Evaluation of the impact of lung and diaphragm ultrasound findings on clinical decisions for chest physiotherapy in patients hospitalized in Intensive Care Units

US-ADEPT: UltraSound for Accurate Decisions in chest PhysioTherapy

……..

RESEARCH PROTOCOL

Principal investigators:
Aymeric LE NEINDRE
Bélaid BOUHEMAD
George NTOUMENOPOULOS

Secondary investigators:

Registered at Clinicaltrial NCT02881814

Summary

1. Context and rationale

In Intensive Care Unit (ICU), the physiotherapist may be involved in the respiratory management of patients, notably with regard to lung aeration disorders, swallowing disorders, weaning from mechanical ventilation, aerosol therapy, oxygen therapy and the implementation of non-invasive ventilation (NIV), but this practice may vary internationally(1–3).

Chest physiotherapy techniques are selected following a systematic evaluation often based on clinical examination, review of measures of cardiopulmonary function/laboratory tests and review of any radiological tests. Evaluation of the patient is essential to determine the need for chest physiotherapy, treatment selection, monitoring the evolution of the patient and to evaluate treatment efficacy. Chest physiotherapy aims to improve airway clearance, alveolar recruitment and ventilation/perfusion matching (2). It typically involves techniques often used in combination (4), and the selection of interventions depends on the pulmonary dysfunction suspected. For example, in the case of retained airway secretions, airway clearance techniques (including patient re-positioning head down and manual chest wall vibrations/compressions and airway suctioning) may be used to promote secretion removal, reducing airway resistance, optimizing lung compliance and decreasing work of breathing (2). For lung collapse/consolidation, chest physiotherapy aims to improve lung recruitment, compliance and ventilation/perfusion matching. For example, positioning and lung hyperinflation may be used to re-expand atelectasis (2,5). Non-invasive ventilation, intrapulmonary percussive ventilation may be additional strategies optimise lung volume restoration and facilitate secretion clearance respectively (2,5,6).

Physiotherapist usually uses a clinical examination, including lung auscultation, and measures of physiological function including the analysis of blood gases and chest imaging findings (7). However, the reduced diagnostic accuracy of the chest x-ray and lung auscultation with regard to the conditions that may require chest physiotherapy such as pulmonary consolidation, pleural effusion, atelectasis or interstitial syndrome (8), implies that clinical decision-making may be less than optimal. Chest CT-scan is the gold-standard reference examination for the evaluation of acute lung injuries (9)but this requires transportation of the critically ill patient, which involves patient risk and additional exposure to radiation.

As an alternative to the CT-scan, lung ultrasound (LUS) presents greater sensitivity and specificity than chest X-ray in the diagnosis of these same diseases. LUS can also be used to assess the diaphragm with greater accuracy and reproducibility than is the case using routine

measurement tools which often provide only global measures of respiratory dysfunction (Maximal Inspiratory Pressure (MIP). Whereas, LUS can also be used to identify diaphragm dysfunction (both bilateral and unilateral dysfunction) with excellent sensitivity and specificity compared with standard of transdiaphragmatic measurements of pressure(10).

Physiotherapists working in critical care may be developing the skills to undertake LUS to assess their patients (9, 10). Lung and diaphragm US assessments may allow them to determine the optimal indications for chest physiotherapy and thus avoid unnecessary or inappropriate treatments (9, 10). The information provided by LUS may modify the physiotherapist's therapeutic management. Given the relatively recent discussions on the use of lung and diaphragm US in chest physiotherapy (11,12), the usefulness of this tool for physiotherapy in critical care has never been evaluated. Xirouchaki et al. (13)assessed the impact of LUS on clinical decisions in critically-ill patients by intensivist sand demonstrated that it significantly affected the medical diagnosis and modified the therapeutic management. Also a recent case report highlighted the impact of LUS on the clinical decision-making by physiotherapists in critical care (14). As far as we are aware, no study has prospectively and systematically evaluated the impact of the information provided by LUS on clinical-decision making by physiotherapists in the use of chest physiotherapy in patients hospitalized in an ICU.

2. Researchhypothesis

The lung and diaphragm ultrasound findings provided to the physiotherapist will modify his/her clinical decision-making in regards to chest physiotherapy treatment in the critical care patient.

3. Objectives

3.1.Principal objective

The principal objective of this study is to evaluate the impact of using the results of lung and diaphragm US on clinical decisions by physiotherapists regarding chest physiotherapy in patients hospitalized in an ICU.

3.2.Secondary objectives

The secondary objectives are to:

1. Determine whether LUS has an impact on clinical decisions in chest physiotherapy:
    - When the findings from a chest CT-scan less than 12hours old are available;
    - For each clinical hypotheses;
    - For each level of certainty of clinical hypothesis;
    - For type of patients (reasons for admission the most represented);
    - For each research center.
2. Determine the level of agreement between the physiotherapist's diagnosis comparing the clinical vs LUS findings, overall, for the level of certainty of clinical diagnosis and for the population where a CT-scan is available;
3. Determine the frequency of changes in the chest physiotherapy following the assessment of the LUS results, overall and for each type of clinical hypothesis;
4. Determine the frequency of changes in the medical treatment (determined by intensivist) following the assessment of the LUS results performed by the physiotherapist, overall and for each type of clinical hypothesis.

4. Judgement criteria

4.1.Principal judgement criterion

Modification of the clinical decision: agreement (yes/no) between the lung and diaphragm US diagnosis and the clinical diagnosis and modification (yes/no) of the chest physiotherapy protocol, expressed using the Net Reclassification Index (NRI).

4.2.Secondary clinical decision-makingjudgementcriteria

1. Modification of the clinical decision:
    - When a chest CT-scan < 12h is available;
    - For each clinical hypotheses;
    - For the level of certainty of clinical hypotheses (Likert scale: strongly certain, certain, neither certain nor uncertain, uncertain, strongly uncertain);

- For type of patients (reasons for admission the most represented);
- For each research center.

2. Proportion of agreement between clinical and LUS diagnosis:
   - Overall;
   - For the level of certainty of clinical hypotheses (Likert scale: strongly certain, certain, neither certain nor uncertain, uncertain, strongly uncertain);
   - When chest CT-scan < 12h is available.
3. Proportion of cases when the chest physiotherapy protocol is modified following the results of the LUS:
   - Overall;
   - For each type of clinical hypothesis;
   - When a chest CT-scan < 12h is available;
4. Modification of the clinical decision of intensivist:
   - Overall;
   - For each type of clinical hypothesis;
   - When a chest CT-scan < 12h is available.

5. Inclusion/exclusion criteria:

5.1.Inclusion criteria

Patients presenting the following criteria will be eligible:

- Hypoxemia(SpO_2/FiO_2< 315 (15))(indication for chest physiotherapy)(*cf. annexe 1*);
- Medical prescription for chest physiotherapy;
- First session of chest physiotherapy;
- Chest X-ray<12h available;
- Physiotherapist/operator qualified in LUS available;
- Patient's consent.

5.2.Exclusion criteria

Patients presenting the following criteria will not be eligible:

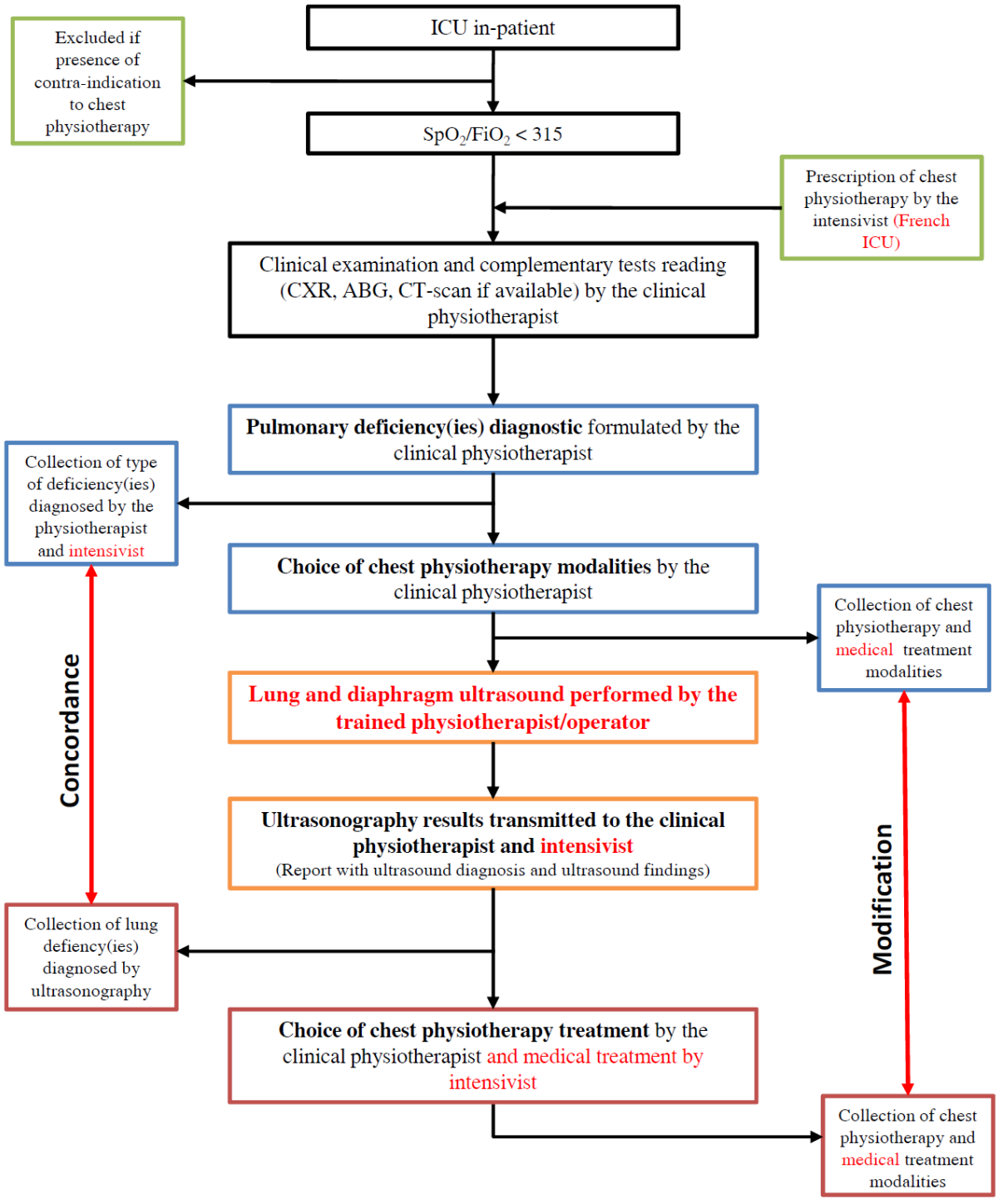
- Presence of a contra-indication for chest physiotherapy;
- Absence of hypoxemia;
- Absence of a prescription for chest physiotherapy;
- Absence of a chest X-ray < 12h from the time of physiotherapy assessment;
- Physiotherapist/operator qualified in LUS not available;
- Lung and diaphragm US not possible (surgical emphysema, dressing, scarring, drains etc.);
- Refusal of the patient or a relative to participate in the study;
- Patients to be discharged on the day of the study;
- Patients in palliative care;
- Withdrawal/limitations of medical care with impending death.

6. Methodology:

6.1.Type of study

This is a multi-centre prospective (patients enrolled on admission) interventional study evaluating a routine assessment/treatment. The study intends to assess the impact of lung and diaphragm ultrasound on the usual physiotherapist's clinical decision-making process. Each included patient will be clinically assessed by a clinical physiotherapist, and then will have a lung and diaphragm ultrasound by another physiotherapist/operator blinded to the clinical assessment findings. The lung and diaphragm ultrasound findings will then be presented to both the intensivist and clinical physiotherapist to evaluate the impact on the independent clinical decision-making by both the intensivist and physiotherapist.

6.2.Studyflow chart



6.3.Study location

- Surgery Intensive Care Unit Department, CHU de Dijon, Dijon, France
- Respiratory Intensive Care Unit and Post-Critical care rehabilitation unit, Hôpital Forcilles, Férolles-Attilly, France
- Medical and surgical Intensive Care Unit Department, Saint-Joseph Hospital Network, Paris, France
- St Vincent's Hospital, Sydney Australia

6.4.Study population

Patients over 18 hospitalized in the ICU and presenting hypoxemia (SpO_2/FiO_2< 315) and who have not been previously given chest physiotherapy on this ICU admission.

6.5.Intervention: nature of the routine care to be evaluated

6.5.1. Procedure 1: Decision-making process in chest physiotherapy

6.5.1.1. Clinical physiotherapist training

The clinical physiotherapist is the physiotherapist who manages patients in the ICU. He is a trained critical care physiotherapist with more than two years of experience, as defined by the French statement for physiotherapist working in the French ICU's(1). The clinical physiotherapist in the Australian ICU will have been trained and oriented to working in the ICU based on a local structured training program dependent on the level of experience of the physiotherapist.

6.5.1.2. Indication and prescription of chest physiotherapy

In the French ICU departments, the intensivist prescribes chest physiotherapy for patients, whereas in the Australian setting, the physiotherapist screens all patients admitted to intensive care and provides interventions based on clinical need. All patients with hypoxemia (SpO_2/FiO_2< 315) will result in referrals for chest physiotherapy by the intensivists in the French ICU(5).All patients with hypoxemia (SpO_2/FiO_2< 315) will be reviewed by the physiotherapists in the Australian ICU as to the requirements for physiotherapy.

6.5.1.3. Clinical examination

When chest physiotherapy is prescribed by the intensivist in the French ICU (or the patient has indications for chest physiotherapy in the Australian ICU as stated 6.5.1.2), the clinical physiotherapist carries out a clinical examination and will analyse the complementary tests (chest X-ray, chest CT-scan and blood gases if available). He/she also consults the patient's medical record to identify reasons for admission to the ICU and the working medical diagnosis if the critical care physician has made one.

The physiotherapists' clinical examination includes:

- Patient observation:
    - Thoracic cage observation: asymmetry of chest wall movement, hyperinflation etc.
    - Respiratory breathing pattern: respiratory rate, dyspnoea, tachypnoea, bradypnoea, Hoover sign, Campbell sign, respiratory pattern (thoracic expansion, abdominal expansion, paradoxical chest or abdominal movement);
    - Physiologic data: SpO_2, heart rate, blood pressure;
- Chest wall palpation: vocal fremitus, tactile chest wall fremitus, subcutaneous emphysema;
- Chest wall percussion: dullness or tympanism;
- Lung Auscultation:
    - Normal breath sound: vesicular sound, bronchial sound;
    - Abnormal sound: crackles, rhonchi, wheeze etc.

Then, the physiotherapist interprets the additional tests:

- Chest X-rays: opacities, consolidation, volume loss, bronchogram, pneumothorax, pulmonary oedema;
- Chest CT-scan (if available):opacities, emphysema pneumothorax, pulmonary oedema;
- Arterial blood gas: hypoxemia (PaO_2<75-80 mmHg), hypercapnia (PCO_2> 45 mmHg), acidosis (pH <7,30), alkalosis (pH >7,44).

After the analysis of the clinical examination findings, the physiotherapist then determines one or several working clinical hypothesis.

6.5.1.4. Clinical hypotheses

Following the examination, he/she will put forward one or several hypotheses concerning the respiratory dysfunction (and not the medical diagnosis) and will either confirm or refute the indications for chest physiotherapy (*cf. annexe 2a*). If chest physiotherapy is indicated, the physiotherapist will specify the protocol to be used. The choice of the treatment modalities with regard to the type of respiratory dysfunction is detailed in annexe 2b.

According to the clinical examination, the clinical physiotherapist formulates one or more of the following clinical hypothesis (*cf annexe 2a*):

- Clinical examination is compatible with retained airway secretions**;**
- Clinical examination is compatible with bronchospasm**;**

- Clinical examination is compatible with pneumonia/consolidation;
- Clinical examination is compatible with atelectasis (~~passive or~~ obstructive~~active mechanism)~~;
-
- Clinical examination is compatible with pleural effusion;
- Clinical examination is compatible with pulmonary edema or global interstitial syndrome;
- Clinical examination is compatible with pneumothorax;
- Clinical examination is compatible with reduced aeration at the most dependent parts of the lungs;
- Clinical examination is compatible with unilateral diaphragm dysfunction ~~(unilateral or bilateral)~~;
- Clinical examination is compatible with bilateral diaphragm dysfunction;
- Clinical examination is inconclusive.

Among the formulated clinical hypotheses, the clinical physiotherapist will choose one primary clinical hypothesis (the choice is left to the discretion of the clinical physiotherapist, based on the probability and priority of the clinical hypothesis in terms of treatment).

A lung and diaphragm US will be done (see below) following the evaluation of the clinical physiotherapist with the physiotherapist who undertakes the US assessment blinded to the clinical assessment findings of the clinical physiotherapist. The clinical physiotherapist will then incorporate the results of the lung and diaphragm US and deem whether they are compatible with the clinical hypotheses put forward. He/she will then specify the chestphysiotherapy protocol according to the results of the US-scan.

6.5.1.5. Choice of chest physiotherapy treatment

The clinical physiotherapist will define the chest physiotherapy treatment modalities according to the formulated clinical hypothesis. The following treatments may be proposed :

- No chest physiotherapy treatment indicated;
- Refer to the intensivist;
- Non-invasive ventilation;
- CPAP (if non-ventilated patient) or PEEP modifications (if ventilated patient);
- Manual or ventilator hyperinflation;
- Mechanical in-exsufflator (Cough Assist ©);
- Rib cage compressions, manual assisted cough;
- Endo or naso-tracheal suctioning;
- Positioning:

- Semirecumbent position (head 45° from bed);
- Laterocubitus;

– Early mobilization:

- Sitting on side of bed;
- Standing;
- Sitting on chair.

The choice of treatment according the clinical hypothesis is defined in annexe 2b. The clinical physiotherapist will define the chest physiotherapy treatment modalities for the primary clinical hypothesis. The chest physiotherapy treatment modalities will be defined both before and again separately after the LUS and Diaphragm US examination.

6.5.2. Procedure 2: Lung and diaphragm US

6.5.2.1. Ultrasound physiotherapist/operator

The LUS will be performed by the physiotherapist/operator, who will be blinded to the clinical evaluation by clinical physiotherapist, the patient's status including the Chest X-rays and CT-scan findings and all of other clinical information. The operator will not take part in the management of the patients concerned.

The ultrasound training of the operator in the French ICU was performed as follow:

– Two days academic theoretical and practical training;

– One year supervised lung ultrasound practice: more than 200 supervised thoracic ultrasound examination performed;

– Two years autonomous thoracic ultrasound practice.

The Australian ICU used a modified version of this training program with a one day theoretical and practical training course and supervised lung ultrasound practice.

6.5.2.2. Ultrasound examination modalities

A referent intensivist will be present when LUS is performed by a french physiotherapist, in order to control the adequate realization of LUS examination. Referent intensivist are trained to LUS. Dr Laurence DONETTI (Forcilles' Hospital), Dr Marc TRAN (St. Joseph's Hospital) and Pr Belaid BOUHEMAD (Universitary Hospital of Dijon) will be referent intensivist.

The CX 50 (Philips) or Edge (Sonosite) ultrasound machine, with 3.5 MHz convex and 10 MHz linear probes, will be used. The convex probe will be used to assess the lung (interstitial syndrome, consolidation, pneumothorax, diaphragm excursion and pleural effusion) and the linear probe will be used to assess to evaluate diaphragm thickness.

The patient will be in semirecumbent position (head 30° from bed) for LUS imaging. Two lines delimit the axillary space: the anterior and posterior axillary lines. These lines define

areas of investigation for each hemithorax—anterior, lateral, andposterior—each of which is divided into upper and lower parts. Each hemithorax includes 6 examination areas (*cf annexe 3a*). The locations of the liver and spleen allow for the identification of the right and left diaphragm cupolas, which separate the thoracic and abdominal compartment. The probe will be used to explore each intercostal space using a longitudinal view. Specific examination modalities for the diaphragm ultrasound are defined in annexe 3a.

6.5.2.3. Lung and diaphragm ultrasoundsemiology

The basics lung ultrasound semiology is described in annexe 3b. The following syndromes will be searched for: normal profile, alveolar-interstitial syndrome, pulmonary consolidation, pleural effusion, pneumothorax and diaphragm dysfunction (16).

The ultrasound syndromes are defined by the following signs in a scanned for the in six-lung zones of each chest wall of the patient:

Normal lung:

- Bat sign;
- A lines;
- Pleural sliding (seashore sign).

A normal profile is compatible with presence of tracheo-bronchial retained secretions and bronchospasm.

Alveolar-interstitial syndrome(16–18)**:**

- A positive region is defined by the presence of three or more B-lines in a longitudinal plane between two ribs;
- In the anterior and lateral thoracic areas;
- Multiple and well-defined B-lines: moderate loss of lung aeration;
- Confluent B-lines: severe loss of lung aeration.

The presence of a focal sonographic pattern of interstitial syndrome is compatible with pneumonia, atelectasis or pulmonary contusion.

The presence of multiple diffuse bilateral B-lines is compatible with pulmonary oedema or ARDS. In the case of pulmonary oedema, the interstitial syndrome is diffuse, homogeneous and bilateral. In the case of ARDS, the interstitial syndrome is diffuse, heterogeneous, bilateral and associated with pleural abnormalities and sub-pleural consolidations.

Lung consolidation:

- Subpleural echo-poor region or tissue-like echo-structure;
- Atelectasis pattern(19,20):

- Abolished pleural sliding;
- Static air bronchogram;
- Lung pulse;
- Passive atelectasis due to compression from the surrounding pleural effusion: homogeneous echogenic structure into the pleural effusion, with smooth margin and linear air bronchogram(21).

- Pneumonia pattern(22–25):
  - Irregular deep margin when the consolidation is partial;
  - Regular deep margin when consolidation involves an entire lobe;
  - Static or dynamic air bronchogram;
  - Fluid bronchogram;
  - Vascular pattern;
  - Bilateral or unilateral.

The aim of physiotherapist is not to identify the medical diagnosis. Regarding the presence of the interstitial syndrome and lung consolidation, the aim is to also define the level of lung aeration present in each of the 12 lung zones:

- Normal aeration (N): presence of lung sliding with A-lines or fewer than two isolated B-lines;
- Moderate loss of lung aeration (B1): multiple, well-defined B-lines (B1 lines);
- Severe loss of lung aeration (B2): multiple, coalescent B-lines (B2-lines);
- Lung consolidation (C): presence of a tissue pattern.

Points will be allocated according to the worst ultrasound pattern observed: N=0, B1=1, B2=2, C=3. Sum of scores for each area defines the LUS score, ranging between 0 and 36(26).The qualitative description of the consolidation allows the physiotherapist to differentiate atelectasis or pneumonia pattern and the adaptation of the chest physiotherapy treatment (*cf annexe 2b*).

Pleural effusion (16):

- Anechoic or hypoechoic structure ;
- Quad sign ;
- Sinusoidsign ;
- Transudates are always anechoic, while exudates are echoic and loculated (18).

Pneumothorax (16) :

- Lung point;

- Absence of pleural sliding (stratospheric sign);
- Absence of B-lines;
- Absence of lung pulse.

Diaphragmdysfunction :

- Diaphragm excursion < 2,5 cm(27);
- Diaphragmthickening fraction < 20% (28).

6.5.2.4. Lung and diaphragm ultrasound report

The physiotherapist/operator will write a detailed LUS-scan report, which will be given to the clinical physiotherapist. When LUS is performed by a french physiotherapist, the LUS report will be checked and validated by the referent intensivist. The LUS-scan report~~It~~ will include the LUS and Diaphragm diagnosis and describe the signs observed in the different regions of the chest (*cf. annexe4*). The clinical physiotherapist is trained to interpret LUS reports. The clinical physiotherapist then determines the options or changes to treatment based on the US findings.

7. Studyprogress

7.1.Study planning

- Ethic comittee submission: December 2016;
- Study comencement: January 2016;
- Inclusion duration : 12 months;
- Length of patient participation: one day;
- End of inclusion: January 2017;
- Total duration of the study: 18 months;
- Congress communications: French Intensive Care Society Congress, ESICM, ERS, ATS, from April 2018;
- Publication: September 2018;
- Target journal: Physical therapy, Intensive Care Medicine or Critical Care Medicine.

7.2.Recruitment method

Patients will be recruited in the Surgical ICU of the CHU de Dijon, Medical-Surgical ICU of Paris St. Joseph's Hospital, Respiratory ICU and Post-ICU Rehabilitation Unit of Forcilles' Hopital and the ICU of St Vincent's Hospital.

Patients admitted to the ICU and who meet the inclusion criteria will be invited to take part in the study. Patients with hypoxemia will be identified by the duty physician at the time of

transfer to the unit or by the principal investigator and the coordinating investigator during the day. Written informed consent will be collected *(cf. annexes 5a and 5b).*

7.3.Number of patients to recruit and duration of participation for each patient

Given the high prevalence of hypoxemia in ICUs, the systematic respiratory assessment in these patients by the physiotherapist and our relatively non-restrictive inclusion criteria, we believe we can recruit more than 300 patients per year.

7.4.Data collected

7.4.1. Pre-inclusion visit

The pre-inclusion visit takes place as soon as a patient meeting the inclusion criteria is hospitalized in the ICU department. During this visit, the principal investigator will give the patient or his relatives the information consent (*cfannexe5*). If the patient gives his/her consent, he/she will be included in the study.

7.4.2. Inclusion visit

The following data will be collected:

- Demographic: age, sex, size, weight, BMI, smoking, alcohol consumption, history of cirrhosis, diabetes or a chronic respiratory disease, heart failure;
- Reason for hospitalization:
    - Chronic respiratory disease decompensation : COPD, obesity hypoventilation, restrictive lung disease;
    - Acute severe asthma;
    - Community-acquired and hospital-acquired pneumonia;
    - ARDS;
    - Acute respiratory distress: infection, acute pulmonary edema, other identified causes, other non identified causes.
    - Pulmonary embolism;
    - Post-operative (urologic, digestive, vascular, and thoracic surgery);
    - Sepsis;
    - Coma;
    - Acute heart failure;
    - Multi-organ failure;
    - Cancer;
    - Continous monitoring;
    - Other (detail).

- Medical diagnosis and medical treatment planned of hypoxemia (or cause of hypoxemia).

7.4.3. Initial clinical physiotherapist visit

The clinical physiotherapist undertakes the patient clinical examination, reviews the chest x-rays and additional tests as available. Moreover, he/she reviews the CT-scan if performed < 12h at the patient's admission including the radiology report. Following the clinical examination, the clinical physiotherapist formulates his/her clinical hypotheses. Among this formulated clinical hypotheses, the physiotherapist chooses a primary clinical hypotheses (the choice is left to the discretion of the clinical physiotherapist, based on the probability and priority of the clinical hypothesis in term of treatment). The primary clinical hypothesis and the secondary clinical hypotheses (if adapted) will be recorded in the case report form (CRF). According the primary clinical hypothesis, the clinical physiotherapist records his chest physiotherapy treatment modalities in the CRF.

The following data will be recorded:

- Medical management:
    - Hypnotics ~~(and dose)~~;
    - Opiates ~~(and dose)~~;
    - Steroids ~~(and dose)~~;
    - Anti-hypertensives ~~(and dose)~~;
    - Antibiotics ~~(and dose)~~;
    - Oxygen therapy (and flow);
    - Mechanical ventilation, NIV (PEEP, IPAP, O_2 dose);
    - Tracheotomy;
- Severity score: SAPS~~OFA~~
- Vital signs: RR, HR, BP SpO_2, FiO_2 (true or estimated), body temperature, RASS, Glasgow coma score;
- Clinical hypotheses of the clinical physiotherapist;
- Choice of chest physiotherapy protocol (before LUS).

7.4.4. Ultrasound physiotherapist/operator visit

Following the clinical physiotherapist visit, the ultrasound physiotherapist/operator performs a lung and diaphragm ultrasound. He is blinded to the patient's status and clinical physiotherapist examination. He/she is not involved in patient management or patient clinical decision-making. The ultrasound findings are recorded in the LUS report (*cfannexe4*). The LUS report is reported to the clinical physiotherapist and to the intensivist. The ultrasound diagnosis(es) is recorded.

7.4.5. LUS reporting to clinical physiotherapist and intensivist

The clinical physiotherapist and intensivist reviews the LUS report. Taking into account these LUS report, the clinical physiotherapist once again selects the chest physiotherapy treatment modalities indicated. The second chest physiotherapy treatment modalities will be recorded, with the reasons for a change of interventions (if indicated). The intensivist will again review any medical decisions that have been made. The new medical treatment for hypoxemia (or cause of hypoxemia) is recorded.

7.4.6. Second visit of the clinician physiotherapist: implementation of the chest physiotherapy treatment

After the review of the LUS report, the clinical physiotherapist may or may not decide to perform the chest physiotherapy treatment, to refer the patient to the intensivist, dependent upon his/her therapeutic strategy choice. The executed chest physiotherapy treatment provided will be recorded. The following data will be recorded:

- Current medical management:
    - Oxygen therapy (and flow);
    - Mechanical ventilation, NIV (PEEP, IPAP);
- Severity score: SOFA
- Vital signs: RR, HR, BP SpO_2, FiO_2 (true or estimated), body temperature, RASS, Glasgow coma score;
- Adverse effects during the chest physiotherapy treatment:
    - Desaturation (< 4% of initial SpO_2);
    - Decrease or increase of blood pressure (> 20% of initial SBP or DBP);
    - Decrease or increase of heart rate (> 20% of initial heart rate);
    - Endotracheal tube removal;
    - Catheter or perfusion removal.

7.4.7. End-research visit

When the patient is deceased or left the ICU, the following data will be recorded :

- ICU length of stay (day);
- Intubation (yes/no);
- Duration of mechanical ventilation (if adapted) (day);
- Number of extubation failure (if adapted) (yes/no);
- Vital status (alive/deceased);
- Duration of médical treatment present at the day of inclusion: antibiotics, hypnotics, opiates, steroids and anti-hypertensives (day).

7.4.8. Patient follow-up synthesis

	Pre-inclusion J 0	**Inclusion J 0**	**First clinical physiotherapist visit J 0**	**LUS J 0**	**LUS results reading by the clinical physiotherapist and intensivist J 0**	**Second clinical physiotherapist visit J 0**	**End-research visit**
Information consent	✓						
Demographic data		✓					
Reason for hospitalization, medical diagnosis if different		✓					
Medical management			✓			✓	
SAPS~~OFA~~, vital signs			✓			✓	
Medical diagnostic for respiratory condition		✓					
Medical treatment planned for respiratory condition		✓					
Clinical hypotheses of the clinical physiotherapist			✓		✓		
Choice of chest physiotherapy protocol			✓		✓		
LUS scan				✓			
LUS-scan report				✓	✓		
New choice of chest physiotherapy protocol						✓	
Adverse effect recording						✓	
New medical treatment planned for hypoxemia					✓		
ICU length of stay, duration of MV, vital status							✓

The data will then be entered in an e-CRF (Redcap.com) and analysed at the St. Joseph Hospital Network.

The statistical analysis will be conducted by the Clinical Research Centre (CRC) of the St. Joseph Hospital Network. An identifier will be attributed to each patient (initials of first name and family name – year of birth) and the data will be entered on an EXCEL file, which will be sent to the statistician in charge of the analysis at the St. Joseph Hospital Network.

7.5.Patient monitoring

None.

7.6.Research stopping rules

The definitive research stopping occurs when a patient meets the exclusion criteria. All of the study exit are defined and recorded in the CRF.

8. Statistical analysis

8.1.Calcul of number of subject

This is a pilot study and we don't have any information about the proportion of clinical decision modification in chest physiotherapy when the physiotherapist uses LUS information. The clinical experience of the investigators (A Le Neindre and G Ntoumenopoulos) allows to estimate an expected NRI of 30%. We want at least 50 events (clinical decision modification). So, we aim to include 150 patients in this study.

8.2.Statistical method

8.2.1. Modification of the clinical decision chest physiotherapy

Calculation of the net reclassification index (NRI) (29):

$NRI\ (\%) = (P_{upevents} - P_{downevents}) - (P_{upnonevents} - P_{downnonevents})$

With:

Events: the results of the lung and diaphragm US are compatible with the clinical diagnosis for a clinical hypothesis.

Non Events: the results of the lung and diaphragm US are not compatible with the clinical diagnosis for a clinical hypothesis.

$\mathbf{P_{upevents}}$: number of «events» when the LUS results modified the chest physiotherapy treatment modalities divided by the total number of «events».

$\mathbf{P_{downevents}}$: number of «events» when the LUS results didn't modify the chest physiotherapy treatment modalities divided by the total number of «events».

$\mathbf{P_{upnonevents}}$: number of «non-events» when the LUS results modified the chest physiotherapy treatment modalities divided by the total number of «non-events».

$\mathbf{P_{downnonevents}}$: number of «non-events» when the LUS results didn't modify the chest physiotherapy treatment modalities divided by the total number of «non-events».

The significance test used will be the correlated proportions test (use of the properties of multinomial distribution). This is an asymptotic test for the hypothesis NRI=0.

$$z = \frac{\widehat{\mathrm{NRI}}}{\sqrt{\frac{\hat{p}_{\mathrm{up,events}} + \hat{p}_{\mathrm{down,events}}}{\#\ \mathrm{events}} + \frac{\hat{p}_{\mathrm{up,nonevents}} + \hat{p}_{\mathrm{down,nonevents}}}{\#\ \mathrm{nonevents}}}}$$

8.2.2. Modification of the clinical decision in CPT for each sub-group

Calculation of the net reclassification index (NRI):

NRI (%) = ($P_{upevents} - P_{downevents}$) – ($P_{upnonevents} - P_{downnonevents}$)

- For the subpopulation with a CT-scan < 12h;
- For eachclinicalhypotheses ;
- For the level of certainty of clinical hypotheses:
    - Likert scale: strongly certain, certain, neither certain nor uncertain, uncertain, strongly uncertain;
- For each type of patient (reason for hospitalization the most represented);
- For each research center.

8.2.3. Agreement between clinical and LUS diagnosis

Calculation of Kappa index:

The clinical diagnosis and the lung ultrasound allow to diagnose the following events : (the retained airway secretions and bronchospasm diagnoses aren't included in the analysis as LUS doesn't allow their diagnosis (LUS may only be compatible with these hypotheses):

- T1: pneumonia/consolidation;
- T2: atelectasis (~~passive or active mechanism~~osbtructive);
- T3: pleural effusion;
- T4: pulmonary edema or global interstitial syndrome;
- T5: pneumothorax;
- T6: reduced aeration at the most dependent parts of the lungs;
- T7: diaphragm dysfunction (unilateral or bilateral);
- T8: examination is inconclusive.

Contingency table:

		Lung ultrasound								Total
		T1	T2	T3	T4	T5	T6	T7	T8	
Clinical diagnosis	T1									
	T2									
	T3									
	T4									
	T5									
	T6									
	T7									
	T8									
Total										

Proportion of observed agreement:

$$P_a = \frac{1}{n} \sum_{i=1}^{p} n_{ii}$$

Theoretical proportion of observed agreement:

$$P_e = \frac{1}{n^2} \sum_{i=1}^{p} n_{i.} n_{.i}$$

Kappa :

$$\kappa = \frac{P_a - P_e}{1 - P_e}$$

The Kappa index will be calculated for the global population, the population where the clinical diagnosis is « strongly certain/certain » and « strongly uncertain/uncertain » and the population with a CT-scan < 12h.

8.2.4. Proportion of cases when the chest physiotherapy protocol is modified following the results of the LUS:

Calculation of proportion: $P_{upevents} + P_{upnonevents}$ for all of the clinical hypothesis, for each clinical hypothesis and in the CT-scan <12h subpopulation.

With a confidence interval at α=0.05.

8.2.5. Modification of theintensivist clinical decision

Calculation of the net reclassification index (NRI):

$NRI\ (\%) = (P_{upevents\text{-}I} - P_{downevents\text{-}I}) - (P_{upnonevents\text{-}I} - P_{downnonevents\text{-}I})$

With:

Events: the results of the lung and diaphragm US are compatible with the medical diagnosis of intensivistfor the patient respiratory condition for a clinical hypothesis.

Non Events: the results of the lung and diaphragm US are not compatible with the medical diagnosis of intensivistfor the patient respiratory condition for a clinical hypothesis.

$\mathbf{P_{upevents}}$: number of «events» when the LUS results modified the medical treatment for the patient respiratory condition divided by the total number of «events».

$\mathbf{P_{downevents}}$: number of «events» when the LUS results didn't modify the medical treatment for the patient respiratory condition divided by the total number of «events».

$\mathbf{P_{upnonevents}}$: number of «non-events» when the LUS results modified the medical treatment for the patient respiratory condition divided by the total number of «non-events».

$\mathbf{P_{downnonevents}}$: number of «non-events» when the LUS results didn't modify the medical treatment for the patient respiratory condition divided by the total number of «non-events».

9. Justification for current care

Lung and diaphragm US is a diagnostic tool used in routine practice in ICUs by predominantly physicians. It has been validated as a tool to screen for pulmonary consolidation, atelectasis, interstitial syndrome, pleural effusion, pneumothorax and diaphragm dysfunction (16,30). The sensitivity and specificity of LUS are greater than those for chest X-ray at diagnosing these diseases in patients hospitalized in ICUs who present signs of acute respiratory failure (hypoxemia). LUS is non-invasive, painless and does not involve radiation. There are no contra-indications and no adverse side effects. We expect to that LUS findings may lead to a modification in decisions concerning chest physiotherapy by both the physiotherapist and the physicians. The choice of the chest physiotherapy and medical treatment protocol are made by the physiotherapist and physician, respectively, in charge of the patient and is based on the clinical assessments and clinical parameters available and according to the benefit/risk ratio. Usually, the availability of these elements varies depends on the clinical situation and physiotherapist and physician establish their treatment plan or may decide not to intervene if treatment is not indicated or could have increased patient risk. The addition of a lung and diaphragm US will not modify this choice based on the patient's

safety. Moreover, the chest physiotherapy techniques and medical treatment used are those conventionally used.

10. Expectedbenefits for patients

We expect that decisions for chest physiotherapy may be modified when the physiotherapist and intensivist have access to the results of lung and diaphragm US as well as the usual clinical and imaging parameters.

The sensitivity and specificity of LUS is greater than that for the tools usually used by intensivists and physiotherapists (auscultation, chest X-ray, clinical examination) to explore respiratory dysfunction and to determine indications for chest physiotherapy. LUS may affect the management of patients with regard to chest physiotherapy by providing a more precise evaluation of the respiratory status and should lead to a more appropriate chest physiotherapy treatment.

The expected benefit for patients is therefore that they will be given a chest physiotherapy protocol that is better suited to the type of respiratory dysfunction. This may include more optimal physiotherapy techniques for the patient, the decision not to intervene if physiotherapy is not indicated and more effective referral to the ICU physician in cases of doubt or suspicion of a condition that may warrant physician intervention.

If the results of this investigation are positive, we plan to conduct another randomised controlled trial, with patients allocated to chest physiotherapy guided by lung ultrasound or clinical examination alone, with the objective to evaluate the impact of the use of LUS on respiratory function, time on mechanical ventilation, mortality rates and hospital length of stay).

11. Risks for patients taking part in the study

No additional treatment or diagnostic studies are administered as part of this study. The lung and diaphragm US will be performed via the trans-thoracic approach. The examination is therefore non-invasive, completely painless and requires no exposure to radiation.

13. Funding

This study will be funded by the CHU de Dijon, the Forcilles' hospital and the Paris St Joseph Hospital Network for the French centre and by the University of Technology Sydney for the Australian centre. Funding will cover the time spent by the physiotherapist doing the LUS-scans, the time spent by the clinical research technician to collect the data, and by the CRA to monitor the study and take part in the statistical analysis.

14. Data recording in the Case Report Form

All of the data will be recorded in an e-CRF (https://projectredcap.org) and will be available for each investigator. All data will be anonymised.

15. Ethical and regulatory aspects

15.1. Information to patients

During the pre-inclusion visit (at the onset of the inclusion criteria) the critical care physician will verbally inform the patient about the aims of the study, and the patient will also be given an explanation sheet. The patient's consent to take part in the study will be collected and recorded in the patient's medical record. The explanation will be repeated by the investigator (physiotherapist) at the time of the LUS. All of the examinations are part of the usual management of such patients. The research will be managed by the Paris St Joseph Hospital Network for French centres and Ethics committee of St Vincent's Hospital for the Australian centres. The information on the research will be provided to the patient *(cf. annexe 5a*) or, if this is impossible because of the emergency situation, to a member of the patient's family *(cf. annexe 5b)*. If a patient could not be informed and could not sign the consent form for this research, and/or if a patient was included with the consent of a family member, the patient will be informed and will be invited to continue to participate in the research as soon as he/she has recovered his/her cognitive abilities.

15.2. Need to submit the study for approval by an ethics committee

Yes.

16. Bibliography

1. Société de Kinésithérapie de Réanimation (SKR). Référentiel de compétences et d'aptitudes du masseur kinésithérapeute de réanimation (MKREA) en secteur adulte. Réanimation. 2011 Mar 12;20(3):725–36.

2. Gosselink R, Bott J, Johnson M, Dean E, Nava S, Norrenberg M, et al. Physiotherapy for adult patients with critical illness: recommendations of the European Respiratory Society and European Society of Intensive Care Medicine Task Force on Physiotherapy for Critically Ill Patients. Intensive Care Med. 2008 Jul;34(7):1188–99.

3. Berney S, Haines K, Denehy L. Physiotherapy in Critical Care in Australia. Cardiopulm Phys Ther J. 2012 Mar;23(1):19–25.

4. Andrews J, Sathe NA, Krishnaswami S, McPheeters ML. Nonpharmacologic airway clearance techniques in hospitalized patients: a systematic review. Respir Care. 2013 Dec;58(12):2160–86.

5. Hanekom S, Berney S, Morrow B, Ntoumenopoulos G, Paratz J, Patman S, et al. The validation of a clinical algorithm for the prevention and management of pulmonary dysfunction in intubated adults--a synthesis of evidence and expert opinion. J Eval Clin Pract. 2011 Aug;17(4):801–10.

6. Strickland SL, Rubin BK, Drescher GS, Haas CF, O'Malley CA, Volsko TA, et al. AARC clinical practice guideline: effectiveness of nonpharmacologic airway clearance therapies in hospitalized patients. Respir Care. 2013 Dec;58(12):2187–93.

7. Hanekom SD, Faure M, Coetzee A. Outcomes research in the ICU: an aid in defining the role of physiotherapy. Physiother Theory Pract. 2007 Jun;23(3):125–35.

8. Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby J-J. Comparative Diagnostic Performances of Auscultation, Chest Radiography, and Lung Ultrasonography in Acute Respiratory Distress Syndrome. Anesthesiology. 2004;100(1):9–15.

9. Zompatori M, Ciccarese F, Fasano L. Overview of current lung imaging in acute respiratory distress syndrome. Eur Respir Rev. 2014;23(134):519–30.

10. Sarwal A, Walker FO, Cartwright MS. Neuromuscular Ultrasound for Evaluation of the Diaphragm. Muscle Nerve. 2013 Mar;47(3):319–29.

11. Le Neindre A, Mongodi S, Philippart F, Bouhemad B. Thoracic ultrasound: Potential new tool for physiotherapists in respiratory management. A narrative review. J Crit Care. 2016 Feb;31(1):101–9.

12. Leech M, Bissett B, Kot M, Ntoumenopoulos G. Lung ultrasound for critical care

physiotherapists: a narrative review. Physiother Res Int. 2015 Jun;20(2):69–76.

13. Xirouchaki N, Kondili E, Prinianakis G, Malliotakis P, Georgopoulos D. Impact of lung ultrasound on clinical decision making in critically ill patients. Intensive Care Med. 2014 Jan 1;40(1):57–65.

14. Leech M, Bissett B, Kot M, Ntoumenopoulos G. Physiotherapist-initiated lung ultrasound to improve intensive care management of a deteriorating patient and prevent intubation: a case report. Physiother Theory Pract. 2015 Jan 29;1–5.

15. Rice TW, Wheeler AP, Bernard GR, Hayden DL, Schoenfeld DA, Ware LB, et al. Comparison of the SpO2/FIO2 ratio and the PaO2/FIO2 ratio in patients with acute lung injury or ARDS. Chest. 2007 Aug;132(2):410–7.

16. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med. 2012 Apr;38(4):577–91.

17. Lichtenstein D, Mézière G, Biderman P, Gepner A, Barré O. The Comet-tail Artifact. Am J Respir Crit Care Med. 1997 Nov 1;156(5):1640–6.

18. Bouhemad B, Zhang M, Lu Q, Rouby J-J. Clinical review: Bedside lung ultrasound in critical care practice. Crit Care. 2007 Feb 16;11(1):205.

19. Lichtenstein DA, Lascols N, Prin S, Mezière G. The “lung pulse”: an early ultrasound sign of complete atelectasis. Intensive Care Med. 2003 Dec 1;29(12):2187–92.

20. Lichtenstein DA, Mezière GA, Lagoueyte J-F, Biderman P, Goldstein I, Gepner A. A-lines and b-lines: Lung ultrasound as a bedside tool for predicting pulmonary artery occlusion pressure in the critically ill. Chest. 2009 Oct 1;136(4):1014–20.

21. Chen H-J, Yu Y-H, Tu C-Y, Chen C-H, Hsia T-C, Tsai K-D, et al. Ultrasound in peripheral pulmonary air-fluid lesions: Color doppler imaging as an aid in differentiating empyema and abscess. Chest. 2009 juin;135(6):1426–32.

22. Cortellaro F, Colombo S, Coen D, Duca PG. Lung ultrasound is an accurate diagnostic tool for the diagnosis of pneumonia in the emergency department. Emerg Med J. 2012 Jan 1;29(1):19–23.

23. Reissig A, Gramegna A, Aliberti S. The role of lung ultrasound in the diagnosis and follow-up of community-acquired pneumonia. Eur J Intern Med. 2012 Jul;23(5):391–7.

24. Bourcier J-E, Paquet J, Seinger M, Gallard E, Redonnet J-P, Cheddadi F, et al. Performance comparison of lung ultrasound and chest x-ray for the diagnosis of pneumonia in the ED. Am J Emerg Med. 2014 février;32(2):115–8.

25. Gehmacher O. Ultrasound pictures of pneumonia. Eur J Ultrasound. 1996 avril;3(2):161–7.

26. Soummer A, Perbet S, Brisson H, Arbelot C, Constantin J-M, Lu Q, et al. Ultrasound assessment of lung aeration loss during a successful weaning trial predicts postextubation distress*. Crit Care Med. 2012 Jul;40(7):2064–72.

27. Lerolle N, Guérot E, Dimassi S, Zegdi R, Faisy C, Fagon J-Y, et al. Ultrasonographic diagnostic criterion for severe diaphragmatic dysfunction after cardiac surgery. Chest. 2009 février;135(2):401–7.

28. Summerhill EM, El-Sameed YA, Glidden TJ, McCool FD. Monitoring recovery from diaphragm paralysis with ultrasound*. CHEST J. 2008 Mar 1;133(3):737–43.

29. Pencina MJ, D'Agostino RB, D'Agostino RB, Vasan RS. Evaluating the added predictive ability of a new marker: from area under the ROC curve to reclassification and beyond. Stat Med. 2008 Jan 30;27(2):157–72; discussion 207–12.

30. Matamis D, Soilemezi E, Tsagourias M, Akoumianaki E, Dimassi S, Boroli F, et al. Sonographic evaluation of the diaphragm in critically ill patients. Technique and clinical applications. Intensive Care Med. 2013 May 1;39(5):801–10.

31. Wettstein RB, Shelledy DC, Peters JI. Delivered oxygen concentrations using low-flow and high-flow nasal canulas. Respir Care. 2005;50(5):604–9.

17. Annexes

Annexe 1: Indications for chest physiotherapy in acute care patient

Annexe 2a: Clinical prediction model by physiotherapist

Annexe 2b: Chest physiotherapy treatment modalities

Annexe 3a: Lung and diaphragm ultrasound procedures

Annexe 3b: LUS semiology

Annexe 4: LUS-scan report

Annexe 5a: Information sheet for patients

Annexe 5b: Information sheet for a patient's relatives

Annexe 1: Indication for chest physiotherapy in acute care patient

The main potential indication for chest physiotherapy in acute care patient is hypoxemia.

Hypoxemia is defined here by $SpO_2/FiO_2 < 315$ (15)

FiO_2 in non-ventilated patient is estimated according to the table below(31):

Table 1. F_{IO_2} During Mouth-Closed and Mouth-Open Breathing

Flow (L/min)	Mean F_{IO_2}		p*
	Mouth Closed	Mouth Open	
Low Flow			
1	0.24	0.28	0.003
2	0.30	0.38	< 0.001
3	0.35	0.43	0.001
4	0.40	0.50	< 0.001
5	0.45	0.56	< 0.001
6	0.48	0.60	< 0.001
High Flow			
6	0.47	0.62	< 0.001
7	0.51	0.64	< 0.001
8	0.50	0.66	< 0.001
9	0.56	0.71	< 0.001
10	0.59	0.73	< 0.001
11	0.60	0.75	< 0.001
12	0.62	0.76	< 0.001
13	0.64	0.77	< 0.001
14	0.68	0.79	< 0.001
15	0.70	0.81	0.001

F_{IO_2} = fraction of inspired oxygen
*All values were significant ($p > 0.003$)

Annexe 2a: Clinical hypothesis model by physiotherapist

Clinical examination is compatible with retained airway secretions			
	Auscultation Rhonchi, crackles, wheeze	**Palpation** Palpable chest wall fremitus	**Cough/Suction** Producing sputum
Clinical examination is compatible with bronchospasm			
Chest X-rays "Hyperinflated lungs"	**Auscultation** Expiratory Wheeze		**Inspection** Prolonged expiratory phase Accessory inspiratory muscles use
Clinical examination is compatible with pneumonia pattern			
Chest X-rays Lobar consolidation or interstitial opacities +/- airbronchogram No volume loss	**Auscultation** Fine crackles Decreased or abolished vesicular sound Bronchial breath sound	**Palpation/percussion** Dullness Increased vocal fremitus	**Inspection** +/- focal decreased chest mobility
Clinical examination is compatible with atelectasis pattern (~~passive or~~ obstructive~~active mechanism~~)			
Chest X-rays Lobar consolidation +/- airbronchogram Volume loss	**Auscultation** Abolished vesicular sound	**Palpation/percussion** Dullness Increased vocal fremitus	**Inspection** +/- focal abolished chest mobility
Clinical examination is compatible with pleural effusion (PE)/(+/- passive atelectasis)			
Chest X-rays Blunting of the costophrenic and/orcardiophrenic angles Meniscus Mediastinal shift (large PE)	**Auscultation** Abolished vesicular sound	**Palpation/percussion** Dullness Decreased vocal fremitus Pleural rub sound	**Inspection** +/- focal abolished chest mobility on the side of the PE
Clinical examination is compatible with acute pulmonary oedema(cardiogenic or not)			
Chest X-rays Cephalization of pulmonary vessels Kerley B lines Peri-bronchial cuffing « Bat wing » pattern	**Auscultation** Bilateral and diffuse fine crackles +/- Wheeze	**Palpation/percussion** Palpable chest wall fremitus	**Inspection** Inspiratory dyspnea
Clinical examination is compatible with pneumothorax			
Chest X-rays Air without lung markings in the least dependant part of the chest unless loculated	**Auscultation** Abolished vesicular sound	**Palpation/percussion** Hyper tympanic Abolished vocal fremitus	**Inspection** Decreased chest mobility
Clinical examination is compatible with reduced of aeration at the most dependent parts of the lungs			
Chest X-rays Lobar consolidation or interstitial opacities at the inferior parts of the lungs	**Auscultation** Decreased or abolished vesicular sound at the lung bases	**Palpation/percussion** Dullness at the lung bases	**Inspection** Decreased chest mobility
Clinical examination is compatible with diaphragm dysfunction			
Chest X-rays Elevation of hemidiaphragm cupola	**Auscultation** Decreased or abolished of basal vesicular sound		**Inspection** Decreased chest mobility Thoracic inspiration Paradoxical respiration
The bilateral or unilateral nature of diaphragm dysfunction is defined by the unilateral or bilateral nature of the previous signs.			
Clinical examination is inconclusive			
No syndrome clearly defined			

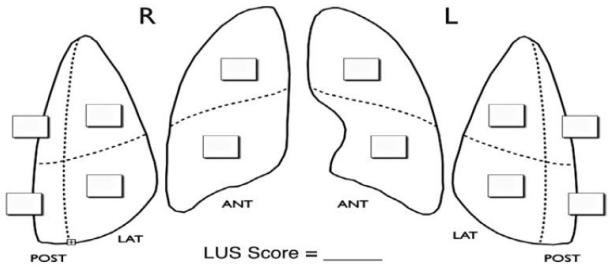
Annexe 2b: Chest physiotherapy treatment modalities

Clinical hypothesis		Chest physiotherapy treatment	
Retained airway secretions	Airway clearance techniques (Rib cage compressions, manual assisted cough, manual lung hyperinflation, ventilator hyperinflation, MIE, ETS/NTS, patient positioning)		
Bronchospasm	Bronchodilators inhalation		
Pneumonia pattern		**Unilateral**	**Bilateral**
	Non intubated	Laterocubitus (diseased lung uppermost) + NIV/CPAP	Seated position + NIV/CPAP
	Intubated	Laterocubitus (diseased lung uppermost) + PEEP	Seated position, prone position + PEEP
Obstructive ~~A~~atelectasis pattern		**Lobar**	**Entire lung**
	Non intubated	Laterocubitus (diseased lung uppermost) + NIV	
	Intubated	Laterocubitus (diseased lung uppermost) + hyperinflation/PEEP	***Refer to medical staff***
Pleural effusion/Passive atelectasis		**Unilateral**	**Bilateral**
		First, refer to medical staff	
	Non intubated	Laterocubitus (diseased lung uppermost) + NIV/CPAP	Seated position + NIV/CPAP
	Intubated	Laterocubitus(diseased lung uppermost)+ PEEP	Seated position + PEEP
Acute pulmonary oedema		***Refer to medical staff***	
	Non intubated	Seated position + NIV	
	Intubated	Seated position	
Pneumothorax	***Refer to medical staff***		
Reduced aeration at dependent parts of the lungs	Seated or upright position, mobilization out of bed		
Diaphragm dysfunction	Seated position, recovery monitoring, IMT		
Clinical examination is inconclusive	***Refer to medical staff***		

MIE = MechanicalInsuflation-Exsuflation ; ETS/NTS = Endotracheal/Nasotrachealsuction ; NIV = Noninvasive ventilation ; CPAP = Continous positive airway pressure ; PEEP = Positive end expiratory pressure ; IMT = Inspiratory muscle training

Annexe 3a: Lung and diaphragm ultrasound procedures (16)

Lung assessment



PSL: Parasternal line; AAL: Anterior axillary line; PAL: Posterior axillary line

Scanning procedure

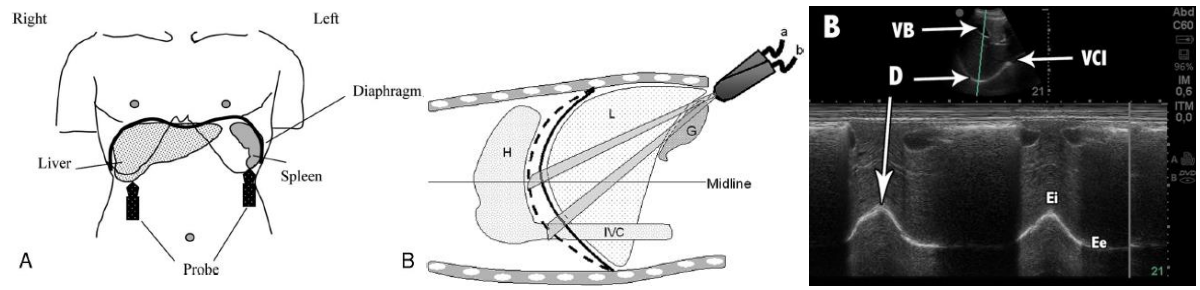
Interstitial syndrome: Investigation is performed at the anterior and lateral thoracic areas. A positive region is defined by the presence of three or more B-lines in a longitudinal plane between two ribs, and a positive exam suggests the presence of two or more positive regions. A convex probe is used.

Consolidation: Examination begins with the lung area of interest (refer to clinical assessment) and may involve the entire lung if necessary. A convex probe is used.

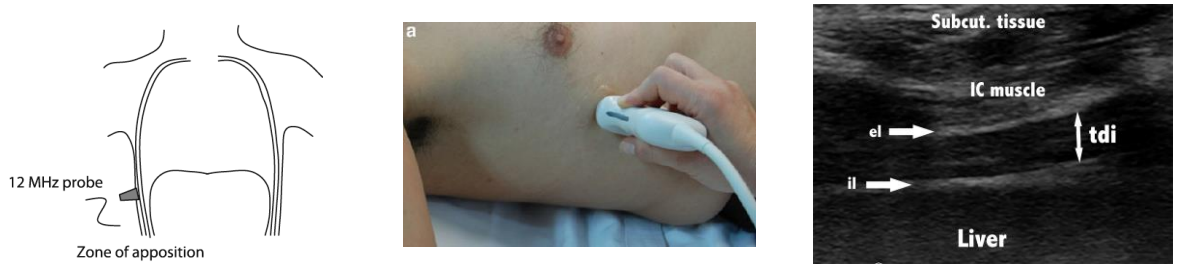
Pneumothorax: In the supine patient, the sonographic technique consists of exploration of the least gravitationally dependent areas progressing laterally. A convex or a linear probe may be used.

Pleural effusion: In the supine patient, the ultrasound probe is placed in the postero-inferior area in the transverse view. The maximum distance between the parietal and visceral pleura (PLD) is measured 3 cm above the inferior pole of the lung at the end of expiration.

Diaphragm assessment – excursion and thickeness*(If ventilated patient use PSV mode with PS = 7 and PEEP = 0)*

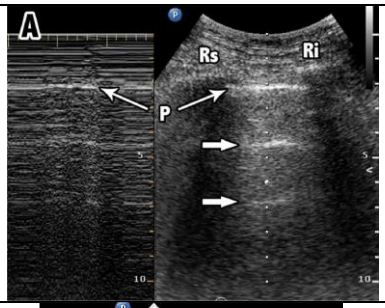
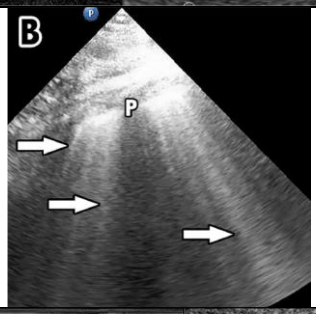
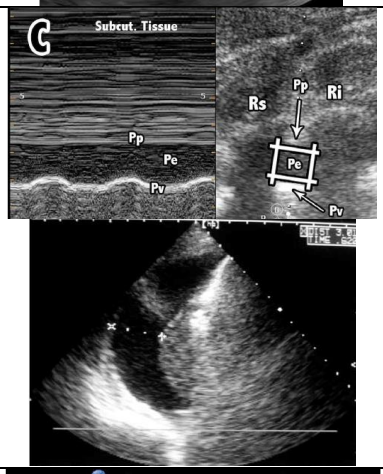
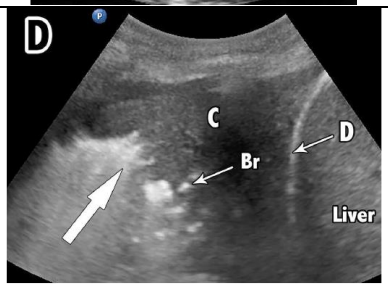
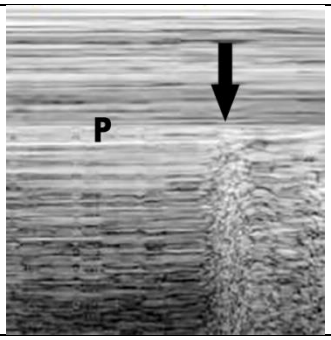
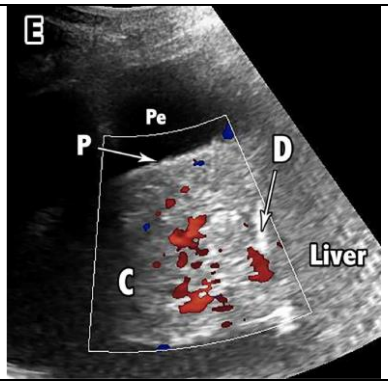


Diaphragm excursion: Anterior subcostal approach: the probe is placed between the anterior axillary line and the mid-clavicular line. B-mode is initially used to determine the best approach and select the exploration line. After the diaphragm is identified, excursion measurements are performed in M-mode: the diaphragm moves toward the probe during inspiration and away from it during expiration. The distance between the end-inspiration and end-expiration points defines the diaphragm excursion. A diaphragm excursion< 2.5 cm (Lerolle Chest, 2009) indicates a diaphragm dysfunction.



Diaphragm thickening: the probe is placed in an intercostal space between the mid-axillary line and the anterior axillary line, 0.5 cm to 2 cm below the costo-diaphragmatic sinus. In B-mode, the diaphragm is observed as a structure made of three distinct layers: a non-echogenic central layer bordered by two echogenic layers. The diaphragm thickening fraction (DTF) measurement is obtained in B-mode using the following formula: DTF (%) = [(end-inspiration thickness – end-expiration thickness)/(end-expiration thickness) x 100]. A DTF < 25% indicates a diaphragm dysfunction.

Annexe 3b: LUS Semiology

<table>
<tr>
<td> 
</td>
<td colspan="2">NORMAL PATTERN
A. Seashore sign (left, M-mode): Tissues above the pleural line are motionless and generate horizontal lines (sea). Below the pleural line, structures (i.e., lung and visceral pleura) are in motion and generate a sandy pattern. Bat sign (right, B-mode): In the intercostal space, the shape of the superior and inferior ribs and pleural line (i.e., hyperechoic line) appear in the shape of a bat. A-lines (right, B-mode): Horizontal repetition artifacts of the pleural line (big arrows) that indicate the presence of lung aeration.</td>
</tr>
<tr>
<td> 
</td>
<td colspan="2">INTERSTITIAL SYNDROME
B.B-lines: Comet-tail artifacts (arrows) that arise from the pleural lines and erase A-lines are nearly always long and always move with lung sliding.</td>
</tr>
<tr>
<td> 
</td>
<td colspan="2">C. PLEURAL EFFUSION
Pleural effusion appears as dependent and anechoic (ie, free of echoes) structures. Pleural effusion occurs between the diaphragm and the pleura, and conducts ultrasounds, C. Sinusoid sign (left, M-mode): During inspiration, the visceral pleura moves toward the parietal pleura; this sign indicates a free pleural effusion. Quad sign (right, B-mode): The visceral pleural, parietal pleura and shadows of the ribs form a quad; this sign indicates a pleural effusion in an intercostal space.
Quantification of pleural effusion: patient in supine with mild trunk elevation at 15°. Ultrasound probe is moved in cranial direction in posterior axillary line. The transverse section perpendicular to the body axis is obtained with pleural separation visible as an anechoic or hypoechoic layer between two pleural layers. The maximal distance between parietal and visceral pleura(Sep) is measured off line at the lung base after freezing the image in end-expiration.</td>
</tr>
<tr>
<td> 
</td>
<td>CONSOLIDATION
D. Shred sign (B-mode): A deep boundary (arrow) with a shredded appearance indicates a partial lobar consolidation. Note the presence of an air bronchogram (Br).</td>
<td> 
</td>
</tr>
<tr>
<td> 
</td>
<td>CONSOLIDATION
E. Tissue-like sign (B-mode) A tissue-like pattern arising from the pleural line (or visceral pleura) of a complete lobar consolidation.</td>
<td>PNEUMOTHORAX
Lung point (M-mode): Refers to the absence of any sliding or moving B-lines at the physical locations where the transition into an area of sliding occurs. Stratospheric sign (M mode): absence of pleural sliding (P).</td>
</tr>
</table>

P = pleural line; Rs = superiorrib; Ri = inferiorrib; Pp = parietal pleura; Pv = visceral pleura; Pe = pleural effusion; C =lung consolidation; D = diaphragm; Br = air bronchogram.

Annexe 4: Lung and diaphragm ultrasound scan report

VENTILATOR SETTINGS *(Surround the mode and fill the settings at the moment of LUS examination)*						
Mode	ACV	SIMV	PCV	PSV	NIV	Spontaneously Breathing
Settings	Tidal volume =		PEEP =	PS =	PEEP =	

PNEUMOTHORAX					
Right	*Present*	*Absent*	**Left**	*Present*	*Absent*
If present, locate the lung point in the diagram below (place an « X »)					

LUNG AERATION

	LAT	*ANT*	*ANT*	*LAT*	
POST / *Superior*	Pleural sliding Lung pulse	Pleural sliding Lung pulse	Pleural sliding Lung pulse	Pleural sliding Lung pulse	Pleural sliding Lung pulse	POST / *Superior*
Inferior	Pleural sliding Lung pulse	Pleural sliding Lung pulse	Pleural sliding Lung pulse	Pleural sliding Lung pulse	Pleural sliding Lung pulse	*Inferior*

Indicate level of lung aeration (0, 1, 2, 3) in the above diagram

LUS score = /36

When lung consolidation is present, indicate the appropriate letter(s)*(in the above diagram, following the « 3 ») :*

a. Deep limiw ith Shred sign
b. Deep limit well defined
c. Dynamic air bronchogram
d. Static air bronchogram
e. Punctiform air bronchogram
f. Linear air bronchogram
g. Fluid bronchogram
h. Vascular pattern

PLEURAL EFFUSION

	Right				Left			
PLD *(cm)*								
Pattern	Anechoic	Heterogeneously echogenic	Homogeneously echogenic	Septated	Anechoic	Heterogeneously echogenic	Homogeneously echogenic	Septated

DIAPHRAGM

	Right		Left	
tdi/tde (cm)				
DTF (%)				
EXC (cm)				

ULTRASOUND DIAGNOSTIC

Normal		**Pneumothorax (L), (R) or Both**	
Alveolar-interstitial syndrome		Focal Homogeneous Moderate	Diffuse Heterogeneous Severe
Lung consolidation			
Pneumonia pattern		Atelectasis pattern	
Unilateral (L)or (R)	Bilateral	Obstructive	Passive
Pleural effusion		Unilateral (L) or (R) Transudative pattern	Bilateral Exsudative pattern
Diaphragm dysfunction		**Loss of aeration in the most dependent parts of the lungs**	
Unilateral (L) or (R)	Bilateral	**No conclusion**	

Scan quality:

Good

Poor

Sonographer:

Annexe 5a: Information sheet for patients

Information sheet for adults taking part in research aiming to evaluate usual care entitled:
«Evaluation of the impact of lung and diaphragm US findings on clinical decisions for chest physiotherapy in patients hospitalized in Intensive Care Unit»

Sir, Madam,

Dr…….. , principal investigator, is inviting you to take part in this research.

Your decision concerning your participation is made of your own free will.

Would you please read the information below very carefully and ask any questions you wish to. You make take as much time as you need to think about taking part or not in this research before reaching your decision.

Context, objectives and procedure of this research

You are hospitalized in an Intensive Care Unit. Your state of health is associated with breathing difficulties which require chest physiotherapy. The aim of the physiotherapy is to improve your breathing. The physiotherapist uses different techniques depending on the specific problems you suffer from. To identify your specific problem he/she will examine you, using a stethoscope to listen to your lungs and refer to the results of the chest x-ray and biological examinations. In this research, we wish to study the impact of including a lung and diaphragm ultrasound scan to know if this examination could modify the physiotherapist's choices with regard to your treatment thanks to the new information it may provide. This LUS-scan will be done by a physiotherapist.

This examination is painless, non-invasive and is perfectly safe. It will be done by a physiotherapist once only and before the respiratory physiotherapy session. An ultrasound scanner with a transducer will be used and a gel will be put on your skin. The examination takes about 15mn.

Constraints in this research

There are no constraints apart from your participation in the research.

Possible adverse effects

As your participation in this research does not involve any treatment other that those currently recommended or any modification of the classical management of patients in critical care, no adverse effects are foreseen.

- **No additional treatment will be given**
- **No additional blood samples will be taken**.

The ultrasonography will be done using a transthoracic approach, which simply means the transducer will be placed on your chest. The examination is therefore non-invasive, completely painless and does not involve exposure to X-rays.

Your participation in this research will involve no additional cost for you.

Ethical and legal aspects

This research was approved by the CPP Ile de France II on…… 2016.

Confidentiality

In the context of this research proposed by Dr..... personal data will be processed to allow analysis of the results of the research.

To this end, your medical information will be sent to the different co-investigators. This information will be identified by a code number. The information may also, in conditions to ensure its confidentiality, be sent to the French healthcare authorities. In compliance with the requirements of the CNIL (law relative to computerized information, files and freedom), you have the right to read and rectify this information. You also have the right to oppose the transmission of information covered by medical confidentiality that may be used and processed in the context of this research.

You also have the right of access either directly or through a physician of your choice to all of your medical information in accordance with article L. 1111-7 of the Public Health Code. These right scan be exercised through the physician who is following you in the context of the research and who knows your identity.

Your decision to take part in this research is made of your own free will.

You can refuse to take part or withdraw your consent at any time without explanation. Refusal to take part or withdrawal of your consent will have no impact on the care you receive.

Do you have any questions?

Dr _____ (tel _____) is available to answer any questions you feel necessary both before and during the research.

Annexe 5b Information sheet for a patient's relative

Information sheet for adults taking part in research aiming to evaluate usual care entitled:
«Evaluation of the impact of lung and diaphragm US findings on clinical decisions for chest physiotherapy in patients hospitalized in Intensive Care Units»

Sir, Madam,

As your relative's condition makes it impossible for him/her to be given or to understand the information for this research, we are giving to you this information and the invitation for Ms. / Mr. (delete as necessary) (family name, first name)…….. to take part in the study presented below, which is under the responsibility of Dr……..principal investigator.

Your decision concerning this participation is made of your own free will.

Would you please read the information below very carefully and ask any questions you wish to. You make take as much time as you need before reaching your decision as to whether your relative should take part or not in this research.

Context, objectives and procedure of this research

Your relative is hospitalized in an Intensive Care Unit. His/her state of health is associated with breathing difficulties which require chest physiotherapy. The aim of the physiotherapy is to improve his/her breathing. The physiotherapist uses different techniques depending on the specific problems he/she suffers from. To identify his/her specific problem the physiotherapist will examine your relative using a stethoscope to listen to his/her lungs and refer to the results of the chest x-ray and biological examinations. In this research, we wish to study the impact of including a lung and diaphragm ultrasound scan to know if this examination could modify the physiotherapist's choices with regard to your relative's treatment thanks to the new information it may provide. This LUS-scan will be done by a physiotherapist.

This examination is painless, non-invasive and is perfectly safe. It will be done by a physiotherapist once only and before the respiratory physiotherapy session. An ultrasound scanner with a transducer will be used and a gel will be put on your relative's skin. The examination takes about 15mn.

Constraints in this research

There are no constraints apart from your relative's participation in the research.

Possible adverse effects

As participation in this research does not involve any treatment other that those currently recommended or any modification of the classical management of patients in critical care, no adverse effects are foreseen.

- **No additional treatment will be given**
- **No additional blood samples will be taken**.

The ultrasonography will be done using a transthoracic approach, which simply means the transducer will be placed on his/her chest. The examination is therefore non-invasive, completely painless and does not involve exposure to X-rays.
Your relative's participation in this research will involve no additional cost for him/her.

Ethical and legal aspects

This research was approved by the CPP Ile de France II on…… 2017.

Confidentiality

In the context of this research proposed by Dr..... your relative's personal data will be processed to allow analysis of the results of the research.
To this end, his/her medical information will be sent to the different co-investigators. This information will be identified by a code number. The information may also, in conditions to ensure its confidentiality, be sent to the French healthcare authorities. In compliance with the requirements of the CNIL (law relative to computerized information, files and freedom), your relative has the right to read and rectify this information. He/she also has the right to oppose the transmission of information covered by medical confidentiality that may be used and processed in the context of this research.
Your relative also has the right of access either directly or through a physician of his/her choice to all of his/her medical information in accordance with article L. 1111-7 of the Public Health Code. These right scan be exercised through the physician who is following him/her in the context of the research and who knows his/her identity.

Your decision for your relative to take part in this research is made of your own free will.
You can refuse this participation or withdraw your consent at any time without explanation. Refusal to take part or withdrawal of your consent will have no impact on the care your relative receives.

Do you have any questions?

Dr _____ (tel _____) is available to answer any questions you feel necessary both before and during the research.