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Correlation of External Somatic and External Cardiac Morphometry In Relation To Gestational Age in Aborted Fetuses

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Abstract: *Evaluation of cardiac structure is essential for definitive diagnosis of cardiac anomalies, which has significant implications in planning and implementing prenatal therapy. Congenital cardiac malformations are the most common anomalies encountered in pediatric clinics. The present study is aimed at analyzing various morphological and morphometric parameters of human fetal hearts by collecting heart specimens from dead and spontaneously aborted fetuses of various gestational ages. A total of 60 apparently normal dead aborted embryos and fetuses of both sexes and of 10 - 40 weeks gestational age were utilized for observing and measuring certain morphological and morphometric parameters of external body and external cardiac parameters. All the external body parameters and external cardiac parameters are moderately correlated except heart height and heart weight that were strongly correlated with body weight. Mean values of all parameters are increasing significantly with gestational age in trimester wise groups whereas in week wise group they are differing significantly. All the parameters are having significant strong positive correlation among each other. Heart height and heart weight were strongly correlated with body weight. The morphometric data and their innovative interpretation have immediate applications in both morphological and functional areas of cardiology, which is helpful in permanent clinical evaluation of fetal heart development.*

Key words: *Aborted fetuses, External fetal body dimensions, External cardiac parameters, Fetal heart height, Fetal heart weight.*

I. Introduction

During fetal stage of development, a high growth rate of organs and fetus shows dynamic changes in morphologic, morphometric and microscopic appearance of organs and during embryonic development organogenesis shows dynamic changes in external features of fetus. Knowledge of these changes can be helpful in evaluation of pregnancy outcome by doing prenatal diagnosis which includes measuring of external dimensions of fetus like CRL, CHL, BPD, HC, AC, FW, etc. and also of certain vital organs like heart, liver, lungs, etc. Evaluation of cardiac structure is essential for definitive diagnosis of cardiac anomalies, which has significant implications in planning and implementing prenatal therapy. Congenital cardiac malformations are the most common anomalies encountered in pediatric clinics with an incidence of 3-9 per 1000 live births in terms of frequency and severity [1]. The morphometric data and their innovative interpretation have immediate applications in both morphological and functional areas of cardiology, which is helpful in permanent clinical evaluation of fetal heart development. Correct assessment of fetal heart dimensions and their evaluation through the study of aborted fetuses in ontogenesis could offer useful dimensional landmarks.

This may be more useful in interpretation of echocardiographic studies and in performing new surgical techniques immediately for correction of prenatally diagnosed cardiac malformations failing which they may often result in fatal disturbance of hemodynamics during fetal and prenatal period [2,3]. All exterior dimensions of heart are closely and strongly correlated with exterior dimensions of fetuses. Developmental changes of internal organs including heart during human development are described rather generally and published data are uncertain.

II. Aims And Objectives

The present study is aimed at assessing gestational age related dynamic changes in fetal hearts by autopsy study of dead and spontaneously aborted fetuses and interpretation of exterior dimensions of heart with exterior dimensions of fetuses and correlating them.

III. Materials And Methods

A total of 60 apparently normal dead aborted embryos and fetuses of both sexes and of 10 to 40 weeks gestational age were utilized for observing and measuring certain morphological and morphometric parameters of external body and external cardiac parameters. These were collected from the department of Obstetrics and Gynaecology, Govt. Maternity hospital, Tirupati after obtaining informed consent from the relatives as per ethical clearance certificate from the Institutional Ethical Committee. The study was conducted in the department of Anatomy, S.V. Medical College, Tirupati by following dissection method. The fetuses were transported in 10% formalin solution and their external somatic parameters (both morphological and morphometric) were observed and recorded. Any congenital malformations were also observed and recorded if present. The fetus has been embalmed using multiple injection technique. The fetal thoracic cavity was opened and contents of thorax were observed in situ. The heart is separated from the surrounding structures after cutting at the level of entry of great vessels. The heart is weighed after its removal from normal position using simple physical balance with blood clots in situ after observing external morphological parameters. The blood clots were not removed completely as attempt to remove the entire clot may result in disruption of the contour of the chambers. The morphometric parameters were observed and recorded using the measuring tape, thread (for heart circumference) and digital calipers (paquimeter) for measuring other parameters. The external fetal morphometric parameters measured were Crown-Rump Length (CRL), Crown – Heel Length (CHL), Head Circumference (HC), Abdominal Circumference (AC), Bi-parietal Diameter (BPD) and Fetal weight (FW) and external cardiac parameters observed were heart height (Hrt. Ht), heart weight (Hrt. Wt.), heart diameter (Hrt.D.), heart width (Hrt. Wd.) and heart circumference (Hrt. C). Total number of fetuses studied were categorized into three trimester groups viz., 0-12weeks; 13-28 weeks & 29 weeks – term based on gestational age. Each group was divided into month wise (4 week period) subgroups. The data collected were analyzed and subjected to the statistical tests. Statistical analysis was done using Microsoft Excel. SPSS software is used for analyzing. The following statistical tests were done – Students 't' test, Karl Pearson's correlation coefficient, ANOVA – f test and linear regression analysis.

IV. Results

A total of 37 (61.67%) male and 23 (38.33%) female fetuses were observed. Highest number of fetuses studied was third trimester age group (Table.1). All the fetuses included in the present study were normal in their external appearance except a case of anencephaly.

Table. 1: Sex-wise distribution of dead fetuses (%)

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The Tables. 2 & 3 revealed that all parameters are increasing significantly with gestational age in both trimester wise and week wise groups.

Table. 2: Gestational age (trimester-wise) averages of external body parameters.

Parameters	Gestational age	N	Mean	Std. deviation	F-value	p-value
C.R.L.(cm)	I Trimester	4	22.675	.5500	9.828**	0.000
	II Trimester	15	26.340	4.4587		
	III Trimester	41	30.537	4.3963		
C.H.L.(cm)	I Trimester	4	34.800	1.0985	21.086**	0.000
	II Trimester	15	41.613	5.6156		
	III Trimester	41	49.832	5.8909		
HC (cm)	I Trimester	4	22.90	.258	10.410**	0.000

	II Trimester	15	26.75	4.264		
	III Trimester	40	30.93	4.338		
AC (cm)	I Trimester	4	21.425	.1708	9.413**	0.000
	II Trimester	15	24.933	4.2220		
	III Trimester	41	28.883	4.2780		
BPD (cm)	I Trimester	4	5.3500	.19149	6.097**	0.004
	II Trimester	15	6.4933	1.24296		
	III Trimester	39	7.2923	1.24782		
FW (g)	I Trimester	4	.513	.2594	10.472**	0.000
	II Trimester	15	.964	.4454		
	III Trimester	41	1.558	.6233		

*significant at p<0.05;**significant at p<0.01.

Crown-rump length (CRL), Crown-Heel length (CHL), Head Circumference (HC), abdominal circumference (AC), Biparietal Diameter (BPD), Fetal Weight (FW)

Table. 3 : Gestational age (week-wise) averages of external body parameters.

Parameters	Gestational age	N	Mean	Std. deviation	F-value	p-value
C.R.L.(cm)	9 - 12 weeks	4	22.675	.5500	4.360**	0.001
	13 -16 weeks	3	24.333	2.5007		
	17 - 20 weeks	2	23.900	4.9497		
	21 - 24 weeks	10	27.430	4.7777		
	25 - 28 weeks	14	29.286	4.4652		
	29 - 32 weeks	7	33.129	4.0492		
	32 wks- term	20	30.505	4.2709		
C.H.L.(cm)	9 - 12 weeks	4	34.800	1.0985	8.778**	0.000
	13 -16 weeks	3	38.000	2.5534		
	17 - 20 weeks	2	35.900	2.4042		
	21 - 24 weeks	10	43.840	5.4635		
	25 - 28 weeks	14	48.057	5.9865		
	29 - 32 weeks	7	51.900	5.4489		
	32 wks- term	20	50.350	5.9145		
HC (cm)	9 - 12 weeks	4	22.90	.258	5.034**	0.000
	13 -16 weeks	3	23.70	.854		
	17 - 20 weeks	2	22.20	2.828		
	21 - 24 weeks	10	28.57	3.982		
	25 - 28 weeks	13	29.85	4.859		
	29 - 32 weeks	7	32.23	3.146		
	32 wks- term	20	31.18	4.370		
AC (cm)	9 - 12 weeks	4	21.425	.1708	4.514**	0.001
	13 -16 weeks	3	22.367	.9074		
	17 - 20 weeks	2	20.850	3.3234		
	21 - 24 weeks	10	26.520	4.1976		
	25 - 28 weeks	14	27.650	4.3279		
	29 - 32 weeks	7	30.371	3.6577		
	32 wks-term	20	29.225	4.4079		
BPD (cm)	9 - 12 weeks	4	5.3500	.19149	4.479**	0.001
	13 -16 weeks	3	5.4667	.25166		
	17 - 20 weeks	2	5.3000	.70711		
	21 - 24 weeks	10	7.0400	1.15489		
	25 - 28 weeks	12	6.6500	1.30349		
	29 - 32 weeks	7	7.6286	.52825		
	32 wks- term	20	7.5600	1.29021		
FW (g)	9 - 12 weeks	4	.513	.2594	5.152**	0.000
	13 -16 weeks	3	.750	.1323		
	17 - 20 weeks	2	.730	.3818		
	21 - 24 weeks	10	1.075	.4974		
	25 - 28 weeks	14	1.259	.6575		
	29 - 32 weeks	7	1.550	.6218		
	32 wks- term	20	1.770	.5354		

*significant at p<0.05;**significant at p<0.01.

Crown-rump length (CRL), Crown-Heel length (CHL), Head Circumference (HC), Abdominal circumference (AC), Biparietal Diameter (BPD), Fetal Weight (FW).

The location of heart and its relations are normal in all fetuses. Among 60 fetuses, rounded contour of heart was observed in 6 cases (10%), prominent vasculature in 4 cases (6.67%) and increased cardio – thoracic ratio in 1 case (1.67%). Gestational age wise distribution of external cardiac parameters of aborted fetuses were presented in Tables. 4 & 5 which are showing one way ANOVA carried out in the sample studied and revealing that the mean values of all parameters are increasing significantly with gestational age in trimester wise groups whereas in week wise group they are differing significantly. The statistical analysis of these parameters indicate that all parameters are varying significantly in week wise groups except heart width which did not show significant difference in week wise. Independent Sample 't' test for gender showed no significant difference between genders of different gestational ages with regard to all the given parameters.

Table. 4: External cardiac parameters - Gestational age (trimester-wise)

Parameters	Gestational age	N	Mean	Std. deviation	F-value	p-value
Hrt.H (mm)	I Trimester	4	25.6700	5.43876	6.625**	0.003
	II Trimester	15	30.3260	5.46292		
	III Trimester	41	35.3344	6.69166		
Hrt.D (mm)	I Trimester	4	13.745	4.6795	8.860**	0.000
	II Trimester	15	18.909	4.2990		
	III Trimester	41	23.482	5.6666		
Hrt.Wd (mm)	I Trimester	4	18.0325	5.88497	4.951*	0.010
	II Trimester	15	25.5347	6.66854		
	III Trimester	41	29.0885	7.52698		
Hrt.Wt (gms)	I Trimester	4	4.5500	2.87634	5.468**	0.007
	II Trimester	15	9.8933	4.14668		
	III Trimester	40	14.0225	7.19158		
Hrt.C (cm)	I Trimester	4	5.25	1.443	7.975**	0.001
	II Trimester	15	7.70	1.850		
	III Trimester	40	8.68	1.704		

*significant at $p<0.05$;**significant at $p<0.01$.
Heart height (Hrt.H), Heart depth (Hrt.D), Heart width (Hrt.Wd), and Heart weight (Hrt.Wt), Heart circumference (Hrt.C).

Table. 5 : Gestational age (week-wise) averages of external cardiac parameters.

Parameters	Gestational age	N	Mean	Std. deviation	F-value	p-value
Hrt.H (mm)	9 - 12 weeks	4	25.6700	5.43876	2.646*	0.026
	13 -16 weeks	3	31.3133	6.93601		
	17 - 20 weeks	2	26.5450	8.98733		
	21 - 24 weeks	10	30.7860	4.79800		
	25 - 28 weeks	14	33.4250	7.50164		
	29 - 32 weeks	7	35.4286	6.24299		
	32 wks –term	20	36.6380	6.24341		
Hrt.D (mm)	9 - 12 weeks	4	13.745	4.6795	2.807*	0.019
	13 -16 weeks	3	19.577	3.3088		
	17 - 20 weeks	2	17.360	9.7722		
	21 - 24 weeks	10	19.019	3.8743		
	25 - 28 weeks	14	23.273	7.5882		
	29 - 32 weeks	7	23.224	5.8213		
	32 wks-term	20	23.719	4.1696		
Hrt.Wd (mm)	9 - 12 weeks	4	18.0325	5.88497	2.228	0.054
	13 -16 weeks	3	28.2667	9.22327		
	17 - 20 weeks	2	17.2700	3.40825		
	21 - 24 weeks	10	26.3680	5.52643		
	25 - 28 weeks	14	28.7207	10.93910		
	29 - 32 weeks	7	27.8643	6.29476		
	32 wks-term	20	29.7745	4.87228		
Hrt.Wt (gms)	9 - 12 weeks	4	4.5500	2.87634	2.295*	0.049
	13 -16 weeks	3	8.7000	2.99040		
	17 - 20 weeks	2	10.1250	9.01561		
	21 - 24 weeks	10	10.2050	3.89033		
	25 - 28 weeks	13	11.5308	6.62415		
	29 - 32 weeks	7	14.9786	7.21335		
	32 wks-term	20	15.3075	7.46272		
Hrt.C (cm)	9 - 12 weeks	4	5.25	1.443	3.173*	0.010
	13 -16 weeks	3	8.50	2.291		
	17 - 20 weeks	2	6.25	2.475		
	21 - 24 weeks	10	7.75	1.671		
	25 - 28 weeks	13	8.24	1.857		

	29 - 32 weeks	7	8.79	1.822		
	32 wks-term	20	8.93	1.592		

*significant at p<0.05;**significant at p<0.01.

Heart height (Hrt.H), Heart depth (Hrt.D), Heart width (Hrt.Wd), Heart weight (Hrt.Wt), Heart circumference (Hrt.C).

A correlation matrix for external body parameters is done and the results were derived in the Table.6, which revealed that all the external fetal body parameters are correlated very strongly with each other. Similar correlation matrix for external cardiac parameters in Table.7 showed that all the parameters are having significant strong positive correlation among each other.

Table.6: Correlation matrices for external body parameter in aborted foetuses

	Body wt.(g)	BPD (cm)	HC (cm)	AC (cm)	CRL (cm)	CHL (cm)
Body Wt.(g)						
BPD(cm)	.774(**)					
HC (cm)	.758(**)	.841(**)				
AC(cm)	.757(**)	.838(**)	.992(**)			
CRL(cm)	.745(**)	.681(**)	.775(**)	.792(**)		
CHL(cm)	.796(**)	.769(**)	.825(**)	.829(**)	.906(**)	

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Body Wt. (weight of fetus); BPD (Bi-parietal diameter); HC (head circumference); AC (Abdominal circumference); CRL (Crown-rump length); CHL (crown-heel length).

Table. 7: Correlation matrices for external cardiac parameters in aborted foetuses

	Hrt.Ht (mm)	Hrt.Dt(mm)	Hrt. Wd(mm)	Hrt. Wt.(g)	Hrt.C(cm)
Hrt.Ht(mm)					
Hrt.Dt(mm)	.850(**)				
Hrt.Wd(mm)	.779(**)	.840(**)			
Hrt.Wt(g)	.844(**)	.833(**)	.740(**)		
Hrt.C(cm)	.866(**)	.883(**)	.909(**)	.817(**)	

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Hrt.Ht(Heart height); Hrt.Dt(heart depth); Hrt.Wd(heart width); Hrt.Wt(heart weight); Hrt.C(heart circumference).

Table.8 shows that all the external body parameters and external cardiac parameters are moderately correlated except heart height and heart weight that were strongly correlated with body weight. Head circumference and abdominal circumference are having weak correlations with all parameters. Crown- rump length and crown-heel length are having moderate correlation with all parameters.

Table. 8 : Correlation matrices for external body and external cardiac parameters in aborted foetuses

	Body Wt.(g)	BPD (cm)	HC (cm)	AC (cm)	CRL (cm)	CHL (cm)	Hrt.Ht (mm)	Hrt.Dt (mm)	Hrt.Wd (mm)	Hrt.Wt. (g)	Hrt.C. (cm)
Body Wt.(g)											
BPD(cm)	.774(**)										
HC(cm)	.758(**)	.841(**)									
AC(cm)	.757(**)	.838(**)	.992(**)								
CRL(cm)	.745(**)	.681(**)	.775(**)	.792(**)							
CHL(cm)	.796(**)	.769(**)	.825(**)	.829(**)	.906(**)						
Hrt.Ht(mm)	.729(**)	.627(**)	.548(**)	.572(**)	.645(**)	.682(**)					
Hrt.Dt(mm)	.602(**)	.454(**)	.436(**)	.472(**)	.602(**)	.603(**)	.850(**)				
Hrt.Wd(mm)	.602(**)	.424(**)	.447(**)	.468(**)	.622(**)	.621(**)	.779(**)	.840(**)			
Hrt.Wt(g)	.709(**)	.652(**)	.549(**)	.545(**)	.594(**)	.604(**)	.844(**)	.833(**)	.740(**)		
Hrt.C(cm)	.694(**)	.672(**)	.510(**)	.543(**)	.656(**)	.654(**)	.866(**)	.883(**)	.909(**)	.817(**)	

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Body Wt.(weight of fetus); BPD (Bi-parietal diameter); HC(head circumference); AC (Abdominal circumference); CRL(Crown-rump length); CHL (crown-heel length); Hrt.Ht(Heart height); Hrt.Dt(heart depth); Hrt.Wd(heart width); Hrt.Wt(heart weight); Hrt.C(heart circumference).

V. Discussion

In review of literature incidence of various cardiac anomalies observed in the present study were not reported. All the specimens collected were of 2nd & 3rd trimesters only. Analysis of external fetal morphometry of aborted fetuses in the present study indicated a significant increase in all the parameters with increasing gestational age in trimester wise group and with varying significance in week wise groups. (Tables.2 &3). These findings are in agreement to those of reported in the literature[4-8]. The present study did not reveal gender differences in aborted fetuses contrary to the reports of Elizabeth Hurlock [9], Watson and Lawrey [10], Schulz et.al.,[11], Brenner et.al.,[12] and Pederson [13].

There is moderate correlation between fetal somatic and cardiac external morphometry in aborted fetuses (Table.8) which is in agreement to the statement of Mason Barr et.al.[14]. The reported values for growth rate of fetal length in the literature cited by Cojocaru et.al.[15] in aborted fetuses varied from >25.4cm at 4th month to 34.5cm at 6th month to 50.0cm at term. In the present study the growth rate of fetal length in aborted fetuses varied from 380cm at 4th month to 43.8cm at 6th month and at term >50.0cm. The values obtained in the present study are higher than that reported by Cojacaru et.al[15]. The reported values for growth rate of fetal weight by Cojocaru et.al[15] in aborted fetuses varied from 283gm at 4th month to 532gm at 6th month to 2500gm at term, which were less in the present study. Majority of specimens observed in the present study were of 2nd & 3rd trimesters only. Similar studies were reported in the literature by several authors.

According to Watson and Lawrey[10] marked changes in external fetal and internal organ dimensions takes place in embryos and fetuses during growth. Our results are in agreement to this statement. Most of the literature was focused on length and width of the heart. The present study is focused on heart depth and heart circumference also in addition to the above said parameters. Limited literature is available on cardiac morphometric parameters of fetuses and these are mostly based on reports on western population. The present study showed strong correlation between heart weight and fetal body weight showing linear growth rate (Table.8) is in agreement with that reported in the literature [10,16-18].

The present study established that the size of heart increases with gestational age agreeing with those reported in literature [7,19-23]. Prediction of heart weight using body weight is in close relation in our study rather than prediction using BPD. This is in agreement with both Tanimura et.al.[18] and Leslie et.al [20].

VI. Conclusion

The morphometric data and their innovative interpretation had immediate applications in both morphological and functional areas of cardiology and helpful in permanent clinical evaluation of fetal heart development. Correct assessment of fetal heart dimensions and their evaluation through the study of aborted fetuses in ontogenesis could offer useful dimensional landmarks.

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