The following is the abstract of the article discussed in the subsequent letter:

Matthie, J. B., Zarowitz, A. De Lorenzo, A. Andreoli, K. Katsarzki, G. Pan, and P. Withers. Analytic assessment of the various bioimpedance methods used to estimate body water. J. Appl. Physiol. 84(5): 1801–1816, 1998.—Knowledge of patient fluid distribution would be useful clinically. Both single-frequency (SF) and impedance modeling approaches are proposed. The high intercorrelation between body water compartments makes determining the best approach difficult. This study was conducted to evaluate the merits of an SF approach. Mathematical simulation was performed to determine the effect of tissue change on resistance and reactance. Dilution results were reanalyzed, and resistance and parallel reactance were used to predict the intracellular water for two groups. Results indicated that the amount of intracellular and extracellular water conduction at any SF can vary with tissue change, and reactance at any SF is affected by all tissue parameters. Modeling provided a good prediction of dilution intracellular and extracellular water, but an SF method did not. Intracellular, extracellular, and total body water were equally predicted at all frequencies by SF resistance and parallel reactance. Extracellular and intracellular water are best measured through modeling, because only at the zero and infinite frequencies are the results sensitive only to extracellular and intracellular water. At all other frequencies there are other effects.

Bioimpedance Measurement of Extracellular Water

To the Editor: The paper by Matthie and others (1) purports to demonstrate the superiority of the Xitron multifrequency bioimpedance analyzer over single-frequency bioimpedance for measurement of extracellular water (ECW). The paper uses the same eight human subjects and data, which this group, in a paper by Patel et al., including Zarowitz but not Matthie, reported previously (2). The paper by Matthie et al. (1), which does not include Patel as co-author, is heavily math oriented but does not reproduce exactly the source data, including individual values for deuterium and bromide dilution in the paper by Patel et al. (2). For example, in Table 1 in the paper by Matthie et al. (1), listing descriptive characteristics of eight cardiac surgery patients, the data differ from the values in Table 1 of the paper by Patel et al. (2). In the paper by Patel et al., the patients’ age is 68 ± 6.8 yr; in the paper by Matthie et al. (1), patients’ age is 68.77 ± 6.77 yr. In the paper by Patel et al. (2), patients’ weight is 90 ± 24 kg. In the paper by Matthie et al. (1), it is 90.94 ± 24.14 kg. Were other data modified?

In my letter to the editor (3) discussing the paper by Patel et al. (2), I suggested that in their subjects with normal body composition, ECW was a sufficiently constant fraction of total body water (TBW) that, using their own dilution data, it could be calculated from TBW as accurately as the bioimpedance measurement. The authors were given the opportunity to respond and chose not to do so. The important point, available evidence suggests, is that neither single- nor multifrequency bioimpedance analysis has been shown to reliably measure documented excess ECW in patients with clinical evidence of fluid overload (4).

REFERENCES


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REPLY

To the Editor: The points raised by Schloerb in his letter are addressed in the order they were introduced. That previously reported data had been reanalyzed was fully disclosed and extensively discussed in our paper (6). That there is variation in the dilution method is an important information to disseminate, and these data provided the opportunity to do so. A new method cannot be validated if the reference method it is being compared against changes dramatically. In addition, we reported entirely new statistics.

Indeed, the mean age of the patients was 68.13 not 68.77 yr. Evidently, the two decimal places for SD, which was 6.77, were typed twice when Table 1 containing descriptive information was created (6). As their patients’ descriptive information, Patel et al. (7) used the prestudy weight rounded up, in this case, to the nearest whole number, rather than weights postsurgery after 4 h of equilibration of deuterium and bromide.

Schloerb suggests that there is no need to measure ECW with impedance because it cannot detect fluid overload and, for healthy subjects, ECW does not vary; thus it can be determined by assuming it to be a fixed percentage of TBW. We believe that it is important to measure both ECW and intracellular water (ICW) because the ECW/ICW ratio is health, age, gender, and activity dependent. The argument by Schloerb et al. (8) was that a wrist to ankle measurement is not sensitive to ascites or fluid accumulation in the trunk. This
cannot be disputed (5, 11), but Schloerb et al. (8) reported near-exact predictions of fluid overload in the trunk by using segmental impedance measurements. Segmental measurements of ECW have recently been used to successfully determine the net fluid balance in 30 surgery patients (9). As Zarowitz and Matthie discussed (11), the impedance method is not ready to be used routinely in surgery or intensive care, but an outright dismissal of such a promising and needed technology appears uninformed. Albeit impedance spectroscopy (that is, fitting impedance spectral data to a physical model) is an engineering and physics-based method, it is a powerful assessment technique used in many fields of science. De Lorenzo has recently published a review for the field of human body composition (1).

Impedance spectroscopy has yielded numerous promising results for characterization of ECW. Most subjects do not have ascites, and body water tends to be distributed (1, 5, 11). Therefore, strong relationships between impedance and dilution-determined water volumes have emerged in populations including, but not limited to, cardiac surgery patients (6). Ho et al. (3) used impedance spectroscopy to accurately predict a deuterium TBW before and after hemodialysis. Because TBW was predicted as ECW + ICW (1), and dialysis patients tend to have an expanded ECW, this study serves as a validation for ECW and ICW. Van Marken Lichtenbelt (10) discovered that growth hormone-deficient patients have an enlarged ECW compared with ICW compartment. For impedance spectroscopy to accurately predict ICW, which is technically far more difficult to predict than ECW, it must be predicting ECW accurately. Katzarski et al. (4) discovered that hypertensive hemodialysis patients had significantly larger ECW volumes than did controls and normotensive patients. It is well known that much of the hypertension in dialysis patients is caused by fluid overload (that is, ECW). For seriously ill intensive care patients with severe wasting, Finn et al. (2) reported an excellent relationship between the impedance and bromide dilution-determined ECW and its change at four time points over 21 days. Normally, if a parameter is not being measured physically, it will not accurately reflect differences between subjects or accurately predict change.

To summarize, the error caused by an inappropriate electrode placement is different than that caused by not properly interpreting the measurement. Our investigation was designed to evaluate the latter (6). The most widely used physical model of biological tissue consists of four variables (1), and this model cannot be computed with impedance measured at one frequency (6). On the other hand, through mathematical modeling, the different parameters of the tissue (e.g., ECW and ICW) can be independently predicted. Impedance spectroscopy has profound implications for the medical field.

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