change was observed in both groups.

As can be seen from the data above, it was SP in the OD group and HR in the control group that showed a significant change with shifting of the posture. This is, SP fell off and HR increased for T compared with S.

DISCUSSION

Sphygmomanometers recently available are so improved as to be easy to handle and to show considerably exact values. The Korotkoff Sound Graph (KSG-303S) offers a method whereby a built-in computer calculates the blood flow of the brachial artery by analysis of hemorheology from the pulse-pressure wave of the brachial artery and Korotkoff sound in the cuff for measuring the blood pressure, and SV found was correlated well with SV found from the ultrasonic cardiac echogram at about the same time. When SV is found, CO is found since HR is known. Furthermore, TPR may be found from the aortic mean pressure, CO and constant number.

It can easily be imagined that shifting of the posture from the supine position to the standing
position causes SP to fall off transiently. But the reflex mechanism works at once to keep the blood pressure at a certain level; this is biological reaction. When the posture has been changed from supine position to the standing position, the venous return decreases instantaneously under the influence of the gravity and so, SV decrease secondarily. However, HR increases in accordance with the decrease in SV so as to keep the blood pressure at a certain level. When the blood pressure falls off transiently with shifting of the posture, the baroreceptor senses it, resulting in the bulb decreasing its stimulation to the nucleus tractus solitarius (NTS). NTS and its activities to the vagus nerve. Because of the control over the sympathetic circulation center (SCC), SCC from NTS being removed, the sympathetic nerve becomes predominant to adjust the blood pressure.

Where, therefore, SP does not restore its original value with the lapse of a certain time after shifting of the posture, factors other than inadequate accommodation of insufficient response of the reflex mechanism need to be considered. For this mechanism to be elucidated, it is reasonable to study changes of hemodynamics in the supine position and the standing position since changes are produced with loading in the standing position. However, this method need not always be employed to find changes, not with the transient reflex, but with the posture of standing position kept continuously. When one attempts to change from the supine position to the standing position on one’s own, one uses the hands or moves the foot or flexes the waist so that other elements enter to preclude observations on the changes in the circulatory dynamics due purely to the influence of shifting of the posture. As for the method by which the posture is made to change passively from the supine position to the standing position, no appropriate one is available now, and it takes at least several seconds, during which most subjects will accommodate themselves to the change in the posture and the blood pressure will rise to a level near SP in the supine position. Then we used a posture-changing method using a tilting table whereby the angle of inclination can be changed ad libitum. Even by this method, the subject may apply unnecessary muscular power to the lower limb or have a psychological tension attempt to keep his posture when the standing-position loading is applied on the tilting table, unlike the case where he has taken the standing position on his own on the ground. Thus, the results are naturally different from those obtained when he changed from the supine position to the standing position on his own.

In the present experiment, therefore, the posture was made to change passively and the angle of inclination was set at 20° in the tilting position. The angle of inclination was set at 20° because the 20° among the angles of 10°, 20°, 20° ~ 90° is reportedly most suitable. That is, it is by the reason that the influence of the muscular power and gravity is slight, enabling one to examine changes of circulatory dynamics in a relatively pure manner.

The reciprocating changes of the vagal activities and sympathetic activities are very important changes in adjusting the heart rate. If there is a difference is the sensing of the baroreceptor between the OD group and the control group, it is presumed to give birth to a difference in the changes of DP between the two since these autonomic nerves are concerned with the vascular contraction as well.

The fact that there was no difference in changes of DP between the control group and the OD group suggests, though indirectly, that there is no difference in the sensing of the baroreceptor between two. Then, why is it that SP fell off in the OD group and did not fall off in the control group when the posture was shifted from S to T?

A report has it that parasympathetic nerve does not play too important a role in the circulatory accommodation. The report also says that stimulation of the parasympathetic nerve markedly decreases the heart rate and that inhibition of the parasympathetic nerve is not strong in the OD group compared with the control group.

On the other hand, SP is influenced mainly by CO. The CO can be found as the product of SV and HR. There is no significant difference in SV and CO between the control group and the OD group. Why is it that there is no
significant difference in CO and that there is
a difference in SP? No explanation can be by
made by CO alone. Involvement of HR saves
as a key to resolving this question. It is not
appropriate to think that the extent of increase
in HR is influenced merely by the extent of
decrease in SV. Rather it should be thought
that the extent of increase in HR is influenced
by the intensity of activities of the autonomic
nerve that governs the increase in HR.
Accordingly, prescribing changes in SP merely
by the increase or decrease of CO is open to
question.

It is in SP, HR and SV that a difference
between the control group and the OD group
is shown when the posture has been shifted
from S to T.

Generally, SV is supposed to decrease on
account of a decrease of the venous return when
the posture has been changed from S to T\(^9\). According
to the data, however, SV shows no
significant decrease and HR tends to increase
in the control group probably because of the
angle of inclination being low at 20\(^\circ\). In the
control group, SV tends to decrease for T
compared with S and moreover the magnitude
of increase in HR is slight, so SP is presumed
to fall off.

From the above it is surmised that there is
no abnormality is sensing at the baroreceptor
and that changes is SP occur due to the decrease
of vagal activities being not predominant or to
the increase of sympathetic nerve being not too
marked.

This theory is based not on direct examination
of the autonomic function, but on a study of the
autonomic function from phenomena. It is not
that other parameters were used. To substantiate this theory, there is need to
examine the autonomic function of children with
OD in the future.

However, a method for examining the slight
reaction will be developed.

Regarding the extent of SP fall mentioned
under minor manifestation in the criteria for
diagnosis of OD, the fall in SP of 5 mmHg or
more with shifting of the posture was assessed
as abnormal. It is by the reason that the present
examination concerns not a study of the reaction
immediately after shifting of the posture but a
study about 1 to 2 minutes after shifting of the
study. That is because the SP fall being 5
mmHg or more at this point is not only due to
a transient decrease in the venous return but
also may be regarded as an abnormal phe-
omenon where SP cannot return to the level
in the supine position. The way this criterion
is set is not necessarily universal. There is an
ample room for further study in the future.

Generally, variations within 10% in the values
measured of the blood pressure are said to be
the limit of error\(^{10}\). According to the theory, variations within about 10 mmHg in the values
measured may be dismissed.

Variations above 10% may be regarded as
abnormal when a pathological judgement is
made in the groups of abnormal range such as
hypertension or hypotension. Where, however,
observations are made on variations in the
normal range, variations above 5 mmHg may
be regarded as abnormal.

In the future, we would like to study change
with time in the hemodynamics in the lapse of
time, say, 5, 10 and 15 minutes after taking the
standing position.

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