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Original Research Article

INCENTIVE SPIROMETRY AND BREATHING EXERCISES WERE NOT ABLE TO IMPROVE RESTRICTIVE PULMONARY CHARACTERISTICS INDUCED BY WATER IMMERSION IN HEALTHY SUBJECTS

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ABSTRACT

Background: Water decreases vital capacity during immersion. Several chest diseases can reduce pulmonary volumes and capacities which could be at least in part similar to that happen in healthy individuals during water immersion.

Objectives: To investigate if respiratory effects of water immersion are partially due to enhanced return venous from legs and arms and if physiotherapeutic techniques incentive spirometry (IS) and breathing exercises (BE) are able to improve pulmonary volumes and capacities in healthy subjects during water immersion.

Design: Randomised, within-participant experimental study.

Participants: 18 healthy subjects.

Intervention: Stage 1 was realized to investigate the cardiorespiratory effects of water immersion with and without a cuff-induced venous compression. Stage 2 was conducted to explain the effects of physiotherapeutic techniques IS and BE during water immersion.

Main outcome measures: The pulmonary function (forced vital capacity - FVC, forced expiratory volume the first second - FEV_1, ratio of FEV/FVC, peak expiratory flow rate - PEFR and forced expiratory flow of 25-75% FVC - $FEF_{25-75\%}$) was evaluated.

Results: Water immersion decreased FVC and FEV_1 after 10 minutes of immersion. After a total compression of arms and legs the reduction on FVC and FEV_1 was not observed, even with only partial compression of legs ($P>0.05$).

Conclusions: Water immersion promotes pulmonary restrictive characteristics due to increased venous return mainly from legs. The application IS and BE did not normalize the spirometric values.

KEY WORDS: Chest physiotherapy, Respiratory techniques, Breathing exercises, Pulmonary function.

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BACKGROUND

Water decreases vital capacity during immersion. This temporarily reduction seems to be due increase on cardiac blood volume and pulmonary circulation, which can increase pulmonary capillary pressure [1,2].

The enhanced thoracic blood volume depends on return venous; however it is unclear if it is dependent from blood of legs and arms or only from legs [2].

Several chest diseases such as lung cancer and sarcoidosis as well as pulmonary complications from cardiac conditions, can reduce pulmonary volumes and capacities [3,4]. This restrictive pattern could be at least in part similar to that happens in healthy individuals during water immersion [1]. In this way, chest physiotherapy has techniques that aims to increase pulmonary vital capacity in the presence of a restrictive thoracic pattern. Incentive spirometry (IS) and breathing exercises (BE) are the most used techniques at clinical practice [5]. They increase the inspiratory time, expand the alveolus and promote alveolar redistribution of liquid as well as a better gas exchange [6-9].

However, the respiratory and cardiovascular effects of IS and BE in patients with reduction on volumes and capacities are unclear, in part due to the presence of associated diseases [6 - 9]. Therefore, the aim of this study was to investigate if the respiratory effects of water immersion are partially due to enhanced return venous from legs and arms or only from legs and, investigate if the physiotherapeutic techniques, incentive spirometry and breathing exercises, are able to improve pulmonary volumes and capacities in healthy subjects during water immersion.

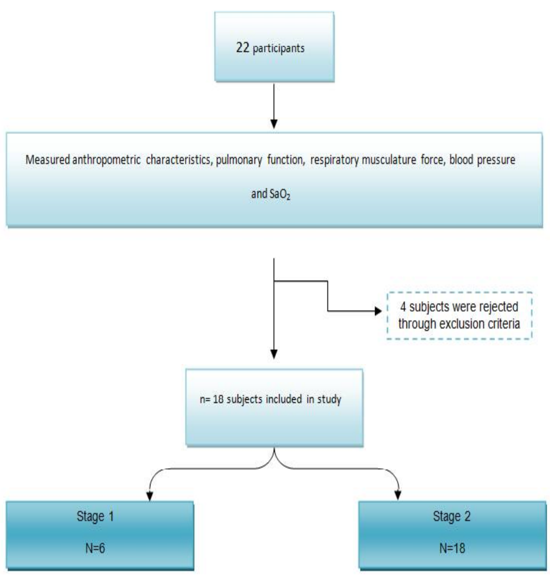
MATERIALS AND METHODS

Design: A randomised and longitudinal study was conducted from September to December of 2014. Experiments were divided into two stages and realized in alternate days. Healthy participants were randomly allocated in Stage 1 or Stage 2 of the study. Stage 1 investigates the respiratory effects of water immersion during 25 minutes with and without a cuff-induced venous compression. Stage 2 was conducted to explain the effects of physiotherapeutic techniques IS and BE during water immersion for 30 minutes. The stage 2 was subdivided in: a) Control - water immersion without intervention physiotherapeutic; b) Intervention IS - water immersion plus IS; c) Intervention BE - water immersion plus BE. All individuals participated of each phase of stage 2, in alternate days and the order was randomly determined.

Participants: Healthy individuals, without diagnosis or symptoms of pulmonary disease, ranging in age from 18 to 30 were included after signing an informed consent. We excluded individuals who had diagnosis of cardiovascular, respiratory, neurological and/or musculoskeletal diseases, who was conducting drug treatment (except oral contraceptives), smokers and former smokers, and who was unable to perform the procedures.

The participants were healthy individuals recruited among students of the University. Twenty two (22) individuals were screened and four (4) were excluded (two because were unable to complete the spirometry test, one had hypertension and one gave up) (Figure 1).

Fig. 1: Design of the study. Design and flow of participants of the study.



The experiments were realized on water immersion until manubrium sternal in orthostatic position with arms under immersion. The water temperature was 31 ± 1.9°C and relative air humidity 77 ± 15. 5%. This work was approved by the UNIPAMPA's Ethics Committee for Research in Humans (protocol Nº: 784.155). All participants gave written informed consent before data collection began.

Intervention

Stage 1: In Stage 1 we aim to clarify the effects of water immersion on pulmonary function. Therefore, six (6) participants were randomised to this stage, placed on water immersion and spirometry test was evaluated before and after water immersion in such moments, as follow: pre-immersion (PI), 10 and 20 minutes after immersion (I 10', I 20').

To evaluate the influence of venous return on pulmonary function during water immersion, a cuff-induced compression was performed around distal third part of each thigh and inflated until 100 mmHg as well as in a third of each arm and inflated until 70 mmHg. To investigate if pulmonary effects are dependent on return venous from legs and arms or only from legs, we evaluated the pulmonary function with only partial compression of legs. Spirometry test was performed, as follow: pre-compression (Pre-C), 10 minutes after total compression of legs and arms (ATC 10') and 10 minutes after compression of legs – partial compression (APC 10').

Stage 2: The stage 2 was subdivided in: a) Control - water immersion without intervention physiotherapeutic; b) Intervention IS - water immersion plus IS; c) Intervention BE - water immersion plus BE.

Stage 2 was performed to evaluate respiratory effects of physiotherapeutic techniques IS and BE during water immersion. At this time, the participants (n=18) passed for 3 different moments / groups on alternate days, in a randomly order. At the control group (CT) they suffer water immersion during 30 minutes without intervention physiotherapeutic. At the incentive spirometry group (IS), they performed IS during 10 minutes after 10 minutes of immersion. At the breathing exercises group (BE), they performed BE during 10 minutes after 10 minutes of immersion. Spirometry test was evaluated before and after water immersion on three above-cited moments / groups, as follow: pre-immersion (PI), 10 minutes post immersion (I 10'), immediately after the intervention (I 20') and 10 minutes after the intervention (I 30').

Incentive Spirometry: To perform the IS volume-oriented (Coach® 4000 ml, Smiths Medical, UK), each participant was encouraged to involve the spirometer nozzle within his lips, avoiding air leakage, holding the spirometer in your field of view and was asked to conduct a sustained inspiration, following pause-inspiratory of 3 seconds. After the break, the participant expired until the expiratory reserve volume and returned to the inspiratory phase. To avoid hyperventilation, every 10 breaths on the device, the subject performed three tranquil breaths out of the spirometer.

Breathing exercises: In a range of breathing exercises, we choose two taking into account the respiratory flow principle of both that increase the inspiratory time and also the volume of air inspired as well as the easier to perform, clinical-based. [10]. The exercises order was randomly determined and the subjects performed 10 BE, followed by 3 free breaths, then changed the BE, during 10 minutes. Both exercises followed the implementation of recommendations of Cuello [11].

To perform the breathing exercise "inspiration in times", each participant was asked to do an inspiration nasal, gentle and short, fractionate the inspiratory time with post inspiratory pauses until total lung capacity. The expiration phase was slow and smooth.

To develop the breathing exercise "maximal inspiration", each participant was asked to do an inspiration nasal, slow and gentle until maximum inspiratory capacity; following of a small volume expired, another maximal inspiration, new brief expiration and a final maximum inspiration. After, the participant performed a smooth expiration between lips until functional residual capacity.

Outcome measures: Blood pressure was measured according to European Society of Hypertension International Protocol [12], through digital sphygmomanometer (TechLine®, Taiwan), SpO_2 were evaluated using oximeter (NONIN Medical, Plymouth, Minessota, USA).

Pulmonary function test was performed according by spirometry test (Spirometer KOKO Legend nSpire Health Inc., Oberthulba, Germany). We analyzed the following variables: forced vital capacity (FVC), forced expiratory volume at the first second (FEV_1), ratio of FEV/ FVC, peak expiratory flow rate (PEFR) and forced expiratory flow of 25-75% FVC ($FEF_{25-75\%}$). The spirometer was configured to orthostatic position. Evaluations and verbal commands were performed by the same experienced evaluator.

Data analysis: Data are expressed as mean ± SEM. Statistical analysis was performed using D'Agostino & Pearson Omnibus Normality Test, One-way or Two-way ANOVA followed by Bonferroni post hoc test. Values of $P < 0.05$ were considered statistically significant.

The sample size was six (6) on first stage and eighteen (18) participants on second stage, based on previous studies with respiratory evaluation, the sample size is enough to provide statistical power to our study [1, 13].

RESULTS

Twenty two participants were recruited and complete flow of them is shown in Figure 1. Baseline characteristics of the sample are presented on Table 1.

Table 1: Mean (SD) of baseline characteristics of the participants.

Characteristics	Participants (n = 18)
Genre, n males	9 (0)
Genre, n females	9 (0)
Age (yr)	22 (0.5)
Height (m)	1,68 (0.08)
Weight (kg)	72 (16)
Body Mass Index (kg/m²)	21 (6)
Respiratory Evaluation	
Maximum Inspiratory Pressure (mmHg)	90 (18)
Maximum Expiratory Pressure (mmHg)	78 (21)
Slow Vital Capacity (L)	4,343 (0.87)
FVC (L)	4,405 (0.787)
FEV_1 (L)	3,839 (0.666)
Ratio of FEV1/FVC (L)	0,88 (0.03)
Hemodynamic Evaluation	
Systolic Blood Pressure (mmHg)	117 (13)
Diastolic Blood Pressure (mmHg)	76 (10)
SpO_2 (%)	98 (0.88)

Data are expressed as means ± SD. No significant results were found in comparison between the subjects (D'Agostino & Pearson Omnibus Normality Test and Student's T-test).

Respiratory effects of water immersion: Water immersion decreased FVC and FEV_1 after 10 minutes of immersion (I 10'), these reduction was maintained during immersion (I 20') (Figure 2A, 2B). The percentage of ratio of FEV_1/FVC decreased after immersion but was within normal values predicted (Figure 2C).

After a total compression of arms and legs with a cuff-induced venous stasis, the reduction on FVC and FEV_1 was not observed (ATC 10'), even with only partial compression of legs (APC 10') (Figure 2).

Effects of physiotherapeutic interventions: FEF $_{25-75\%}$, CVF and FEV_1 decreased after water immersion in control group, these effects were observed during the immersion time (Table 2; Figures 3 and 4).

The physiotherapeutic techniques IS and BE were not able to normalize FEF $_{25-75\%}$, CVF and FEV_1 after water immersion. Moreover, the decrease on spirometry values were maintained during immersion (Table 2; Figures 3 and 4). The percentage of ratio of FEV_1/FVC decreased after water immersion and did not change after interventions (Figure 5).

Table 2: Cardiorespiratory evaluation on control, incentive spirometry and breathing exercises interventions.

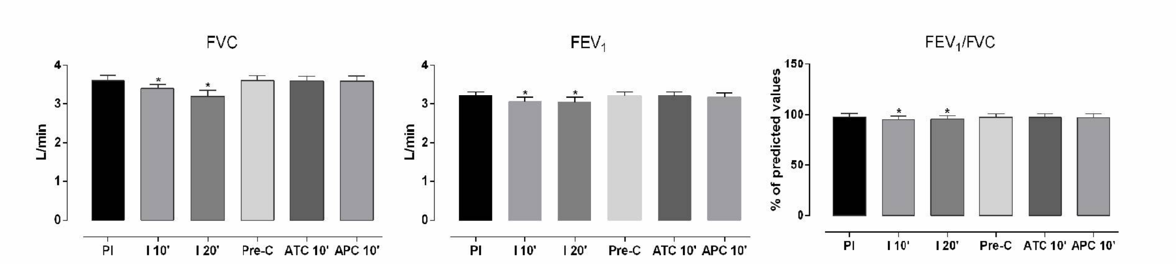
Control				
Parameters	PI	I 10'	I 20'	I 30'
SpO_2 (%)	97.9 ± 0.2	97.8 ± 0.3	98.2 ± 0.2	98.2 ± 0.2
PEFR (L/min)	8.7 ± 0.5	8.4 ± 0.5	8.6 ± 0.5	8.7 ± 0.5
FEF 25-75% (L/min)	4.4 ± 0.2	4.3 ± 0.2*	4.2 ± 0.2*	4.2 ± 0.2*
Incentive Spirometer Intervention				
SpO_2 (%)	97.7 ± 0.21	97.4 ± 0.5	98.2 ± 0.5	96.2 ± 0.8
PEFR (L/min)	8.6 ± 0.4	8.4 ± 0.4	7.8 ± 0.4	7.9 ± 0.5
FEF 25-75% (L/min)	4.5 ± 0.2	4.3 ± 0.2*	4.5 ± 0.3*	4.2 ± 0.2*
Breathing Exercises Intervention				
SpO_2 (%)	97.8 ± 0.2	97.8 ± 0.3	98.8 ± 0.2*	97.8 ± 0.2*
PEFR (L/min)	8.7 ± 0.5	8.6 ± 0.5	8.5 ± 0.4	8.3 ± 0.5
FEF 25-75% (L/min)	4.5 ± 0.3	4.3 ± 0.2*	4.3 ± 0.2*	4.1 ± 0.2*

Data are expressed as means ± SEM. PEFR= Peak Expiratory Flow Rate, FEF 25-75%= Forced Expiratory Flow. PI= pre-immersion, I 10', I 20' and I 30'= 10, 20, 30 minutes after immersion. * $P < 0.05$ when compared to PI (Student's t-test).

DISCUSSION

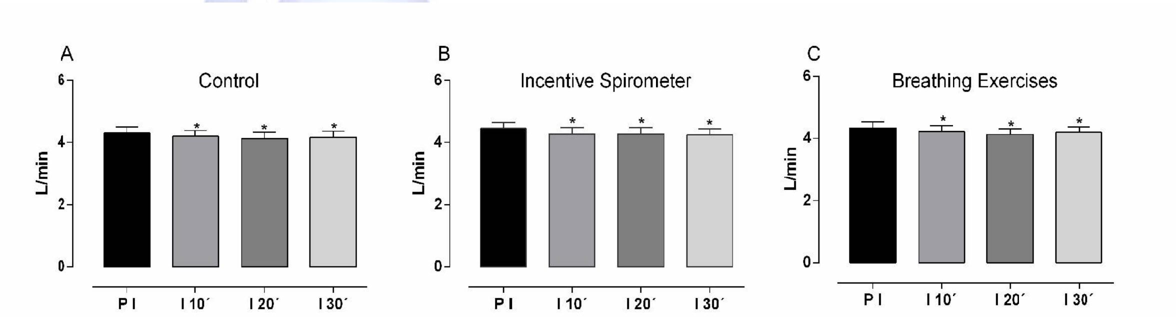
Our study showed that healthy individuals develop pulmonary restrictive pattern after water immersion, with reduction on FVC and FEV_1. Moreover, these effects are partially due to increased venous return from legs, since with a cuff-induced venous stasis these reductions were not observed. This is the first study to evaluate the effects of physiotherapeutic techniques IS and BE in participants with pulmonary restrictive characteristics induced by water immersion. However, both techniques of

Fig. 2: Effects of water immersion on spirometric values with and without total and partial cuff-induced compressions.



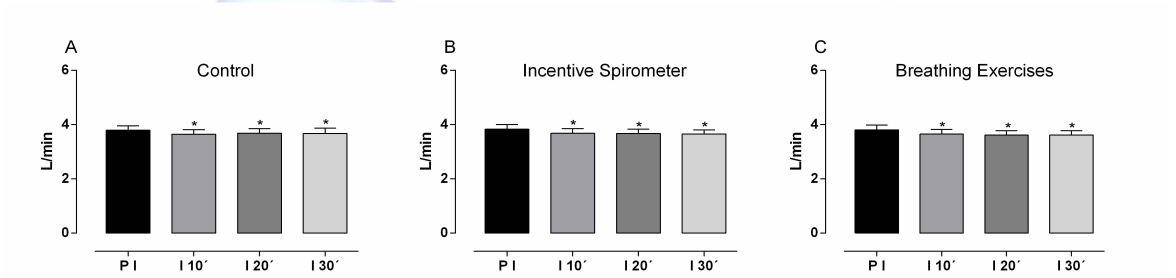
FVC (A), FEV_1 (B) and ratio of FEV_1/FVC (C), comparisons among times in each group. PI= pre-immersion, I 10', I 20'= 10 and 20 minutes after immersion, Pre-C= pre-compression, ATC 10'= 10 minutes after total compression (legs and arms), APC 10'= 10 minutes after partial compression (legs). *P <0.05 when compared with pre immersion of each group (Student's t-test).

Fig. 3. Effects of physiotherapeutic techniques in FVC values after water immersion.



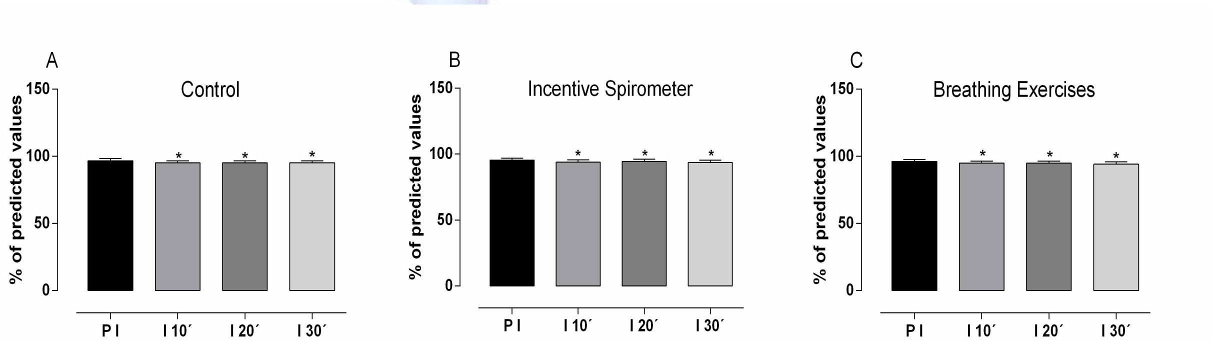
Control (A), Incentive Spirometry (B), Breathing Exercise (C). IS= Incentive Spirometry, BE= Breathing Exercise, PI= pre-immersion, I 10', I 20', I 30'= 10, 20 and 30 minutes after immersion. *P <0.05 compared with PI position within each group (Student's t-test).

Fig. 4: Effects of physiotherapeutic techniques in FEV_1 values after water immersion.



Control (A), Incentive Spirometry (B), Breathing Exercise (C). IS= Incentive Spirometry, BE= Breathing Exercise, PI= pre-immersion, I 10', I 20', I 30'= 10, 20 and 30 minutes after immersion. *P <0.05 compared with PI position within each group (Student's t-test).

Fig. 5: Effects of physiotherapeutic techniques in the values of ratio of FEV_1/FVC FEV_1 after water immersion.



Control (A), Incentive Spirometry (B), Breathing Exercise (C). IS= Incentive Spirometry, BE= Breathing Exercise, PI= pre-immersion, I 10', I 20', I 30'= 10, 20 and 30 minutes after immersion. Values expressed as percentage of spirometry values predicted for Brazilians [26]. *P <0.05 compared with PI position within each group (Student's t-test).

respiratory therapy were not able to reverse these short-term reductions.

The decrease on pulmonary function observed is in agreement with already reported by Burki [14] that showed reduction on vital capacity after 5 minutes of water immersion. Furthermore, it has been reported be due to venous return and increase on atrial volume during water immersion until the neck [15]. The decline in lung function can occur by the increase on cardiac blood volume leading to enhanced atrial pressure and consequently higher pulmonary capillaries pressure [1,16]. Additionally, we showed that the increased venous return is independent of blood volume from arms, which is similar to findings by Bevegård et al [17] that the increase on cardiac blood volume by physical exercise is the same as when perform exercises with legs and arms or only legs.

Restrictive pulmonary diseases as well as several pulmonary complications from cardiac diseases decrease lung volumes and capacities by different mechanisms [1,16,18]. The current study showed pulmonary restrictive characteristics in healthy individuals after water immersion by increased thoracic blood volume. Among pulmonary complications, cardiac patients in Acute Decompensate Heart Failure (ADHF) have decrease on pulmonary volumes and capacities. In this stage of disease, due to cardiac contractility insufficiency, there is an increase on capillaries pulmonary pressure, as a consequence of decrease on ejection fraction and systolic volume as well as increase on atrial pressure [19,20]. The reduction on cardiac output leads to lower flow and perfusion in kidneys which could activate a cascade of compensatory mechanisms and increase plasmatic volume. These mechanisms also contribute to higher pulmonary capillary pressure, which can cause pulmonary congestion and hypoxia in ADHF patients [21]. Our goal is to propose another possibility to study the effects of respiratory techniques in health subjects with pulmonary characteristics routinely seen in cardiac patients with ADHF without interference of associated diseases. Certainly, cardiac patients have a lot of others complications that we could not mimetize and we need to take into account for results.

Chest physiotherapy has techniques that encourage patients to inspire deeply once deep breathing opens collapsed alveoli, prevents atelectasis and restores lung volume. IS and BE are used to improve lung volume and hematosis by performing successive inspirations (i.e. inspiratory sighs) or maximal inspiratory effort [6-9]. The above-studied techniques did not change or improve lung function in our experimental condition. However, the positive effects of these techniques were already seen by several authors in different situations such as COPD, asthma, post-operative and stroke [11,13,22,23]. In pulmonary diseases, IS and BE treatments improve arterial blood gases, dyspnea and quality of life [24]. Moreover, Tomich [13] when compared these two techniques in healthy subjects, showed that IS is better than BE to increase inspiratory duty cycle and demonstrated similar results in respiratory rate values and electromyographic activity of the sternocleidomastoid. In our experimental condition, the causal agent of pulmonary restrictive characteristics was maintained. In this sense, we believe that treatment or control of causal agent of pulmonary complications is essential to show the positive effects of physiotherapeutic techniques and improve lung function.

The reduction on $FEF_{25-75\%}$ after water immersion was expected due the decrease on FVC values, once $FEF_{25-75\%}$ is directly dependent on this variable when the spirometric test is correctly performed [25]. In addition, it is known that FEF is related with permeability of distal airways, the reduced $FEF_{25-75\%}$ observed is in agreement with the increased chest blood volume and higher capillaries pressure.

CONCLUSION

These results demonstrate that pulmonary restrictive characteristics during water immersion are due to increased venous return mainly from legs. Our study propose to investigate the effects of physiotherapeutic techniques IS and BE in this experimental condition of pulmonary restrictive characteristics by increased thoracic blood volume, similar which happens with patients after cardiac decompensation. The application of respiratory techniques, IS and BE did not normalize the spirometric values (FVC, FEV_1 and $FEF_{25-75\%}$) which points to the importance of control and treatment of causal agent of pulmonary complication.

ABBREVIATIONS

IS - Incentive spirometry
BE - breathing exercises
FVC - forced vital capacity
FEV_1 - forced expiratory volume at the first second
FEV/FVC - ratio of forced vital capacity and forced expiratory volume at the first second
PEFR - peak expiratory flow rate
$FEF_{25-75\%}$ - forced expiratory flow of 25-75% FVC
ADHF - Acute Decompensate Heart Failure

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Conflicts of interest: None

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