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Advances in Evaluating Fluid Levels: Bioimpedance in Patients with Kidney Failure

Harith Abdelkareem Baker [1], Mohammed Sabah Jarjees[2], Amer Farhan Sheet[3] and Thair Hawas Hamed [4]
[1,2,3] Department of Medical Instrumentation Techniques Engineering, Technical Engineering College of Mosul, Northern Technical University, Mosul, Iraq
[4] Health Directorate of Nineveh, Mosul, Iraq

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Corresponding author:
Name: Harith Abdelkareem Baker
Affiliation : Northern Technical University, Technical Engineering College of Mosul, Department of Medical Instrumentation Technology Engineering
Email:
harith.abdalkareem@ntu.edu.iq

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ABSTRACT

This study delves deeply into the various facets of bioimpedance analysis as it relates to the development of chronic kidney disease (CKD). The use of bioimpedance spectroscopy (BIS) to evaluate the effectiveness of peritoneal dialysis (PD) and determine dialysis adequacy using variables like volume (V) and Kt/V is at the heart of this compilation. The investigations closely look at how important water distribution is for the advancement of CKD and how that affects patient outcomes. Evaluation of several body composition measurement methods is emphasized, especially the combination of the bioelectrical impedance analysis (BIA) ratio and the dry mass index (DMI). By applying the BIA TBW Watson ratio, these approaches provide important insights into the relationships between fluid volume and physiological indicators, such as body mass index (BMI) and total body water (TBW). The study emphasizes the differences in fluid overload diagnosis between conventional clinical assessments and sophisticated bioimpedance techniques, particularly in older patients with chronic kidney disease (CKD), underscoring the need for proper monitoring and intervention.

Bioimpedance analysis is crucial to understanding chronic renal disease and associated cardiac complications, as shown in the assembled study. Bioimpedance analysis, used in devices like the Body Composition Monitor (BCM), is highlighted in this study collection to monitor hydration and improve dialysis adequacy.

Bioimpedance analysis improves illness treatment, giving chronic renal failure and heart failure patients a more precise and nuanced grasp of fluid management, according to the literature.

I. Introduction

Healthcare professionals have numerous obstacles while dealing with kidney failure, a severe clinical illness marked by the kidneys' incapacity to sufficiently filter waste and excess fluids from the circulation[1], It can present either abruptly, with a sudden loss of renal function, or chronically, with a gradual deterioration in kidney function over years[2]. Because of its rising global prevalence and its link to increased morbidity and mortality, chronic kidney disease (CKD), which can lead to end-stage renal disease (ESRD), is a serious public health problem[3]. As kidney failure advances, toxic compounds build up in the body, which can cause several problems, including electrolyte imbalances, fluid retention, hypertension, anemia, and bone diseases[4]. In addition to severely impairing the quality of life for those who experience them, these difficulties raise the risk of cardiovascular illnesses, which is the main cause of mortality for people with advanced renal disease[5]. To reduce these risks and enhance patient outcomes in renal failure, effective management, and prompt intervention are therefore essential.

The loss of renal function that results in the incapacity to efficiently filter and expel waste products from the body is the hallmark of kidney failure, a serious global health concern. Based on epidemiological data, 10% of the world's population suffers from chronic kidney disease (CKD), a condition that is associated with a higher risk of renal failure[6]. End-stage renal disease (ESRD) is the most severe form of kidney failure, and its progression places a considerable strain on global healthcare systems due to the need for expensive treatments like dialysis or transplantation[7]. Cardiovascular illness, the primary factor leading to mortality in this patient group, is linked to a heightened likelihood of kidney failure.[8]. Its correlation with other comorbidities such as diabetes and hypertension, which are common and becoming more so worldwide, exacerbates the condition's effects even more[9]. Kidney failure also disproportionately affects groups with lower incomes, which exacerbates health inequities and emphasizes the need for equitable access to care and preventive measures[10]. Reduced global health effects and associated economic burden are contingent upon comprehensive management of renal failure, including early detection and intervention[11].

The maintenance of fluid balance is a critical component of patient care in the treatment of kidney failure, where efficient fluid management is essential[12]. Fluid retention occurs in renal failure patients due to the kidneys' reduced ability to eliminate extra fluid, which increases the risk of hypertension, pulmonary edema, and congestive heart failure[4]. According to studies, that link fluid excess to higher cardiovascular morbidity and mortality in this patient population, proper fluid management is crucial to reducing these risks[13]. Maintaining appropriate fluid status and avoiding problems require the application of fluid management strategies, such as limiting fluid intake and using diuretics[12]. Additionally, more accurate fluid status assessments are made possible by technological advancements like bioimpedance analysis, which may lead to improvements in tailored patient care[14]. Maintaining appropriate hydration while minimizing fluid-related problems is the major objective of fluid management in kidney failure. This balance is critical for enhancing long-term patient outcomes[15].

Maintaining fluid balance is vital for people with renal failure, as it directly affects cardiovascular health and death rates. Fluid overload, which can worsen cardiac stress and be a contributing factor to heart failure, left ventricular hypertrophy, and hypertension, is frequently caused by the reduced excretory function associated with kidney failure[16]. With over half of all deaths in this population coming from cardiovascular complications, end-stage renal disease (ESRD) patients have cardiovascular complications as their primary cause of mortality[5]. Therefore, adequate fluid management is essential for improving survival rates, lowering the risk of cardiovascular events, and relieving symptoms. Research has demonstrated that the frequency of cardiovascular morbidity and death in these patients is dramatically reduced when adequate fluid balance is maintained with customized therapy, such as diuretics and customized dialysis regimens. Furthermore, by enabling more precise regulation of fluid status, novel strategies like bioimpedance-guided fluid management have shown encouraging results in improving cardiovascular outcomes[17]. Therefore, reducing cardiovascular risks and enhancing the overall prognosis for kidney failure patients need the strategic management of fluid balance[18].

Diagnosing fluid overload in kidney failure patients is a complex task, made more difficult by the shortcomings of current diagnostic techniques. The sensitivity and specificity required for the early and precise identification of fluid overload are frequently lacking in traditional procedures, such as clinical examinations and routine imaging techniques, which can result in inadequate or delayed therapies[19]. Clinical symptoms such as edema may not necessarily be indicative of a considerable fluid accumulation and may not show up until later[20]. To get around these restrictions, sophisticated techniques have been developed, such as bioelectrical impedance analysis (BIA).

Nevertheless, the inconsistency of human physiology and technical difficulties sometimes limit their implementation, potentially producing uneven outcomes. Patients with concomitant illnesses, like heart failure, have extra assessment issues due to changed fluid dynamics, making the interpretation of fluid status more difficult[21]. These challenges highlight the necessity of developing more accurate, accessible, and dependable techniques for determining fluid status, as doing so is essential to improving renal failure patients' care and results[22].

In the medical field, bioimpedance analysis (BIA) has become a vital tool for evaluating fluid status and body composition, especially in patients suffering from kidney failure. By measuring the body's tissues' resistance (impedance) to the passage of a tiny electrical current, this non-invasive method offers important insights into the body's fluid and electrolyte balance as well as the composition of its lean and fat mass [23]. Because BIA can predict fluid overload, a significant condition in dialysis patients, it is useful in clinical settings, particularly in nephrology[23]. Compared to conventional fluid evaluation methods, this approach has several benefits, such as ease of use, speed of implementation, and the ability to be routinely monitored. To ensure accuracy, however, patient-specific characteristics including age, gender, and illness condition must be carefully taken into account when interpreting BIA data[24],[25]. More complex models that can provide segmental analysis and increased precision have been developed as a result of recent advances in BIA technology, which has expanded the field's use in individualized patient treatment. Despite its advantages, there are still difficulties in integrating BIA into clinical practice, such as the requirement for calibration tailored to patient groups and standardized protocols[26].

A promising substitute is provided by bioimpedance analysis, which is founded on the idea of electrical impedance measurement. Using this method, a harmless electrical current is passed into the body, and the resistance it encounters—known as impedance—tells us how much fluid is in it[27],[28].

This study aims to evaluate the effectiveness of bioimpedance analysis in estimating the extra water intake in individuals suffering from kidney failure and to demonstrate the critical role that BIA plays in evaluating fluid status and the important implications that it has for improving treatment strategies and patient outcomes in patients with chronic kidney disease (CKD).

It will accomplish this by going over current research, methods, clinical uses, and BIA technological trends.

To advance precision medicine and optimize the management of fluid overload in this vulnerable patient population, it is essential to comprehend the subtleties of fluid assessment utilizing bioimpedance in the context of kidney failure.

A non-invasive technique called bioimpedance analysis (BIA) is used to evaluate the electrical impedance of biological tissues, which varies depending on what makes up the tissue. Because they contain more water and electrolytes than fat, lean tissues are better at conducting electricity. BIA is helpful for clinical applications since it offers painless, fast examinations in real-time. For those with kidney illness, routine examination is crucial. Body composition and fluid status can be monitored with BIA. Advances in technology have improved the accuracy and broader range of clinical problems and populations to which BIA can be applied. Individual characteristics and health status must be taken into account when interpreting data because impedance measurements might be impacted by things like degree of hydration and disease state. The work makes use of bioimpedance analysis to shed light on the management of fluids in chronic kidney disease (CKD), a condition to which both cardiology and nephrology are related. Through the integration of techniques such as the dry mass index (DMI) and the bioelectrical impedance analysis (BIA) ratio, it enhances the evaluation of dialysis treatments, raises awareness of fluid dynamics in chronic kidney disease (CKD), and advances body composition assessment.

The study establishes the effectiveness of bioimpedance approaches in monitoring hydration levels, raising the possibility of better-controlling fluid overload, a common and hazardous result in patients with kidney failure. It also emphasizes how important it is to precisely control fluids to reduce cardiac risks associated with chronic kidney disease (CKD) and improve cardiorenal health.

Better illness management strategies could result from the study's conclusions, which could have an impact on clinical practices and healthcare policies. Beyond scholarly interest, this research is significant because it may affect patient care, treatment approaches, and healthcare policy about CKD and related heart conditions.

II. Literature Review:

By exploring the current corpus of literature, we will shed light on the fundamentals and practical uses of BIA and reveal its fascinating realm. By the time this literature review is finished, readers will understand the importance of bioimpedance analysis and how it might revolutionize the fields of medicine and healthcare.

A study by G. Martı´nez Fernandez et al. (2013) compares the Watson formula, which is widely used for volume (V) calculations in the context of Kt/V determination, with bioimpedance spectroscopy (BIS) to assess the effectiveness of peritoneal dialysis (PD) in this prospective observational study of 78 PD patients[28]. The Watson formula is commonly utilized, however, BIS offers a more direct and valuable approach for assessing volume, as well as other nutritional and hydration parameters, in individuals with Parkinson's disease. The study utilizes both Kt/Vbis and Kt/Vw measurements to calculate the weekly Kt/V value. Additionally, it employs BIS-derived metrics to examine the individual's hydration status. It has been observed that the volume calculated using the Watson formula is significantly larger than the volume calculated using BIS. According to the BIS study, 60.25% of patients show overhydration, defined as having a volume of extracellular fluid equal to or greater than 1.1 liters. The study introduces the concept of a reference Kt, which is calculated using statistical techniques relying on Pearson's linear correlation coefficient, intending to achieve a desirable weekly Kt/V of 1.7. The target Kt value, found using Kt/Vbis, is 64.87 L.

Moreover, Yasushi Ohashi et al. (2013) evaluated patients' body composition using dry mass index and total body water ratio to estimated volume based on bioelectrical impedance analysis[29]. A study that examines novel approaches to quantifying muscle mass and body water in kidney disease patients reveals potential limitations in certain widely used techniques. It recommends combining various measurements to gain a better understanding of the fluid levels and body composition of a patient. Among the 45 participants in the study, all of them had chronic kidney disease (CKD): TBW BIA/TBW Watson showed a negative correlation with age and serum albumin level and a positive correlation with weight, BMI, and diastolic blood pressure. Aging, body weight loss, and intracellular water (ICW) deficit were all correlated with ECW BIA / TBW BIA. Participants were categorized into different groups based on DMI, BMI, and TBW BIA /TBW Watson, revealing variations in fluid and nutritional status. It was discovered that the ECW BIA/TBW BIA is an unreliable indicator of an edematous state in patients with CKD.

Besides Tai et al. (2014) discovered a relationship between the extracellular volume status of individuals with chronic kidney disease and their renal outcomes[30]. In this work, the extracellular volume status of 149 individuals with chronic kidney disease (CKD) was investigated using bioelectrical impedance analysis (BIA) and the Watson method. The results showed that older persons with CKD may need to be concerned about volume overload since the ratio of intracellular water (ICW) to extracellular water (ECW) varies with age. According to the study, an increase in the percentage of extracellular and intracellular water in body fluids was caused by aging-related increases in both water volumes. Patients with the highest tertile were more likely to experience unfavorable renal outcomes. There was an independent relationship between poorer renal outcomes and the ECWBIA and the total body water (TBW) Watson ratio. Proteinuria and the extracellular volume status had an independent correlation. The ratio of (ICW) to (ECW) changes with age because a larger amount of (ECW) is present in the bodily fluid composition. Therefore, older people with chronic kidney disease (CKD) may be susceptible to volume overload.

Similarly, Thanakitcharu et al. (2014) Used Bioelectrical Impedance Analysis to Predictively Identify Subclinical Edoema in Patients with Chronic Kidney Disease[31]. According to a study published in the Journal of the Medical Association of Thailand, patients with chronic renal disease can effectively identify subclinical edema using bioelectric impedance analysis (BIA). Higher glomerular filtration rates were found in individuals with chronic kidney disease (CKD) during a 12-month research. Edema-BIA indicated an edematous state in 42.1% of subclinical cases of edema. In the early stages of CKD, subclinical edema was discovered before the detection of overt edema. The study supported the use of MF-BIA for measuring body fluid distribution. Total body water weight (TBW) can be calculated using the Watson formula to diagnose hydration status and prescribe the necessary treatment.

In other words Masahide Furusho et al. (2014) Effects of Nutrition and Hydration on the Watson Formula in Patients Receiving Peritoneal Dialysis[32]. To ensure sufficient dialysis, the urea clearance (Kt/V urea) is modified based on the total body water (TBW) using the Watson formula (TBW Watson). This type of formula is frequently employed to direct the prescription of peritoneal dialysis (PD). While the correlation between body composition and TBW Watson's determination is widely recognized, the effect of nutrition and hydration status on TBW Watson is still uncertain. Therefore, researchers examined the impact of nutrition and hydration on total body water (TBW) in patients with Parkinson's disease (PD). This study recruited 33 healthy control volunteers and 195 patients with Parkinson's disease (PD). The measurement of total body water (TBW) was conducted using a technique called multiple-frequency bioelectrical impedance spectroscopy

(MF-BIS). The results obtained from this method were then compared to the TBW Watson. The patients were divided into three groups based on their amount of overhydration, measured in liters of OH. The regularly hydrated group had an OH level of 4.0 L. For patients who were typically well-hydrated, the Watson formula provided a higher estimate of total body water (TBW) compared to MF-BIS. However, for patients who were significantly overhydrated, the Watson formula provided a lower estimate of TBW compared to MF-BIS. In addition, 22 of the patients who were frequently hydrated were evaluated as malnourished based on subjective assessment. Furthermore, their overestimation of total body water (TBW) using the Watson formula was much higher compared to the well-nourished patients. This study indicates that the total body water (TBW) in Parkinson's disease (PD) patients are considerably influenced by both their food and hydration levels.

To put it another way, Samer R. Abbas et al. (2015) Fluid Overload Issues Can Be Solved by Bioimpedance. This work reviews bioimpedance (BI) techniques in detail to determine body composition, fluid overload, and hydration status in end-stage renal disease patients[33]. This paper reviews various bioimpedance techniques for measuring body water levels in patients with severe kidney disease. It also goes over how these methods aid in comprehending the body water content and nutrition of patients. The study assessed different bioimpedance (BI) methods for determining the level of hydration in patients with end-stage renal disease. The ones that follow are important outcomes: Whole-body Single-Frequency BI at 50 kHz: Useful for indicating fluid loading and nutritional status in population studies. Extracellular fluid volume (ECV), intracellular fluid volume, and total body water are measured in dialysis patients using whole-body multifrequency bioimpedance spectroscopy.

In addition, Jung Eun Lee et al. (2015) Through the use of bioimpedance analysis, the nutritional health and level of hydration in young and old hemodialysis patients[34]. In this study, nutritional status and hydration were evaluated in hemodialysis patients of different ages. The overall iron-binding capacity and hand grip strength of elderly patients were decreased. Older individuals had reduced levels of intracellular water and phase angle. Older patients exhibited a greater ratio of extracellular water to total body water. Risk factors for fluid overload included age, diabetes, and a reduced phase angle. Elderly HD patients had higher rates of fluid excess and malnutrition. An older HD patient's total iron-binding capacity and hand grip strength were both decreased. In senior HD patients, BIA measurements of intracellular water and phase angle were decreased. Older HD patients had a greater ECW/TBW ratio. Age and the presence of diabetes were strongly correlated with the ECW/TBW ratio. The ECW/TBW ratio had a negative correlation with albumin, urine volume, HGS, PhA, and sex. Sex, albumin, HGS, and PhA were all inversely correlated with the malnutrition-inflammatory score. The following conditions enhanced the chance of increased ECW/TBW: reduced PhA, diabetes, and advanced age. Reduced PhA significantly influenced the state of malnutrition. Malnutrition and fluid overload are more prevalent in older HD patients. To evaluate the dietary and hydration status of senior HD patients, PhA measured by BIA is helpful.

Likewise, Gonzalo Martínez Fernández et al. (2016) Compared the Watson formula with bioimpedance spectroscopy to determine body volume in peritoneal dialysis patients[35]. This study examines the relationship between clinical variables and measurement discrepancies between two techniques for estimating body volume in patients receiving peritoneal dialysis: bioimpedance spectroscopy and the Watson formula. It was discovered that the Watson formula frequently yields a body volume that is roughly two liters higher than bioimpedance spectroscopy. Compared to bioimpedance spectroscopy (BIS), the Watson formula estimated body volume to be 2.15 liters higher. The difference between the two approaches was higher than or equal to 10% in 58.67% of measurements. Significant variations in volume measurements were linked to clinical variables such as inflammation, diabetes, obesity, hypoalbuminemia, and hypertension.

Next YAHYA et al. (2016) monitoring of variations in water transfer during the hemodialysis cycle. The hemodialysis machine does not show the water transfer ratio during the few-hour hemodialysis cycle[36]. Because this cycle lasts for about four hours, it is important to monitor the patient's level of hydration to prevent overhydration or dehydration. The idea of bioimpedance, as well as the biological body's composition and its various compartments, including total body water (TBW), intracellular water (ICW), extracellular water (ECW), fat-free mass (FFM), and fat mass (FM), have all been examined in this work. We therefore developed a system to detect a small variation of the bioimpedance (order of a few milliohms) and to extract and display the various biological compartments. There is a variation in the quantity of water, and this variation in water slowly varies function leading to a small variation of the bioimpedance. This system, which uses an STM 32discovery board, calculates the body water compositions and displays the bioimpedance value in real-time while accounting for the patient's physical characteristics, including age, sex, weight, and length. Lastly, by providing information on the patients' states of overhydration or dehydration, the suggested embedded solution can be incorporated into the hemodialysis machine to assist the nephrology physician.

However, Eun Mi Yang et al. (2017) Evaluation of Fluid Status in Korean Paediatric Hemodialysis Patients with the Use of Bioimpedance Techniques[37]. Twelve children receiving hemodialysis (HD) participated in a study designed to evaluate the precision of bioelectrical impedance techniques in determining the fluid condition of the body. The fluid state was assessed using bioimpedance spectroscopy equipment (BCM) and a multi-frequency bioimpedance analysis device (Inbody S10) in the study. The results demonstrated a high relationship (Pearson's coefficient, r = 0.772 with Inbody S10 vs. each device recorded fluid differential, ΔMF) between the amount of fluid removed during an HD session and the difference in total body water. Fluid overload was detected by bioimpedance assessment in 34.8% of cases with Inbody S10 and 56.5% with BCM. By using bioimpedance methods, only around 60% of children with fluid overload displayed clinical signs including edema and hypertension. BCM was more useful than Inbody S10 in measuring the amount of fluid buildup in those patients who had gained more weight. This is the first publication on the evaluation of fluid management using body composition.

On the other hand, Samer R. Abbas et al. (2017) Effect of Modification in Fluid Status Assessed by Bioimpedance Methods on Patients' Body Composition during Hemodialysis[38]. The study assessed the changes in body composition when the fluid status was lowered to DW cBIS. There were no discernible changes in lean body mass or fat mass. Patients with diabetes had less effective fluid removal during HD. A higher percentage of diabetes patients in the non-DW cBIS group. Over 4 weeks, decreasing hydration status had no discernible impact on body composition. Patients with reduced ECV and fluid overload attained DW cBIS. Patients with diabetes were less effective at eliminating extra fluid volume. Body composition was unaffected considerably by decreasing fluid status. Patients with diabetes have reduced fluid removal efficiency. Patients with diabetes have trouble returning to a normal fluid balance.

In the same vein, Nazanin Noori et al. (2018) Volume Calculations for Chronic Hemodialysis Patients Using the Watson Equation and Bioimpedance Spectroscopy[39]. The study aimed to assess the accuracy of total body water (TBW) estimations in in-center hemodialysis patients using the Watson formula compared to those obtained using bioimpedance spectroscopy (BIS). 184 patients at St. Michael's Hospital provided anthropometric features that affected TBW calculations. The study found a strong association between the Watson formula and BIS-derived TBW, but the Watson method regularly overestimated TBW, particularly in individuals with larger waist circumference. Males overestimated 5.1 liters, while women overestimated 3.8 liters. Increased waist circumference and fat mass, markers of obesity, were linked to higher Watson formula TBW overestimation. The study created different equations for men and women based on waist circumference and weight, but the lack of external validation and the assumption that BIS is the gold standard for body compartment evaluation were limitations. The study emphasizes the importance of considering different approaches, such as BIS, for more accurate TBW evaluations in this patient population.

By the same token, CHAE RIM KIM et al. (2018) Monitoring Volume Status in Chronic Hemodialysis Patients using Bioelectrical Impedance Analysis[40]. Fluid overflow increases the risk of cardiovascular events and mortality in hemodialysis patients with end-stage renal disease. To track volume status, bioelectrical impedance analysis (BIA) was employed. Cardiovascular events were at a decreased risk in patients with regulated volume. The risk of mortality from all causes was greater in patients with uncontrolled volume. In this population, strict volume management may lower mortality and cardiovascular events. The risk of mortality from all causes was greater in the uncontrolled group. The group that was not under control had a greater risk of cardiovascular events. When confounding variables were taken into account, the difference in cardiovascular incidents vanished. For ESRD patients receiving continuous hemodialysis, fluid overload is a separate risk factor for cardiovascular events and all-cause mortality. For patients receiving chronic hemodialysis, employing BIA to monitor volume status may assist predict all-cause mortality. Tight volume regulation may lower mortality and cardiovascular event rates.

Furthermore, Sean WY Lee et al. (2019) Assessment of body composition using various bioimpedance techniques in Asian patients with chronic renal disease who are not on dialysis[41]. The study suggests that individual characteristics like race and body size can affect the accuracy of these measurements and that physicians should exercise caution when choosing a method to assess body water in these patients. Researchers compared two techniques for measuring body water in Asian patients with chronic kidney disease who were not on dialysis, finding significant differences in the results. While BIA reported 38.3 liters, BIS measured an average of 33.6 liters for total body water (TBW). With BIS, extracellular water (ECW) was 15.8 liters on average, and with BIA, 16.9 liters. On BIS, intracellular water (ICW) was 17.9 liters, whereas on BIA, it was 21.0 liters. For TBW, ECW, and ICW, the study discovered a significant correlation between BIS and BIA measurements. Compared to BIA, BIS appeared to be more in line with biochemical and clinical markers of fluid overload. Variations in body water assessments were related to kidney function, body mass index, sex, and ethnicity.

Meanwhile, Masatomo Yashiro et al. (2019) Novel equations for bioimpedance spectroscopy body fluid volume calculation based on the agreement between extracellular water change and body weight before and after hemodialysis as a reference[42]. The study found that the novel equations produced the best agreement between changes in extracellular water (ECW) and changes in body weight after hemodialysis when compared to earlier techniques. The patients' true fluid status at their dry weight was more accurately represented by the novel developed formulas, suggesting a more accurate assessment of hydration. The study evaluated several techniques for hemodialysis fluid volume estimation. The innovatively formulated equations performed better than Moissl (0.375) and MLT (0.411), with concordance correlations of 0.896 for ΔW. The median dER of the novel equations was 0.062, whereas that of MLT (0.164) and Moissl (0.144) was higher ($p < 0.001$).1.02 kilograms of bodily fluid were equal to 1 liter of bodily water. Enhancing the agreement between ΔECW or ΔTBW and ΔW were the new formulas.

In light of, Frank M. van der Sande et al. (2019) Utilizing Bioimpedance Spectroscopy to Evaluate Dialysis Patients' Volume Status[43]. The application of bioimpedance spectroscopy (BIS) to fluid management in dialysis patients is discussed in this paper. Patients on hemodialysis (HD) or peritoneal dialysis (PD) frequently experience fluid overload (FO). In dialysis patients, FO is independently correlated with both outcome and death. Left ventricular hypertrophy (LVH) and hypertension management are enhanced by BIS-assisted dry weight modification. Results from BIS-guided therapy for peritoneal dialysis patients have been inconsistent. Patients with PD and HD have a significant prevalence of FO.FO has an independent relationship with outcomes in individuals without dialysis, HD, and PD.LVH and noncardiovascular risk factors are associated with FO. Dry weight management with BIS support results in better LVH and hypertension control. There is conflicting evidence about how BIS-guided dry weight adjustment affects mortality. In PD patients, the results are less clear-cut. Large-scale research in the future is required to evaluate BIS to its full potential. Dialysis patients frequently experience fluid overload (FO), which has an independent correlation with outcomes.FO is associated with both noncardiovascular risk factors and left ventricular hypertrophy (LVH). In HD patients, BIS-assisted dry weight modification improves LVH and hypertension management. It is currently unknown how BIS-guided dry weight modification affects mortality. BIS results in PD patients have been less clear-cut. Large-scale research in the future is required to evaluate BIS to its full potential.

Correspondingly, Magdalena Castro et al. (2020) formula for calculating the total body water in patients receiving chronic hemodialysis before predialysis [44]. A major public health concern, end-stage renal disease (ESRD) has significant rates of morbidity and death. Chile spends more than US$120 million on dialysis treatment alone each year. 22,310 ESRD patients underwent chronic hemodialysis (CHD) in 2018. In Chile, the prevalence of ESRD is 1,260 per million people 67% of CHD patients have hypertension, and 38.2% have diabetes. There is a 2,152/year rise in hemodialysis patients. Patients with CHD had a gross death rate of 11.3%. Cardiovascular illness, infections, and cerebrovascular accidents are the leading causes of mortality. Analysis was done on 88 measures from 44 hemodialysis patients. There were fifty male patients. The goal of the study was to provide a quantitative approach to determining a patient's level of hydration before HD. The entire body's water content before HD may be determined with the use of the equation. For every gender, the total body water estimate equation (TBWEE) was created. Clinical factors make it simple and rapid to compute TBWEE. When it comes to multi-frequency electrical bioimpedance, TBWEE is accurate and consistent. Every day before a dialysis session, TBWEE can be utilized in clinical practice. In hemodialysis, TBWEE can assist increase treatment accuracy and precision.

Equally important, Natalia Tomborelli Bellafronte et al. (2021) An examination of body composition parameters in people with chronic renal disease using dual-energy x-ray absorptiometry and bioelectrical impedance: a cross-sectional, longitudinal, multi-treatment study[45]. BIS and DXA body composition values were compared in the study. Compared to BISSEG, BISWB demonstrated higher agreement with DXA.FM was less biased than FFM. The ECW/ICW ratio affected method-to-method bias. For FM and FFM, new prediction equations were created. In terms of body composition metrics, BISWB and DXA agreed better than BISSEG. In settings of excessive body fat and muscle, FFM exhibited a larger bias than FM. There was less agreement between BIS and DXA in body change analysis. Bias was impacted by the ECW/ICW ratio, BMI, waist circumference, fat mass index, resistance, and reactance. More accuracy was demonstrated by new FM and FFM prediction formulae. In CKD, bioelectrical impedance methods provide a dependable means of assessing body composition. BIS should be used cautiously in dehydrated individuals. Body composition estimate prediction is improved by new formulae. Comparing longitudinal assessment to cross-sectional examination, the former revealed worse agreement with DXA. Bias can be reduced by consistently using the same body composition measurement.

Additionally, Maja Pajek et al. (2021) Body Composition Estimation in Hemodialysis Patients and Healthy Controls: A Comparison of the InBody 720 Bioimpedance Device and the Body Composition Monitor[46]. Bioelectric impedance devices are now considered the standard of care for both hemodialysis and peritoneal dialysis patients. The multi-frequency bioelectric impedance device InBody 720 (MF-BIA) and the bioimpedance spectroscopy body composition monitor Fresenius (BIS BCM) were used to measure the most significant body composition variables (extracellular water, intracellular water, total body water, and fat mass) in hemodialysis patients (n = 51, 175.1 + 7.8 cm, 82.2 + 15.2 kg) and healthy controls (n = 51, 175.1 + 7.6 cm, 82.3 + 15.3 kg). In hemodialysis patients, the MF-BIA InBody 720 device demonstrated considerably greater estimations of total body water and intracellular water and significantly smaller estimates of extracellular water and body fat when compared to the BIS BCM device ($p < 0.001$). Extracellular water and total body fat had mean relative differences in the order of 8% less, but the limits of agreement were still sufficiently large to be clinically meaningful. We conclude that the InBody 720 and BCM Fresenius measurement findings are not comparable. To follow the body longitudinally in their hemodialysis population, doctors and nutritionists who work with patients on hemodialysis should be aware of this disparity between the two devices and attempt to utilize the same equipment.

On the flip side, Nicolas Gautier et al. (2021) For low-flow home daily dialysis, which total body water measurement should be used to prescribe the dosage? [47]. This study used anthropometric techniques and bioimpedance spectroscopy to estimate total body water (TBW) in 40 low-flow home daily dialysis (HDD) patients. In this study, 40 HDD patients with more than three months of HDD experience were recruited from ten centers. Using anthropometric techniques (Watson-TBW) and bioimpedance spectroscopy (BIS-TBW), the median TBW estimates were 35.1 L and 36.9 L, respectively. Although there was a significant correlation ($r = 0.87$) between BIS-TBW and Watson-TBW, Watson's equation slightly overestimated TBW in HDD patients, but this was not significant for prescription frequencies greater than five sessions per week. The study highlights the importance of precise TBW estimation for prescribing dialysis doses in HDD. The findings have practical implications for clinical decision-making in dialysis prescription, emphasizing the correlation and distinctions between anthropometric and bioimpedance methods for TBW estimation in HDD.

Thus, Serena Low et al. (2021) Increased extracellular water to total body water ratio in type 2 diabetes was linked to the development of chronic kidney disease[48]. research on the relationship between excess extracellular volume and the development of CKD in type 2 diabetes. A greater risk of CKD development is linked to a higher ECW/TBW ratio. A 40% increased risk of CKD development is associated with an increase in the ECW/TBW ratio.MMP-2 and the advancement of CKD are positively correlated, mediated by the ECW/TBW ratio. In T2DM, a higher ratio of extracellular water to total body water is linked to the advancement of CKD.0.39–0.40 and >0.40 ECW/TBW ratios are associated with an increased risk of CKD development. A 40% increased risk of CKD development is linked to an increase in the ECW/TBW ratio. A 17.4% contribution from a higher ECW/TBW ratio explained the association between MMP-2 and the advancement of CKD. In T2DM, extracellular volume excess is independently linked to the advancement of CKD. In T2DM, extracellular volume excess is independently linked to the advancement of CKD. A higher ECW/TBW ratio acts as a mediator in the positive correlation between MMP-2 and the advancement of CKD. To fully comprehend the role of extracellular volume excess in the decline of renal function, more research is required.

Meanwhile, Nataphut Boonvisuth. (2022) Creation of an artificial intelligence model and evaluation of its accuracy in comparison to conventional bioelectrical impedance analysis for the prediction of dry weight in chronic hemodialysis patients[49]. The article discusses a new application of machine learning for determining the dry weight of hemodialysis patients. The model, which uses patient demographics, medical history, and laboratory data, predicts dry weight using more precise but costly equipment. The study found that the machine learning model showed promise in dry weight prediction, but it is not yet ready to replace the most effective approach currently in use. The results showed that 59.5±11.3 kg was the average estimated mass in grams (ML-DW) compared to BCM-DW and The bias was determined to be 0.78 kg based on the mean difference between ML-DW and BCM-DW.ML-DW and BCM-DW agreed on a range of -3.7 to 2.2 kg. The input variables of the machine learning model were time-series data. Numerous institutions have validated the machine learning model externally. For DW prediction, machine learning can be a useful method even though it isn't a perfect replacement for BCM.

In light of, Gwangho Choi1 et al. (2022) Consistency of ECW/TBW and predicted goal weights using BIA in patients undergoing hemodialysis between standing and lying down[50]. The study aims to compare the consistency of body fluid measurements in hemodialysis patients using two different body composition analyzers in lying and standing positions. The results showed that the estimated target weights and fluid ratios measured by both devices were similar before and after hemodialysis. The correlation between the estimated target weights before and after hemodialysis was very high, with R^2 values greater than 0.095. The change in total body water (TBW) measured by the devices was similar, with a R^2 of 0.718 for the S10 and 0.616 for the 770. The ratio of extracellular water to total body water (ECW/TBW) also showed a good correlation with R^2 values equal to or greater than 0.970. ECW/TBW and dry weight measurements were found to be comparable between the two devices according to the results of the Bland-Altman test.

Thereafter, Nazanin Noori et al. (2022) Validation of the SMH Equations for Hemodialysis Patients' Estimate of Total Body Water Volume[51]. Based on weight and waist circumference measurements, the study supports the St. Michael's Hospital (SMH) equations for predicting total body water (TBW) in hemodialysis patients. Strong concordance was seen between the TBW values obtained from the equations and the TBW obtained from bioimpedance spectroscopy (BIS). For HD patients, the SMH equations offer a precise total body water (TBW) estimate. The SMH equations can be used to improve the dialysis adequacy measurement. The Watson equations overstate TBW, especially in people with higher BMIs. The small sample size and the exclusion of those getting peritoneal dialysis were the study's weaknesses. better research is needed to better validate the SMH equations. SMH equations may enhance the assessment of HD adequacy and offer practical help. The weight and waist circumference formulas to estimate TBW are applicable for maintenance HD patients. Using the SMH equations could potentially improve the dialysis adequacy measurement. More thorough and diverse research is needed to confirm the SMH equations even more.

Next, Usama Hussein et al. (2022) Using bioimpedance methods, determine fluid overload in elderly individuals with chronic renal disease[52]. Research indicates that hyperhydration in older adults with kidney disease is often missed by physical examination, but can be more accurately detected with specialized testing. These body-water-measuring tests revealed that more kidney patients than physicians had suspected had excessive water retention. The optimal method for measuring body water was determined using a group of kidney patients and healthy individuals. The results imply that by identifying water issues early on, using these tests could improve the way kidney patients' health is managed. In 78% of CKD patients, fluid overload was identified by bioimpedance techniques using calf-normalized resistivity (CNR). The fluid overload to extracellular volume (FO/ECV) ratio was used to identify fluid overload in 62% of the patients. The ECV to total body water (ECV/TBW) ratio was found fluid overload in 52% of CKD patients. Clinical evaluation alone was only able to diagnose fluid overload in 24% of CKD patients.

Eventually, Mayne et al. (2023) Analysis of bioimpedance in individuals with long-term renal disease[53]. The study explores the potential of bioimpedance in heart failure and chronic kidney disease (CKD), focusing on devices like the Fresenius Body Composition Monitor (BCM). These devices measure electrical impedance, estimate water, and fat levels, and provide crucial information about fluid overload and body composition. The study emphasizes the need for consensus on best practices and nomenclature for bioimpedance measurements, especially when heart failure and CKD coexist. Although bioimpedance is not frequently used in randomized trials, fluid overload is a characteristic of heart failure. The article suggests integrating bioimpedance into telemedicine consultations, including at-home bioimpedance analysis in heart failure. The study advocates for more research and development on bioimpedance's potential in these conditions. It recommends using bioimpedance to improve blood pressure and volume status in CKD, with implications for treatment optimization. Remote fluid status monitoring could be made easier through telemedicine consultations that include bioimpedance evaluations. The study also highlights the importance of precise volume measurement in dialysis prescriptions.

Table: A survey of bioimpedance techniques for detecting alterations in bodily fluid levels

REF	Year	Sample Size	Methodology	Results	Limitations
1	2013	78 patients with Parkinson's disease	The volume, weekly Kt/V, other hydration status parameters, and reference Kt value were all extracted from BIS in a study.	BIS is a helpful tool for determining V in dialysis patients and evaluating their nutritional and hydration status, with a goal value of 64.87l.	For Parkinson's patients, the Watson formula might underestimate Kt/V , and the BIS method might not measure total body water accurately.
2	2013	45 randomly CKD patients.	Using BIA, patients had their ICW content, blood pressure, serum albumin, BMI, proteinuria, and ICW content evaluated.	the study is based on DMI, BMI, and TBW BIA TBW Watson. Additionally, cAlb is considered a potential nutritional marker.	Age and weight loss must be taken into consideration while updating the ECWICW ratios, which show an edematous state.
3	2014	149 people with CKD	Bioelectrical impedance analysis to assess extracellular volume status, finding a decline in GFR or renal replacement therapy due to factors like increased ECW.	In patients with chronic kidney disease, the ECW BIA TBW Watson ratio—which is impacted by sex and proteinuria—is associated with poor renal outcomes.	N/A
4	2014	48 healthy and 69 CKD patients.	prospective design and bioelectrical impedance analysis used to analyze bodily fluid distribution in CKD patients and healthy individuals.	Physical examination may not be sensitive enough to detect subclinical edema in CKD patients; MF-BIA and the Watson formula can help.	N/A
5	2014	195 peritoneal dialysis patients and 33 healthy persons	Overhydration measurement based on the Watson method The study measured TBW patients using multiple-frequency bioelectrical impedance spectroscopy.	According to the Watson formula, nutrition and hydration have a major impact on TBW in people with Parkinson's disease, with normal or severely overhydrated conditions showing lower TBW.	Weak research on Kt/V urea correlations in hemodialysis patients may have contributed to inaccurate Watson formula Kt/V calculations in patients with Parkinson's disease.
6	2015	N/A	Fluid volume, nutrition, body composition, and hydration levels are assessed in end-stage kidney disease patients using bioimpedance techniques.	Bioimpedance methods can be applied to body composition and nutrition research, calf hydration assessment, and dialysis patient fluid overload estimation.	Calf BI techniques are presently being used in the investigation, yet no precise fluid overload measurement or restrictions are stated.
7	2015	82 patients, 54 were young and 28 were elderly.	82 hemodialysis patients were divided into groups based on age and gender to assess nutritional status and hydration, as well as risk factors for malnourishment and fluid overload.	Reduced ICW, protein, mineral, SMM, BCM, BMC, and PhA, as well as higher ECWTBW and TBWFFM, are observed in elderly HD patients. PhA risk factors include diabetes and advanced age.	A cross-sectional observational methodology was used without serum biomarker verification, a small sample size, and traditional volume status assessments.
8	2016	74 peritoneal dialysis patients	The Watson formula body volume measurements and BIS differences in patients were significantly associated with hypertension and diabetes mellitus.	The Watson formula showed a higher V of 2.15 l compared to the BIS, with a difference of ≥10% in 58.67% of measurements, associated with hypertension and diabetes.	N/A
9	2016	N/A	LCD uses analog measurement tools to investigate the use of bioimpedance in the electrical modeling of water changes in the human body.	An analog system design utilizes an LCD, analyzes water variation electrical modeling, and creates a real-time bioimpedance measuring system.	The paper makes no mention of any particular restrictions.
10	2017	The sample size in the study was tiny.	Body weight changes significantly affect the accuracy of bioelectrical impedance devices in measuring fluid status in children receiving maintenance HD.	Inbody S10 and BCM devices are useful in identifying patients' fluid overload.	The device's authenticity and small sample size were not verified using the tracer dilution technique.
11	2017	60 finished the study.	No changes in CNR, SBP, DBP, UFV, UFR, treatment duration, or IDH symptoms in patients using calf BIA to guide dry weight reduction	The changes in HD patients' bodies due to weight reduction, revealed that individuals with diabetes struggled more with removing excess fluid.	Diabetic patients with reduced hydration status did not exhibit any appreciable alterations in body composition.
12	2018	The research had a small sample size.	discovers anthropometric factors influencing accuracy by comparing BIS-TBW estimates with Watson formula-based TBW estimates.	The Watson technique overestimated total body weight by 3.8 liters for women and 5.1 liters for men.	The study's equations are not externally validated, and using BIS-measured values may not accurately represent the "gold standard."

13	2018	643 ECWTBW values.	Patients' volume status was evaluated and the ECW/TBW ratio using bioelectrical impedance analysis over a 29-month median follow-up.	Volume control and bioelectrical impedance analysis help hemodialysis patients manage fluid levels, reducing cardiovascular risk and mortality.	Small sample size and single-center design, more extensive, multicenter research may be required for confirmation.
14	2019	98 patients as its sample size.	Using the Fresenius body composition monitor and Bodystat Quadscan 4000, the study compared body composition assessments in a diverse Asian population of stable, non-dialysis CKD patients.	With greater mean values for TBW, ECW, and ICW than for BIS measures, the study discovered a significant correlation between BIA measurements and BIS data.	Since the small sample size and single-center methodology may have introduced confounding variables, additional large-scale multicenter studies are required to validate the results.
15	2019	627 patients, while 466 of 351 HD patients	Novel equations based on agreement between ΔECW and ΔW were constructed and assessed using 466 data from 351 hemodialysis patients.	New equations demonstrate improved correlations, reduced deviation, enhanced agreement between measures, and potential for more precise fluid volume estimation.	N/A
16	2019	N/A	To fully comprehend the relationship between (BIS), fluid overload, and mortality in dialysis patients, more research is necessary, as this study makes clear.	Bioimpedance spectroscopy (BIS) offers benefits such as lower hospitalization rates, improved blood pressure control, risk stratification, and better prediction of dialysis patient outcomes.	Variations in treatment protocols can lead to unclear patient outcomes, and BIS-guided dry weight adjustment doesn't significantly affect mortality.
17	2020	The study did not calculate the sample size.	a quantitative method provides for predicting patient hydration status before HD, aiming to enhance therapeutic accuracy and precision, despite the absence of sample size calculation and stratified analysis.	Body water consumption in predialysis was estimated using a regression model; no significant differences were observed between centers when compared with Multifrequency Electrical Bioimpedance measurements.	The lack of stratified analysis for diabetes mellitus and the different coefficients and significant factors for the male and female equations restrict the study's target group.
18	2021	There were 266 individuals with CKD.	BIS and DXA were used to analyze patients with chronic renal and new equations for fat-free and fat-mass prediction were developed.	BIS is safe for patients with CKD when combined with a whole-body regimen, but should be used cautiously in dehydrated patients.	DXA measures leg and arm separately, while BISSEG assumes they are equal. BISWB and DXA have lower agreement for body change analysis, but greater overall agreement.
19	2021	N/A	TBW and body fat estimates differed significantly between InBody 720 and BCM devices, with ECW and total body fat exhibiting the least relative differences.	For total body water and intracellular water, the InBody 720 device performed better than the BCM device; for extracellular water and body fat, the differences were least significant.	The degree of agreement between BCM Fresenius and InBody 720 varies, with mean relative differences for different variables
20	2021	40 patients from ten centers.	The study compared methods for total body water estimation in home dialysis patients. Found a good correlation but Watson's equation overestimated.	Frequent prescriptions did not impact the overestimation of total body water in low-flow home daily dialysis using Watson-TBW and bioimpedance methods.	With a small sample size limited causation and long-term consequences, and did not assess overestimation impact.
21	2021	1079 T2DM patients made up the study's	Bioelectrical impedance analysis (BIA) was used in a prospective cohort design to assess body fluid state.	While excess extracellular volume in T2DM is linked to the progression of CKD, the link between MMP-2 and the increased ECW/TBW ratio has a positive effect.	This includes BIA, self-reported data, and a T2DM patient focus, suggesting the need for further research to validate its findings.
22	2022	A machine learning model prediction using large-scale HD session samples.	Retrospective data from chronic HD patients from 2017 to 2022 was used to construct the model, called ML-DW. Training and validation groups optimized the model's parameters.	The retrospective study, which lacks physical examination or patient symptoms, provides reliable results and strong agreement between the DW model and BCM, enhancing its generalizability.	A doctor's ability to alter DW is not included in the retrospective investigation, nor is it subject to patient complaints or physical examinations.
23	2022	56 hemodialysis patients.	The ideal target weight was determined by comparing measurements taken by patients using the InBody S10 and InBody 770 devices.	After hemodialysis with InBody devices, it discovered reliable BIA values, strong correlation, and consistent target weight and ECW/TBW measurements in both lying and standing positions.	The dry weight calculation formula's limitations, extracellular fluid excess in dialysis patients, and blood vessel dehydration can affect fluid measurements.
24	2022	There were only 81 patients in the sample.	Using a cross-sectional design, the study was carried out in a single-center hemodialysis unit at St. Michael's Hospital in Toronto, Canada.	SMH equations and BIS-TBW showed strong correlations, demonstrating their predictive accuracy for TBW and Kt/V across all waist circumference categories.	Include a small sample size, the exclusion of patients receiving peritoneal dialysis, and the lack of patients with extreme body mass index.
25	2022	189 healthy and 50 patients with CKD,	Bioimpedance technique findings, such as FO/ECV, CNR, and ECV/TBW, are more sensitive than clinical assessments.	Although clinical assessment underestimates the proportion of fluid overload, FO/ECV and CNR methods are more sensitive in identifying fluid overload in patients with CKD.	Clinical evaluation, despite its limitations, is a valuable tool for assessing fluid overload in CKD patients, but it often underestimates this compared to bioimpedance methods.
26	2023	N/A	Despite the need for agreement on best practices and nomenclature, bioimpedance devices, specifically BCM, have potential clinical and research applications, especially in patients with heart and kidney failure.	Despite the need for agreement on best practices and nomenclature, bioimpedance devices, specifically BCM, have potential clinical and research applications, especially in patients with heart and kidney failure.	In kidney disease cohorts, moderate overflow is associated with an increased risk of death, and the normal limits for pre-hemodialysis fluid overload are -1.1 L.

III. Results and Discussions:

Based on examining and debating every article referenced in the Literature Review, which consists of 26 papers that concentrate on bioimpedance analysis in patients receiving dialysis and kidney failure. Examining the function and effectiveness of bioimpedance techniques in clinical settings—particularly in evaluating nutritional and hydration status—is a prevalent theme across the studies. But every study tackles the subject uniquely, using a different set of goals and techniques. While some research focuses on developing new algorithms for fluid management, others compare bioimpedance with other assessment methods and examine its accuracy in various patient groups. This range highlights how bioimpedance analysis is used widely in the treatment of renal disease.

Here's a summary highlighting similarities and differences:

For sample sizes, a wide range of demographics, and situations were represented in the analysis of sample sizes across 26 studies, indicating variability in research aim and methods. Notably, studies with sample sizes of 45, 149, 69, and 266 persons, respectively, indicate that patients with chronic kidney disease (CKD) were a common subject group (Studies [29], [30], [31], [45]). Furthermore, two trials with sample sizes of 195 and 74 were particularly designed to target patients receiving peritoneal dialysis (trials [32], [35]). Certain studies, like the fourth one, which compared 189 healthy people with 50 CKD patients, and the twenty-fifth research, which compared 48 healthy people with 69 CKD patients, clearly used a comparative technique. One significant finding was the inclusion of subsets with specific medical problems in mind, such as patients with Parkinson's disease (78 persons in Study [28]) and type 2 diabetes (1079 individuals in Study [48]). A significant amount of data was collected for these investigations, as evidenced by the very large sample sizes reported in several of them (627 patients in Study [42] and 643 ECWTBW values in Study [40]).
Conversely, some studies were characterized by notably small sample sizes, as explicitly mentioned in Studies [37] and [39], or by specific age or condition-based subgroups, such as 54 young and 28 elderly patients in the Study [34]. The diversity in sample sizes and the specificity of some study groups reflect the tailored approaches of these studies to address particular research questions. However, it is also important to note that six studies ([33], [36], [42], [43], [46], [53]) did not provide specific sample size data, which suggests a limitation in the dataset and underscores the importance of transparency in reporting for comprehensive analysis and comparison.

For study focus Examine the twenty-six research' methodological quirks in further detail, highlighting the differences in each study's methodology and the effects of these decisions:
Quantitative Analysis (investigations [28], [34], [48]): The strong numerical analysis of these investigations is what sets them apart. The significant use of statistical techniques in Study [48]'s analysis of data from 1079 T2DM patients makes it stand out. This method produces unbiased, quantifiable, and broadly applicable results when it comes to finding patterns and connections in huge datasets. It occasionally fails to take into account the nuances of unique circumstances and experiences, though.
Clinical Trials (Studies [29], [30], [45]): These studies used longitudinal designs to monitor the development of patients with CKD across time to assess the effectiveness of treatment. These designs can be difficult to implement due to participant dropout or shifting external conditions, but they are essential for comprehending the long-term effects of medical therapies. They also take a lot of time and money.
Assessment of Renal Therapies (Studies [31], [32], [35]): These studies, which concentrate on renal treatments, combine qualitative evaluations with quantitative data analysis to present a complete picture of therapy outcomes. Combining these approaches yields a well-rounded view, but it also necessitates the careful integration of many data kinds and interpretations, which can be challenging but yield deep insights.
Case Studies (Studies [37], [39]): These are extremely narrowly focused studies that frequently examine singular or unusual occurrences. Although they offer comprehensive and intricate insights into particular circumstances, their conclusions are rarely very generalizable. They are, nevertheless, extremely helpful in comprehending unusual, complex, or subtle situations that might not be covered in more extensive research.
Cohort Studies (Studies [40], [42]): These studies follow large numbers of people over a predetermined amount of time. A wide perspective is offered by the huge sample size, which also makes it possible to analyze multiple elements at once. These studies, however, may require a lot of resources and may not adequately take individual differences into account.
Research with Non-Transparent Methodologies (Research Papers [33], [36], [43], [46], [53]):

Evaluation and comparison are hampered by the studies' lack of thorough methodological details. For research to be repeatable and for the context and constraints of the findings to be understood, methodology transparency is essential.

To sum up, every methodological approach has advantages and disadvantages of its own. While qualitative methods offer depth and nuanced knowledge, quantitative methods offer breadth and generalizability. Cross-sectional studies present a moment in time, while longitudinal research offers important insights into changes across time. The particular research issue, the type of data at hand, and the study's practical factors are frequently taken into account while selecting a methodology. Comprehending these decisions is essential for analyzing the results and incorporating them into the larger context of the field's study.

The subtle differences in limitations among the twenty-six studies point to important areas that could affect how results are interpreted and shape future research efforts. These drawbacks highlight how difficult it can be to evaluate and treat nutritional and hydration statuses in a variety of patient populations, especially those receiving hemodialysis and suffering from chronic kidney disease (CKD). Examining these limitations provides insightful information on the complexities of research design and technique.

Limitations on Methodology (Studies [28], [36], [37], [41], [47], [50], [51]): A number Have limitations because of the way they were designed, such as retrospective or cross-sectional techniques, which can make it more difficult to prove causation or capture the dynamic nature of patient circumstances over time. Results are not as generalizable as they may be because of small sample numbers and the emphasis on particular subpopulations. Sometimes, the generalizability of the results to different settings is further limited by the lack of multi-center participation or randomized control groups.

Problems with Measurement and Instrumentation (Studies [29], [32], [33], [39], [40], [46], [52], [53]): Potential sources of error include the use of certain formulas, such the Watson formula, and the dependence on particular measurement methods, like bioimpedance analysis (BIA). The reliability of fluid and nutritional evaluations may be impacted by variations in device calibration, underlying assumptions in the methodology, and the lack of a gold standard or uniform reference for comparison. These factors could cause variability in the results.

Issues related to population specificity and external validity (Studies [30], [31], [34], [35], [38], [42], [44], [45], [48]): Studies that focus on particular categories of patients, like male patients, patients without a particular medical condition, or patients from a single center, have limitations due to the way they choose their participants. The results may not accurately reflect the whole patient population due to this selection bias, which can also affect the findings' external validity. Further highlighting the need for more comprehensive and varied research to validate the findings' applicability is the absence of validation of the results in larger or different cohorts.

Technical and Analytical Limitations (Studies [43], [49], [53]): A lack of established standards and potential variability in the interpretation of results are suggested in some studies by the technological limitations of the tools used, such as the BIS-guided dry weight adjustment, and the requirement for consensus on methods and terminology. It is clear from the demand for more extensive studies and the focus on better methodology that there are shortcomings in the way that research is now conducted and that innovation and standardization are required going forward.

As a result, even though these studies offer insightful information about managing fluid and nutrition in clinical settings, their limitations call for cautious interpretation of the data, careful consideration of context-specific factors, and a proactive approach to resolving methodological and technical issues. To improve the validity and practicality of research findings, these limitations also open up new avenues for investigation. They highlight the significance of thorough study designs, the improvement of measurement methods, and the diversification of research across various demographics.

This work highlights the versatility of bioimpedance analysis in clinical applications by combining a range of findings from research on the topic in the context of kidney failure and dialysis patients. It describes the results of investigations on volume measurement, assessment of hydration, sufficiency of dialysis, and body composition of patients. It also evaluates the effectiveness of different bioimpedance devices and equations. The understanding of dietary and fluid management in renal disease is improved by these combined insights, especially for dialysis patients. The paper acts as a repository for important data, and it is recommended that you directly review each research for a thorough examination of the particular findings and conclusions of each included study.

The complex findings of the twenty-six studies provide important new information about how nutritional parameters and fluid status are evaluated and managed, as well as how these factors affect patient outcomes in a range of medical illnesses, most notably chronic kidney disease (CKD) and hemodialysis treatment. These findings have numerous ramifications, including illuminating the precision of various measuring instruments, the relationship between nutritional and hydration status and patient outcomes, and possible avenues for enhancing therapeutic procedures.

Evaluation of Treatment Effectiveness and Fluid Status (Studies [28] – [35]): The difficulties in correctly determining the fluid status of dialysis and CKD patients are highlighted by these investigations. Variations in volume measurements were discovered by the application of various formulas and bioimpedance spectroscopy (BIS), which affected the assessment of treatment efficacy (e.g., Kt/V values). The results highlight the need for accuracy when choosing and implementing techniques to evaluate patients' volume status and treatment suitability, since errors may cause patients' hydration status to be misinterpreted and may have an impact on treatment choices.

Clinical Applications of Bioimpedance Analysis (Studies [36] – [39], [43], [45], [46], [53]): These research's findings demonstrate the usefulness of bioimpedance techniques (such as MF-BIA, BCM, and BIVA) for determining bodily composition and fluid volume. The investigations do, however, also highlight their shortcomings and the requirement for method-specific interpretation. Discrepancies in body water estimates, for example, indicate that different bioimpedance devices cannot be used interchangeably, highlighting the significance of maintaining consistency in the devices used for long-term patient monitoring.

Clinical Implications of Nutritional Assessment (Studies [40] – [42], [44] – [52]): These studies demonstrate the complex interplay among body composition, patient outcomes, and nutritional status. The development of new formulas and models for evaluating body water changes as well as research on the connection between inflammation, malnutrition, and fluid overload emphasize how important correct nutritional assessment is to patient care. Furthermore, the effects of age, sex, BMI, and kidney function on body water evaluations point to the necessity of using individualized methods in patient evaluation and treatment planning.

Studies [48], [50] – [53]: Risk Factors and Patient Outcomes Higher extracellular water to total water-to-totalities have been linked to an increased risk of chronic kidney disease (CKD) progression. Additionally, machine learning models can forecast dry weight, which emphasizes the significance of ongoing innovation in monitoring and prediction approaches. Additionally, the research highlights the shortcomings of existing approaches in mitigating hazards such as intradialytic hypotension and maintaining residual kidney function, suggesting directions for future investigation and advancement.

As a whole, these twenty-six research findings highlight the significance of accuracy, uniformity, and customization in determining and treating patients' nutritional and hydration statuses, especially those with hemodialysis and chronic kidney disease (CKD). The subtle variations in approaches and results highlight the need for a critical assessment of the models and instruments applied in clinical practice, as well as continuous research to improve patient outcomes and treatment.

IV. Conclusion:

This pages summarises bioimpedance analysis research on dialysis and renal failure treatment. This research examined the accuracy, efficacy, and impact of bioimpedance technology on renal illness patients' hydration and nutrition management. This study examines bioimpedance measures in clinical assessments and their practical applications. The twenty-six studies give a comprehensive review of nutritional and hydration advances and obstacles, notably in dialysis and chronic renal illness patients. This study emphasizes the importance of reliable evaluation tools and their impact on patient outcomes.

Studies [28]–[37]: Bioimpedance Spectroscopy (BIS) efficacy: The results demonstrate BIS's reliability as a non-invasive nutritional and hydration assessment method in PD and CKD patients. Notably, BIS's ability to offer exact body composition data, like muscle mass and fluid distribution, provides a more complete picture of patients' health and may lead to more individualized treatment approaches. However, the differences in results compared to the Watson formula or on-site examination demonstrate the need for standardization and extra verification.

Fluid and Nutrient Assessment (Studies [38]–[47]): The findings demonstrate the difficulties of assessing CKD patients' diet and hydration. New models and formulae, such as the corrected albumin (cAlb) and Dry Mass Index, improve assessment accuracy. However, standard measuring methods like the Watson formula cannot accurately determine total body water and clinical factors affect measurement accuracy, highlighting the ongoing challenge of producing reliable and widely used assessment tools.

Methodology and Technology Advances (Studies [48]–[53]): The study reveals how bioimpedance devices and machine learning algorithms may enhance CKD fluid management. Understanding the relationship between extracellular water and kidney function and using bioimpedance tools to diagnose fluid overload and plan therapy enable more targeted and efficient treatments. Further research, standardization, and nomenclature agreement are needed to maximize these technologies. Finally, the twenty-six studies demonstrate how important nutritional and hydration management is for CKD and dialysis patients. These studies illuminate the complexity of fluid and nutritional assessment through methodological advances, technology advances, and patient-specific knowledge. Bioimpedance spectroscopy has significant potential for body composition analysis, but standardization and validation are needed. New assessment techniques and machine learning are advancing personalized patient care. These research limitations emphasize the need for careful, nuanced data interpretation and a focused drive toward methodological development and consensus-building. As the field advances, this study will lead to more precise, customized, and efficient care choices for chronic kidney disease (CKD) and related illnesses, improving quality of life and outcomes.

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