

(i)

A ROENTGENOLOGICAL EVALUATION
OF THE CARDIAC SILHOUETTE IN ADULT AFRICANS IN
KENYATTA NATIONAL HOSPITAL (K.N.H.) - NAIROBI.

A dissertation submitted in part-fulfilment for the degree of Master of Medicine (Radio-Diagnosis) of the University of Nairobi, Kenya.

By

Dr. Harry D.J. Mziray, M.D. (Dar.).

July, 1988.

**MEDICAL LIBRARY
UNIVERSITY OF NAIROBI**

University of NAIROBI Library



0324946 3

DECLARATION

This dissertation is my original work and has not been submitted for a degree in any other University.

Signed
Dr. H.D.J. Mziray.

This dissertation has been submitted for examination with my approval as the University Supervisor.

Signed
M.N. Wambugu

Dr. (Mrs.) M.N. Wambugu, M.B.Ch.B., M. Med.
Lecturer,
Dept. of Diagnostic Radiology,
University of Nairobi.

D E D I C A T I O N

TO MY DEAREST LATE MOTHER, EGLER IDAVA MWAJABU

'Vita Breva Ars Vero Longa'

-Life is short and the art is long

- The occasion fleeting

- Experience fallacious and

- Judgement Difficult.

TABLE OF CONTENTS

	<u>Page</u>
SUMMARY	1
INTRODUCTION	3
OBJECTIVES	9
METHODOLOGY (MATERIALS AND METHODS)	10
CASE MATERIAL.. .. .	19
RESULTS	20
DISCUSSION	36
CONCLUSIONS	48
RECOMMENDATIONS	50
REFERENCES	52
ACKNOWLEDGEMENTS	58
APPENDICES	60

- 1 -

SUMMARY

Roentgenological Evaluation of the Cardiac Size of Adult Kenyan Africans using the following parameters, namely: The Transverse Diameter of the Heart (TD), The Cardiothoracic Ratio (CTR), The Frontal Cardiac Area (AA), and The Relative Cardiac Volume (RV) - was done on 465 normal subjects and 68 patients with known cardiac pathologies. The other parameters, like the Aortic Transverse Diameter (AD), the Aortic Index (AI) and the Calculated Cardiac Volume (CV), were included because they were found to be complementary in the Cardiac Silhouette Assessment; however, they do not major in the Discussion and Conclusions of this study.

These parameters were assessed against variable demographic and physical characteristics, in order to ascertain which of the methods is/are least influenced by these factors. Their 'pick-up rates' of the Abnormals was, also, assessed and their Baseline values determined. Overall, the RV Method was shown to be relatively the most accurate, whereas the TD Method depicted as the most practical and yet relatively reliable, and is thus recommended for routine use.

The Baseline Values were found to be **comparable** with those reported elsewhere in non-African, mainly Caucasian populations.

However, several pitfalls were evident in the study findings, therefore, further research in the subject is stressed and recommended.

INTRODUCTION

The Roentgenological evaluation of the Heart developed on the basis of the application of clinical percussion [15] and indeed the roentgenological estimation of heart size is one of the most frequently applied method of all diagnostic procedures in the evaluation of the cardiac patient [7].

Historically, the roentgenological examination of the heart dates back almost to the very beginning of clinical Radiology, and over the years various special roentgenological methods have been worked out and these have been of importance to present-day Cardiac Radiology in that they have contributed to our knowledge of the normal versus abnormal radiological appearances of the heart and its normal vis-a-vis abnormal haemodynamics. Also, their uses have been of important diagnostic value as well. For example, in 1917 a method for Radiological Heart Volume Determination was reported in the German Literature by Rohrer [14, 28]. This was subsequently revised and improved upon using teleoroentgenography replacing the more labourious orthodiagraphy of the original method [5, 15], and later, during the 1930s onwards this approach was routinely used in continental Europe, notably in Sweden by workers like LILJESTRAND, LYSHOLM (1939), MAUREA, NYLIN, SOLLBERGER (1955) and others [33].

There are 6 (six) basic Imaging Techniques used for evaluating the heart namely:-

- (i) Plain Film Radiography.
- (ii) Fluoroscopy.
- (iii) Cardiac Series (i.e., Postero-Anterior Chest Radiograph. Lateral Chest Radiograph, Right Anterior Oblique with Barium Swallow and Left Anterior Oblique without Barium Swallow).
- (iv) Cardiac Catheterization and Coronary Arteriography.
- (v) Echo-cardiography, and
- (vi) Radiolotope Scanning [7].

With the advent of recent advances in the field of Imaging no major breakthrough and indications of Computed Tomography (CT) in cardiac evaluation have emerged. However, Nuclear Magnetic Resonance (N.M.R.) has shown the greatest potential compared to any other non-invasive technique so far, and is being developed to measure the working of the heart and its blood flow, where its future value in cardiac diagnosis gives it greater promise in prevention and management of Cardiac Diseases [25]. However, of late Echocardiography has, also, developed fast and it has, as well become an important diagnostic tool in the management of heart diseases.

This study subject matter falls within the field of Cardiovascular Radiology, a sub-speciality shared by both Radiologists and Cardiologists [7] and it is precisely under Plain Film Radiography (P.F.R.).

No doubt the euphemism "P.F.R. is the bread and butter of the Diagnostic Radiologist" [7] is an undisputable fact worldwide, more so to the practicing Diagnostic Radiologist in the Third World, where the other afore-said Imaging Techniques are still a rarity. It is in such working environments where most of us will be

working, and will be expected to meet the demands and challenges of the speciality. Besides P.F.R. can, also, be applied using the Basic Radiological System (B.R.S.) advocated by the World Health Organization (W.H.O.) in developing countries, where in many such countries radiological services are either non-existent or inadequate [1, 34]. Indeed P.F.R. is handy and it is possible to perform it quickly and can be used routinely by any generally-trained Radiologist in any Department with ordinary (or B.R.S.) equipment [4, 34]. Yet different schools of thought prevail amongst authors on Cardiovascular Radiology on the usefulness of P.F.R. with regard to Cardiac Silhouette Assessment.

On the one hand, some scholars [21] maintain that P.F.R. techniques are not useful tools, as they play only a very minor role in the total diagnosis of a cardiac condition since changes in the cardiac contour occur late in the disease process and usually at this stage a diagnosis will have been made on other grounds. They [31] are advancing the point that although for ordinary diagnostic work Postero-Anterior (P.A.), Lateral, and occasionally an over penetrated PA, are adequate for most diagnostic examinations of the heart, and that for routine purpose examinations of the heart size and volume the Cardiothoracic Ratio (C.T.R.) assessment is enough. How ever, volumetric measurements of the heart are only rough estimations and are of little practical value unless

applied with contrast studies. Another critic [9] asserts that the CTR method is a fallacy and an exercise in futility whereas methods for calculating areas and volumes are too cumbersome and advocates on experience as the only answer, whereby a range of normals is known and an appreciation of the abnormal by inspecting hundreds of cardiac and non-cardiac subjects' films and then apply this databank to the task at hand.

On the other hand, views of quite a number of authors [2, 8, 17, 20, 23, 24, 27] implies that PFR has a place in patients suspected of cardiac conditions. They [8, 16, 27, 29] only differ in the methodology, i.e., which of the various PFR methods available in cardiac Silhouette Assessment provides the most accurate results and/or which can be applied to daily practice.

The CTR method, according to Danzer's opinion [8] merits its practicability and usefulness in the estimation of cardiac size, especially in mild to moderate cardiac enlargement. However, this popular method has received criticism [14, 29] that a true determination of the cardiac size necessitates evaluation of the cardiac silhouette on both PA and Lateral chest views, as cardiac enlargement is the most consistent indicator of cardiac disease and its greatest accuracy and best correlation can only be obtained by determining the cardiac volume, whose parameters are apparently measured from these views, plus the mensuration of the Height and Weight of the patient [2, 12, 16, 24]. Similar opinions as these from Western Authors have been documented from a study done in Japan [20].

The Frontal Cardiac Area, advocated by Harry Ungerleider et al [22] (abbreviated A.A. i.e., Actual Area, in my study) is not very much in favour because it is reportedly [17] an inaccurate and cumbersome method. Also, because it is not three-dimensional in approach (so are the TD and CTR methods), as such it is disadvantaged in that the effect of cardiac position, the thoracic configuration, chamber enlargement(s) will apparently influence the magnitude of the frontal area of the heart. Whereas, the Cardiac Volume (C.V.) method permits comparison with normal standards without much regard to body habitus or chest configuration e.g., in Pregnancy [18] or in the Straight Back Syndrome [10]. So advocates of this school of thought affirms that this method is the most accurate index of cardiac size mensuration [2, 14, 17, 20, 27]. Last but not least, a well renowned British worker and an authority in CXR Diagnosis [29, 30] maintains that the Transverse Diameter (T.D.) is the best practical yardstick for measuring the heart size and indeed a perusal of the literature shows other articles [20, 33] in favour of this TD method.

Bearing on all these, it is clearly evident in the available literature that the study of the Cardiac Silhouette has been carried out by various workers in the past, in other parts of the world, outside Africa [All 1-34]. However, no doubt these studies were done in order that ultimately data can be correlated with others obtained elsewhere so that worldwide standardized values can eventually be established. Yet there is no evidence,

going through the available literature to show that a similar study has been undertaken and documented in this part of the world i.e., the East African population, whereas current available established figures obtained elsewhere are supposedly applicable here!

Therefore, there is a need at least to establish whether figures obtained from essentially non-African, mainly Caucasian populations are comparable to ones that are found in our African set-up, here in Kenya.

Furthermore, of late cardiovascular diseases have become a major entity of concern to the Developing World as well - and so this calls for the establishment of our medical facilities taking into consideration this progressing problem, e.g., formulation of a management protocol geared to this end, our economic handicaps notwithstanding. So we have to establish our standard baseline values which could be adjusted to the already existing parameters in developed world or elsewhere, instead of us blindly "rushing" to make use of the "High-Tech" facilities on Cardiac Radiology, available in the Developed World today.

The foregoing, thought-provoking literature material on Cardiac Silhouette Mensuration and its bearing to the Kenyan African Population influenced this study design. This study intends to objectively review and evaluate some of these reported Methods' findings in practical terms and, also, attempt in so doing, to quantitatively

establish baseline values of the Adult Cardiac Silhouette in the Kenyan African population, bearing in mind that such values have not been documented so far.

OBJECTIVES

The study objectives are:-

1. To review/evaluate the Different P.F.R. Methods used for Cardiac Silhouette Assessment in Adults, and ascertain, in so doing, their correlations, if any, with Demographic characteristics (Sex and Age), and the following variables: Height, Weight, Blood Pressure, Body Surface Area (B.S.A.) and Body Build.
2. To assess their sensitivities in picking up cases when applied to sick patients with suspected cardiac conditions, clinically.
3. To work out standard baseline values in the Adult Kenyan African, using the derived recommendable method(s), from (1) and (2) above.

METHODOLOGY (MATERIALS AND METHODS)

(A) MATERIAL

The material for this study consisted of selection of patients in a prospective manner. As this hospital is a referral one, and it is centrally placed, thus data obtained were expected to be representative of the cross-sectional Kenyan African population. Only Adults from eighteen years of age and above both males and females of African origin were included in the study.

(i) ALL Adult Subjects who were either sent for a medical examination or for screening from the Casualty Department or Medical Outpatient clinic - referred for a check chest radiograph were randomly selected by a simple Random Method. However, the selection was not strictly random, as in cases where the radiological examination or the clinical findings were considered not meeting the criteria set, had to be excluded. The criteria was to select a normal control group first and this was based on:

(a) A negative past-medical history of any cardiac problem or associated medical condition(s) (subjective or objective).

(b) Subjects of normal clinical cardiac status as determined on clinical evaluation of each case.

- (c) (b) + a negative qualitative radiological evidence of cardiomegaly, if (a) above unreliable.

(ii) In addition, the above material was augmented by a selected group of subjects in whom a diagnosed cardiac condition was at least known clinically. These were the subjects referred from the Cardiac Clinic or Medical Wards for follow-up. About 10% of the control group number was the targetted material for this selected group.

A Blood Pressure (B.P.) machine (Aneroid Model), A Weighing Machine- both in perfect working conditions, A tape measure and transparent calibrated ruler and overlay were used in taking the parameters' readings required for the study.

(B) METHODS

(i) Each subject was briefly interrogated to obtain the relevant Demographic Characteristics and clinical history. Then the Weight, Height and BP readings were obtained and accordingly recorded into the prepared Data Sheet for each subject (Appendix F). A routine physical examination was, also, performed to each subject with greater emphasis accorded to the cardiac status quo, body habitus and clinical haemoglobin level in order to ascertain healthy

versus unhealthy subjects. The required information was entered into the Data Sheet as well.

- (ii) Then Two chest radiographs - Postero-anterior (PA) AND Lateral views of a Film-Focus-Distance (F.F.D.) of Two metres (6 ft.) were taken [14, 17] - High radiographic standards were observed throughout to obtain good quality films.
- (iii) Broadly roentgenological mensurations of the Heart Shadow were of three types:-
- (a) linear diameters.
 - (b) linear measurements for calculations of Frontal Cardiac Area, and
 - (c) linear measurements for calculations of Cardiac Volume.
- Thus appropriate readings obtained from these radiographs (PA and Lateral) were taken (Fig. 1, 2 and 3). These parameters were accordingly recorded into the Data Sheet. Film copying when felt necessary was undertaken for further analysis and future record, in radiographs of interest and whose follow-up was deemed unreliable - before the films were submitted for routine departmental reporting and despatch.
- (iv) A standard Nomogram for B.S.A. Determination [11] was, also, used (Appendix A). (NB. Sketched
- contd. page 16 -

TELEOROENTGENOGRAPHIC MEASUREMENTS ON FRONTAL AND LATERAL FILMS.



FIG 1 DIMENSIONS UTILIZED IN DERIVING THE CARDIAC TRANSVERSE DIAMETER, CARDIOTHORACIC RATIO, CARDIAC FRONTAL AREA AND THE RELATIVE CARDIAC VOLUME FROM A P-A CHEST RADIOGRAPH

(NB: For details of these dimensions and derivations, please see Appendices B, C, and D)

TELEOROENTGENOGRAPHIC MEASUREMENTS ON FRONTAL AND
LATERAL FILMS

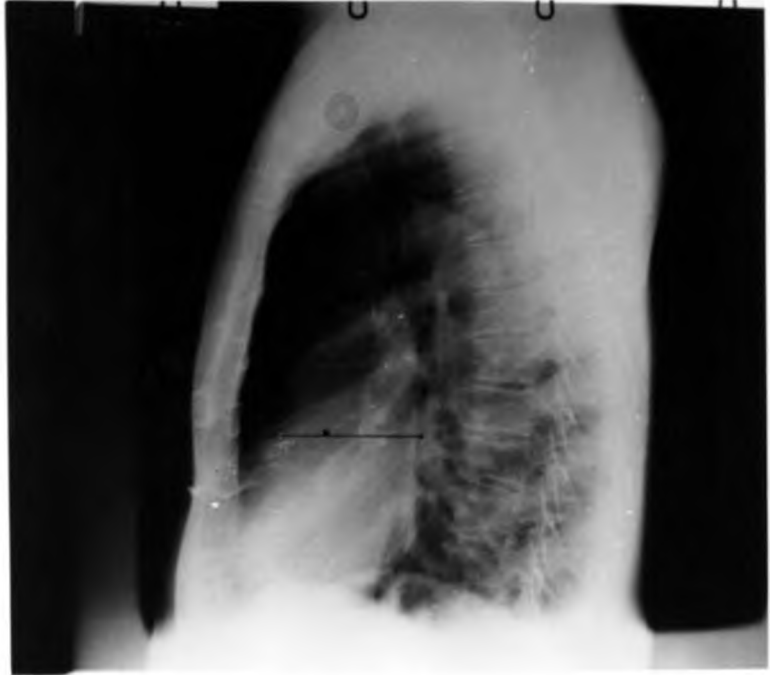


FIG. 2 DIMENSION UTILIZED IN DERIVING THE RELATIVE
CARDIAC VOLUME FROM A LATERAL CHEST RADIOGRAPH.

(NB: For details of this dimension and its application in the calculation of Relative Cardiac Volume (RV) see Appendix D)

TELEOENTGENOGRAPHIC MEASUREMENTS ON FRONTAL AND LATERAL FILMS

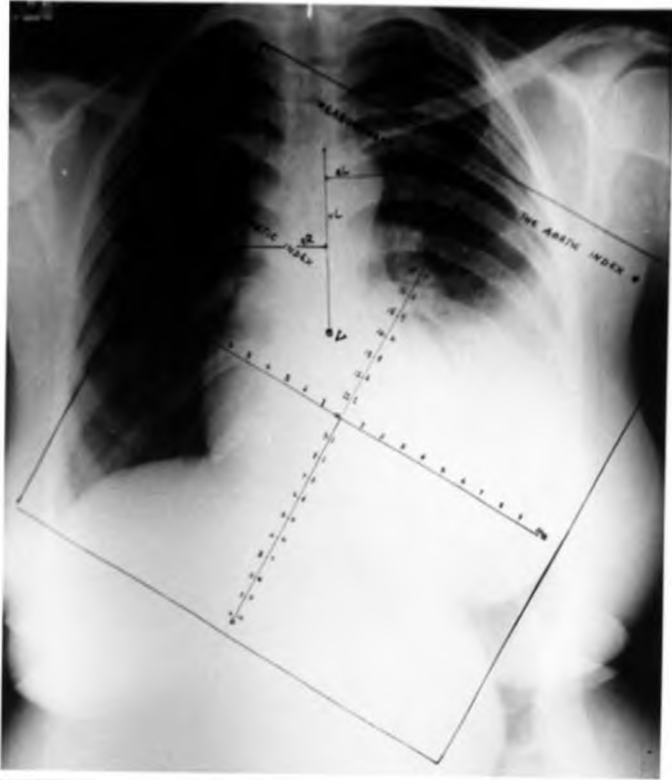


FIG. 3 DIMENSIONS UTILIZED IN DERIVING THE AORTIC INDEX FROM A P-A CHEST RADIOGRAPH WITH A TRANSPARENT OVERLAY USED

(NB: For details of these dimensions and their application in deriving the Aortic Index see Appendix E).

illustrations demonstrating how each method's parameters were obtained are included, with brief outline on how their calculated values were derived shown, vide infra, in each Method illustration, see Appendices B, C, D, & E).

- (v) Statistical Analyses were subsequently performed using a Computer - An S.P.S.S. (Statistical Package for Social Scientists) version of the Kenya Medical Research Centre.

(C) MEDICO-LEGAL CONSIDERATIONS AND LIMITATIONS OF THE STUDY.

Non-invasive methods were used in the study and only the standard acceptable radiographs (i.e., PA and Lateral views) were taken, thus the radiation-dose level was not expected to exceed the acceptable WHO levels, as is expected of this examination. A request to undertake this study was, however, in this respect formally submitted to the Ethical Committee of Kenyatta National Hospital (KNH) and was accordingly given a go-ahead officially.

The limitations were:-

- (i) Only ADULTS (i.e., subjects above 18 years of age) were included in the study.
- (ii) Co-operation, honesty and memory from the subjects were relied on - e.g. in obtaining the Age of the Subject, closest

possible approximation was used for quantitative analytical accuracy.

(iii) Co-operation and Efficiency of the X-ray Department Technical Staff especially Radiographers, both in the X-ray Rooms and Dark Rooms, was of crucial and vital importance for the success of the study. However, a Pilot Study was conducted prior to the start of the actual study, to ensure uniformity of the methods, exposure factors, radiographic technique, film quality etc.

(iv) The study period, of necessity, could not be in terms of years, but lasted about six months only.

(D) SAMPLE SIZE ESTIMATION

The sample size was drawn from subjects satisfying the Inclusion Criteria and the minimum significant sample size was determined applying a statistical formula relevant to this type of study, i.e., the estimation of the sample size using a Continuous Variable [22]. This was based on the findings of Kobayashi et al [20] who in a more or less similar study design obtained the following results:

The mean relative cardiac volume/sq. metre of the body surface Area (Vol/m²) was equal to 420 ± 40 for

Males and 370 ± 40 for Females.

The study covered a total of 924 subjects of which 792 were healthy aged 20-70 years.

Therefore, in mathematico-statistical terms $N=792$, Mean (Males) = 420cc/m^2 , $SD = 40$, $SE = 1.421$ ($SE = SD/\sqrt{N}$) and Mean (Females) = 370cc/m^2 , $SD = 40$, $SE = 1.421$. Thus the combined $SE = \sqrt{SE_1^2 + SE_2^2} = 2.01$.

On the basis of the above figures, using the Continuous Variable Approach the following formula below for estimating the minimum sample size was applied, viz:

$$n \geq \frac{2[(z_{\alpha/2} + z_{\beta})^2 \times SE_c]^2}{\delta^2}, \quad \text{where } z_{\alpha/2} = 1.96,$$

the value corresponding to the 5% level of significance, $z_{\beta} = 1.64$, the value corresponding to the 90% power of the test.

$\delta = 0.5$, the error allowance that we are ready to make in order to achieve the specified difference, and $SE_c = 2.01$, the combined SE.

$$\text{Hence } n \geq \frac{2[(1.96 + 1.64)^2 \times 2.01]^2}{0.5^2} \geq 2 \times 209.44$$

Therefore $n \geq 419 \simeq 420$

Thus the minimum sample size that ought to be taken in order to establish a significant difference at 5% level was estimated to be 420 HEALTHY subjects and the selected sample of UNHEALTHY subjects was

arbitrary targetted to be at least TEN PER CENT (10%) of the Control sample.

CASE MATERIAL

The minimum sample size was estimated, using the continuous variable method applied on a similar study, and this was found to be at least 420 subjects for the control (at 5% level), and a selected sample of Abnormals targetted arbitrarily to be at least 10% of the control sample.

Thus a total of five hundred and thirty three subjects were included in this 6 months study of which 465 (87.2%) were in the control group. Of the controls 303 (65%) were males and 162 (35%) females. Whereas of the 68 Abnormal patients, 44 (64.7%) were males and 24 (35.3%) females. The total mean age was found to be 32.9 years, with an Age Range between 18 years and 74 years.

RESULTS

Using measurements obtained from bi-plane chest radiographs, several parameters were calculated, obtaining values which were applied in the determination of the cardiac silhouette status quo, from which its quantitative evaluation was made.

As per objective (1) and (2) vide supra, the following observations were discerned:

(I) Evaluation of Demographic Characteristics

1. Generally, the overall data for each PFR Method evaluated show that the Male values are higher than those of Females in both the Control and Abnormal Groups, except with the CTR value where they are about the same in the controls and higher in Females than Males in the Abnormals (Table 1).
2. There is a notable increase of Values of the Abnormals as compared to those of the Controls.

PFR METHOD	CONTROL MALES=303		CONTROL FEMALES=162		ABNORMALS MALES=44		ABNORMALS FEMALES = 24	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
TD	12.49	1.12	11.71	1.37	14.32	1.88	14.36	1.89
CTR	0.46	0.06	0.46	0.06	0.51	0.06	0.55	0.07
AA	115.36	15.71	103.13	16.37	143.9	30.9	144.9	38.7
CV	633.55	128.61	531.52	116.46	870.1	278.2	847.3	239.9
RV	354.65	64.36	317.81	62.78	466.9	141.0	500.7	203.3
AD	5.79	0.79	5.47	0.83	6.56	1.23	6.56	1.31
AI	145.81	17.81	136.31	62.08	157.5	24.9	150.04	22.1

TABLE 1 THE MEAN AND SD VALUES OF DIFFERENT PFR METHODS (VS) SEX FOR THE CONTROLS AND THE ABNORMALS

KEY NB: PFR Method = Plain Film Radiographic Method
 TD = The Transverse Diameter of the Heart
 CTR = The Cardiothoracic Ratio
 AA = The Actual (Calculated) Area of the Heart (i.e., Calculated Frontal Cardiac Area)
 CV = The Calculated Volume of the Heart
 RV = The Relative Volume of the Heart
 AD = The Aortic Transverse Diameter
 AI = The Aortic Index (Lodwicks')

TABLE 2 ANALYSIS OF VARIANCE OF CARDIAC PARAMETERS WITH RESPECT TO SEX

VARIABLE	LEVEL OF SIGN	SIGNIF.
1. Height (HT), Cardiac Left (CL), Longitudinal & Transverse Diameter of Heart (L & B), Internal Chest Diameter (ID), AP Diameter of Heart (D) and BSA	$p \leq 0.001$	***
2. Cardiac Right (CR) Aortic Diameter (AD)	$p \leq 0.01$	**
3. Lodwick's Aortic Right (AR)	$p \leq 0.05$	*
4. Blood Pressure (BP) Weight (WT) Body Build	$p \geq 0.05$	NS

TABLE 2 ANALYSIS OF VARIANCE OF CARDIAC PARAMETERS WITH RESPECT TO SEX

KEY

*** = HIGHLY SIGNIFICANT (99.9% CONFIDENCE LEVEL)

** = SIGNIFICANT AT 99% CONFIDENCE LEVEL

* = SIGNIFICANT AT 95% CONFIDENCE LEVEL

NS = NOT SIGNIFICANT AT 95% CONFIDENCE LEVEL

Comparative evaluation of factors affecting the Cardiac Silhouette for each sex, conspicuously showed that Height, Measured parameters of the Cardiac Silhouette, and the B.S.A. have a significant variance whereas poor or no significance was noted in BP Weight and Body Build (Table 2).

AGE GROUPS Male & Female in N & Abn. groups.		1	2	3	4	5	6	T
		<20y.	20-29y.	30-39y.	40-49y.	50-59y.	60+	
NORMALS	M	32	140	69	29	19	14	303
	F	40	53	24	22	12	11	162
	T	72	193	93	51	31	25	465
ABNORMALS	M	1	16	12	5	7	3	44
	F	4	3	8	1	4	4	24
	T	5	19	20	6	11	7	68

TABLE 3: THE DISTRIBUTION OF THE NORMAL AND ABNORMALS IN AGE/SEX GROUPS.

KEY

- N = Normal
- Abn = Abnormal
- y = years
- T = Total

TABLE 4: THE DIFFERENT PFR METHODS' VALUES (VS) AGE IN MALES AND FEMALES - CONTROL GROUP.

PFR METHODS	AGE GROUPS SEX	Group 1 < 20		Group 2 20-29		Group 3 30-39		Group 4 40-49		Group 5 50-59		Group 6 60+	
		MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
1. TD	M	12.07	1.02	12.45	1.16	12.44	0.95	12.87	1.08	12.68	1.12	13.08	1.47
	F	11.12	1.57	11.72	1.21	11.90	1.04	11.97	1.40	11.58	1.43	12.86	1.16
2. CTR	M	0.462	0.05	0.466	0.08	0.453	0.04	0.465	0.04	0.462	0.04	0.474	0.05
	F	0.431	0.06	0.462	0.05	0.463	0.05	0.480	0.05	0.468	0.05	0.516	0.06
3. AA	M	112.03	15.14	116.18	16.68	113.15	12.44	119.59	16.9	111.00	16.03	122.76	15.58
	F	97.75	12.08	103.6	20.14	106.94	10.51	107.37	16.9	99.66	19.77	107.43	11.13
4. CV	M	599.81	125.34	630.04	132.8	623.4	98.4	676.85	145.68	635.52	142.53	703.64	143.9
	F	491.91	90.46	532.72	129.85	545.82	90.7	567.49	122.9	519.51	144.51	579.7	113.1
						52.98		373.77	74.64	351.3	66.6	391.7	75.3
						46.77		340.37	64.85	325.97	72.98	348.21	64.44
						5.80	0.66	6.19	0.76	6.67	0.86	6.5	1.15
						5.62	0.89	6.02	0.64	6.3	0.7	6.09	1.3
		22.22	142.1	13.4	149.2	14.6	155.76	16.5	159.79	16.99	159.71	26.9	
		15.5	129.26	13.51	136.5	20.2	137.1	15.9	138.25	24.1	145.0	19.0	

TABLE 5 REGRESSION EQUATIONS FITTED ON AGE GROUPS FOR THE DIFFERENT PFR METHODS' VALUES DERIVED FROM TABLE 4

PFR METHOD	MALES			FEMALES		
	T	P	SIGNIF.	T	P	SIGNIF.
1. TD	3.168	0.0017	* * *	3.67	0.0003	* * *
2. CTR	0.118	0.9064	NS	4.954	0.000	* * *
3. AA	1.133	0.2582	NS	2.002	0.0469	*
4. CV	2.461	0.0144	* *	2.519	0.0127	* *
5. RV	1.754	0.0495	[NS]	3.034	0.0028	* * *
6. AD	7.89	0.000	* * *	7.876	0.000	* * *
7. AI	7.772	0.000	* * *	2.369	0.0190	* *

KEY: NS = NOT SIGNIFICANT AT 5% LEVEL
 [NS] = NOT SIGNIFICANT AT 5% LEVEL BUT SIGNIFICANT AT 10% LEVEL
 * = SIGNIFICANT AT 5% LEVEL
 ** = SIGNIFICANT AT 2% LEVEL
 *** = SIGNIFICANT AT 1% LEVEL
 T = NORMAL DISTRIBUTION LEVEL
 P = LEVEL OF SIGNIFICANCY

FIG. 4 MEAN VALUES OF CTR (VS) AGE GROUPS IN MALES AND FEMALES

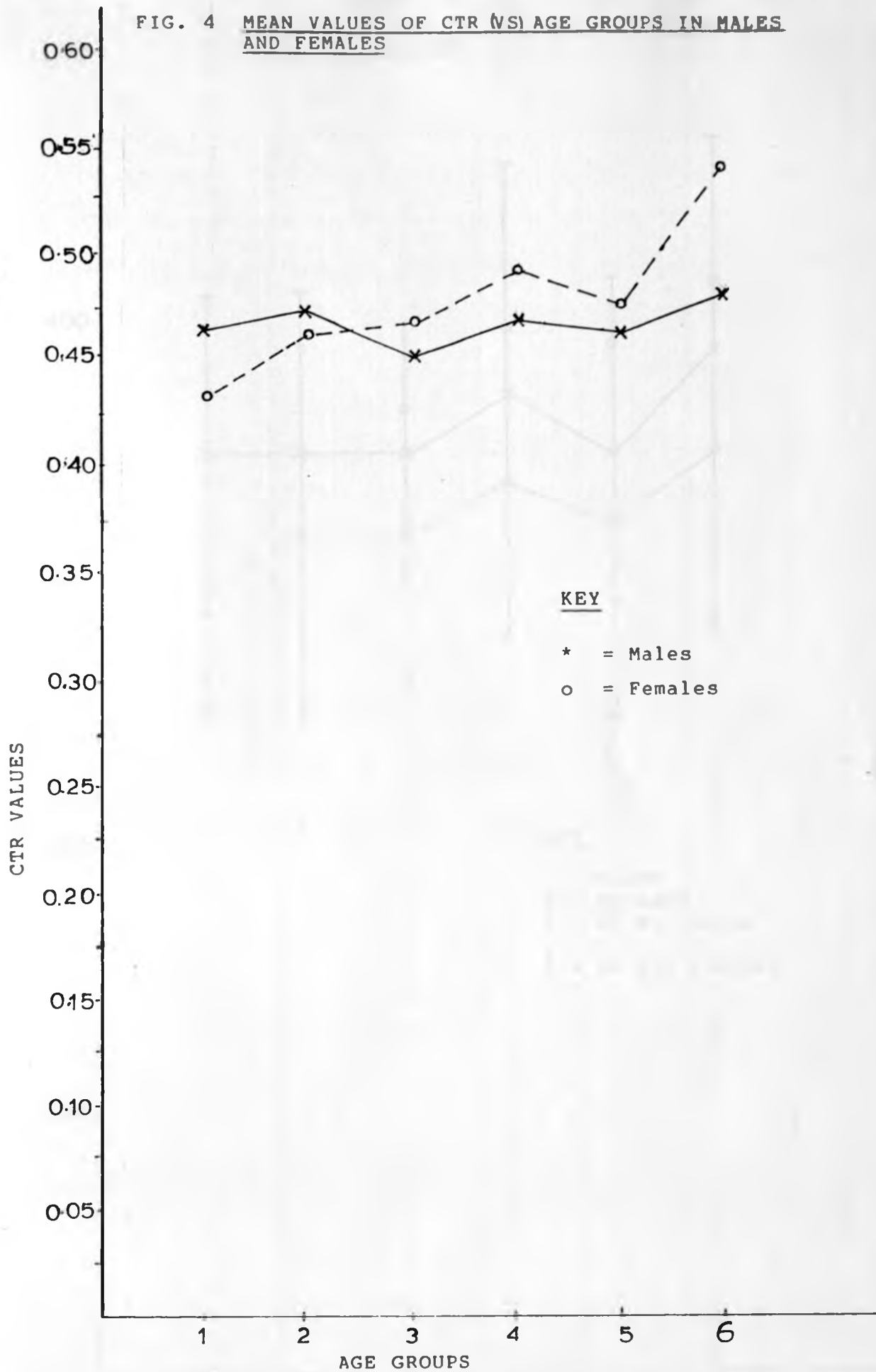
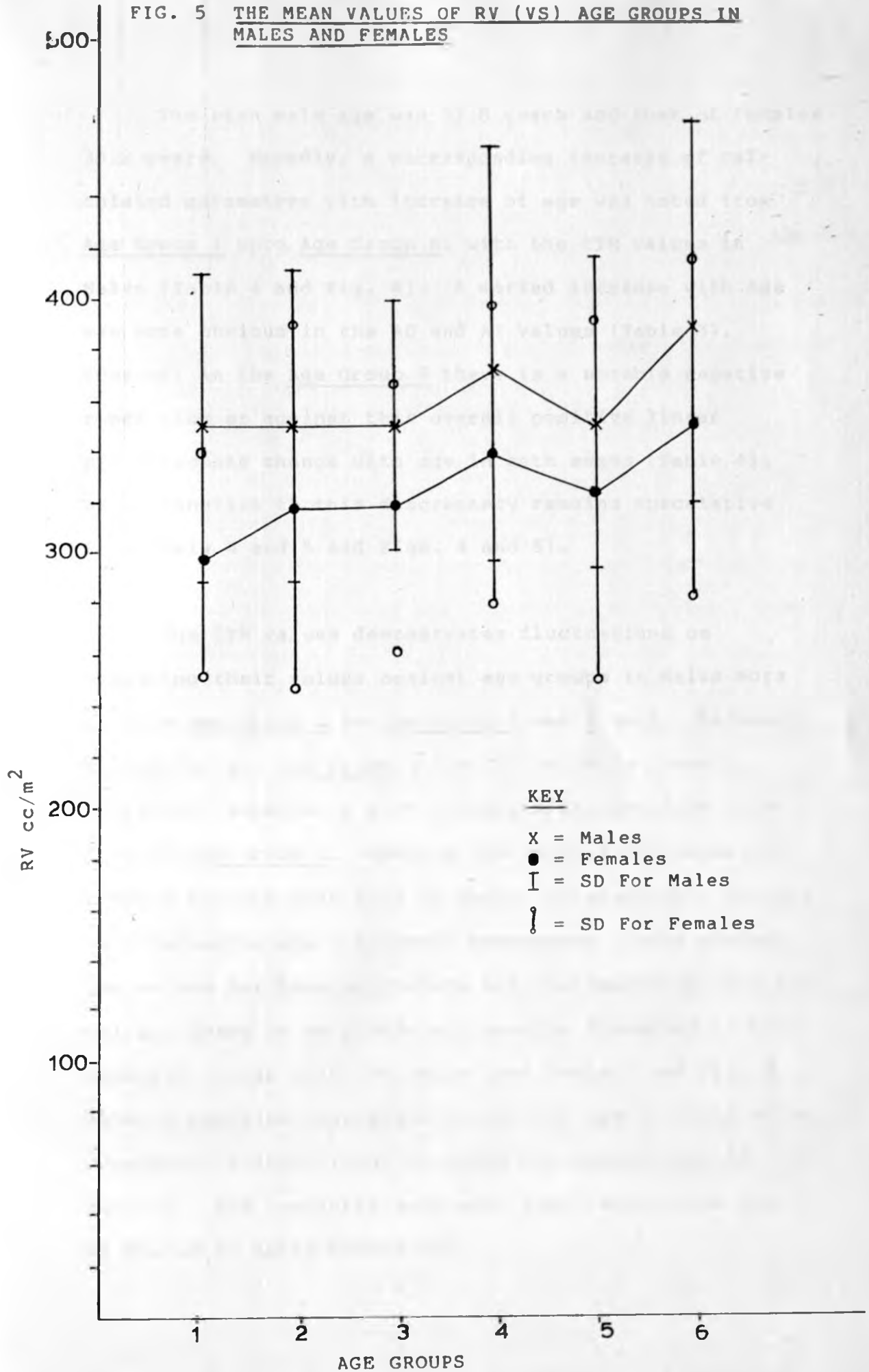


FIG. 5 THE MEAN VALUES OF RV (VS) AGE GROUPS IN MALES AND FEMALES



KEY

X = Males

● = Females

I = SD For Males

! = SD For Females

The mean male age was 32.8 years and that of females 33.2 years. Broadly, a corresponding increase of calculated parameters with increase of age was noted from Age Group 1 upto Age Group 6, with the CTR values in Males (Table 4 and Fig. 4). A marked increase with Age was more obvious in the AD and AI values (Table 5). However, in the Age Group 5 there is a notable negative regression as against this overall positive linear proportionate change with age in both sexes (Table 4). An explanation to this discrepancy remains speculative (see Table 4 and 5 and Figs. 4 and 5).

The CTR values demonstrates fluctuations on comparing their values against age groups in Males more so from Age Group 2 to Age Group 3 and 4 to 5. Although in Females at Age Group 6 the CTR value is clearly increased, especially when reflected/extrapolated from that of Age Group 1. Whereas the initial CTR value for females is less than that of males, interestingly enough, with increasing age a reversal phenomenon occurs whereby the values for females exceeds the corresponding ones for males. There is no viable explanation discerned to this observed change with CTR value (See Table 4 and Fig. 4). Also, a positive regression trend with age is found to be completely insignificant in Males but significant in Females. The insignificancy was, also, noted with the AA Method in Males (Table 5).

(II) Evaluation of Physical Factors - Height, Weight, Body Build, BP and BSA with the Different PER Methods.

Correlation - i.e., a measure of the strength of the relationship between one or a series of variables is of greater interest than the form of relationship that exists between them. This relationship of correlation between one or a series of variables is given a value called Coefficient of Correlation (γ). A value $\gamma = +1$ implies that a variation in one factor is accompanied by a direct proportional variation in the other, $\gamma = -1$ means that the relationship is inverse but still directly proportional, $r = 0$ indicates a complete lack of relationship. The value has to be of the order of 0.6 before there is a (20%) significant reduction in the dispersion or scatter around a regression line. Apparently, in Cardiac Silhouette Mensuration ' γ ' varies somewhat with cardiac parameters, physical factors etc., and is thus influential in determining which parameter or which criteria of correlation will produce the most accurate evaluation of the heart.

It is important to note that when there is no significant correlation, this implies that a factor or variable is not influenced or is least affected by the other variable(s), and it is thus independent and more reliable in its application than the one(s) influenced (or affected) by the other factors.

So in the same line of reasoning on correlation, by computation, in my series, the following output observations were obtained when this measure was programmed:

(Table 6 summarizes the findings discerned from the hard-copy and Visual Display of the S.P.S.S.).

Observations adluced from these results are:-

- | | |
|------|---|
| (i) | In general terms, except for the R.V. Method, <u>ALL</u> Methods invariably either in the male or female groups show a distinct influence by <u>Age</u> , <u>Body Build</u> , <u>Weight</u> , <u>B.S.A.</u> and <u>Height</u> . |
| (ii) | With respect to the RV Method there is only a slight influence shown by <u>Age</u> in females and <u>Weight</u> in males. This is a negligible effect. This, therefore, implies that the <u>RV Method</u> appears to be the least affected or influenced by most of the variable factors and thus it is fair to conclude that relatively, it is the most independent criteria of correlation, as it were, making it the most accurate yardstick for evaluation of the heart size. |

TABLE 6 : CORRELATIONS OF DIFFERENT PFR METHODS WITH PHYSICAL AND OTHER FACTORS.

PFR METHOD FACTORS	TD		CTR		AA		RV		AD		AI	
	M	F	M	F	M	F	M	F	M	F	M	F
1 AGE	**	**	O	**	O	O	O	*	**	**	**	*
2 B.B	**	**	O	*	**	**	O	O	O	O	O	O
3 HEIGHT	O	*	*	O	**	**	O	O	**	O	**	O
4 WEIGHT	**	**	O	**	**	**	*	O	**	*	**	*
5 BSA	**	**	O	*	**	**	O	O	**	O	**	*
6 BPs	**	**	O	*	O	O	O	O	O	**	O	O
7 Bpd	**	O	O	O	O	O	O	O	O	O	O	O

[NOTE: For simplicity of illustrating the correlation values displayed the magnitude of strength of the relationship (i.e., correlation) corresponds to the number of asterics (*) in the interaction between the variables. 'O' implies no relationship.]

KEY:

(**) ≡ HIGHLY SIGNIFICANT CORRELATION.

(*) ≡ SIGNIFICANT CORRELATION.

(O) ≡ NO CORRELATION

BB = BODY BUILD

BSA = BASAL SURFACE AREA

BPs = BLOOD PRESSURE SYSTOLIC

Bpd = BLOOD PRESSURE DIASTOLIC

M = Male

F = Female

(III) ASSESSMENT OF PFR METHODS 'PICK-UP RATES' WHEN APPLIED TO PATIENTS WITH CARDIAC LESIONS.

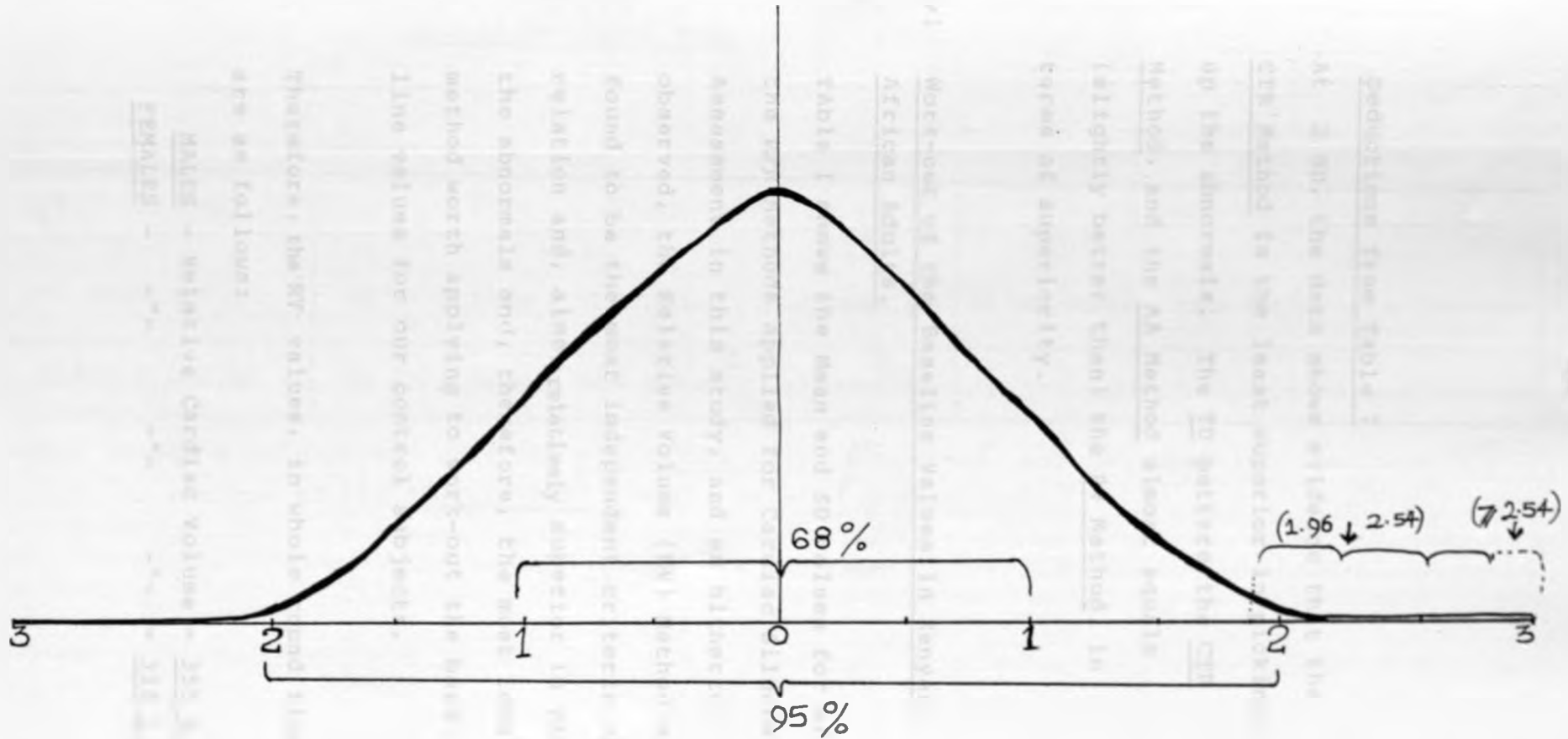
This was the Abnormal Selected Group where a total of 68 subjects (12.7% of the control number) were included. Forty-four of these were Males and twenty four females.

To determine this objective, the two most extreme levels of standard deviation (SD^S) i.e., at 95% confidence level (1.96 - 2.54 and ≥ 2.54 level), in a Normal Distribution Curve, were gauged by programming the computer, in order to observe, in each of the four PFR Methods used for detecting cardiomegaly, which one would give the lowest upto the highest number of 'picked-up' subjects and thus evaluate their superiority in detection of cardiomegaly (NB: Figure 6 illustrates the Normal Distribution Curve, Below). The following methods, namely The TD, CTR, AA, and RV were tested and their results evaluated, viz. as shown in Table 7 below:

SEX \ PFR METHOD	TD	CTR	AA	RV
	$\geq 2 SD$	$\geq 2 SD$	$\geq 2 SD$	$\geq 2 SD$
MALES	41%	23%	50%	41%
FEMALES	46%	46%	50%	63%
TOTAL	42%	31%	50%	49%

TABLE 7 THE PICK-UP RATE OF THE ABNORMALS IN PERCENTAGES AT $\geq 2 SD^S$ IN THE FOUR DIFFERENT PFR METHODS USED FOR DETECTING CARDIOMEGALY.

OF THE STANDARD NORMAL DISTRIBUTION CURVE.



Deductions from Table 7

At 2 SD, the data shows evidence that the CTR Method is the least superior in picking-up the abnormal. The TD betters the CTR Method, and the AA Method almost equals (slightly better than) the RV Method, in terms of superiority.

(iv) Work-out of the Baseline Values in Kenyan African Adults.

Table 1 shows the Mean and SD values for all the PFR Methods applied for Cardiac Silhouette Assessment in this study, and as hitherto observed, the Relative Volume (RV) Method was found to be the most independent criteria of correlation and, also, relatively superior in picking the abnormal and, therefore, the most ideal method worth applying to work-out the baseline values for our control subjects.

Therefore, the RV values, in whole round figures are as follows:

$$\begin{array}{l} \text{MALES} - \text{Relative Cardiac Volume} = \underline{355 \pm 65\text{cc/m}^2} \\ \text{FEMALES} - \text{"} - \text{"} - \text{"} = \underline{318 \pm 63\text{cc/m}^2} \end{array}$$

TABLE 8* COMPARISON OF SIMON'S AND MY SERIES' T.D. VALUES IN THE ABOVE FIFTIES

(I.E., 50+ YEARS OLD)

(T.D. in cm)		
MY SERIES	AT 50-59 YEARS = 12.6 (Males), 11.6 (Females)	At 60+ YEARS = 13.1 (Males) 12.9 (Females)
SIMON'S SERIES	AT 50-74 YEARS = 13.4 (Males), 11.5 (Females)	AT 75-95 YEARS = 13.6 (Males) 12.7(Females)

*[NB: TABLE 8 is relevant when the DISCUSSION PART is reached, and has been included here at the end of the RESULTS PART for the sake of convention]

DISCUSSION

(A) METHODOLOGY

Experimental errors of the Methods

The total experimental errors of any such method can be regarded as the sum of:

- (a) Errors due to technique - including all factors acting during the physical and radiological examinations and
- (b) Personal errors in reading the films.

In the case of the former, the variation of the volume throughout the heart cycle, position of the patient, the heart rate etc., contributed to these errors. Apparently variations due to respiratory and cardiac cycle phases at the moment of x-ray exposure have been investigated [14]. In this regard, it was shown that these variations caused negligible error when the film is taken in suspended respiration at the end of a quiet inspiration.

With respect to the latter factors the effect was found to be more in pathological situations due to poor condition of most such subjects and because the outline of the heart would often be less distinct in such patients than in healthy people, thus rendering the measurements less accurate.

Invariably, observer bias was, also, inherent and the experience of the observer was realized to be of decisive importance in minimizing the method errors-

this fact was noted after working on more than a hundred subjects during the Pilot Study period.

For this study, it was found that the most practicable ways of reducing these errors were:-

- (i) To accommodate myself thoroughly to the fine details of the set methods for carrying out the study, and attain a level of experience as far as possible from the beginning and in the course of the study process.
- (ii) To re-examine all subjects whom their clinico-radiological data were deemed unsatisfactory.
- (iii) To take measurements (radiological) under optimal conditions on dry films using a transparent calibrated ruler and overlay.
- (iv) Use figures obtained from one observer only, in order to reduce the observer bias, since figures derived from different observers the question of observer bias arises, and is then of crucial importance.
- (v) At one sitting, to examine about ten, upto a maximum of fifteen subjects, in order to reduce visual error and observer fatigue.

Therefore, throughout the course of the study it was made sure that all subjects were examined according to

the standardized techniques set, and as large a sample as possible per requirement was obtained and all available was made use of in the analyses, adhering strictly to the criteria set in evaluation.

(B) RESULTS

Evaluation of the different PFR methods used for Cardiac Silhouette.

As already depicted in the Introduction, the main PFR Methods under evaluation in this study are basically:

1. The TD Method.
2. The CTR Method.
3. The AA Method.
4. The RV Method

The other parameters (e.g., AD & AI -used for assessing the Aortic Pedicle in the Cardiac Silhouette) have been included because they were found to be complementary in the Cardiac Silhouette Evaluation and thought to be useful in the current and/or future evaluation of the Cardiac Silhouette in the Material collected. Therefore, they will not major in the Discussion and Conclusions of this study.

(i) Linear Parameters - TD and CTR Methods

In this series, the TD values [Mean = 12.5 cm (Males), 11.7 (Females); Range = 11.4 - 13.6 (Males), 10.3 - 13.1 (Females)] were found to be slightly lower than those reported in Europe, where according to Simon [29] in his

series most normal people, the upper limit of the Cardiac TD was 15.5. cm, whereas the normal subjects aged between 50 - 75, their TD values appeared to be roughly the same as those observed in my study findings, as demonstrated in Table 8.

My Data (Table 4 and 5) indicates a progressive and significant increase of the TD value with increasing age, with a slight decrease at the 50-59 Age Group, then picking-up again, thereafter. Yet my series do not show TD value changes in the very old in particular, as will be evident in Table 4 and Table 8 viz-a-vis the findings of Simon. However, this study undoubtedly show evidence that the TD increases with Age (Table 5). Apparently Simon [29] asserts that there is no evidence that the TD of the heart increases in magnitude with Age in the very old. However, his assertion in accordance with the findings from his distinguished radiological work may still be challenged, since as yet his findings have not been verified to be a universal phenomenon.

In this series the increase of the TD with Age (but not with the very old) is clearly shown and it would be wrong to just assume Simon's findings to apply to our situation. More work is needed to verify his observations.

The TD, a linear parameter, like the CTR, is markedly influenced by other factors, like body habitus, height or weight (Table 6). However, some authors'

experience [20, 30, 33] seem to suggest that in heart size measurements the TD value is useful. For example, Kobayashi et al [20] in their conclusions state that among other parameters, the TD value is useful in determining cardiomegaly. This usefulness is, also, well documented by Simon [33] who maintains that the heart size is best measured by the TD, all the physical factors being "classical" as he puts it!, and in fact in his criteria for normality [29] he affirms that the TD is normally less than sixteen centimetres with a change of ≤ 1.5 cm from previous film values, in serial measurements. Indeed, in my findings the TD method was shown to be relatively sensitive, at least better than the CTR Method, in picking up the abnormal (Table 7). Thus the authors' experience augmented by the observations on this study findings seem to confirm this somewhat surprising impression on the place of the TD value in cardiac size measurement.

In my short experience while carrying out this study, of all the PFR Methods for Cardiac Silhouette Evaluation, the TD measurement appeared to be the least cumbersome. Indeed, in practical terms it was the most straight forward and easy to take! Certainly if further confirmatory evaluation is made and a consensus of opinion reached, it is my conviction that, instead of the 'popular' CTR Method routine application, this method could be recommended for future routine clinical use as it is easy to perform, relatively reliable and requires only a single (PA) chest radiographic examination from

which only a single measurement is taken without further need for calculations to obtain the value. Moreover, the use of this value in the Ungerleider-Gomez's formula as pointed out in Kobayashi et al's work [20] highlights it as an important multipurpose yardstick in Roentgenological cardiac size evaluation.

With regard to the CTR Method, as already pointed out in my results (Refer Table 4, Table 5, and Fig. 4), its values shows haphazard fluctuations with increasing Age in the Males, giving a non-significant trend of increase, whereas in the Females a significant positive regression with Age is evident (Table 5), with the reversal phenomenon depicted (Fig. 4). This observation may well be due to an actual body change that is taking place between sexes at around this period (? hormonal, ? effect of pregnancy in Females, ? chest diameter change in Males and Females, ? different sexual physical activities .. etc) or maybe just the inherent pitfalls obtained in this method. These are merely my speculations. Further study and evaluation of this disproportionate change of the CTR with Sex and Age is called for, since infact it has not hitherto been documented. Nevertheless, this does not permit me to disentangle from the generally held views on the CTR Method's shortfalls. Some of them have in fact been conspicuously depicted in my findings notably its correlation with physical factors and its low pick-up rate of the abnormal (Table 6 & 7). This method, popular to the clinician worldwide, to date, has received criticisms by many [9, 14, 20, 29, 33] whereas

its usefulness is less well documented in the literature. Danzer [8], the pioneer of this method, in his series of 500 patients, came up with the conclusions that this method, for practical purposes, is useful in the estimation of heart size, especially in moderate or early cardiomegaly. The same opinion was shared by the late Dr. Paul Dudley White [9] who, shortly before he died vehemently defended it against its challengers asserting that he had religiously recorded CTRs orthodiagraphically, on all his patients for years and found it a valuable and reliable assessment of change in heart size!

On the contrary, Simon [29] points out that the thorax shrinks with age, especially so in the very old, so that the CTR changes are not necessarily because the heart size has changed (increased). This affects its usefulness as a yardstick for measuring cardiac size in this and other age groups. Dave [9] completely rejects this CTR Method and is of the opinion that it is a hopeless exercise.

Hanson [14] in the 1960s had this to comment on this method's usefulness. "As a result of criticism of this Ratio, it has gradually fallen into disrepute, although its application and the magical "normal value" of 0.50 are still in evidence".

(ii) Area and Volume Parameters - AA and RV Methods.

With the AA (Actual Area) Method - (syn. to Calculated Actual Frontal Method: Ungerleider/Gubner method)

in my series generally, a poorly significant increase with Age, was noted (Table 5). With a mean value of 115.4 cm^2 for Males and 103.1 cm^2 Females (Table 1). The influence of physical factors notably Body Build, Height and Weight were much pronounced than of Age or BP (Table 6). These observations apparently agrees well with the findings of Ungerleider et al [33] where they realised that the influence of sex and age in adults, on the heart size is relatively small compared to the factors of weight and height. Yet Meschan et al [27] came up with the findings that Weight is a better criterion than Height, failing only in the presence of obesity when the height factor compensates for it. In this series both criteria were equal in correlation (Table 6).

This method, like the TD and CTR Methods has been criticised as not being reliable since it is not three-dimensional, when we are dealing with a three-dimensional organ, and cannot, therefore, expect a good degree of accuracy in estimation of its size when it is measured in only two planes [5, 14]. In this respect it is said to be significantly influenced by physical factors related to body habitus and chest configuration, thus reducing its reliability.

Apparently this study findings have depicted that this method is relatively accurate, at least better than the TD and CTR (Table 7), and almost as good as the RV Method. This method involves taking several measurements and calculations, and is, therefore, open to a

cummulation of experimental errors. Also, it cannot be applied as a routine procedure because of its involvements, and as Dave [9] puts it "... if there is a scientific bone in our bodies, we must reject a formula for cardiac mensuration that includes only two of a number of major variables (length, height and depth of the heart; and of thorax, patient's sex, age, height, weight and heart rate) whereas methods that take into consideration all the variables are too cumbersome for routine use". For him [9], he stressed experience as the only ANSWER.

However, considering all the facts which support the above assertion, this study findings does not seem to show that this method and the other PFR Methods for cardiac silhouette evaluation for that matter, as exercises in futility, as claimed by Dave. I am of the opinion that visual experience alone, subjective as it is, certainly does not provide a scientific answer to PFR evaluation of the cardiac silhouette. There is a definite field of usefulness for measurements in evaluating the heart as a whole, since it is a fact that any quantitative approach done in a standard fashion and compared over a period of time is apt to give a reliable assessment of change. Whereas, in lesser degrees of enlargement assessment of change, more often than not, escape detection with a simple qualitative evaluation of the Cardiac Silhouette by Inspection, no matter how experienced the observer's eye may be!

With regard to the RV Method, as depicted in the Results, unlike the other methods, there was no significant correlation observed with the physical factors (Table 6), and this implied that this method was the most independent and thus the most reliable in its application to Cardiac Size Mensuration. It was, also, found to be quite potent in picking-up the Abnormals, almost equalling the AA Method (Table 7).

A review of the literature revealed an agreement to the Relative Volume values of my series to those of Jonsell's series [15] where in the majority of his series, values varied between 300 and 400 cc/m² with a minimum of 250 cc/m² and a maximum of 450 cc/m². Similar figures were independently obtained by Hanson et al [14] where they realized that the normal average volumes usually fell in the range of 300-400 cc/m² as well.

Indeed, a close correlation has already been shown to exist between the radiologically calculated heart volume and the real heart volume [13]. More work had, also, been tried by Karlberg and Lind [24] in their endeavour to obtain a more accurate comparison of heart volume with a physiological variable applying their "capacitance surface" concept. The basis of the RV Method was derived from the pioneering works of Rohrer (1917) [28] and Kahlstorf (1932) [16] based on Rohrer - Kahlstorf's formula.

It is recognised that this procedure (i.e., the R.V. Method) is not faultless. In fact one of the points against this method is that the different errors inherent of the method are multiplied and makes the determination too in-exact [15]. The shortfalls of this Method was depicted in this study findings (see Table 5 and Table 7), where it was evident that its positive regression trend was not significant at 5% level in the Males, (but significant at 10% level) whereas its pick-up rate was about the same (in fact slightly less) as that of the AA Method. This may well be attributed to the experimental errors accrued in the course of carrying out the study.

Supporters of this method [5, 14] argue that the inherent errors which were obtained in the original orthodiagraphic measurements are now greatly obviated, much so in serial examinations where the small technical and theoretical errors assume a constancy, which in effect enhances the Methods' accuracy even further. In my series, serial examinations were not carried out thus this could, also, contribute somewhat to the overall magnitude of the Methods' errors. However, with this reservation, in this series elsewhere this method has apparently shown better results as compared to the others (See Table 5 in Female Group, Table 6 and Table 7).

Thus overall, with the relative inadequacies portrayed in the other methods vide my study findings-

still my contention seem to agree with the present-day generally held views on PFR on Cardiac Silhouette Evaluation that the Relative Volume (RV) Method is the most reliable.

Last but not least, the author would wish to highlight that it appears from previous studies and from the present one that several factors need to be considered for evaluation of the accuracy of a test result, some of which were dwelled in, in the initial part of this discussion, and may well be not comprehensively adhered to because of the limitations outlined earlier on - hence the shortfalls evident in the findings.

However, the advocates of PFR Methods application in Cardiac Mensuration [6] impress upon the fact that statistically it has been proven beyond doubt that the normal range of a roentgenological cardiac mensuration is no greater than that of Blood Pressures (BPs) obtained from a series of normal individuals, and that probably a simple roentgen measurement of cardiac size is of the same order of reliability as a single blood pressure (BP) reading in determining the presence of Hypertension!

Furthermore, in all these PFR cardiac investigations it has been observed that the total experimental errors of the methods are basically at roughly similar level, and reasonably lower level, as compared with many other methods used for various medical investigations - to date.

CONCLUSIONS

1. In all the PFR Methods, except the CTR, the male values are higher than those of females.
2. Overall, there is a positive proportionate change with age shown, except with the CTR Method where fluctuating changes were noted. The reported "no change of the Cardiac TD with age in advanced age" calls for further elucidation.
3. Generally, in both sexes ALL the Methods, except the Relative Volume Method, showed a distinct influence by physical factors, notably the Body Build.
4. Of all the PFR Methods evaluated, the TD Method has shown to be practical, simple and still a relatively reliable approach for routine clinical use in cardiac mensuration, when only a PA chest radiograph is available. In this respect, Ungerleider-Gomez's work referred in the Discussion in relation to the TD value, needs to be evaluated further to highlight the new perspectives of this linear parameter.
5. Overall the Relative Volume Method has been demonstrated to be the most accurate and thus most reliable for evaluating the heart size, where both PA and Lateral Chest radiographs, and Body dimensions must be available.

6. Applying the Relative Volume Method (found to be most reliable) on my series, the Kenyan African baseline values were found to be comparable to those obtained from non-African, mainly Caucasian populations.

RECOMMENDATIONS

1. Attention should be brought to all practicing clinicians and radiologists that:-
 - (i) The CTR Mensuration (widely used and believed to be a useful index in Cardiac Size Assessment, to-date - more so in our set up) has been found to be not quite reliable, relatively. However, further evaluation to clarify its shortcomings and its disrepute is called for.
 - (ii) The TD parameter is relatively more simpler, reliable and practical than the CTR, and is recommendable in routine clinical work, especially in serial cardiac size evaluation.
 - (iii) The Relative Volume (RV) Method, though elaborate, is a quite useful and reliable approach for an accurate cardiac silhouette mensuration.
2. A long-term prospective study on this subject, with use of much standardized and improved techniques and clinical appraisal for evaluation, in a group of completely normal subjects, in a country-wide approach is recommended, in order to come up with consolidating conclusions for this study findings, bearing in mind that this is the only reported series on this subject matter, in this part of the world.

3. Derived measurements should not be regarded as final, but rather should be employed to complement careful study of individual cardiac Chambers: clinically, by fluoroscopy, by cardiac series, and if need be, by further specialized procedures like Cardiac Catheterization, Echo cardiography etc., and each case should be considered and taken on the light of the presenting symptomatology.

4. PFR in Cardiac Silhouette Assessment is of some value and has a place in present-day Cardiovascular Radiology in the Developing Countries if not world-wide.

REFERENCES

1. ABRAMS, H.L.; McNEIL, B.J.:
CT - Cost and Efficiency Implications.
Amer. Journal of Roent. 131: 81-87 (1978).
2. AMUNDSEN, P:
The Diagnostic Value of Conventional Radiological
Examination of the Heart in Adults.
Acta Radiol. supp. 181, 1959.
3. BJORCK, G.:
On the Relationship between Heart Volume and other
various Physical Factors.
Acta Radiol. 25: 372-378, 1944.
4. BREDERHOFF, J.; RECOVEANU, N.T.:
The Radiological Services throughout the World.
Diagnostic Imaging 51: 121-133, 1982.
5. COMEAU, W.J.; WHITE, P.D.:
An Evaluation of Heart Volume Determinations by
Rohrer-Kahlstorf formula as a Clinical Method of
Measuring Heart Size.
Amer. Heart J. 17: 158, 1939.
6. COOLEY, R.N.; SLOAN, R.D.:
Radiology of the Heart and Great Vessels.
p 4-73, Baltimore - The Williams & Wilkins Co., 1956.

7. DAFFNER, R.H.:
Introduction to Diagnostic Radiology. A correlative
Approach.
Publisher C.V. Mosby Co., 1978 Ed., p. 125-169.
8. DANZER, C.S.:
The C.T.R. Mensuration.
Am.J.M.Sc. 157: 513, 1919.
9. DAVES, M.L.; MARVIN, L.:
Cardiac Roentgenology. Shadows of the Heart.
Year Book Medical Publishers Inc. ch. 1 p. 9, 1981 Ed.
10. DE LEON ET AL:
The Straight Back syndrome.
Circulation 17: 197, 1965.
11. DU BOIS, E.F.:
Basal Metabolism in Health and Disease.
Philadelphia, Lea & Febiger, p. 114, 2nd Ed. 1927.
12. EEK, S:
Heart Index or Heart Volume in Judgement of Congenital
Heart Disease.
Acta Paediat (Uppn) 37: 61-67, 1949.
13. FRIEDMAN, C.E.:
Heart Volume, Myocardial Volume and Total Capacity
of the Heart Cavities in certain Chronic Heart Diseases.
Acta Med. Scand. Suppl. 257, 1951.

14. HANSON, J.S.:
Radiological Examination of Heart Volume. A valuable
Diagnostic Tool.
J.A.M.A. 176: 16-18, April 8, 1961.

15. JONSELL, S.:
A Method of Determination of Heart size by Teleroent-
genography (Heart Volume Index).
Acta radiol. 20: 325-340, 1939.

16. KAHLSTORF, A.:
Ueber eine orthodiagraphische Hertzvolumenbestimmung.
Fortschr Röntgenstr 45 (1932) 123.

17. KEATS, T.E.; ENGE, I.P.:
Cardiac Mensuration by the Cardiac Volume Method.
Radiology 85: 850, 1965.

18. KEATS, T.E.; MARTT, J.
Selective Dilatation of the Right Atrium in Pregnancy.
Am. J. Roentgenol. 91: 307, 1964.

19. KJELLBERG, S.R.; RUNDE, U.; SJÖSTRAND, T.:
The Relation of the Cardiac Volume to the Weight and
Surface Area of the Body, the Blood Volume and the
Physical Capacity for Work.
Acta Radiol. 31: 113-122, 1949.

20. KOBAYASHI, A.; SHIRAISHI, T.; NAKAZAWA, M.; HASEGAWA, T.:
Roentgenological Detection of Cardiomegaly using Bi-
Plane Chest X-Ray Films.
XVTH Internat. Congr. of Radiol. Confer. on C.V.S.
p. 102-3, 1984.
21. KREEL, L.:
Outline of Radiology.
Heinemann, 1971 Ed.
22. KREEL, L. ET AL:
Medical Imaging, Year Book.
Med. Publisher 1979 Ed., p. 132-135.
23. LILJESTRAND, G.; LYSHOLM NYLIN, G.;
ZACHRISON, C.G.:
Normal Heart Volume in Man.
Amer. Heart J. 17: 406-415 (April), 1939.
24. LIND, J.:
Heart Volume in Normal Infants, Roentgenological study.
Acta. Radiol. Supp. 82, p. 3-127, 1950.
25. LONGMORE, D.:
Spectrum No. 198, p. 1-2, 1986.

26. LYSHOLM, E.; NYLIN, G.; QUARNÄ, K.:
The Relation between the Heart Volume and Stroke
Volume under Physiological and Pathological Condi-
tions.
Act. Radiol. 15: 237, 1934.
27. MESCHAN, I.:
An Atlas of Anatomy Basic to Radiology.
W.B. Saunders Co., p. 725, 1975 Ed.
28. ROHRER, F.:
Volumbestimmung von Körperhöhlen und Organen auf
orthodiagraphischem Wege FortschrGeb Röntgenstr
24: 285 1916/17.
29. SIMON, G.:
The Anterior View Chest Radiograph - Criteria for
Normality Derived from a Basic Analysis of the
Shadows.
Clin. Radiol. (1975) 26, 429-437.
30. SIMON, G.:
Principles of Chest X-Ray Diagnosis.
Butterworths Med. Publications, London, 1956.
31. SUTTON, D.:
A Textbook of Radiology.
E & S Livingstone, 1969 Ed. p. 432.

32. SWINSCOW, T.D.V.:

Statistics at Square One.

The MacMillan Press Ltd., 3rd Ed., 1978.

33. UNGERLEIDER, H.:

Measurement of the Heart and Aorta in Adults and
Children.

Amer. Heart. J. 24: 494, 1942.

34. W.H.O. TECHNICAL REPORT:

Future Use of New Imaging Technologies in Developing
Countries.

WHO Geneva (1985).

ACKNOWLEDGEMENTS

I sincerely wish to express my profound words of thanks to the following:

Dr.(Mrs.) M.N. Wambugu, Lecturer, Department of Diagnostic Radiology, my Supervisor for her valuable constant guidance, advice and suggestions provided throughout the preparation of this dissertation.

Dr. J.M.K. Kikonyi, Chairman and Senior Lecturer, Department of Diagnostic Radiology for his noteworthy comments, suggestions and encouragement during the initial and final stages of this work.

Prof. E.A. Franken, Chairman, Department of Radiology, University of Iowa Hospitals, Iowa City, for his crucial initial encouragement, guidance and advice, when he was a Visiting Professor in our Department.

Dr. R.N. Bowry and Dr. V.K. Talwar , Consultant Radiologists of the Department of Radiology, Nairobi Hospital, for their valuable suggestions and motivation during the course of this study.

Mr. M. Omondí, a Radiographer in the KNH X-ray Department for his immense contribution in the collection of the material.

Mr. F. Muthami, a Kenya Medical Research Institute (KEMRI) statistician, for his useful statistical and computer science expertise without which this paper completion would not be a reality.

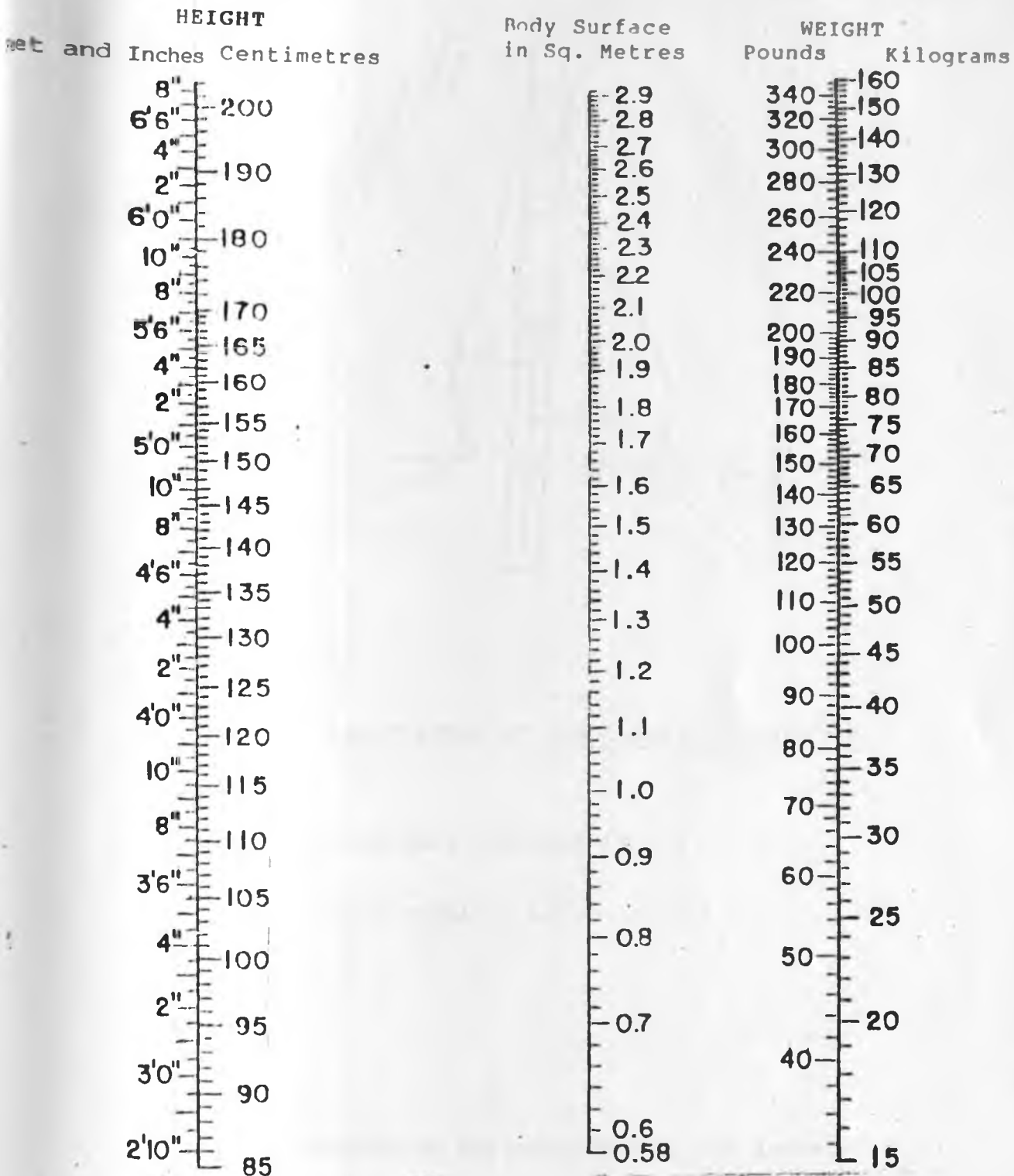
My dear wife, Mrs. Rosemary H. Mziray and my little son David Rama Mziray, whose patience, understanding and encouragement made this immense work a reality.

Miss Mary Okoth for her valuable secretarial services throughout the preparation and finalization of this dissertation.

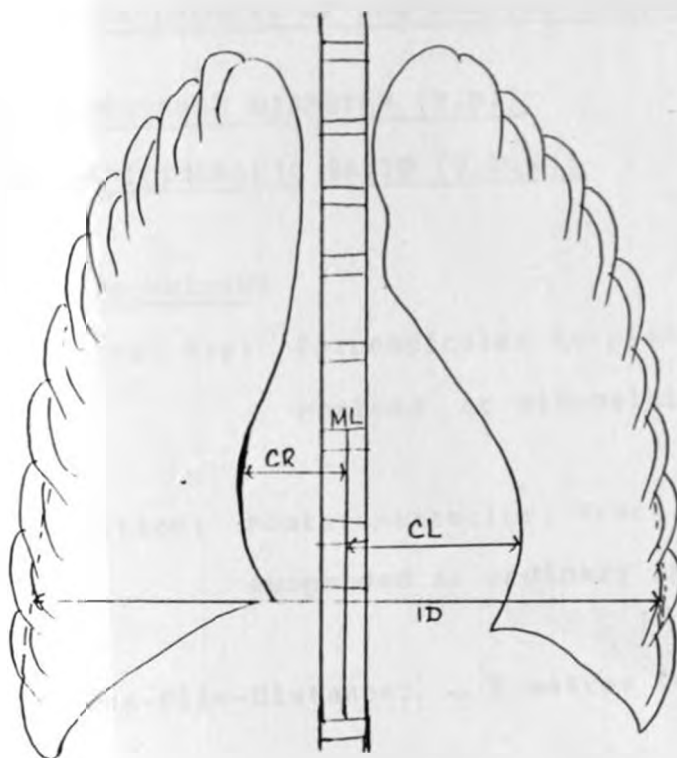
Last but not least, all the patients for their patience and understanding during the undertaking of this Study's Material.

APPENDIX A

NOMOGRAM FOR THE DETERMINATION OF BODY SURFACE AREA OF ADULTS



APPENDIX B₁



MEASUREMENT OF THE CARDIAC SILHOUETTE

- 1) THE TRANSVERSE DIAMETER (T.D.)
- 2) THE CARDIOTHORACIC RATIO (C.T.R.)

(FOR TECHNIQUE AND MEASUREMENTS SEE APPENDIX B₂).

APPENDIX B₂

MEASUREMENT OF THE CARDIAC SILHOUETTE

1. THE TRANSVERSE DIAMETER (T.D.)
2. THE CARDIOTHORACIC RATIO (C.T.R.)

I P.F.R. Technique:

1. Central Ray: Perpendicular to plane of film
centred at midposition of chest.
2. Position: Postero-anterior, Erect, Breathing
suspended at ordinary inspiration.
3. Focus-Film-Distance: \approx 2 metres (6 ft.)

II Measurements:

See Illustration of Appendix B₁.

- (i) CR (= cardiac right) = Maximum transverse diameter of the right side of the heart, which is a line drawn from the midline of the spine to the most distant point on the right cardiac margin.
- (ii) ML (= midline) = Midline of the spine.
- (iii) CL (= cardiac left) = Maximum transverse diameter on the left side of the heart.
- (iv) ID (= internal chest Diameter) = Greatest internal diameter of the thorax, which is usually at the level of the apex or one space lower, measuring the inner borders of the ribs.

Appendix B₂ contd.

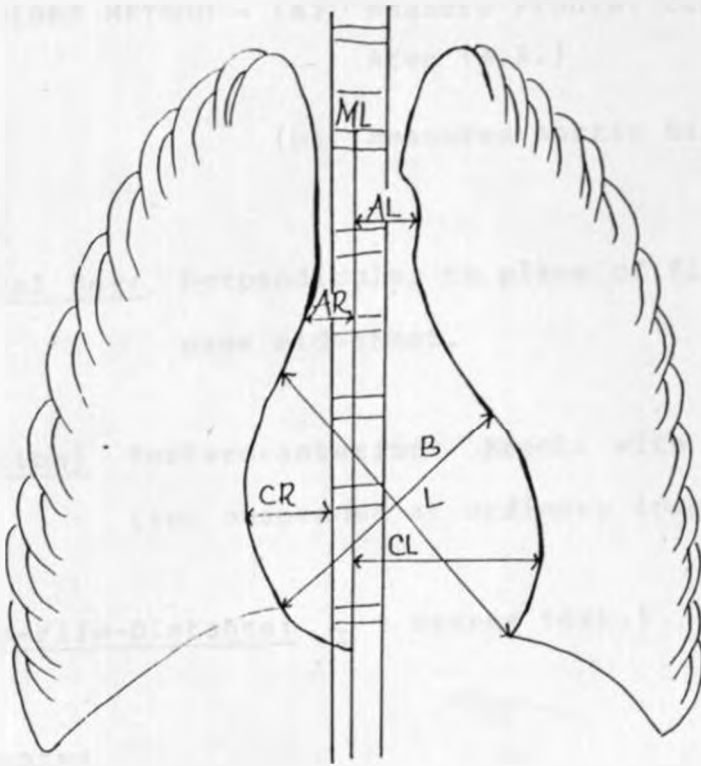
(v) The TD (Transverse Diameter of the Heart)

$$= CR + Cl.$$

(vi) The CTR (Cardiothoracic Ratio)

$$= \frac{\text{Maximum Transverse Diameter of Heart (TD)}}{\text{Maximum transverse diameter of thorax (ID)}}$$

APPENDIX C₁



MEASUREMENT OF THE CARDIAC SILHOUETTE

THE UNGERLEIDER METHOD - (a) Measure Frontal Cardiac Area (A.A.).

(b) Measures Aortic Diameter.

(FOR TECHNIQUE AND MEASUREMENTS SEE APPENDIX C₂).

APPENDIX C₂MEASUREMENT OF THE CARDIAC SILHOUETTE

THE UNGERLEIDER METHOD - (a) Measure Frontal Cardiac Area (A.A.)

(b) Measures Aortic Diameter.

I Technique:

(a) Central Ray: Perpendicular to plane of film centred over mid-chest.

(b) Position: Postero-anterior. Erect, with respiration suspended at ordinary inspiration.

(c) Focus-Film-Distance: \approx 2 metres (6ft.)

II Measurements:

See Illustration of Appendix C₁.

(i) CR = Maximum projection to the right heart border from midline.

(ii) CL = Maximum projection to the left heart border from midline.

(iii) L = Long diameter - this is the line extending from the junction of the cardiac and vascular silhouette on the upper part of the right heart border obliquely downward to the apex on the left.

(iv) B = Broad diameter - the greatest diameter perpendicular to the long diameter. This should, as a rule, extend from the upper

Appendix C₂ contd.

limit of the left ventricular contour to the lowermost point of the right heart border. When the heart was transversely placed, it was sometimes necessary to extend the lower right heart border in its natural curve to delineate the margin of the broad diameter.

(v) AR = Maximum extension of vascular pedicle to right of midline.

(vi) AL = Maximum extension of vascular pedicle to left of midline.

(vii) Aortic Diameter (AD) = AR + AL.

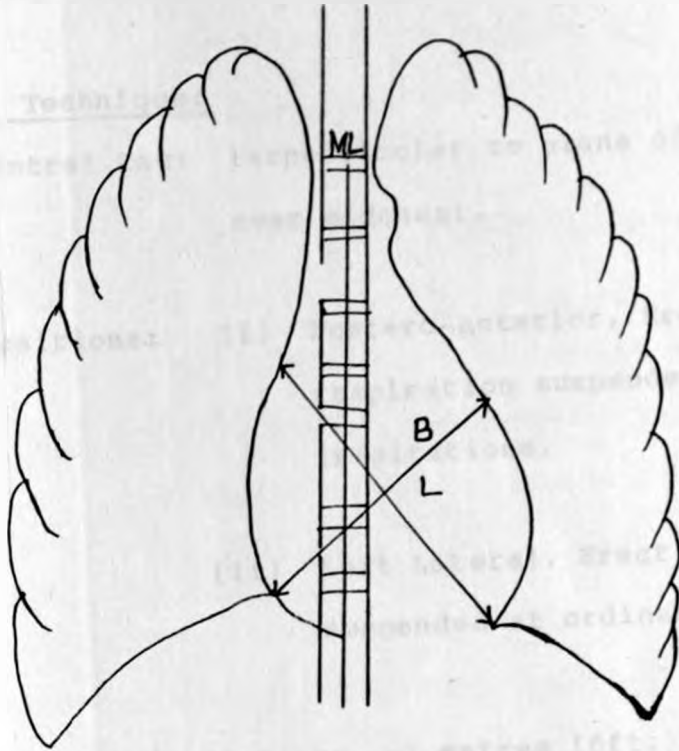
Calculations:

Calculated Frontal Area (Actual Cal. Area) (AA) = $\pi/4$ L X B

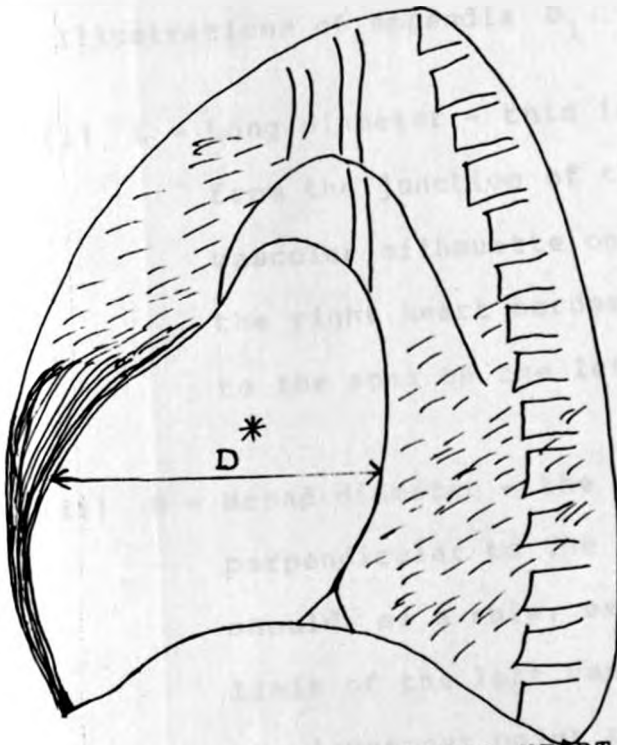
i.e., A.A. \approx 0.78 L X B

APPENDIX D
1

MEASUREMENT OF THE CARDIAC SILHOUETTE



PA VIEW OF NORMAL HEART



LATERAL VIEW OF NORMAL HEART

CARDIAC VOLUME METHOD - RELATIVE VOLUME

(FOR TECHNIQUE AND MEASUREMENTS SEE APPENDIX D₂).

MEASUREMENT OF THE CARDIAC SILHOUETTE
CARDIAC VOLUME METHOD - RELATIVE VOLUME

I P.F.R. Technique:

1. Central Ray: Perpendicular to plane of film, centred over midchest.
2. Positions: (i) Postero-anterior, Erect with respiration suspended at ordinary inspirations.
(ii) Left Lateral, Erect with respiration suspended at ordinary inspiration.
3. Focus Film Distance \approx 2 metres (6ft.).

II Measurements:

See Illustrations of Appendix D₁.

- (i) L = Long diameter - this is the line extending from the junction of the cardiac and vascular silhouette on the upper part of the right heart border obliquely downward to the apex on the left.
- (ii) B = Broad diameter - the greatest diameter perpendicular to the long diameter. This should, as a rule, extend from the upper limit of the left ventricular contour to the lowermost point of the right heart border. When the heart was transversely placed, it was sometimes necessary to

Appendix D₂ contd.

extend the lower right heart border in its natural curve to delineate the margin of the broad diameter.

(iii) D = Represents the greatest horizontal depth of the cardiac shadow - In some cases where it was difficult to determine the posterior heart border, measurement was made from the anterior border of the contrast-filled oesophagus.

III Use of the DuBois B.S.A. Determination Nomogram for obtaining the Basal Surface Area (BSA) - see Appendix B.

IV Calculations:

(i) Calculated Heart Volume (Cal. Vol.)

$$= 0.42* \times L \times B \times D.$$

0.42* = the value of K—a constant—at an F.F.D. of 200cm(6ft.) [17].

(ii) Relative Heart Volume (RV)

$$= \frac{\text{Cal. Vol.}}{\text{BSA in m}^2} = \frac{0.42 \times L \times B \times D}{\text{B.S.A. in m}^2}$$

MEASUREMENT OF THE CARDIAC SILHOUETTE

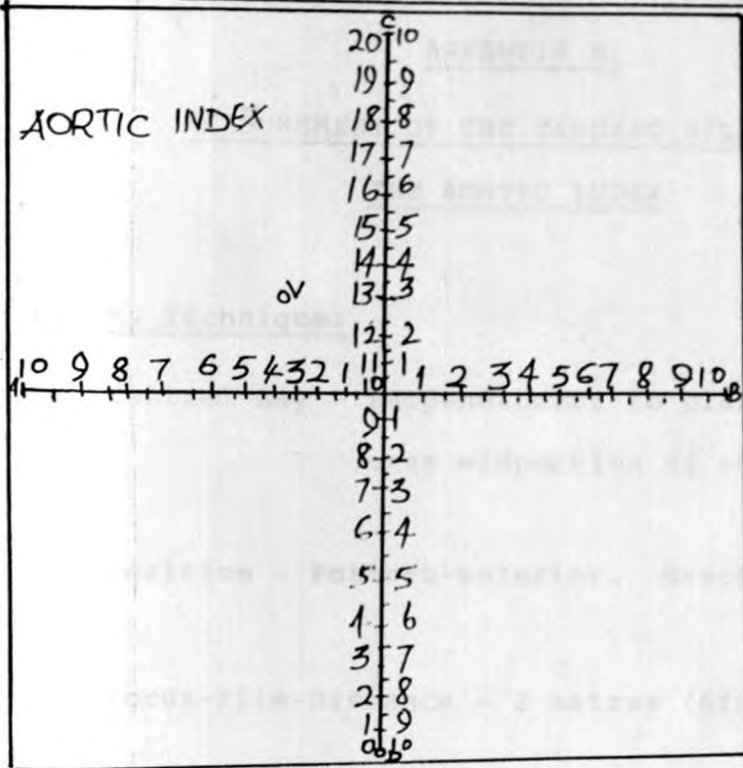


FIG. A Transparent overlay used for determining aortic index. When the overlay is properly centered over the cardiac shadow. V is approximately at the aortic valve.

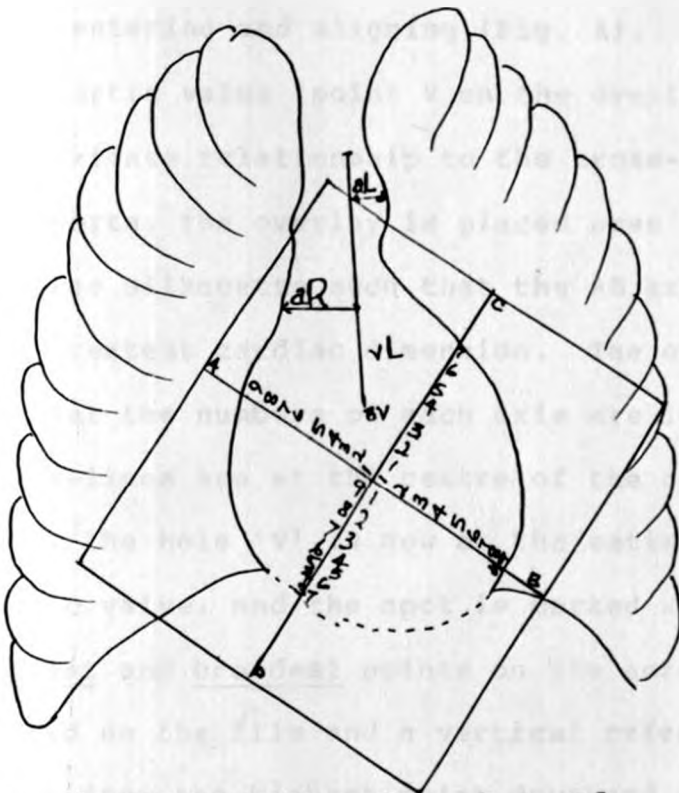


FIG. B [AORTIC INDEX = vL + aR + aL].

THE AORTIC INDEX

(FOR TECHNIQUE AND MEASUREMENTS SEE APPENDIX E₂).

APPENDIX E₂

MEASUREMENT OF THE CARDIAC SILHOUETTE

THE AORTIC INDEX

I P.F.R. Technique:

1. Central Ray - Perpendicular to plane of film centred over midportion of chest.
2. Position - Postero-anterior. Erect.
3. Focus-Film-Distance - 2 metres (6ft.).

II Measurements:

See Illustrations in Appendix E₁

A transparent overlay was made with cross-lines for centering and aligning (Fig. A). The position of the aortic valve (point V on the overlay) bears an approximate relationship to the cross-lines. To measure the aorta, the overlay is placed over the shadow of the cardiac silhouette such that the AB axis is aligned with the greatest cardiac dimension. The overlay is adjusted so that the numbers on each axis are identical and the cross-lines are at the centre of the cardiac silhouette. Then, the hole 'V' is now at the estimated site of the aortic valve, and the spot is marked with a pencil. The highest and broadest points on the aortic arch are then marked on the film and a vertical reference line is drawn from the highest point downward (Fig. B). Again using the AB and CD axes of the transparent overlay,

the height (vL) and width (aR + aL) of the aortic shadow are determined.

III Calculations:

These measurements when TOTALLED, constitute the AORTIC INDEX - i.e., A.I. = vL + aR + aL.

APPENDIX F

DATA SHEET, EVALUATION OF THE CARDIAC SILHOUETTE

A Demographic Data:

1. Name of Patient 2. Age
3. Sex 4. IP/OP Number
5. Tribe 6. Prov. Diagnosis (if any)
.....
7. Reference: Casualty Cardiac Clinic
Ward Other (specify)
8. Occupation

B Physical Examination Findings Data:

1. Height 2. Weight 3. BP
4. Body Build Asthenic (thin)
(✓) Tick Average
Thenic (thickset)
Obese
Undetermined
5. Clinical Cardiac Status (CCS)- Normal
(✓) ? Normal
Cardiomegaly
Undetermined
6. Hb Estimation Clinically - Anaemic
Not Anaemic
Undetermined

C Measured Radiological Data:

(NB. FFD = 6FT ~ 2 METRES)

- (i) TD Method (a) CR =
- (b) CL =

MEDICAL LIBRARY
UNIVERSITY OF NAIROBI

Appendix F contd.

- (ii) CTR Method (a) CR =
(b) CL =
(c) ID =

- (iii) Ungerleider Method (a) L = (b) B =
(c) AR = (d) AL =

- (iv) Cardiac Volume (RV) Method (a) L =
(b) B =
(c) D =

- (v) Aortic Index (Lodwick's) Method (a) VL =
(b) aR =
(c) aL =