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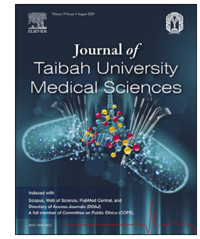

Original Article

# Effects of the thoracic block technique on vital signs, blood gases, and lung compliance in children with atelectasis

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**الملخص**

**أهداف البحث:** دراسة تأثير تقنية الإحصار الصدري على العلامات الحيوية وغازات الدم الشرياني وامتثال الرئة لدى الأطفال المصابين بالانخماص الأحادي الجانب والذين يتم تهويتهم ميكانيكيا.

**طريقة البحث:** أربعة وأربعون طفلا يخضعون للتهوية الميكانيكية بانخماص أحادي الجانب، تراوحت أعمارهم من 4 أشهر إلى 4 سنوات، من كلا الجنسين. تم ضمهم من مستشفى أبوالريش، وحدة العناية المركزة - جامعة القاهرة. تم تقسيمهم إلى مجموعتين ضابطة ودراسة: المجموعة (أ) ضمت اثنين وعشرين طفلا تلقوا برنامج العلاج الطبيعي للصدر، المجموعة (ب) ضمت اثنين وعشرين طفلا تلقوا نفس برنامج العلاج الطبيعي للصدر بالإضافة إلى تقنية الحصار الصدري. تم استخدام أقطاب تخطيط القلب الكهربائي وجهاز التنفس الصناعي الميكانيكي وتحليل غازات الدم لتقييم معدل التنفس ومعدل ضربات القلب والامتثال الديناميكي وغازات الدم الشرياني على التوالي.

**النتائج:** أظهرت النتائج انخفاضا ملحوظا في معدل التنفس ومعدل ضربات القلب في مجموعة الدراسة مقارنة بالمجموعة الضابطة. كانت هناك زيادة معنوية في ضغط الأوكسجين في الدم الشرياني و تشبع الدم بالأكسجين في كلا المجموعتين، وكانت هذه الزيادة أكثر وضوحا في المجموعة (ب) من المجموعة (أ) على التوالي. كان هناك انخفاض كبير في الضغط الجزئي لثاني أوكسيد الكربون في كلا المجموعتين، وكان هذا الانخفاض أكثر أهمية في المجموعة (ب) من المجموعة (أ) وزيادة كبيرة في امتثال الرئة الديناميكي في كلا المجموعتين، وكانت هذه الزيادة أكثر أهمية في المجموعة (ب) من المجموعة (أ).

**الاستنتاجات:** قد يؤدي تطبيق تقنية الإحصار الصدري على الأطفال المصابين بالانخماص على التهوية الميكانيكية إلى تحسن غازات الدم الشرياني، والامتثال الديناميكي للرئة وليس له أي تأثير سلبي على معدل ضربات القلب ومعدل التنفس مقارنة بتقنيات العلاج الطبيعي للصدر فقط.

**الكلمات المفتاحية:** غازات الدم الشرياني؛ انخماص؛ امتثال الرئة؛ التهوية الميكانيكية؛ تقنية الكتلة الصدرية؛ علامات حيوية

**Abstract**

**Objectives:** This study was aimed at examining the effects of the thoracic block technique on vital signs, arterial blood gases, and lung compliance in children with unilateral atelectasis receiving mechanical ventilation.

**Methods:** Forty-four boys and girls with unilateral atelectasis and receiving mechanical ventilation, ranging in age from 4 months to 4 years, were recruited from the Abo El-Reesh Hospital intensive care unit at Cairo University. They were assigned to control and study groups: group A included 22 children receiving chest physical therapy, and group B included 22 children receiving the same chest physical therapy program as well as the thoracic block technique. Electrocardiography, mechanical ventilation, and blood gas analysis were conducted to assess the respiratory and heart rates, dynamic compliance, and arterial blood gases, respectively.

**Results:** Respiratory rate and heart rate were significantly lower in the study group than the control group ($p = 0.03$). $PaO_2$ and $SaO_2$ increased in both groups, and the increase was more significant ($p = 0.01$ and $0.001$, respectively) in group B than group A. A significant decrease in $PaCO_2$ was observed in both groups, and the

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decrease was more significant in group B than group A ($p = 0.02$). A significant increase in dynamic lung compliance was observed in both groups, and the increase was more significant in group B than group A ($p = 0.01$).

**Conclusions:** Applying the thoracic block technique rather than chest physical therapy techniques alone in children with atelectasis receiving mechanical ventilation may lead to improvements in arterial blood gases and dynamic lung compliance, and has no negative effects on heart rate and respiratory rate.

**Keywords:** Arterial blood gases; Atelectasis; Lung compliance; Mechanical ventilation; Thoracic block technique; Vital signs

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## Introduction

Pediatric community-acquired pneumonia is defined as "the appearance of pneumonia signs and symptoms in a previously healthy child as a result of an infection which has been developed outside of the hospital."[1] Pulmonary atelectasis refers to a lung that has partially collapsed or insufficiently expanded. As the atelectasis condition worsens, the blood circulating through the area dissolves the trapped gas in the alveoli, thereby causing hypoxia and pulmonary vasoconstriction.[2] Lung collapse negatively affects lung compliance, pulmonary vascular resistance, and oxygenation status, and the arterial blood gases (ABG) demonstrate arterial hypoxemia.[3,4] A primary negative predictor of unsuccessful extubation in children overall is the presence of lobar collapse, which impairs gas exchange.[5]

In critical care units and postoperative recovery units, atelectasis is a frequent pulmonary alteration that may indicate that a child requires extra respiratory care, such as oxygen supplementation and artificial ventilation, if the manifestations are severe.[6] Chest physiotherapy (CPT) for those children is a non-invasive therapy that clears the lungs by clearing the airways. Physical therapists use postural drainage, cupping, shaking, and deep respiratory exercises to remove mucus, improve respiration efficiency, and prevent lung collapse.[7]

The thoracic block technique (TBT) is a manual technique that combines non-invasive artificial ventilation (with a mask) or invasive artificial ventilation (with an endotracheal tube) with manual compression of most un-collapsed areas of the lung during exhalation, such that only the atelectic region was free. Re-inflation of the alveoli may increase oxygenation status by decreasing or resolving improper ventilation issues, through alteration of thoracic pressure or proper positioning.[7] The positive pressure from this technique improves the ventilation/perfusion relationship, decreases the work of breathing, increases gas exchange surfaces, encourages re-expansion of already-collapsed alveoli, and decreases intrapulmonary pressure, thereby contributing to greater oxygenation. This non-invasive method is applied through external manual compression on one side of the chest and is a safe technique.[8]

Few studies have focused on the effects of the TBT on atelectasis in children. Previous research conducted by our team[9] has indicated that the TBT increases the percentage of fully improved lobes of atelectatic lungs, according to chest X-rays, thus laying groundwork for investigating the effects of the TBT on more variables affected by atelectasis. Therefore, this study conducted a trial to examine a technique that might effectively reverse the effects of atelectasis in children, thus increasing their rate of recovery and decreasing their mortality rate.

## Materials and Methods

### *Study design*

This controlled clinical trial enrolled 44 children treated at our intensive care unit (ICU), who were assigned to one of two groups according to closed envelopes. In the control group (group A), 22 children received the CPT program only, whereas in the study group (group B), 22 children received the CPT program and the TBT. G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) was used for calculating sample size, on the basis of data on respiratory rates obtained from a pilot study conducted in five children per group. The required sample size was found to be 20 children per group. On the basis of an estimated dropout rate of 10%, this number was increased to 22 children per group. Calculations were based on $\alpha = 0.05$, power = 80%, and effect size = 0.92. Post hoc power analysis was conducted and yielded an average power of 85% for the study. The study procedures were explained to the parents, who provided signed consent for participation. The study was registered at clinicaltrials.gov under number NCT05821998.

### *Participants*

As shown in the flowchart (Figure 1), at the beginning of the study, 54 children were recruited, but 10 children did not continue. Four children were excluded for not meeting the inclusion criteria, one child died, and five children were extubated before the second re-evaluation.

Forty-four children (23 boys and 21 girls) were recruited from the Abo El-Reesh Hospital ICU, Cairo University. The children ranged in age from 4 months to 4 years; were diagnosed with community acquired pneumonia; received mechanical ventilation; had unilateral partial to total lung atelectasis, as detected by chest X-ray; and received partial sedation only for ventilator synchronization. Children were excluded from this study if they were medically unstable (e.g., had bradycardia, tachycardia, or tachypnea), or had pneumothorax, rib fracture, or uncontrolled convulsions.

### *Instrumentation*

- Electrocardiography was used to monitor the heart rate (HR) and respiratory rate (RR).

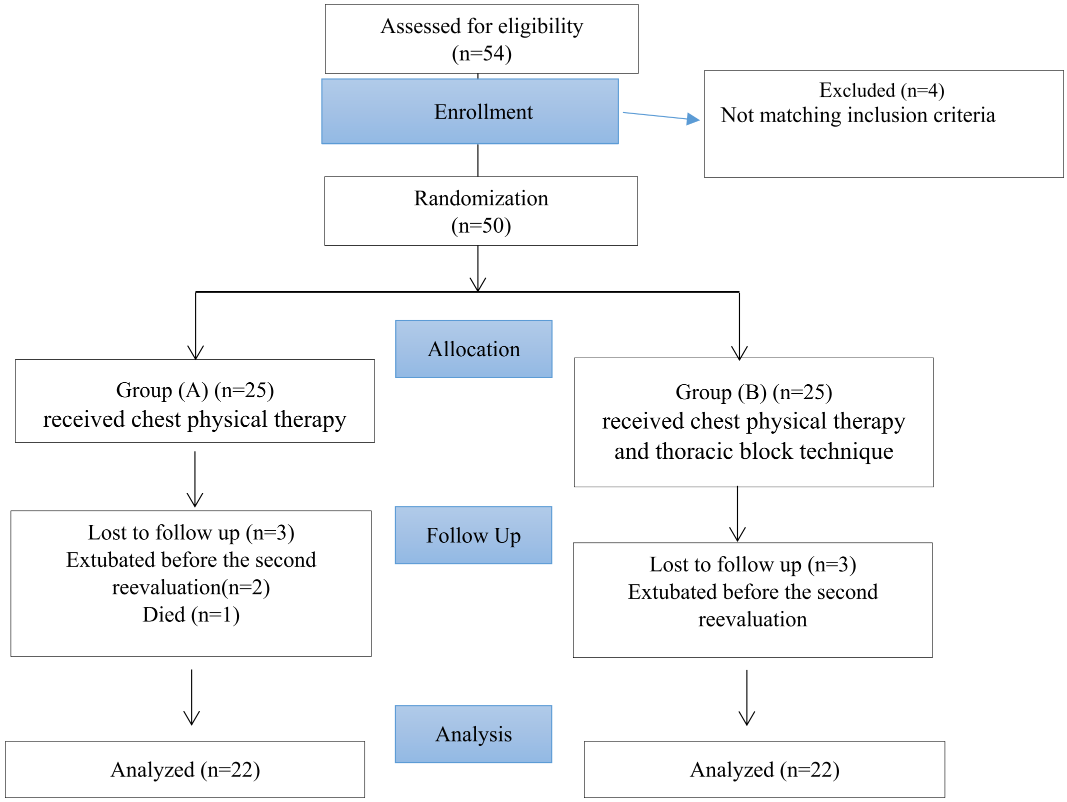


**Figure 1:** Flow chart of the study.

- An ABG analyzer (GEM premier 3000, produced in the United States in 2000) was used for ABG analysis to measure $PaO_2$, which provides information on oxygenation status, and $PaCO_2$ in the blood, which is an indicator of ventilation status and $SaO_2$.
- A mechanical ventilator (Maquet Critical Care AB, Solna, Sweden) was used to measure dynamic lung compliance (Cdyn). Cdyn represents the difference in volume with respect to the difference in pressure across tidal breath.

### Procedures

#### Evaluation

1. **Heart rate and respiratory rate:** Each child was placed in supine position, with the head of the bed elevated 30°. Electrocardiography leads were positioned on the chest, one near each clavicle and one near the fourth intercostal gap at the left mid-axillary line.[8] HR and RR from the monitor were recorded before the session and 10 minutes after the session had ended, for regular monitoring. Monitoring proceeded to ensure that the child was stable, but only data from the first and last days were statistically analyzed.
2. **Arterial blood gases:** The obtained samples were placed in the blood gas analyzer to detect $PaO_2$, $PaCO_2$, and $SaO_2$. ABG was measured on the first day before the session and the tenth day after the session.
3. **Dynamic lung compliance:** Dynamic lung compliance was measured directly from the ventilator on the first day before the session and the last day after the session.

### Intervention

#### CPT program

Physical therapy started from the second day after ICU admission. Both groups received the CPT program for 30 minutes, in one session daily for 10 days.

1. **Percussion:** The child was placed in side lying posture and the therapist clapped with his hand (cupped) for 5 minutes on the dorsal, lateral, and frontal regions of the thorax on each side.[10] Percussion applied across bone prominences, the last few ribs, the spine, drainage tubes, the sternum, the abdomen, sutured areas, the kidneys, the liver, or below the rib cage is not advised and was avoided.[11]
2. **Vibration:** The child was placed in a side-lying posture on each side, and in supine position. A mechanical vibrator (Unix UM-30 electronic, Seoul, Korea) was placed on the child's anterior and posterior chest. Another maneuver involved having the child lie supine while receiving manual chest vibration for 5 minutes on the upper, middle, and lower chest zones.[12]
3. **Modified postural drainage:** The child was placed in one of the following positions for 15 minutes: supine, to drain the anterior basal lobe, with the head raised 15°−30°; side-lying, to drain the medial and lateral basal lobes; or

side-lying to prone, to drain the posterior basal lobe. Inverted position was avoided, and the affected lung was uppermost.[13]

*Thoracic block technique*

The study group received CPT as well as the TBT. The child's head was raised 30° while lying on the back. The physical therapist placed one hand on the front of the chest and the other hand on the back. Manual compression was applied on one side of the chest as the child exhaled, such that only the atelectasis area, as detected previously by chest X-ray, was left free. Ultra-sonography guidance was not used, and the children received partial sedation only for ventilator synchronization. Depending on the child's response (e.g., crying or remaining still in a calm state, or changes in HR), the procedure was repeated several times consecutively. Compression was maintained for 20 seconds and was followed by a 20-second rest. Each child underwent ten sessions, with one session per day for 10 days.[8] In the presence of hemodynamic instability, such as bradycardia (as detected by electrocardiography using electrodes connected during the session) and decreased $SpO_2$ (detected with a pulse oximeter on the child's finger or toe), the treatment was discontinued.

*Statistics*

Descriptive statistics and unpaired t-tests were used for comparison of ages between groups. Shapiro Wilk test was used for determining the normality of the data distribution. To test for homogeneity between groups, Levene's test for homogeneity of variances was used. Unpaired t-test was conducted for comparison of $PaO_2$, $PaCO_2$, $SaO_2$, Cdyn, HR, and RR between groups. Paired t-test was conducted for comparisons before versus after treatment $PaO_2$, $PaCO_2$, $SaO_2$, Cdyn, HR, and RR in each group. For all statistical tests, the level of significance was set at $p < 0.05$. All statistical measures were conducted in Statistical Package for Social Sciences (SPSS) version 25 for Windows.

**Results**

No significant differences in demographic data were observed between groups regarding age, weight, height, BMI, and sex (Table 1). For the HR and RR, no significant differences were observed between groups before treatment ($p = 0.84$ and $p = 0.43$). Significant increases in HR and RR were observed in the control group after treatment. No significant differences in HR and RR were observed before and after treatment in the study group (Table 2). HR and RR were significantly lower in the study group than the control group after treatment (Table 4).

For blood gases, no statistically significant differences in $PaO_2$, $PaCO_2$, and $SaO_2$ were observed among groups before treatment ($p = 0.53$, $p = 0.52$, and $p = 0.86$, respectively). A significant increase in $PaO_2$ and $SaO_2$ after treatment was observed in both the control and study groups ($p < 0.05$); moreover, a significant decrease in $PaCO_2$ after treatment was observed in both the control and study groups ($p < 0.05$) (Table 3).

In addition, $PaO_2$ and $SaO_2$ were significantly greater in the study group than the control group after treatment ($p < 0.05$), whereas $PaCO_2$ was significantly lower in the study

**Table 1: Comparison of participant characteristics between the study and control groups.**

| | Control group | Study group | MD | t-value | p-value |
|---|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | | | |
| Age (months) | 8.3 ± 3.7 | 10.2 ± 4.7. | −1.9 | 1.48 | 0.13 |
| Weight (kg) | 8.29 ± 1.27 | 8.75 ± 1.49 | −0.46 | −1.08 | 0.28 |
| Height (cm) | 69.63 ± 4.90 | 70.93 ± 5.28 | −1.3 | −0.84 | 0.40 |
| BMI (kg/m$^2$) | 17.11 ± 2.13 | 17.29 ± 1.48 | −0.18 | −0.32 | 0.75 |
| Sex, n (%) | | | | | |
| Girls | 10 (45.5%) | 11 (50%) | | ($\chi^2 = 0.09$) | 0.76 |
| Boys | 12 (54.5%) | 11 (50%) | | | |

SD, Standard deviation; MD, Mean difference; $\chi^2$, Chi squared value; p-value, Probability value.

**Table 2: Comparison between pre- and post-treatment mean HR and RR values in the control group and study group.**

| Item | Pre-treatment | Post-treatment | MD | % change | t- value | p-value | Sig |
|---|---|---|---|---|---|---|---|
| | $\overline{X}$ ± SD | $\overline{X}$ ± SD | | | | | |
| HR (beats/min) (control group) | 126.55 ± 15.35 | 139.09 ± 18.38 | −12.54 | 9.91 | −2.96 | 0.007 | S |
| RR (breaths/min) (control group) | 32.36 ± 7.08 | 34.86 ± 5.36 | −2.5 | 7.73 | −2.86 | 0.009 | S |
| HR (beats/min) (study group) | 127.5 ± 16.42 | 128.64 ± 12.3 | −1.14 | 0.89 | −0.3 | 0.76 | NS |
| RR (breaths/min) (study group) | 30.63 ± 7.36 | 31.72 ± 4.36 | −1.09 | 3.56 | −0.61 | 0.54 | NS |

$\overline{X}$: Mean; SD: Standard deviation; MD: Mean difference; t value: Paired t-value; p-value: Probability value; S: Significant.

**Table 3: Comparison between pre- and post-treatment mean $PaO_2$, $PaCO_2$, $SaO_2$, and Cdyn values in the control group and study group.**

| Item | Pre-treatment $\overline{X} \pm SD$ | Post-treatment $\overline{X} \pm SD$ | MD | % of change | t- value | p-value | Sig |
|---|---|---|---|---|---|---|---|
| $PaO_2$ (mm Hg) (control group) | 47.22 ± 6.27 | 64.59 ± 12.01 | −17.37 | 36.79 | −7.12 | 0.001 | S |
| $PaCO_2$ (mm Hg) (control group) | 49.5 ± 5.72 | 39.36 ± 6.86 | 10.14 | 20.48 | 4.98 | 0.001 | S |
| $SaO_2$ (%) (control group) | 78.31 ± 8.69 | 87 ± 8.36 | −8.69 | 11.10 | −3.5 | 0.002 | S |
| Cdyn (ml/cm $H_2O$/kg) (control group) | 0.78 ± 0.25 | 1.03 ± 0.26 | −0.25 | 32.05 | −4.61 | 0.001 | S |
| $PaO_2$ (mm Hg) (study group) | 48.36 ± 5.85 | 72.81 ± 9.02 | −24.45 | 50.56 | −11.49 | 0.001 | S |
| $PaCO_2$ (mm Hg) (study group) | 50.77 ± 7.21 | 35.22 ± 5.13 | 15.55 | 30.63 | 14.12 | 0.001 | S |
| $SaO_2$ (%) (study group) | 77.91 ± 7.25 | 94.81 ± 4.56 | −16.9 | 21.69 | −11.83 | 0.001 | S |
| Cdyn (ml/cm $H_2O$/kg) (study group) | 0.81 ± 0.27 | 1.24 ± 0.23 | −0.43 | 53.09 | −6.95 | 0.001 | S |

**Table 4: Comparison of post treatment mean HR, RR, $PaO_2$, $PaCO_2$, $SaO_2$, and Cdyn values between the control and study groups.**

| | Control group $\overline{X} \pm SD$ | Study group $\overline{X} \pm SD$ | MD | t- value | p-value | Sig |
|---|---|---|---|---|---|---|
| HR (beats/min) | 139.09 ± 18.38 | 128.64 ± 12.3 | 10.45 | 2.21 | 0.03 | S |
| RR (breaths/min) | 34.86 ± 5.36 | 31.72 ± 4.36 | 3.14 | 2.12 | 0.03 | S |
| $PaO_2$ (mm Hg) | 64.59 ± 12.01 | 72.81 ± 9.02 | −8.22 | −2.56 | 0.01 | S |
| $PaCO_2$ (mm Hg) | 39.36 ± 6.86 | 35.22 ± 5.13 | 4.14 | 2.26 | 0.02 | S |
| $SaO_2$ (%) | 87 ± 8.36 | 94.81 ± 4.56 | −7.81 | −3.85 | 0.001 | S |
| Cdyn (ml/cm $H_2O$/kg) | 1.03 ± 0.26 | 1.24 ± 0.23 | −0.21 | −2.71 | 0.01 | S |

group than the control group after treatment ($p < 0.05$) (Table 4).

Regarding dynamic lung compliance, no significant difference in Cdyn was observed between groups before treatment ($p = 0.74$). Cdyn was significantly greater after treatment in the control group ($p = 0.001$), showing a 32.05% improvement, as well as in the study group ($p = 0.001$), showing a 53.09% improvement (Table 3). Cdyn was significantly greater in the study group than the control group after treatment ($p = 0.01$) (Table 4).

## Discussion

Untreated atelectasis and decreased mucociliary clearance can prolong mechanical ventilation times and pediatric ICU length of stay.[14] Our results showed statistically significant improvements in ABGs, Cdyn, RR, and HR in favor of the study group receiving the TBT, among children with atelectasis on mechanical ventilation.

Significant changes in HR and RR were observed, and the percentage increase indicated clinical deterioration of children in the control group. The study group showed more significant clinical improvements in HR and RR than the control group.

After CPT, the HR and RR increased, possibly because of the stimulatory effects of percussion and vibration, and a transition in secretion from the central to the peripheral airways, thereby leading to breathing difficulty. These factors contributed to tachycardia and tachypnea, which lasted longer than 10 minutes in some patients. After 10 minutes of application of the TBT, the HR and RR didn't change as compared to pre-treatment values, possibly because the TBT had a less stimulating effect than CPT, and the use of a proper time frame for recording allowed the children to become more relaxed and regulate their breathing.

Our results were consistent with those reported by Gomes et al.,[15] who have explored the effects of CPT on lung collapse in newborns with invasive mechanical ventilation, and observed increases in HR and RR. Even in healthy individuals, the stimulatory effects of percussion can produce tachycardia, thus causing tachypnea and increasing $VO_2$ to meet oxygen demand.[16] However, the TBT did not significantly increase the HR or RR, and therefore had no negative effects on vital signs.

The results of our study are in line with those reported by Diniz et al.,[6] who have examined the effects of the TBT on children with atelectasis and children without respiratory disease. They have found that the TBT temporarily increased the RR with respect to pre-treatment values, but the RR returned to baseline values after 10 minutes of treatment. The findings might be explained by children's capacity to adjust the rate of exhalation and the duration of each exhalation while the chest is compressed, thus allowing them to inhale just before reaching the volume of elastic equilibrium. Because of these processes, the respiratory device's passive mechanical features elicited a dynamic increase in RR, and some children screamed during and immediately after the maneuver. Crying might also have increased the RR. After 10 minutes, the children became calm, and the RR returned to resting values.

Regarding ABG, improvements in $PaO_2$ and $SaO_2$ were observed in both groups. The study group receiving TBT showed more significant increases in $PaO_2$ and $SaO_2$ than the control group. Although a decrease in $PaCO_2$ in both groups was observed, thus indicating improvement, group B showed a more significant decrease in $PaCO_2$ than group A, thus indicating clinically greater improvement in oxygenation status.

This finding might be explained by the TBT and the specially designed CPT program being more effective in raising $PaO_2$, $SaO_2$, and lowering $PaCO_2$ than the CPT program alone. The use of manual chest compression in addition to positive pressure to raise intrathoracic pressure has been reported to promote atelectatic area reopening and to oxygenate the blood.[6] The TBT improves ABG by making more alveoli available for gas exchange, thus leading to removal of more $CO_2$ from the blood and better oxygenation.

Our results were consistent with those reported by Kole and Metgud,[17] who have studied the effects of lung squeezing technique and rolling on $PaO_2$, $SaO_2$, and $SpO_2$ in preterm neonates with chest problems, and have observed significant improvements in oxygenation status. The studies differed in that Kole and Metgud used a lung squeezing technique in which chest compression was applied to both sides for only 5 seconds and then released for neonates, and explored its effects on ABGs, whereas our study applied the TBT on the healthy side for 20 seconds for older children, and explored its effects on ABGs and other variables.

Our findings were consistent with results reported by El Tohamy et al.,[18] who have examined the effects of CPT on ABG in neonates and have reported improvements in $PaCO_2$, $PaO_2$, and $SaO_2$ levels in children. In addition, our results agree with those reported by Zeng et al.,[19] who have examined pulmonary CPT effects and found increased $PaO_2$ in the study group, and greater incidence of atelectasis in the control group than the study group. The displacement and evacuation of chest secretions during physical therapy sessions in critically ill children considerably enhances bronchial cleanliness and gas exchange, optimizes the mechanics of breathing, and is reflected in ABG.[20]

Regarding dynamic compliance, improvements were observed in the control and study group, and a higher increase in Cdyn was observed in the study group than the control group. The TBT can prevent or treat improper ventilation conditions with adjustment of the alveolar pressure and proper placement, thereby improving pulmonary perfusion and, in children with atelectasis, positively affecting lung compliance.[6]

Our results were consistent with those reported by Biarzi et al.,[21] who have observed that the manual chest compression approach enhances lung compliance. This increase was explained by the negative pressure caused by manual chest compression, which in turn increased the transpulmonary pressure. This aspect is a key advantage of manual chest compression over mechanical ventilator use to increase tidal volume, because the latter requires increasing inspiratory pressure, which can potentially harm lung tissues through barotrauma.

Our results were also consistent with those of Via et al.,[22] who have reported that manual chest compression and decompression increase tidal volume because of the high elastic forces in the thoracic cage, thereby increasing transpulmonary pressure and negative pressure in the pleura, and resulting in a greater pressure difference, and increased flow and inspired tidal volume.

The increase in Cdyn in the current study might be explained by the recovery of a substantial number of atelectatic alveoli, decreased areas of overdistension of healthy lung units, and reversal of non-homogeneous ventilation distribution, as observed in infants with diseases characterized by altered surfactant activity.

### *Study strengths*

Prior studies have not sufficiently examined the role of the TBT in reversing the effects of atelectasis and enhancing the recovery rate of children receiving mechanical ventilation. Therefore, this study suggests important clinical implications for applying the TBT together with CPT for these children, to improve their blood gases and dynamic lung compliance, and decrease adverse effects on HR and RR.

### *Study limitations*

Some children screamed during or immediately after the technique. Crying in children may contribute to a substantial increase in RR.

## Conclusion

Using the TBT with CPT causes greater improvements in ABG values and dynamic lung compliance than designed CPT techniques alone, and has no adverse effects on vital signs (HR and RR) in children with atelectasis who are mechanically ventilated.

### *Recommendations*

Future studies may examine the effects of the TBT on children receiving CPAP or nasal oxygen support; assess the effects of the TBT on neonates; compare the effects of the TBT and manual hyperinflation on children with atelectasis; investigate the effects of the TBT on weaning time and ICU length of stay; and explore the effects of the TBT on chest expansion.

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## Conflict of interest

The authors have no conflict of interest to declare.

## Ethical approval

The study was approved by the Ethical Research Committee of the Faculty of Physical Therapy, Cairo University, Egypt P.T.REC/012/004401, 14/2/2023.

## Consent

The study procedures were explained to the parents, who signed consent forms before the study procedures were performed.

## Authors contributions

AAA, KES, and AFI contributed the idea and study design. NHA was responsible for clinical evaluation of the children. AAA shared with clinical application of the intervention. AFI wrote the manuscript. AAA, KES, and AFI were involved in data analysis and interpretation. AAA and AFI revised the final draft. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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