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The Usefulness of Monitoring Pleural Effusion Treatment by the Internal Thoracic Impedance Method

Abstract

Background: Internal thoracic impedance (ITI) is a sensitive and reliable method used to detect pulmonary fluids accumulation as, pulmonary edema or pleural effusion. The current study deals with this noninvasive method in heart failure patients, its usefulness in detecting pleural effusion before the appearance of clinical symptoms and for demonstrating increased ITI during its resolution.

Methods: A prospective controlled study performed in a single department of internal medicine belonging to a university-affiliated hospital between the years - 2012-2013. Sixty two patients (ages ranging from 41 to 94) were recruited for the study, of whom 31 with bilateral or right pleural effusion of any etiology (study group) and 31without pleural effusion (control group) who were admitted because of heart failure (HF). ITI was continuously measured by the RS-207 monitor. The predictive value of ITI monitoring was determined by 8 measurements taken every 8 hours. Pleural effusion was diagnosed and followed by main clinical signs and also chest X ray as a gold standard modality before and at the end of the monitoring.

Results: During the 56 hours of treatment, the median ITI of the study group increased by 21.5% -from 33.1±4.2 to 42.1±3.9 ohm (P < 0.001) as compared to the non significant changes in the control group 59.4±5.2 (P = NS). Prominent changes were observed in the respiratory rate (RR) of the study group: there was a decrease from 31.2±4.2to 19.7±2.3 (36.5%) - as compared to no changes for the controls, and a mean increase of elevation from 83.5±5.3% (9.1%) in O2 saturation to 92.4±1.5% as compared to94.3±2.1 (p-NS) for the controls.

Conclusion: ITI methodology is useful for the diagnosis and monitoring of treatment of HF patients with pleural effusion as it enables diagnosis in the preclinical stage. ITI may provide early and better treatment, and can prevent complications such as respiratory distress, intubation and make hospitalization unnecessary. There were no significant ITI changes in HF patients as compared to the mixed general population.

Keywords: Impedance; Plethysmography; Internal thoracic impedance; Pleural effusion

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Abbreviations: HF: Heart Failure; ITI: Internal Thoracic Impedance; TTI: Transthoracic Impedance; O_2%: Oxygen Saturation; RR: Respiratory Rate; sBP: Systolic Blood Pressure; dBP: Diastolic Blood Pressure

Introduction

Pleural effusion cause considerable distress to patients and are difficult to treat because of the deteriorating arterial oxygen saturation and respiratory distress [1]. Early diagnosis and treatment of pleural effusion might interrupt its development that progressively leads to severe respiratory distress and sometimes to mechanical ventilation and death. The only possible solution for early diagnosis (i.e., before the appearance of clinical symptoms) and treatment would be continuous monitoring of every patient at risk of developing acute HF. X-rays is not suitable and cannot be used for prolonged monitoring due to the danger of frequent exposure to radiation. The increased content of extravascular fluid in lungs can be detected via monitoring of their impedance (electrical resistance) [3-8]. Accumulation of water in the lung leads to a decrease in its impedance [9].

In previous studies we have shown the suitability of the RS-207 monitor (R. S. Medical Monitoring, Jerusalem, Israel) for measuring ITI and early diagnosis of pulmonary edema and pleural effusion from different etiologies [1-16]. So far, not any studies have dealt with early diagnosis of pleural effusion in pure HF cohort who, most frequently, suffer from pleural effusion, by use of this noninvasive and inexpensive method. Moreover, the currently available methods for the early detection and monitoring of pulmonary edema were not studied for pleural effusion and are not sufficiently reliable and may themselves lead to complications [1-10]. The changes in the extravascular fluid content in the lungs in humans and animals can be easily monitored by a noninvasive procedure based on impedance plethysmography of right lung [8-15]. Total transthoracic impedance (TTI) consists of ITI and skin contact impedance.

The Edema Guard Monitor (EGM) model RS-207 (R. S. Medical Monitoring, Jerusalem, Israel [12], in contrast to the other currently available impedance monitors, measures the ITI of the right lung, which roughly equals lung impedance, by automatically calculating skin electrode impedance and subtracting it from

the TTI [8,15]. These results showed much higher sensitivity compared with the 1.5% changes found when using TTI methods. This monitor was successful for the early detection of pleural effusion in the general population [16], but there have been no reports describing its application for the elderly. The aim of our study was to evaluate the suitability of the RS-207 in detection and monitoring pleural effusion in heart failure patients during both the asymptomatic and symptomatic stages.

Materials and Methods

A prospective cohort study of consecutive patients admitted to the Department of Internal Medicine "C" of the Tel Aviv Medical Center between July 2012- August 2013. The inclusion criteria for the study group were heart failure due to ischemic heart disease or valvular heart disease complicated by bilateral or right lung pleural effusion. The exclusion criteria were: thoracic deformation, wearing a pacemaker, pregnancy, coma and respiratory failure due to diseases i.e., pulmonary edema and embolism. The protocol of the investigation corresponded to the principles outlined in the Declaration of Helsinki, and the study protocol was approved by the local Ethics Committee of the Tel Aviv Medical Center and the Israeli Ministry of Health, number 0504-11-TLV. The study is registered at Clinical Trials.gov with the registration number NCT01601444._All the participants gave written informed consent before being enrolled in the study. The authors confirm that all ongoing and related trials for this intervention are registered.

The diagnosis of pleural effusion was based on clinical signs of arterial hypoxemia (<92%) and on the following symptoms and signs: progressive dyspnea at rest (>20 respirations), tachycardia (>90 beats/min), diaphoresis, cyanosis, dullness on percussion, crepitation rales, [15] and gold standard -roentgenographic evidence of fluid existence. ITI measurements were taken continuously. Clinical examination, and measurements of oxygen saturation (O_2%), respiratory rate, pulse, systolic (sBP) and diastolic blood pressure (dBP) evaluation were to be repeated every 8 hours until successful conservative treatment or pleural puncture had been achieved. Follow-up chest x-ray was performed after the monitoring has been terminated.

Heart failure patients with pleural effusion were treated either pharmacologically (mainly based on the diuretics furosemide and aldospirone) or by right lung pleural paracentesis. ITI monitoring of pleural effusion was carried out by the placing three electrodes in the front and three electrodes in the back of the right side of thorax [8]. The result is the value of internal thoracic electrical resistance (impedance), the ITI. These method by which ITI is estimated is described in detail elsewhere [8,15].

Results

Ninty patients were initially enrolled in our study. 28 of the patients were excluded from the study because of poor compliance. The other 62patients were congruent with the inclusion and exclusion criteria, and they made up our study group: 31 patients (22 females and 9 males) mean age 79±11.3 with pleural effusion and 31 patients (25 females and 6 males) mean age 80 ±13.4in the control group. The mean follow up time was 3 days. The baseline clinical characteristics of the study participants are shown in Table 1.

The baseline clinical characteristics of the study participants are shown in Table 1. The etiology of pleural effusion in the study group were ischemic (76%) or valvular cardiomyopathy (24%). Their mean left ventricular ejection fraction of dilated cardiomyopathy patients was 38.7% and their mean NYHA class was 2.8. Thirty-nine percent of the study patients had a confirmed diagnosis of non-insulin-dependent diabetes mellitus, 55% had hypertension and 24% were current or past smokers. Twenty five of the patients with pleural effusion 80% (Group 1) underwent pleural puncture. The mean amount of extracted pleural effusion was 890 cc.

All 62 patients were monitored continuously. We used 8 measurements every 8 hours to explore the predictive value of ITI monitoring (changes in ITI are slow, even after pleural tap). The changes of the ITI and other between 6 and 8 measurements were not significant. Figure 1 shows the changes in ITI during treatment and monitoring with significant difference between study groups. The mean initial ITI at the beginning of the monitoring was 33.1±4.2 ohm in the study–group 1, whereas the ITI in the control group-2 was 59.4±5.2ohm. During the treatment the ITI rose to 42.1±3.9 ohm (p<0.001) -21.5 % change, while in group 2 there were no changes (p=NS) during the same monitoring period (Table 2).

Similarly significant changes were seen in O2 saturation levels for both groups: the baseline median O2 % saturation for the group 1 was 83.5±5.3 and it rose to 92.4±1.5% at the end of the monitoring 9.1 % rise in comparison to non significant changes (93-94%), respectively, for the group 2(P = NS) (Figure 2). The most significant and prominent changes between the two groups were observed in respiratory rate. They are displayed in Figure 3. In the patients group 1, the respiratory rate decreased by 36.5%- from 31.2± 4.2 to 19.7±2.3 (P=0.001), as compared to group 2, where respiratory rate remain unchanged 15.6±4.9 per minute (p=NS).

Figure 4 shows significant pulse rate differences between the two groups In group 1 the average pulse rate at the beginning of the follow up was 96.1+8.0, while at the end of the follow up the pulse rate was 73.1±5.1 (p=0.001), whereas , in the control group the average pulse rate at the beginning and at the end of the follow up was 72.3±12 (p=NS), representing a decline of 27.2% (P < 0.001) in comparison to group 2 where there were no changes (P = NS). A similar tendency can be observed in the changes of the systolic blood pressure (sBP) Figure 5. The mean initial sBP in the group 1 patients with pleural effusion- was 159.5±14.6mmHg and at the last -eighth measurement it was 133.6±4.7 mmHg (p<0.001). Table 2, representing a difference of 16.2% (P <0.001) for group 1, in comparison to group 2 where changes have been registered as significant (P <0.01) (Figure 5) and may be explained by the stress of hospitalization and different diseases. Fig 6 displays the significant changes in the diastolic blood pressure (dBP) in both groups, in group 1 the initial mean dBP was 85.9±14 mmHg and at the end of the monitoring –72.6±7.0 mmHg (p=0.001) a change of 18.6%, while in group 2 it was 79 and 73 mmHg respectively, a change of 6% (p=NS).

Table 2 summarizes the differences between the values of the clinical parameters at baseline (time 0 hours) and at the end of the monitoring (time 56 hours) and treatment. Important findings were determined in a group of 26 patients who underwent right

sided pleural paracentesis – with a mean drained volume of 890 mL. As expected, these patients showed faster elevation in ITI (mean of 6.8±2.1 ohm) at the end of the first hour after the procedure, compared to a mean of 2.4 ohm in the entire group. In the group of patient with paracenthesis the mean overall ITI elevation at the end of the 56 hours was 12.6 ohm ,that is 33.8% ($P < 0.01$) in comparison to ITI rise of 10.3% in the entire group (31.5%, $P < 0.01$). Measurements of oxygen saturation (O_2%), respiration rate, pulse rate, systolic (sBP) and diastolic (dBP) blood pressure showed faster improvements as expected.

Spearman correlation coefficients of ITI level at baseline and all measurements during monitoring and differences in all stages with various clinical parameters were as follows: O_2% -0. 84 (p<0. 001), RR -0.71 (p<0.001), pulse -0.75(p<NS), sBP-0.58 (p<0. 001), dBP -0.34 (p<0.001) No correlation was found between ITI, clinical parameters BMI and age. Clinical parameters oxygen saturation, respiratory rate, pulse, systolic and diastolic blood pressure and ITI of the HF patients were compared to mixed cohort of patients with pleural effusion transudate and exudate of different etiologies [16]. There were no significant differences (not shown data).

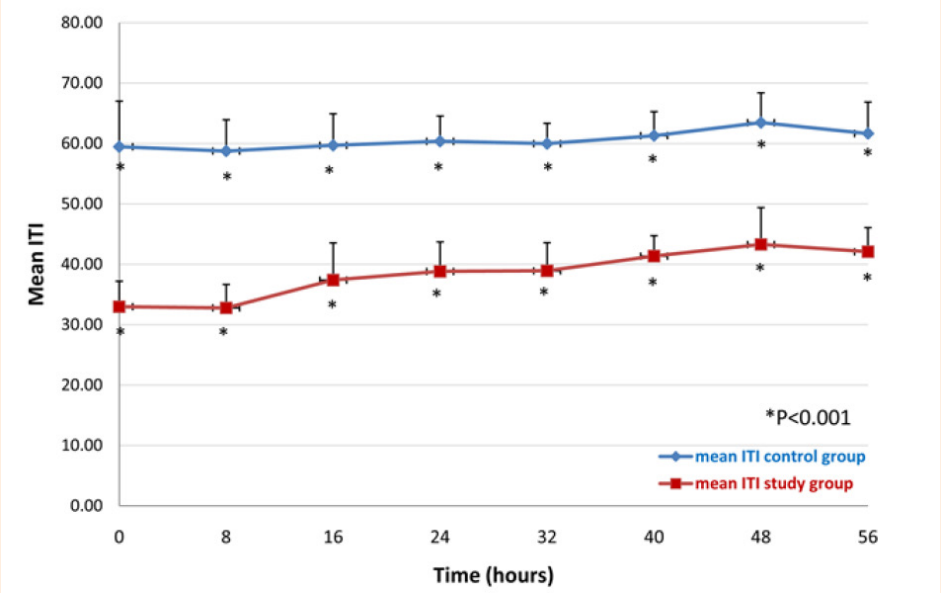

Figure 1: Mean ITI changes over the monitoring and treatment.

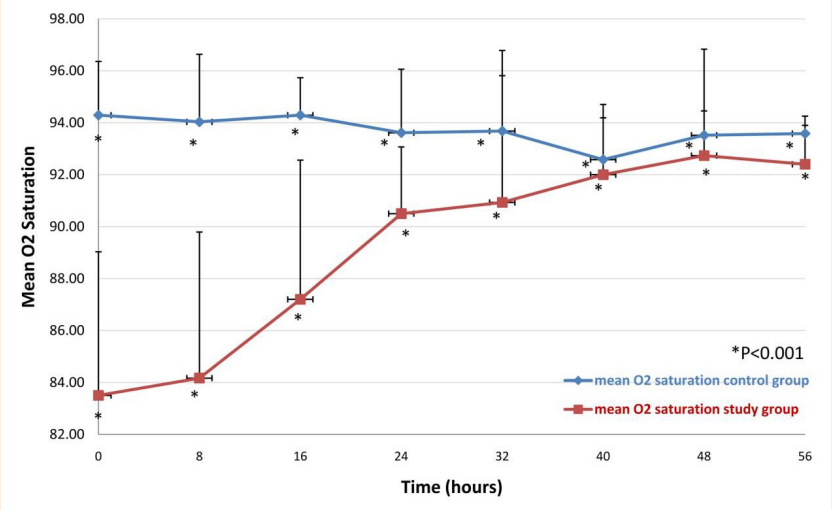

Figure 2: Mean oxygen saturation over the monitoring and treatment.

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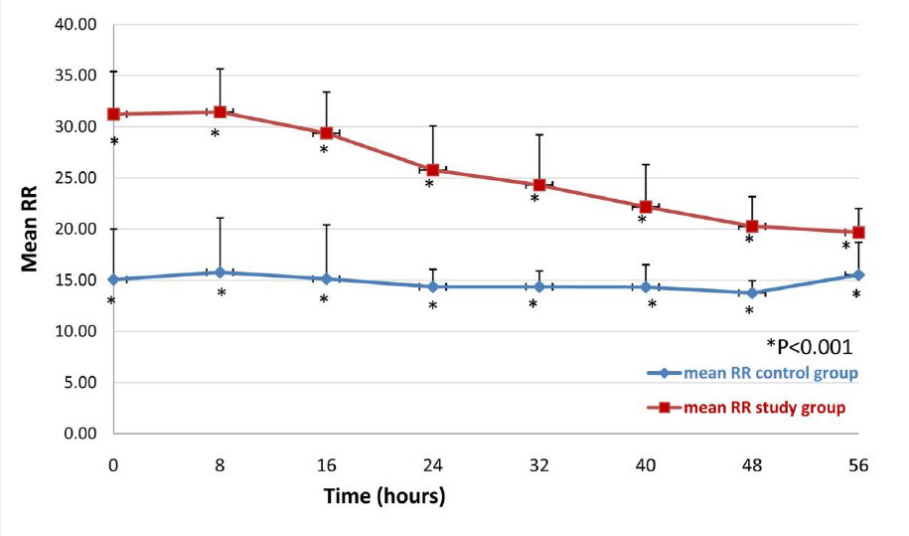

Figure 3: Mean respiratory rate changes over the monitoring and treatment.

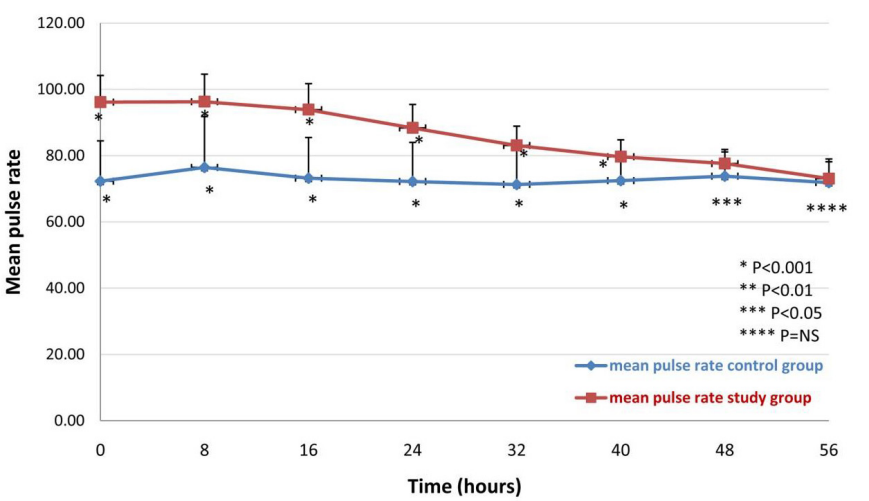

Figure 4: Mean pulse rate changes over the monitoring and treatment.

Table 1: Initial baseline characteristics of the patients on admission.

Patients	ITI ohm	O_2 %	RR/min	Pulse/min	sBP mmHg	dBP mmHg
Group 1 ± SD	32.9	83.5	31.23	96.13	159.23	85.9
	4.2	5.53	4.15	8.04	14.55	14.49
Group 2± SD	59.45	94.29	15.06	72.29	140	79.16
	7.54	2.07	4.93	12.17	9.91	18.32
P value	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P=0.117

ITI: Internal Thoracic Impedance; O_2: Oxygen Saturation; RR: Respiratory Rate; sBP: Systolic Blood Pressure; dBP: Diastolic Blood Pressure; SD: Standard Deviation; P: P Value

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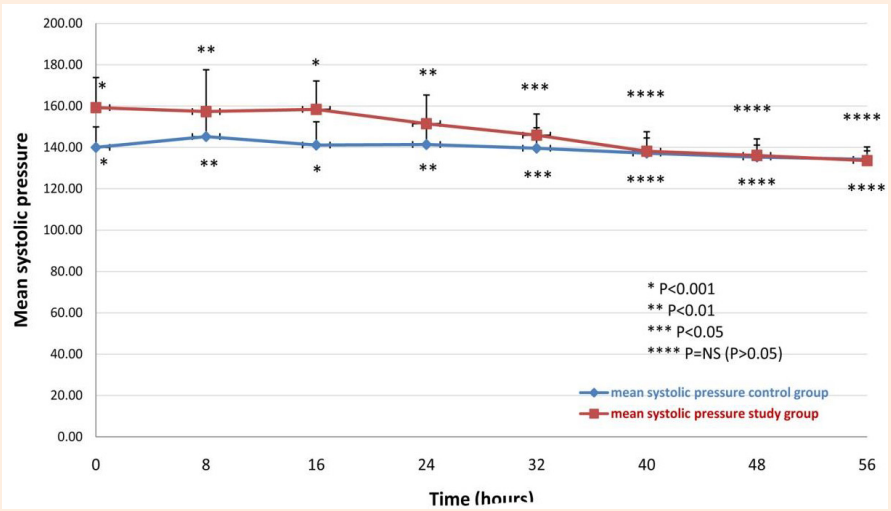

Figure 5: Mean systolic blood pressure changes over the monitoring and treatment.

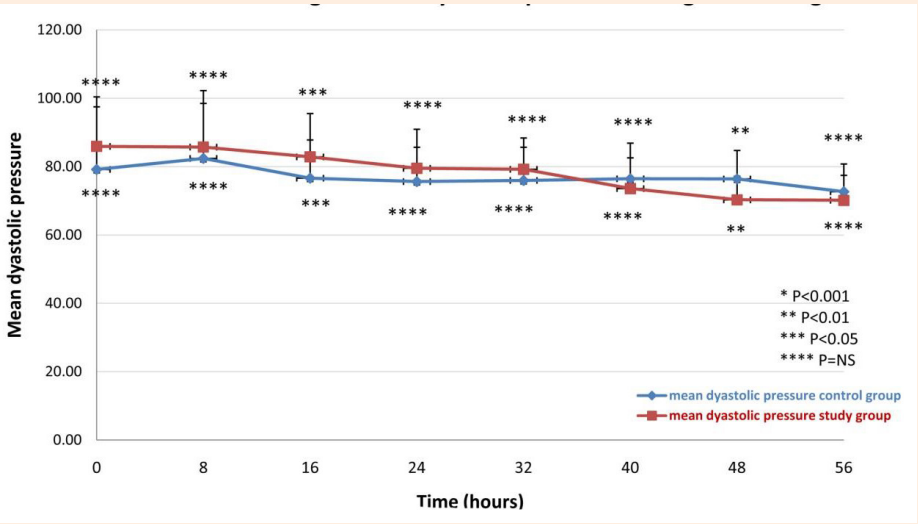

Figure 6: Mean diastolic blood pressure changes over the monitoring and treatment.

Discussion

Accumulation of pleural effusion leads to a decrease of pulmonary electrical resistance (impedance). The current study deals with the diagnosis of pleural effusion in elderly population [8-22]. Its results demonstrate that continuous ITI monitoring of patients with pulmonary effusion is a useful and accurate method for diagnosis and prediction of respiratory distress and for proper preventive therapeutic management. Dynamic changes of ITI values in patients with symptomatic pleural effusion were monitored together with other cardinal hemodynamic parameters as changes in heart rate, respiration rate, O2% concentration, sBP and dBP. Changes of the above-cited main clinical parameters were in line to the elevation of ITI, which explains the disappearance of fluid from the right lung pleural space that was being monitored. Pleural effusion was predominant in right lung. A decrease in ITI of approximately 12-21% was previously shown to reflect the maximal capacity of lung interstitium to accumulate fluid and to predict impending pulmonary edema [15, 17-20]. Current results of this study revealed that the ITI levels in the presence of pulmonary effusion were significantly lower by 44% (33 ohm) as compared to those of patients without pulmonary effusion.

The ITI of symptomatic patients was very low like in patients with pleural effusion from various etiologies [16]: specifically, in HF patients it was a -33 ohm in comparison to 32 ohm of the patients with pleural effusion from various etiologies. However, it is significantly higher than in overt pulmonary edema [15]. These results indicate that this method can be widely applied in the clinical setting. It is important to stress that even after successful treatment and disappearance of other clinical symptoms the ITI remained still significantly lower than in the group of patients without pleural effusion- conclusion being drawn that residual fluid was left and the lung is still 'wet", in point of fact it is impossible to evacuate all the fluid.

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Both groups were similar in age, nevertheless there were significant differences in their BMIs. Obese patients could be expected to have a higher TTI but not a higher ITI. A special mathematic algorithm using the equation, with 3 electrodes from each side of the chest, subtracts chest wall impedance (including subcutaneous adipose tissue) from the transthoracic impedance (TTI) [8]. The were no correlations between the age and BMI and ITI values during the study period. The patients in group 1 received the treatment by diuretics or pleural puncture according to clinical signs and symptoms, and roentgenological findings. The ITI measurements showed an elevation of 32.3% following the treatment.

In addition, after the values of several clinical signs (respiration rate, heart rate, O2%, sBP and dBP) underwent a significant improvement (mostly for a period of 32-40 hours) during treatment, they did not manifest any further detectable clinical signs and did not change significantly during further monitoring. For example, after oxygen saturation reached 93% (normal) following 40 hours of monitoring and treatment, it did not change significantly during further follow-up until the 56th hour (the 8th measurement). The same pattern was noticed in the pulse where the significant decline of rate was found during the first 5 measurements. In contrast, the post-treatment ITI values of the study group were lower as compared to the non-significant ITI fluctuations in the control group, indicating significant residual fluid volume which did not, in fact, cause clinical symptoms especially at rest position. The patients in group 2 showed small and mostly non significant ITI changes in the control group which may be explained by stress-inducing factors of the active disease (e.g., fever, dyspnea. All patients revealed low ITI in the range of 28-33 ohm as compared to group 2 whose ITI was in the range of 60-68 ohm. There were no overlapping values between the two groups. All the same, this method cannot distinguish pleural

effusion from pulmonary edema because it measures ITI of pulmonary fluids in general The mean baseline differences of the ITI between the two groups were ~26± 3.1 ohm, and it decreased to ~19.4±3.4 ohm after the treatment. This in comparison to patients with pleural effusion from of different etiologies where the value was 25 ohm [16] and to the overt pulmonary edema where the differences at the peak and resolution between patients and control group were 21 ohm [8]. Good correlation of ITI was found with other clinical parameters (O_2, RR Pulse, sBP, dBP values measured at the outset with all parameters used to evaluate patients clinical condition. These correlations remained significant at least after 40 hours of monitoring.

ITI modality is useful for identifying the presence of pleural fluid in the HF much earlier than clinical symptoms and signs (O_2, RR Pulse, sBP, dBP) [15]. This method is useful for the early diagnosis of pleural effusion and initiation, adding or elevation of diuretic dose for treatment, in patients with heart failure, can be effectively treated in an ambulatory setting. We think that the ITI of ambulatory patients can be measured once daily by the RS-207 monitor much in the same way that BP is measured, and that the patient can seek and receive appropriate treatment in the event that there is a decrease in impedance below acceptable values.

Conclusion

The monitoring of ITI in HF patients is a useful methodology and may be especially effective for ambulatory patients with recurrent pleural effusion. It may also enable early diagnosis and early treatment of yet asymptomatic or not life-threatening dyspnea, prevent respiratory distress and intubation. ITI monitoring with ITI result of 33 ohm or less may, in patients with previous pleural effusion, be considered as the diagnosis of significant pleural fluid accumulation and in need of early intervention. We considered that the RS-207 monitor can be useful for both hospitalized patients and ambulatory ones with chronic or recurrent severe pleural effusion from congestive heart failure and enable the latter to receive early treatment and prevent hospitalization.

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