Case Report

Severe obesity in haemodialysis: the utility of bioimpedance vector analysis

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**Introduction**

A non-invasive assessment of hydration can be performed at the bedside by evaluating the bioelectrical impedance of the human body. The alternating current that passes through the extracellular and intracellular electrolytic solutions (except for bone and fat) generates an impedance vector (\(Z\)) with two components (i.e. a point with two co-ordinates): resistance (\(R\)), the real part of \(Z\), which depends on body fluid volume, and reactance (\(X_c\)), the imaginary part of \(Z\), which depends on the capacitance of membranes and tissue interfaces being crossed. With the bioelectrical impedance vector analysis (BIVA), a semiquantitative assessment of soft-tissue hydration can be obtained from pattern analysis (RXc graph method) of direct \(R\) and \(X_c\) measurements, and can be standardized for the subject’s height (H) (i.e. \(R/H\), and \(X_c/H\)) without knowledge of body weight, and without the need of assumptions on body geometry and body composition (which are required by quantitative, conventional bioimpedance analysis) [1–6].

Following the RXc graph method, hydration is established by a comparison of the measured tissue impedance with percentiles (50, 75 and 95% tolerance ellipses) of the reference vector distribution from a healthy population of the same race and gender (Figure 1) [2]. The impedance vectors of both obese and oedematous subjects are shorter than normal, but vectors from obese subjects (body mass index (BMI) 31–80 kg/m\(^2\)) can be discriminated from those of oedematous patients with 91% accuracy, since vectors from obese subjects fall above the straight line of boundary between fat and fluid overload (Figure 1) [3].

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**Case**

A 57-year-old woman (Figure 2, with written consent to publication) came under our observation in May 1998 with clinical and laboratory signs of uraemia, including nausea, vomiting, hypertension, serum creatinine 11.9 mg/dl, blood urea nitrogen 239 mg/dl, anaemia (Hb 8.6 g/dl), and secondary hyperparathyroidism (parathyroid hormone (PTH) 27.6 pmol/l, 3.6 times the normal value). In addition, she presented with proteinuria (3–5 g/day) and modest dysproteinaemia (proteinaemia 6.5 g/dl, albuminaemia 2.7 g/dl). Her body weight was 185 kg for a stature of 170 cm, with a BMI of 64 kg/m\(^2\). The diagnosis of primary obesity had been established at 23 years of age (112 kg, BMI 39 kg/m\(^2\)). The patient had been treated for arterial hypertension (angiotensin-converting enzyme (ACE) inhibitors) over the last 5 years. It was impossible to perform adequate instrumental evaluation with X-ray, ultrasonography, computed tomography, and magnetic resonance imaging, because of the patient’s size. Impedance measurements were performed at the...
Fig. 1. ‘RXc path graph’ of impedance vectors (represented with points in the R-Xc plane), measured in the patient at the start of dialysis sessions, over 1 year of follow-up, before (solid symbols) and after (open symbols) lpectomy. Labels a and b indicate vectors just before (181 kg) and after (162 kg) lpectomy respectively. Label c indicates vectors measured when body weight increased (170 kg) and hypertension appeared. Label d indicates vectors measured when body weight decreased and blood pressure returned to previous normal values following transient vigorous ultrafiltration. Race- and gender-specific tolerance ellipses of the reference healthy population (50, 75, and 95%) are depicted with the discriminant line between fat and fluid overload regions on the RXc graph. H is the subject’s height in metres (m), R the resistance, and Xc the reactance.

bedside according to the standard, tetrapolar, whole-body (hand–foot) technique using a single-frequency (50-kHz) analyser (BIA-101, Akern-RJL Systems, Florence, Italy).

In June 1998 the patient began HD, first by positioning a central venous catheter and subsequently through a left distal arteriovenous fistula (bicarbonate dialysis, 3 times weekly, in sessions lasting 270 min, hemophane filter with an area of 2 m², blood flow 350 ml/min; Kt/V 1.1), with a residual diuresis of 1 litre per day. Because the calibration of bed scales at 130 kg made it impossible to monitor the patient’s weight during HD, fluid removal was established following clinical criteria.

During the first dialysis sessions, the patient suffered from hypotensive episodes that were overcome by incrementing the dialysis time and maintaining ultrafiltration rates less than 0.8 l/h. Thereafter, she remained symptom-free and had a normal blood pressure, both during dialysis and at home. Ultrafiltrate volume and interdialytic weight gain were 3–4 kg. At that time, pre-dialysis impedance vectors were short, below the tolerance ellipses, and were scattered on the verge of the linear threshold discriminating between the obese and the oedematous (Figure 1, path with vectors represented with solid circles, one every 3 weeks). These vectors indicated that, in addition to both fat and fluid overload, there was a modest fluctuation of tissue hydration over time (6 months). BIVA was then used in monitoring long-term fluid balance, using the boundary between fat and fluid overload as the target of pre-dialysis vector position on the RXc graph.

Fig. 2. Picture of the patient (age 57, stature 170 cm, and weight 181 kg) before lpectomy.

In November 1998 the patient underwent lpectomy (18 kg), bringing her average body weight down from 181 to 163 kg (BMI 56 kg/m²) with a consequent improvement in physical activity and quality of life. Clinically, the patient continued to be symptom-free, both during dialysis and at home. Analysis of the RXc graph after lpectomy (Figure 1, vectors with label b) revealed no definite migration of the impedance vector.

In the subsequent months body weight increased from 162 to 170 kg (Figure 1, vectors with label c), and
pre-dialysis blood pressure peaked to 180–200/90–100 mmHg. Both body weight and blood pressure decreased following removal of more fluid over a few sessions, until the pre-dialysis weight reached 159 kg (Figure 1, vectors with label d). In short, the post-lipectomy path of the impedance vector was characterized by a shortening and down-sloping trajectory during body weight increase with hypertension (indicating body fluid overload) and by a lengthening and steepening trajectory during body weight and blood pressure decrease (indicating a negative fluid balance).

Finally, pre- to post-HD vector migrations (i.e. lengthening and steepening of pre-HD vectors, not shown) after lipectomy were comparable to those before lipectomy, since the amount of fluid removal per session was also comparable.

Discussion

In patients undergoing chronic HD treatment, the identification of optimal weight is based on clinical criteria obtained through a trial-and-error procedure. Operational definitions of the so-called dry weight require that hypotension and/or cramps become manifest during a HD session in the absence of oedema [7], or that blood pressure is normal during the inter-dialytic period in the absence of antihypertensive treatment [8]. However, cramps, hypotension, or hypertension can be caused by diseases and conditions other than renal failure. Nevertheless, in most lean subjects, clinical signs together with accurate monitoring of pre- and post-dialysis weight allow a satisfactory management of hydration status.

Body weight change in the long-term is not easy to interpret, since it can be altered by changes in fat, muscle mass and tissue hydration. In severe obesity, body weight itself cannot be accurately determined, and interpretation of body weight change is problematic. For instance, it is not easy to discriminate between pitting oedema and ‘pitting fat’ (Figure 2). In the present patient, estimation of total body water based on body weight (e.g. by Watson formula) [9], would range from 61 (pre-lipectomy) to 56 (post-lipectomy) and to 55 litres (last HD sessions), falsely indicating that more fluid would have been lost after lipectomy (5 of 18 kg) than after vigorous ultrafiltration (1 of 11 kg).

Difficult identification of reference sites for electrode placement on trunk and limbs increases the measurement error of segmental bioimpedance, whose clinical utility, however, has not yet been established in renal patients [10]. Fortunately, the accuracy of whole-body impedance measurements (for both inter-subject and intra-subject measurement errors) is comparable between obese and lean subjects [3]. However, total body water estimates from conventional regression equations of whole-body bioimpedance become inaccurate when impedance vectors shorten out of the 95% tolerance ellipse, due to the hyperbolic relationship between body fluid volume and bioimpedance [6]. For instance, equations from literature [3,6], starting from the same impedance readings and ignoring body weight would predict values ranging from 42–50 (pre-lipectomy) to 42–45 (post-lipectomy) and 37 litres (last HD sessions), or from 57–63 (pre-lipectomy) to 54–63 (post-lipectomy) and 50 litres (last HD sessions), when including body weight in the equation.

In our case, long-term monitoring of tissue hydration with BIVA indicated an adequate fluid balance (i.e. asymptomatic HD sessions and normal blood pressure both in dialysis and at home) when vectors fluctuated on the boundary between fat and fluid overload, despite different body weights. An expected result was the small vector migration after lipectomy that replicated findings from a study using energy restriction [3]. Interestingly, a modest downward deviation of vectors from the boundary was associated with hypertension (Figure 1, label c), indicating that body weight increase was due to fluid accumulation instead of soft-tissue increase (which was erroneously attributed to the improved clinical condition following lipectomy). The reverse was also documented by the transient removal of fluid during dialysis, which brought the vector back close to the target boundary (Figure 1, from c to d label). This included a twofold vector lengthening compared with pre- to post-lipectomy, which indicated a high sensitivity of the method for detecting tissue hydration change and a low sensitivity for detecting anhydrous, fat mass loss. This specific sensitivity can be utilized in monitoring tissue hydration without knowledge of body weight in all clinical conditions, particularly in maintenance HD. It is worth noting that body fluid volume variations in the order of 3 kg in subjects with impedance vectors within the gender-specific 75% tolerance ellipses (e.g. lean HD subjects), are associated with a three- to fourfold vector displacement as compared with subjects with short vectors, which are below the 95% tolerance ellipse (geometric properties of fluid volume-bioimpedance curve) [4,6].

In conclusion, we observed, in a severely obese HD patient, a long-term fluctuation of impedance vector on the boundary between fat vs fluid overload regions of the RXc graph when the clinical course was asymptomatic. A downward deviation of vectors from the boundary was associated with hypertension and body weight increase due to fluid retention. A normal blood pressure was obtained with transient vigorous ultrafiltration that brought vectors back to the boundary. This BIVA pattern may be useful in monitoring hydration of maintenance HD patients with severe obesity, in whom body weight cannot be monitored accurately.

References


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