Journal of Institute of Science and Technology, 2014, **19(2)**: 129-134, © Institute of Science and Technology, T.U.

CT Number and Linear Attenuation Coefficient Variation in Hypertensive Patients with Brain Hemorrhage and Infarction Using CT Scan

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ABSTRACT

The aim of this paper is to study the variation of brain matter of Nepalese patients using CT scan. CT number and linear attenuation coefficient (LAC) of cortical bone are found largest among other brain matters, indicating the largest density. All brain matters except cortical bone show low association indicating slight changing trend with age. The cortical bone under 10 years shows low value of LAC and CT number, indicating cortical bone towards maturation whereas cortical bone shows no significant increase with age above 10 years. There is no much significant relation by gender in brain hemorrhage and infarction.

Keywords: CT image, Hounsfield unit, texture analysis, brain hemorrhage, brain infarction.

INTRODUCTION

Major innovation, X-ray computed tomography (CT), was introduced into diagnostic imaging in early 1970s. This innovation is recognized as the most significant event in medical imaging. The importance of CT is related to several of its features, including provision of cross-sectional images of anatomy, availability of contrast resolution superior to traditional radiology, construction of images from x-ray transmission a "black box". The productions of images from digital data are processed by computer and can be manipulated to yield widely varying appearances (Hendee & Ritenour, 2002).

The gray levels in a CT slice image correspond to X-ray attenuation reflecting the proportion of X-rays scattered or absorbed as passing through each voxel. X-ray attenuation is primarily a function of X-ray energy and the density and composition of the material being imaged (Ketcham, 2012).

LAC (μ_t) of each tissue pixel is compared with LAC of water (μ_w) using following expression.

$$\Rightarrow \quad CTnumber = 1000\left(\frac{\mu_t - \mu_w}{\mu_w}\right) \quad \mu_t = \frac{\mu_w}{1000}(1000 + CTnumber)$$

When, μ_w =0.191 per cm, then we get:

$\mu_t = 0.000191(1000 + CTnumber)$ per cm.

Water is used as reference material because its LAC is close to those of soft tissue and it is reproducible material for machine calibration. The LAC of typical bone and water are of 0.38 cm^{-1} and 0.19cm^{-1} respectively and the CT number of bone is +1000 (Farr & Allisy-Roberts, 2002).

Hypertension is a condition and characterized with an abnormal increase in blood pressure where systolic blood pressure is greater than 160 mmHg and /or a diastolic blood pressure is 95mmHg or greater (Segen & Wade, 2004). Hypertension predisposes to atherosclerosis and has specific effect on particular organs of heart, brain, kidneys, and blood vessels (Waugh & Grant, 2006).

Brain hemorrhage is known as bleeding in the brain which caused due to swell of an artery in the brain and then it bursts, which can resulted the brain cells being killed anywhere in or on the brain. CT findings of brain hemorrhage are done by clinical practice and acute hemorrhage (0-72hrs) appears hyperdense to human brain unrestricted semi liquid clot appears hypodense within the acute hematoma. Sub-acute hemorrhage (4-14 days) becomes virtually isodense with the adjacent brain parenchyma. It shows a peripheral post contrast enhancement. Chronic hemorrhage (>2 weeks) appears hypodense to the adjacent brain. High attenuation within chronic hematomas is usually secondary to the re-bleeding. A target sign on post contrast image can be seen if re-hemorrhage takes place within an organizing hematoma; if re-bleeding occurs outside an organized hematoma and it can resemble with a tumorial hemorrhage (Bhargava, 2006).

The brain is prevented from receiving blood, leading to tissue damage, stroke, and possible fatality is known as a brain infarction (http://www.wisegeek.com). Acutely infracted tissue is isodense with brain initially, it then becomes darker (decreased attenuation) in the acute phase, returns to a more normal attenuation during the next 2-3 weeks (fogging effect), and then markedly decreases in attenuation as it enters the chronic phase. Contrast-enhanced images often show gyriform enhancement during the fogging period (Jonathan & Allen, 2006). In this context, the objective of this paper is to find the CT number and LAC of brain matters, and also to know the relation of brain hemorrhage and infarction by age-gender along with LAC of gray and white matter by gender.

MATERIALS AND METHODS

The non-systematic prospective experiment-observational study was undertaken at the Department of Radiology and Imaging, Om Hospital and Research Centre, Kathmandu, Nepal. The experimental observations conducted during May to September, 2011. CT scanner of Siemens Company, Somatom Esprit and co-operative equipment of Om Hospital, has been selected and it conducted with fixed photon energy by keeping 130kVp and 260mAs the dependency, which is only carried out by the density of brain matters. The brain matters are of different densities, hence CT number and LAC of brain matter varies. The parameters are collected as Hounsfield Unit (HU) of white matter, gray matter, CSF, Cortical bone, ICB and infarction. In the experimental observations, 20 patients are from brain hemorrhage while 20 from brain infarction including equal number of each sex. The data are organized and then analyzed by using tabulation and diagrams. Mean, correlation, and the test of independence are used.

RESULTS AND DISCUSSION

The results of the CT number and LAC of brain matter of hemorrhagic male and female patients are presented in Table 1. It is found that in both hemorrhagic male and female brain CT number and LAC of CSF, white matter, gray matter, ICB and cortical bone are gradually in increasing order and are distinct, which indicating that CT diagnosis of brain hemorrhage is more effective. However, other brain diseases may have CT number as close as in brain hemorrhage which needs proper diagnosis. It is commonly observed that CT number of ICB ranges from 50 and reaches below 80 in the most observational cases. CT number for other brain matter does not change appreciably from that of the normal brain. This finding is similar for both male and female patients.

Table 1. CT number and LAC of brain matter of hemorrhagic male and female brain

SN	Age/ Sex	Attenuation (HU) of X-rays with											
		WM	μ_{wm} (cm^{-1})	GM	μ_{gm} (cm^{-1})	CSF	μ_{CSF} (cm^{-1})	CB	μ_{cbone} (cm^{-1})	ICB	μ_{ICB} (cm^{-1})	Inf	μ_{inf} (cm^{-1})
Hemorrhagic male brain													
1	25/M	30.4	0.196806	41.6	0.198946	9.6	0.192834	1587.0	0.494117	64.90	0.203396		
2	31/M	29.0	0.196539	41.0	0.198831	10.0	0.192910	1760.0	0.527160	71.56	0.204668		
3	51/M	32.4	0.197188	39.8	0.198602	11.6	0.193216	1394.0	0.457254	51.80	0.200894		
4	53/M	32.0	0.197112	42.0	0.199022	2.4	0.191458	1359.0	0.450569	67.88	0.203965		
5	56/M	26.8	0.196119	40.0	0.198640	11.0	0.193101	1092.0	0.399572	51.08	0.200760		
6	61/M	30.4	0.196806	33.6	0.197418	10.8	0.193063	1414.0	0.461074	66.60	0.203720		
7	63/M	27.0	0.196157	37.4	0.198143	7.6	0.192452	1355.0	0.449805	67.32	0.203860		
8	68/M	30.0	0.196730	42.0	0.199022	8.2	0.192566	1234.0	0.426694	66.80	0.203760		
9	73/M	28.0	0.196348	39.4	0.198525	5.4	0.192031	1558.0	0.488578	54.32	0.201380		
10	78/M	31.4	0.196997	40.0	0.198640	8.0	0.192528	1506.0	0.478646	70.96	0.204550	Nil	Nil
Hemorrhagic female brain													
1	6/F	25.6	0.195890	37.6	0.198182	3.2	0.191611	886.0	0.360226	63.04	0.203041		
2	9/F	27.0	0.196157	38.4	0.198334	8.0	0.192528	1008.0	0.383528	54.80	0.201467		
3	22/F	29.0	0.196539	41.0	0.198831s	7.6	0.192452	1396.0	0.457636	64.30	0.203281		
4	35/F	28.8	0.196501	42.2	0.199060	10.0	0.192910	1446.0	0.467186	68.40	0.204064		
5	36/F	29.8	0.196692	39.8	0.198602	11.4	0.193177	1622.0	0.500802	64.76	0.203369		
6	55/F	30.8	0.196883	40.4	0.198716	11.6	0.193216	1272.0	0.433952	62.96	0.203025		
7	56/F	32.0	0.197112	42.0	0.199022	12.0	0.193292	1343.0	0.447513	64.66	0.203350		
8	67/F	31.0	0.196921	41.0	0.198831	11.6	0.193216	1625.0	0.501375	68.56	0.204095		
9	80/F	30.0	0.196730	39.0	0.198449	7.0	0.192337	1193.0	0.418863	58.42	0.202158		
10	83/F	30.4	0.196806	41.2	0.198869	9.4	0.192795	1257.0	0.431087	63.58	0.203144		

Table 2. CT number and LAC of brain matter of infracted male and female brain

SN	Age/ Sex	Attenuation (HU) of X-rays with											
		WM	μ_{wm} (cm^{-1})	GM	μ_{gm} (cm^{-1})	CSF	μ_{CSF} (cm^{-1})	CB	μ_{cbone} (cm^{-1})	ICB	μ_{ICB} (cm^{-1})	Inf	μ_{inf} (cm^{-1})
Infracted male brain													
1	8/M	27.0	0.196157	37.4	0.198143	10.0	0.192910	921.0	0.366911			15.38	0.193938
2	45/M	30.0	0.196730	39.4	0.198525	8.4	0.192604	1539.0	0.484949			14.24	0.193720
3	55/M	30.0	0.196730	41.2	0.198869	11.0	0.193101	1417.0	0.461647			15.4	0.193941
4	58/M	30.2	0.196768	38.8	0.198411	10.4	0.192986	1507.0	0.478837			15.84	0.194025
5	66/M	29.8	0.196692	39.6	0.198564	3.2	0.191611	1277.0	0.434907	Nil	Nil	13.76	0.193628
6	67/M	28.6	0.196463	40.0	0.198640	9.8	0.192872	1658.0	0.507678			14.74	0.193815
7	68/M	29.2	0.196577	39.2	0.198487	9.2	0.192757	1326.0	0.444266			15.08	0.193880
8	69/M	28.0	0.196348	40.4	0.198716	9.0	0.192719	1338.0	0.446558			14.08	0.193689
9	78/M	30.4	0.196806	39.6	0.198564	9.4	0.192795	1437.0	0.465467			15.98	0.194052
10	87/M	28.6	0.196463	38.0	0.198258	8.0	0.192528	1623.0	0.500993			14.68	0.193804
Infracted female brain													
1	46/F	31.2	0.196959	40.8	0.198793	7.0	0.192337	1176.0	0.415616			15.20	0.193903
2	55/F	29.4	0.196615	38.4	0.198334	8.8	0.192681	1244.0	0.428604			16.30	0.194113
3	58/F	30.4	0.196806	40.2	0.198678	9.8	0.192872	1124.0	0.405684			16.52	0.194155
4	62/F	29.2	0.196577	40.4	0.198716	7.8	0.192490	1130.0	0.406830			15.02	0.193869
5	70/F	30.8	0.196883	40.4	0.198716	6.0	0.192146	1075.0	0.396325	Nil	Nil	17.86	0.194411
6	75/F	28.8	0.196501	39.6	0.198564	10.0	0.192910	1177.8	0.415960			15.84	0.194025
7	79/F	30.6	0.196845	40.6	0.198755	8.4	0.192604	1250.0	0.429750			13.56	0.193590
8	83/F	30.0	0.196730	38.8	0.198411	8.0	0.192528	973.0	0.376843			14.24	0.193720
9	85/F	28.0	0.196348	37.8	0.198220	11.2	0.193139	1362.0	0.451142			16.36	0.194125
10	86/F	29.0	0.196539	39.6	0.198564	10.2	0.192948	1206.0	0.421346			16.20	0.194094

NOTE: SN-Serial Number, WM –White Matter, GM- Gray Matter, CSF-Cerebrospinal fluid, CB-Cortical Bone, ICB-Intracranial Bleed

Table 2 gives the brain matter variation in case of brain infarction for males and females. It is found that CT number of infarction in infracted brain ranges from more than 10 to less than 22 in most cases, it greatly resembles with the CT number of CSF in certain cases therefore careful speculation only yield proper diagnosis. These variations usually depend on how old the disease was. The CT number of ICB is nil as bleeding is absent in present case. Other brain matter variation is found insignificant as in previous case of brain hemorrhage compared with normal brain.

(a) **(b)**

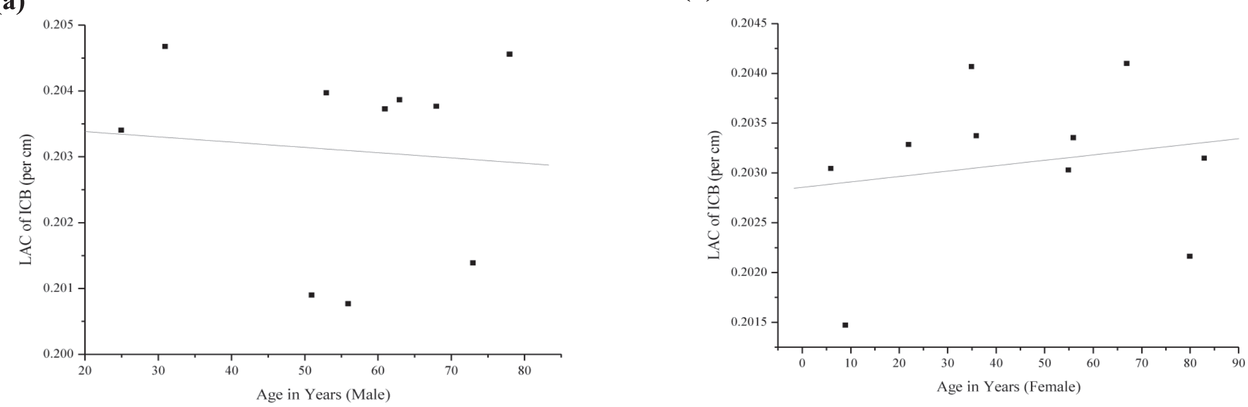


Fig 1. (a) Graph showing no significant correlation (r= – 0.09144) between LAC of ICB and age of brain hemorrhage male patient (b) Graph showing no significant correlation (r=0.18962) between LAC of ICB and age of brain hemorrhage female patient

Variation between LAC of ICB and age of male and female patients shows no significant association (Fig. 1). It is also seen that the correlation between LAC of ICB and age of each sex in brain hemorrhage patients is found insignificant. This result indicates that the disease can occur at any age. In both the cases the value of correlation coefficient is low. However, in male patients the correlation is negative while in female patients the correlation coefficient is found small but positive. Large number of patients were recorded with increasing age as risk factors like obesity, stress, consumption of more fat and others are more likely at that age.

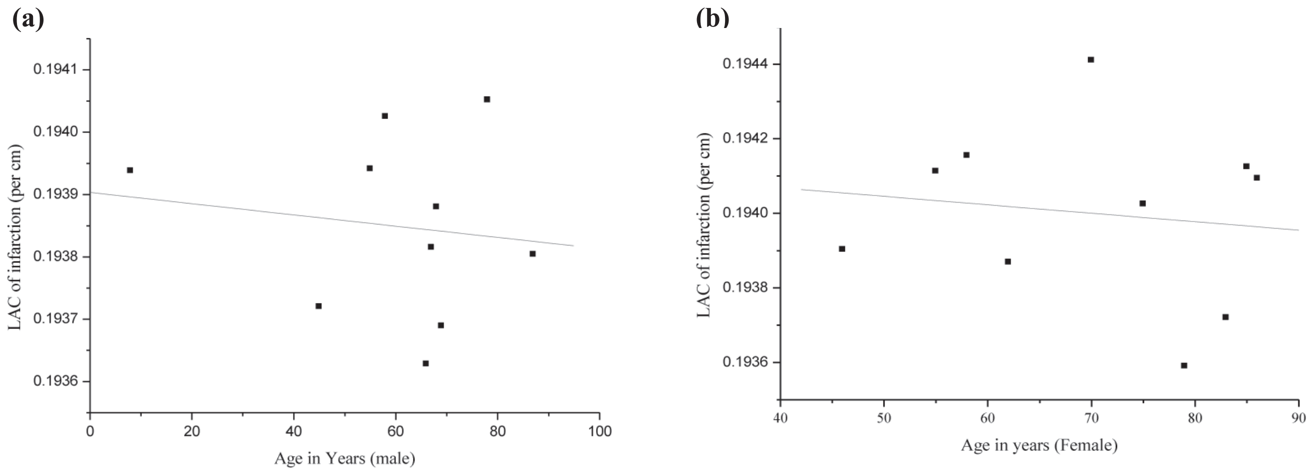


Fig 2. (a) Graph showing no significant correlation (r=-0.1369) between LAC of infarction and age of brain infarction male patient, and (b) Graph showing no significant correlation (r=-0.13429) between LAC of infarction and age of brain infarction female patient

Variation between LAC of infarction and age of male and female patients' brain shows no significant association (Fig. 2). The result shows that degree of correlation is low between LAC of infarction and age of each sex in case of brain infarction patient. In both sexes correlation coefficient is small and negative. This reveals that the disease is possible at any age groups of patients. However, the people of higher age are at higher risk due to sedentary lifestyle, stress and lack of physical exercise, which are usually observed less in the lower age groups of patients.

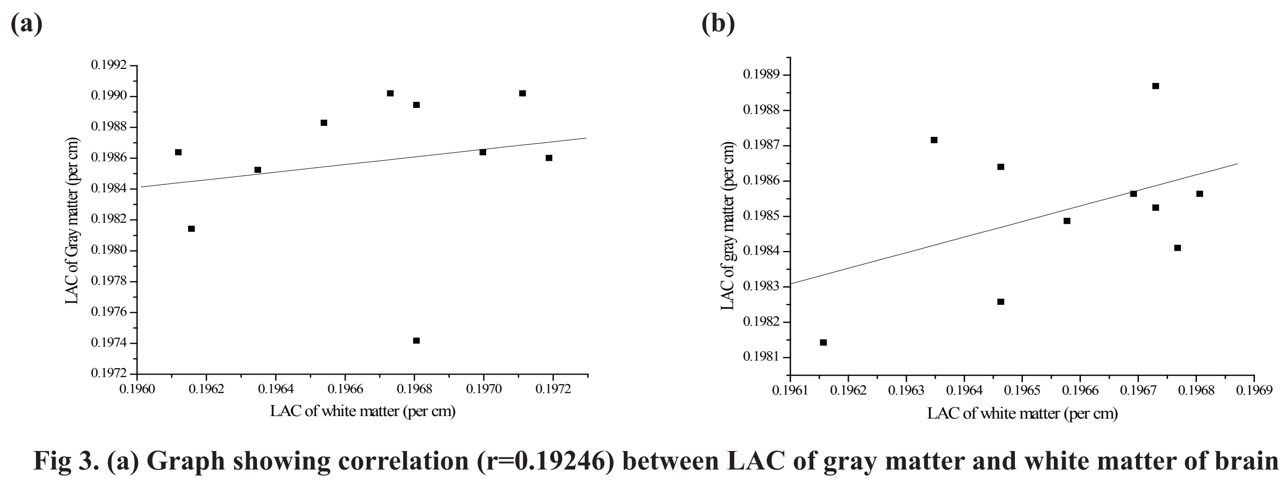


Fig 3. (a) Graph showing correlation (r=0.19246) between LAC of gray matter and white matter of brain hemorrhage male patient (b) Graph showing correlation(r=0.44186) between LAC of white and gray matter of brain infarction male patient

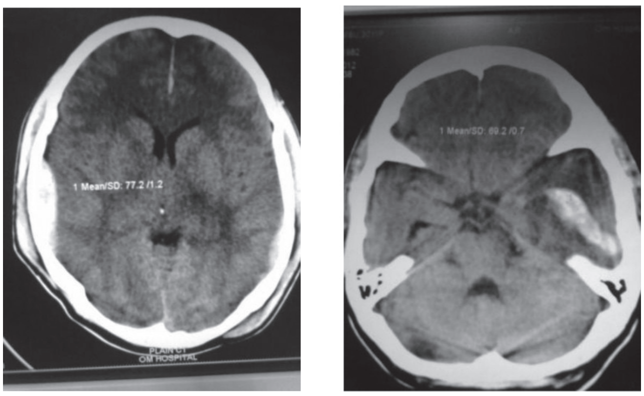
Fig. 3 shows that the variation between LAC of white and gray matter of male brain is found significantly associated for both diseases. It is also seen that there is a positive relation between LAC of white and gray matter in brain hemorrhage and brain infarction patients for male. This result equally holds in case of female patients for both the diseases. In addition to this result, the development of white and gray matter goes side by side.

Table 3: χ^2 test for ICB of hemorrhagic male and female brain patient and infarction of infracted male and female brain patient

LAC of	ICB of brain hemorrhage for male and female patient					Infarction of infracted male and female brain patient				
	0.200760-0.202158	0.202158-0.203720	0.203720-0.204095	≥0.204095	Total (RT)	0.193590-0.193720	0.193720-0.193938	0.193938-0.194052	≥0.194052	Total (RT)
Male	3	1	4	2	10	2	4	3	1	10
Female	1	7	1	1	10	1	3	1	5	10
Total(CT)	4	8	5	3	N=20	3	7	4	6	N=20
χ^2=7.63						χ^2=4.14				

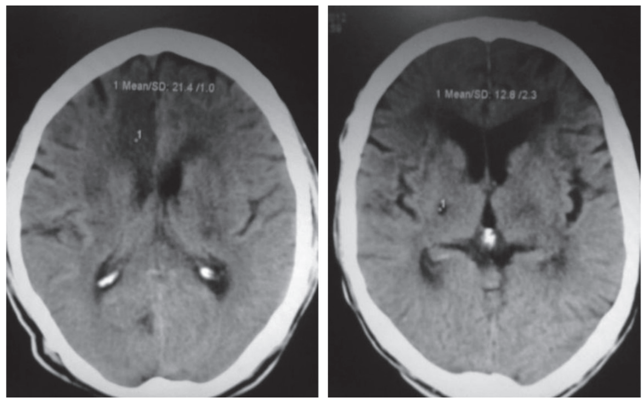
Table 3 presents the association between male and female patients in case of brain hemorrhage and infarction. The insignificant chi-square values suggest that there is no association between LAC of infarction of infracted male and female brain. This shows that there is no evidence of the occurrence of hemorrhage in male, which linked with occurred in female. This result also holds good for the patients of brain infarction for both sexes.

The ICB and infraction can be detected easily through CT technique. Some CT images out of large observations are depicted in Figs. 4 & 5. Fig 4(a) represents the CT image of hemorrhagic female patient of age 35 years whereas Fig. 4(b) shows the CT image for male patient of age 25 of the same disease. Texture analysis of CT image enables us to identify the CT number of brain matter. The CT number and standard deviation taken during the observation are shown in the image pointing by white spot. The bleeding in the brain is clearly seen in the Fig. 4.



(a) (b)

Fig 4. Hemorrhagic brain (a) (35/F) and (b) (25/M)



(a) (b)

Fig 5. Infracted brain (a) (75/F) and (b) (45/M)

Fig. 5(a) shows the CT image of 75 years of female patient with brain infarction. The Fig. 5(b) refers to that of 45 years male patient of the same disease. The texture analysis of CT image showing decrease in attenuation is represented by white spot in each image where the CT number as well as standard deviation measured is also depicted. The variation in two images is usual as the portion of blockage, history and duration of disease may differ.

The range of CT number and LAC of brain matters mentioned lies clinically accepted range and is also in agreement with similar studies conducted by Reddinger (1998), Mishra (2009) and Silwal (2010). The CT number and LAC of cortical bone are found largest among other brain matters indicating largest density. It is found that all brain matters except cortical bone shows lower association indicating slight change trend with age. The cortical bone associated with age under 10 years shows low value of LAC and CT number indicating cortical bone towards maturation. Above 10 years, cortical bone shows no significant increase with age in male whereas in female slightly decreasing value of cortical is observed. These findings are found consistent with the several findings elsewhere (Reddinger, 1998; Mishra, 2009; Silwal, 2010; Cosgrove *et al.* 2007; Good *et al.* 2001; Koenraad *et. al.* 2001).

The white and gray matter of brain are found to be significantly associated. The hemorrhagic patients by gender are found significantly different where male patients shows lower association than that of female patients. Indeed brain infarction patients showed similar results for gender, however; gender differences in size vary by more specific brain regions. Studies revealed that men have a relatively larger amygdalae and hypothalamus whereas women have a relatively larger caudate and hippocampi. Women have a higher gray matter as compared to that of men but men have a higher white matter and cerebrospinal fluid as compared to that of female. Indeed, high variability between individuals is well established elsewhere (Cosgrove *et al.* 2007).

The significant dynamic change is well observed in brain structure through adulthood and aging with substantial variation between individuals (Good *et al.* 2001). It is also showed that men had a steeper decline in global grey matter volume, although in both sexes, which varied by region with some areas exhibiting little age effect. Further overall white matter volume does not appear to decline with age, although there is variation between brain regions. In fact, the discrepancy observed is accounted as from the head circumferences, which do not change significantly through childhood, but increase is due to mostly to an increase in skull thickness, not in brain size (Koenraad *et. al.* 2001). The brain is also found to be 12 per cent larger for male on average as compared to that of female where the difference is statically significant even controlling height and weight. The study also conducted shows that woman has 4.3 per cent higher gray matter content than that of men. The gray matter gradually loosed due to ageing, however; CSF volume has found to be lower in female with age as compared to that of male.

CONCLUSION

The present paper concludes as follows:

- The CT number and LAC of brain matters observed from this study are in agreement with clinically accepted range.
- ICB is only found in hemorrhagic brain where infarction is completely absent and infarction is only found in infracted brain where ICB is entirely absent.
- There is low degree of association between CT number of brain matters and age but the association is high between age and CT number of cortical bone. However it is found nearly constant in male with increase in age and low in child under age of 10 years irrespective of the sex.
- The association is found high in the development of white and gray matter whereas CT number of CSF is found slightly decreasing with age for both sexes.
- Insignificant association is found individually in the CT number and LAC variation of brain matters of brain hemorrhage and brain infarction.

ACKNOWLEDGEMENTS

Authors are thankful to the Imaging Unit of Om Hospital and Research Center for providing necessary Data for this paper.

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