Proceedings of the 2005 IEEE
Engineering in Medicine and Biology 27th Annual Conference
Shanghai, China, September 1-4, 2005

Analysis of Water Compartment in Dengue Patients

F.Ibrahim[1], K.F. Ooi[1], N.A. Ismail[2], M.N. Taib[3], *Member IEEE*, W.A.B. Wan Abas[1]

Abstract— **This paper describes the water compartments in healthy subjects and dengue patients on the day of defervescence of fever using bioelectrical impedance analysis. A total of 223 healthy subjects (65 males and 158 females) and 210 dengue patients (119 males and 91 females) in Hospital Universiti Kebangsaan Malaysia (HUKM), were studied. The ages for healthy subjects vary between 14 and 60 years old with mean age of 26.05 years while the ages for the dengue patients vary between 12 and 83 years old with mean age of 30.14 years. The parameters of water compartments investigated were total body water (TBW), extracellular water (ECW) and intracellular water (ICW). There were significant difference between healthy subjects and dengue patients for both male ($p<0.05$) and female ($p<0.001$) beginning on fever day 0 till fever day 4. The mean TBW and ECW values of dengue patients obtained were found to be higher than the normal healthy subjects while the mean ICW was lower. The mean TBW and ICW for male were higher than female while the mean ECW for male was lower than female for healthy subjects and dengue patients.**

I. Introduction

MEASUREMENT of body composition is important to assess the pathophysiology of human health and diseases. Many techniques are currently available for estimating body composition, but are limited to clinical laboratory include densitometry, isotope dilution and total body potassium [1]. Recently, a new and noninvasive bioelectrical impedance analysis (BIA) has been used to estimate body composition and body hydration in adult human [2-5]. BIA method has become an increasing popular modality in assessment of body composition because of the portability, rapidity and inexpensive nature of these technical modalities. Bioelectrical impedance application in evaluating hydration status of the dengue patients is relatively new. To date, no known literature describe the water compartments in Malaysian population.

In this study, we focused on the measurement of water compartments in BIA for Malaysian healthy subjects and dengue patients. The parameters for the water compartments investigated are total body water (TBW), extracellular water (ECW) and intracellular water (ICW).

Manuscript received April 22, 2005. This work was supported in part by the Sultan Iskandar Johore Foundation, Malaysia.

F. Ibrahim is with the Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, 50603, Kuala Lumpur, Malaysia (phone : 603-7967-4581; fax: 603-7967-4579; email fatimah@um.edu.my).

K.F. Ooi was with the Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, 50603, Kuala Lumpur, Malaysia.

N.A. Ismail is with Department of Applied Statistics, Faculty of Economics and Administrations, University of Malaya (nazina@um.edu.my).

M.N.Taib is with Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shaha Alam, Selangor, Malaysia (dr.nasir@ieee.org).

W.A.B. Wan Abas is with the Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, 50603, Kuala Lumpur, Malaysia (drirwan@hotmail.com).

II. Subjects And Methods

A. Subjects

The subjects are divided into 2 groups: Group 0 is the control healthy subjects while Group 1 is the dengue patients. Group 0 consists of a total of 223 volunteers with no past medical history. Subjects were non-randomly volunteers, recruited through advertisement in the University Malaya's monthly news bulletin 'BERITA UM', internal posters circulation, and internal University Malaya's email (uminfo@list.um.edu.my). Some of the volunteers were from general public recruited during the University Malaya convocation exposition 2002 and the University Malaya Second College Creative Week Open day 2002. On the other hand, group 1 consists of a total of 210 dengue patients aged 12 years old and above, serologically confirmed dengue patients during their hospitalization in University Kebangsaan Malaysia (HUKM) in the years of 2001 and 2002.

B. Method

For each subject, informed consent form was obtained and anthropometrics measurements (height and weight) were taken at admission. Demographic data were recorded using standardized questionnaire data collection forms designed for the study. All subjects were abstained from eating and drinking for 4 hours and physical exercise for 12 hours prior to the BIA measurement. These protocols were implemented to ensure an accurate body composition result [6]. The BIA safety measurements procedure and other safety precautions were made known to the subjects.

C. BIA Measurement

Subjects were asked to lie supine on their bed and two electrodes were placed on the right hand, one at the base of knuckles and another slightly above the wrist joint. Another two electrodes were placed on the right foot, one near the base of the toes and the other slightly above the ankle joint. A constant current less than 1mA at a single frequency of 50 kHz [6] was injected to the base of the toes and the signal was pick-up by the other two sensor electrodes (slightly above the ankle and wrist joint). Each measurement took

approximately 3 minutes. Bioelectrical impedance measurement was performed with a biodynamic Model 450 bioimpedance analyzer, from Biodynamic Corporation USA. The subject's profile such as age, sex, height and weight were entered to the BIA 450 analyzer. The analyzer directly measures bioelectrical tissue conductivity and uses regression analysis to compute the mass distribution and water compartments (TBW, ECW and ICW).

III. Statistical Analysis

The statistical analysis was performed using SPSS statistical package version 12 for Window XP. The clustered error bar chart displaying 95% confidence interval of water compartments were drawn. Univariate Analysis of Variance (ANOVA) was used to estimate the mean and standard error as well as 95% confidence interval of water compartments for gender and groups.

IV. Results And Discussions

The BIA measurements have been conducted to 223 healthy subjects (65 males and 158 females) while 210 dengue patients (119 males and 91 females). For the healthy subjects, the Malay contributes to 63.68% followed by Chinese 30.04%, Indian 2.24% and others 4.04% while for the dengue patients, the Malay contributes to 55.24% followed by Chinese 28.57%, Indian 7.14% and others 9.05%. The subjects' distribution with gender and groups is illustrated in Fig. 1. The subjects' distribution with race and group is illustrated in Fig. 2. The ages of healthy subjects vary between 14 and 60 years old with mean age of 26.05 years while the ages of the dengue patients vary between 12 and 83 years old with mean age of 30.14 years.

The clustered error bar chart displaying 95% confidence interval of ICW and ECW with gender and groups were drawn as shown in Fig.3 and Fig.4 respectively. Univariate Analysis of Variance (ANOVA) was used to estimate the significant different of mean value for water compartment between dengue and healthy subjects.

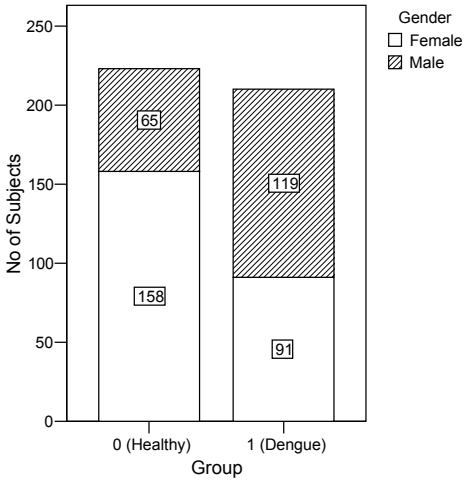

Fig.1 The subject's distribution with gender and groups.

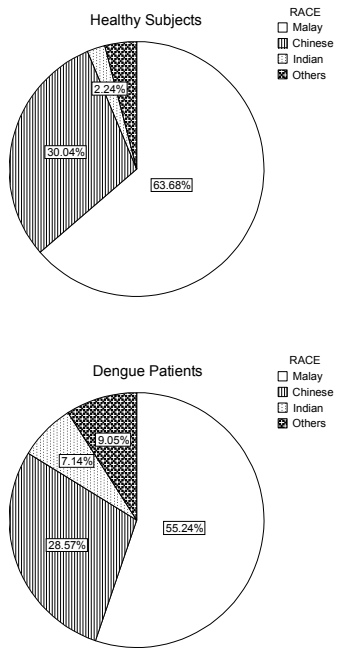

Fig.2 The subject's distribution with race and groups.

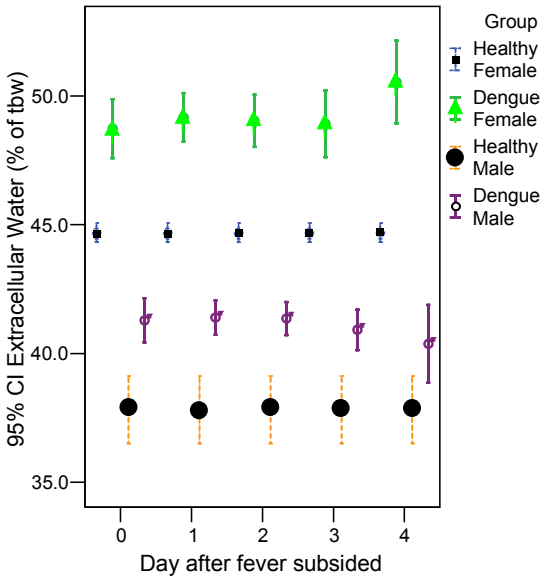

Fig. 3 Confidence interval distribution of Intracellular Water (ICW) for day after fever subsided with gender and groups.

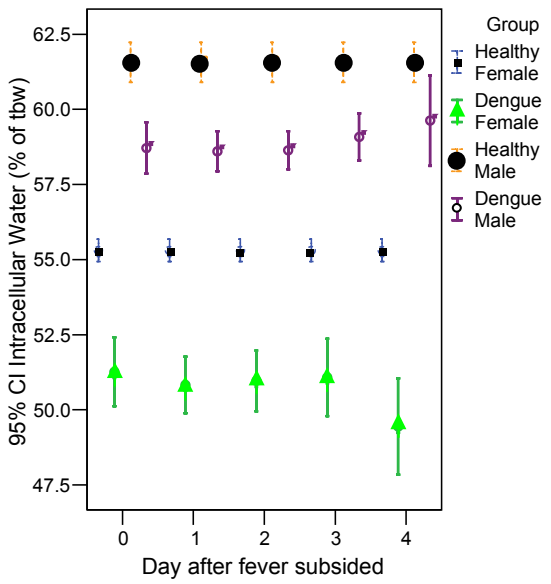

Fig. 4 Confidence interval distribution of Extracellular Water (ECW) for day after fever subsided with gender and groups.

From Fig.3 and Fig. 4, there were significant different between healthy and dengue groups for male ($p<0.05$) and female ($p<0.001$) beginning on the fever day 0 till fever day 4.

From Fig. 3, the mean ICW of dengue patients for both gender were lower than the normal healthy subjects. For example, the mean ± standard errors of ICW for female dengue patient on fever day 1 was 50.83±0.34 % which is lower than the control healthy subjects 55.31±0.23% ($p<0.001$). However, the mean value of healthy and dengue group were higher in male than female. The mean ± standard error of ICW for male was 58.60±0.32%, which is higher than female dengue patients on day 1 (50.83±0.34%). Moreover, the mean value of dengue patients for both gender were increasing from fever day 1 till fever day 3 (See Table I).

On the other hand, the mean ECW of dengue patients for both female and male were higher than the normal healthy subjects (Fig. 4). However, the mean ECW was higher in female than in male, e.g. the mean ± standard error for healthy female and male were 44.69±0.23% and 37.82±0.54% correspondingly. The mean ± standard errors of ECW for male dengue patient on fever day 2 was 41.36±0.46 % which is higher than the control healthy subjects 37.82±0.54 % ($p<0.001$). Moreover, the mean value of dengue patients for both gender were decreasing from fever day 1 till fever day 3 (See Table I).

For TBW, there were significant trend and mean difference for female between healthy and dengue groups with $p<0.001$. However, there were only significant different for male between group for day fever 0, 1 and 2 with $p<0.05$. From Table I, the mean TBW for female and male healthy subjects, which were 27.52 liters and 38.92liters, were lower than the dengue patients. However, the standard error and mean value for male subjects was higher than the female subjects.

TABLE I
THE INTRACELLULAR AND EXTRACELLULAR WATER MEAN CLASSIFICATION RESULTS FOR GENDER AND GROUPS (GENDER CODING; FEMALE=0, MALE=1)

Days	No of Sample	Gender	Mean ± Standard Error		
			ICW(%)	ECW(%)	TBW(liters)
0	45	0	51.26±0.43	48.74±0.43	29.87±0.55
1	71	0	50.83±0.34	49.17±0.34	30.84±0.43
2	63	0	50.96±0.36	49.04±0.36	30.51±0.46
3	52	0	51.08±0.40	48.92±0.40	30.52±0.51
4	28	0	49.44±0.55	50.54±0.55	31.67±0.69
Control	158	0	55.31±0.23	44.69±0.23	27.52±0.29
0	62	1	58.72±0.38	41.29±0.56	42.56±0.96
1	89	1	58.60±0.32	41.40±0.46	42.65±0.80
2	90	1	58.64±0.31	41.36±0.46	42.30±0.80
3	63	1	59.08±0.38	40.92±0.55	41.44±0.95
4	29	1	59.63±0.55	40.37±0.81	40.28±1.40
Control	65	1	61.57±0.37	37.82±0.54	38.92±0.94

Lower ICW and higher ECW in dengue patient have been previously reported [7]. Plasma albumin levels decreased in the dengue cases and translocation of albumin in intravascular space could theoretically increase the osmotic pressure of the extravascular space. This would allow movement of fluid from the ICW compartment into the ECW compartment [11].

V. Conclusion

The BIA technique provides a non-invasive, simple to use, and reliable method for evaluating hydration status of the dengue patients [7, 8, and 9]. The higher of ECW and the lower of ICW in dengue patients when compared to healthy subjects show how fluid is shifted the intracellular compartment to the extracellular compartment. It is correlated to an increased vascular permeability that gives rise to loss of plasma from the vascular compartment in dengue disease [10]. The finding indicates that water compartment provides a valuable tool in bioelectrical impedance measurements to examine the daily progress of the pathphysiology changes of the dengue disease.

Acknowledgment

We would like to express greatest appreciation to all the dengue patients involved, the authorities and the staff of HUKM for hosting and supporting this research, with

HUKM Ethics approval code D-004-2000. We also would like to express special thanks to Dr. S. Ismail for clinical data collection, and Prof. Dato' L.S. Kit for the serological support.

REFERENCES

[1] V.H. Hayward, "Valuation of body composition," Current issues. Sport Med.;22,pp. 146-156, 1996.

[2] H.C. Lukaski, W.W. Bolonchuk, C.B. Hall, and W.A. Siders, "Validation of Tetrapolar Bioelectrical Impedance method to assess human body composition," Journal of Applied Physiology, vol. 60(4), pp. 1327-1332, 1986.

[3] J.F. Sutcliffe, "A review of In Vivo experimental methods to determine the composition od human body," Phys. Med. Biol., vol.41, Issue 5, pp. 791-833, 1996.

[4] W.D. Van Marken Lichtenbelt, K.R. Westerterp, L. Wouters, and S.C.M. Luijendijk, "Validation of bioelectrical impedance measurements as a method to estimate body water compartments," American Journal Clinical Nutrition, vol. 60, pp. 159-166, 1994.

[5] R.N. Baumgartner, W.C. Chumlea, and A.F. Roche, "Bioelectrical impedance for body composition," Ex. Sp. Sci. rev., vol. 18, pp. 193-224, 1990.

[6] Biodynamics Model 450 Bioimpedance Analyzer user's guide, "Basic Principles of Bioimpedance Testing," First edition, copyright© Biodynamics Corporation, pp. 1-22.

[7] P. Klassen, M. Mazariegos, P. Deurenberg, N.W. Solomons, and P. Furst, "Hydrational status assessed by Bioelectrical Impedance Spectroscopy and Dilution Method in patients with classical Dengue Fever," Annals of the New York Academy of Sciences, 904 163-170, 2000.

[8] M. Mazariegos, P. Klassen, N. W. Solomons, and P. Furst, "Bioelectrical impedance spectroscopy in health and disease: corresponding between whole body and segmental biolelectrical impedance spectroscopy indices in patients with classical dengue fever [In Vivo body composition studies: Part 1. Methods and instrumentation: bioelectrical impedance analysis]," Annals of the New York Academcy of Sciences, 904 205-209, 2000.Biodynamics Model 450 Bioimpedance Analyzer user's guide, "Basic Principles of Bioimpedance Testing," First edition, copyright© Biodynamics Corporation, pp. 1-22.

[9] F. Ibrahim, C.G. Chan, M.N. Taib, and W.A.B. Wan Abas, "The characteristic hydration status changes by bioelectrical impedance assessment in female Dengue Haemorrhagic fever (DHF) patients," The Medical Journal of Malaysia, 57 Supplement D 98, 2002.

[10] J.A. Mattar, MD, FCCM, "Application of total body bioimpedance to the critically I11 Patient," The Society of Critical Care Medicine, vol. 4, no 4, 1996.

[11] Daniel, H.L., Timothy, P.E., Siripen, K., Wanya, C., Ananda, N., Sharone, G., Francis, A.E. and Alan, L.R. (2002) Assessment of body fluid compartment volumes by multifrequency bioelectrical impedance spectroscopy in children with dengue. Transactions of the Royal Society of Tropical Medicine and Hygiene, 96, 295-299.