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Transverse diameter of the chest and of the heart of infants in the course of physiological cardiorespiratory adaptation

By

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The morphology of the lungs and heart was analysed in 824 newborn infants with normal cardiorespiratory adaptation. Under normal conditions, the air content of the lungs became satisfactory in the first 6—12 hours and normal in all cases after 24 hours.

The values for the transverse diameter of the chest and heart were brought into correlation with birth weight, body length and gestational age. The transverse diameter of the chest and heart did not change during the early postnatal period (between 6—12 hours and 5 days). Both diameters were correlated with birth weight. The closest correlation was found in newborns under 1500 g, a varying one in those between 1500 and 2000 g and a close correlation in the category over 2000 g.

The correlation of the two diameters with body length was linear and close, without any difference between the values obtained at different times of examination. A rather loose correlation was found between the transverse diameter of the chest and heart, and gestational age.

It is a debated question in X-ray diagnostics how the lungs and heart appear and how large the cardiac shadow is in newborn infants under physiological conditions, in other words how long it takes for the respiration and circulation to adapt themselves completely to extrauterine life. In this respect, the data are conflicting. Still, their precise knowledge is of importance since the retardation of adaptation always means a pathological process, observed most frequently in post-asphyxic states. To recognize this by X-ray examination, one must be familiar with the physiological pattern.

The first X-ray examinations in infants were performed by Bamberg and Putzig [9]. Later, De Buys and Samuel [17] studied the question in 52 newborns in the first 28 postnatal hours. They found the size of the heart variable and independent of the body measurements of the newborn. The heart shadow was studied by Voss [46] and Brock [12]. Vogt [45] described the frequent occurrence of cardiomegaly in newborn age. The role of asphyxia in the phenomenon was emphasized by Weymuller et al. [50] as well as by Wasson [47]. Unfortunately, none of these investigations allowed unequivocal conclusions to be drawn, because in most of them only few infants were examined, the roentgenograms were made with long exposition time and it was not always possible to distinguish between pathological and physiological conditions.

The transverse diameter of the chest (TTD) and that of the heart (CTD) were measured on newborn roentgenograms by Farrel [22], Dunham and D'Amico [20] and Bakwin and Bakwin [8]. These authors established the average diameters but reported different values for the size of the heart. Martin and Friedel [39] studied cyanotic and non-cyanotic newborns; they were the first to describe the cardiomegaly and atelectatic foci in the lungs in cyanotic infants. Their control group consisted, however, of infants with slight asphyxia, and the studies did not comprise all weight categories. Important anthropometric data were published by Maresh and Washburn [38] as well as by Lanzavecchia et al. [35]; these and other authors related the transverse diameters to body length, body surface or gestational age [11, 17, 29, 30, 35, 36, 38, 43].

All these observations were based on few data only, besides they failed to reveal the normal relationships that would allow pathological alterations to be recognized. It seemed therefore useful to study by X-rays in a large newborn population the relationship of TTD and CTD to a) birth weight; b) body length; c) gestational age at various points of time after birth. First of all, an attempt was made to construct a standard that would allow the reliable quantitative evaluation of pathological alterations.

Materials and Methods

Investigations were performed on 824 newborn infants. Their adaptation to extrauterine life was undisturbed in every case. The normal group consisted of infants with no maternal disease, undisturbed pregnancy, and normal clinical, X-ray and blood-biochemical parameters, corresponding to postnatal age [1, 2, 3, 4, 5, 6, 18, 21, 29, 31, 32, 34, 37, 42, 44, 46, 49, 51].

The method used was a retrospective analysis of data selected on the basis of roentgenograms and case records collected during the past five years.

X-rays of the chest were made under standard conditions, in supine position antero-posteriorly. In the first 24 postnatal hours lateral X-rays were also made. From the roentgenograms we determined the state of the lungs, their air content, outlines of the vessels, the form and size of the heart and the height of the diaphragm. In addition, TTD and CTD were measured.

TTD was measured from the edge of the most lateral costal line, CTD was obtained from the sum of perpendicular straight lines drawn from the median line of the most remote left and right points of the heart. In several cases, also other diameters were measured in order to determine the size and form of the chest. The changes in these values were proportional to the change of the two main diameters; therefore they were not studied in the whole material.

The infants investigated were grouped according to birth weight. Babies under 1500 g and those over 3000 g were analysed in a global way because of the low number of cases. Infants between the above two weight limits were analysed in 500 g steps.

As regards body length at birth the

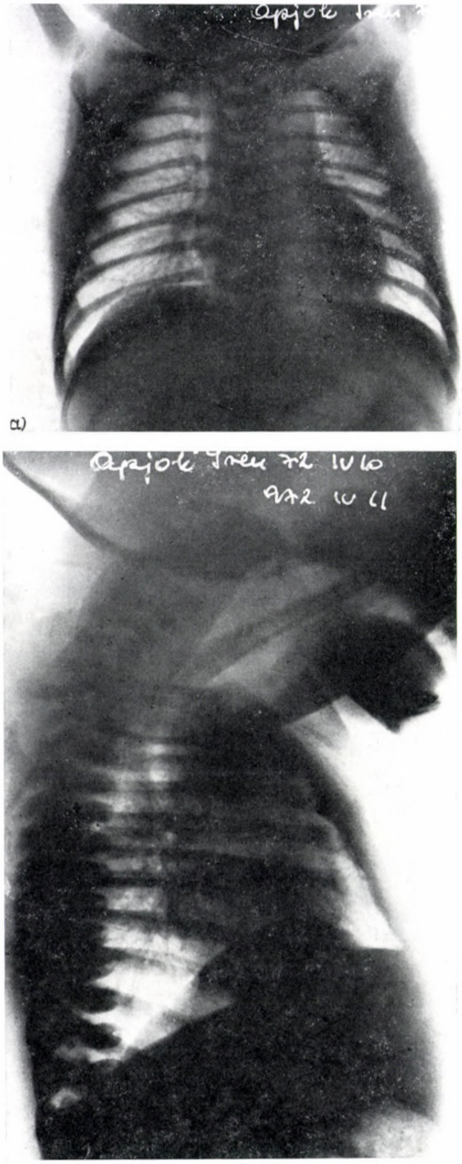

Fig. 1

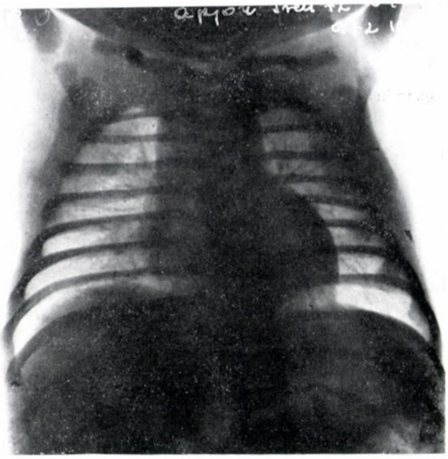

Fig. 2

As regards the time of X-ray examination, five groups were made within the mentioned categories on the basis of birth weight and length (6—12, 24, 48, 72 and 120 hours) and three groups (6—24, 48 and 72—120 hours, respectively) according to the gestational age.

The investigated relationships were

a) relation of TTD and CTD to birth weigth, birth length and gestational age;

b) changes in the diameters during the first five postnatal days.

Standards were constructed for TTD and CTD in relation to birth weight and body length on the basis of the values corresponding to 90, 50 and 10%. These standards were plotted graphically.

Special emphasis was laid on a) the increase in pulmonary aeration; b) the changes of the chest and heart diameter during the postnatal period; c) the relation to birth weight of the size of the chest and heart.

Most authors found the adaptation of the lungs and heart to change within wide limits [14, 15, 20, 34, 39, 40, 41, 47, 50, 52]. In contrast, our observations failed to reveal any essential alteration in the appearance of the lungs or in the position of the diaphragm during the period from the 6th to 12th hour to the fifth day after birth (Figs. 1a, 1b, 1c).

infants were grouped in increasing order at one-cm steps.

As regards gestational age three groups were formed, one between 37 and 42 weeks and the two others under and beyond that period.

TABLE Ia

Time of examination hour of life		Chest				
		Birth weight, g				
		< 1500	1500—2000	2001—2500	2501—3000	> 3000
12	n	56	43	31	—	—
	$\overline{x}$	1237	1743	2275		
	$\overline{y}$	8.0	9.0	10.0		
	r	0.70	0.22	0.71		
		$P < 0.001$	$0.1 > P > 0.05$	$P < 0.001$		
24	n	30	80	33	38	36
	$\overline{x}$	1288	1768	2238	2803	3338
	$\overline{y}$	8.4	9.1	9.9	10.6	11.1
	r	0.59	0.28	0.40	0.55	0.67
		$P < 0.001$	$0.05 > P > 0.01$	$0.05 > P > 0.001$	$P < 0.001$	$P < 0.001$
48	n	37	28	32	36	31
	$\overline{x}$	1269	1737	2269	2747	3420
	$\overline{y}$	8.2	9.0	9.8	10.6	11.2
	r	0.85	0.39	0.49	0.65	0.84
		$P < 0.001$	$0.05 > P > 0.01$	$P < 0.001$	$P < 0.001$	$P < 0.001$
72	n	46	31	34	31	35
	$\overline{x}$	1277	1768	2301	2793	3324
	$\overline{y}$	8.3	9.4	10.3	10.8	11.2
	r	0.81	0.69	0.61	0.62	0.62
		$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$
120	n	—	31	38	34	33
	$\overline{x}$		1767	2272	2799	3270
	$\overline{y}$		9.3	10.4	10.7	11.2
	r		0.52	0.48	0.51	0.59
			$0.01 > P > 0.001$	$0.01 > P > 0.001$	$0.01 > P > 0.001$	$P < 0.001$

n = Number of subjects
$\overline{x}$ = Mean birth weight of the given group
$\overline{y}$ = Mean transverse diameter of chest
r = Correlation coefficient

Air content of the lungs was satisfactory in most cases after 6—12 hours and normal in all cases after 24 hours.

The size of the chest and heart did not change significantly in the individual weight groups during the period from the 6th hour to the fifth day after birth (Tables Ia and Ib).

A correlation was found between birth weight and TTD. The correlation coefficients revealed a close correlation between birth weight and TTD in infants under

TABLE Ib

Time of examination, hour of life		Heart				
		Birth weight, g				
		< 1500	1500–2000	2001–2500	2501–3000	> 3000
	n	56	43	31		
	$\bar{x}$	1237	1743	2275		
12	$\bar{y}$	3.8	4.3	4.5	—	—
	r	0.69	0.19	0.49		
		$P < 0.001$	$0.1 < P$	$0.01 > P > 0.001$		
	n	30	80	33	38	36
	$\bar{x}$	1288	1768	2238	2803	3338
24	$\bar{y}$	3.9	4.3	4.6	4.8	5.1
	r	0.38	0.26	0.47	0.40	0.61
		$0.05 > P > 0.01$	$0.05 > P > 0.01$	$0.01 > P > 0.001$	$0.02 > P > 0.01$	$P < 0.001$
	n	37	28	32	36	31
	$\bar{x}$	1269	1737	2269	2747	3420
48	$\bar{y}$	3.8	4.3	4.4	4.8	4.9
	r	0.65	0.58	0.55	0.73	0.85
		$P < 0.001$	$0.01 > P > 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$
	n	46	31	34	31	35
	$\bar{x}$	1277	1768	2301	2793	3324
72	$\bar{y}$	3.8	4.3	4.4	4.7	4.9
	r	0.61	0.52	0.63	0.66	0.30
		$P < 0.001$	$0.01 > P > 0.001$	$P < 0.001$	$P < 0.001$	$0.1 > P > 0.05$
	n		31	38	34	33
	$\bar{x}$		1767	2272	2799	3270
120	$\bar{y}$	—	4.2	4.5	4.7	4.9
	r		0.38	0.47	0.30	0.17
			$0.05 > P > 0.1$	$0.01 > P > 0.001$	$0.1 > P > 0.05$	$0.1 < P$

n = Number of subjects
x = Mean birth weight of the given group
y = Mean transverse diameter of heart
r = Correlation coefficient

1500 g and in those over 2000 g. The correlation was less expressed in the 1500–2000 g weight group; at 6–12 hours it was not even significant statistically.

Similar results were obtained for birth weight and CTD. Here, however, the correlation was not significant in the group over 3000 g by 72 and 120 hours.

The individual values for TTD and CTD in the 1500–2000 g group showed a pattern similar to the above. These values changed within wide ranges.

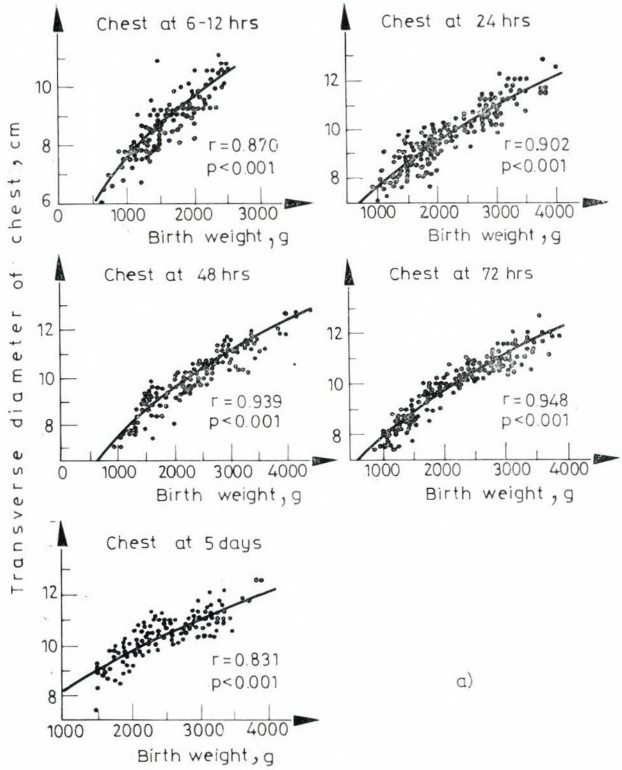

FIG. 3a

Analysis of the relationship between diameter and birth weight revealed differences in the intra-coordinate position of the hits in the groups under 1500 g and over 2000 g. The hits in the former group were mainly located around the steep regression line, when investigated in linear regression. The regression line fitted well to the hits also in the group over 2000 g, but the b value was lower than in the previous group. For the whole population their values proved significant, even though the values for the low-weight group were evidently lower than those for the mature group.

The transverse diameter of the chest in the newborn can be expressed by the simple geometric model, $d = c\sqrt{\ }$. where d = transverse diameter of the chest; c = constant, m = birth weight.

Regression analysis with parabolic approach showed that the curve fitted well to the hits; this was the curve with the most significant r values (Figs 3a and 3b).

The percentual standard of the diameters was also constructed (Figs. 4a and 4b).

Examination of the relationship between body length at birth and TTD and CTD revealed a linear relation (Figs. 5a and Table II).

The b value was higher in regression equations concerning the chest than in those concerning the heart, a fact clearly mirrored by the lines in the diagram. The regression lines of the chest were steeper than those of the heart. A difference was found in the value for the coefficients concerning the CTD of infants examined after 72 hours, as well as the TTD of infants

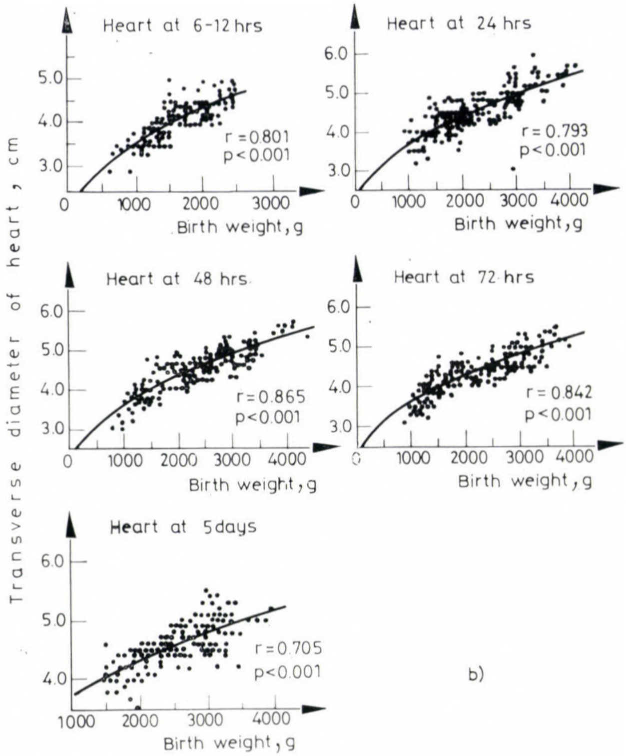

FIG. 3b

examined after five days. We cannot offer any explanation for these findings.

The percentual standard was constructed from 668 values (Figs 6a and 6b). No extra standard was constructed for the various points of time of examination because, on the basis of the regression analyses, no essential difference could have been expected between the various age groups.

TTD and CTD were studied in three groups with a gestational age under 33, between 33 and 36 and between 37 and 42 weeks, respectively. Only 449 newborns could be analysed since the time of the last menstruation was not always exactly known and thus the gestational age could not be calculated.

The correlation between transverse diameters and gestational age was not as close as in the case of birth length. In several groups the correlation was not significant. Using multiple regression analysis, there was a good linear correlation between TTD and CTD, but it was loose in the case of gestational age *vs.* TTD and CTD.

As to the height of the diaphragm, in most cases it was situated at the height of the eighth rib without reaching the seventh or ninth rib.

DISCUSSION AND CONCLUSIONS

The form and shape of the chest can be characterized by various diameters. Most characteristic are the transverse and sagittal diameters. In the material of Zsebők [52] the mean TTD was 10.9 cm in boys and 10.6 cm in girls at the height of the 7th and

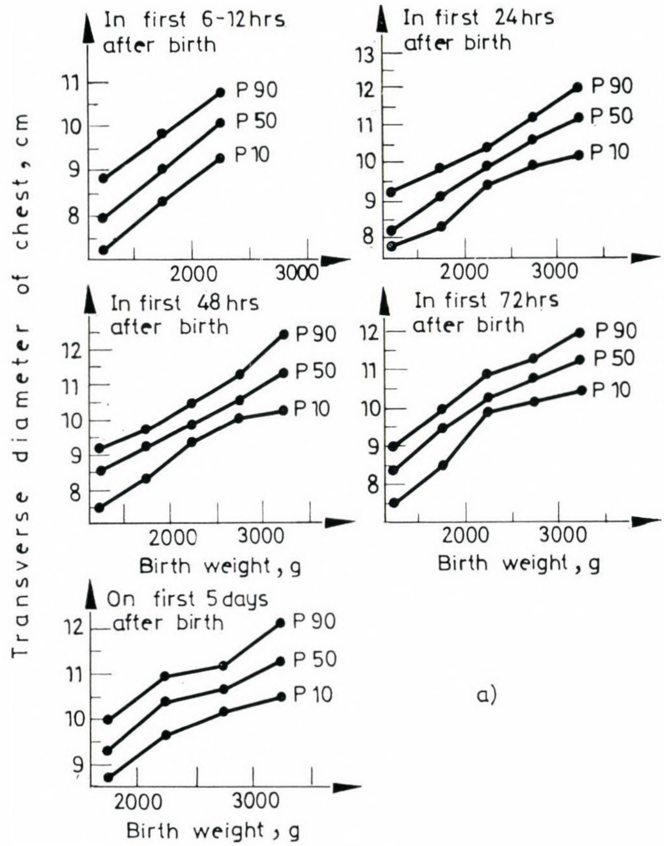

FIG. 4a

8th ribs. For these same values Farrel [22] found 9.1 cm in boys and 8.9 cm in girls. Martin and Friedel [39] observed a TTD of 9.04 ± 0.005 cm in one-day-old normal newborns, a value very close to the 9.0 ± 0.8 cm described by Bakwin and Bakwin [8]. According to Dunham and D'Amico [20] the TTD is 11.4 cm in the newborn.

We calculated mean values corresponding to birth weight groups and not to the whole material investigated. Analysis according to birth weight was justified by the fact that the two transverse diameters depend considerably on birth weight (Tables IIa and IIb).

The changes in the size and transverse diameters of the heart were analysed by Burnard and James [15, 16]. Our previous investigations led to similar results.

We failed to find any data in the literature which would deal with the relationship between birth weight, birth length and gestational age on the one hand and CTD on the other, or, with changes within the early (first five days) neonatal period in every birth weight and length category.

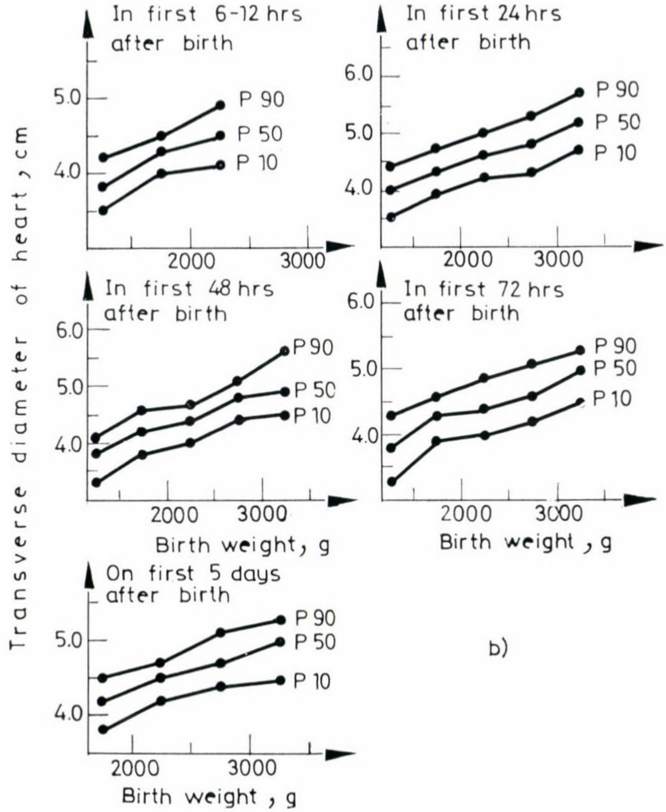

Fig. 4b

Our observations revealed a close correlation between birth weight and transverse diameters. The correlation was especially close in newborns under 1500 g. The greatest deviations were found in the category over 2000 g. These observations together with the regression shown in the parabolic curve indicate that in low-weight newborn infants weight-gain runs parallel with organ development. This parallelism is less pronounced in the category over 2000 g. Infants between 1500 and 2000 g are considered a transient group. The explanation of this finding may lie in the functional change of the cardiovascular system. Expansion stability in this category differs qualitatively from that of other groups [26].

For practical purposes the percentual standard of TTD and CTD was also constructed. This may be of help in the individual judgement of the size of TTD and CTD in the newborn infant.

The closest correlation was found between body length at birth and transverse diameters (Figs. 5a and 5b and Tables IIa and IIb). The rela-

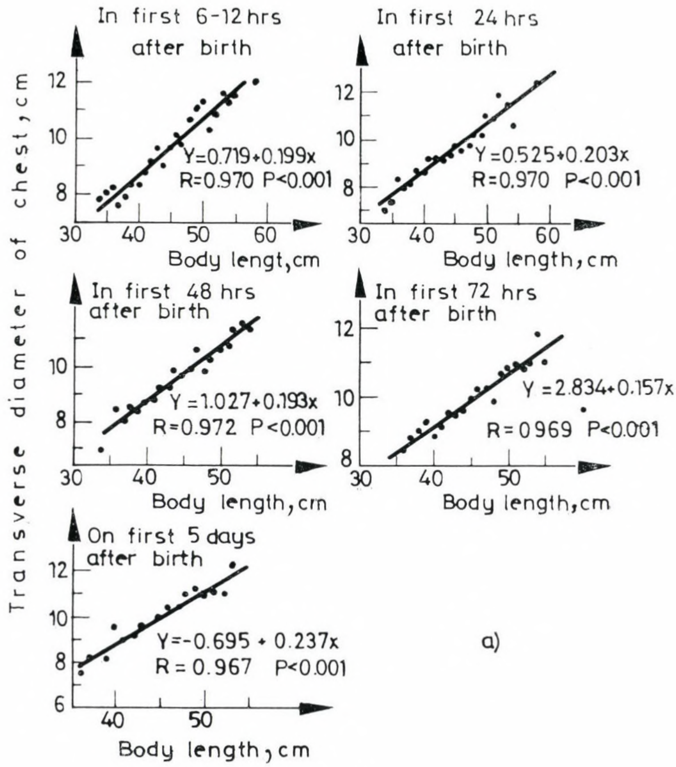

FIG. 5a

tionship was linear. No difference was found between low-weight and mature newborns.

The diameter of the heart increases in the early postnatal period. This does not, however, mean that the heart really increases during the 5 days after birth; it is due to the fact that low weight infants were examined at an earlier point of time than the infants with higher weight.

In this connection the question arises why we judge the size of the chest and heart on the basis of the transverse diameters and not on the basis of surface, volume or weight of the organs, like other authors did [1, 33, 37]. Our simplified procedure is justified by the fact that the diameters change in a similar way as surface, volume and weight do. This method is well suited for everyday practice; on the other hand, more reliable data cannot be obtained by means of more complicated methods either.

As regards percentual standards, the values for the 90 percentage of the heart are low in the length category of 41—43 cm. Up to 50 cm, the increase in proportion to body weight is steady on the curve of the chest and of the heart.

The correlation between gestational age on the one hand and TTD and

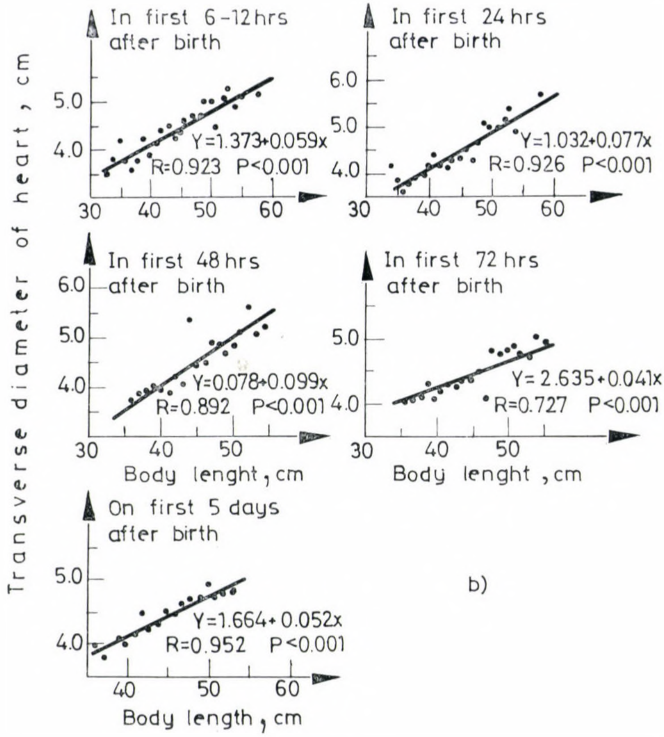
Transverse diameter of heart, cm
In first 6-12 hrs after birth
Y=1.373+0.059x
R=0.923 P<0.001
In first 24 hrs after birth
Y=1.032+0.077x
R=0.926 P<0.001
In first 48 hrs after birth
Y=0.078+0.099x
R=0.892 P<0.001
In first 72 hrs after birth
Y= 2.635+0.041x
R=0.727 P<0.001
Body lenght, cm
Body lenght, cm
On first 5 days after birth
Y=1.664+ 0.052x
R=0.952 P<0.001
Body length, cm
b)

FIG. 5b

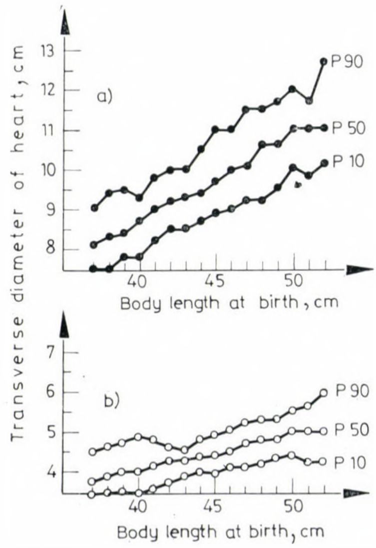
Transverse diameter of heart, cm
a)
P 90
P 50
P 10
Body length at birth, cm
b)
P 90
P 50
P 10
Body length at birth, cm

FIG. 6

TABLE II

	N	Age at X-ray investigation				
		6—12 hours	24 hours	48 hours	72 hours	5 days
		130	217	164	177	136
Mean	z	4.305	4.412	4.494	4.554	4.602
	$\bar{y}$	9.236	9.546	9.662	10.133	10.472
	$\bar{x}$	43.077	44.370	44.613	45.847	47.140
Maximum	$\bar{x}$	58	58	54.0	55	56.0
Minimum		30	34	39	30	36.0
Maximum	$\bar{y}$	12.5	13.2	12.4	12.6	12.5
Minimum		6.1	6.8	6.5	7.7	7.5
Maximum	z	5.5	5.7	6.1	5.7	5.6
Minimum		2.9	2.8	3.0	3.4	3.5
Correlation	RYZ	0.212 $0.1 < P < 0.05$	0.740 $P < 0.001$	0.749 $P < 0.001$	0.752 $P < 0.001$	0.656 $P < 0.001$
	RXZ	0.722 $P < 0.001$	0.687 $P < 0.001$	0.615 $P < 0.001$	0.594 $P < 0.001$	0.605 $P < 0.001$
	RXY	0.845 $P < 0.001$	0.801 $P < 0.001$	0.801 $P < 0.001$	0.745 $P < 0.001$	0.745 $P < 0.001$
Deviation	z	0.498	0.551	0.665	0.47	0.422
	$\bar{y}$	1.257	1.184	1.162	1.025	1.063
	$\bar{x}$	4.696	4.76	5.815	5.228	3.918
Standard error	z	± 0.053	± 0.038	± 0.051	± 0.038	± 0.036
	$\bar{y}$	± 0.133	± 0.081	± 0.091	± 0.082	± 0.091
	$\bar{x}$	± 0.498	± 0.325	0.455	0.417	0.336
Equation		$z = 1.147 + 0.013x + 0.280y$	$z = 0.705 + 0.030x + 0.247y$	$z = 0.045 + 0.026x + 0.339y$	$z = 1.021 + 0.007x + 0.317y$	$z = 1.355 + 0.028x + 0.183y$

$\bar{x}$ = Body length at birth
$\bar{y}$ = Transverse diameter of chest
z = Transverse diameter of heart

CTD on the other was loose in our material. Therefore no percentual standard was constructed in this gestational age group. The correlation seems to be of less importance and, thus, hardly useful in the everyday practice. A comparison with either the standard deviation or the percentual values of our material is believed to be of help in the recognition of pathological conditions if birth weight and body length are known.

The authors quoted dealt little with the height of the diaphragm. Wasson [47] only reported that the right diaphragm was located slightly higher than the left one. Dunham and D'Amico [20] observed that the diaphragm stood higher on the 7th postnatal day than in the first hours after birth. At this age diaphragmic respiration dominates and therefore the diaphragm is less arched than in adults [45]. In our material the diaphragm was at the height of the eighth rib in the majority of cases and was located lower in few cases only.

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