**CAROLINE GOMES MÓL**

# Capacidade muscular inspiratória com suporte abdominal: um estudo observacional prospectivo em pacientes graves

Tese apresentada à Faculdade de Medicina da Universidade de São Paulo para obtenção do título de Doutora em Ciências

Programa de Ciências da Reabilitação
Orientadora: Profa. Dra. Clarice Tanaka

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Thesis presented to the Faculdade de Medicina,Universidade de São Paulo
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Rehabilitation Sciences Program
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## DEDICATÓRIA

*Dedico este trabalho aos meus pais,* ***Nicolau*** *e* ***Maria José****, meus alicerces, exemplos de vida. Vocês que sempre me incentivaram e nunca mediram esforços para que eu pudesse me dedicar aos estudos e seguir meus sonhos, mesmo que distante fisicamente. Sem o apoio, ensinamentos e amor incondicional de vocês não seria possível chegar até aqui!*

*Dedico também ao meu marido,* ***Renan****, meu companheiro e grande incentivador!*

***Todo o meu amor a vocês.***

# DEDICATION

*I dedicate this work to my parents,* ***Nicolau*** *and* ***Maria José****, my foundations, examples of life. You always encouraged me and never measured efforts so that I could dedicate myself to studies and follow my dreams, even if physically distant. Without your support, teachings, and unconditional love it would not be possible to get this far!*

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***With all my love for you!***

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Agradeço à minha família Paulista, **"Mendes Rodrigues"**, que sempre me acolheu tão bem.

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Finally, I would like to thank all the **patients, technicians and nursing assistants, nurses, physicians, and physiotherapists at the ICHC FMUSP ICUs**. Working with you made me a better and more human professional!

Esta tese está de acordo com as seguintes normas, em vigor no momento desta publicação:

Referências: adaptado de International Committee of Medical Journals Editors (Vancouver).

Universidade de São Paulo. Faculdade de Medicina. Divisão de Biblioteca e Documentação. Guia de apresentação de dissertações, teses e monografias. Elaborado por Anneliese Carneiro da Cunha, Maria Julia de A. L. Freddi, Maria F. Crestana, Marinalva de Souza Aragão, Suely Campos Cardoso, Valéria Vilhena. 3a ed. São Paulo: Divisão de Biblioteca e Documentação; 2011.

Abreviaturas dos títulos dos periódicos de acordo com o List of Journals Indexed in Index Medicus.

This thesis is in accordance with the following standards, operative at the time of this publication:

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Journal title abbreviations according to the Indexed List of Journals Index Medicus.

**SUMMARY**

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Mol CG. *Capacidade muscular inspiratória com suporte abdominal*: um estudo observacional prospectivo em pacientes graves [tese]. São Paulo: Faculdade de Medicina, Universidade de São Paulo; 2021.

**Introdução:** Pacientes graves apresentam risco de desenvolver complicações relacionadas à doença crítica e ao tempo de internação na UTI, como a disfunção dos músculos respiratórios e a perda de aeração pulmonar. Dessa forma, duas questões de pesquisa foram desenvolvidas: o suporte abdominal pode influenciar a capacidade dos músculos inspiratórios em pacientes gravemente enfermos em respiração espontânea? Existe alguma relação entre a excursão do diafragma (DE), a força muscular inspiratória e a aeração pulmonar em pacientes críticos? **Objetivos:** Nosso objetivo principal foi investigar a capacidade muscular inspiratória em pacientes graves com e sem suporte abdominal. Objetivos secundários também foram propostos para responder à questão de pesquisa 2: investigar a relação entre aeração pulmonar, DE e pressão inspiratória máxima (PImáx); investigar se a disfunção do movimento do diafragma avaliada por ultrassom pode ser prevista a partir das características clínicas do paciente. **Métodos:** Adultos internados na unidade de terapia intensiva (UTI) por pelo menos 48 horas e respirando espontaneamente foram incluídos. Para responder à questão de pesquisa 1, os pacientes foram avaliados durante três padrões respiratórios diferentes: respiração corrente (1); esforço inspiratório máximo sem suporte abdominal (2) e esforço inspiratório máximo com suporte abdominal (3). Para a execução do padrão respiratório (3), uma faixa abdominal com tensão padronizada de 10 mmHg foi posicionada para promover suporte abdominal. Para o padrão (2), a faixa foi posicionada sem qualquer tensão. Para os padrões (2) e (3), as avaliações foram realizadas durante um esforço inspiratório máximo com ênfase no deslocamento abdominal para fora durante a inspiração. As medidas de desfecho incluíram o escore de aeração pulmonar (LUS), pressão inspiratória máxima (PImáx), capacidade vital (VC), excursão do diafragma (DE) e fração de espessamento do diafragma (TFdi). Dos trinta pacientes incluídos, 24 realizaram PImáx e DE durante um esforço inspiratório máximo avaliado no momento basal, durante o padrão respiratório 1, o que possibilitou a análise proposta na questão de pesquisa 2. **Resultados:** Trinta pacientes foram avaliados. A PImáx foi significativamente maior durante o padrão respiratório (3) comparado ao padrão (2). Todas as comparações de DE entre os três padrões de respiração mostraram diferenças significativas [DE (3)> (2)> (1)]. Considerando a TFdi, houve diferença significativa entre os padrões (2) e (3) [TFdi (3)> (2) = (1)]. Houve uma relação altamente significativa ($p \leq 0{,}001$) entre a excursão do diafragma durante a respiração profunda e o LUS das regiões pulmonares dependentes (r = - 0,772) e o LUS total (r = - 0,651).

A área sob a curva de DDRS para predição de disfunção do diafragma foi 0,759: Um DDRS ≥ 2 teve uma sensibilidade de 81,8% e uma especificidade de 61,5%. **Conclusão:** Em pacientes graves internados em UTI, o suporte abdominal promove maior aumento da PImáx, DE e TFdi quando comparado ao padrão sem suporte abdominal. Além disso, a disfunção do diafragma contribui para a perda de aeração pulmonar, especialmente em áreas pulmonares dependentes e um escore de risco de disfunção diafragmática ≥ 2 é preditivo de disfunção do diafragma.

**Descritores:** Diafragma; Músculos respiratórios; Músculos abdominais; Ultrassonografia; Cuidados críticos; Especialidade de fisioterapia.

Mol CG. *Inspiratory muscle capacity with abdominal support*: a prospective observational study in critically ill patients [thesis]. São Paulo: “Faculdade de Medicina, Universidade de São Paulo”; 2021.

**Background**: Critically ill patients are at risk of many complications related to critical illness and ICU length of stay, as respiratory muscles dysfunction and lung aeration loss. Therefore, we constructed two different research questions: can abdominal support influence the inspiratory muscles’ capacity in critically ill patients in spontaneous breathing? Is there any relationship between diaphragm excursion (DE), inspiratory muscle strength and lung aeration in critically ill patients? **Aims:** Our main purpose is to investigate the inspiratory muscle capacity in critically ill patients with and without abdominal support. Secondary aims were also proposed to answer research question 2: to investigate the relationship between lung aeration, DE and maximal inspiratory pressure (MIP); to investigate if the diaphragm motion dysfunction assessed by ultrasound could be predicted from the patient's clinical characteristics. **Methods:** Adults admitted to the intensive care unit (ICU) for at least 48 hours and breathing spontaneously were included. To answer research question 1, patients were assessed during three different breathing patterns as follows: tidal breathing (1); maximal inspiratory effort without abdominal support (2) and maximal inspiratory effort with abdominal support (3). During the breathing pattern (3), a standardized 10mmHg-belly belt was positioned to promote abdominal support. For the pattern (2), the belt was positioned without any tension. For the patterns (2) and (3), the assessments were performed during a maximal inspiratory effort emphasizing the abdominal outward displacement during inspiration. Outcome measures included lung ultrasound score (LUS), maximal inspiratory pressure (MIP), vital capacity (VC), diaphragm excursion (DE) and diaphragm thickening fraction (TFdi). Within the thirty patients included, 24 had MIP and DE during a maximal inspiratory effort assessed at the baseline moment, during breathing pattern 1, which enabled the analysis proposed in research question 2. **Results:** Thirty critically ill patients were assessed. Maximal inspiratory pressure during the breathing pattern (3) was significantly higher than in the pattern (2). All comparisons of DE between the three breathing patterns showed significant differences [DE (3)>(2)>(1)]. Considering TFdi, there was a significant difference between the patterns (2) and (3) [TFdi (3)>(2)=(1)]. There was a highly significant ($p \leq 0.001$) relationship between deep breathing diaphragm excursion and LUS of dependent lung regions ($r = -0.772$) and total LUS ($r = -0.651$). The area under the curve of DDRS for prediction of diaphragm dysfunction was 0.759: A DDRS $\geq 2$ had a sensitivity of 81.8% and a specificity of 61.5%. **Conclusion:** Abdominal support improves MIP, DE and TFdi of critically ill patients in spontaneous breathing when compared to the pattern without abdominal support. Additionally, diaphragm dysfunction contributes to lung aeration loss, especially in dependent lung areas. A DDRS $\geq 2$ is predictive of diaphragm dysfunction.

**Descriptors:** Diaphragm; Respiratory muscles; Abdominal muscles; Ultrasonography; Critical Care; Physical therapy specialty.

## PRESENTATION

The project entitle “Inspiratory muscle capacity with abdominal support: a prospective observational study in critically ill patients” is part of a main project called “Respiração diafragmática modificada: impacto na função respiratória.” (Ethic Committee approval no. 2.878.005 - **APPENDIX I**). This project was idealized and executed by the Divisão de Fisioterapia do Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo.

The main purpose of this project was to investigate the inspiratory muscle capacity with and without abdominal support. However, during the patients’ assessments another research question caught our attention: is there any relationship between diaphragm excursion (DE), inspiratory muscle strength and lung aeration in critically ill patients? So, we performed a secondary analysis from the original research to answer this question.

This research allowed us to participate in important international scientific conferences, with poster presentations:

1) American Thoracic International Conference 2018, San Diego - California, United States of America
   Period: May 18th to 23th
   Presented poster: “Modified diaphragmatic breathing: an alternative to improve diaphragmatic mobility and respiratory function in critically ill patients” (**APPENDIX II**)

2) European Respiratory Society International Congress 2018, Paris – France
   Period: September 15th to 19th
   Presented poster: “Impact of diaphragmatic mobility in lung aeration loss in critically ill patients” (**APPENDIX III**)

3) European Respiratory Society International Congress 2020, Viena – Austria
   Period: September 5th to 9th
   Presented poster: “The effects of abdominal support in diaphragm function in critically ill patients: a pilot observational study” (**APPENDIX IV**)

We also have submitted a manuscript entitled “Inspiratory muscle capacity with abdominal support: a prospective observational study in critically ill patients” in the Clinics Journal (**APPENDIX V**).

# 1. INTRODUCTION

Intensive Care Unit (ICU) mortality has significantly decreased in the last few years[1,2]. Despite the increased number of survivors, patients are vulnerable to short and long-term morbidity and also at risk of many complications related to critical illness and ICU length of stay (ICU-LOS)[2-4].

Critically ill patients remain inactive for a long time so that muscles are exposed to lower mechanical loads, which can lead to peripheric and respiratory muscle weakness[4-6]. In addition, supine position changes respiratory muscles' mechanics and gravity forces action on the rib cage and abdominal compartment, reducing lung aeration and the diaphragm capacity to generate force[4-6].

Respiratory muscle weakness is a frequent complication related to critical illness which can impair both inspiratory and expiratory muscles[7-9]. Inspiratory muscles have been largely investigated and their dysfunction has been related to illness severity and poor prognosis[7-9]. Conversely, the understanding of expiratory muscles' function in critically ill patients is still largely unknown, although recent research has been bringing important reflections on their role during breathing in those patients[8-11]. Despite being considered as an expiratory muscle, the abdominal wall can also be recruited to improve inspiratory muscle capacity and the efficiency of diaphragm contraction, especially in situations with an increased work of breathing[8,12-16]. Thus, there is an important synergism between the diaphragm and abdominal wall muscles capable of improving transdiaphragmatic pressure and inspiratory muscles' function preserving lung aeration[16].

Therefore, PICO strategy was used and two different research questions were constructed:

- Can abdominal support influence the inspiratory muscles' capacity in critically ill patients in spontaneous breathing?
- Is there any relationship between diaphragm excursion (DE), inspiratory muscle strength and lung aeration in critically ill patients?

# 2. AIMS

Our main purpose is to investigate the inspiratory muscle capacity in critically ill patients with and without abdominal support. Diaphragm excursion (DE), diaphragm thickening fraction (TFdi), maximal inspiratory pressure (MIP) and vital capacity (VC) were the parameters collected at inspiratory muscle capacity assessment.

Secondary aims were also purposed to answer research question 2:

- To investigate the relationship between lung aeration, DE and MIP.
- To investigate if the diaphragm motion dysfunction assessed by ultrasound could be predicted from the patient's clinical characteristics.

# 3. METHODS

This observational and prospective study was conducted at the Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (University of São Paulo Faculty of Medicine Clinics Hospital), in São Paulo, Brazil. It was performed between October 2017 and December 2019 in two ICUs, one surgical and the other medical. The study was approved by the Institutional Ethics and Research Committee (no. 2.878.005, **APPENDIX I**) and the signed informed consent form was obtained from all the subjects included.

## 3.1 Participants

Adults, admitted to the ICU for at least 48 hours, breathing spontaneously with a Glasgow coma scale score ≥ 14 were included. Those subjects with neurological diseases, thoracic traumas, ascites, hemodynamic instability, or pain on the moment of the assessment were not included.

## 3.2 Procedures

Demographic and clinical data such as age, gender, diagnosis, clinical history, nutritional status, Simplified Acute Physiology Score III (SAPS III), lung aeration, ICU length of stay (ICU-LOS) and total hospitalization length were collected from the medical records. All assessments were performed by the same trained and blinded researcher (physical therapist with 6 years of experience). Ultrasound assessments were performed using a sonographer Mindray Z5 (Shenzhen Mindray Bio-Medical Electronics Co., Ltd.).

### 3.2.1 Research question 1

All the patients were assessed by ultrasound, manovacuometry and spirometry in supine position with 45 degrees of trunk flexion during different breathing patterns:

**- Breathing pattern (1).** Patients were instructed to close their eyes and breathe quietly to allow assessments during tidal breathing.

**- Breathing pattern (2).** Subjects performed a maximal inspiratory effort emphasizing the outward displacement of the abdominal wall[17-19]. For this breathing pattern, a belt was positioned around the abdominal circumference (**Figure 1**) without any tension.

**Figure 1:** Abdominal belt and pressure biofeedback unit illustration.

**- Breathing pattern (3).** Subjects performed a maximal inspiratory effort emphasizing the outward displacement of the abdominal wall with the belt embracing abdominal circumference positioned with a standard pressure of 10 mmHg. This tension was applied to simulate the tonic activity of the abdominal wall muscles during breathing, producing a slight increase in intra-abdominal pressure. A pressure biofeedback unit (Stabilizer Pressure Biofeedback Unit, Chattanooga Group Inc., Hixson, TN 37343, USA) was used to standardize and control the tension applied.

To avoid learning bias and ensure blindness, the assessment sequence of patterns (2) and (3), was randomly distributed. A second researcher was responsible for placing the belt in the adequate position and for setting the pressure as “free of pressure” or 10 mmHg accordingly. The evaluation field was covered with a sheet, keeping only the ultrasound transducer access window for data collection.

Diaphragm excursion (DE), diaphragm thickening fraction (TFdi), maximal inspiratory pressure (MIP) and vital capacity (VC) were the parameters collected at inspiratory muscle capacity assessment. During breathing pattern (1), lung aeration and DE was measured. Vital capacity, MIP and DE were assessed during the breathing patterns (2) and (3). Additionally, TFdi from the latest 12 subjects was also collected for the three breathing patterns.

### 3.2.1 Research question 2

Within the thirty patients included, 24 had lung ultrasound score (LUS), MIP and DE during a maximal inspiratory effort assessed at the baseline moment, during breathing pattern 1, which enabled the analysis proposed in research question 2 .

As diaphragm impairment can be caused by many conditions related to critical illness[20-22], we created a diaphragm dysfunction risk score (DDRS) to predict the risk for diaphragm dysfunction. The DDRS was calculated as the sum of points resulting from each risk factor: age > 70-year = 1; age > 80-year = 2; sepsis = 1; inferior abdominal surgery = 1; superior abdominal surgery = 2; immunosuppression = 1; SAPS III > 40 = 1; mechanical ventilation > 48 hours during ICU stay = 1; moderate malnutrition characterized by weight loss > 5% in 2 months, or body mass index between 18,5 - 20,5 kg/m$^2$ + food intake in the last week less than 50 to 60% of needs = 1; severe malnutrition characterized by weight loss > 5% in 1 month ( >15% in 3 months), or body mass index <18,5 kg/m$^2$ + food intake in the last week less than 0 to 25% of needs = 2.

## 3.3 Outcome measures

### 3.3.1 Lung Ultrasound Score

Lung ultrasound score (LUS) was used to evaluate lung aeration, as described by Soummer et al (2012)[23]. For the LUS assessment the chest wall was divided in 12 regions, six each side as shown in **Figure 2**. Each chest region was assessed and scored according to the worst ultrasound characteristics: 0 - normal aeration; 1 - interstitial syndrome (moderate loss of aeration); 2 - alveolar edema (severe loss of aeration); 3 - lung consolidation (total loss of lung aeration). LUS can range from 0 to 36, according to the sum of the twelve chest regions (higher values are related to higher lung aeration loss). In addition to the LUS, the score related to the sum of the four lower chest regions (**Figure 2** - chest regions 4 and 6) was calculated separately and used to characterize the aeration of the dependent lung regions (LUS-dependent).

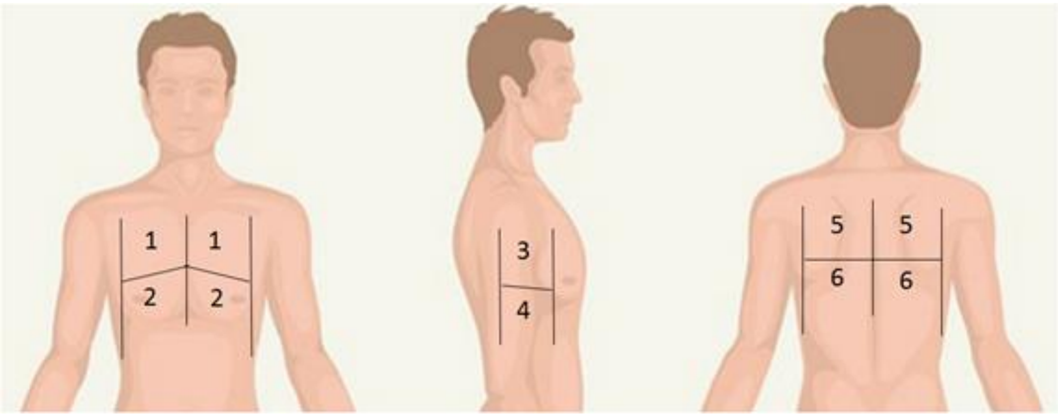


**Figure 2:** Chest regions for lung ultrasound assessment

### 3.3.2 Diaphragm Excursion

A convex transducer (2 to 5-mHz ) was placed in the right midclavicular line, with a cranial inclination at the subcostal area to visualize the right diaphragm dome in B-mode ultrasound[24] (**Figure 3**). The DE was taken between the two distal edges of the hyperechoic line produced by the diaphragm dome using M-mode (**Figure 4**). During the breathing patterns (2) and (3), DE was assessed during a maximal inspiration starting from residual volume to reach total lung capacity, emphasizing the outward displacement of the abdominal wall. Three measurements were acquired during each breathing pattern, and the highest value was considered for analysis.

**Figure 3:** Transducer positioning for diaphragm excursion assessment.

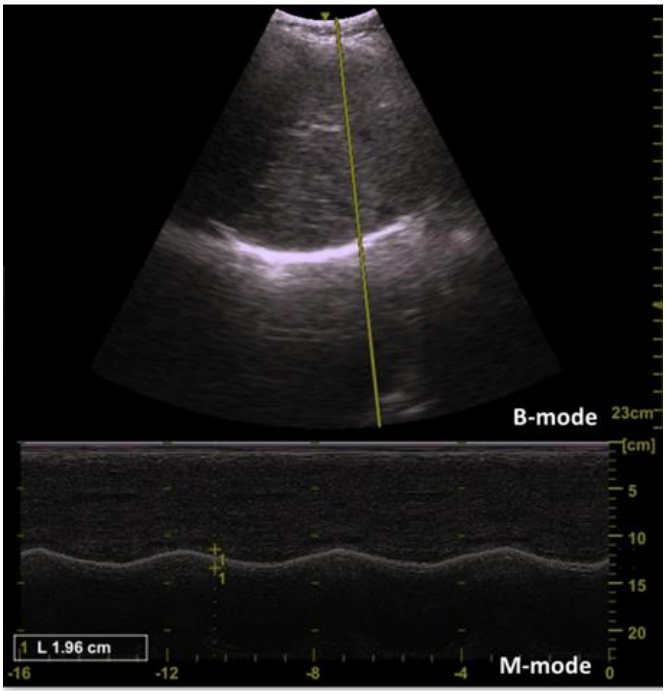


**Figure 4**: Measurement of diaphragm excursion. The diaphragm cupola was identified using B-mode ultrasonography and then, the diaphragm excursion was taken between the two distal edges of the hyperechoic curved line produced by the diaphragm cupola using M-mode.

As established previously[25,26], diaphragm motion dysfunction during quiet breathing was defined by a DE < 10 mm in men and < 9 mm in women. During deep breathing, diaphragm motion dysfunction was defined as a DE < 47 mm in men and < 36 mm in women[26].

### 3.3.3 Diaphragm Thickening Fraction

To assess TFdi the linear transducer (7 to 12-mHz) was positioned in the diaphragm zone of apposition (ZOA), located between the anterior and midaxillary lines, approximately in the 8th to 11th intercostal space[27,28]. M-mode ultrasound was used to measure the diaphragm thickness at the end of inspiration and at the end of expiration[27,28] (**Figure 5**). The increment in diaphragm thickness during inspiration relative to end-expiratory thickness was calculated in percentage to measure the TFdi. During breathing patterns (2) and (3), TFdi was assessed during a maximal inspiration starting from residual volume to reach total lung capacity, emphasizing the outward displacement of the abdominal wall.

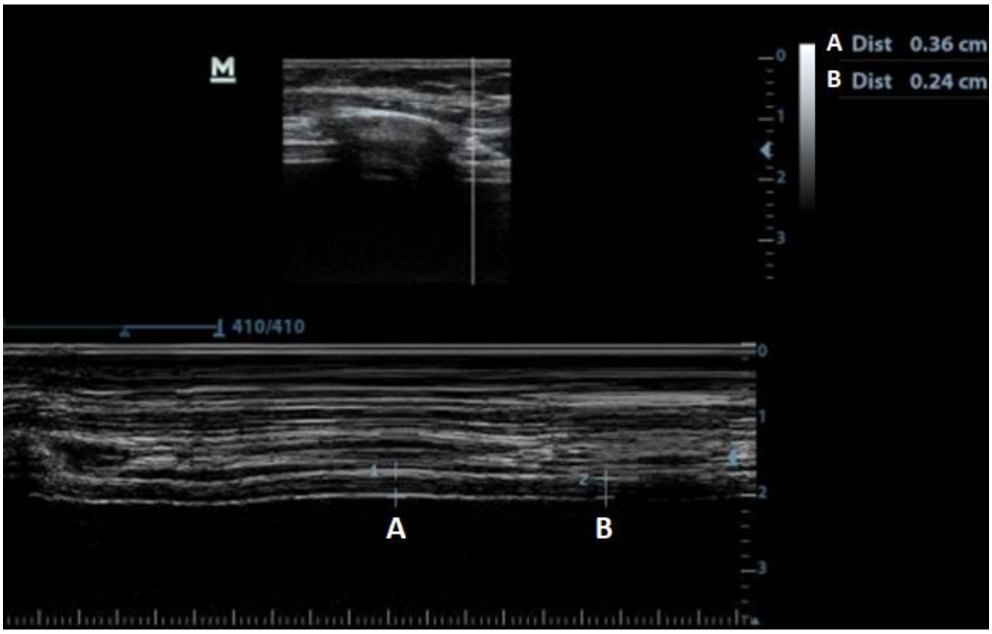


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**Figure 5:** Measurement of diaphragm thickening fraction: A- expiratory diaphragm thickness; B- inspiratory diaphragm thickness.

### 3.3.4 Maximal inspiratory pressure

A digital manovacuometer (MICRO Rpm Pressure Mater) attached to a face mask with inflatable cushion was used to assess MIP (**Figure 6**). Subjects were instructed to perform a maximal expiration until residual volume, followed by a maximal inspiration[29]. At least three measures were collected according to acceptability and reproducibility research recommendations[30], and the highest value was used for analyses. Decreased inspiratory muscle strength was defined as MIP < 60 cmH2O for women and < 80 cmH2O for men[30].

**Figure 6:** Digital manovacuometer used to assess maximal inspiratory.

### 3.3.5 Vital Capacity

To assess vital capacity, a digital spirometer (Datospir micro spirometer) attached to a disposable mouthpiece was used (**Figure 7**). A nasal clip was employed to avoid air leaks during the breathing maneuver. Slow vital capacity maneuver was performed, and the subjects were instructed to breathe slowly in tidal volume, and then to perform a maximal expiration until residual volume followed by a maximal inspiration. At least three measures were acquired according to acceptability and reproducibility research recommendations, and the highest value was used for analyses[26,31].

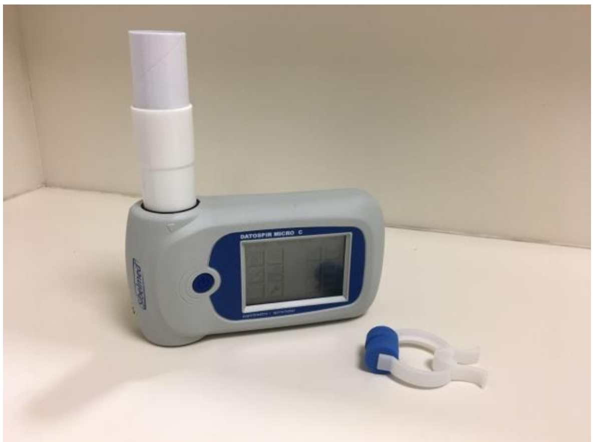


**Figure 7:** Digital spirometer used to assess vital capacity.

## 3.4 Data analysis

Data were analyzed using the "Statistical Package for Social Science" (SPSS) software, version 25.0 for Windows®. Continuous variables were expressed as mean and standard deviation or medians and interquartile range. Categorical data were expressed as absolute and relative frequencies. All the statistical tests were 2-sided ($p<0.05$).

### 3.4.1 Research question 1

Based on a pilot study, the sample size was calculated as 30 participants using version 3.1 G power software, considering 20% of sample loss, $\alpha=0.05$ and a Power $(1-\beta) = 0.80$. VC and MIP during breathing patterns (2) and (3) were compared using Wilcoxon matched-pairs signed-rank test or paired sample t-test, according to data distribution. A one-way repeated measures analysis of variance (ANOVA) was conducted to compare DE and TFdi within the breathing patterns.

### 3.4.2 Research question 2

Spearman Product-Moment Correlation tests were applied to assess correlations between LUS, DE and MIP. Multiple linear regression was used to perform a multivariate analysis; the dependent variables tested were LUS and LUS-dependent, and covariates were determined by linear correlation analysis.

Characteristics of patients with and without diaphragm dysfunction were compared by chi-square test or the Mann-Whitney U rank test, accordingly. The ability of the DDRS for predicting diaphragm motion dysfunction was evaluated using receiver operating characteristic (ROC) curve analysis. The area under the curve with a 95% confidence interval was used to indicate the discriminatory power of the scoring system.

# 4. RESULTS

### 4.1 Research question 1

Thirty subjects were included (**Figure 8**) and had their assessment sequence randomized after the tidal breathing evaluations: 50% were assessed first during the pattern (2), and the other 50% started the assessments with the pattern (3).

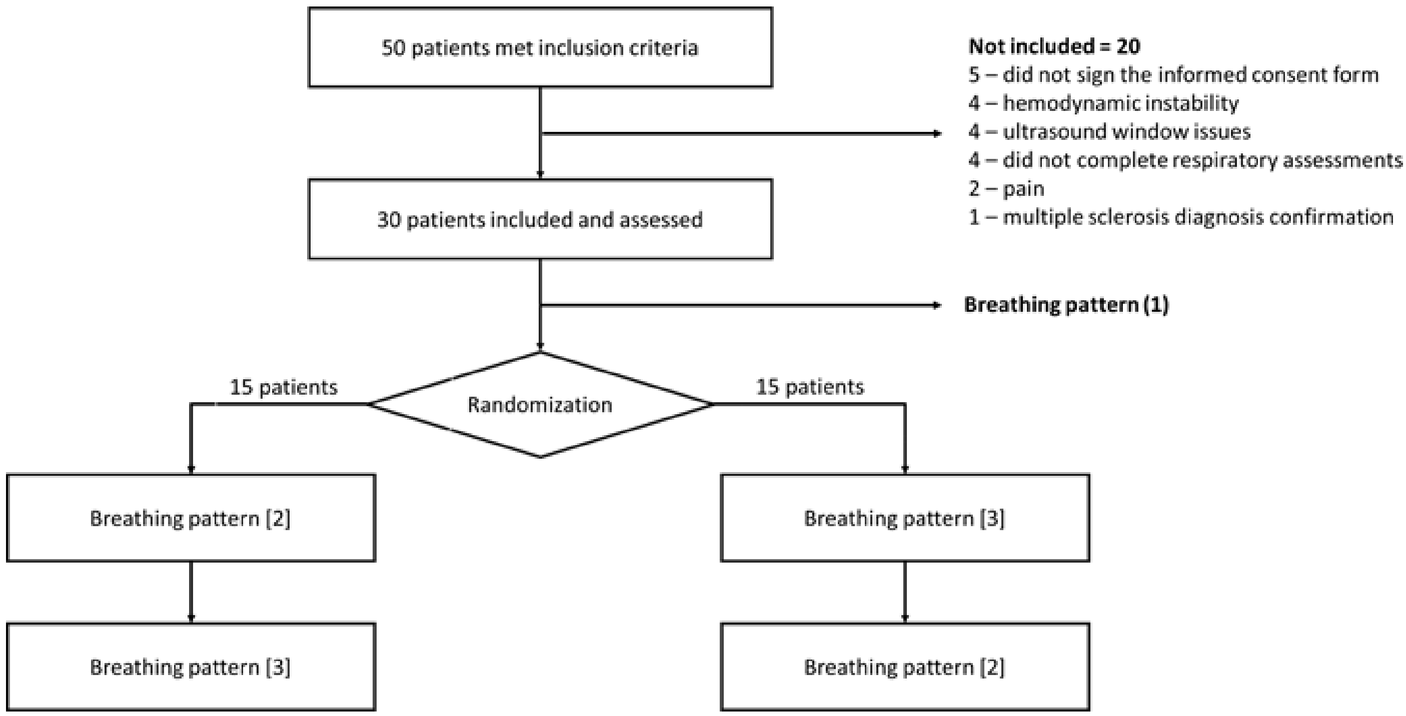


**Figure 8:** Study population flowchart

Clinical characteristics of the 30 subjects are presented in **Table 1**. Out of the 30 subjects included, four had previously received mechanical ventilation (MV) during their ICU stay for 2.3 days on average.

**Table 1 –** Patients' clinical characteristics (N=30)

| **Characteristics** | |
|---|---|
| Age, years | 55.5 ± 17.9 |
| Male, n (%) | 18 (60.0) |
| Nutritional Status, n (%) | |
| Normal | 13 (43.3) |
| Mild impairment | 6 (20.0) |
| Moderate impairment | 8 (26.7) |
| Severe impairment | 3 (10.0) |
| ICU admission cause | |
| Abdominal surgery, n (%) | 8 (26.7) |
| Other surgery, n (%) | 13 (43.3) |
| Medical, n (%) | 9 (30.0) |
| Hospitalization LOS*, days | 9.8 (4.0-10.3) |
| ICU-LOS*, days | 4.3 (2.0-6.0) |
| SAPS III | 45.7 ± 15.0 |
| Lung Ultrasound Score | 8.1 ± 3.9 |
| Lung Ultrasound Score dependent | 6.1 ± 2.5 |

**Abbreviations:** LOS – length of stay; ICU - intensive care unit
*****median (25%–75% interquartile range)

**Table 2** represents the values of VC, MIP, DE and TFdi during baseline (1), diaphragmatic breathing pattern (2) and diaphragmatic breathing pattern with abdominal support (3), and comparison between the paired measures.

**Table 2 –** Inspiratory muscle capacity during breathing patterns (1), (2) and (3), and comparison between the paired measures.

| **Outcomes** | **N** | **Breathing pattern (1)** | **Breathing pattern (2), without abdominal support** | **Breathing pattern (3), without abdominal support** | **p** |
|---|---|---|---|---|---|
| VC*, *L* | 30 | - | 2.3 ± 0.7 | 2.4 ± 0.8 | 0.085 |
| MIP**, *cmH₂O* | 30 | - | 44.0 (31.5-66.3) | 51 (39.8-78.8) | < 0.001 |
| Diaphragm excursion*, *mm* | 30 | 22.0 ± 5.4 | 47.2 ± 15.6 | 58.5 ± 16.4 | < 0.001 |
| TFdi*, % | 12 | 38.0 ± 9.7 | 40.8 ± 19.7 | 76.2 ± 27.5 | < 0.001 |

**Abbreviations:** VC - vital capacity; MIP - maximal inspiratory pressure; TFdi– diaphragm thickening fraction;
***** media ± standard deviation
******median (25%–75% interquartile range)

Comparison of DE between the breathing patterns (1) (22.0±5.4 mm), (2) (47.2±15.6 mm) and (3) (58.5±16.4 mm) showed significant differences as demonstrated in **Figure 9A** [DE (3)>(2)>(1); p<0.001]. Considering TFdi, the results also demonstrated a significant difference (p<0.001) within the repeated measures during the breathing patterns (1) (38.0 ± 9.7%), (2) (40.8±19.7%) and (3) (76.2±27.5%), as represented in **Figure 9B** [TFdi (3)>(2); (2)=(1); p<0.001].

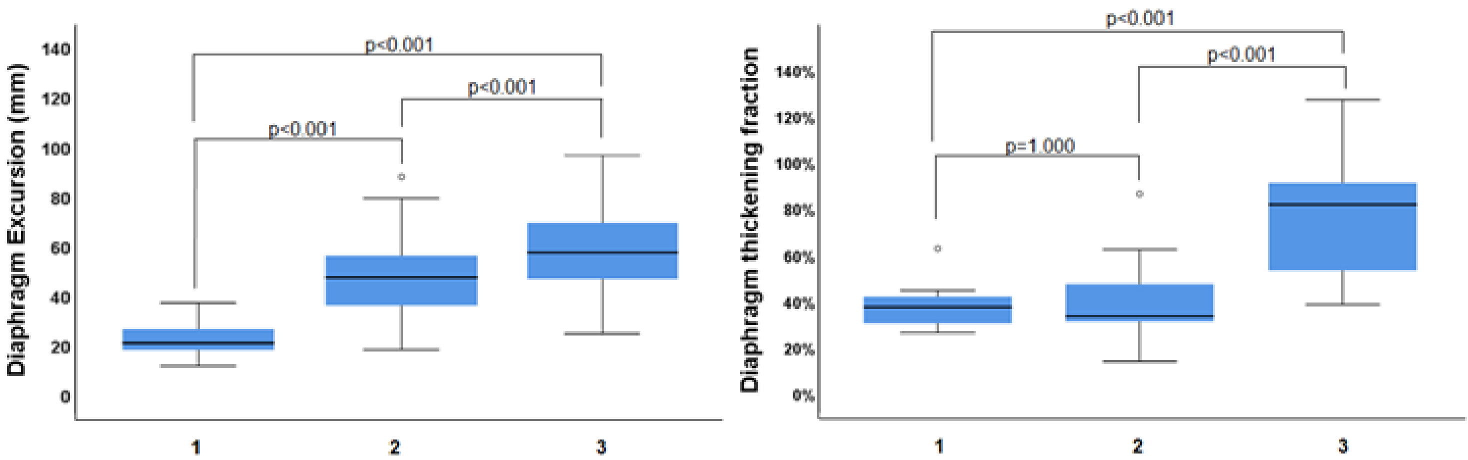


**Figure 9**: One-way repeated measures analysis of variance comparing DE (A) ann TFdi (B) during the three different breathing patterns.

### 4.2 Research question 2

Within the thirty patients included, 24 had MIP and deep breathing DE assessed during baseline assessments for the correlation analysis. As shown in **Table 3**, diaphragm motion dysfunction was not evidenced during quiet breathing and present in 11 patients during deep breathing. Seventy five percent of patients had a decreased inspiratory muscle strength as attested by a reduced MIP. LUS and LUS dependent were very close, indicating that the aeration loss was predominantly observed in dependent lung regions.

**Table 3** Clinical characteristics of patients of the sample with and without diaphragm motion dysfunction during deep breathing. Diaphragm motion dysfunction is defined as a diaphragm excursion < 47 mm in men and < 36 mm in women during deep breathing. Decreased inspiratory muscle strength is defined as a Maximal Inspiratory Pressure < 60 $cmH_2O$ in women and < 80 $cmH_2O$ in men. Data are presented as median (25%–75% interquartile range). P value obtained by chi-square or Mann-Whitney U test as appropriate.

| | **Sample** n=24 | **Normal diaphragm motion** n=13 | **Diaphragm motion dysfunction** n=11 | ***p*** |
|---|---|---|---|---|
| **Diaphragm excursion** (Quiet breathing) | 22.1 (20.0-27.3) | 22.5 (20.8-29.8) | 20.7 (17.3-22.9) | 0.119 |
| **Diaphragm excursion** (Deep breathing) | 45.1 (40.7-57.4) | 56.4 (46.0-68.3) | 40.4 (35.7-44.7) | <0.001 |
| **Maximal Inspiratory Pressure** | 46.0 (37.5-68.0) | 46.0 (39.5-80.5) | 46.0 (36.0-68.0) | 0.733 |
| **Decreased inspiratory muscle strength, n (%)** | 18 (75.0) | 10 (76.0) | 8 (73.0) | 1.000 |
| **Lung Ultrasound Score** | 9 (6-12) | 8 (4-12) | 9 (8-12) | 0.252 |
| **Lung Ultrasound Score dependent** | 7 (4-9) | 6 (4-8) | 8 (6-10) | 0.035 |
| **Diaphragm Dysfunction Risk Score** | 2.0 (1.0-3.0) | 1.0 (0.5-2.0) | 3.0 (2.0-3.0) | 0.027 |

As shown in **Figure 10**, no diaphragm motion dysfunction was detected during quiet breathing and no correlation was evidenced with LUS and LUS-dependent. A statistically significant correlation was found between DE and LUS. A tight correlation was found between DE and LUS-dependent (**Table 3**). A statistically significant weak correlation was found between MIP and LUS or LUS-dependent.

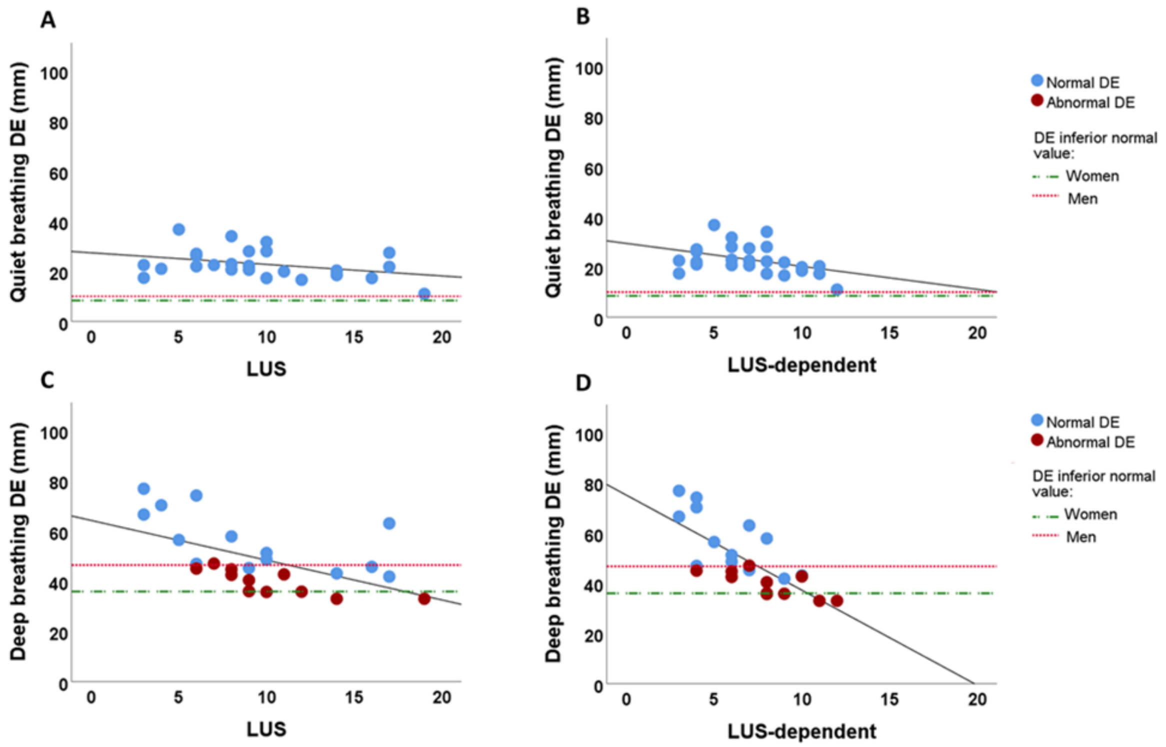


**Figure 10:** Correlations between diaphragm excursion (DE) and lung ultrasound score (LUS) and lung ultrasound score of dependent lung regions (LUS-dependent) during quiet (A and B) and deep (C and D) breathing.

A multiple regression analysis was performed to verify the contribution of MIP and deep breathing DE to LUS and LUS-dependent variance. The model explains 37.1% (F2.21=7.790, p=0.003) of LUS variance and 57.9% (F2.21=16.806, p<0,001) of LUS- dependent variance. The standard regression coefficients shows that deep breathing DE contribute individually to the variance of LUS (beta= - 0.481; t= -2.804; p= 0.011) and LUS-dependent (beta= - 0.669; t= - 4.761; p < 0.001). Individually, MIP did not contribute to LUS (p=0.069) and LUS-dependent (p=0.071) variance.

As shown in **Figure 11**, a DDRS ≥ 2 predicted with a sensitivity of 81.8 % and a specificity of 61.5 % diaphragm motion dysfunction. The area under the curve (AUC) for predicting deep breathing diaphragm motion dysfunction was 0.759 (95%CI= 0.542–0.908, p = 0.011).

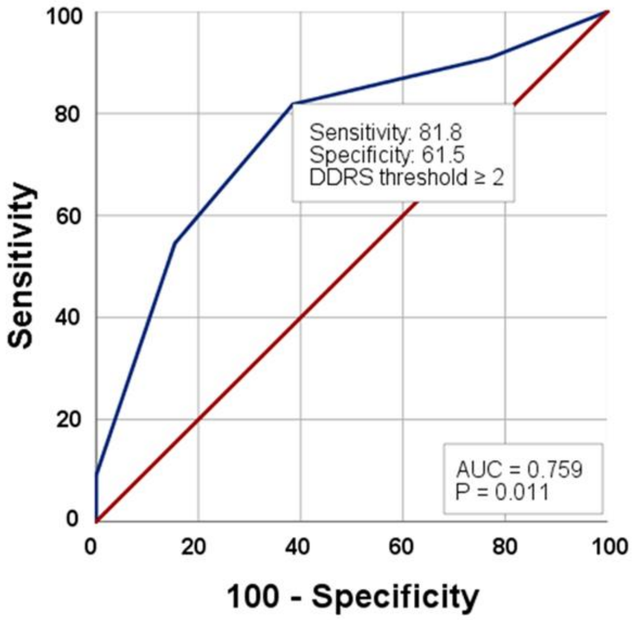


**Figure 11** - Receiver operating characteristic (ROC) curve analysis for predicting deep breathing diaphragm motion dysfunction. AUC = area under the curve. DDRS = diaphragm dysfunction risk score.

# 5. DISCUSSION

To our knowledge, there is no evidence about the effects of abdominal support in critically ill patients and our study provides an important insight into the effects on the inspiratory muscles' capacity in those patients. Our main findings are that abdominal support increases maximal inspiratory pressure, diaphragm excursion and thickening fraction without a significant improvement in VC, when compared to a breathing pattern with a compliant abdominal wall. Additionally, we also have found a significant correlation between DE and LUS and that a DDRS $\geq 2$ predicted diaphragm motion dysfunction.

### 5.1 Research question 1

Maximal inspiratory pressure is broadly used in clinical practice as an indirect measure of inspiratory muscle strength and our results demonstrated that abdominal support significantly increased MIP. Apparently, the abdominal support can change the mechanics of the respiratory muscles, increasing the intra-abdominal pressure and moving the diaphragm cranially at end expiration, contributing to an optimal length for tension generation[8,12,32]. Additionally, elastic energy is stored as the end-expiratory lung volume decreases beyond functional residual capacity, facilitating the next inspiration[13-16]. These changes in breathing biomechanics places the diaphragm muscle fibers in an advantageous length-tension position, allowing it to exert greater force at their lower rib's attachments, which could explain the increased MIP during the breathing pattern with abdominal support. The diaphragm is the most important respiratory muscle, having a major contribution to the capacity to generate force during inspiration[12,33]. In addition to the increased MIP, our study found increased DE and TFdi with abdominal support, reinforcing the significant contribution of the diaphragm.

Previous studies in tetraplegic patients showed that abdominal support has a facilitatory effect on the lower rib cage expansion, mostly related to the increase in the lower ribs expansion and diaphragm appositional force[12,16,34,35]. In accordance with our results, Wadsworth et al.[36] have also shown higher values of MIP in tetraplegic patients with a support applied to the abdominal circumference with an abdominal binder.

During the maximal inspiratory effort with abdominal support, a slight increase in VC was observed. Vital capacity has a nonlinear and disproportional relationship with respiratory muscle strength, in which little variation in lung volumes can be observed when MIP values reach 60% or more of predicted values[30,37], which could explain the lack of significance between the VC in the supported and unsupported breathings patterns.

Interestingly, we observed a progressive improvement of DE from the breathing patterns (1), (2) to (3) while TFdi remained similar during the breathing patterns (1) and (2) and improved in the pattern (3). These findings could be explained by the different recruitment patterns of the costal and crural diaphragm portions. According to De Troyer et al.[38], the isolated activation of the costal diaphragm portion produces a significant increase in the lower rib cage expansion. Conversely, the isolated activation of the crural diaphragm increases the abdominal and diaphragm motion without expanding the lower rib cage[38]. As the TFdi is assessed at the ZOA, it mostly reflects the length changes of the costal muscular fibers of the diaphragm. Consequently, when an outward displacement of the abdomen is emphasized without abdominal support, as during the breathing pattern (2), little or no contraction of the costal portion of the diaphragm is elicited, explaining why an improvement in TFdi during the breathing pattern (2) when compared to the pattern (1) was not observed. When the abdominal support was applied, there was a significant increase in TFdi, which could be related to the emphasis in costal diaphragm contraction due to the increase in intra-abdominal pressure[38]. Although costal and crural diaphragm have been described with distinct neural-mechanical characteristics, their action together is involved in the central tendon caudal displacement[35,36,39,40]. Thus, the progressive improvement in DE through the breathing patterns is probably related to the progressive recruitment of the crural and costal diaphragm from the breathing patterns (1), (2) to (3).

**5.2 Research question 2**

The correlations found between LUS, DE and MIP illustrate the close relationship existing between lung aeration loss and the dysfunction of the inspiratory muscle’s strength and diaphragm excursion in critically ill patients. In fact, 46% of the patients had evidence of diaphragm motion dysfunction as attested by a limited DE during deep breathing and 75 % demonstrated compromised inspiratory muscle strength as attested by the decreased MIP (30). Very likely these disorders can be integrated in ICU-acquired myopathy and critical illness-associated diaphragm weakness[41-43]. Because of respiratory muscle impairment, all the patients included in the present study demonstrated some degree of lung aeration loss evidenced by transthoracic ultrasound.

Our study demonstrates that lung aeration loss, specifically in dependent lung regions is associated with less diaphragm motion during deep breathing and lower values of MIP. Additionally, the diaphragm motion has shown a greater contribution to lung aeration loss than inspiratory muscles strength. These results suggest that, although breathing integrates many muscles, diaphragm movement plays an important role in maintaining pulmonary aeration. During inspiration the diaphragm moves caudally and produces an expansion of the pleural cavity which decreases intrapleural pressure and promotes an increase in lung volumes[33]. Additionally, the costal fibers of the diaphragm attached to the lower ribs are responsible for opening the lower rib cage and consequently, promote aeration of the pulmonary basis[33].

Diaphragm excursion measurements during deep breathing represent the displacement of the diaphragm dome during a maximal inspiratory effort and it has been considered a clinically important measure, especially in those patients with inspiratory weakness[44-46]. Jum and Kim [45,46] reported that DE during deep breathing could be a reliable predictor of changes in pulmonary function in patients after abdominal surgery and a good instrument to investigate postoperative diaphragmatic dysfunction. Another study has investigated the changes of lung compliance and DE in patients who underwent major laparoscopic pelvic surgery, and they have described a significant decrease in diaphragm motion accompanied by a decrease in lung compliance. All this evidence added to our results indicates that the diaphragm movement impairment, especially during a deep breathing, can contribute to lung aeration loss and respiratory impairment.

There is a well-established relationship between critical illness, diaphragm myopathy and respiratory muscle weakness[42,43]. Diaphragm atrophy occurs rapidly, in the first 24 hours of mechanical ventilation[47,48]. Besides mechanical ventilation, muscles and respiratory function can also be affected by many conditions related or not to critical illness: sepsis and systemic inflammation[42,43], abdominal surgery[42], corticosteroids[21], disease severity scores such as simplified acute physiology score or sequential organ failure assessment[20,41], malnutrition[49], immobility, and age-related sarcopenia[41,49]. The DDRS used in the present study was based on these predisposing factors and a value $\geq 2$ was predictive of diaphragm motion dysfunction during deep breathing with a sensitivity of 81.8% and a specificity of 61.5%. Therefore, the DDRS could help to identificate patients at risk of developing diaphragm dysfunction, allowing physicians and physiotherapists to implement early diaphragm rehabilitation and inspiratory muscle training.

### 5.3 Limitations

The present study has some limitations. Firstly, the TFdi method of assessment was added later in the study protocol. Therefore, only 12 subjects had this important measurement collected. Secondly, we did not assess ventilation distribution through the lungs area during the three breathing patterns and we assessed only subjects breathing spontaneously to avoid positive pressure influence in respiratory muscles mechanics and recruitment. And, lastly, DDRS score was not prospectively validated. Further research should be developed to investigate patients in mechanical ventilation and with diaphragm weakness, monitoring ventilation distribution as well and to validate the ability of DDRS to predict diaphragm dysfunction.

**5.4 Clinical relevance and final considerations**

Our results bring important contributions to clinical practice by demonstrating that abdominal wall muscular support has a significant role in increasing inspiratory muscle capacity during a maximal inspiratory effort. This improvement in the respiratory muscles' mechanics can be especially interesting in the context of the ICU, in which patients experience many situations of mechanical disadvantage and increased breathing work , whether related to muscle weakness or due to the pathological process itself[3-5,7,8,10]. Furthermore, our study highlights that breathing patterns which emphasize the outward displacement of the abdominal wall, as diaphragm breathing exercises[50], are less efficient at improving respiratory mechanics and the synergism between the diaphragm and the abdominal wall. Finally, it is important to highlight that the belt was used only as a methodological tool to simulate the usual abdominal muscular support; the belt may be useful in situations where it is not possible to promote an active muscular recruitment, as in tetraplegic or deeply sedated patients.

Furthermore, the ability to diagnose diaphragm motion dysfunction combined with the evidence of compromised lung aeration, should allow the physiotherapist to implement early diaphragm and inspiratory muscle rehabilitation in selected populations of critically ill patients preventing lung aeration loss.

# 6. CONCLUSION

In conclusion, a breathing pattern with abdominal support has a significant contribution to the inspiratory pump action, promoting a higher increase in MIP, DE and TFdi when compared to a pattern without abdominal support.

Additionally, lung aeration loss, diaphragm motion dysfunction and inspiratory muscle weakness are common complications in critically ill patients and tightly related. A DDRS $\geq 2$, based on the presence of sepsis, abdominal surgery, treatment by corticosteroids, simplified acute physiology score $\geq 40$, malnutrition, and age, seems to be a good predictor for deep breathing diaphragm dysfunction.

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# 8. APPENDIX

## APPENDIX I - Ethic Committee approval

USP - HOSPITAL DAS CLÍNICAS DA FACULDADE DE MEDICINA DA UNIVERSIDADE

**PARECER CONSUBSTANCIADO DO CEP**

**DADOS DA EMENDA**

**Título da Pesquisa:** Respiração diafragmática modificada: impacto na função respiratória
**Pesquisador:** Clarice Tanaka
**Área Temática:**
**Versão:** 3
**CAAE:** 61289416.9.0000.0068
**Instituição Proponente:** Hospital das Clínicas da Faculdade de Medicina da USP
**Patrocinador Principal:** Financiamento Próprio

**DADOS DO PARECER**

**Número do Parecer:** 2.878.005

**Apresentação do Projeto:**
Projeto apresentado adequadamente, bem contextualizado e direcionado ao objetivo do estudo.

**Objetivo da Pesquisa:**
Verificar o efeito da respiração diafragmática modificada na ventilação pulmonar, força dos músculos respiratórios e mobilidade diafragmática em:
- Indivíduos assintomáticos;
- Indivíduoszcom Doença do Refluxo Gastroesofágico;
- Indivíduos internados em UTI;
- Indivíduos portadores de disfunções hepáticas internados em UTI e enfermaria ou em tratamento ambulatorial.Objetivo Secundário: Verificar a correlação entre a aeração pulmonar, mobilidade diafragmática e pressão inspiratória máxima em indivíduos internados em UTI.

**Avaliação dos Riscos e Benefícios:**
Sem riscos e sem benefícios diretos ao sujeito da pesquisa.

**Comentários e Considerações sobre a Pesquisa:**
Estudo relevante pois utiliza como instrumento a ultrassonografia e estuda de forma mais detalhada o músculo diafragma e sua relação com a força de músculos respiratórios.
A pesquisadora principal informa exclusão de uma pesquisadora (Elissa Hanayama Dottori) e envia modificações no projeto de pesquisa.

**Endereço:** Rua Ovídio Pires de Campos, 225 5º andar
**Bairro:** Cerqueira Cesar **CEP:** 05.403-010
**UF:** SP **Município:** SAO PAULO
**Telefone:** (11)2661-7585 **Fax:** (11)2661-7585 **E-mail:** cappesq.adm@hc.fm.usp.br

**Considerações sobre os Termos de apresentação obrigatória:**

TCLE adequado

**Recomendações:**

Sem recomendações

**Conclusões ou Pendências e Lista de Inadequações:**

sem pendências

**Considerações Finais a critério do CEP:**

**Este parecer foi elaborado baseado nos documentos abaixo relacionados:**

| Tipo Documento | Arquivo | Postagem | Autor | Situação |
|---|---|---|---|---|
| Informações Básicas do Projeto | PB_INFORMAÇÕES_BÁSICAS_1207252_E1.pdf | 27/08/2018 14:45:31 | | Aceito |
| Outros | FormularioSubmissaodeEmendas2708.pdf | 27/08/2018 14:43:24 | Clarice Tanaka | Aceito |
| Outros | JustificativaEmenda2708.pdf | 27/08/2018 14:42:58 | Clarice Tanaka | Aceito |
| Projeto Detalhado / Brochura Investigador | ProjetoRespiracaoDiafragmaticaModificadaVERSAO2.docx | 27/08/2018 14:42:07 | Clarice Tanaka | Aceito |
| TCLE / Termos de Assentimento / Justificativa de Ausência | TCLEVERSAO2.docx | 27/08/2018 14:41:36 | Clarice Tanaka | Aceito |
| Outros | Cartasdeanuencia.pdf | 29/12/2016 14:19:51 | Clarice Tanaka | Aceito |
| TCLE / Termos de Assentimento / Justificativa de Ausência | TCLE.docx | 21/10/2016 23:27:10 | Clarice Tanaka | Aceito |
| Projeto Detalhado / Brochura Investigador | ProjetoRespiracaodiafragmatica.docx | 21/10/2016 23:08:26 | Clarice Tanaka | Aceito |
| Folha de Rosto | Folha_de_rosto.pdf | 21/10/2016 16:36:49 | Clarice Tanaka | Aceito |
| Outros | Cadastro_onlinepesquisa.pdf | 21/10/2016 16:35:25 | Clarice Tanaka | Aceito |

**Situação do Parecer:**

Aprovado

**Necessita Apreciação da CONEP:**
Não

SAO PAULO, 06 de Setembro de 2018

**Assinado por:**
**ALFREDO JOSE MANSUR**
**(Coordenador)**

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## APPENDIX II – Poster presentation in the American Thoracic International Conference 2018, San Diego - California, United States of America

**A50 CRITICAL CARE: YOU GOT TO MOVE IT, MOVE IT - SEDATION AND MOBILIZATION IN THE ICU** / Thematic Poster Session / Sunday, May 20/9:15 AM-4:15 PM / Area D (Hall A-B2, Ground Level) - San Diego Convention Center

### Modified Diaphragmatic Breathing: An Alternative to Improve Diaphragmatic Mobility and Respiratory Function in Critically Ill Patients

C. G. Mol[1], M. A. Aquino[2], R. B. Reis[3], C. C. Oliveira[3], B. M. Lucena[4], L. S. Malbouisson[4], C. Tanaka[2]; [1]Departamento de Fisioterapia, Faculdade de Medicina da Universidade São Paulo, Sao Paulo, Brazil, [2]Departamento de Fisioterapia, Faculdade de Medicina da Universidade São Paulo, São Paulo, Brazil, [3]Divisão de Fisioterapia, Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil, [4]Divisão de Anestesia, Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil.

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RATIONALE: Diaphragmatic breathing is considered an important physiotherapy tool to improve efficiency of breathing in critically ill patients. During inspiration the patient is asked to move the abdominal wall outward while reducing upper rib cage motion. However, the abdominal wall has an important effect on the inspiratory action by offering the support to the diaphragm's central tendon so that the muscular fibers may act on the opening of the lower rib cage. This study compared the conventional diaphragmatic breathing with a modified mode with a greater abdominal wall support, on the diaphragmatic mobility and respiratory function in critically ill patients. METHODS: Patients admitted in Intensive Care Units (ICU) for at least two days, breathing spontaneously and cooperative to perform the assessment were included. Patients with neurological diseases, hemodynamic instability, thoracic traumas or impossibility of ultrasonographic evaluation were excluded. Assessments were performed in supine position, 45 degrees of trunk elevation in both conventional and modified diaphragmatic breathing mode with sequence randomly assigned. In the modified mode a belt embracing the abdominal circumference was used to simulate the concentric action of the abdominal wall. The tension of the belt was standardized in 10 millimeters of mercury using a pressure biofeedback equipment (Chattanooga Group Inc., USA). The conventional mode was performed using the belt without any pressure. For both mode patients were asked to move the abdominal wall outward during inspiration. Tidal volume (TV) and vital capacity (VC) were evaluated using a spirometer, maximal inspiratory pressure (MIP) using a digital manovacuometer and diaphragmatic mobility (DM) using M-mode ultrasonography. A blind trained researcher performed all the evaluations and a second researcher performed the randomization and belt placement, blinding it using a sheet. Three trials were collected for each variable, allowing a resting period between trials. Statistical analyses were performed using Minitab 16.0 for Windows, considering the highest value. Paired sample t-test was used to compare the effects of conventional and modified diaphragmatic breathing mode ($\alpha$=0.05). RESULTS: Seven out of nine patients completed the evaluations. 57% were male, age ranging from 19 to 68 years. Apache II score was 15.57±2.70 at admission and the ICU length of stay until the evaluation day was 5.86±3.85 days.Table 1 presents the descriptive data and paired t test analysis.

Table 1 - Paired sample t-test comparing effects of conventional and modified diaphragmatic breathing exercises.

| | *Conventional Diaphragmatic Breathing* Mean ± SD* | *Modified Diaphragmatic Breathing* Mean ± SD* | *p-value* |
|---|---|---|---|
| ***Tidal Volume*** (Litre) | 0,493 ± 0,098 | 0,571 ± 0,098 | **0,025** |
| ***Vital Capacity*** (Litre) | 2,094 ± 0,766 | 2,241 ± 0,783 | **0,006** |
| ***Maximal Inspiratory Pressure*** (Centimeters of water) | 38,43 ± 8,26 | 51,71 ± 9,16 | **0,001** |
| ***Diaphragmatic Mobility*** (Milimeters) | 41,71 ± 6,07 | 51,27 ± 9,92 | **0,003** |

* Standard Deviation

CONCLUSION: Modified diaphragmatic breathing improved efficiency of breathing in critically ill patients, evidenced by increased MIP (34,58%), DM (22,92%), TV (15,95%) and VC (7,02%).

This abstract is funded by: None

**APPENDIX III – Poster presentation in the European Respiratory Society International Congress 2018, Paris - France**

EUROPEAN RESPIRATORY *journal*
FLAGSHIP SCIENTIFIC JOURNAL OF ERS

# Impact of diaphragmatic mobility in lung aeration loss in critically ill patients

Caroline Gomes Mól, Monize Karla Alves Aquino, Renato Batista Reis, Catherine Cely Oliveira, Nataly Gomes Benites De Camargo, Rita Ferreira De Souza, Clarice Tanaka

European Respiratory Journal 2018 52: PA2330; **DOI:** 10.1183/13993003.congress-2018.PA2330

Article | Info & Metrics

**Abstract**

**Introduction:** Intensive Care Unit (ICU) patients are at risk of complications due to immobility and prolonged stay. The impact in the diaphragm can lead to reduced pulmonary volumes and alveolar collapse. The aim of this study was to investigate the relationship between diaphragmatic mobility (DM) and lung aeration in critically ill patients.

**Methods:** Cooperative patients admitted in ICU for at least 2 days, breathing spontaneously were included. Patients with neurological diseases, haemodynamic instability and thoracic traumas were excluded. Patients were assessed in supine position, 45 degrees of trunk flexion, using an ultrasound with 2 to 5-mHz convex probe. Three trials were collected for DM during tidal and deep breathing, considering the highest value for analysis. Twelve regions of chest wall were assessed and a Lung Ultrasound Score (LUS) ranging from 0 to 36 was calculated according to the worst pattern observed in each area. Higher values are related to lung aeration loss (Soummer, A. et al. Crit Care Med. 2012; 40:2064–72). In addition to the total LUS, the score related to the inferior pulmonary area (IPS) was also analysed. Pearson Product-Moment Correlation test were applied between MD, LUS and IPS ($\alpha<0.05$).

**Results:** Fifteen patients were evaluated: 60% male, 50±15 years old, 14±4 of Apache II score, and 5±3 days of the ICU length of stay. Tidal DM showed inverse correlations with LUS ($r^2$= -0.65; p=0.009) and IAS ($r^2$= -0.83; p<0.001). Deep DM showed inverse correlation only with IAS ($r^2$= -0.66; p=0.007).

**Conclusion:** DM reduction is associated with lung aeration loss in critically ill patients breathing spontaneously evidenced by ultrasonographic assessment of diaphragm and lung.

**Footnotes**

Cite this article as: European Respiratory Journal 2018 52: Suppl. 62, PA2330.

This is an ERS International Congress abstract. No full-text version is available. Further material to accompany this abstract may be available at www.ers-education.org (ERS member access only).





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**APPENDIX IV – Poster presentation in the European Respiratory Society International Congress 2020, Viena - Austria**

EUROPEAN RESPIRATORY journal
FLAGSHIP SCIENTIFIC JOURNAL OF ERS

# The effects of abdominal support in diaphragm function in critically ill patients: a pilot observational study

Caroline Gomes Mól, Monize Alves Aquino, Renato Batista Dos Reis, Catherine Cely Oliveira, Clarice Tanaka
European Respiratory Journal 2020 56: 3029; **DOI:** 10.1183/13993003.congress-2020.3029

Article | Figures & Data | Info & Metrics

**Abstract**

**Background:** Although considered as expiratory muscles, the abdominal muscles have an important role in the rib cage expansion.

**Aim:** To investigate the effects of abdominal wall in diaphragm function in critically ill patients.

**Methods:** Cooperative ICU patients admitted for at least 2 days and breathing spontaneously were included. Patients with neurological diseases or thoracic traumas were not included. Patients were assessed in 3 breathing conditions: baseline (1); without (2) and with (3) abdominal support. For condition 3, a standardized 10mmHg-belly belt was positioned to simulate the abdominal wall muscular support. For condition 2, the belt was positioned without any tension. For both conditions, 2 and 3, patients were instructed to breath deeply emphasizing the abdominal wall outward displacement. A blind trained researcher assessed diaphragm excursion (DE) and diaphragm thickening fraction (TFdi) using ultrasonography. A second researcher performed the belt positioning. A one-way repeated ANOVA was applied to compare conditions ($\alpha$=0.05).

**Results:** 12 patients were assessed; 66% male; age ranging from 27 to 88 years; SAPS III score 51±16; ICU length of stay 5±3 days. Variables comparison between conditions are shown in Figure 1. **CONCLUSION:**Abdominal wall support improved diaphragm function in critically ill patients, evidenced by increased DE and TFdi during breathing condition 3.

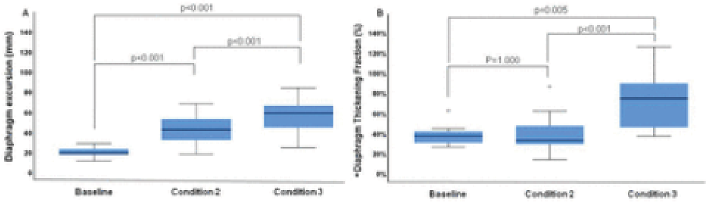


Figure 1: One-way ANOVA comparing DE (A) and Tfdi (B) during 3 breathing conditions: baseline (1); condition 2 (without abdominal support) and condition 3 (with abdominal support).

* (diaphragm thickness at inspiration – diaphragm thickness at end-expiration) x 100

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Respiratory muscle Physiotherapy care Critically ill patients

## Footnotes

Cite this article as: European Respiratory Journal 2020; 56: Suppl. 64, 3029.

This abstract was presented at the 2020 ERS International Congress, in session “Respiratory viruses in the "pre COVID-19" era”.

This is an ERS International Congress abstract. No full-text version is available. Further material to accompany this abstract may be available at www.ers-education.org (ERS member access only).

## APPENDIX V – Manuscript submitted in the Clinics Journal

**CLINICS - Manuscript ID CLINICS-2021-3595**
1 mensagem

**CLINICS Editorial Office** <onbehalfof@manuscriptcentral.com> 14 de novembro de 2021 19:53
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14-Nov-2021

Dear Mrs. Mol:

Your manuscript entitled "Inspiratory muscle capacity with abdominal support: a prospective observational study in critically ill patients" has been successfully submitted online and is presently being given full consideration for publication in CLINICS.

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# Inspiratory muscle capacity with abdominal support: a prospective observational study in critically ill patients

| | |
|---|---|
| Journal: | *CLINICS* |
| Manuscript ID | CLINICS-2021-3595 |
| Manuscript Type: | Original Article |
| Date Submitted by the Author: | 14-Nov-2021 |
| Complete List of Authors: | Mol, Caroline; Universidade de São Paulo Faculdade de Medicina, Fisioterapia, Fonoaudiologia e Terapia Ocupacional<br>Oliveira, Catherine; Universidade de São Paulo Hospital das Clínicas, Fisioterapia<br>Tanaka, Clarice; Faculdade de Medicina, Physiotherapy |
| Manuscript Subject Area: | Critical care |
| Keyword - Click <A HREF='http://www.nlm.nih.gov/mesh/MBrowser.html' target="_blank">here</a> to find your MeSH terms.: | Diaphragm, Abdominal muscles, Ultrassonography, Critical Illness, Physical Therapy Specialt |
| | |