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Active Cycle of Breathing Techniques Contributes to Pain Reduction in Patients With Rib Fractures

Prospective clinical trial

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Abstract

Aim: The purpose of the study was to examine the effectiveness of the active cycle of breathing techniques (ACBT) in pain reduction and in preventing pulmonary complications in patients with rib fractures.

Materials-Methods: Ninety (90) patients with rib fractures, aged from 45 to 75 years, (58.02, ± 9.55) were randomly assigned to the ACBT group (N = 45, performed the ACBT trial) and control group (N = 45). All patients received routine physiotherapy for 7 days. The dependent variables were: pain score during cough, body temperature and the number of white blood cells (WBC).

Results: Multivariate analyses (2 x 7 MANOVA) were used for statistical analyses. Significant multivariate interaction between group and time was found ($p < .05$). The univariate post hoc analysis determined significant interaction for the pain ($p < .01$) and the number of WBC ($p < .01$). No significant interaction was found for body temperature ($p > .05$). Further significant pain differences between the two groups were evident on day 3 ($p < .05$), day 4 ($p < .01$), day 5 ($p < .01$), day 6 ($p < .01$) and day 7 ($p < .01$).

Conclusion: Overall, the ACBT appeared to reduce pain in patients with rib fractures but did not prevent pulmonary complications compared to routine physiotherapy

Keywords

Physiotherapy, Rib fractures, Pain, Atelectasis, Pneumonia.

Introduction

The cornerstone of management for rib fractures is to provide adequate analgesia to the patients and to prevent of pulmonary complications such as atelectasis and infection [1, 2]. Chest trauma initiates a circle of pain-infection requiring immediate treatment [3].

Adequate analgesia and effective physiotherapy are all essential components in the management of rib fractures if complications are to be avoided [4, 5, 6, 7]. To this end, a variety of physiotherapy techniques (positioning, early mobilization, effective cough, the active cycle of breathing techniques (ACBT) and incentive spirometer training), is widely used [2, 8, 9, 10]. Positioning improves ventilation/ perfusion (V/Q) matching, increasing lung volumes, reduces the work of breathing and results mucociliary clearance [8]. Early mobilization provides cardiopulmonary fitness and functional independence [2, 8]. Incentive spirometry is used to prevent and reverse lung atelectasis [2].

The ACBT is a cycle of relaxed diaphragmatic breathing (breathing control-BC) with deep and slow inspiration, thoracic expansion (TE) exercises and forced expiration technique (FET) [2, 4]. It can be adopted for all patients and is flexible, in terms of the sequence of BC, TE, and FET2. Deep and slow inspiration mechanism promotes an increase in transpulmonary pressure and when associated with a post-inspiratory pause, increases the functional residual capacity [11]. This, in turn, leads to a greater alveolar stability, which can confirm the use of BC in the prevention of atelectasis [11]. Thoracic expansion exercises are active deep breathing exercises emphasizing inspiration and combining a 3-sec hold before the passive relaxed expiration. The forced expiration technique is a combination of one or two forced expirations (huffs) and periods of breathing control [2]. The ACBT combines airway clearance with the promotion of ventilation and contributes to the prevention of infections [2, 4]. Specifically, the ACBT is proposed by Middleton et al [4] for the prevention of complications in rib fractures. Furthermore, exercise training accelerates the wound healing process [12,13]. Finally, neurological pain mechanisms support strong evidence for pain reduction/inhibition as a result of physiotherapy [14-19].

Based on the above, the purpose of the present study was to evaluate the effectiveness of specific physio-

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therapy in pain reduction and in preventing pulmonary complications in patients with rib fractures

Methods

Sample

A purposive sample of ninety-seven (97) patients with rib fractures, who had been admitted to the department of General Thoracic Surgery of the 'KAT' General Hospital in Athens, Greece, was invited to participate in the study. Ninety (90) patients attended the study and signed the informed consent form. The participants were above 45 years old [20] and had at least three rib fractures [21] which had occurred on the day of admission. Patients were excluded if they were comatose, required mechanical ventilation, had sustained an unstable spinal fracture, spinal cord injury or other form of injuries (e.g. fractures of other bones, etc). Given that the degree of pulmonary dysfunction usually peaks at 72 hours and generally resolves within 7 days, the length of hospital stay was 7 days [22]. The Research Ethics Committee of the Hospital 'KAT' approved our study protocol.

Measurement instruments

The following measures were used for the purposes of the study: a) a visual analogue scale for the evaluation of pain level, varying from 0 (no pain) to 10 (the worst pain) and b) the flow-oriented incentive spirometer Triflo II (Hudson RCI, Temecula, CA, USA) [23] for the increase of respiratory volumes. Moreover, the criteria of temperature (> 38.3 0C), white blood cells/mm3 (> 10.000), purulent tracheo-bronchial secretions, worsening of pulmonary gas exchange levels and persistent radio-graphic pulmonary infiltrates (> 24 hours) were used for defining pneumonia [24].

Procedure

The number of rib fractures was recorded and used for the stratified random sampling procedure. Specifically, the present sample incorporated participants with either 3, 4 or 5 fractures. The participants were randomly assigned to the experimental (N= 45) and control groups (N= 45) according to their respective number of rib fractures (matched paired). All participants were aware they were partaking in a physiotherapy intervention program. All measurements were calculated by trained research assistants blinded to the patients' allocation.

All patients received analgesic therapy (D-propoxyphen HCl: 75 mgr / 6h i.m, or HCl pethidine 0.50 mgr / 8h, i.m for the first 3 days followed by

Table 1 Descriptive statistics of the participants

Variable	Mean	SD	N patiens
ACBT group			
Gender			
Men			37
Women			8
Age (years)	59.13	10.17	45
Smoking			
Smokers			25
Non-smokers			20
Type of injury			
Mobile accident			31
Fall			14
Number of fractures			
3 fractures			24
4 fractures			14
5 fractures			7
Type of concominant injuries			
Pneumothorax			25
Pulmonary contusion			23
Haemothorax			21
Control group			
Gender			
Men			33
Women			12
Age (years)	56.91	8.86	45
Smoking			
Smokers			31
Non-smokers			14
Type of injury			
Mobile accident			24
Fall			21
Number of fractures			
3 fractures			21
4 fractures			16
5 fractures			9
Type of concominant injuries			
Pneumothorax			18
Pulmonary contusion			23
Haemothorax			15

paracetamol 500mgr per os plus codeine phosphate 30 mgr per os / 6h) on a daily basis for the remaining 4 days. None of the patients required parenteric analgesics for more than the 3 first days.

The routine chest physiotherapy comprised: a) frequent positioning, b) early mobilization, c) effective coughing, supported with the patient's hands or with a pillow but not with a rib belt and d) flow-oriented incentive spirometer Triflo II. In the present study, the flow-oriented incentive spirometer was used 4 times daily and all patients were instructed to execute deep and slow inspiration and sustain the inflation for a minimum of 3-sec. The participants performed 8 to 10 respiratory cycles per session, at a minimum, every hour, in the sitting position. The group that performed the ACBT twice a day for the first three days and once a day for the remaining four days. Both routine physiotherapy and specific physiotherapy were supervised and performed relatively by two trained physiotherapists, blinded to the group allocation. The pain during cough was measured once every day, at noon, after the physiotherapy session and approximately two hours after receiving analgesics. The count of white blood cells and the body temperature was recorded on a daily basis. Tracheobronchial secretions were evaluated during the physiotherapy session. Blood gases were measured when needed and CXR was evaluated at admission day as well as when prescribed by the respective physician.

Statistical analysis

Power analysis

A pilot study was conducted for the estimation of the effect size [25, 26] of ACBT in pain reduction in patients with rib fractures after 7 days of treatment. Thus, a small sample of 16 participants was used (8 patients for the control and 8 patients for the ACBT groups). The effect size, calculated with the formula suggested by Cohen [26], was found to be 3.07. With effect size = 3.07, alpha = .05, power of .80 and 7 measures, the required sample size to detect significance was 12 (6 for each group) [27, 28].

The Statistical Package for the Social Sciences (SPSS) with 2X7 MANOVA was used for data analysis [25]. Specifically, we examined the multivariate interaction between group and time, with respect to the dependent variables: pain, body temperature and the count of white blood cells. Following significant multivariate interaction, univariate 2X7 ANOVAs were used for each dependent variable separately. The t parameter estimates with a difference contrast were used as a simple main effect test to examine differences between experimental and control groups, across time [25]. Eta-squared ($\eta 2$) was used for the expression of the total variance explained by the interaction between time (7 measures) and group (experimental-control) with respect to the dependent variables measured. Finally, orthogonal polynomial analysis was conducted to evaluate the trend for the repeated measures conducted (e.g. linear, quadratic, cubic order, e.t.c.), for each dependent variable separate. In other words, orthogonal polynomial analysis was used to examine whether the effect of the independent variable (treatment) was linear, quadratic or cubic, etc., on the dependent variables examined (e.g. pain, WBC, e.t.c.), across time [25].

Results

The participants included 71 men (78.9%) and 19 women (21.1%) whose ages ranged from 45 to 75

Table 2 Mean pain score across time

Measures performed	Mean pain score	SD	N patiens
1st day			
ACBT group	8.73	1.12	45
Control group	8.64	1.07	45
2nd day			
ACBT group	8.15	1.31	45
Control group	8.13	.87	45
3rd day			
ACBT group	6.95	1.38	45
Control group	7.29	.92	45
4th day			
ACBT group	5.24	1.23	45
Control group	6.67	.85	45
5th day			
ACBT group	3.78	.97	45
Control group	6.20	.87	45
6th day			
ACBT group	2.58	.72	45
Control group	5.42	.86	45
7th day			
ACBT group	1.89	.57	45
Control group	4.51	.84	45

Table 3 Mean number of white cells across time

Measures performed	Mean Number of white cells	SD	N patiens
1st day			
ACBT group	9,307	1,656	45
Control group	9,862	2,608	45
2nd day			
ACBT group	9,049	1,714	45
Control group	9,065	2,152	45
3rd day			
ACBT group	8,700	1476	45
Control group	8,933	1,896	45
4th day			
ACBT group	8,238	1,496	45
Control group	8,436	1,646	45
5th day			
ACBT group	7,779	1,827	45
Control group	7,849	1,467	45
6th day			
ACBT group	7,523	1,338	45
Control group	7,196	1,381	45
7th day			
ACBT group	6,556	1,233	45
Control group	7,174	1,270	45

years old. Their demographic characteristics may be found in table 1. In addition, the mean pain score and number of white cells of both groups, across time, are presented in tables 2 and 3 respectively. Furthermore, no pathologic findings on the chest x-rays or expectorated purulent tracheobronchial secretions were reported by the physicians throughout the study. Consequently, data from the above variables (e.g. x rays and blood gases) is not presented.

Initially, the reliability of pain measures was determined through the Intraclass Correlation Coefficient (ICC). The results were at the appropriate range, with ICC of: a). 902 for the total sample, and b). 903 and .932 for the experimental and control groups separate.

The factorial analysis 2X7 MANOVA, examing the interaction between group and time, was significant for the three dependent variables ($\Lambda = 0.18$, $F = 17.71$, $p < .05$, $\eta 2 = .82$). The univariate post hoc analysis showed significant interaction for pain ($F = 86.74$, $p = .00$, $\eta 2 = .50$) (Fig. 1) and number of white blood cells ($F = 3.78$, $p = .01$, $\eta 2 = .04$) (Fig 2). No significant interaction was found for body temperature ($F = 1.23$, $p = .30$, $\eta 2 = .01$). The t parameter estimates were used to examine the pain and white blood cell differences between experimental and control groups,

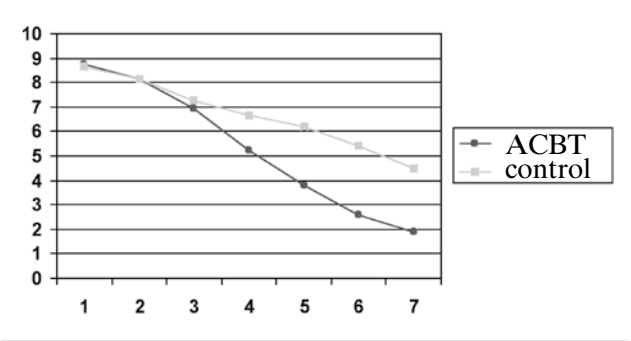

Fig. 1 The interaction between group and time ($F = 86.74$, $p = .00$, $\eta 2 = .50$) with respect to pain

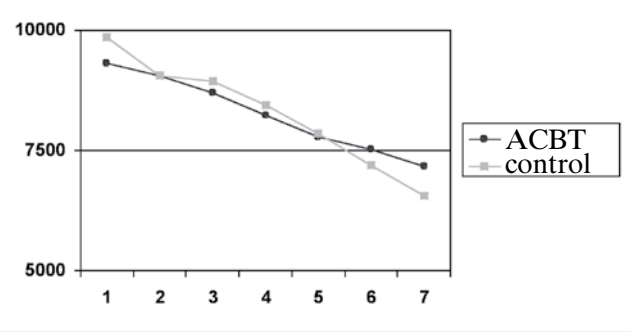

Fig. 2 The interaction between group and time ($F = 3.78$, $p = .01$, $\eta 2 = .04$) with respect to the number of white blood cells

across time. Significant pain differences between groups were evident on day 3 ($t = -2.07$, $p = .04$, $\eta 2 = .46$), day 4 ($t = -6.63$, $p = .00$, $\eta 2 = .33$), day 5 ($t = -10.96$, $p = .00$, $\eta 2 = .57$), day 6 ($t = -15.1$, $p = .00$, $\eta 2 = .72$) and day 7 ($t = -16.01$, $p = .00$, $\eta 2 = .74$), respectively, while no significant differences were found on day 1 ($t = .39$, $p = .70$, $\eta 2 = .002$) and day 2 ($t = .10$, $p = .92$, $\eta 2 = .00$). Examination of the mean scores revealed that the experimental group had lower mean pain scores compared to the control group in the above measures. Significant white blood cell differences between groups were evident only on day 7 ($t = 2.34$, $p = .02$, $\eta 2 = .06$). Finally, orthogonal polynomial analysis revealed significance for: a) cubic with respect to pain ($F = 51.90$, $p = .00$, $\eta 2 = .54$), b) linear for temperature ($F = 18.80$, $p = .00$, $\eta 2 = .30$)

and c) linear for number of white cells (F = 82.85, p = .00, η2 = .65), for the experimental group. In turn, significance was found for: a) the 5th order with respect to pain (F = 5.34, p = .03, η2 = .11), b) linear for temperature (F = 37.14, p = .00, η2 = .46) and c) linear for white cells (F = 111.87, p = .00, η2 =.72) for the control group. Concerning pain, examination of the line graph with the respective mean scores, for the experimental group, revealed a wide effect between days: a) 3 and 4 (F = 262.19, p = .00, η2 = .86), b) 2 and 3 (F = 143.75, p = .00, η2 = .77), c) 5 and 6 (F = 137.43, p = .00, η2 = .76) and d) 4 and 5 (F = 132.72, p = .00, η2 = .75). The effect between days: a) 6 and 7 (F= 40.00, p = .00, η2 = .48) and b) 1 and 2 (F = 18.90, p = .00, η2 = .30) was somewhat lower, meaning that the ACBT had a wider effect during days 2, 3, 4, 5 and 6, compared to the first and last day of treatment. In turn, for the control group a wide effect was found between days: a) 6 and 7 (F = 102.67, p = .00, η2 = .70), b), 2 and 3 (F = 101.49, p = .00, η2 = .69), c) 5 and 6 (F = 75.91, p = .00, η2 = .63) and d) 3 and 4 (F = 52.58, p = .00, η2 = .54). In turn, the effect between days: a) 1 and 2 (F= 33.93, p = .00, η2 = .43) and b) 4 and 5 (F = 17.11, p = .00, η2 = .28) was lower for the control group. Therefore, the control group continued pain reduction throughout the ACBT, and even at the last day of treatment it reached its highest significance (F = 102.67, p = .00, η2 = .70).

Discussion

The present study examined the effectiveness of specific chest physiotherapy, the active cycle of breathing techniques, in pain reduction and in preventing pulmonary complications for patients with rib fractures. Overall, it appeared that the active cycle of breathing techniques reduced pain to a wider extent than the regular treatment alone and these differences were evident from the third day of treatment. Furthermore, a significant effect was found for the number of white blood cells only on the last day of treatment, but no significance was found for the body temperature. Finally, trend analysis revealed that pain was reduced significantly across day to day treatment, for both groups. For the ACBT group, eta-squared (η2) values revealed that the smallest effect was evident between the: a) first and second (first assessment) and b) sixth and seventh day (sixth assessment), while the reduction of pain decreased similarly across days 3 to day 6 when it reached its widest effect (between the third and fourth day of treatment). Accordingly, for the control group, the pain reduction that emerged through the first assessment was wider in the second assessment, deteriorated during the third assessment (days 3 and 4), to reach its lowest value during the fourth assessment (days 4 and 5). In turn, pain reduction increased for the control group once again during the fifth (days 5 and 6) and sixth (days 6 and 7) assessments. Overall, it appeared that pain reduced faster and in a similar pattern for participants in the experimental group compared with participants in the control group who, in turn, experienced ups and downs in their experience of pain reduction.

Many studies have shown the effectiveness of analgesics given for pain control in patients with rib fractures [5,7,29]. In the present study, it appeared that the active cycle of breathing techniques (ACBT) reduced the level of pain. This might be explained by: a) the anti-inflammatory and healing effect of exercise [12, 13, 30, 31], b) the "gate control theory of pain" [12-16] and the 'descending pain mechanisms [12, 13, 14, 17] and c) the placebo effect [12].

More specifically, Gleeson [30] stated that exercise is associated with a reduced incidence of infection. Petersen and Petersen [31] suggested that exercise interventions offer protection against all-cause mortality. Moreover, Emery et all [12] reported that a relatively short-term exercise intervention is associated with enhanced rates of wound healing among healthy older adults. In addition, Emery et al [12] stated that exercise activity may be an important component of health care to promote wound healing. Finally, Keylock et al [13] demonstrated that exercise accelerates the wound healing process which, in turn, may be the result of an exercise-induced anti-inflammatory response in the wound.

The "gate control theory of pain" [14-18] and the "descending pain mechanisms" [14, 15, 16, 19] are two neurological mechanisms that explain the perception of physical pain. In the present study, it appeared that rib movements during ABCT might be the stimulus activating the A-beta fibers and inhibited pain for the experimental group, correspondingly to analgesics and across time. In addition, pain productionduring thoracic expansion and huffing might have activated the periaqueductal gray matter (PAG), which in turn produced profound analgesia via the descending PAG pathways.

Certain pulmonary complications, such as pneumonia, usually appear within the first 4 days after trauma [22, 24]. Although the sample age was above 45 years

[21], no atelectasis or pneumonia was produced in either group. This finding is in accordance with other studies, supported by evidence for the chest physiotherapy in preventing pulmonary complications (such as atelectasis or pneumonia) [1, 2, 8-10, 32].

Finally, according to Potter et al [14], there is likely to be a placebo effect for every intervention program. Cognitive psychologists suggest that cognitive functions such as beliefs, motivation, attending, the sense of receiving any kind of treatment or attention, may assist the augmentation or reduction of the influence of other stimuli within the central nervous system [15]. Moreover, attending any therapeutic intervention may significantly reduce pain perception [33]. Finally, Meng et al [34] stated that coping-related expectations, among other variables, are significant predictors of rehabilitation success.

Certain limitations in the present study included the following: a) the purposive sample consisted of volunteers, patients who were admitted to the department of General Thoracic Surgery and met the inclusion criteria, b) no pulmonary function tests were conducted because, due to pain, patients were not able to complete the 6 seconds of expiratory effort recommended by the European Respiratory Society, c) no anti-inflammatory and healing indices were measured, d) there was no follow-up after the 7 days because the focus was on this acute and critical period [22], e) no disability level was evaluated, due to the absence of follow-up.

In conclusion, it appeared through the present study that pain reduced faster and more smoothly across time following the ACBT, compared to the control group. However, for both experimental and control groups, pain reduction was evident even at their last day of treatment. Therefore, pain reduction requires repeated re assessments after the seventh day of treatment, before a permanent conclusion is drawn regarding the effect of ACBT across time.

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Η Επίδραση του Δραστικού Κύκλου των Αναπνευστικών Τεχνικών (ACBT) στη Μείωση του Πόνου και στην Πρόληψη των Πνευμονικών Επιπλοκών σε Ασθενείς με Κατάγματα Πλευρών

Προοπτική Κλινική Μελέτη

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Περίληψη

Σκοπός: Ο σκοπός αυτής της έρευνας ήταν να εξετασθεί η επίδραση του δραστικού κύκλου αναπνευστικών τεχνικών στην μείωση του πόνου και στην πρόληψη των πνευμονικών επιπλοκών σε ασθενείς με κατάγματα πλευρών.

Μέθοδος: Ενενήντα (90) ασθενείς με κατάγματα πλευρών, ηλικίας 45 έως 75 ετών (58.02, ± 9.55) χωρίστηκαν τυχαία και τυφλά σε πειραματική (N=45) και ομάδα ελέγχου (N=45). Όλοι οι ασθενείς υποβλήθηκαν στην συνήθη αναπνευστική φυσικοθεραπεία για 7 ημέρες. Η πειραματική ομάδα υποβλήθηκε στις αναπνευστικές τεχνικές του δραστικού κύκλου. Οι εξαρτημένες μεταβλητές ήταν: ο πόνος κατά την διάρκεια του βήχα, η θερμοκρασία σώματος και ο αριθμός των λευκών αιμοσφαιρίων.

Αποτελέσματα: Για την στατιστική ανάλυση χρησιμοποιήθηκε πολυμεταβλητική ανάλυση (2 x 7 MANOVA). Βρέθηκε σημαντική αλληλεπίδραση μεταξύ ομάδας και χρόνου ($p < .05$). Στην συνέχεια, η μονομεταβλητική ανάλυση ανέδειξε σημαντική αλληλεπίδραση για τον πόνο ($p < .01$) και για τον αριθμό των λευκών αιμοσφαιρίων ($p < .01$). Δεν βρέθηκε σημαντική αλληλεπίδραση για την θερμοκρασία σώματος ($p > .05$). Επιπλέον, μεταξύ των δύο ομάδων βρέθηκαν σημαντικές διαφορές αναφορικά με τον πόνο την 3η ημέρα ($p < .01$), την 4η ημέρα ($p < .01$), την 5η ημέρα ($p < .01$), την 6η ημέρα ($p < .01$) και την 7η ημέρα ($p < .01$).

Συμπέρασμα: Η εξειδικευμένη αναπνευστική φυσικοθεραπεία με την εφαρμογή του δραστικού κύκλου αναπνευστικών τεχνικών σε σύγκριση με την φυσικοθεραπεία ρουτίνας φάνηκε ότι συμβάλλει στην μείωση του πόνου σε ασθενείς με κατάγματα πλευρών αλλά όχι στην πρόληψη των πνευμονικών επιπλοκών.

Λέξεις κλειδιά

Φυσικοθεραπεία, Κατάγματα πλευρών, Πόνος, Ατελεκτασία, πνευμονία