Respiratory and circulatory effects of lateral body positioning

The result from 11 healthy volunteers

The white paper

Martin Ričl, Joao Batista Borges M.D., Ph.D. (2x), Leoš Tejkl Ing., Dominik Hladík M.D., Nela Rezbáriková M.D., Mikuláš Mlček M.D., Ph.D.

Date 30.6.2020
Client LINET Group SE
Version Internal document
Status Completed

The content

1 Abstract 3

2 Introduction 4

3 Methods 4

3.1 Setup 5

3.2 Study protocol 6

4 Measurements and data analysis 7

4.1 User experience with LINET Multicare and Hill-Rom Progressa 7

4.2 Maximum tilt and the body twist 7

4.3 Ventilation distribution and ventilation homogeneity 9

4.4 Changes in functional residual capacity (FRC) 10

5 Changes in blood pressure 10

6 SpO_2 and other measured parameters 11

7 Subjective evaluation of the lateral tilt by volunteers 12

8 The conclusion 12

9 Reference 13

1 Abstract

Objective: To compare respiratory and cardiovascular effects of lateral body positioning performed with Multicare-Opticare platform-based rotation (ALT) and Hill Rom-Pulmonary surface mattress-based rotation (CLRT).

Methods: Respiratory and cardiovascular assessments on eleven healthy spontaneously breathing volunteers during the same protocolized sequence of body positions made with the two beds. After going through the whole protocol (two beds), all volunteers responded to a questionnaire.

Main Results: During the sequence of body positions, the LINET Multicare Opticare system performed better than the Hill-Rom Progressa Pulmonary in the following evaluations: subjective evaluation of the user experience, max body tilt, twist of the body, and ventilation homogeneity. And, after the sequence of body positions, lung inflation, return to iso-NIBP line and prediction of change, and subjective evaluation by the volunteers was also better with the LINET bed.

Conclusions: Lateral tilting performed with the Multicare-Opticare platform-based rotation (ALT) bed provided better respiratory and cardiovascular effects than when performed with the Hill Rom-Pulmonary surface mattress-based rotation (CLRT) bed.

Keywords: body positioning, respiratory system, cardiovascular system, LINET Multicare, Hill-Rom Progressa Pulmonary surface, ALT, CLRT

2 Introduction

Acute respiratory distress syndrome (ARDS)[1] is a life-threatening lung condition that prevents enough oxygen from getting to the lungs and into the blood. The physiological and clinical effects of prone position on ARDS have been studied for many years[2]. In 2013 was demonstrated that the early application of prolonged prone-positioning sessions significantly decreased mortality of patients with severe ARDS[3]. Nowadays, the prone position has become increasingly recommended in patients with severe ARDS[4].

The effects of lateral position, another potentially beneficial kind of body positioning, remain largely unknown. Patient rotation is generally used for the prevention of pressure injuries[5] and airways and pulmonary hygiene. Some published data suggest that patient rotation may be used also as a strategy for the prevention of ventilator-associated pneumonia[5]. There is a need for a better understanding of the respiratory and cardiovascular effects of lateral tilt both in normal volunteers and in patients.

This study was performed in the Laboratory of experimental physiology, 1st Faculty of Medicine, Charles University in Prague, in which meaningful comparisons were made between the platform-based rotation (ALT - Multicare) and mattress-based rotation (CLRT – Progressa Pulmonary).

3 Methods

Eleven spontaneously breathing healthy volunteers (medical students) were studied while resting in two different ICU bed systems: LINET Multicare bed frame plus Opticare mattress and Hill-Rom Progressa Pulmonary system.

The effects of lateral tilt on the respiratory and cardiovascular systems were measured by non-invasive methods. To evaluate the feelings of comfort and safety during the sequence of body positions, after going through the whole protocol each volunteer responded to a questionnaire.

Data measured and analysed

1. **LINET ALT vs. Hill Rom CLRT user experience**
2. **Body inclination by 6 inclinometers (Sagittal plane: Forehead, 1st intercostal space, processus xiphoideus, ribs arch; distal femur Left/Right)**
3. **EELI (End-expiratory lung impedance), ventilation distribution Left/Right; Enlight 1800**
4. **NIBP Edan (Noninvasive blood pressure) Left/Right**
5. **SpO_2 Nihon Kohden – Blood oxygen saturation**
6. **Massimo Radical 7 with Rainbow technology (SpO_2, PVi, Pi, SpHb, SpCO, PR, SpMet)**
7. **Subjective evaluation - questionnaire, comfort, and general feelings**

3.1 Setup

The volunteers were placed on the bed. On the Multicare bed, they were stabilized by the set of stabilization cushions for ALT, whereas on the Progressa bed their bodies were not stabilized (Hill Rom does not provide anybody support cushions for CLRT). Eleven volunteers were studied.

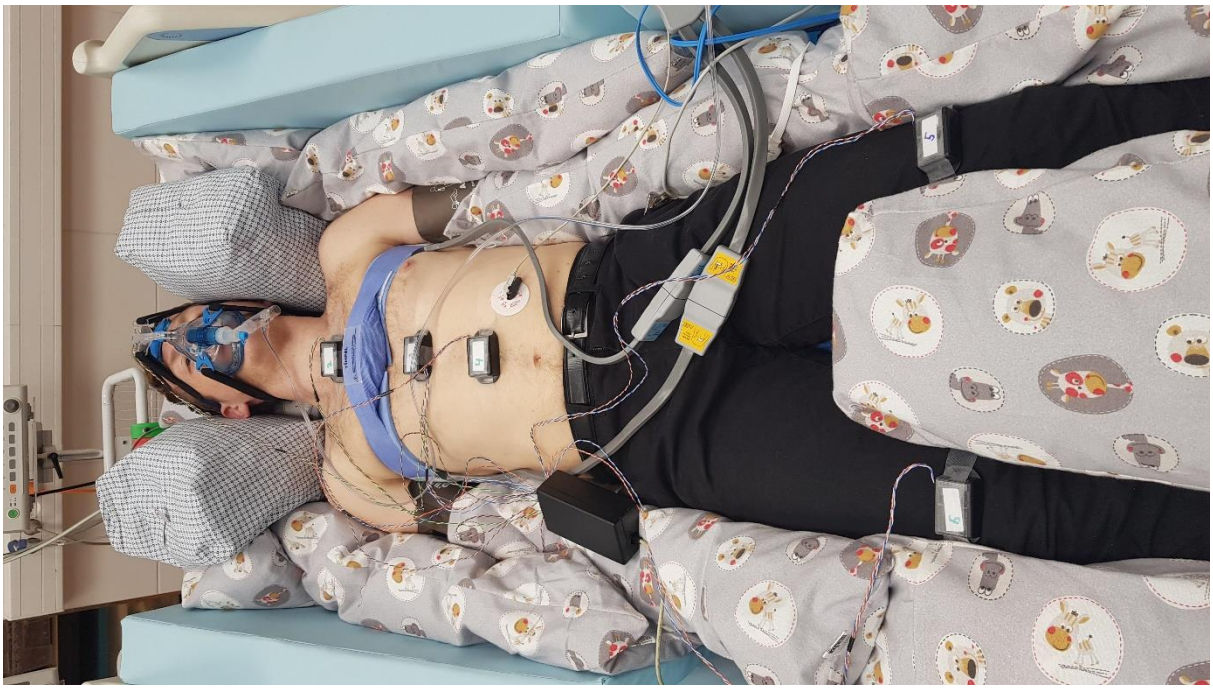

Figure1: *Body and sensors setup on the LINET Multicare bed*

Figure 2: *Body and sensors setup on the Hill Rom bed*

3.2 Study protocol

1. **5 minutes rest in supine position → measurements**
2. **5 minutes rest in semirecumbent 30° position → measurements**
3. **5 minutes rest in maximum Lateral Left + semirecumbent 30° position → measurements**
4. **5 minutes rest in semirecumbent 30° position → measurements**
5. **5 minutes rest in maximum in Lateral Right + semirecumbent 30° position → measurements**
6. **5 minutes rest in semirecumbent 30° position → measurements**
7. **Change the bed and repeat the same sequence**

4 Measurements and data analysis

4.1 User experience with LINET Multicare and Hill-Rom Progressa

Following the protocol, the body position was changed after 5 minutes resting in each position, immediately after doing all the measurements. The user experience is a matter that is influenced by individual preferences. LINET provides a simple and user-friendly design, whereas Hill-Rom provides more graphics and animations. For performing the lateral tilt, Multicare has fewer steps to change the position and, in general, is more practical, allowing immediate action to tilt the body. Also, to change the body position back to supine, Multicare allows immediate action, which is extremely important in situations as unexpected and acute hemodynamic instabilities or cardiac arrest. Besides, Multicare offers the possibility of defining the angle, whereas Progressa does not - the tilt is defined by "%" of maximum tilt.

Parameter / Action	LINET	Hill Rom
Prepare to Max tilt	On the main display, one-button action	Only through CLRT programming, turn assist doesn't tilt to max
To reach max tilt	On Display or ACP control → press and keep the tilt button until max tilt is achieved (5 sec)	On display → Pulmonary functions CLRT menu → program 100% tilt on the chosen side → start therapy, wait until max tilt is achieved (45 seconds)
To change to the max tilt on the opposite side when desired	On Display or ACP control → press and keep the tilt button until max tilt is achieved (10 sec)	On display, → CLRT menu → Stop therapy → reprogram the cycle → start therapy (1,5 minute)
Options to reach max tilt	Manual control or ALT program	CLRT program

Comparing the two procedures of performing maximum tilt, Multicare offers more control and flexibility, takes less time to achieve maximum tilt, and allows to take immediate action to change body position.

4.2 Maximum tilt and the body twist

Six custom-made inclinometers that provided continuous, real-time data, were placed on the volunteers' bodies. Inclination if each body part was measured continuously during the whole protocol. Average body inclinations in the lateral maximum position were calculated.

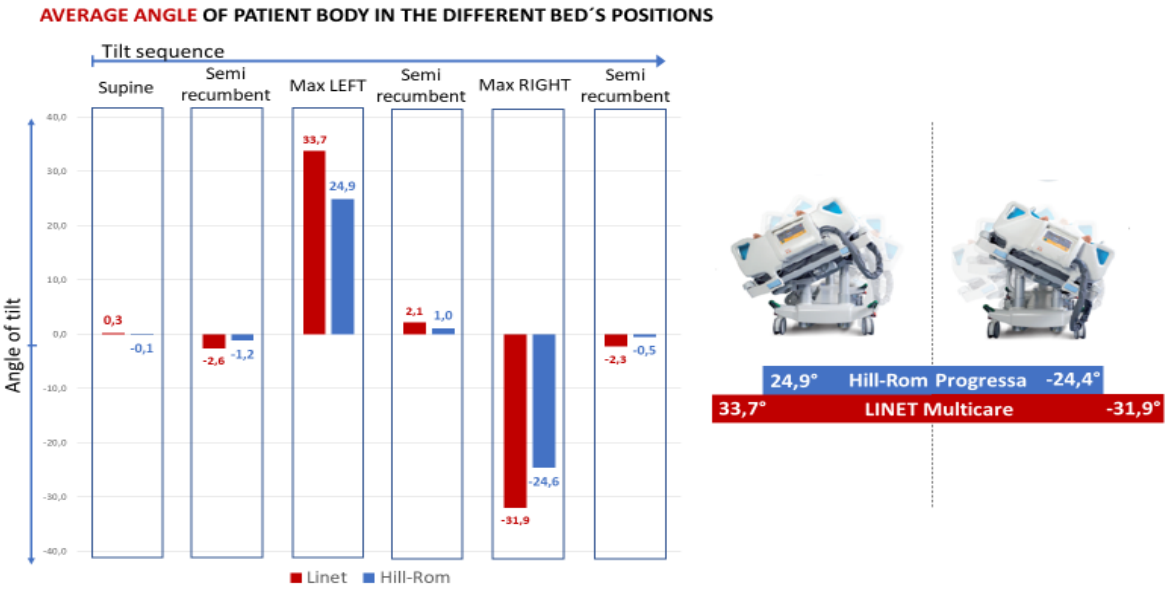

Figure 3: *In each position, the largest difference between all inclinometers were calculated. This value was taken as representative of the body twist. The data shows that tilting on Multicare resulted in a larger average body tilt and also less twisted than on Hill-Rom*

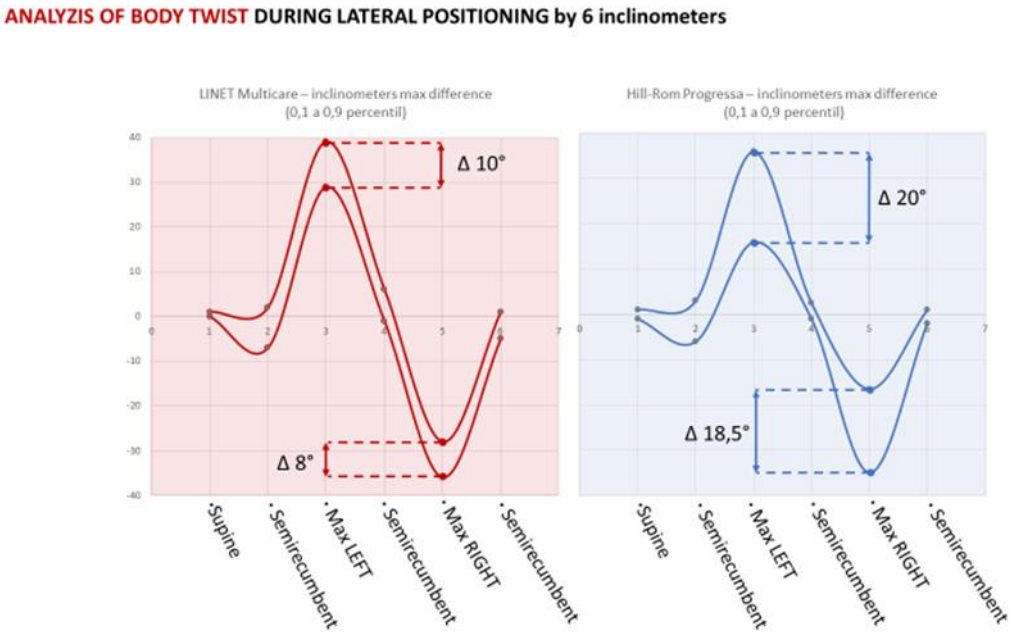

Figure 4: *Analysis of body twist in different positions. Found maximum difference between inclinometers on each volunteer in each position (Δ value), represents the level of the body twist measured on each individual.*

LINET Multicare afforded to tilt the body in a larger degree of tilt. These findings demonstrate that the gravitational forces at play are stronger on LINET Multicare when compared with Hill-Rom Progressa Pulmonary. On the other hand, the twisting of the body was approximately 100% larger on the Hill-Rom Progressa bed.

Position	LINET Multicare	Hill-Rom Progressa
Max lateral left	Δ 10°	Δ 20°
Max lateral right	Δ 8°	Δ 18,5°

4.3 Ventilation distribution and ventilation homogeneity

Electrical impedance tomography (EIT)-based ventilation distribution maps[6] were acquired after resting in each position five minutes. Consistently, in the majority of the volunteers, a relevant ventilation inhomogeneity was founded on the Progressa Pulmonary bed. A plausible explanation for that may be related to the construction of Pulmonary surface with two big longitudinal air cells. Different pressures in these two cells may create different pressures applied on the dorsal part of the chest and, consequently, generate such ventilation inhomogeneity. The inhomogeneity was detected also in a fully flat supine position, which suggests that body twisting did not play a role. At the end of the protocol on the Progressa Pulmonary bed, a partial reduction of the ventilation inhomogeneity was also detected, likely due to the positive effects of body positioning on ventilation distribution.

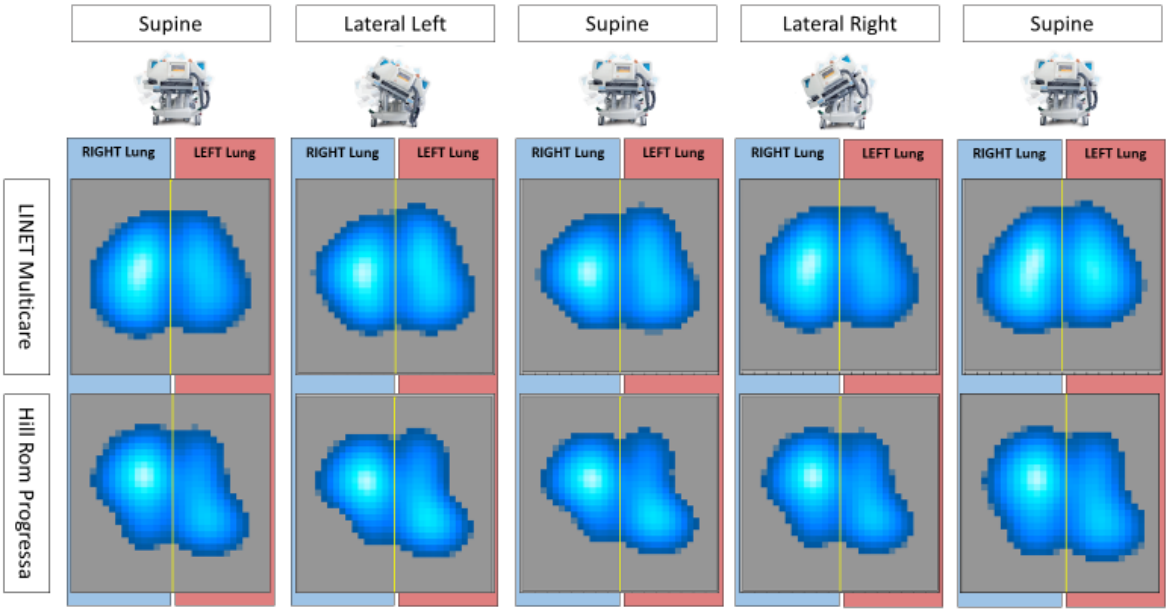

Figure 5: *EIT-based ventilation distribution maps on different beds and positions.*

4.4 Changes in functional residual capacity (FRC)

Functional Residual Lung Capacity (FRC) is the amount of volume remaining in the lung after a normal exhalation. Changes in FRC are very well correlated and can be estimated by changes in End-Expiratory Lung Impedance (EELI), which is continuously acquired by EIT and can be computed from the EIT data. Changes in EELI were estimated in all body positions in all volunteers. After 5 minutes of resting in each position, EELI was analysed and compared with the corresponding EELI value in the first semirecumbent position – used as a reference. A very important result is the net gain, i.e. the relative gain in EELI (FRC) between the first step before the sequence of lateral tilts and the last one.

The net gain on EELI (FRC) after the sequence of body positions on the Multicare bed was 40% of the initial tidal volume, which can be estimated as a gain of 200 ml of air. On the Hill-Rom Progressa Pulmonary system was 16% of initial tidal volume, which can be estimated as a gain of 80 ml of air.

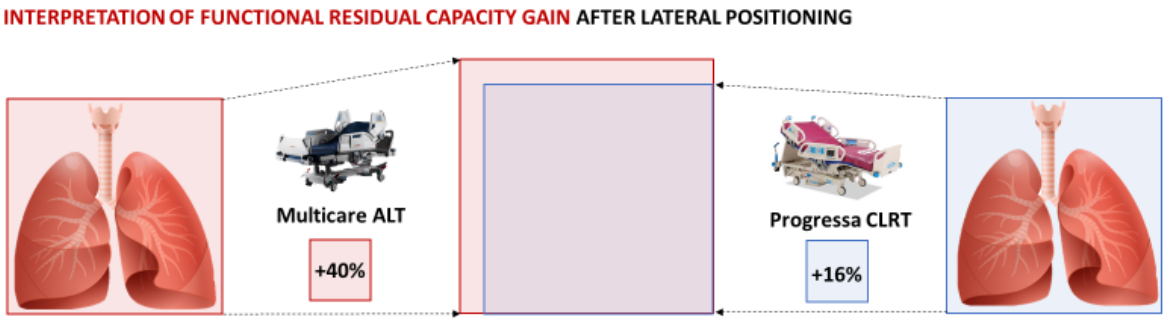

Figure 6: *Illustration of the net gain on EELI (FRC) after the sequence of lateral tilts.*

5 Changes in blood pressure

Blood pressure on left and right arms were measured for all steps of the protocol. They were measured by pressure cuff on the left arm at the level of left ventricle in supine or semirecumbent position.

Lateral tilt affected the value of the measured blood pressure due to the position of the body. The range of differences - caused by the position change of pressure cuff – was between -7% to + 14% of mean arterial blood pressure. This information must be shared with caregivers. It doesn't mean that lateral positioning changes the blood pressure, but it means that the blood pressure measurement is affected by the position change of pressure cuff during lateral tilting.

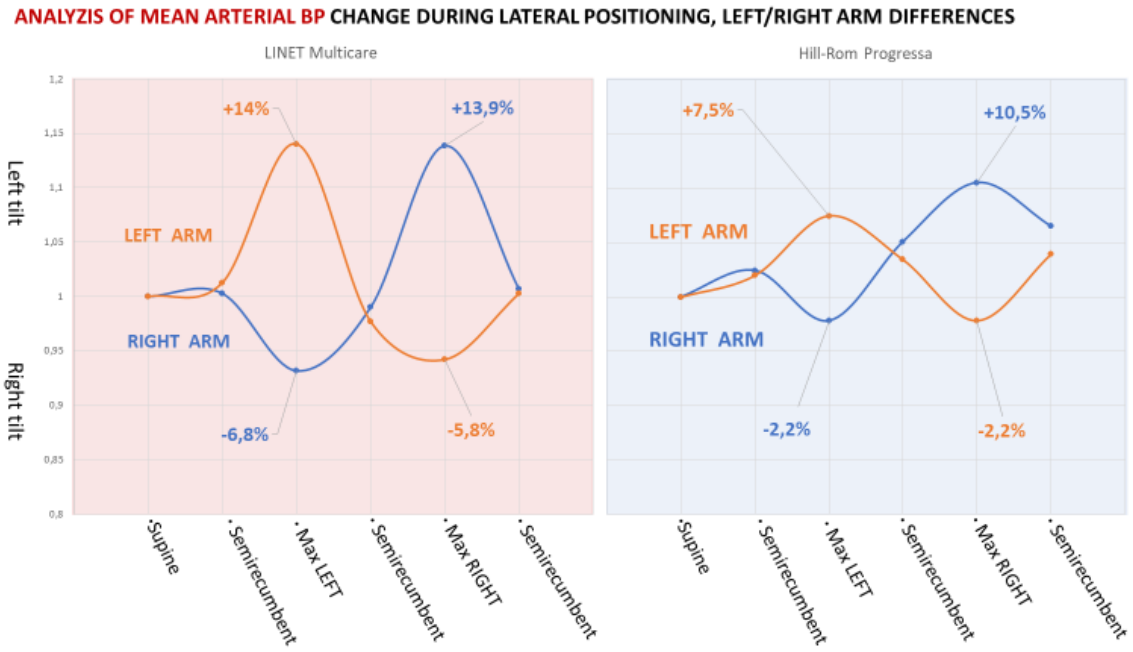

Figure 7: *Analysis of Mean Blood Pressure during lateral tilt.*

The results exhibit the differences in measured Blood Pressure due to different body positions. These deviations are very predictable. On the Multicare bed, it was +14% at the arm in the lower position and -6% at the arm in the upper position. On the Hill-Rom bed, these differences were smaller due to the lesser tilt angle and, consequently, a lower effect of gravity. On the Multicare bed, the pressure curve ended on iso-pressure line (1 on Y-axis), which indicates full Blood Pressure normalization after the sequence of body positions. On the Hill-Rom bed, the pressure curve did not return to iso-pressure line after the sequence of body positions

6 SpO_2 and other measured parameters

Average Oxygen Saturation (SpO_2) was 98%. No important SpO_2 changes or SpO_2 impairments were detected. By Rainbow technology, from Massimo Radical, the seven following parameters were measured with no relevant changes:

- SpO_2 – Oxygen Saturation
- PVi – Pressure Variation index
- Pi – Perfusion index
- SpHb – Total Haemoglobin
- SpCO - Carboxyhaemoglobin
- PR – Pulls Rate
- SpMet – Methaemoglobin

7 Subjective evaluation of the lateral tilt by volunteers

At the end of the whole protocol, each volunteer was asked to fill in a questionnaire. The questions were prepared to evaluate the feelings of comfort and safety during the sequence of body positions.

The volunteers felt the tilt very safe on both beds. On Multicare bed, they subjectively evaluated the feeling of body instability, body shift, and body twist as smaller in comparison with the Hill- Progressa bed. Overall comfort was evaluated higher on the Multicare Opticare bed.

Question:	LINET Multicare (Average)	Hill-Rom Progressa (Average)
	0-10 (10 the best or the most)	**0-10** (10 the best or the most)
What was your general level of comfort?	8,73	6,55
How much did you feel the body shift during lateralization?	3,18	4,36
Did you feel any instability while being positioned to max tilt?	1,82	4,18
Did you feel any twist of your body during the tilt?	1,09	4,45
Did you feel unsafe during the tilt?	1,00	1,82

8 The conclusion

Lateral body positioning performed with the Multicare-Opticare platform-based rotation (ALT) bed provided better respiratory and cardiovascular effects than when performed with the Hill Rom-Pulmonary surface mattress-based rotation (CLRT) bed.

9 Reference

1. Bellani G, Laffey JG, Pham T, et al. Epidemiology, Patterns of Care, and Mortality for Patients With Acute Respiratory Distress Syndrome in Intensive Care Units in 50 Countries. JAMA 2016;315:788-800.
2. Kallet RH. A Comprehensive Review of Prone Position in ARDS. Respiratory care 2015;60:1660-87.
3. Guerin C, Reignier J, Richard JC, et al. Prone positioning in severe acute respiratory distress syndrome. N Engl J Med 2013;368:2159-68.
4. Baston CM, Coe NB, Guerin C, Mancebo J, Halpern S. The Cost-Effectiveness of Interventions to Increase Utilization of Prone Positioning for Severe Acute Respiratory Distress Syndrome. Crit Care Med 2019;47:e198-e205.
5. Kang SY, DiStefano MJ, Yehia F, Koszalka MV, Padula WV. Critical Care Beds With Continuous Lateral Rotation Therapy to Prevent Ventilator-Associated Pneumonia and Hospital-Acquired Pressure Injury: A Cost-effectiveness Analysis. Journal of patient safety in 2019.
6. Frerichs I, Amato MB, van Kaam AH, et al. Chest electrical impedance tomography examination, data analysis, terminology, clinical use and recommendations: consensus statement of the TRanslational EIT developmeNt stuDy group. Thorax 2017;72:83-93.