Shimane J. Med. Sci. Vol. 4, pp. 127–133, 1980

Statistical Comparison of Echocardiographically Determined Left Ventricular Size Estimated by X-Y Digitizer System between Normotensive and Early Hypertensive Children

The Shimane Heart Study

(X-Y digitizer system/early hypertensive children/cardiac hypertrophy)

KATSUTOSHI ABE, CHUZO MORI, TOSHIKAZU NISHIO, MASAKAZU SAITO, NORIYUKI HANEDA, YUTAKA TOMITA, and TAKESHI SOEDA

Department of Pediatrics, Shimane Medical University, Izumo 693, Japan

(Received July 3, 1980)

Recent cardiovascular studies in spontaneous hypertensive rats (SHR) showed that cardiac hypertrophy can be found at the prehypertensive stage. The Shimane Heart Study was carried out since the spring of 1978 for analogous findings in human beings. The population studied included 407 normotensive and 93 early hypertensive children from 9 to 17 years old. We estimated left ventricular posterior wall thickness (LVPWTd) and left ventricular muscle volume (LVMV) on echocardiographic recording paper by X-Y digitizer system which we developed. To make these values independent of age and body size, LVMV/BSA and LVPWTd/LVIDd are calculated. Here BSA and LVIDd are body surface area and left ventricular internal dimension, respectively. Both indices which exhibit left ventricular hypertrophy were significantly larger in early hypertensive children than in normotensive children. Thus, cardiac hypertrophy begins at the early hypertensive stage in human beings as well as in SHR.

Cardiac hypertrophy in hypertension has usually been regarded as a secondary response to the increased pressure load. However, morphological, vectorcardiographic and biochemical studies of cardiac hypertrophy in spontaneous hypertensive rats (SHR) have indicated that left ventricular hypertrophy (LVH) originates in the early hypertensive stage (1–4). These facts suggest that left ventricular hypertrophy might not only be secondary to persistent hypertension but also be partly induced by primary genetic disposition to cardiovascular structural changes.

It seems reasonable that analogous changes may also occur in the early hypertensive stage in human beings (3) (5) (6). "The Shimane Heart Study" was begun in the spring of 1978, for the purpose of clarifying the time

Abbreviations used are : LVMV, left ventricular muscle volume ; LVPWTd, left ventricular posterior wall thickness ; IVSTd, interventricular septal thickness ; LVIDd, left ventricular internal dimension ; BSA, body surface area course of cardiac hypertrophy in pediatric hypertension.

Left ventricular muscle volume (LVMV) and $D^2 (SV_1+RV_5)$ have hitherto been reported to be pertinent indices for estimation of left ventricular size (7−9). Adopting corrected LVMV and LVPWTd (left ventricular posterior wall thickness), we have evaluated the left ventricular size of both normotensive and hypertensive children and our findings are reported herein.

MATERIALS AND METHODS

Study Population

The study included 407 normotensive and 93 early hypertensive Japanese children from 9 to 17 years old. Details are listed in Table I. Hypertension in this study was defined as blood pressure over 130/80 at the ages from 9 to 15 years old and 140/90 from 16 to 18 years old.

TABLE I. *Number of Subjects*

Age (yrs)	Normotensive children		Hypertensive children	
	Boys	Girls	Boys	Girls
9−10	74	67	1	3
12−15	68	58	38	36
16−18	81	59	14	1
Total	223	184	53	40
	407		93	

Examination

Echocardiography was carried out utilizing transducers with a frequency of 3.5 MHz for younger children and 2.25 MHz for older children. Ultrasonoscope and echocardiogram recorder were Fukuda Denshi SSD-110S type and ECO 125S type, respectively. Paper speed for recording was 50 mm/sec or 100 mm/sec.

On standard left ventricular echocardiographic recordings, interventricular septal thickness (IVSTd), left ventricular posterior wall thickness (LVPWTd) and left ventricular internal dimension (LVIDd) were measured at the end-diastole, practically at the starting point of QRS complex on ECG. The LVMV was then estimated by the method of Troy *et al.* with some modification (7). The formula used here was given as the following equation :

$$LVMV=\frac{4}{3}\pi\left(LVIDd+\frac{IVSTd+LVPWTd}{2}\right)\left(\frac{LVIDd}{2}+\frac{IVSTd+LVPWTd}{2}\right)^2-\frac{4}{3}\pi(LVID)\left(\frac{LVIDd}{2}\right)^2$$

Practical analyses of echocardiograms were performed by X-Y digitizer system developed by our group. This includes Sony Tektronix 4956 type Graphics Tablet, Sony Tektronix 4051 type Programmable Graph Generator and Sony Tektronix 4631 type Hard Copy Unit, illustrated in Fig. 1. The

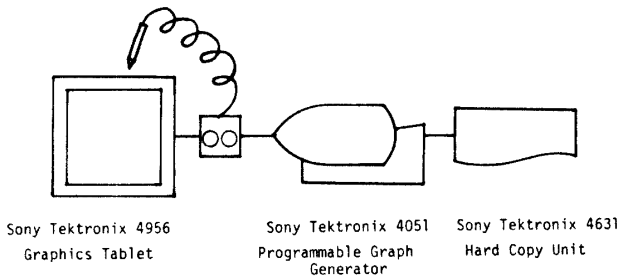

Fig. 1. Configuration of X-Y digitizer system.

values of IVSTd, LVPWTd, LVIDd, and LVMV were displayed with ID number on the CRT of the Graph Generator and copied immediately by the Hard Copy Unit.

RESULTS

LVMV was closely correlated with body surface area (BSA); r=0.907 in boys and r=0.837 in girls (7). LVMV of early-hypertensive children (●) was increased as compared with control (hatched area), as illustrated in Fig. 2 (boys) and Fig. 3 (girls).

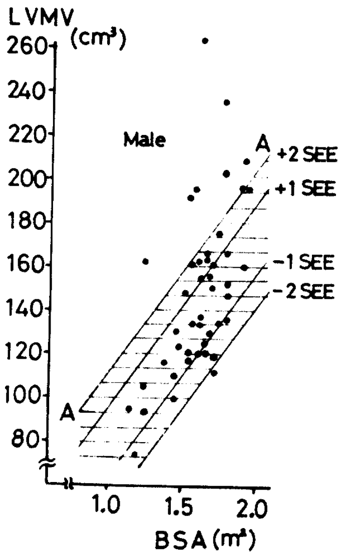

Fig. 2. Relation between BSA and LVMV (Boys).

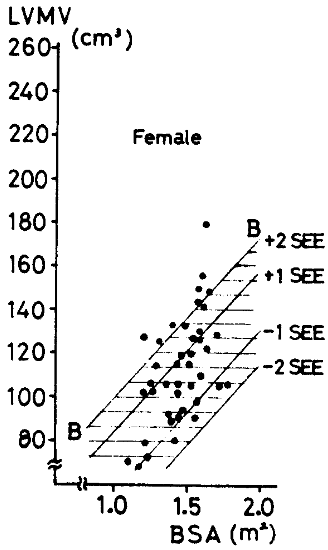

Fig. 3. Relation between BSA and LVMV (Girls).

LVMV and LVPWTd are pertinent indices of left ventricular hypertrophy, but these values change with age. To exlude the influence of age and body size, these values were corrected for body surface area (BSA) and left ventricular internal dimension (LVIDd). Being independent of age and body size, LVMV/BSA and LVPWTd/LVIDd are considered to be more accurate indices of LVH. These values are listed in Table II.

TABLE II. *LVMV/BSA and LVPWTd/LVIDd*

Sex	Normotensive children Number	Normotensive children Means±S. D.	Hypertensive children Number	Hypertensive children Means±S. D.	Test
LVMV/BSA					
Male	203	83.8±12.3	47	91.9±20.2	$p<0.01$
Female	166	72.6±10.8	40	78.5±14.1	$p<0.02$
LVPWTd/LVIDd					
Male	203	0.198±0.026	47	0.217±0.039	$p<0.002$
Female	166	0.201±0.023	39	0.222±0.032	$p<0.001$

LVMV/BSA are plotted in Fig. 4 (boys) and Fig. 5 (girls). The differences between normotensive and early hypertensive children were statistically significant ; $p<0.01$ in boys and $p<0.02$ in girls.

LVPWTd/LVIDd are plotted in Fig. 6 (boys) and Fig. 7 (girls). The differences between normotensive and early hypertensive children were statistically even more significant ; $p<0.002$ in boys and $p<0.001$ in girls.

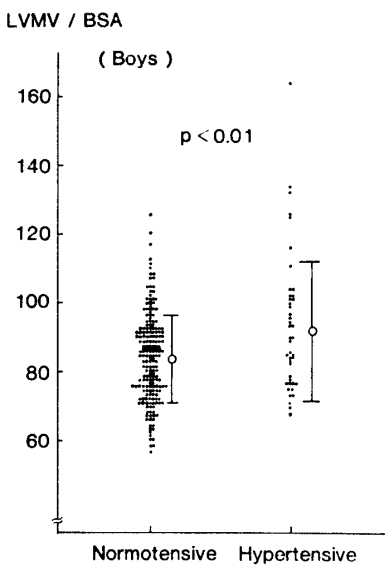

Fig. 4. LVMV/BSA in normotensive and hypertensive children (Boys).

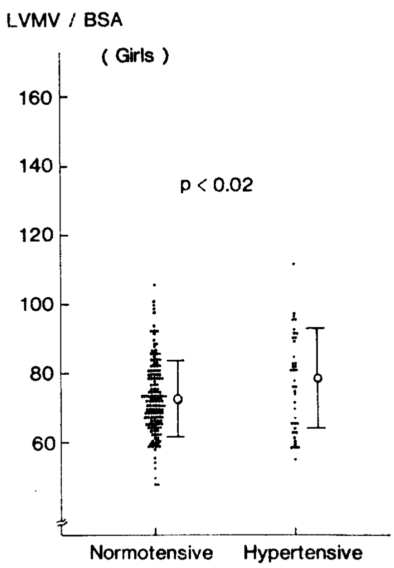

Fig. 5. LVMV/BSA in nomotensive and hypertensive children (Girls).

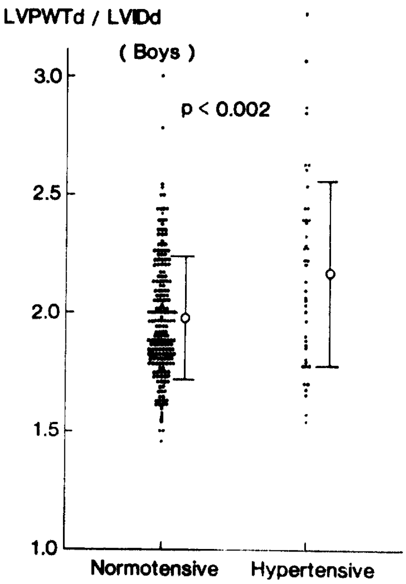

Fig. 6. LVPWTd/LVIDd in normotensive and hypertensive children (Boys).

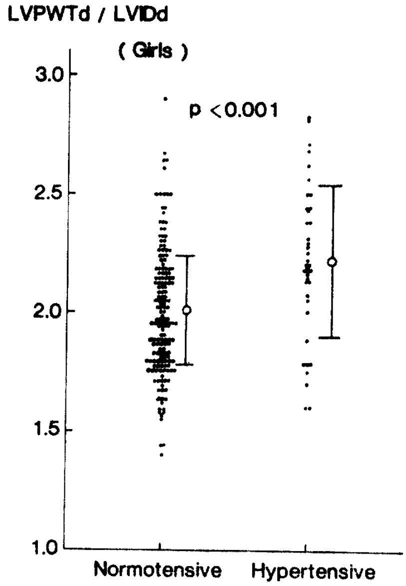

Fig. 7. LVPWTd/LVIDd in normotensive and hypertensive children (Girls).

DISCUSSION

Most hypertension in children had been regarded as secondary, with essential hypertension occurring only rarely. However, recent further epidemiological studies indicated that the level of blood pressure in adolescence is closely related to hypertension in adulthood (10) (11). Therefore, hypertension in children has attracted special interest recently.

Blood pressure levels are usually presented relative to age, indicating a progressive increase with age. The manner of evaluating blood pressure by percentiles is now commonly used. Children whose systolic and/or diastolic pressures are repeatedly above the 95th percentile and the 90th percentile are considered to be hypertensive and borderline hypertension, respectively (11) (12). The blood pressures over 130/80 and 140/90, presented as the definition of hypertension in this study, correspond to 90th percentile at the age from 12 to 15 years old and from 16 to 18 years old, respectively (5) (6). Absence of LVH, impaired renal function and hypertensive retinopathy had been considered to be implicit in the diagnosis of borderline hypertension (10).

However, recent morphological and vectorcardiographic studies of cardiac hypertrophy in spontaneous hypertensive rats have indicated that LVH developed even in the prehypertensive stage (1—4). Moreover, these results were confirmed by biochemical investigation ; synthesis of cardiovascular protein was accelerated in SHR, and this increased synthesis results in cardiovascular hypertrophy (3). The Shimane Heart Study, that is, the extensive field study of school aged children was undertaken in expectation for analogous findings (3) (5). Echocardiographic studies showed that LVMV/BSA and LVPWTd/

LVIDd in early hypertensive children were significantly larger than in normotensive children, as listed in Table II and as illustrated in Figs. 4 to 7. It is concluded that muscle volume and wall thickniess of the left ventricle has already increased in the early hypertensive stage. Similar results in juvenile hypertension were recently reported by Culpepper *et al.* (13). They studied echocardiographically 10 children with borderline hypertension and normotention, respectively. More accurate results are expected from our analysis as numerous subjects were involved.

On estimating echocardiogram, the X-Y digitizer system, which we developed and operate using BASIC language, requires a shorter time and gives further accurate values than manual measurements. The system including microcomputer is suitable for various two dimensional measurements of mass data obtained from field studies of school children due to programmable functions.

Early hypertensive adolescents with increased LVMV are regarded to have a risk factor for essential hypertension in adulthood, as hypertrophy of the left ventricule results from not only secondary response to hypertension but also genetic predisposition (3). We are now attempting to devise a more pertinent and easily measured index for prediction of left ventricular size of prehypertensive children, if possible without echocardiographic examination, so that we may provide adequate treatments for the inhibition of progressive hypertension.

This study was supported in part by grants from the Science and Technology Agency and the Ministry of Education, Japan.

REFERENCES

1) Sen, S., Tarazi, R. C., Khairallah, P. A., and Bumpus, F. M. (1974) Cardiac hypertrophy in spontaneous hypertensive rats. *Circ. Res.* **35**, 775–781
2) Yamori, Y., Ohtaka, M., Horie, R., and Nara, Y. (1978) Vectorcardiographic features in the young SHR. *Jpn. Heart J.* **19**, 581–582
3) Yamori, Y., Mori, C., Nishio, R., Ooshima, A., Horie, R., Ohtaka, M., Soeda, T., Saito, M., Abe, K., Nara, Y., Nakao, Y., and Kihara, M. (1979) Cardiac hypertrophy in early hypertension. *Am. J. Cardiol.* **44**, 964–969
4) Frohlich, E. D. and Tarazi, R. C. (1979) Is arterial pressure the sole factor responsible for hypertensive cardiac hypertrophy ? *Am. J. Cardiol.* **44**, 959–963
5) Nishio, T., Mori, C., Saito, M., Soeda, T., Abe, K., and Nakao, Y. (1978) Left ventricular hypertrophy in early hypertensive children ; Its importance as a risk factor for hypertension. *Shimane J. Med. Sci.* **2**, 157–166
6) Mori, C., Nishio, T., Saito, M., and Abe, K. (1979) Detection of risk factor by the field examination. *Nippon Rinsho* **37**, 3758–3766 (in Japanese)
7) Saito, M., Mori, C., Nishio, T., Soeda, T., and Abe, K. (1978) Normal values of echocardiogaphy in pediatrics. I. Left ventricular muscle volume (LVMV). The Shimane Heart Study. *Shimane J. Med. Sci.* **2**, 63–69
8) Abe, K., Mori, C., Nishio, T., Saito, M., Soeda, T., Tomita, Y., and Nakao, Y. (1979) Relation of the distance-corrected electrocardiographic and vectorcardiographic voltage with the echocardiographically determined left ventricular muscle volume. The Shimane Heart Study. *Shimane J. Med. Sci.* **3**, 104–109

9) Mori, C., Abe, K., Nishio, T., Saito, M., Soeda, T., Tomita, Y., and Nakao, Y. (1980) Basic study for computer analysis of the pediatric electrocardiogram. Relation of the distance-corrected precordial electrocardiographic voltage with the echocardiographically determined left ventricular muscle volume. *Jpn. Cir. J.* **44** (in press)
10) Jolius, S. (1978) Clinical and physiological significance of borderline hypertension at youth. *Pediatr. Clin. North Am.* **25**, 35–45
11) Voors, A. W., Webber, L. S., and Berenson, G. S. (1978) Epidemiology of essential hypertension in youth—Implications for clinical practice. *Pediatr. Clin. North Am.* **25**, 15–27
12) Londe, S. (1978) Causes of hypertension in the young. *Pediatr. Clin. North Am.* **25**, 55–65
13) Culpepper, W., Hutcheon, N., Arcilla, R., and Cutilletta, A. (1978) Left ventricullar hypertrophy in juvenile hypertension. *Circulation* **58** (Suppl. 2), II–51