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Original Research Article

A STUDY OF THE ASSESSMENT OF VOLUME STATUS IN CHRONIC KIDNEY DISEASE PATIENTS ON HEMODIALYSIS BY LUNG ULTRASONOGRAPHY

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ABSTRACT

Background: Assessing extracellular fluid volume is one of the most difficult tasks for physicians caring for haemodialysis (HD) patients. The study explores the feasibility and utility of Lung ultrasound (LUS) for evaluating volume status in Chronic Kidney Disease (CKD) Patients on HD.
Materials and Methods: LUS evaluation of B-Lines was the primary study and its relevance concerning the assessment of volume status was compared with Inferior Vena Cava (IVC) diameter, Weight, Blood Pressure (BP), and clinical parameters.
Results: The correlation of pre-HD B-lines and pre-HD IVC diameter was very strong (r=0.871), but the correlation of post-HD B-lines and post-HD IVC diameter was only reasonable (r=0.453). Also, the correlation of mean difference in B-lines pre and post-HD with weight loss was very strong (r=0.883) and with that of clinical signs and symptoms was strong (r=0.734). Despite the correlation between pre-HD B-lines and pre-HD BP being reasonable (SBP r=0.448/DBP r=0.508), the correlation between post-HD B-lines and post-HD BP was found to be very weak (SBP r=0.073/ DBP r=0.104).
Conclusion: LUS B-lines can be used to evaluate the volume status of CKD patients on MHD, with the additional possibility of being used as a method of determining a person's dry weight (DW).
Keywords: Lung ultrasound, Fluid volume, B-line, IVC diameter, Chronic kidney disease, Haemodialysis.

INTRODUCTION

Assessing extracellular fluid volume is one of the most difficult tasks for physicians caring for HD patients. Most nephrologists have made such decisions based on the concept of "dry weight (DW)," which has traditionally been defined as "the weight at the end of a dialysis treatment below which the patient, more often than not, will develop symptoms of hypotension".[1] Not surprisingly, this imprecise DW determination results in a significant error, allowing patients to leave the HD centre hypervolemic, normovolemic, or hypovolemic. Hypervolemic patients are more likely to develop volume-dependent hypertension, left ventricular hypertrophy, and congestive heart failure. Hypovolemic patients, on the other hand, may experience symptoms of volume depletion and intradialytic hypotension. More accurate methods of measuring the fluid compartments of the body are required to better estimate a patient's DW and maximize the chances of achieving and maintaining normovolemia.

The optimal pre-HD fluid status window appears to be narrow, with recent studies linking even subclinical (moderate) fluid overload to increased mortality risk, as well as a similar risk in patients with pre-HD fluid depletion.[2,3] Fluid depletion has been linked to intradialytic morbidity and impaired tissue perfusion, which contribute to the development of cardiovascular remodelling and morbidity.[4] Thus, a precise estimation of pre-HD fluid status may, in theory, aid in the prevention of both long-term and short-term complications.

Lung ultrasound (LUS) is a new imaging modality studied in the ICUs and emergency departments.

Multiple small studies have shown that the sensitivity and specificity of the lung USG are comparable to a CT scan of the chest.[5] Furthermore, it is less expensive, safer, and requires less expertise to operate. LUS is a bedside diagnostic tool that does not emit ionizing radiation and has diagnostic precision equivalent to that of a CT scan in identifying most lung pathologies.[6]

AIM:

To evaluate the volume status in hemodialysis-dependent chronic kidney disease patients by:

- LUS
- IVC diameter
- Clinical parameters

Objectives:

- To analyze if LUS is a reliable method of assessing volume status in CKD patients by assessing B-lines artefacts pre and post-HD.
- To correlate the findings of fluid status of LUS (B-lines) with that of body volume status determined by IVC diameter pre and post-HD.
- To correlate the findings of LUS (B-lines) with that of clinical parameters (respiratory distress, weight, and supine BP pre and post-hemodialysis) for volume assessment.

MATERIALS AND METHODS

A cross-sectional study was performed on all consenting adult CKD patients above 18 years of age on HD for the last three months at the least. Patients with acute events in the last 3 months, patients with pulmonary fibrosis and heart failure NYHA-IV were excluded from the study. LUS evaluation of B-Lines was the primary study and its relevance concerning assessment of volume status was compared with IVC diameter, Weight, BP and clinical parameters.

A pre-operating sheet was used for the collection of information. In addition to demographic data and those related to kidney disease, comorbidities, and dialysis prescription, all episodes of respiratory distress, intradialytic hypotension, cramps, or post-dialytic asthenia during the last three HD sessions were collected. The weight assessment parameters were measured in two phases: One hour before the HD session and between 30 to 60 minutes following the end of the same session. Therefore, the parameters collected are weighed under the usual conditions of the centre using an electronic scale. The supine BP measurement was carried out pre and post-HD after a 10-minute rest, using a validated electronic device.

LUS was done with a 7 Mhz vascular probe to look for an alveolar-interstitial syndrome characterized by the presence of specific artefacts called "B-lines" or "comet tails" [Figure 1]. LUS examination was performed on the patients in the supine position, with a longitudinal scan from the second to the fourth intercostal space of the left hemithorax and from the second to the fifth intercostal space of the right hemithorax at the midclavicular and midaxillary lines of each side and in the prone position from second to fifth intercostal space on each side. B-lines were defined as hyperechogenic linear artefacts emerging from the pleural line up to the bottom of the screen and are coherent with respiratory movements. The number of B-lines was determined by the sum of the B-lines found in each examined site. Thus, the selected number reflects the extravascular accumulation of fluid in the lung.

Figure 1: B-lines

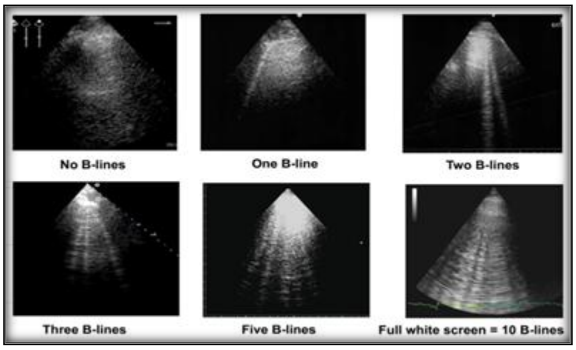

Figure 2: B-lines characteristics

We used an ultrasound with a 3.5 Mhz cardiac probe to explore the IVC within the subxiphoid window at 2.5 cm of the IVC-right atrial junction. The diameter of the IVC was measured while breathing out. We classified the patient as dehydrated if the IVC < 15mm, euvolemic if the IVC is 15-25mm, and hypervolemic if the IVC > 25mm.

Pulmonary congestion by fluid overload was retained in patients with the following characteristics [Figure 2]: 1. Multiple artefacts per scan (at least three artefacts) 2. Positivity diffuses in more than one scan per side 3. Bilateral Positivity. Thus, a positive ultrasound test for pulmonary edema was defined as the presence of multiple, diffuse, and bilateral artefacts.

Study Variables: The subjective dry weight is the prescribed weight taken from the patient logbook, estimated by the attending nephrologist, and based on clinical criteria such as weight, BP, presence of edema, or vascular congestion. Clinical assessment of fluid status was evaluated according to the subjective DW. Accumulated weight was defined as weight gain from the subjective DW. Weight loss will be the difference between weight before and after dialysis. Residual weight was defined as the difference between the obtained weight after dialysis and the subjective DW.

RESULTS

The study population consist of equal sex distribution comprising of 50% each [Table 1]. The descriptive statistics of the study is given in Table 2. Accordingly, the minimum age was 32 years and the maximum age was 78 years with mean of 57.10 encompassing homogenous age distribution. The mean of the subjective dry weight was 64.70 kgs with a minimum of 38 kgs and maximum of 88 kgs. The mean accumulated weight was 2.446 kgs and the mean residual weight was 0.020 kgs. The minimum and maximum weight loss was 0.8 and 4.2 kgs respectively with mean of 2.357 kgs. Concerning pre-HD SBP, the minimum and maximum SBP was 120 and 178 mmhg respectively with mean SBP of 151.27 mmhg and the minimum and maximum pre-HD DBP was 70 and 90 mmhg respectively with mean of 83.60 mmhg. The minimum and maximum post-HD SBP was 110 and 170 mmhg respectively with mean of 144.6 mmhg and the minimum and maximum post-HD DBP was 70 and 90 mmhg respectively with mean of 81.66 mmhg. The minimum and maximum pre-HD IVC diameter (mm) are 15 and 28 mm respectively with mean of 19.866 mm and the minimum and maximum post-HD IVC diameter are 14 and 18 mm respectively with mean of 15.266 mm. Finally, the number of B-line artefacts pre-HD was 12 in minimum and 29 in maximum with mean of 19.9 and post-HD, the minimum artefacts was 10 and the maximum was 17 with mean of 14.133 [Table 3]. From the findings, we found that 40 percent of the patients had respiratory distress pre-HD and 100 percent of the patients were free of respiratory distress post-HD [Figure 10]. We also found that 40 percent of the patients had positive chest auscultatory findings pre-HD and 100 percent of the patients were free of any chest auscultatory findings post-HD indicating optimal fluid removal during dialysis in concordance with findings of clinical parameters, IVC, and lung USG [Figure 11]. 20 percent of the patients had intradialytic hypotension during the last 3 sessions of HD and 16.7 percent of the patients had episodes of cramps during the last 3 sessions of HD. The findings were concordant with those of clinical parameters, IVC, and LUS.

Table 1: Frequency of Sex Distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	15	50.0	50.0	50.0
	Male	15	50.0	50.0	100.0
	Total	30	100.0	100.0	

Table 2: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
AGE	30	32	78	57.10	11.598
SUBJECTIVE DRY WEIGHT (Kgs)	30	38	88	64.70	14.693
ACCUMULATED WEIGHT (Kgs)	30	0.5	4.5	2.446	1.178
WEIGHT LOSS (kgs)	30	0.8	4.2	2.357	1.0997
RESIDUAL WEIGHT (kgs)	30	-1.0	0.6	.020	0.3231
(Sys) PRE-HD BP IN SUPINE POSITION	30	120	178	151.27	14.147
(Dia) PRE-HD BP IN SUPINE POSITION	30	70	90	83.60	8.041
(Sys) POST HD BP IN SUPINE POSITION	30	110	170	144.60	12.770
(Dia) POST HD BP IN SUPINE POSITION	30	70	90	81.666	7.914
PRE-HD B-LINE ARTEFACTS	30	12	29	19.9	5.358
POST-HD B-LINES ARTEFACTS	30	10	17	14.133	1.814
PRE-HD IVC DIAMETER (mm)	30	15	28	19.866	3.683
POST-HD IVC DIAMETER (mm)	30	14	18	15.266	1.172
Valid N (listwise)	30				

Table 3: Frequencies of B-line artefacts

		PRE-HD B-LINE ARTEFACTS	POST-HD B-LINES ARTEFACTS
N	Valid	30	30
	Missing	0	0
Mean		19.90	14.13
Std. Error of Mean		.978	.331
Median		18.00	14.00
Mode		16	14
Std. Deviation		5.359	1.814
Range		17	7
Minimum		12	10
Maximum		29	17

The correlation of pre-HD B-lines and pre-HD IVC diameter (figure 3) was very strong (r=0.871). The correlation of post-HD B-lines and post-HD IVC diameter (figure 4) was only reasonable (r=0.453).

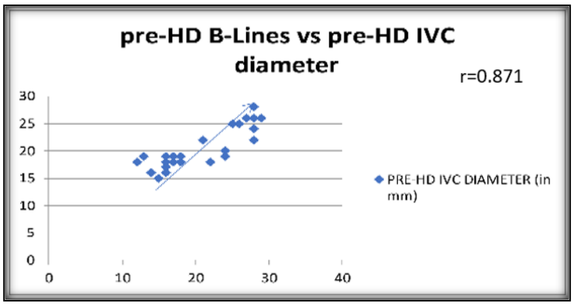

Figure 3: Correlation of pre-HD B-lines with pre-HD IVC diameter

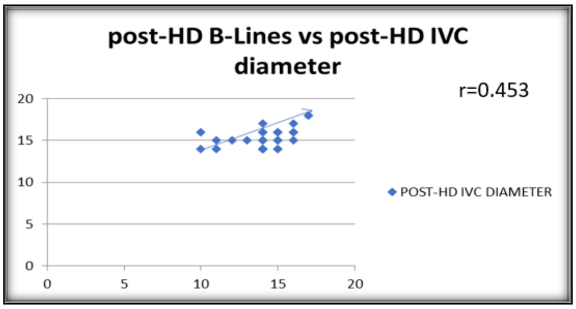

Figure 4: Correlation of post-HD B-lines with post-HD IVC diameter

The correlation of mean difference in B-lines pre and post-HD with weight loss (figure 5) was very strong (r=0.883) and with that of clinical signs and symptoms was strong (r=0.734). Despite the correlation between pre-HD B-lines and pre-HD BP (figure 6,7) being reasonable (SBP r=0.448/DBP r=0.508), the correlation between post-HD B-lines and post-HD BP (figure 8,9) was found to be very weak (SBP r=0.073/ DBP r=0.104).

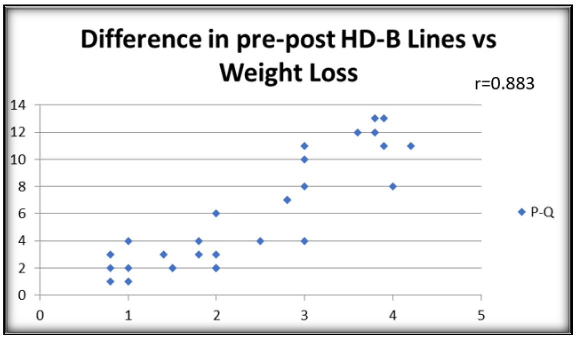

Figure 5: Correlation of difference in pre-post HD B-lines with Weight loss

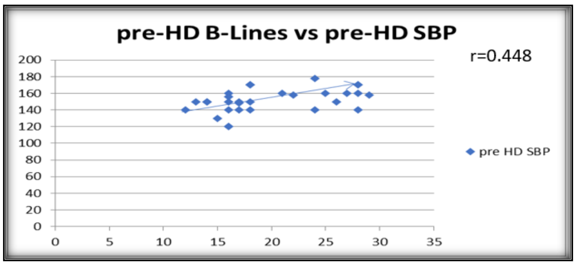

Figure 6: Correlation of pre-HD B-lines with pre-HD SBP

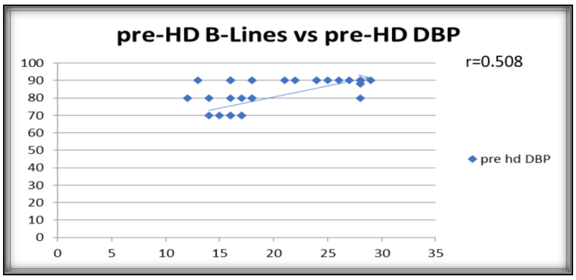

Figure 7: Correlation of pre-HD B-lines with pre-HD DBP

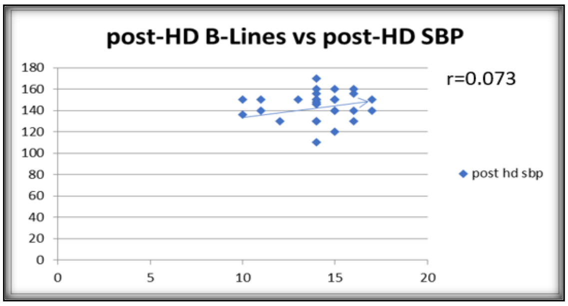

Figure 8: Correlation of post-HD B-lines with post-HD SBP

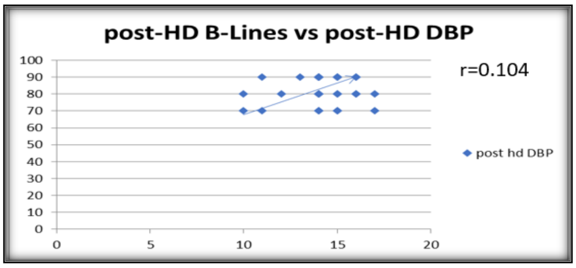

Figure 9: Correlation of post-HD B-lines with post-HD DBP

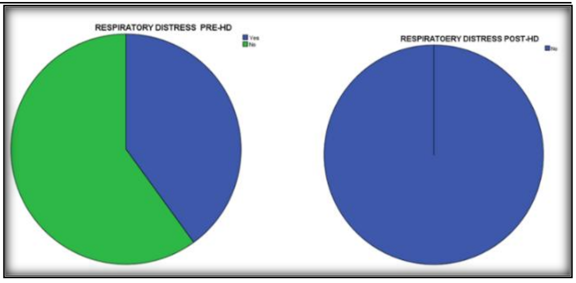

Figure 10: Pre-post HD respiratory distress findings

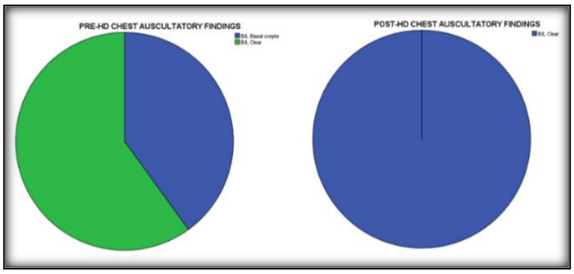

Figure 11: Pre-post HD auscultatory findings

DISCUSSION

The study was designed to see the correlation between pre and post-HD clinical parameters with findings of pre and post-HD B-line findings using LUS to try and find if inference in LUS is a reliable method of volume evaluation in patients with CKD undergoing maintenance hemodialysis (MHD).[7,8] Despite being a small study, there is a homogenous coverage of study population with respect to sex and age.

The mean SBP pre and post-HD was 151.27 and 144.60 mmhg respectively and the mean DBP pre and post-HD was 83.60 and 81.66 mmhg respectively [Table 2]. Past study suggested that SBP was consistently associated with atherosclerotic changes (not DBP).[9] In the study, we observed comparatively larger swing in SBP to DBP post-HD ultrafiltration (UF) suggesting that volume status may have a more important role in SBP than previously thought.[10,11]

The number of B-line artefacts pre-HD was 12 in minimum and 29 in maximum with mean of 19.9. Post-HD, the minimum artefacts was 10 and the maximum was 17 with mean of 14.133 [Table 3].[12]

Out of 30 patients, 40% had positive clinical and chest auscultatory findings pre-HD and the minimum sum total of B-line artefacts associated with positive chest auscultatory findings was 21 with mean of 25.83, which may be taken as the threshold for clinical volume overload. The minimal threshold of B-line artefact for subclinical volume overload however is difficult to determine. The minimum B-line artefact post-HD was 10 with mean of 14.133 which was associated with no clinical findings in all cases. In this study, pulmonary congestion by fluid overload (irrespective of clinical findings) was retained in patients with the following characteristics [Figure 2]: 1. Multiple artefacts per scan (at least three artefact) 2. Positivity diffuses in more than one scan per side 3. Bilateral Positivity. Thus, a positive ultrasound test for pulmonary edema was defined as the presence of multiple, diffuse, and bilateral artefacts with sum minimum of 12 B-line artefacts. This corresponds well with our finding of the sum minimum B-line artefacts post HD of 14.133. However, this alone is not enough to define subclinical volume overload and further studies are needed to definitely quantify subclinical volume overload and thus DW, possibly by using multiple parameters in conjunction with one another.

The correlation of pre-HD B-lines and pre-HD IVC diameter was very strong (r=0.871) while the correlation of post-HD B-lines and post-HD IVC diameter was only reasonable (r=0.453). Kraemer M et al has shown that IVC has its shortcomings.[10] Similarly, in our study, the post-HD B-lines correlation with the post-HD IVC diameter being only reasonable can be explained because IVC status primarily corresponds to the intravascular volume and not real tissue hydration status (e.g. extravascular lung water/pulmonary edema) which likely is the primary residual volume post-HD after UF.[11,12]

Concordant findings can also be seen with findings of clinical symptoms and clinical examination parameters although its correlation with that of BP was minimal unlike another study by Leypoldt JK et al.[13] Despite the correlation between pre-HD B-lines and pre-HD BP being reasonable (SBP r=0.448/DBP r=0.508), the correlation between post-HD B-lines and post-HD BP was found to be very weak (SBP r=0.073/ DBP r=0.104). This may be due to human or technical error but it suggests further evaluation regarding the relevance of post-HD BP in evaluating the volume status of an individual.[14] This may have the same explanation as above i.e. post-HD volume is primarily extravascular which may not correspond well with BP.[11,12]

The correlation of mean difference in B-lines pre and post-HD with weight loss was very strong (r=0.883) and with that of clinical signs and symptoms was strong (r=0.734). This suggest that LUS findings correspond well with both the intravascular and interstitial volume status unlike IVC which is selective primarily for intravascular volume status.[11,12,21]

In the study, 40% of the patients had respiratory distress before HD with 100% being symptom-free post-HD (figure 10). 40% of the patients had positive chest auscultatory findings pre-HD and 100% of the patients were free of any chest auscultatory findings post-HD [Figure 11]. These findings were concordant with that of LUS findings (r=0.734) suggesting that LUS can be as relevant in the estimation of volume status as the other traditional clinical methods.[15-17] Also, 20% of the patients had intradialytic hypotension during the last 3 sessions of dialysis and 16.7% of the patients had episodes of cramps during the last 3 sessions of dialysis and the findings were concordant with that of LUS findings. Thus, LUS can be used to estimate dry weight just as relevant as the other traditional clinical methods but further studies regarding the optimal DW and B-lines (excluding the other pulmonary factors that may produce the same artefacts) need to be done to see if B-lines can be a reliable mode for DW estimation in a CKD patient on MHD.[15,16] If so, given the resource limitations in most health centre in India or other developing countries, apart from the traditional clinical approach for the estimation of DW, LUS can be a reliable alternative for the same. Also, the fact that the number of B-lines did decrease during fluid removal even in asymptomatic patients suggests that the artefacts seen before HD were due to subclinical fluid overload and thus LUS can be a reliable sensitive mode of volume evaluation even in optimal weight patients in conjunction with other parameters.[18,19] This is significant because even subclinical volume overload is associated with significant morbidity and mortality.[20]

Concerning the objective of the study, we found that LUS is as reliable a method for evaluation of the volume status in a CKD patient as other methods i.e. IVC and Clinical parameters. IVC diameter shortcomings include the inability to assess interstitial volume status and asymptomatic pulmonary edema which can be overcomed by LUS.[11,12,18,21] Other studies in the past have evaluated the role of LUS in the evaluation of volume status in CKD patients on MHD.[7] However, in this study, we also explored the possibility of using LUS as a method of determining the DW of a patient. DW is a complicated entity that most of the time depends on the subjective judgment of the physician based on clinical parameters or bio-impedance.[1] In this study, a correlation between intra-dialytic hypotension, episodic cramps, malaise, and changes in LUS was seen.[15,16] This has raised the possibility of using LUS as a method, if not independent but supportive, in determining DW. Further studies are needed to see the exact correlation between the various clinical parameters determining the DW of an individual and the quantitative LUS B-Line findings to determine if evaluation of the B-Lines can be a reliable method for determining the DW of a patient.

Acute event (infection episode or hospitalization) within the last 3 months; lung conditions like pneumonia, embolism/infarction, effusion/ pneumothorax, atelectasis, and pulmonary fibrosis; heart failure: are some the conditions that can bring about aberrations in LUS findings and thus patients with the underlying conditions were excluded from the study.

CONCLUSION

The volume status of a CKD patient on MHD plays a very important role in the morbidity and mortality of the patient. Traditionally we have relied on clinical examinations/symptoms and weight evaluation to determine the volume status of an individual patient which is not necessarily optimal and has its many shortcomings. LUS is a readily available mode of investigation in most centers and can be a reliable mode of volume estimation in patients of CKD on MHD. Volume status may have a more important role in SBP than previously thought apart from atherosclerotic changes. Also, volume status has minimum association with DBP. IVC diameter may have limited role in estimation of extravascular volume. The minimum sum total of B-line artefacts associated with positive chest auscultatory findings was 21 with mean of 25.83, which may be taken as the threshold for clinical volume overload. The study found that LUS B-lines correlate well with other modes of volume estimation and may have a role in the estimation of DW in conjunction with other parameters. However, there is poor correlation between B-line artefact and post-HD BP. Definite parameters for defining subclinical volume overload is needed.

The limitations of the study include small sample size from a single centre, IVC diameter estimated only during expiration without collapsibility index and non-inclusion of Bio-impedance in the study.

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