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Review

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Use of Bioimpedance in Pediatrics

Mehmet Alp Dirik[1], Ilke Beyitler[2]

[1]Department of Radiology, Dr Suat Gunsel Kyrenia University School of Medicine, Kyrenia, Cyprus
[2]Department of Pediatrics, Near East University School of Medicine, Nicosia, Cyprus

ORCID IDs of the Authors: M.A.D. 0000-0001-9427-2821; I.B. 0000-0002-7758-9015

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ABSTRACT

Bioimpedance analysis is an easy, rapid, cheap, noninvasive, effective, and portable technique that can be utilized in several pediatric health conditions. The fluid status evaluation, edema, obesity, malnutrition, inflammation, infection, pain, attention deficit/hyperactivity disorder, nephrourological evaluation, gastroesophageal reflux, and neonatal problems are some of the issues studied with bioimpedance. As the pediatric-age group is usually difficult to manage, such practical and accurate methods are promising for better results.

Keywords: Bioimpedance, children, utility

INTRODUCTION

Bioelectrical impedance is a noninvasive, cheap, portable, and accurate analytical technique in which measurements are taken with regard to the electrical characteristics of biological materials. Impedance is defined as the opposite current to an alternate electric flow formed with resistance and reactance. It has been especially used in the assessment of fluid content of tissues by measuring resistance toward the current flow in both intracellular and extracellular fluids. Capacitance between cell membranes and tissues, as well as total fluid of a body segment, is measured. A low-voltage electrical current is applied, and measurements of body resistance against it are obtained in children, as well as in adults (1, 2). In children, the method has an advantage of getting several measures rapidly in just a few seconds, as it is generally difficult to keep children immobile. Bioelectrical impedance methods are bioimpedance spectroscopy (BIS), single-frequency bioimpedance analysis, and multi-frequency bioimpedance analysis. Although it seems to be a practical diagnostic tool, few difficulties when applying bioimpedance in the pediatric-age group may be experienced during the placement of electrodes onto different body parts. Evaluation and interpretation of the observed results are probably another difficult part of the analysis (3, 4).

MATERIAL and METHODS

We conducted a literature review concerning studies using bioimpedance for diagnosis, especially in the pediatric-age group. We searched the available studies in the English language and analyzed the data about using bioimpedance in pediatric health and diseases that have a wide area of utilization.

Fluid Status

Bioimpedance spectroscopy and multi-frequency bioimpedance analysis were used in 12 pediatric hemodialysis patients to determine the body fluid before and after hemodialysis sessions. Twenty-three measurements were obtained showing significant correlation between the fluid removal and differences in total body fluid measured by both devices. The fluid accumulated due to overhydration was better detected with a BIS device (4).

In an observational study including 14 children regarding hemodialysis, 130 single-frequency bioimpedance analysis measures were taken to determine the hydration status. The percentage change in the resistance was correlated with the percentage of body weight change and the percentage of blood volume change. The percentage of change in resistance was also higher in patients with symptoms such as lightheadedness, headache, cramping, and restlessness during dialysis. The bioimpedance technique was suggested to be effective and can be more widely used in a routine fluid volume evaluation of children on dialysis (1).

Corresponding Author: Ilke Beyitler
E-mail: ilkebeyit82@yahoo.com

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However, the fluid status in a cohort of pediatric hemodialysis patients was evaluated by measuring the inferior vena cava (IVC) diameter and BIS, showing that overhydration detected by BIS and IVC diameters was not found to be correlated. The IVC diameter was only found to predict hypertension related to a volume overload. The BIS measurement was reported as not a significantly effective method for assessing the fluid volume due to its ineffectivity in detecting the intravascular volume (5).

Edema

Bioimpedance spectroscopy has been defined as a reliable method for analyzing edema, as it gives information on the intracellular, extracellular, and total water content of a certain body part. Based on this feature, it is suggested that it can be successfully used for the detection of post-thrombotic lymphedema in arms and legs, which consists of the fat and muscle tissue, as well as water (3).

Peripheral edema was effectively detected by bioelectrical impedance measures in 900 patients with acute and chronic heart failure by placing electrodes on the hand, wrist, foot, and ankles. Because soft tissues of limbs form 90% of body bioimpedance, it is suggested as a trustable method of demonstrating peripheral edema (6).

Cerebral bioimpedance was used to detect cerebral edema in hypoxia-induced neonatal piglets by attaching the electrodes on the scalp. Non-invasive measurements were well correlated with invasive values obtained with a subdural catheter. Bioimpedance results were also in correlation with intracranial pressure. The technique is suggested as a good marker of intracranial events and cerebral edema due to hypoxia (7).

Body Composition: Obesity and Malnutrition

The percentage of body fat in 89 children who were 5 to 18 years old was analyzed by a bioelectrical impedance analysis and dual-energy x-ray absorptiometry (DXA). The portable bioimpedance analyzer was a tetrapolar device with four electrodes placed on the feet. Measurements of two different techniques were similar to each other, supporting the use of bioimpedance for body fat detection (8).

Obese adolescents' whole body fat mass was measured by means of an bioimpedance analysis and DXA, showing correlated results, and both methods were effective in detecting the body fat percentage (9).

Single-frequency bioimpedance analysis and BIS were compared in a study that analyzed the body fat percentage before and after exercise. The results suggested that both methods were similarly effective in the body fat evaluation. However, a single-frequency bioimpedance analysis was more effective in estimating the body fat percentage in that group (10).

A cross-sectional study compared nutritional condition of 292 hospitalized children with 234 healthy controls. The bioimpedance analysis was more sensitive in detecting malnutrition and undernutrition compared with anthropometric measures of the World Health Organization criteria. It was recommended to evaluate hospitalized children with the bioimpedance analysis to detect malnutrition as early as possible and to be able to avoid related complications (11).

In a prospective cohort study, 486 children were involved, and a higher birth weight was correlated with higher fat mass percentage and fat mass in later childhood that was measured by bioimpedance technique (12).

Gestational weight gain of mothers and birth weight of newborns were found as positively correlated in a cross-sectional study. The bioimpedance analysis was a reliable method of measuring the fat mass and fat-free mass of individuals (13).

Cardiovascular risk parameters of pediatric juvenile idiopathic arthritis patients were determined with segmental body fat composition analyzer by measuring the body mass and body fat percentage. The percentage of fat tissue in patients was found similar in patients and healthy controls (14).

Children with late-diagnosed vesicoureteral reflux (VUR) were evaluated with the bioimpedance analysis regarding their growth. The body mass, fat mass, fat-free mass, and cell mass were measured. It was shown that growth is negatively affected in children with VUR and that it should be diagnosed earlier to avoid such morbidities (15).

Inflammation

Bioimpedance analysis measures were taken in a large cross-sectional study by electrodes placed on the metacarpal bones, hands, and wrist of the upper extremities, and foot, fibula, and metatarsal bones of the lower extremity. Results were found to be positively correlated with stress monitored by cortisol and inflammation monitored by means of the high-sensitive C-reactive protein levels. Bioimpedance is suggested to be useful in diagnosis, detection of complications, and treatment response of patients with stress, inflammation, and nonspecific symptoms such as that of metabolic syndrome (16).

The presence and localization of periodontal tissue inflammation were observed in the bioimpedance values by means of different conductivity and frequencies of the inflamed site (17).

As the diagnosis of inflammation of periodontal and peri-implantal tissues in dentistry is done by naked-eye observation of hyperemia or edema, the bioimpedance measurements were suggested to be effectively used in another study to detect these areas both before and after treatment (18).

The airway inflammation in asthmatic children was evaluated, and the extracellular bioelectrical conductivity of the lower respiratory tract decreased after avoiding the exposure to house dust mites at high altitudes (19).

Infections

The bioimpedance analysis was used in differentiating patients with dengue fever from the control group of healthy people. Reactance, intracellular water, its ratio to extracellular water, and ratio of extracellular mass to body cell mass were factors correlated with symptoms of the infection group (20).

Fever due to an influenza A infection outbreak in Amazonas demonstrated that patients with fever had a significantly increased reactance and decreased resistance and impedance

that may be attributed to a decrease in the extracellular water body content. The values were shown to return to normal after treatment (21).

Pain

An aminolaevulinic acid cream was applied as a photosensitizer in people undergoing dermal photodynamic therapy, and BIS measures were taken. The aim was to compare the pain felt in the group that used the cream and the control group. Skin impedance was significantly lower in people treated with aminolaevulinic acid (22).

Attention Deficit/Hyperactivity Disorder

Forehead electrodes were used to assess the bioimpedance analysis measures in children diagnosed with attention deficit/hyperactivity disorder (ADHD). Conductivity was significantly higher in the ADHD group than healthy controls. The method is recommended as a noninvasive easy way for early diagnosis and monitorization of treatment response (23).

Nephrourological Evaluation

A bioimpedance analysis was performed in children with VUR before and after voiding. Bladder and ureter fluid measures were decreased in patients with VUR, while the values were not decreased in patients without VUR (2).

Creatinine clearance and 24-hour urinary protein excretion were accurately estimated by measuring the body cell mass with bioimpedance in patients with chronic kidney disease. Results were used to predict the quantification of renal functions effectively (24).

Children with nutcracker syndrome were evaluated by means of a bioimpedance analysis, which demonstrated results according to the left renal vein entrapment. The patients had slimmer body, with lower bioimpedance measures. It was suggested to restore the aortomesenteric fat tissue with nutrition, which may resolve the left renal vein entrapment (25).

Bioimpedance was compared in normal rat bladders and those with infravesical obstruction. In rats with infravesical obstruction, voiding did not normalize the vesical circulation, while it was normalized in normal rats (26).

Anesthesia was given to a porcine model, and percutaneous needle inserted into the kidney showed a decrease in tissue bioimpedance measures, suggesting that the needle bioimpedance technique may be used in percutaneous procedures (27).

Gastroesophageal Reflux

Small esophageal mucosa changes were detected by BIS in an animal model by measuring the dilation of intercellular spaces and resistivity. It may be possible to detect gastroesophageal reflux in very early stages with this method (28).

Neonatal Period

The cardiac output of mechanically ventilated newborns was measured by thoracic bioimpedance and compared with values on a Doppler ultrasound. The methods were well correlated, so the results suggested that bioimpedance may be a noninvasive and reliable method of cardiac output measurement (29).

Thoracic bioimpedance was used to assess the cardiac output in term and preterm animal neonates. A significant correlation was observed between bioimpedance and the thermodilution indicator method. The method may be useful in infants, as well as children (30).

A prospective blinded controlled study evaluated 114 measures of bioimpedance in preterm newborns. Electrodes were used for heart and transcutaneous oxygen monitorization. Resistance and reactance were compared and did not show interference with each other, suggesting that this way of oxygen monitorization by bioimpedance is valid in newborns (31).

Newborns with respiratory distress after birth were shown to have more thoracic fluid than healthy controls, which was measured by bioimpedance at birth and 24 hours after birth (32).

Cerebral impedance was used in newborn piglets born with hypoxia and several measurements taken in the first 12 hours of life. Although the hypoxic group values were different from the control group, the difference was not significant, suggesting further evaluation (33).

The pharmacokinetics of gentamicin was evaluated by a multi-frequency bioimpedance analysis in infants in a neonatal intensive care unit. Gentamicin distribution between therapeutic and toxic levels was predicted with this method (34).

Correlation with Ultrasonography

Detection of lymphedema using bioimpedance has been defined as an easy and reliable method. There have been only limited studies comparing the bioimpedance analysis and ultrasonography (US) correlation (35).

In another study, lung US and BIS were compared, and it was concluded that BIS can be used together with clinical findings and blood pressure measures to evaluate the fluid status of children with end-stage renal disease (36).

Nineteen patients with nephrotic syndrome and the control group of 25 healthy people were evaluated with a multi-frequency bioimpedence analysis. Hypovolemia was not observed in the nephrotic syndrome attack. Bioimpedance can be routinely used as a practical method to control the hydration condition of nephrotic syndrome patients (37).

Also, the use of bioimpedence has been useful in the evaluation of fat deposition in non-alcoholic fatty liver disease, and results were positively correlated with US (38).

The evaluation of the effectiveness of lung US in detecting changes in the volume load of patients undergoing hemodialysis and comparison with the gold standard bioimpedance technique indicated that bioimpedance and US may show different but complementary findings. Bioimpedance may be more effective in the hydration status detection, while US may show cardiac and overhydration findings. The effect of dialysis can also be demonstrated (39).

CONCLUSION

It can be concluded that bioimpedance is an effective and easy method of diagnosis in a variety of pediatric health issues, al-

lowing urgent appropriate management and interventional therapies according to their necessity.

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