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~~LIST OF PROCEDURES DONE~~

PROJECT REPORT

TITLE OF THE PROJECT: BRAIN ASYMMETRY IN SITUS INVERSUS

NAME T.A. SUBRAMANIAN

PROGRAMME: D.M. NEUROLOGY

MONTH & YEAR
OF SUBMISSION: NOVEMBER, 1988.

CERTIFICATE

I, Dr. T.A. SUBRAMANIAN .....hereby declare that I have actually performed all the procedures listed/carried out the project under report.

Signature.....

Place: TRIVANDRUM

Name in T.A. SUBRAMANIAN
capital letters

Date: 12..11..1988

C E R T I F I C A T E

Certified that the project entitled BRAIN ASYMMETRY IN SITUS INVERSUS has been done by DR. T.A. SUBRAMANIAN under my guidance and supervision.

14.11.88.

Sd/-
DR. P.K. MOHAN. M.D., D.M.,
ASSOCIATE PROFESSOR AND HEAD OF-
DEPARTMENT OF NEUROLOGY,
SCTIMST, TRIVANDRUM.

A C K N O W L E D G E M E N T

I wish to express my gratitude to Dr. P.K. Mohan Head of Department of Neurology SCTIMST TRIVANDRUM for encouraging me to take up this project and guiding me throughout. I wish to thank Prof. K.G. Balakrishnan Head of Department of Cardiology SCTIMST TRIVANDRUM for permitting me to study patients with Anomolous Visceral and or cardiac situs. I am indebted to Dr. Santosh Joseph and Prof. V.R.K. Rao Department of Radiology SCTIMST TRIVANDRUM, without whose co-operation this study would not have been possible. I will be failing in my duty if I don't acknowledge the support extended by Prof. M.S. Valiathan Director SCTIMST TRIVANDRUM for this project. My friend Dr. Sanjeev Thomas was kind enough to provide me the data on cerebral dominance in control population.

SCTIMST TRIVANDRUM,

12th NOVEMBER, 1988.

DR. T.A. SUBRAMANIAN
P.G. RESIDENT NEUROLOGY.

PROJECT SYNOPSIS

Title of the Project:		BRAIN ASYMMETRY IN SITUS INVERSUS
Duration	:	6 Months
Aim and Scope of the study	:	To study the pattern of Brain asymmetries using Computerised Tomography head and pattern of cerebral dominance for hand, leg, eye and ear in patients with anomolous visceral and or cardiac situs and compare these patterns with those observed in people with normal visceral and cardiac situs. Also evaluate the correlation between anatomical asymmetries observed on CT Head and functional lateralisation suggested by study of Hand/Leg/Ear dominance.
Summary	:	Seven subjects with anomolous visceral and or cardiac situs and normal neurological status underwent standardised tests of dominance for Hand/Leg Ear and Eye and CT Head. In the study group a pattern of Predominant or strong right side dominance for hand, leg, eye and ear and an inversion of normal radiological asymmetries viz. PETALIA, tilt of STRAIGHT SINUS and position of SYLVIAN FISSURE was observed suggesting an anatomical inversion of hemispheres. Occurrence of right side predominance for Hand, Leg, Eye and Ear despite inversion of radiological asymmetries suggests that structural brain asymmetries can occur independent of functional dominance for Hand, Leg, Eye and Ear. The occurrence of anatomical brain inversion in a setting of anomolous visceral and or cardiac situs suggests that visceral and cerebral asymmetries go hand in hand and could possibly result from a single embryological insult.

CONTENTS

BRAIN ASYMMETRY IN SITUS INVERSUS

INTRODUCTION

Studies on Human Brain Asymmetry provide better understanding of cerebral dominance and the mechanisms underlying abnormality of lateralisation. The direction of Brain asymmetries in humans, is consistent throughout most of the population. Most individuals are right handed with left hemispheric dominance for speech, and postmortem[1] and radiological[2] studies have suggested an anatomic basis for such asymmetries. The relationship postulated between Brain asymmetrie and other asymmetries found in human body is a major point of difference among various theories. Corballis and Morgan[3] (1978) have proposed that both visceral and brain asymmetries are the result of a single embryologic left - right gradient found in a developing oocyte. In contrast Annet M[4] (1978) has proposed that Brain asymmetries and asymmetries of other internal organs are inherited independently. A study of Brain asymmetries in SITUS INVERSUS can test these hypotheses effectively.

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REVIEW OF LITERATURE:- Brain is an asymmetrical organ and Anatomical Biochemical as well as Neurophysiological differences exist between the sides. RL_1

ANATOMICAL ASYMMETRIES:

TABLE - I

Structure	Handedness								Comments
	RH				LH				
	N	L	RL	R	N	L	RL	R	
Frontal Lobe[5]	297	28	23	49					Petalia in East African Skulls No handedness, percentages
Frontable Lobe[6]	174	9	21	70	49	21	40	39	Width by CT SCAN: Adults and Children: percentages.
	206	7	63	30	58	21	60	19	Petalia by CT SCAN: Adults and percentages.
Frontable Lobe[7]	130	18	26	56	121	32	40	36	CT Width. Right/Left handers percentages.
	130	14	20	66	121	36	28	37	CT Petalia Right/Left Handers Percentages
Frontal Lobe[8]	50	8	56	36	25	16	56	28	CT: Petalia: Percentages, LH includes ambidextrous.
	50	22	42	36	25	20	32	48	CT Width. Right/Left handers percentages. LH includes ambidextrous.
Frontal Lobe[9]	125-132	18	43	39	17-12	18	35	47	CT. Width. Right/Left Handers Percentages
	125-132	11	51	38	17-22	24	41	35	CT Lengths, Right/Left nanders percentages.

TABLE I Contd.

Structure	Handedness									Comments
	N	L	RL	R	N	L	LH	RL	R	
Frontal lobe[10]	300	20	36	44						CT width. Handedness not mentioned percentages.
	300	18	60	22						CT Petalia. Percentages No mention of Handedness.
Frontal lobe[11]	5	1	0	4						Petalia in Endocasts of Solman No Handedness.
Frontal lobe[12]	40			80						Volume of frontal lobe from YAKOVLEV COLLECTION Adults, children, and infants. No Handedness percentages.
Inferior Frontal gyrus[13]	100	24.5		26.7						Mean convexity area of opercular portion. Adults. No handedness.
	85	21.7		25.8						Mean convexity area of opercular portion. Infants and fetuses. No handedness.
Inferior frontal gyrus[14]	102	26	61	13						Brains with extrasulcus in Pars opercularis: Adults + children. No handedness percentages.
Inferior frontal gyrus[15]	54	44	39	17						Convexity area of pars opercularis and pars triangularis. No handedness: adults children.
	10	66	17	17						
	4	0	100	0						Infants
Inferior frontal gyrus[16]	12	8	1	3						Total area of frontal operculam.
Inferior frontal gyrus[14]	10	6	3	1						Total volume of opercular architectonic area 44. No handedness adults + children.

TABLE I Contd.

Structure	Handedness RH N	RH L	RH LR	RH R	LH N	LH L	LH LR	LH R	Comments
Temporal Lobe[17]	75	75	12	13					Area of PT. No Handedness Percentages.
Temporal Lobe[18]	100	65	24	11					Length of lateral edge of PT, adults. No handedness: Percentage.
Temporal Lobe[19]	100	75	12.5	12.5					Area of PT. Adults. No Handedness. Percentages.
Temporal Lobe[20]	16	81							Length of PT. No handedness Percentages. Adults.
	14	86							Infants
	16	69	0	31					Area of PT. No handedness. Percentages Adults.
	14	79							Infants
Temporal Lobe[13]	100	82	8	10					Area of PT. No handedness. Percentages. Adults.
	100	56	32	12					Infants
Temporal Lobe[21]	21	67							Length of PT. No handedness Adults. Percentages
Temporal Lobe[22]	30	3	47	50					Percentages with more than Heschl's gyrus. Adults and Children. No handedness.
Temporal Lobe[23]	103	77	1	22					Area of P.T. No handedness Percentages
Temporal Lobe[15]	54	83	9	7					Area of PT. No handedness. Percentages Adults.
	10	70	20	10					Children
	4	50	50	0					Infants.

TABLE I Contd.

Structure	Handedness RH				Handedness LH				Comments
	N	L	LR	R	N	L	LR	R	
Temporal Lobe[16]	12	10		2					Area of PT
Temporal Lobe[24]	4	3	1						Volume of Architectonic area TPT. Children and Adults. No handedness
Occipital Lobe[5]	297	52	24	24					Petalia in East African skulls. No handedness. Percentages.
Occipital Lobe[6]	156	64	20	16	50	22	32	16	Width by CT Scans. Adults and Children. Percentages.
	269	69	22	9	62	56	24	20	Petalia by CT Scan. Adults and Children percentages.
					40	37	39	24	Width by CT Scan. Adults and Children Percentages. Familial LH.
					37	59	22	19	No familial LH
					41	29	32	39	Petalia by CTS can. Adults + Children. Percentages. Familial LH.
					39	59	15	26	No familial LH.
Occipital Lobe[7]	130	66	25	9	121	38	33	27	CT. Width. Right/Left Handers percentages.
	130	77	11	13	121	36	29	35	CT. Petalia. Right Left Handers Percentages.

RL_4

TABLE I Contd.

RL5

Structure	Handedness RH N	RH L	RH LR	RH R	LH N	LH L	LH LR	LH R	Comments
Occipital Lobe[8]	50	36	44	20	25	64	32	4	CT Width. Right/Left Handers. Percentages LH includes Ambidextrous
	50	60	20	20	25	44	36	20	CT Petalia. Right/Left handers Percentages. LH includes Ambidextrous
Occipital Lobe[9]	125-132	59	23	19	17-22	50	30	20	CT. Width Right/Left handers. Percentages
	125-132	60	16	24	17-22	60	15	25	CT. Length. Right/Left Handers. Percentages.
Occipital Lobe[10]	300	56	29	15					CT. Petalia. Percentages. No Handedness
Occipital Lobe[11]	5	4	1	0					Petalia in Endocasts of Soloman. No handedness
Occipital Lobe[12]	40			80					Volumes of occipital lobe from YAK OVLEV Collection. Adults, Children, Infants. No handedness. Percentages.
Parieto[10] occipital area	300	49	31	20					CT. Width measurement. Percentages. No Handedness
Occipital horn[25]	87	60	30	10	13	38	31	31	Length by PEG. Percentages
Occipital horn[26]	75	39	44	17					Length by PEG. Children. Some with neurological abnormalities. No handedness. Percentages.

TABLE I Contd.

Structure	Handedness								Comments
	RH				LH				
	N	L	LR	R	N	L	LR	R	
Parietal Lobe[27]	8	5	1	2					Volume of Architectonic area P.G. Direct Correlations with asymmetry in PT. Adults and children. No handedness.
Sylvian Fissure[28]	44	5	9	86	19	11	72	17	Height of Posterior end of sylvian fissure on carotid Angiograms. Adults and children. percentages.
Sylvian Fissure[29]	100	7	26	67	18	7	71	22	Height of Posterior end of Sylvian fissure on carotid angiogram. Adults and children. percentages.
Sylvian Fissure[21]	36	75							Length of Sylvian Fissure adults. No handedness. Percentages.
Sylvian Fissure[30]	25	84	0	16					Length of Sylvian Fissure. adults No handedness. Percentages.
Sylvian Fissure[31]	38	21	21	58	20	15	35	50	Height of Posterior end of Sylvian Fissure on carotid angiogram. percentages.
Sylvian Fissure[10]	300	70							CT observation of further position of posterior end of sylvian fissure . Percentages. No handedness.
Thalamus[32]	9	8	0	1					Volume of Nucleus Lateralis posterior. Adults. children. No Handedness.
Bulbar Pyramids[33]	123	73	10	17	7	86	0	14	Side from which decussation is higher in the brainstem. Adults and children. Percentages.

Pineal position[6] More Often Left of midline than Right.

TABLE I Contd

RL7

Structure	Handedness RH N	RH L	RH LR	RH R	LH N	LH L	LH LR	LH R	Comments
Pineal position[10]	Left of Midline 45% central 53%				Right of Midline 2%				
Straight Sinus[8]	50	18	72	10	50	25	75	25	Tilt of straight sinus in CT posteriorly in Right/Left handers. Percentages.
Frontal Horn[34]	100	62	6	32					CT measurements in 100 normal adults. No difference in R-L Anterior horn measurements. No handedness.
Frontal Horn[35]	Left septocaudate distance wider than Right Left anterior Horn and size of skull larger in boys.								CT measurement in normal children. No handedness

List of Abbreviations

R = Right - More than Left L = Left more than Right RL = Right = Left RH = Right Handed LH = Left Handed

CT = Computerised tomography PT = Planum Temporale TPT = Temperoparietal architectonic region

A = Angiogram PG = Architectonic area in Inferior Parietal Lobule PEG = Pneumo encephalogram.

TABLE II

Observation	Author
1. Brodmann area 22 has greater Choline Acetyl transferase activity on the left side with more pronounced asymmetry over posterior portion of left superior temporal gyrus	Amaducci (1981)[36]
2. Content of Norephenephrine inthalamus higher in left pulvinar and Right venterobasal-complex	Oke (1978)[37]

TABLE III

NEUROPHYSIOLOGICAL ASYMMETRIES

Test	Observations/Comments
1. EEG[28]	Asymmetry of Alpha rhythm seen in 60% Adults. In 50% higher voltage seen on Right side without concurrent correlation with handedness. Asymmetry between sides Less than 20% in 8.3% More than 20% in 17" More than 50% in 1.5%
2. Event Related Potential[39]	Spectral analysis of visual and Auditory evoked responses in Right and Left handed subjects show left hemispheric speech dominance.
3. Cerebral Blood flow[40,41]	(40) ophthalmic artery pressure by ophthalmodynamometry reflects Ipsilateral Internal carotid arterial pressure and Blood Flow characteristics.

	Right Handers				Ambidextrous				Left Handed			
	N	L	LR	R	N	L	LR	R	N	L	LR	R
Extreme	68	1%	18%	81%	9	11%	67%	22%	13	62%	23%	15%
Moderate	20	15%	25%	60%								

(41) Radioisotope cerebral blood flow mapping.

Right Handers				Left Handers			
N	L	LR	R	N	L	LR	R
60	25%	13%	62%	25	64%	8%	28%

4. Cerebral Metabolism[42]

- Using Fluorodeoxyglucose (Radioisotope labled) and Positron Computerised Tomography.
- Metabolic pattern over occipital lobes symmetrical.
- In Right handed individuals verbal stimulus evokes left sided asymmetries in activity and Non verbal stimulus evokes right sided asymmetries.

Abbreviations: L = Left more than Right R = Right more than Left LR = Left = Right

MATERIALS AND METHODS

Seven patients five males and two females in the age group of 7-18 years (Mean 11.85 years) registered in the cardiology section of Sree Chitra Thirunal Institute for Medical Science and Technology Trivandrum with anomolous visceral situs or cardiac situs or both were enrolled for the present study (TABLE IV). These patients did not have any history of serizures or neurological deficits.

TABLE - IV

	NAME	AGE/SEX	HOSPITAL NUMBER	DIAGNOSIS
1.	ROSHINI	11 F	8803196	DEXTROCARDIA, SITUS INVERSUS OSTIUM SECONDUM ASD.
2.	SHEEJA	11 F	10583	DEXTROCARDIA SITUS INVERSUS CORRECTED TGV.
3.	SHAJI	9 M	19227/82	DEXTROCARDIA SITUS INVERSUS TGV/VSD/PS.
4.	CILIKUMAR	16 M	8803570	MESOCARDIA SITUS INVERSUS TGV.
5.	ROY	18 M	37840	MESOCARDIA SITUS INVERSUS VSD PS.
6.	PRAVEEN	7 M	17024	DEXTROCARDIA SITUS SOLITUS SINGLE VENTRICLE. PS.
7.	RANJAN	11 M	0946	LEVOCARDIA SITUS INVERSUS CORRECTED TGV.

A.S.D. ATRIAL SEPTAL DEFECT P.S. PULMONARY STENOSIS
V.S.D. VENTRICULAR SEPTAL DEFECT
T.G.V. TRANSPOSITION OF GREAT VESSELS

A. Initial neurological Evaluation: These patients underwent Neurological assessment following which they were subjected to standardised battery of tests for determination of hand, leg eye and ear dominance (Appendix A)[43]. All of them underwent Computerised Tomographic Examination of the head.

B. Determination of Dominance of hand, leg, eye and ear: All patients underwent tests for handedness which involved performance of Coarse movements, Fine movements and Time bound precission movements, leg preference for Fine as well as Coarse movements and eye and ear preference for specific tasks and their performance rated by two observers.

C. Computerised Tomographic Scan Head: (CT HEAD) All seven subjects underwent CT HEAD STUDY using HITACHI SCANNER MARKCTWL. The scans were obtained in a set of parallel planes angulated 15° to the orbitomeatal line and the images recorded onto transparent films. Using an overhead projector the images in the transparent film were projected onto a Screen and the contours of the inner outer tables traced and the midline structures identified.

1. Determination of Petalia:- The lowest section showing the Frontal horns and Trigones identified and the section chosen for measurement of hemispheric asymmetry. The

sagittal line was drawn through the anterior falx, septum pellucidum extending upto the inner table of the occipital bone and perpendiculars to the anterior and posterior extents of the inner table drawn thereby defining the antero posterior diameter of the skull (AP). Where there were asymmetry in the frontal or occipital protruberances, the degree of petalia was quantified by dividing the differences in the AP projection $L_R - L_L$ by AP Diameter of the skull.

$$PET = \frac{L_R - L_L}{AP}$$

(R) sided petalia was indicated by +ve and (L) sided petalia by -ve values (Reference - 8) Figure 1.A.

2. Determination of widths of Frontal and Occipital lobes:

Additional lines were drawn perpendicular to the sagital line at points lying at distance 16% and 90% of total posterior to anterior diameter of the skull. These points were so selected that their respective perpendiculars would traverse the occipital lobes and the region of the middle inferior frontal gyrus respectively (Reference 8, Figure 1A). The right and left transeverse deminisions were compared in each region by dividing their difference by their sums.

$$W = \frac{T_R - T_L}{T_R + T_L}$$

Again positive value signifies right sided

predominance and negative value left sided predominance. Differences were recorded if the absolute value was equal or greater than 0.02 which corresponded to a difference of approximately 1mm. (Viz accuracy of a millimeter scale).

3. Position of Straight sinus:- Wherever possible the position of Straight sinus in relation to sagittal line commented upon in the CT Frame used for computing petalia and widths of Frontal/Occipital lobe.

4. Position of Pineal gland:- Wherever possible the position of Pineal gland in relation to the sagittal line commented upon in the CT frame used for computing Petalia and widths of Occipital and Frontal lobes.

5. FRONTAL HORN: In the CT section showing the Frontal horns and Trigone clearly the outer most portions of the frontal horns of the lateral ventricles identified and their position V_R/V_L in relation to the sagittal line measured and at the same position. The distance between the sagittal line and the inner table of skull measured FR/FL and the EVAN's INDEX V_L/F_L VS V_R/F_R on either side compared figure 1.A./IB.

6. SYLVIAN FISSURE:- The CT Head Section showing the Third ventricle, atria and insular region was used to identify the posterior as well as the medial extent of Sylvian Fissure and the position of this point in relation to the inner table of skull on either side commented upon Figure 2.

7. Occipital horn:- The CT Head section displaying the occipital horns clearly was used to identify its posterior most extent. A perpendicular was drawn at the posterior extent of the inner table and the relative position of the occipital horns commented upon. Figure - II.

RESULTS

The patients population was divided into four groups based on their cardiac and visceral status.

GROUPS	NUMBERS OF PATIENTS	DESCRIPTION
GROUP I	7	ABNORMAL VISCERAL AND OR CARDIAC SITUS. REPRESENTS THE ENTIRE GROUP OF PATIENTS WITH ANOMOLOUS CARDIAC/VISCERAL SITUS.
GROUP II	1	NORMAL VISCERAL SITUS WITH ABNORMAL CARDIAC SITUS
GROUP III	1	ABNORMAL VISCERAL SITUS WITH ABNORMAL CARDIAC SITUS
GROUP IV A	5	ABNORMAL VISCERAL SITUS WITH ABNORMAL CARDIAC SITUS
IV A	3	ABNORMAL VISCERAL SITUS - SITUS INVERSUS ABNORMAL CARDIAC SITUS - DEXTROCARDIA
B	2	ABNORMAL VISCERAL SITUS - INVERSUS ABNORMAL CARDIAC SITUS - MESOCARDIA.

TABLE - VI DATA ON HAND/LEG/EYE DOMINANCE

PATIENTS GROUP - DATA ON DOMINANCE	GROUP I (%)				GROUP II (%)				GROUP III (%)				GROUP IVA(%)				GROUP IV B(%)			
	No.	R	L	RL	No.	R	L	RL	No.	R	L	RL	No.	R	L	RL	No.	R	L	RL
I. HANDEDNESS																				
1. Coarse Movements																				
Hand preferred for																				
a. Combinghair	7	100	0	0	1	100	0	0	1	100	0	0	3	100	0	0	2	100	0	0
b. Using a Spoon	7	85.7	14.3	0	1	100	0	0	1	100	0	0	3	100	0	0	2	50	50	0
2. Precision Movements																				
Hand preferred for																				
a. Cutting	7	85.7	14.3	0	1	100	0	0	1	0	100	0	3	100	0	0	2	100	0	0
b. Passing a needle through printed dots	7	100	0	0	1	100	0	0	1	100	0	0	3	100	0	0	2	100	0	0
3. Time Bound Precision tests																				
a. Cutting a circle out of paper	7	85.7	14.3	0	1	100	0	0	1	0	100	0	3	100	0	0	2	100	0	0
b. Passing a needle through printed dots	7	57.1	42.9	0	1	100	0	0	1	0	100	0	3	66.6	33.3	0	2	50	50	0
II. LEG DOMINANCE																				
1. Coarse Movements																				
a. Kicking	7	100	0	0	1	100	0	0	1	100	0	0	3	100	0	0	2	100	0	0
b. Leg crossing	7	100	0	0	1	100	0	0	1	100	0	0	3	100	0	0	2	100	0	0
2. Precision movements																				
a. Foot used for drawing a circle	7	85.7	14.3	0	1	100	0	0	1	100	0	0	3	66.6	33.3	0	2	100	0	0
b. Accuracy of circle drawn	7	42.9	14.3	42.9	1	0	0	100	1	0	0	100	3	66.6	33.3	0	2	50	0	50
III. EYE DOMINANCE	7	57.1	42.9	0	1	0	100	0	1	0	100	0	3	66.6	33.3	0	2	100	0	0
IV. EAR DOMINANCE	7	85.7	14.3	0	1	100	0	0	1	100	0	0	3	66.6	33.3	0	2	100	0	0

DATA ON CT HEAD ASYMMETRIES

TABLE - VII

NORMAL	REF	No. Pts.	FRONTAL WIDTH L LR R	FRONTAL LENGTH* L LR R	OCCIPITAL WIDTH L LR R	OCCIPITAL LENGTH* L LR R	PINEAL POSITION L LR R	ST.SINUS POSITION L LR R	OCC.HORN L LR R	SYL.FIS L LR R	EVAN'S INDEX L LR R
DATA ON RIGHT HANDED	6	174	9 21 70								
	6	206		7 63 30			L				
	6	150			64 20 16						
	6	269				69 22 9					
	7	130	18 26 56	14 20 66	66 25 9	77 11 13					
	8	50	22 42 36	8 56 36	36 44 20	60 20 20		8 72 20			
	9	125-132	18 43 39	11 51 38	59 23 19	60 16 24					
	10	300	20 36 44	18 60 22	49 31 20		45 53 2			70	
**PEG DATA	25**	87							60 30 10		
	26**	75							39 44 17		
	21	36								75	
	30	25								84 - 16	
	34										PROMINENT - L SEPTO -CAUDATE
	35										
PATIENT DATA											
GROUP I		7	29 29 43	57 43 0	71 0 29	14 0 86	Data on 5 60 20 20	Data on 6 67 17 17	Data on 6 67 33 0	Data on 6 P 29 0 71 M 29 0 71	14 14 72
GROUP II		1	0 0 100	100 0 0	100 0 0	0 0 100	100 0 0	100 0 0	No data 0 0 0	Data on 1 P 0 0 100	0 0 100
GROUP III		1	0 0 100	0 100 0	100 0 0	100 0 0	100 0 0	100 0 0	100 0 0	Data on 1-M 0 0 100 P 0 0 100 M 0 0 100	0 100 0
GROUP IV		5	40 40 20	60 40 0	60 0 40	0 0 100	Data on 3 33 33 33	Data on 4 50 25 25	60 40 0	P 40 0 60 M 40 0 60	20 0 80
GROUP IV. A.		3	0 67 33	33 67 0	67 0 33	0 0 100	Data on 2 0 50 50	Data on 2 50 0 50	67 0 33	P 33 0 67 M 33 0 67	33 0 67
GROUP IV. B.		2	100 0 0	100 0 0	50 0 50	0 0 100	Data on 1 100 0 0	50 50 0	50 0 50	P 50 0 50 M 50 0 50	0 0 100

* = PETALIA P = POSTERIOR EXTENT OF SYLVIAN FISSURE M = MEDIAL EXTENT OF SYLVIAN FISSURE

** PEG = PNEUMOENCEPHALOGRAM OCC. = OCCIPITAL SYL. = SYLVIAN FIS. = FISSURE REF. = REFERENCE.

DISCUSSION

I. Data on Hand Leg/Eye and Ear dominance

The tests for Hand, Leg, Eye and Ear preference showed very strong or predominant right sided preference with none showing a left sided predominance. The occurrence of right sided dominance in the setting of anomolous visceral and or cardiac situs is of considerable significance. Three large studies[44-46] on situs inversus have found that the incidence of left handedness in these groups was the same as in the normal population suggesting thereby the predominance of right handedness in humans is unrelated to asymmetries of other internal organs.

II. Data on CT Asymmetrics

(A) Hemispheric projections: (Petalia): In the present study a trend towards left frontal petalia or frontal symmetry was observed with none showing right frontal petalia. All but one (Group III) had predominance of right occipital petalia.

These observations are at variance with the predominant left occipital petalia, frontal symmetry or right frontal petalia observed in normal right handed individuals by several authors[6-10].

(B) Hemispheric widths: A trend towards wider left occipital lobe was observed in all the groups except IVB but no consistent pattern was evident in frontal lobe widths. A pattern of wider Right frontal lobe and left occipital lobe has been highlighted by various authors 6-10 in normal right handed individuals and also in these individuals there is a tendency for the wider right frontal lobe and left occipital lobe to project further in comparison to their opposite halves. In left handers there tends

to be a higher percentage of individuals without striking asymmetries and with asymmetries which are the reverse of those most commonly seen in right handers. In the present study a combination of right occipital petalia with frontal symmetry or left frontal petalia was noticed despite the fact that the study population had shown strong or predominant Right hand dominance thereby showing a lack of correlation between hand dominance and cerebral asymmetries. Lack of correlation between cerebral symmetry and handedness has been highlighted by Chang Chui et al[8]. There was a tendency for left occipital lobe to be wider but despite this the right occiptal petalia was more prominent.

C. Pineal gland: Pineal gland seemed to be more often to the left of midline except in group IV and particularly in IVA where it was either in midline or lie to the right of midline. Pineal position to the left of midline or in midline has been observed in normal population and has been ascribed to be due to a wider right central hemisphere.

D. Straight Sinus: Straight sinus tilt to the left was observed more than right or central location in this study and this is in contrast to the predominant central alignment or right ward tilt reported in normal right handed individuals[8]. Straight sinus alignment to the right side may be due to a wider left occipital lobe which is seen in normal right handed individuals and in the present study a straight sinus tilt to the left observed despite a tendency for the left occipital lobe to be wider thereby proving

the lack of correlation between occipital width and the straight sinus inclination.

E. Occipital horn: There was a trend towards more posterior extension of the occipital horn on the left side in all the groups except group IV B where the occipital horn extended posteriorly on the right side. Pneumoencephalo graphic data[25,26] reveal a tendency for the occipital horn to project further more often on the left side than on the right side.

F. Sylvian Fissure: Sylvian fissure was observed to extend more medially and posteriorly on the right side more often than the left side in all four groups. Shapiro et al[10] observed that the posterior end of the left syliven fissure entended more posteriorly then the right side in 70% of the patients.

G. Frontal Horn Dimensions/Evan's Index: Evan's Index on the right side appeared to larger more often on the left except in group III. The fallacies regarding ventricular measurement on CT Head as against Premoencephalogram have been highlighted by LeMay[47]. She observed the body of the lateral ventricle to the slightly larger on the right side. Gyldensted[34] found the septo caudate distance wider on the left side in 62%, right side in 32%. With greater difference among males than females. They however did not find any difference in the measurements of Right and Left Frontal horns. Pedersen[35] found that in children the left septocaudate was wider more often than right and the width of the left anterior horn and the size of the skull were larger in boys.

Several radiological observations on the pattern asymmentry in the present study group viz. the petalia, tilt of the streight sinus and position of the sylvien fissure have shown an inversion of the commonly observed radiological asymmetries suggesting a possible anatomical hemispheric inversion. Pieniadz et al[48] have observed significant correlation between the occipital length asymmetry on CT Scan and the Planum Temporale length found at autopsy. The feel that CT Scan asymmetries may be the indices of underlying anatomical asymmetries which in turn might underline functional asymmetry observed in human being especially those pertaining to language. Asymmetries pertaining to the Planum temporale[13,14,18,20] have been implicated to underline the cerebral dominance for speech. In this context the observed inversion of Brain anatomical pattern in Situs Inversus/Dextrocardia has profound significance. Despite anatomic brain inversion there was a strong or predominant Right sided preference for Hand, Leg, Ear and Eye which suggests that anatomical pattern do not correlate well with dominance for hand, leg, ear and eye. Deuel et al[49] did not find any significant correlation between hemespheric configuration and handedness and felt that although there may be statistical relationship between cerebral configuration and handedness in large groups of subjects, hemispheric asymmetries found on routine CT Head cannot serve as predictors of cerebral dominance in children. Corballis and Morgan[3] had proposed that both visceral and brain asymmetrices are the result of single embryological Left Right gradient, and the observation of inversion of cerebral hemispheric asymmetries in Situs Inversus/dextrocardia suggesting an inversion

of cerebral hemispheres is inaccordance with the views expressed by them. Detailed studies of functional lateralisation as well as autopsy studies of brains in patients with Situs Inversus/Dextrocardia will define the significance of the inversion of commonly observed. Radiological asymmetries in CT Head. The report of occurrence of aphasia in a patient with situs inversus and left hemispheric infarct by woods[50] makes the correlation between structural asymmetries and functional lateralisation more intriguing.

CONCLUSIONS

1. A pattern of predominant or strong pattern for right side dominance for hand leg ear and eye was observed in patients with anomolous visceral and or cardiac situs.

2. The occurrence of Right side prominance for hand leg eye and ear in a setting of anomolous visceral and or cardiac situs suggests that the pattern of dominance occurs independent of the visceral/cardiac situs.

3. An inversion of commonly observed radiological asymmetries in CT Heads ie. Petalia, tilt of straight sinus and position of sylvian fissure was observed in patients with anomolous visceral and or cardiac situs.

4. Inversion of radiological asymmetries in CT Head suggests the possibility of anatomical cerebral hemespherical inversion.

5. Despite inversion of radiological asymmetries in patients with anomolous visceral and or cardiac situs there was predominant or strong pattern for right sided dominance for hand leg, eye and ear suggesting that structural brain asymmetries can occur independent of functional dominance for hand, eye ear and leg.

6. Detailed studies of functional lateralisation as well as autopsy studies including the cytoarchitectonic patterns of Brains in patients with anomolous cardiac/ visceral situs are required to define the significance of inversion of commonly observed radiological asymmetries in CT Head.

7. The occurrence of radiological asymmetries suggesting a possible cerebral hemispheric inversion in a setting of anomolous visceral/cardiac situs seems to support Corballis and Morgan's[3] theory that both Visceral and Brain asymmetries are the result of single embryological left-Right gradient.

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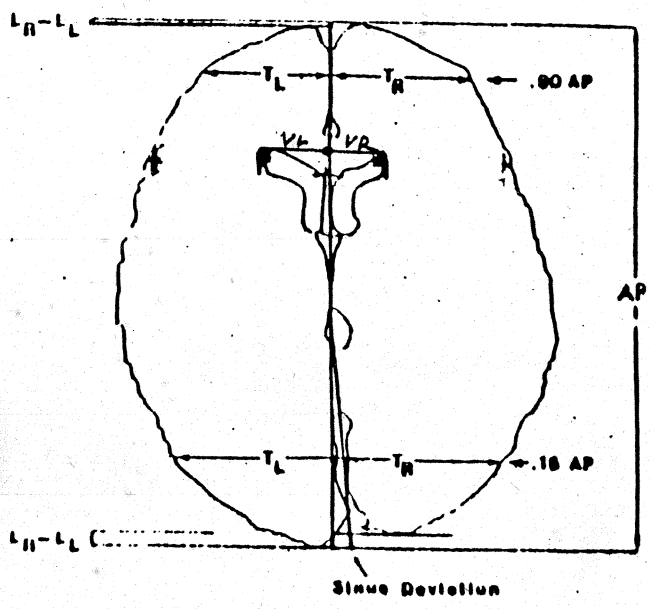


FIGURE I. A.

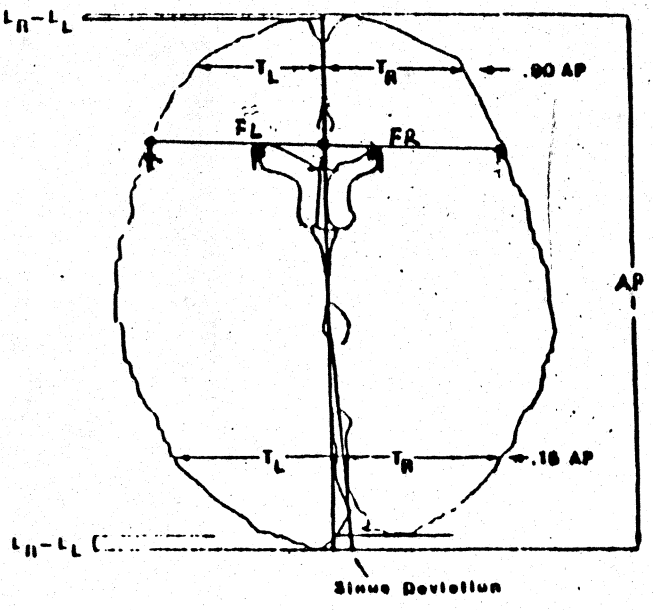


FIGURE. IB.

CT HEAD ASYMMETRIES SEEN IN ANOMOLOUS VISCERAL AND/OR CARDIAC SITUS

FIGURE - II: Shows (A) More Posterior and Medial Extent of Sylvian Fissure Right Side.

(B) Leftward inclination of straight sinus

(C) More posterior location of left occipital ~~sinus~~ horn

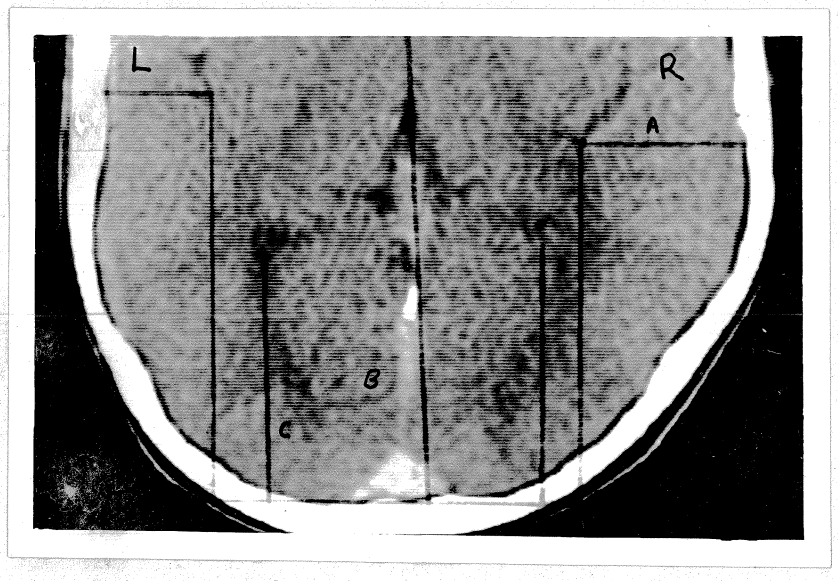


FIGURE - III: Right Occipital Petalia [A]

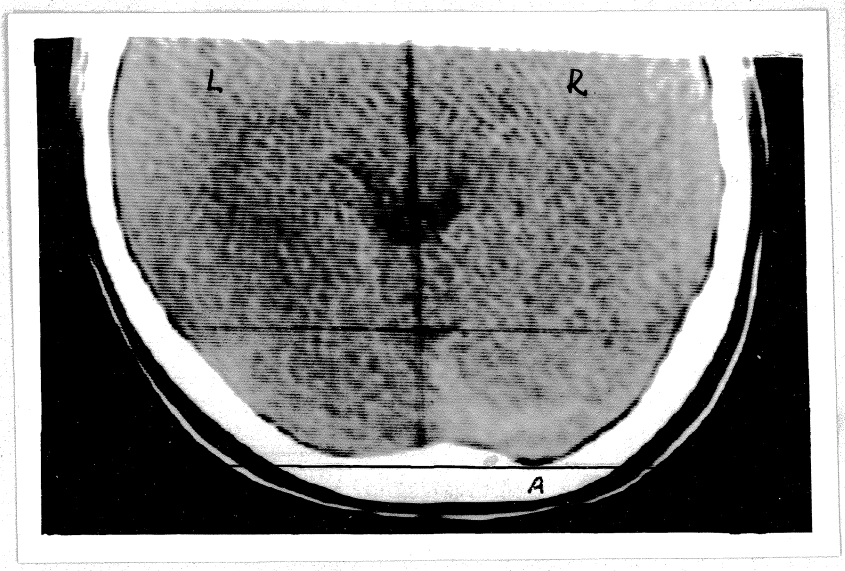
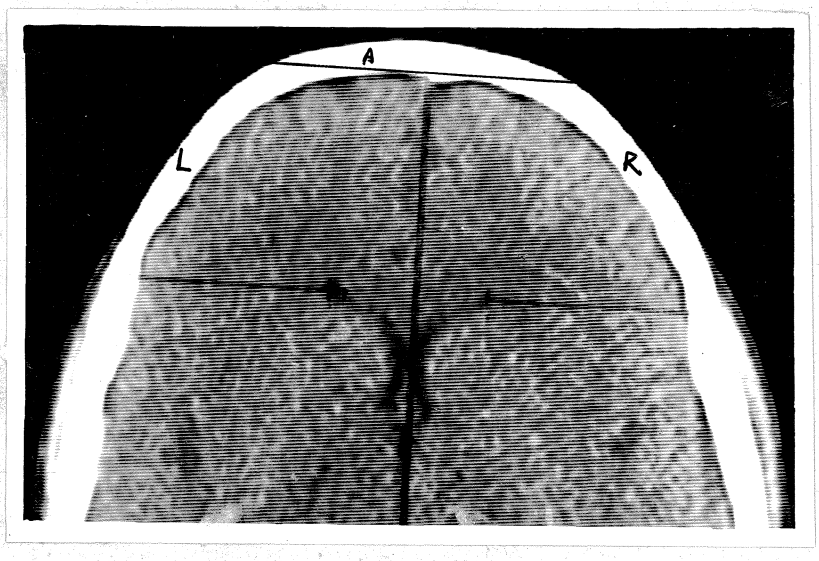


FIGURE IV: Left Frontal Petalia [A]



CT HEAD ASYMMETRIES IN NORMAL INDIVIDUALS

FIGURE V: Left Occipital Petalia [A]

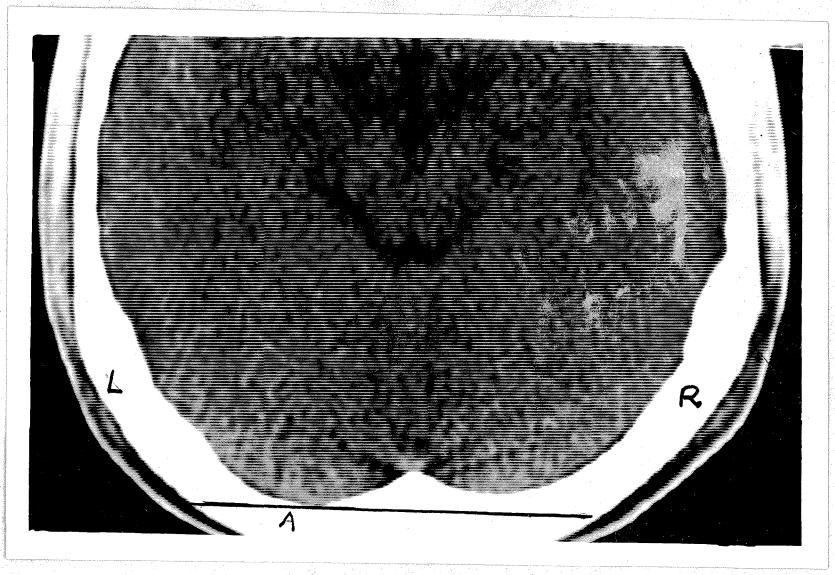


FIGURE VI: Shows (A) Right Frontal Petalia

(B) Left Occipital Petalia

(C) Tilt of Straight sinus to right side

(D) Central position of pineal

(E) More posterior extent of left occipital horn, Choroid plexus of occipital horn left side.

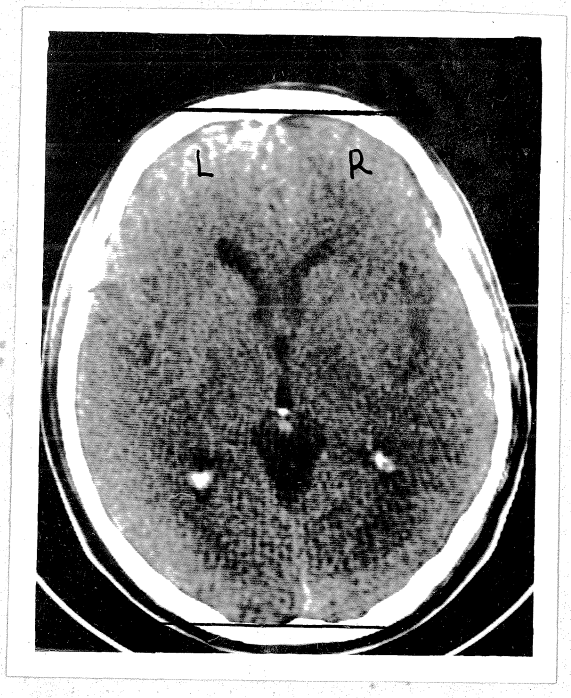
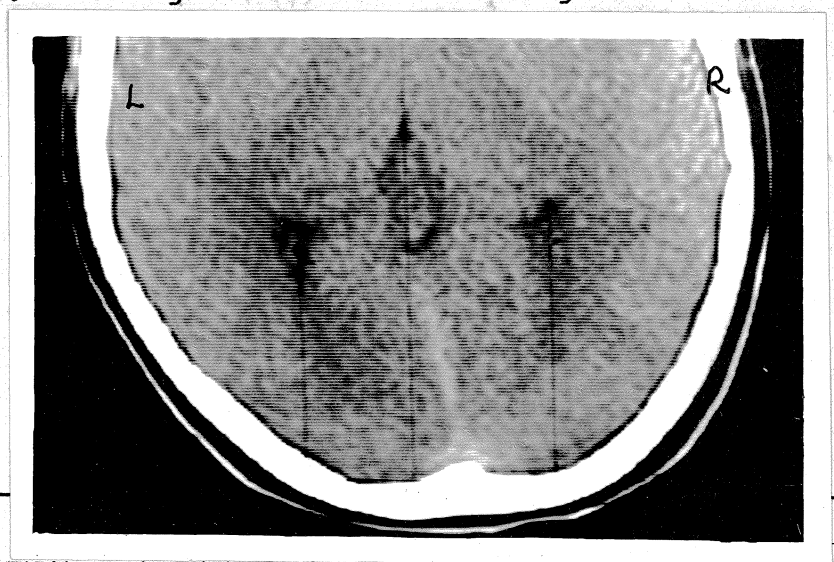


FIGURE VII: Straight sinus tilt to right side



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Title of the project:- A study of Cerebral Dominance in children and young adults with normal visceral situs.

Duration - 6 months.

Aim and Scope - To study the pattern of Cerebral Dominance for hand, leg, eye and ear the given polulation and to observe for any possible correlation between different organ dominance, between coarse movements and precision movements, and innate and acquired functional movements. Further to identify a few bedside tests to ascertain the cerebral dominance of a person in a clinical setting.

Summary - 20 subjects were studied for cerebral dominance using a battery of tests for hands legs, eyes and ears. The results were analysed in terms of tests for coarse movements, tests for precision movements and tests for time bound precision movements. A handful of bedside tests for cerebral dominance of these organs functioning are identified.

METHODOLOGY

Study Population

Twenty children admitted to the cardiology ward of the Institute formed the study population. Their age ranged from 6 to 20 years. Mean age 10.35 years. (Male 15 and Female 5) All of them had normal visceral situs and no Neurological disorders. Children with congenital heart disease but normal visceral situs were selected to match the population of another controlled study of cerebral dominance in children with abnormal visceral situs and congenital heart diseases.

Test Setting

Two persons were given the tests at a time, each one sitting opposite other at a table. Height of the chair was adjusted to suit the convenience of the subject. First, each test was demonstrated and explained to the subject. (a) Tests for hand preference material was displayed in front of the subject equidistant from either hand, at equal facility for either hand. (b) A stop watch was used to accurately measure the time, whenever necessary. The first response of the candidate was recorded wherever side preferance was involved. Dexterity of a movement was assessed by visual impression. Identical test material was given for all subjects.

A. Tests for Hand Preference

I. Card shuffling and dealing:- A set of playing cards is kept on the table in front of the subject and he is instructed to pick up the cards, shuffle and arrange them in four differant groups. The hand prefered to take the cards, dexterity of shuffling and dealing are noted after repetition of the test with the opposite hand.

2. Cutting a circle out of a paper. A paper, on which a standard size circle is printed, and a pair of scissors were kept on the table close to each other. The subject was requested to take the scissors and cut out the circle precisely along the circle outline. The time taken to complete the task with either hand and the dexterity of cutting and the hand prefered to cut are noted.

3. Winding a thread on a reel. An empty reel and a long piece of thread are kept along side on the table. The hand prefered to pick up the thread and wind are noted. Subject is instructed to keep the reel stationary.

4. Threading beads on a rod. A set of 8 beads in a cup and a suitable thin rod are kept on the table. Subject has to pick up the rod and fix it firmly to the edge of the table and thread thebeads one after the other with the opposite hand. The hand prefered and the time taken to complete the task with either hand are noted.

5. Clapping The hand which is kept above the other while clapping is noted.

6. Folding the arms across chest. Subject is instructed to keep the hands folded across the chest. The hand which is kept in front of the other while doing so is noted.

7. Screwing the cap of a bottle. The hand prefered to (a) pick up the bottle and (b) to open the screwcap of the bottle are noted.

8. Manual Preference.

a. A small ball is kept on the table. The hand prefered to pick up and throw the ball are noted.

b. Hand prefered to pick up a comb and to comb the hair are noted.

c. The hand prefered to pick up a spoon to simulate eating is noted.

d. Hand prefered for writing with a pen is noted.

9. Goramina's Test. The subject is instructed to draw a circle and a straight line, each in a single stroke, with either hand. The better of the two performances is noted.

IO. Dropping pebbles in a bottle. An empty bottle with narrow opening and a set of eight pebbles in a cup are kept at a fixed distance from each other. Subject picks up the pebbles one at

a time and drops them in the bottle. The hand prefered and the time taken to complete the task with either hand are noted.

II. Passing a needle through dots. The test material consists of a panel of 25 fine circles each of I mm diameter on a paper. The subject has to carefully prick through each of the circle with either hand using a pin. The hand prefered and the time taken with either hand are noted.

B. LEG PREFERENCE.

I. Subject is instructed to sit on a chair with legs crossed and the leg coming above the other is noted.

2. Subject stands with both feet together and steps on to the stairs. The foot advanced first, to do so is noted.

3. Subject stands steady on one foot and draws the big toe of the other foot over a circle drawn on the ground. The foot prefered and the accuracy of the circle drawn with either foot are noted.

4. The foot prefered while hopping on a single foot is noted.

5. The foot prefered to kick a ball kept in front of the subject is noted.

6. The subject taps in a series on the floor with the forefoot of either lower limb. The dexterity of tapping with either of the foot is noted.

C. EYE PREFERENCE

I. The eye prefered to look through a pinhole, kept at eye level is noted.

2. The eye prefered to look through a paper tube is noted.

3. The eye prefered to look in to an empty bottle is noted.

D. EAR PREFERENCE

I. Subject stands six meters away from the examiner facing the opposite direction. The side to which he turns to face the examiner when his name is called is noted.

2. The ear which the subject prefers to listen to the ticking of a watch kept equidistant from both ears is noted.

Finally the results of all the tests are classified in to three categories.

I. Tests involving coarse movements.

II. Tests involving precision movemnts.

III. Tests involving time bound precision movements.

I A. Tests involving coarse movements

A Up per Limb.

I. Hand prefered for taking cards.

2. Hand prefered for shuffling cards

3. Dexterity of shuffling.

4. Dexterity of dealing cards.

5. Clapping - Hand kept above the other.

6. Folding arms across chest - Hand kept in front.

7. Hand prefered to pick up a bottle.

8. Hand prefered to open the bottle.

9. Hand prefered to throw a ball.

IO. Hand prefered to comb hair.

II. Hand prefered to use a spoon.

I2. Hand prefered to write.

IB. LOWER LIMB.

I. Leg kept above while sitting cross legged.

2. Leg advanced in climbing.

3. Foot preferred in hopping.

4. Foot prefered in kicking a ball.

II TESTS FOR PRECISION MOVEMENTS

IIA UPPER LIMB

I. Hand prefered in cutting a circle.

2. Dexterity of cutting a circle .

3. Hand prefered for beading.

4. Coramina's Tests

5. Putting pebbles in a bottle.

6. Passing needle through dots.

IIB. LOWER LIMB.

I. Foot prefered for drawing a circle.

2. Dexterity of drawing a circle.

3. Dexterity of tapping on floor.

III. TIME BOUND PRECISION MOVEMENTS.

1. Time taken to cut a circle out of paper.
2. Time taken to thread beads on a rod.
3. Time taken to put pebbles in a bottle.
4. Time taken to pass needle through dots.

C TESTS FOR EYE PREFERENCE.

D. TESTS OFR EAR PREFERENCE.

****

RESULTS

The response of each subject ot the full battery of tests is given in Table III. to VI. In the case of folding the arms in front of the chest, 30% (6 Subjects) kept the right hand in front of the left and 70% (I4 Subjects) did it in the reverse way. Apart from this single test all other tests were preferentially doneby the right hand by majority of persons. This could be interpreted that the right hand moves first and is arranged across the chest and the left hand simply completes the activity, in which case again the manual preference shifts to the right side regarding that test.

There was no person who did allthe tests with either right hand or left hand. Similarly there was no absolute concordance in the use of hand leg eye and ear. For example subject no IO who used left hand for almost all activities used the right leg, and right eye for doing the tests. There was only one subject who performed more than 50% of the tests with the left hand. Table VI summarises the frequencies with which either side was deployed in performing the different catogories of tests. This clearly shown that lateralisation is manifest best in case of hands then legs followed by eyes and lastly ears. In the case of hands the lateralisation was clearly more evident for precision movements. But in the case of legs the reverse was observed. In fact this

drift away from dextrality is due to the ambidextrous response (23%) for precision movements. There were no time bound precision movements for lower limbs which could have given a more objective answer. Tests for eyes and ears showed 65% and 55% dextrality respectively. A total of four tests couldnot be completed in three subjects due to technical reasons.

TABLE III

Test. / Patient No.	Left Hand preference 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	Total
HAND PREFERENCE - COARSE MOVEMENTS		
Hand - Taking cards	2	
Hand - Shuffling cards	I	
Dexterity of shuffling	I	
Dexterity of dealing cards	2	
Clapping - Hand kept above	3	
Folding armskept in front	I4	
Hand - To pick a bottle	II	
Hand - To open a bottle	2	
Throwing a ball	I	
Hand - To comb hair	I	
Handd- To use spoon	0	
Hand - To write	0	
HAND PREFERED - PRECISION MOVE:		
Hand - Cutting a circle	0	
Dexterity of cutting	I	
Hand - For beading	I	
Coramina' Test	3	
Hand - Putting pebbles	I	
Hand - Passing needle	0	
HAND TIME-BOUND PRECISION MOVE:		
Cutting circle-Less time taken	0	
Beading thread-Less time taken	I0	
Putting pebbles inbottle ,,	8	
Passing needle thro' dots ,,	2	
LEG PREFERENCE & COARSE MEVEMENTS		
Leg kept above while sitting	5	
Leg advanced in climbing	7	
Foot prefered in hopping	9	
Foot prefered in kicking	0	
LEG - PRECISION MOVEMENTS		
Foot prefered in drawing	2	
Dexterity of drawing circle	I	
Dexterity of tapping floor	2	
EYE PREFERENCE		
Eye - To look thro' pinhole	7	

Test. / Patient No.	Right Hand preference 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	Total
HAND PREFERENCE - COARSE MOVEMENTS		
Hand - Taking cards		I8
Hand - Shuffling cards		I9
Dexterity of shuffling		I7
Dexterity of dealing cards		I8
Clapping - Hand kept above		I7
Folding armskept in front		6
Hand - To pick a bottle		9
Hand - To open a bottle		I8
Throwing a ball		I9
Hand - To comb hair		I9
Handd- To use spoon		20
Hand - To write		I9
HAND PREFERED - PRECISION MOVE:		
Hand - Cutting a circle		20
Dexterity of cutting		I6
Hand - For beading		I9
Coramina' Test		I7
Hand - Putting pebbles		I9
Hand - Passing needle		20
HAND TIME-BOUND PRECISION MOVE:		
Cutting circle-Less time taken		I9
Beading thread-Less time taken		I0
Putting pebbles inbottle ,,		I0
Passing needle thro' dots ,,		I7
LEG PREFERENCE & COARSE MEVEMENTS		
Leg kept above while sitting		I5
Leg advanced in climbing		I3
Foot prefered in hopping		I0
Foot prefered in kicking		20
LEG - PRECISION MOVEMENTS		
Foot prefered in drawing		I9
Dexterity of drawing circle		I1
Dexterity of tapping floor		9
EYE PREFERENCE		
Eye - To look thro' pinhole		I3

TABLE IV

HAND MOVEMENTS

Subject	Coarse Move: (12 Tests)			Precision Move: (6 Tests)			Precision - Time (4 Tests)		
	Rt.	Lt.	R/L	Rt.	Lt.	R/L	Rt.	Lt.	R/L
1.	11	1		6			4		
2.	11	1		6			4		
3.	10	2		6			4		
4.	12			6			2	2	
5.	12			6			2	2	
6.	10	2		6			4		
7.	7/11	3/11	1	6			3		1
8.	10	2		6			1	3	
9.	10	2		5	1		4		
10.	4	8		3	2	1	2	2	
11.	12			6			2	2	
12.	10	2		6			4		
13.	10	2		6			4		
14.	10	2		6			3	1	
15.	11	1		5/5			2	2	1
16.	11.	1		6			3	1	
17.	9	3		5	1		1	2	1
18.	10	2		4/5	1		3/3		
19.	10	2		5	1		2	2	
20.	9	2	1	6			2	2	
Percentage of Total	83%	16%	1%	94%	5%	1%	71%	25%	4%

TABLE - V.

LEG MOVEMENTS

Coarse Move: Precision Move:

LEG MOVEMENTS

Subject	Coarse Movements (4 Tests) Rt.	Lt.	R/L	Precision Movements (3 Tests) Rt/	Lt.	R/L
I.	3	I		2		I
2.	3	I		3		
3.	3	I		2		I
4.	I	3		2		I
5.	3	I		I		2
6.	2	2		3		
7.	3	I		I		2
8.	4			2		I
9.	3	I		3		
I0.	2	2		I	2	
II.	3	I		3		
I2.	3		I	I	2	
I3.	4			3		
I4.	3	I		3		
I5.	2	2		I		2
I6.	2	2		3		
I7.	3	I		I		
I8.	4			2		I
I9.	3	I		2		I
20.	4			2	I	
Percentage	73	26	I	69	8	23

TABLE VI

Table showing the cerebral dominance of

Hands, Legs, Eyes and Ears for differant functions

Organ	Coarse Movement			Precision Movement			Time Bound Precision Move			Total
	Rt. %	Lt. %	R/L %	Rt. %	Lt. %	R/L %	Rt. %	Lt. %	R/L %	
I. Hand	83	I6	I	94	5	I	7I	25	4	I00
2. Leg	73	26	I	69	8	23	..	..	..	I00
3. Eye	65	55								I00
4. Ear	55	45								I00

Appendix A. Ref 43

CEREBRAL DOMINENCE ASSESSMENT IN LEVOCARDIAC PERSONS

Name: Age

Address Sex M / F

1. Card shuffling & dealing
   - a. Hand prefered for taking the cards
   - b. Hand prefered for shuffling the cards
   - c. Dexterity of shuffling the cards
   - d. Hand prefered for dealing the cards
   - e. Dexterity of dealing the cards

2. Cutting a circle out of paper.
   - a. Hand prefered for cutting
   - B. Dexterity for cutting
   - c. Time taken for cutting (Seconds) R L

3. Winding a thread on a reel
   - a. Hand prefered for picking the thread
   - b. Hand prefered for winding the thread

4. Threading beads on a rod
   - a. Hand preference for picking & threading
   - b. Time taken to complete the task(Seconds) R L

5. Clapping

   Hand which is kept above the other

6. Folding arms across the chest.

   The arm which comes in front

7. Screwing the cap of a bottle
   - a. Hand prefered to pick the bottle
   - b. Hand prefered to open the bottle

8. Manual preference
   - a. Hand prefered for throwing a ball.
   - b. Hand prefered for combing hair
   - c. Hand prefered for using a spoon
   - d. Hand prefered for writing

9. Coramina's test.

10. Dropping pebbles in a bottle

a. Hand preference to put pebbles

b. Time taken to complete the task (Sec) R L

11. Passing a needle through dots

a. Hand prefered to do the task

b. Time taken to complete the task(Sec)

LEG PREFERENCE

1. Leg combing above while sitting
2. Leg advanced first in climbing stairs
3. Circle drawing with foot
   a. foot prefered
   b. accuracy of circle better with
4. Foot prefered for hopping
5. Foot prefered for kicking
6. Dexterity of tapping on floor with one foot

EYE PREFERENCE

1. Looking through a pinhole
2. Looking through a tube
3. Looking into a bottle

EAR PREFERENCE

1. Side to which one turns to listen to sound
2. Listening to the ticking of a watch