Comparison of Total Body Water Measured by Bioimpedance Spectroscopy to Urea Kinetic Modeling and Anthropometric Estimates in Hemodialysis Patients

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ABSTRACT

Monitoring of fluid, body composition and nutritional changes is important in clinical nephrology. The Body Composition Monitor (BCM) measures whole-body bioimpedance and determines extracellular and intracellular resistance by using the Cole-model[1] to estimate total body water (TBW). Urea kinetic modeling (UKM) allows the estimation of urea distribution volume over a defined period of time. We studied the bias between estimated UKM volume (V_{UKM}) to anthropometric volume (V_{ant}) estimates and measured TBW volume via BCM (V_{BCM}). Pre-hemodialysis (HD), electrodes for the BCM assessments were placed on the non-arteriovenous access arm and ipsilateral leg, respectively, with the patient in a supine position. V_{ant} was calculated using the Watson equations[2]. In order to calculate V_{UKM}, we entered the specified values from the most recent HD treatment into the open-source JavaScript tool, "Solute-Solver" (http://ureakinetics.org). We visually compared the estimated V_{UKM} versus the V_{BCM} in a scatter- and Bland-Altman (BA) plot. For error investigation, we studied the computed bias (V_{UKM} minus V_{BCM}) as a function of BMI and stray capacitance in a BA plot. We then calculated the difference between V_{ant} and V_{UKM} and illustrated the comparison in a scatter and BA plot. The scatter plot showed agreement and the BA plot had no systematic trends or proportional error in the main analysis. Neither BMI nor stray capacitance explained bias and variance in the bias between both estimates. V_{ant} and V_{UKM} plots showed agreement with a mean bias of -2.3±5.1 but without proportional error. Both V_{BCM} and the V_{UKM} as the "Bronze Standard" of TBW estimation seemed to agree reasonably well. Neither body composition measurement nor kinetic modeling approach showed any significant influence on the accuracy and precision of the estimate. According to BCM availability, estimated V_{UKM} or measured V_{BCM} could be used alternatively in practice to support clinical decision when pharmacokinetic considerations are concerned.

INTRODUCTION

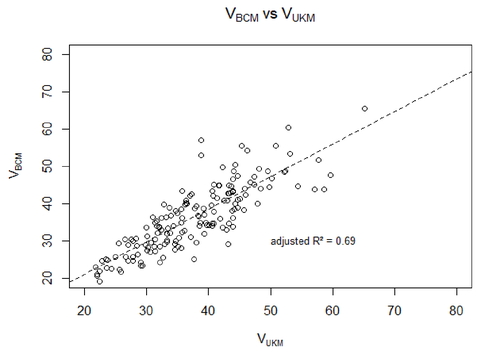
Measuring and monitoring fluid levels is essential in clinical nephrology and allows for the prescription of dialysis dose. There is no possible way to measure total body water (TBW) with absolute accuracy but there are various estimation methods that are used in clinical practice today.

BCM - The Body Composition Monitor (BCM) is a bioimpedance spectroscopy device that measures extracellular and intracellular resistance. It utilizes the Cole model[1] algorithm to determine volume (V_{BCM}).

UKM - Urea Kinetic Modeling (UKM) is another method to estimate dialysis dose and utilizes the urea distribution volume (V_{UKM}), calculated over a defined period of time, as the closest estimation for TBW.

V_{ant} - Anthropometric volume (V_{ant}) is estimated using age, height, and weight only. Watson[2] pioneered linear regression equations to estimate TBW in both men and women.

We studied the bias between V_{BCM}, V_{UKM}, and V_{ant} to determine which method could provide the most accurate estimate of TBW.



METHODS

BCM - Pre-hemodialysis (HD) treatment, electrodes for the BCM assessments were placed on the non-arteriovenous access arm and ipsilateral leg, respectively, with the patient in a supine position[3]. Results were stored on individualized patient cards and later exported to the Fresenius Medical Care database which we extracted and merged with patient demographic, labs, and treatment data.

UKM - Data points were inputted to the open-source JavaScript tool, "Solute-Solver". It uses a series of equations to measure the intradialytic clearance of urea and determine the dialysis dose:

Kt/V

where, K, clearance, measured in mL/min

t, treatment time, min

V, volume, mL

V_{ant}

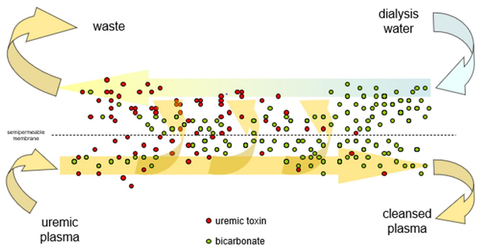
The Watson equations:

Men: $2.447 – 0.0951\ A + 0.1074\ h + 0.3362\ w$

Women: $-2.097 + 0.1069\ h + 0.2466\ w$

where, A is age in years, *h* is height in cm and *w* is weight in liters.

We visually compared all volume methods in Bland-Altman graphical analyses as well as scatter plots. We further investigated key values in body composition and UKM such as, BMI, age, lean tissue index, and adipose tissue index.

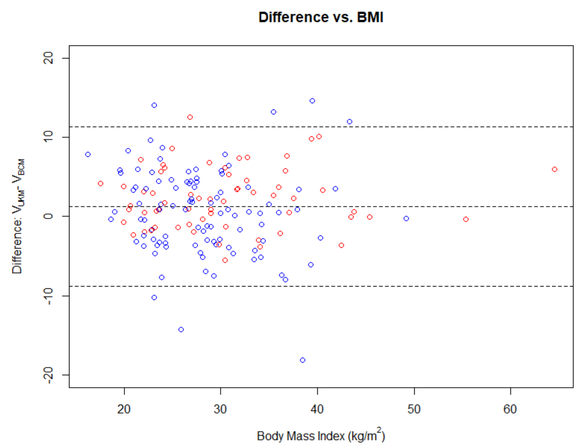


RESULTS

Retrospective study conducted on 161 HD patients.

- 60.86% male
- Age 61 ± 15 years
- Post-HD weight 81.6 ± 22 liters

The Bland-Altman plots of V_{UKM} and V_{BCM} do not trend in either direction indicating no proportional error. However, the center dashed line is slightly above 0 on the difference scale indicating an over-estimation of V_{UKM}. We plotted this bias as a function of BMI as well as the ratio of extracellular to intracellular volume. Both showed a very low adjusted R^2 of -0.006 and 0.02 respectively, indicating the absence of a relationship. Intracellular volume showed more agreement with adjusted R^2 of 0.13. Additionally, age was plotted as a function of the ratio of extra- intracellular volume and showed significant correlation: $R^2 = 0.26$. V_{ant} and V_{UKM} plots showed agreement with a mean bias of -2.3±5.1 but without proportional error.



DISCUSSION & CONCLUSIONS

Conclusion: The correlation between ICV and the V_{UKM} and V_{BCM} bias could be explained by the urea equilibration from the intracellular to the extracellular compartment after the HD treatment. Additionally, a loss of muscle mass and intracellular volume is expected as we age. The V_{ant} tends to be an underestimation because it does not account for the excess fluid that is common in HD patients. According to BCM availability, estimated V_{UKM} or measured V_{BCM} could be used alternatively in practice to support clinical decision when pharmacokinetic considerations are concerned.

Discussion: Since there is no current "Gold Standard" method to measure total body water, we utilize models and equations such as UKM in clinical practice. We found that BCM compares favorably to V_{ant} and agrees well with UKM urea distribution volume estimation. This is a popular area of study, and our results agree. Longitudinal studies are needed to evaluate the potential of including BCM measurements alongside UKM to support clinical decision making.

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