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Multi-Segment Bioimpedance for Diagnosis and Follow-Up of Treatment for Lymphedema

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Abstract

Background: The present study aimed to evaluate the use of multi-frequency, multi-segment bioimpedance for the diagnosis and therapeutic follow-up of clinical stages II and III lymphedema of the lower limbs.

Methods and Results: A diagnostic clinical trial was conducted to evaluate the sensitivity and specificity of multi-frequency, multi-segment bioimpedance compared to volumetry for diagnosing and therapeutically following up clinical stages II and III lymphedema of the lower limbs. Treatment comprised the intensive Godoy Method® (eight hours per day for five days). One hundred limbs from 50 patients were evaluated, with 64 true-positive diagnoses, two false positives, three false negatives, and 31 true negatives, resulting in a sensitivity of 95.52% and specificity of 93.94%.

Conclusion: Multi-frequency and multi-segment bioimpedance analysis is effective in the diagnosis and therapeutic follow-up of clinical stages II and III lymphedema of the lower limbs, achieving similar results to those obtained using water displacement volumetry. (**International Journal of Biomedicine. 2024;14(3):454-457.)**

Keywords: lymphedema • multi-segment bioimpedance • diagnosis • treatment

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Introduction

Lymphedema is a chronic progressive disease caused by insufficient lymphatic drainage characterized by the accumulation of lymphatic fluid in the interstitial space. It may be congenital or secondary. In secondary lymphedema, the lymphatic system is intact at birth but damaged at some point in life and becomes deficient.[1-3]

Clinical history and physical examinations are the most important parts of a diagnosis. However, complementary exams that evaluate volume are fundamental to the diagnostic confirmation and the monitoring of the response to therapy. Volumetry using the water displacement method is the gold standard, but the measurement of circumferences is more widely used for practical reasons.[4-5] Bioelectrical impedance analysis (bioimpedance) is another option but requires standardizing the exam and devices.[6-8] Other complementary exams, such as lymphoscintigraphy, magnetic resonance lymphangiography, ultrasonography, and computed tomography, as well as the differential diagnosis, can also assist in the diagnosis of lymphedema.[9-11] Lymphoscintigraphy is the gold standard exam for determining functional and anatomic data but does not provide volumetric measurements.[6] Magnetic resonance lymphangiography also furnishes functional and anatomic data and can currently be considered the gold standard in anatomic evaluation.[9]

The combination of the clinical examination and complementary exams enables arriving at the best diagnosis.

However, differences in clinical manifestations may occur. Primary lymphedema normally initiates in the extremities and advances in a proximal direction, whereas proximal involvement is more frequent in secondary lymphedema. Bioimpedance enables the evaluation of the segments of the limb or the entire limb. In contrast, volumetry is an exam for evaluating only part of a limb, normally below the knee.

The present study aimed to evaluate the use of multi-frequency, multi-segment bioimpedance for the diagnosis and therapeutic follow-up of clinical stages II and III lymphedema of the lower limbs.

Materials and Methods

The sample consisted of 50 patients (women and men) with a clinical diagnosis of lower limb lymphedema. Evaluations and treatment were performed at the Clínica Godoy-Sao Jose do Rio Preto-Brazil.

Study Design

A diagnostic clinical trial was conducted to evaluate the sensitivity and specificity of multi-frequency, multi-segment bioimpedance compared to volumetry for diagnosing and therapeutically following up clinical stages II and III lymphedema of the lower limbs. Treatment comprised the intensive Godoy Method® (eight hours per day for five days). Patients who met the eligibility criteria were enrolled in the study according to order of arrival at the clinic.

Inclusion criteria: Clinical stages II and III lower limb lymphedema of any etiology.

Exclusion criteria: Active infection or difficulty undergoing volumetric analysis due to weight.

Patients with clinical stages II and III lower limb lymphedema of any etiology underwent intensive five-day treatment using the Godoy method. All patients were evaluated by volumetry (water displacement method), multi-frequency multi-segment bioimpedance (InBody S10 device), circumference measurements, and weight before and after treatment. Bioimpedance was used to determine the volume of liquids in each limb and the extracellular water/total body water (ECW/TBW) ratio. In cases of bilateral lymphedema, physiological edema was considered when changes of less than 150 mL occurred after treatment.

Statistical analysis

The data were entered into an Excel table and evaluated using the diagnostic test. Descriptive statistical analysis of the data and the diagnostic test were performed. Fisher's exact test was used for the comparisons, considering a 5% alpha error.

Results

One hundred limbs from 50 patients were evaluated, with 64 true-positive diagnoses, two false positives, three false negatives, and 31 true negatives, resulting in a sensitivity of 95.52% and specificity of 93.94% (Table 1). Table 2 displays the values of each limb in evaluating the volume of liquid by bioimpedance, volumetry, and the ECW/TBW ratio. The diagnosis of lymphedema by bioimpedance is given when the ECW/TBW ratio is greater than 0.390.

Table 1.

Predictive values of diagnostic test, sensitivity, specificity and likelihood ratio.

Predictive value of +ve test (post-test likelihood of disease)
0.969697 (0.894783 to 0.996309). 96.97% (89.48% to 99.63%); change = 30%
Predictive values of -ve test
(post-test likelihood of no disease)
0.911765 (0.763225 to 0.98142). 91.18% (76.32% to 98.14%); change = 58%
(post-test disease likelihood despite -ve test)
0.088235 (0.01858 to 0.236775). 8.82% (1.86% to 23.68%); change = -58%
Sensitivity (true positive rate)
0.955224 (0.874673 to 0.990669). 95.52% (87.47% to 99.07%)
Specificity (true negative rate)
0.939394 (0.797736 to 0.992574). 93.94% (79.77% to 99.26%)
Likelihood Ratio
LR (positive test) = 15.761194 (4.86538 to 56.968105)
LR (negative test) = 0.047665 (0.016289 to 0.132137)

Table 2.

The volume of liquids in each limb determined by bioimpedance (columns 1 and 2), extracellular water/total body water ratio (columns 3 and 4), and water displacement volumetry (columns 5 and 6).

	1 Right Limb-bio	2 Left Limb-bio	3 Right Limb-bio	4 Left Limb-bio	5 Right Limb-vol (ml)	6 Left Limb-vol (ml)
1	13.14	4.10	0.463	0.382	2272	7566
2	5.39	18.61	0.374	0.467	2892	13905
3	5.11	5.16	0.396	0.40	2973	2915
4	7.76	5.36	0.402	0.376	7904	2868
5	2843	5662	0.364	0.440	6.76	13.72
6	10.7	6.92	0.428	0.401	5728	3697
7	6.77	6.58	0.421	0.416	6330	6246
8	14.81	9.86	0.421	0.380	4720	3496
9	10.44	7.1	0.418	0.392	4862	3088
10	5.32	6.39	0.376	0.400	3190	3980
11	12.48	5.08	0.452	0.377	5973	2946
12	5.17	10.75	0.373	0.429	2542	10115
13	4.38	3.22	0.408	0.364	3084	2477
14	9.42	8.73	0.418	0.416	3974	3686
15	5.36	5.70	0.418	0.427	3522	3842
16	5.37	9.39	0381	0.433	3149	6865
17	5.32	5.69	0.388	0.399	2296	2537
18	4.71	4.04	0.426	0.412	3157	2395
19	5.28	7.33	0.360	0.398	2957	4675
20	4.35	4.75	0.377	0.387	2667	3186
21	5.04	7.12	0.374	0.416	2878	4091
22	4.95	11.47	0.375	0.461	2789	8135
23	13.58	10.85	0.445	0.446	5596	4851
24	6.09	5.62	0.403	0.387	5907	5361
25	10.89	7.38	0.427	0.383	4948	2889
26	5.27	7.19	0.369	0.410	2426	3451
27	7.46	7.34	0.424	0.435	3907	3745
28	4.05	6.99	0.389	0.411	2421	4452
29	7.42	9.43	0.392	0.432	3963	4787
30	5.82	7.69	0.377	0.400	2727	3961
31	5.35	5.30	0.403	0.402	3674	3393
32	8.7	7.17	0.403	0.394	3942	5800
33	9.12	9.09	0.435	0.445	7051	6803
34	6.16	5.23	0.404	0.388	3004	2491
35	10.22	9.30	0.396	0.394	4704	4029
36	7.58	8.22	0.393	0.409	5603	6691
37	7.71	15.13	0.390	0.455	3837	10608
38	9.13	8.09	0.404	0.393	3518	4002
39	6.84	12.33	0.387	0.452	2997	5262
40	4.76	5.08	0.376	0.388	2603	2843
41	6.98	6.05	0.390	0.383	3988	3425
42	5.64	5.76	0.414	0.420	3538	3301
43	4.42	4.09	0.400	0.383	3059	2325
44	9.70	9.24	0.401	0.408	5783	5747
45	6.26	5.76	0.391	0.387	3779	3396
46	7.38	6.54	0.406	0.394	3494	3001
47	5.40	8.52	0.371	0.425	3044	6064
48	6.64	5.83	0.406	0.407	3100	2919
49	5.11	5.12	0.413	0.421	4113	4104
50	11.72	5.54	0.435	0.381	5534	2761

In 19 patients (38%) with bilateral lymphedema initially detected in 100% by bioimpedance, the volume reduction in the limbs after treatment was greater than 150 mL, determined by volumetry. In 35 patients, 70% of the left and 60% of the right legs had edema; this difference was non-significant (*P*-value = 0.3, Fisher's exact test). The analysis of volumes determined by bioimpedance of each limb found a correct diagnosis rate of 100%, considering unilateral lymphedema. Analyzing the diagnosis of lymphedema in cases of bilateral edema, the ECW/TBW ratio determined by bioimpedance revealed diagnostic agreement in 100% of cases. The analysis of volumetry in cases of unilateral lymphedema with a volumetric reduction greater than 150 mL found diagnostic agreement in 100% of cases.

Discussion

The present study evaluated the use of multi-frequency, multi-segment bioimpedance for the diagnosis and therapeutic follow-up of clinical stages II and III lower limb lymphedema, compared to the diagnostic gold standard (volumetry). Treatment comprised the intensive Godoy Method® (eight hours per day for five days), which resulted in an average 50% reduction of the volume of edema.[3,10]

Reductions greater than 200 mL in each limb with lymphedema occurred in 100% of patients submitted to treatment in this period. Therefore, the results enabled a comparison of the two-volume evaluation methods for diagnosing lymphedema. There is no consensus regarding the use of bioimpedance for the diagnosis of lymphedema.[6-8] Moreover, the parameters of the devices need to be standardized, and the best option needs to be identified.

In the present study, bioimpedance proved effective in both the diagnosis and follow-up of these patients during treatment, leading to the correct diagnosis in cases of unilateral lymphedema in 100% of patients. This figure was 95% when correlating the presence of edema based on the ECW/TBW ratio. Therefore, a 100% correct diagnosis rate was achieved when combining these data. The results were the same as those found for volumetry, confirming a volume reduction of more than 200 mL during treatment.

Regarding bilateral lymphedema (38% of patients), bioimpedance led to correct diagnoses in all cases, confirmed by the loss of more than 200 mL of volume during treatment. Therefore, bioimpedance is a reliable exam for evaluating bilateral lymphedema.

Regarding volumetry (gold standard), this method confirmed 100% of the edema and reduced volume more than 200 mL during treatment. However, diagnostic difficulty occurs in cases of bilateral lymphedema, for which small differences may generate doubts. Therefore, combining the two methods is important to achieving the best result.

Another important aspect is that multi-frequency, multi-segment bioimpedance furnishes data on the entire body and enables the determination of intracellular and extracellular liquids, as well as liquids in the upper and lower limbs and trunk. This provides additional data for the final diagnosis; reactance impedance, and phase angle. The authors have identified subclinical and clinical systemic lymphedema cases using bioimpedance and mobilization of body fluids during treatment conditions associated with lipedema and obesity.[13-16] Therefore, bioimpedance is a fundamental tool for a more precise diagnosis of edema and lymphedema.

This diagnostic assessment, followed by a therapeutic assessment, is essential to check both diagnostic methods. The treatment method allows volume reductions of 50% in five days, allowing an evaluation in a short time. Another important fact is that the edema volumes in these patients are important and normally above one kilogram. This requires greater diagnostic accuracy about small volumes.

Conclusion

Multi-frequency, multi-segment bioimpedance analysis is effective in the diagnosis and therapeutic follow-up of clinical stages II and III lymphedema of the lower limbs, achieving similar results to those obtained using water displacement volumetry.

Ethical Considerations

This study received approval from the institutional review board of the São Jose do Rio Preto School of Medicine (#4.726.181).

Conflict Interest and Financial Support

The authors declare no financial support and conflict of interest.

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