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The Role of Body Composition Analyzer in the Preoperative Assessment of Breast Cancer Patients

Lijuan Zhang*, Qiaoling Zhong*, Yun Ding, Jinlan Li, Qinghua Luo, Liping Zhang, Yuezhou Guo, Na Li#, Huizhen Zhang#

State Key Laboratory of South China Oncology, Cancer Prevention and Treatment Center Affiliated to Sun Yat-sen University, Guangzhou, China
Email: lina@sysucc.org.cn, zhanghzh@sysucc.org.cn

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Abstract

Background: The segmental multi-frequency bioelectrical impedance analysis (SMF-BIA) is a useful method for evaluating physical health and nutritional status in various clinical settings. But less is known about its role in the preoperative assessment of breast cancer patients. Herein, we try to monitor the changes in body composition of preoperative patients by SMF-BIA and figure out its association with clinical features. **Methods:** The changes in body composition were monitored by SMF-BIA in 563 female patients with breast cancer. Monitor body moisture and collect relevant data on the day before surgery as a prospective study. Retrospective analysis will be conducted based on preoperative data and pathological results after lymph node resection, Spearman's correlation coefficients were calculated to investigate the correlation among parameters. **Results:** We found that the body water, extracellular water ratio, and bioelectrical impedance of the affected upper limbs of patients with different tumor stages or different numbers of lymph node metastases were significantly different from those of their healthy upper limbs ($P < 0.05$). Among them, the body water and extracellular water ratio of the affected upper limbs were notably higher than those of the healthy ones ($P < 0.05$), while the bioelectrical impedance (1 kHz, 5 kHz) of the affected upper limbs was lower than that of the healthy ones ($P < 0.05$). Moreover, tumor stage was significantly correlated with the extracellular water ratio and bioelectrical impedance (1 kHz, 5 kHz) of the affected upper limbs ($P < 0.05$), and the number of lymph node metastases was significantly correlated with the difference in body

*Lijuan Zhang, Qiaoling Zhong contributed equally to this study.
#Corresponding author.

water and extracellular water ratio ($P < 0.05$). **Conclusion:** SMF-BIA can help monitor the changes in body composition of breast cancer patients and provide detailed information for making a personalized treatment plan and individual nursing schedule. However, the value of SMF-BIA in preoperative assessment still needs to be validated in large prospective clinical trials.

Keywords

Breast Cancer, Body Composition, Tumor Stages, Lymphatic Metastasis, Multi-Frequency Bioelectrical Impedance Analysis

1. Background

Breast cancer is the most common malignancy worldwide. Recently, there are about 304,000 new cases in China every year, and the proportion of young patients is gradually increasing [1]. Although the survival rate of breast cancer patients has been improved greatly with the development of medicine, it is of great significance to ameliorate the side effects of breast cancer treatment and improve the quality of life of patients [2]. Breast cancer-related lymphedema (BCRL) is one of the most common and distressing complications of breast cancer survivors after surgery. Upper limb swelling, pain, immobility, and other side effects, which can be caused by BCRL, have a great impact on the quality of life [3]. To prevent lymphedema after breast cancer surgery and provide patients with more accurate treatments and better nursing plans, medical staff needs to conduct a comprehensive assessment of patients before surgery.

The segmental multi-frequency bioelectrical impedance analysis (SMF-BIA) is a safe, economical, convenient, noninvasive, and commonly used method for assessing body composition in clinical practice and scientific research [4] [5]. The principle of this method is to obtain the electrical impedance of each segment of the human body by measuring the frequency current acting on each segment of the human body and further analyze its organization composition [6] [7]. It not only facilitates monitoring the severity of diseases, like sepsis, diabetes, liver and kidney failure, but also provides effective guidance for scientific exercise, reasonable fitness, weight loss, and rehabilitation [8] [9]. Additionally, SMF-BIA can be used in the prediction of hemodialysis vascular access failure [10]. However, its role in the preoperative assessment of breast cancer patients is still unclear.

Therefore, 563 breast cancer patients were enrolled in our study. In addition to collecting their clinical data, the body composition was measured by the Inbody S10 analyzer before operation. Through analyzing the differences in body composition of patients with different tumor stages as well as the different numbers of lymph node metastasis, we aimed to figure out the value of SMF-BIA in preoperative evaluation. Furthermore, revealing the correlation between SMF-BIA parameters and clinical characteristics may provide precise guidance for treatment selection.

2. Materials and Methods

2.1. Participants

Convenience sampling was adopted in this study. From January 2022 to October 2023, 563 female patients with breast cancer were recruited in Sun Yat-sen University Cancer Center. The inclusion criteria are as follows: 1) diagnosed by a pathologist as unilateral breast cancer for which surgical treatment was planned; 2) age ≥ 18 years old; 3) possession of normal cognitive and communication skills and having the ability to facilitate physical examinations; and 4) agreed to participate in this study. The exclusion criteria are as follows: 1) complicated with other systemic tumors or severe liver and kidney dysfunction; 2) tumor recurrence, distant metastasis, or metastatic cancer; 3) pregnancy; 4) menstrual period; and 5) other conditions, including severe dehydration, edema, ascites, effusions in the serous cavity, or placement of pacemakers and metals in the body, which could affect the measurement results.

2.2. Research Tools

For the measurement of body composition, the SMF-BIA Inbody S10 (InBody Co., Ltd., Korea) was used according to the manufacturer's instructions. The measurements include body mass index (BMI), total body water, extracellular water, segment water, extracellular water ratio (% ECW), and bioelectrical impedance values at 1 kHz and 5 kHz.

2.3. Method of Data Collection

This study was approved by the Ethics Committee of our hospital (GYX2020-002). All patients have signed informed consent. A lymphedema specialty nurse was trained on the formal procedures to measure the patients' body composition by using the Inbody S10 SMF-BIA analyzer. Patients were asked to maintain their position until the measurements were completed, with eyes straight ahead, body upright, arms spread at an angle of about 30˚ from the body, and feet shoulder-width apart. The detailed process was presented in our previous report [11]. Total body water, extracellular water, segment water, extracellular water ratio, and bioelectrical impedance values at 1 kHz and 5 kHz were collected for preoperative assessment.

2.4. Statistical Analysis

The statistical analysis was conducted using SPSS V25.0. Data were described as frequency and mean ± standard deviation. Paired Samples T-test or one-way analysis of variance (ANOVA) test was used for comparison between different groups. The Greenhouse-Geisser method was used as the modified statistic (F) if the spherical test is not satisfied, and the Bonferroni method was used for pairwise comparison. Spearman's correlation coefficients were calculated to investigate the correlation among parameters. The *P* value was two-sided and considered statistically significant when it less than 0.05.

3. Results

Patient Characteristics

All patients are female between 22 to 76 years (averaged at 47.68 ± 10.32 years old), with an average height of (157.92 ± 5.13) cm and an average weight of (57.47 ± 8.25) kg. Of the 563 patients, 203 (36.06%) were overweight or obese; 386 (68.56%) suffered from stage I/II cancer, and 276 (49.02%) had left-sided breast cancer. Additionally, 404 (71.76%) patients had more than 10 axillary lymph nodes dissected, and 311 (55.24%) had lymph node metastasis. Detailed information on the patients is shown in Table 1.

Table 1. General demographic and disease-related information.

Variable	Frequency (n)	Percentage
Age		
<40	125	22.2
40 - 64	402	71.4
≥65	36	6.4
BMI (Kg/M^2)		
<18.5	30	5.3
18.5 - 23.9	330	58.6
24.0 - 27.9	174	30.9
≥28.0	29	5.2
Staging		
I	112	19.9
II	274	48.7
III	155	27.5
IV	22	3.9
Affected		
Left	276	49.0
Right	287	51.0
Number of Lymph Nodes Swept		
0	6	1.1
<10	153	27.2
10 - 19	260	46.2
≥20	144	25.6
Transfer or Not		
No	252	44.8
<3	149	26.5
3 - 5	66	11.7
>5	96	17.1

Difference of water content and bioelectrical impedance in upper limbs of patients with breast cancer at different tumor stages before operation.

We found that there were notable differences among the upper limbs water difference and extracellular water ratio of the affected upper limbs of patients with different tumor stages (Table 2). Moreover, the body water, extracellular water ratio, and bioelectrical impedance of the affected upper limbs of patients with stage III breast cancer were significantly different from those of the healthy ones (Table 3). Besides, the upper limbs water difference in stage IV is significantly higher than that in stage II (0.050 ± 0.188:0.003 ± 0.055, $P < 0.05$). However, there is no significant difference between the affected and healthy upper limbs of patients in other tumor stages.

Table 2. The difference of body moisture in patients with different tumor stages.

Group	n	%	Total Body Moisture	Extracellular Moisture	Upper Limb Moisture in Affected Area	Moisture on Upper Limb	Upper Limb Moisture Difference	Extracellular Water Ratio	Extracellular Water Ratio in Affected Upper Limb	Extracellular Water Ratio Difference in Upper Limb
Stage I	112	19.9	29.208 ± 2.890	11.105 ± 1.101	1.461 ± 0.224	1.455 ± 0.233	0.007 ± 0.068	0.380 ± 0.005	0.376 ± 0.015	0.002 ± 0.016
Stage II	274	48.7	29.160 ± 3.264	11.075 ± 1.222	1.468 ± 0.260	1.465 ± 0.256	0.003 ± 0.055	0.380 ± 0.007	0.375 ± 0.004	0.000 ± 0.003
Stage III	155	27.5	29.572 ± 3.103	11.256 ± 1.189	1.503 ± 0.234	1.488 ± 0.238	0.014 ± 0.068	0.381 ± 0.007	0.376 ± 0.005	0.001 ± 0.003
Stage IV	22	3.9	29.955 ± 3.068	11.500 ± 1.198	1.532 ± 0.391	1.483 ± 0.269	0.050 ± 0.188	0.384 ± 0 .010	0.379 ± 0.008	0.003 ± 0.007
P			0.433	0.224	0.326	0.698	0.014	0.079	0.041	0.035

Table 3. Differences of upper limb moisture and bioelectrical impedance in patients with different tumor stages.

Group		n	%	Upper Limb Moisture in Affected Area	Moisture on Upper Limb	*P*	Extracellular Water Ratio in Affected Upper Limb	Extracellular Water Ratio in Healthy Upper Limb	*P*	Bioelectrical Impedance (1 KHz)	Bioelectric Impedance of Healthy Side (1 KHz)	*P*	Bioelectric Impedance of Affected Side (5 KHz)	Bioelectrical Impedance (5 KHz)	*P*
Tumor Staging	Stage I	112	19.9	1.461 ± 0.224	1.455 ± 0.233	0.296	0.376 ± 0.015	0.373 ± 0.007	0.1	422.517 ± 41.825	428.664 ± 64.291	0.222	413.158 ± 46.199	419.413 ± 48.444	0.068
	Stage II	274	48.7	1.468 ± 0.260	1.465 ± 0.256	0.45	0.375 ± 0.004	0.374 ± 0.004	0.325	421.386 ± 51.085	421.759 ± 49.741	0.698	413.688 ± 50.762	414.084 ± 49.461	0.673
	Stage III	155	27.5	1.503 ± 0.234	1.488 ± 0.238	0.007	0.376 ± 0.005	0.375 ± 0.004	0.001	411.827 ± 50.082	417.771 ± 48.312	0.001	404.851 ± 48.899	410.105 ± 47.533	0.001
	Stage IV	22	3.9	1.532 ± 0.391	1.483 ± 0.269	0.23	0.379 ± 0.008	0.376 ± 0.006	0.065	405.582 ± 72.388	416.250 ± 51.933	0.128	400.427 ± 72.326	410.127 ± 51.776	0.172

Difference of water content and bioelectrical impedance in upper limbs of patients with different lymph node metastasis before breast cancer surgery.

This study shows that the water content of affected upper limbs was significantly higher than that of the healthy ones, in which the patients had axillary lymph node metastases. For the patients with more than 5 lymph node metastases,

the extracellular water ratio of the affected upper limbs was obviously higher than that of the healthy ones, while the 1 kHz bioelectrical impedance of the affected upper limb was lower than that of the healthy ones ($P < 0.05$). For the breast cancer patients with axillary lymph node metastases, the 5 kHz bioelectrical impedance of the affected upper limbs was observably lower when compared with that of the healthy ones ($P < 0.05$). Details are shown in Table 4.

Table 4. The difference of upper limb moisture and bioelectrical impedance in patients with different lymph node metastasis number.

Group		n	%	Upper Limb Moisture in Affected Area	Moisture on Upper Limb	*P* Value	Extracellular Water Ratio in Affected Upper Limb	Extracellular Water Ratio in Healthy Upper Limb	*P* Value	Bioelectrical Impedance (1 KHz)	Bioelectric Impedance of Healthy Side (1 KHz)	*P* Value	Bioelectric Impedance of Affected Side (5 KHz)	Bioelectrical Impedance (5 KHz)	*P* Value
Lymphatic Metastasis	No Transfer	252	44.8	1.464 ± 0.243	1.464 ± 0.245	0.952	0.375 ± 0.011	0.374 ± 0.006	0.067	422.890 ± 48.223	424.833 ± 57.471	0.415	414.699 ± 49.676	416.448 ± 49.653	0.311
	<3	149	26.5	1.486 ± 0.263	1.476 ± 0.258	0.025	0.375 ± 0.004	0.375 ± 0.004	0.089	414.472 ± 52.161	416.979 ± 49.605	0.055	407.158 ± 51.168	409.766 ± 49.137	0.04
	3 - 5	66	11.7	1.486 ± 0.309	1.457 ± 0.260	0.046	0.376 ± 0.007	0.375 ± 0.005	0.05	421.089 ± 57.812	429.420 ± 51.122	0.07	413.744 ± 57.364	421.545 ± 51.174	0.009
	>5	96	17.1	1.501 ± 0.220	1.486 ± 0.224	0.038	0.376 ± 0.005	0.375 ± 0.004	0.016	410.635 ± 45.921	416.197 ± 43.901	0.01	403.205 ± 45.483	408.335 ± 43.667	0.013

Correlation between preoperative tumor stage and number of lymph node metastasis of breast cancer and water body and bioelectrical impedance.

Tumor stages are significantly correlated with extracellular water ratio and bioelectrical impedance (1 kHz, 5 kHz) of the affected upper limbs ($r = 0.115$ for extracellular water ratio, $r = -0.107$ and -0.098 for bioelectrical impedance (1 kHz, 5 kHz), $P < 0.05$). The number of lymph node metastases is significantly correlated with the body water difference and extracellular water ratio of the affected upper limbs ($r = 0.114$ for the body water difference, $r = 0.097$ for the body water difference, $P < 0.05$). The details are shown in Table 5.

Table 5. Correlation of different tumor stages, number of lymph node metastases and body moisture and bioelectrical impedance.

Group		Total Body Moisture	Extracellular Moisture	Upper Limb Moisture in Affected Area	Moisture on Upper Limb	Affected/ Healthy Side Upper Limb Moisture Difference	Extracellular Water Ratio	Extracellular Water Ratio in Affected Upper Limb	Affected kHz 1 Bioelectric Impedance	Healthy Side kHz 1 Bioelectric impedance	Affected kHz 5 Bioelectric Impedance	Healthy Side kHz 5 Bioelectric Impedance
Tumor Staging	r	0.065	0.077	0.062	0.045	0.061	0.061	0.115*	−0.107*	−0.06	−0.098*	−0.065
Number of Lymph node Metastases	r	0.55	0.058	0.058	0.031	0.114*	0.019	0.097*	−0.08	−0.029	−0.082	−0.036

*significant correlation.

4. Discussion

The previous preoperative evaluation of breast cancer includes laboratory tests, such as blood cells and biochemical routines, which can mirror the patient's overall nutritional status and changes, as well as local ultrasound and mammography,

which provide key information for determining the extent of local tumor growth and invasion. In addition, chest radiographs, ultrasound of abdominal organs, etc. are also needed to find out the distant metastasis of tumors [12]-[14]. However, none of these inspections can sensitively reflect the subtle changes in local tissues. By detecting the changes in local humidity and electrical impedance, the segmental multi-frequency bioelectrical impedance analysis (SMF-BIA) helps to assess the patient's preoperative condition more comprehensively [15] [16].

During this study, we found that the ratio of body water and extracellular water in the upper limbs of breast cancer patients with different tumor stages before surgery was significantly different from that of healthy patients. This suggests that with the progress of the disease, there will be some slight changes in the body composition of patients. Additionally, the results showed that for the patients with stage III breast cancer, there were notable differences in upper limb water, extracellular water ratio, and bioelectrical impedance values at 1 kHz and 5 kHz between the affected and healthy upper limbs. As we all know, breast cancer metastasizes through the lymphatic system [17] [18]. The notable differences may be related to the obstruction of lymphatic reflux caused by tumor metastasis to lymph nodes. However, there is no significant difference in body composition and bioelectrical impedance between the affected and healthy upper limbs of the patients with stage IV breast cancer, which may be due to the small sample size of patients at this stage in our study.

Axillary lymph node dissection is a main treatment-related risk factor for BCRL [19]. Studies show that ALND may result in greater lymphatic disruption than SLNB and increase the incidence of BCRL [20]. Herein, scientifically and rationally conducting a comprehensive preoperative evaluation for breast cancer patients and setting up an appropriate surgical plan, especially about the scope of lymph node resection, which is essential to prevent BCRL. Our study demonstrated that the upper limb water and bioelectrical impedance of patients had already changed before the operation, which may be related to the inflammatory response caused by malignant tumors and the obstruction of lymphatic reflux caused by tumor metastasis to lymph nodes, thus leading to the change in body composition. In other words, lymphatic metastasis may occur when there are significant differences in the upper limb water or electrical impedance values between the affected and healthy upper limbs, which can be taken as a reference for clinical treatment.

Our study displayed that the tumor stage was positively correlated with the extracellular water ratio of the affected upper limbs, and negatively correlated with the bioelectrical impedance (1 kHz, 5 kHz), indicating that the more advanced the tumor stage of breast cancer patients, the more extracellular fluid. Considering that the impedance value of low-frequency current reflects the changes in extracellular fluid components, it can also indicate the status of lymphedema [21]. Having an advanced disease may increase the probability of developing lymphedema, which is in line with those of previous studies [22]. Ribeiro Pereira and its

colleagues prospectively observed a hospital-based cohort of women undergoing axillary lymph node dissection for 10 years and found that the patients with advanced disease have a higher risk of lymphedema [21]. Additionally, we also found that the number of lymph node metastases is positively correlated with the upper limb water difference and the extracellular water ratio of the affected upper limbs, revealing that the more lymph nodes metastasis, the greater the upper limb water difference and the more extracellular water. The above data demonstrated that the SMF-BIA was sensitive enough to detect subtle changes in local tissues and could assist in judging lymph node metastasis before surgery, so as to accurately formulate individualized surgical treatment plans.

The present study was designed to explore the application of SMF-BIA in the preoperative assessment of breast cancer patients and analyze the differences in their body composition with different tumor stages or various numbers of axillary lymph node metastases. The results suggested that SMF-BIA was sensitive enough to detect the changes in body composition of breast cancer patients before surgery, which was conducive to find out the patient with a high risk of lymphatic metastasis. By acquiring this detailed information, we could prepare individualized treatment and nursing plans, which might reduce the incidence of postoperative lymphedema to a certain extent.

The limitation of this study is that the relatively small sample size can lead to uneven distribution of the patients in different tumor stages or with the various numbers of lymph node metastasis. At the same time, more important clinical features, including laboratory testing, and imaging examination, should be taken into consideration and make a more comprehensive evaluation of the patient. In addition, our results came from a retrospective analysis, which should be further confirmed in well-designed prospective studies.

5. Conclusion

We found that SMF-BIA has potential value in monitoring the changes of body composition of patients with breast cancer before surgery, and provides more detailed information for making accurate nursing plans. A long-term follow-up study is still needed to establish a comprehensive lymphedema risk prediction model.

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Conflicts of Interest

No competing financial interests exist.

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