Effect of Cryotherapy on Pain Associated with Chest Tube Removal after Thoracotomy

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ABSTRACT

Context: Chest tube removal (CTR) is described as one of the worst feelings for critically ill patients after thoracotomy. Unrelieved pain causes undesired consequences that have adverse effects on patient quality of care. Analgesics usually manages CTR pain, but patients respond differently to drugs and might not provide complete relaxation. Cryotherapy is commonly applied as a non-pharmacological intervention for relieving CTR pain.

Aim: This study aimed to evaluate the effect of cryotherapy on pain associated with chest tube removal after thoracotomy.

Methods: This study was conducted in the cardio-thoracic critical care units at Cardiovascular and Thoracic Academy, affiliated to Ain Sham University Hospital. A purposive sample of 140 patients undergoing thoracotomy was included in this study. They were divided into control and study group (70 patients in each group). Data were obtained using the Chamber-Price Modified Pain Rating Scale (CPPRS), Standardized Linear Scale for Pain Assessment, and Modified McGill Pain Questionnaire-Short Form (MPQ-SF).

Results: The results reveal that 50%, 67.1% of the control and study group patients were in the age group 51-≥60 years. 62.9, 81.4% of the control and study group were males. Besides, there were highly statistically significant differences regarding peripheral pulse, apical pulse, and respiratory rate throughout CTR pain assessment times and a highly statistically significant difference regarding blood pressure immediately after CTR between the study and control groups. Also, statistically significant differences regarding physiological and behavioral parameters, pain intensity, and quality (sensory and affective descriptors) were found between the study and control groups immediately and 30 minutes after cryotherapy was applied after chest tube removal.

***Conclusion*:** Cryotherapy effectively improved hemodynamic, physiological, and behavioral parameters, relieving pain intensity and improving pain quality after chest tube removal for patients with thoracotomy. The current study recommends **c**onducting periodic in-service educational programs for critical care nurses regarding the benefits, methods, contraindications, and side effects of cryotherapy for relieving pain associated with CTR after thoracotomy. Motivate nurses in critical care units to use cryotherapy as a non-pharmacological therapy for relieving pain associated with chest tube removal.

Keywords: Cryotherapy, pain, chest tube removal, thoracotomy

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1. Introduction

A thoracotomy is a safe surgical operation to make an incision in the chest wall. It can be divided into anterolateral and posterolateral thoracotomies. It is indicated to provide access to thorax contents to confirm cardiac, esophageal, and pulmonary diagnoses and for removing fluids, foreign objects, air, tumors resection, biopsy, and repair of thorax structures (heart, blood vessels, esophagus, and lungs). Also, it is performed to manage cardiac diseases such as congenital cardiac defects and valvular and coronary artery disease *(Lewis, 2020; Nistor et al., 2020).*

Thoracotomy includes a variety of issues related to recovery, such as pain management, wound care, and limitation of activity because of incision. Also, it includes interference with normal thoracic pressures in the cavity associated with the opening of the chest wall and air entry, blood, and fluid accumulation that may lead to lungs collapse. So, it is important to solve these issues by draining secretions, fluids, and air to allow lung expansion and prevent complications *(Chang et al., 2023; Eldridge, 2021).*

Many patients after thoracotomy need a chest tube placement in emergency or non-emergency events as a frequent procedure. Chest tube indicated to remove air, blood, and other fluids from the thoracic cavity. It helps maintain hemodynamic stability, achieve normal cardiac and pulmonary functions, and prevent complications such as pneumothorax, hemothorax, or pleural effusion *(Chawla et al., 2020; Mohammadi et al., 2018).*

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A chest tube was removed when completing its function, and the causes for placement were solved with no excess air, blood, and other fluids in the chest cavity. Patients usually report pain ranging from moderate to severe when the chest tube is removed with negative emotions during critical care stays *(Dave, 2016; Elmetwaly & El Sayed, 2020; Hyzy & Mcsparron, 2020).*

Chest tube removal (CTR) pain caused by endothelial tissue that adheres to the tube was sheared by pulling force during removal. Uncontrolled pain causes psychological suffering in addition to respiratory dysfunction, decreased chest expansion and lung volumes, decreased cough effectiveness, sputum clearance, hypoxia, tachycardia, and poor prognosis with increased intensive care unit stay *(Mazloum et al., 2018).*

Therefore, pain management after thoracotomy following CTR is an important care strategy. Two main pharmacological (narcotic and non-narcotic analgesics) and non-pharmacological modalities manage pain. Pharmacological methods are usually used for relieving pain. Unfortunately, it is associated with various mental and physical side effects (hypotension, respiratory distress, poor vital functions, drowsiness, nausea and vomiting, and gastrointestinal bleeding), and it is expensive *(Sheykhasadi et al., 2019; Urden et al., 2020).*

Therefore, non-pharmacological methods for CTR pain, such as heat and cold therapy, acupuncture, relaxation, touch therapy, imagination, hypnotism, and aromatherapy, are recommended. These methods are simple, low-cost, and not associated with negative or adverse effects *(El Geziry et al., 2018; Khalil, 2018; Sandvik et al., 2020).*

Cryotherapy is commonly applied as a non-pharmacological intervention for relieving CTR pain because the application of cryotherapy slows the nervous stimuli conductance, tissue metabolism, hypoxia, edema, and nerve conduction velocity that increases pain threshold. Also, it decreases blood flow, which causes numbness of tissue around the chest tube *(Garcia et al., 2020; Sandhya & Jebarose, 2020).*

Cryotherapy reduces analgesic consumption and enhances patient autonomy, improving mobility and pain control with fewer side effects. It is easy to be applied by critical care nurses and with the patient's cooperation *(Aktaş & Karabulutb, 2019; Çelik & Ozer, 2020).*

Critical care nurses play an important role in CTR pain management, which is considered a high nursing priority. Pain after Chest tube removal can be managed by effective nursing assessment and evaluation using the best suitable nursing skills and being aware of non-pharmacological methods to increase patient comfort and satisfaction without any undesirable effects, so using cryotherapy, is recommended in relieving CTR pain *(Sandhya & Jebarose, 2020).*

2. Significance of the study

Patients after thoracotomy had at least one chest tube to maintain heart and lung functioning. Unfortunately, removing the chest tube was a painful procedure with more consumption of pharmacological interventions. The cold application was recommended to relieve CTR pain; in a study about the effect of superficial cooling on pain associated with chest tube removal after thoracotomy in Alexandria, Egypt, it showed that immediately after chest tube removal, the majority of the control group (92%) complained of severe pain and 8% complained of mild to moderate pain. On the other hand, none of the superficial cooling group complained of severe pain, 32% complained of mild to moderate pain, and 68% did not complain of pain. Ten minutes after chest tube removal, almost all intervention groups (96%) did not complain of pain, while most of the control group complained of severe (60%) to moderate (32%) pain *(El-Hady et al., 2007).*

Also, a study about the cold application and breathing exercises to reduce pain and anxiety during chest tube removal in Shebin AL Khom, Egypt, revealed that there was a significant reduction in pain intensity with the cold application group compared to the control group *(ELMokadem & Ibraheem, 2017).*

The cold application can be used as a convenient non-pharmacologic intervention and a pain relief technique during chest tube removal due to its simplicity and inexpensive therapy with fewer complications or no side effects. This study is an attempt to strengthen the evidence of the efficiency of cryotherapy in decreasing pain in critically ill patients after chest tube removal.

3. Aim of the study

This study aims to evaluate the effect of cryotherapy on pain associated with chest tube removal after thoracotomy.

3.1. Research hypotheses

The study hypothesizes that:

- Patients exposed to cryotherapy after chest tube removal will experience improvement in physiological and behavioral pain parameters compared to controls.
- Patients exposed to cryotherapy after chest tube removal will experience reduced pain intensity and quality compared to controls.

4. Subjects & Methods

4.1. Research Design

Quasi-experimental design (study & control groups) was used in carrying out this study. Quasi-experiment design is an empirical interventional study used to estimate the causal impact of an intervention on a target population without random assignment *(Sidhu, 2019).* The independent variable was cryotherapy, and the dependent variable was hemodynamic, physiological and behavioral parameters, and pain quality and intensity.

4.2. Study setting

The study was conducted in the cardio-thoracic critical care units at Cardiovascular and Thoracic Academy affiliated to Ain Sham University Hospital, Cairo. The academy provides outpatient clinics and inpatient services, interventional cardiology, emergency, blood bank, laboratory services, and cardiorespiratory rehabilitation centers for thousands of patients free of charge or at low cost. It is also an education and research center for cardiovascular and thoracic research. This ICU is located on floor number eight,

with a total capacity of 10 beds. It was prepared to provide postoperative care immediately after thoracotomy then the patients were transferred to the ward.

4.3. Subjects

A purposive sample of 140 adult patients was divided into two equal groups; G1 was the control group, and G2 was the study group (70 patients in each group) of both genders. The sample size was calculated statistically by power analysis considering the total number of patients with thoracotomy admitted to the cardio-thoracic intensive care units at Cardiovascular and Thoracic Academy affiliated with Ain Shams University after thoracotomy during the year (2018/2019). They were 285 patients.

So, the sample size was calculated by adjusting the power of the test to 80% and the confidence interval of 95% with the margin of error accepted adjusted to 5% and a known total population of 140 patients using the following equation:

$$n = \frac{N \times p(1-p)}{\left[\left[N-1\times\left(d^2 \div z^2\right)\right] + p(1-p)\right]}$$

Nxp(1-p)	=(285*(0.5*(1-0.5)))/
N-1	=(285-1)*
d^2/z^2	=0.0025 / 3.8416+
p(1-p)	=0.5*(1-0.5)
N	=140
N	= Community size
Z	= Class standard corresponding to the level of significance equal to 0.95 and 1.96
D	= The error rate is equal to 0.05
P	= Ratio provides a neutral property = 0.5

(Chow, et al., 2007).

Inclusion criteria

- All patients are undergoing thoracotomy.
- Have at least one chest tube in the immediate postoperative period.
- Fully conscious.
- Able to communicate.
- Not on painkillers immediately (one hour) before tube removal.
- Hemodynamically stable.

Exclusion criteria

- Patients who are suffering from hemiparesis, peripheral neuropathy, and hypothyroidism.
- The sample was randomly distributed to two groups: 70 patients as a control group (1) who received the routine hospital care for CTR and 70 patients as a study group (2) who were free from analgesic medication effects immediately before CTR and receiving cryotherapy for CTR. The researcher selected patients who fulfilled the research criteria daily and anonymously distributed them between both groups (the control and study).

4.4. Tools of data collection

4.4.1. Chamber-Price Modified Pain Rating Scale CPPRS

It was developed by *Chamber and Price (1967)* and adopted by the researcher to suit the aim of the study. It was written in the English language in questionnaire form to evaluate the hemodynamics, physiological, and behavioral parameters of the patient's pain immediately and after 30 minutes after applying cryotherapy after chest tube removal. This tool consists of three parts:

Part 1 (Patient's profile sheet) consisted of the patient's demographic data, such as age, gender, level of education, marital status, and occupation.

Part II (Hemodynamic parameters) was used to evaluate skin temperature, peripheral pulse, apical pulse, respiratory rate, blood pressure, arterial oxygen saturation, and capillary refill immediately and 30 minutes after chest tube removal.

Scoring system

It was classified as follows; the normal finding was (yes), and the abnormal finding was (no) according to normal value as followings: Skin temperature was (36 – 37.6◦ c), peripheral pulse was 60 – 100 b/m, apical pulse was 60 – 100 b/m, respiratory rate was 12– 20 c/m, blood pressure was 100 - 139 / 65 - 89 mmHg, Sao2 was 95-99% and capillary refill was classified to normal 1–3 seconds or delayed.

Part III (Physiological and behavioral parameters of patient's pain). This part was used to evaluate physiological and behavioral parameters of the patient's pain, such as attention toward pain, irritability, patient verbal report of pain, nonverbal response to pain (body movement, posture, and facial expression), vocal sounds, perspiration, and nausea immediately after chest tube removal and 30 minutes after chest tube removal. It is adapted from *Elsharkawy (1991), Kwekkeboom and Herr (2001), and Urden et al. (2014).*

Scoring system

The score of the scale was graded from 1 to 3 degrees for each parameter. The researcher selected the suitable answer for each parameter for the patient. The total score was obtained by summating the selected grade for each parameter. This score indicates pain intensity: 9 means no pain, 10–15 indicates mild pain, 16–21 moderate pain, 22–26 severe pain, and 27 unbearable pain.

4.4.2. Standardized Linear Pain Assessment Scale

This tool was written in the English language. It was developed by *McCaffery and Pasero (1999).* Moreover, adopted by the researcher to evaluate pain intensity immediately and 30 minutes after applying cryotherapy after chest tube removal.

Scoring system

It was 10 points numerical scale with "0" representing no pain, "1-3" representing mild pain, "4-6" representing moderate pain, "7-9" representing severe pain, and "10" representing unbearable pain.

4.4.2. Modified McGill Pain Questionnaire-Short Form (MPQ-SF)

It was developed by *Melzack (2005)* and written in the English language in questionnaire form to evaluate pain quality immediately and 30 minutes after chest tube removal. This tool consisted of two parts sensory pain descriptors and affective pain descriptors. It was adopted from *Elsharkawy (1991); Sauls (2002*).

Part I: Sensory pain descriptors

It was characteristics to evaluate sensory pain, such as throbbing, cramping, gnawing, aching, burning, tender, stabbing/ sharp, dull, heavy, splitting, or no pain.

Part II: Affective pain descriptors

This part included four characteristics to assess affective pain such as tiring/exhausting, cruel/punishing, choking, and fearful.

4.5. Procedures

The preparatory phase included reviewing related literature and theoretical knowledge of various aspects of the study using books, articles, internet periodicals, and journals to develop tools for data collection.

The tool's content validity was ascertained by a panel of seven experts from Medical-Surgical and Critical Care Nursing academic staff who reviewed the content of tools for clarity, accuracy, relevance, and comprehensiveness, and the necessary modifications had done accordingly. The reliability of the tools was tested in the current study using alpha Cronbach's model of internal consistency. The Chamber-Price Modified Pain Rating Scale CPPRS res *ults were*0.96, Standardized Linear Scale for Pain Assessment was 0.95 ,and the Modified McGill Pain Questionnaire-Short Form (MPQ-SF) was 0.60.

Official permission was obtained by submission of official letters issued from the dean of the faculty of nursing, Ain Shams University, to the director of Ain Shams University hospitals and the Director of Cardiovascular and Thoracic Academy. The title and aim of the study are explained, as well as the main data items and the expected outcomes.

Ethical consideration: The research approval was obtained from the Faculty of Nursing Scientific Research and Ethical Committee before starting the study. The researcher clarified the objectives and aim of the study to patients included in the study before starting after obtaining written consent. The researcher assured the anonymity and confidentiality of the patients included in the study. The patients under study were informed that they were allowed to participate or not in the study and that they had the right to withdraw at any time.

A pilot study was carried out on 10% (14 patients) of sample size to test the feasibility of the research process, applicability, clarity, and efficiency of the tools. The patients in the pilot study were included in the sample because no modification was done after conducting the pilot study.

Fieldwork: The researcher assessed all admitted postoperative patients with thoracotomy for meeting the inclusion criteria to be enrolled in the current study. The actual work of this study started and was completed within six months, from the beginning of April to the end of October 2021. Data were collected by the investigator three days per week, at morning and afternoon shifts in the previously mentioned setting. The researcher followed the Ministry of Health and Population's protocol to minimize the risk of transmission of coronavirus disease.

The equipment used in this study consisted of cold packs (ice bags) (size: 15×12 cm) with zip lock (clamp) filled two-thirds with ice cubes; a disposable towel or sterile gauze to cover cold packs; a watch with a secondhand to measure the duration of the applications of cold packs.

Subjects were divided into two groups; G1 (control group) and G2 (study group); each group consisted of 70 patients after thoracotomy who were undergoing chest tube removal. The study group included patients who managed by using cryotherapy (ice packs) on both sides of chest tube removal. In contrast, the control group included patients receiving routine hospital nursing care (no painkiller is administered following CTR) for chest tube removal pain.

The first interview for both groups (1 and 2) included assessing the patient's demographic data; patient vital signs were obtained from the patients using the Chamber-Price Modified Pain Rating Scale CPPRS, Part I: Patient assessment record (Patient's profile sheet). During the first interview at the beginning of the morning shift, the researcher explained to the participants that the pain would be evaluated immediately and 30 minutes after chest tube removal.

For study group: The researcher was notified by the nurse (member of intensive care unit staff) that the patient was ready for CTR after the physician's decision according to the established protocol, which included: The lung should be fully expanded and confirmed by x-ray with no respiratory complications, fluid drainage output should be less than 100 to 200 ml/day, stable clinical condition, the cause that required insertion of the chest tube should be resolved and if the tube becomes blocked or is not working correctly.

The researcher prepared the ice packs to be ready for use through brought them from the freezer or the refrigerator and disinfecting them with a disinfectant solution (by wiping them with a sterile sponge wetted them with 70% alcohol to avoid infection to the chest tube insertion port) at the patient's bedside.

Immediately after chest tube removal and the insertion port closed with sutures, disinfected, and covered with a sterile dressing, patients received cryotherapy using ice bags on either side of the chest tube covering a 6-square inch (15 cm) area around the tube port (use one layer of sterile gauze or towel as a barrier between the ice bag and patient skin to avoid skin burn). Immediately after applying cryotherapy following chest tube removal (time one measurement), hemodynamic, physiological, and behavioral parameters, pain intensity, and quality were measured using Chamber-Price Modified Pain Rating Scale CPPRS, Standardized Linear Pain Assessment Scale, and Modified McGill Pain Questionnaire-Short Form.

The researcher stayed with the patient, kept the patient in position without change throughout the ice pack application, and ensured that the ice pack was kept in place for the next 30 minutes. Thirty minutes after applying cryotherapy from CTR (time two measurement), hemodynamic, physiological, and behavioral parameters, pain intensity, and quality were measured using the same assessment tools. It was noticed that no patient complained of side effects regarding ice application. The total procedure lasted about 30 minutes, and the patient was returned to a comfortable position.

The control group: The researcher was notified by the nurse (member of the intensive care unit staff) that the patient was ready for CTR after the physician's decision according to the established protocol. The control group took routine care without the researcher's interference. Immediately and 30 minutes after chest tube removal, hemodynamic, physiological, and behavioral parameters, and pain intensity and quality were measured using the same study tools (time one and two measurements).

Evaluation phase: The effect of cryotherapy on hemodynamic, physiological, and behavioral parameters and pain intensity and quality determined through comparison between the study group and control group findings were assessed, and the data were compared and tabulated accordingly.

4.7. Data Analysis

The collected data were organized, categorized, tabulated, and statistically analyzed using the statistical package for social science using SPSS program version 25. Quantitative data were presented as mean and standard deviation (SD). Qualitative data were presented as frequencies and percentages. Independent samples t-test (Student t-test) was used to compare quantitative data between two independent groups. The chi-square test (or Fisher Exact test) was used to compare qualitative data between different groups. The observed differences and relations were considered as follows: $p>0.05$ insignificance (No difference), $p\leq0.05$ significance difference, and $P \leq0.001$ highly significant difference.

5. Results

Table 1 reveals that 50% of the control group and 67.1% of the study group were aged between 51- ≥ 60 Years. In relation to gender, 62.9% of the control group, compared to 81.4% of the study group, were males. Regarding education, 42.9% of the studied groups were highly educated. Regarding marital status, 88.6% of the control group, compared to 95.7% of the study group, were married. Meanwhile, 44.3% of the control group, compared to 50% of the study group, were workers. Moreover, non-statistically significant differences were revealed between both groups regarding all their demographic characteristics except gender and occupation.

Table 2 reveals highly statistically significant differences regarding peripheral pulse, apical pulse, and respiratory rate in both measurements, and a highly statistically significant difference in blood pressure was revealed in the first measurement time.

Table 3 reveals highly statistically significant differences between the study and control groups' total physiological and behavioral pain scores at p-value <0.001 immediately and 30 minutes after CTR.

Table 4 shows statistically significant differences in total physiological and behavioral parameters mean scores between the study group and control group at p-value <0.001 in the two-measurement time. Also, it reveals a decrease in the study group's total mean scores of 13.74±2.73 versus the control total mean score of 19.5±4.04 immediately after CTR. This decrease in the total mean score was continued after 30 minutes after CTR as the study group shows a mean of 9.93±1.78 versus 14.4±2.68 of the controls.

Table 5 reveals highly statistically significant differences in pain intensity scores between the study and control groups at p-value <0.001 immediately and 30 minutes after CTR.

Table 6 reveals highly statistically significant differences regarding pain intensity scores between the study and control groups at p-<0.001 in the two measurement times. In addition, it shows a lower mean intensity score for study group 3±1.75 compared to 6.06±2.14 with a highly statistically significant difference immediately after CTR. It was also the case that after 30 minutes of CTR, there was a reduced pain intensity total mean score for the study group, 0.63 ±1.12 compared to the controls, 3.31±1.74 with a statistically significant difference (p <0.001).

Table 7 reveals that immediately after CTR (time one measurement), there were statistically significant differences regarding sensory descriptors of chest tube removal pain between the study and control group at p-value = 0.02. As well as, regarding time two (30 minutes after CTR), there was a high statistical difference regarding sensory descriptors of chest tube removal pain between both groups at p-value <0.001.

Table 8 reveals highly statistically significant differences regarding affective descriptors of chest tube removal pain between the study and control groups at p values of 0.004 and <0.001 immediately and 30 minutes after CTR, respectively.

6. Discussion

Chest tube removal (CTR) was the most distressing, worst, and most painful experience memory during a critical care unit stay. CTR pain ranged from moderate to severe, caused by separation from attached and adhered tissue. Unrelieved CTR pain had an adverse pulmonary effect as weak respiratory muscle, decreased chest expansion, lung volumes, capacity-producing hypoxemia, decreased cough effectiveness, and increased lung infections. Also, it caused tachycardia, increased cardiac output, and vasoconstriction. These complications lead to poor prognosis and increased morbidity and mortality *(Mazloum et al., 2018).*

The need for effective pain management became a vital concern by focusing on adding complementary therapy with pharmacological therapy to enhance pain relief and reduce the dose of narcotics medications. Analgesics were usually recommended modality to reduce CTR pain. However, patients had different responses and might not attain complete relaxation. Non-pharmacological physical therapy, including cryotherapy (cold therapy), had been recommended earlier *(El Geziry et al., 2018; Ozcan & Karagozoglu, 2020; Sandvik et al., 2020).* So, this study aimed to evaluate the effect of cryotherapy on pain associated with chest tube removal after thoracotomy.

Two matched groups were recruited for this study as there were no statistically significant differences between the two groups regarding their demographic characteristics except for gender and occupation.

Table (1): Comparison of demographic characteristics between study and control groups (n=140).

demographic characteristics	Control group (n = 70)		Study group (n = 70)		Chi-square Test	P. value
	No.	%	No.	%		
Age						
18 – 35 Years	6	8.6	5	7.1		
36 – 50 Years	29	41.4	18	25.7	4.42	0.11
51- ≥ 60 Years	35	50	47	67.1		
Gender						
Male	44	62.9	57	81.4	6.01	0.01
Female	26	37.1	13	18.6		
Level of education						
Cannot read and write	11	15.7	8	11.4		
Reading and writing	0	0	0	0		
Primary	5	7.1	1	1.4	4.03	0.25
Secondary	24	34.3	31	44.3		
Highly educated.	30	42.9	30	42.9		
Marital Status						
Married	62	88.6	67	95.7		
Single	6	8.6	1	1.4	3.73	0.22
Divorced	0	0	0	0	FE	
Widow	2	2.9	2	2.9		
Occupation						
Employee	14	20	14	20		
Worker	31	44.3	35	50	10.84	0.01
Retirement	4	5.7	13	18.6		
Housewife	21	30.0	8	11.4		

Table (2): Comparison of hemodynamic parameters between study and control groups after chest tube removal (n=140).

Hemodynamics parameters (Normal value)	Immediately after CTR**						30 minutes after CTR**					
	Control group (n = 70)		Study group (n = 70)		Chi Square* Test	p-value	Control group (n = 70)		study group (n = 70)		Chi Square* Test	p-value
	No.	%	No.	%			No.	%	No.	%		
Skin temperature												
Yes	70	100	70	100	-	-	70	100	70	100	-	-
No	0	0	0	0			0	0	0	0		
Peripheral pulse												
Yes	28	40	59	84.3	29.18	<0.001	49	70	69	98.6	21.57	<0.001
No	42	60	11	15.7			21	30	1	1.4		
Apical pulse												
Yes	28	40	59	84.3	29.18	<0.001	49	70	69	98.6	21.57	<0.001
No	42	60	11	15.7			21	30	1	1.4		
Respiratory Rate												
Yes	28	40.0	59	84.3	29.18	<0.001	49	70	69	98.6	21.57	<0.001
No	42	60	11	15.7			21	30	1	1.4		
Blood pressure												
Yes	36	51.4	66	94.3	32.51	<0.001	69	98.6	69	98.6	0.00	1.00
No	34	48.6	4	5.7			1	1.4	1	1.4		
SaO2												
Yes	64	91.4	69	98.6	3.76	0.12	70	100	70	100	-	-
No	6	8.6	1	1.4	FE		0	0	0	0		
Capillary refill												
Normal	70	100	70	100	-	-	70	100	70	100	-	-
Delayed	0	0	0	0			0	0	0	0		

** FE: Fisher Exact test **CTR: Chest tube removal*

Table (3): Comparison between study and control groups regarding total physiological and behavioral pain scores after chest tube removal (n=70)

Physiological and behavioral pain scores	Immediately after CTR*				30 minutes after CTR			
	Control group	Study group	Chi-Square Test	P-value	Control group	Study group	Chi-Square Test	P-value
No Pain								
No.	0	9			6	53		
%	0	12.9			8.6	75.7		
Mild pain								
No.	7	36			36	16		
%	10	51.4			51.4	22.9		
Moderate pain								
No.	32	25	60.42	<0.001	28	1	70.27	<0.001
%	45.7	35.7			40	1.4		
Severe Pain								
No.	31	0			0	0		
%	44.3	0			0	0		
Unbearable pain								
No.	0	0			0	0		
%	0	0			0	0		

**CTR: Chest tube removal*

Table (4): Comparison between the study group and control group regarding total physiological and behavioral parameters mean score after chest tube removal (n=140)

Physiological and behavioral parameters	Immediately after CTR*				30 minutes after CTR			
	Control group	Study group	Student t-test	P-value	Control Group	Study Group	Student t-test	P-value
Mean ± SD	19.5±4.04	13.74±2.73	9.89	<0.001	14.4±2.68	9.93±1.78	10.71	<0.001

**CTR: chest tube removal*

Table (5): Comparison between study and control groups regarding their pain intensity immediately and after 30 minutes of chest tube removal (n=140)

Pain intensity grade	Immediately after CTR*				30 minutes after CTR			
	Control group	Study group	X^2	P. value	Control group	Study group	X^2	P. value
No pain								
No.	0	8			4	52		
%	0	11.4			5.7	74.3		
Mild pain								
No.	4	38			34	18		
%	5.7	54.3			48.6	25.4		
Moderate pain								
No.	34	24	69.25	<0.001	32	0	78.07	<0.001
%	48.6	34.3			45.7	0		
Severe pain								
No.	32	0			0	0		
%	45.7	0			0	0		
Unbearable pain								
No.	0	0			0	0		
%	0	0			0	0		

**CTR: Chest tube removal*

Table (6): Comparison between the study group and control group regarding total pain intensity mean score after chest tube removal (n=140)

Pain intensity score	Control group	Study group	Student t-test	P-value
	Mean±SD	Mean±SD		
Immediately after CTR*	6.06±2.14	3.00±1.75	9.25	<0.001
30 min. after CTR	3.31±1.74	0.63±1.12	10.86	<0.001

**CTR: Chest tube removal*

Table (7): Comparison between study and control groups regarding their sensory descriptors of pain immediately and after 30 minutes of chest tube removal (n=140)

Sensory descriptors		Immediately after CTR*				30 minutes after CTR*			
		Control Group	Study Group	Chi-Square Test	P-value	Control group	Study group	Chi-Square Test	P-value
Absent	No.	0	9			4	53		
	%	0	12.9			5.7	75.7		
Throbbing	No.	2	3			0	0		
	%	2.9	4.3			0	0		
Cramping	No.	0	0			5	0		
	%	0	0			7.1	0		
Gnawing	No.	10	9			1	0		
	%	14.3	12.9			1.4	0		
Aching	No.	1	1			2	0		
	%	1.4	1.4			2.9	0		
Burning	No.	20	26	18.4	0.02	18	4	83.54	<0.001
	%	28.6	37.1			25.7	5.7		
Tender	No.	6	3			19	5		
	%	8.6	4.3			27.1	7.1		
Stabbing/ Sharp	No.	14	13			6	6		
	%	20	18.6			8.6	8.6		
Dull	No.	1	1			7	1		
	%	1.4	1.4			10	1.4		
Heavy	No.	4	1			8	1		
	%	5.7	1.4			11.4	1.4		
Splitting	No.	12	4			0	0		
	%	17.1	5.7			0	0		

**CTR: Chest tube removal*

Table (8): Comparison between study and control groups regarding their affective descriptors of pain immediately and after 30 minutes of chest tube removal (n=140).

Affective pain descriptors	Immediately after CTR				30 minutes after CTR			
	Control Group	Study Group	Chi-Square Test	P-value	Control Group	Study Group	Chi-Square Test	P-value
Absent								
No.	0	9			4	54		
%	0	12.9			5.7	77.1		
Tiring/ Exhausting								
No.	23	13			6	0		
%	32.9	18.6			8.6	0		
Cruel/ Punishing								
No.	25	17	15.16	0.004	12	0	77.10	<0.001
%	35.7	24.3			17.1	0		
Chocking								
No.	11	13			15	5		
%	15.7	18.6			21.4	7.1		
Fearful								
No.	11	18			33	11		
%	15.7	25.7			47.1	15.7		

**CTR: Chest tube removal*

The result of the present study shows that half of the control group, compared to two-thirds of the study group, were aged between 51-≥ 60 years; this might be explained because heart diseases are common in this age, and age is considered a major, well-known, non-modifiable risk factor for causing cardiovascular disease in the older population *(Rodgers et al., 2019).*

This finding was in agreement with *Awad (2019),* who conducted a study entitled "Application of cold therapy on procedural pain among post coronary artery bypass grafting patients" and found that three-quarters of the studied patients were their age more than 60 years old. Although, this finding was contradicted by *El Hady et al. (2007),* in a study to assess the effect of superficial cooling on CTR and found that about two-thirds of the studied subjects were in the age group between (35-50) years.

Regarding gender, the present study shows that two-thirds of the control group and the majority of the study group were males. This finding might be due to the males constituting most of this study sample, and it is evidenced that cardiac disease is more common in males than females. The male gender is one of the non-modifiable risk factors for cardiac disease that needs thoracotomy to be managed. This finding agreed with *Chandra et al. (2022)* in a study to assess race/gender as a risk factor for heart failure and changes in

cardiac structure and function and found that males showed worse systolic performance with a high risk for cardiac diseases.

This finding was congruent with *Sandhya and Jebarose (2020)* in a study to evaluate the effectiveness of ice pack application in reducing pain severity among the control and the ice pack group of patients with chest tubes and found that half of the control and the majority of the study group were males. This finding disagreed with *Bastani et al. (2016),* who mentioned in a study entitled "Comparing the effect of acupressure and cryotherapy on the pain caused by the removal of chest drain tube in elderly patients undergoing open heart surgery" and found that half of the control group and two-thirds of the study group were females.

Concerning the level of education, the present study indicates that more than two-fifths of the studied subjects were highly educated. This finding is likely due to most people having high education to get governmental and special sector jobs. This finding agreed with *EL Mokadem and Ibraheem (2017)* in a study entitled "Cold application and breathing exercises to reduce pain and anxiety during chest tube removal" and found that two-thirds of the study subjects were highly educated. Although, this finding disagreed with *Mazloum et al. (2018)* in a study to examine the effect of ice on improving the quality of pain related to CTR among patients after cardiac surgery and found that most studied subjects were illiterates.

Regarding marital status, the current study revealed that most subjects were married, possibly due to half of the control group compared to two-thirds of the study group aged between 51 and ≥60 years. This finding came following *Awad (2019),* who reported that two-thirds of the studied subjects were married.

Regarding occupation, the current study reveals that two-fifths of the control group compared to half of the study group were workers; this might be due to the findings of the present study showed that one-third and two-fifths of the studied subjects had secondary education, so they usually work as workers and not an employee because most governmental and special sectors require highly educated persons to get their jobs.

These findings were similar to *Yarahmadi et al. (2018)* study entitled "The combined effects of cold therapy and music therapy on pain following chest tube removal among patients with cardiac bypass surgery." They found that half of the studied group were working.

Regarding hemodynamic parameters between the study and control groups, the current study shows statistically significant differences regarding peripheral pulse, apical pulse, and respiratory rate between the study and control groups immediately and 30 minutes after CTR. As well as there was a statistically significant difference regarding blood pressure between the study and control groups immediately after CTR. This finding might be explained by the application of cryotherapy to affect nerve conduction velocity and reverse pain impulse through stimulating descending inhibitory neurons that block ascending nociceptive nerves so the brain will not consider CTR as the painful impulse. As well as application of cryotherapy directly to muscles results in the inhibition of the motor reflex loops, which preserve contraction and spasticity hence, reducing muscle spasms accompanied by CTR. So, it has analgesic, anti-spasmodic, and vasoconstrictive effects *(Kaprocki, 2019; Lister et al., 2020).*

These findings came in accordance with *Hanna et al. (2019),* who conducted a study entitled "Effect of cryotherapy versus transcutaneous electrical nerve stimulation on patients with hypertension" and found a significant difference in systolic and diastolic blood pressure between studied groups after cryotherapy application.

In addition, these findings were consistent with *Elmetwaly and El Sayed (2020),* who found highly statistically significant differences in the hemodynamic parameters following CTR with the cold application and breathing exercise during and following 10-15 minutes.

Moreover, these findings were congruent with *Yaman Aktaş et al. (2020),* who found significant differences between the studied groups regarding blood pressure and heart rate during the 24-h period. However, no statistically significant differences were noticed between the studied groups regarding respiration and oxygen saturation ($p > 0.05$).

Furthermore, these findings disagreed with *Kunter and Gezer (2019)*, in a study entitled "The effect of cold application before breathing exercises on sternotomy pain: A quasi-experimental study," and found non-statistically significant differences regarding blood pressure, pulse rate, respiration rate and oxygen saturation between the studied groups.

Meanwhile, these findings disagreed with *Zencir and Eser (2016)* in a study to evaluate the use of cold therapy to relieve pain and breathing exercises between patients with median sternotomy. They reported a non-statistically significant difference regarding oxygen saturation between the control and cold gel therapy groups, evidenced in this study.

In addition, these findings were incongruent with *Payami et al. (2014),* in a study to evaluate the effectiveness of cold therapy in combination with Indomethacin suppository to reduce pain following CTR in patients undergoing open heart surgery and found a non-statistically significant difference regarding blood pressure, heart rate and respiration immediately after CTR.

Concerning physiological and behavioral pain parameters between the study and control groups, the current study reveals statistically significant differences between total physiological and behavioral parameters immediately and after 30 minutes. Also, the study shows a reduced total mean pain score among the study group compared to the controls immediately and 30 minutes after CTR. These results support the stated research hypotheses that patients exposed to cryotherapy after chest tube removal experienced an improvement in physiological and behavioral pain parameters compared to controls. This effect was due to the physiological effects of the cryotherapy application that decreased nerve conduction velocity, muscle tone, reduced inflammatory process, and increased pain threshold.

These findings were congruent with *Mammen (2012),* who reported a statistically significant difference between physiological and behavioral pain (calmness and physical movement) among the studied groups, with a mean of 6.90±1.15 for the control group and 5.20±0.92 for study group 5-10 minute after CTR. In addition, these findings agreed with *Al-Otaibi et al. (2013),* who found a statistically significant difference regarding mean behavioral parameters among the studied groups (p=0.008). Also, these findings agreed with *Keawnantawat et al. (2018),* who stated that pain scores in the experimental group were statistically significantly decreased compared with the control group, that evidenced that cold therapy was effective in relieving pain after a heart operation in the acute phase.

Concerning comparison between study and control groups regarding their pain intensity, the current study reveals highly statistically significant differences in pain intensity total scores between study and control groups immediately and 30 minutes after 30 CTR. Also, it reveals highly statistically significant differences regarding total pain intensity mean score between the study and control groups immediately and 30 minutes after 30 CTR. Also, the current study shows a lower total mean intensity score for the study group compared to the control immediately and 30 minutes after CTR.

The result of the current study illustrates that pain intensity scores associated with CTR were significantly reduced with the use of cryotherapy (ice packs) compared to without cryotherapy application which supports the hypothesis of the current study that patients who were exposed to cryotherapy after chest tube removal would experience reduce pain intensity associated with CTR compared to controls. These results might be related to decreased sensory and motor nerve conduction velocities with cryotherapy application, which was defined as the direct analgesic effect of the cold application. Moreover, the cold application plays a vital role in stimulating cold receptors on the skin that lead to inhibition and block pain signals, which is called the indirect analgesic effect of cryotherapy *(Lister et al., 2020; Mohammadi et al., 2018).*

Also, the analgesic effect of cold application could be explained by the decrease in the conduction velocity of small non-myelinated nerve fibers responsible for transmitting pain stimuli from the periphery to the center, leading to paralyzing peripheral nerves. Meanwhile, the signal for the cold was transmitted faster than the signal for pain in nerve fibers, so the cold was sensed more intensely than the pain, indirectly increasing the pain threshold *(Hsieh et al., 2017; Kaprocki, 2019).*

These findings were in line with *EL Mokadem and Ibraheem (2017),* who found a statistically significant decrease in pain intensity attained at the three measurement points (immediate, 15, and 30 minutes) following CTR in the studied groups compared to the control group. Also, these findings agreed with *Kunter and Gezer (2019),* who found that cold application with breathing exercises was effective in reducing pain intensity, with a statistically significant difference between the study and control groups.

Moreover, these findings were congruent with *Al-Otaibi et al. (2013),* who revealed that the application of cold effectively decreased pain intensity after CTR. Whereas the pain intensity scores evaluated by visual analog score immediately after chest tube removal was higher than another score, then showed a decrease in the scores 15 minutes after CTR in the cold application group, showing the effectiveness of cryotherapy in the same line with the present study.

In addition, these findings agreed with *Ertuğ and Ülker (2011)* in a study to evaluate the effect of the cold application on reducing pain after chest tube removal. They reported statistically significant differences regarding pain intensity with cold application after cold application.

Also, these findings agreed with *Demir and Khorshid (2010),* in a study entitled "The effect of cold application in combination with standard analgesic administration on pain and anxiety during chest tube removal: a single-blinded, randomized, double-controlled study," who stated that pain scores significantly decreased in the experimental group. However, the patients in the current study had the property that they did not receive analgesia. Meanwhile, these results were congruent with *Sinha et al. (2016),* who stated that cold application had a statistically significant effect on decreasing pain after chest tube removal between cardiac patients after surgery.

In addition to that, these findings agreed with *Hasanzadeh et al. (2016),* in a study to evaluate the effectiveness of cold therapy and lavender oil inhalation among patients with cardiac surgery after CTR and reported that patients received cold therapy and lavender oil inhalation had significantly decrease in pain intensity compared with the control group immediately 5-, 10- and 15-mins following CTR. Also, these findings aligned with *Sandhya and Jebarose (2020),* who found a statistically significant difference regarding pain intensity with cold application among the two groups after the intervention revealed its efficacy.

Moreover, these findings agreed with *Gorji et al. (2014),* in a study entitled "Comparison of ice packs application and relaxation therapy in pain reduction during chest tube removal following cardiac surgery," they found that pain intensity in the cold therapy group at 15 minutes after CTR was lower than the control group. Meanwhile, these findings aligned with *Bastani et al. (2016),* who found statistically significant differences between the cryotherapy and control group regarding the pain intensity immediately after and 15 minutes following CTR.

Also, these findings aligned with *Zencir and Eser's (2016)* study to evaluate the use of cold therapy to relieve pain and breathing exercises between patients with median sternotomy. They reported that cold therapy was significantly effective in reducing pain in the early period of post–cardiac surgery. In addition, these findings were congruent with *Çevik et al. (2020),* in a study to assess the effectiveness of cold gel pack application to reduce sternum pain after open-heart surgery and found that pain intensity scores were statistically significantly decreased with the use of cold gel packs compared to the placebo group.

Moreover, these findings agreed with *Pishkarmofrad et al. (2016),* in a study entitled "Effects of localized cryotherapy on the severity of thoracic pain in patients undergoing coronary artery bypass grafting" and found that application of cryotherapy using ice packs statistically significantly decreased the pain of the patients undergoing CABG after surgery. Also, these findings followed *Elmetwaly and El Sayed (2020),* who stated a highly statistically significant difference regarding the mean pain scores during and 10 - 15 minutes after chest tube removal among the studied groups.

Meanwhile, these results were congruent with *Sinha et al. (2016),* who reported a reduction in mean pain score for the study group after cold application, compared to the control group (without cold application) at zero minutes, 15 minutes, and 30 minutes) of CTR among postoperative cardiac surgery patients.

Although, these findings were incongruent with *Hsieh et al. (2017),* who showed that, although the mean pain score in the experimental group after CTR was lower than that in the placebo group, there was no statistical difference regarding pain intensity scores among the studied groups and that revealed that cold application was not effective in reducing pain than placebo treatment. This discrepancy with the current study might be explained by the fact that the previous study was a small sample (N=30) for each group; cold application lasted only for 10 minutes that not enough to get its effect as well as pain was a subjective feeling; it was very difficult to exclude the placebo effect even in the study group so that the results could be controversial.

In addition, these findings contradicted *Sajedi-Monfared et al. (2021),* who found that the pain intensity score in the experimental group was lower than in the control immediately and 15 min after CTR in the experimental. However, this reduction was not statistically significant, so cold therapy was ineffective in relieving pain. This variation with the current study could be referred to as differences in ice bag dimensions as in these studies, the ice bags were small at 0.07 m and lasted for only 15 minutes after CTR. As well as in these studies, each group was small and contained 30 patients.

Moreover, these findings were incongruent with *Sauls (2002),* who reported non-significant differences in pain scores between the experimental and control groups and showed that cold application was ineffective in reducing pain. This variation between this study and the current study might be due to the small sample size (n = 25 per group), ice application lasted only 10 minutes as well as *Sauls (2002)* used tap water at 30.5°C to 31.6°C which was lower than the normal body temperature with a placebo effect that was different from the effect of the ice pack.

Meanwhile, these findings disagreed with *Yarahmadi et al. (2018),* who stated a non-statistically significant difference in pain intensity scores between the experimental and control groups at 15 minutes following chest tube removal (p=0.07), Although pain intensity during CTR was statistically significantly lower in cold therapy group compared to the control group.

In addition, these findings were incongruent with *Aktaş and Karabulut (2019),* in a study to examine the application of cold therapy, lidocaine spray, and music therapy for decreasing pain and anxiety after CTR and found that the cold application group did not show statistically significant differences in pain intensity score immediately and 20 min after CTR and that revealed that cold application was not effective in pain relieving. The discrepancy between this study and the present study might be attributed to the small sample size (n=30 for each group), and patients might have a different response to pain depending on physical illness and cultural and emotional experiences.

Concerning comparison between the study and control groups regarding their sensory descriptors of pain, the current study reveals statistically significant differences between the study and control groups regarding sensory descriptors and affective descriptors of pain immediately and thirty minutes after CTR. This finding could be explained by the concept of pain as a multidimensional phenomenon. Also, patients usually use their own expressions and judgments to quantify and express their sensory and affective components experienced following CTR. In addition, patients considered the application of cryotherapy to relieve CTR pain as a kind of care and attention, and individuals tended to change their behavior regarding pain expression when they felt interested and received particular attention. This phenomenon was identified as the Hawthorne effect.

These findings agreed with *Mazloum et al. (2018),* who stated that about half of patients used hot-burning and shooting descriptors, and more than one-third stated aching, heavy, and fearful descriptors immediately after CTR. This discrepancy with the current study might be due to using different tools to describe pain. Meanwhile, these findings follow *Sandhya and Jebarose (2020),* who stated that most of the control group used stabbing descriptors of pain, and about one-quarter experienced sharp and burning pain. Also, in the experimental group, most patients used sharp descriptors of pain, and about one-third had the stabbing type of pain.

Besides, these findings were congruent with *Pinheiro et al. (2015),* in a study to examine the use of lidocaine and multimodal analgesia for relieving CTR pain and reported that the most frequent descriptors of pain experienced by the subjects were sharp and burning. In addition, these findings were in the same line with *Hasanzadeh et al. (2016),* who stated that patients mostly selected the words "fearful" and "tender to express their quality of pain after CTR. Also, these findings were in the same line with *Puntillo and Ley (2004),* in a study, "Appropriately timed analgesics control pain due to chest tube removal," and found that about half of patients used fearful descriptors to describe the pain associated with CTR and two-fifths of them stated sharp, tender and hot-burning. In addition, these findings agreed with *El-Hady et al. (2007),* who found that most people described their pain after CTR as a fearful descriptor that might be due to poor patient preparation with an increased level of anxiety.

Moreover, these findings disagreed with *Demir and Khorshid (2010),* who stated that the majority of patients used the "stinging" descriptor to describe their quality of pain

experience, and about three-quarters stated the "sore" descriptor. This discrepancy with the current study might be due to using different tools to describe pain besides the concept of pain as a multidimensional phenomenon. Also, patients usually use their expressions and judgments to report their pain quality experienced following CTR.

In addition, these findings agreed with *Çelik and Ozer (2020),* in a study entitled "Effect of cold application on chest incision pain due to deep breathing and cough exercises," who stated a statistically significant difference regarding pain quality (sensory and affective descriptors) that experienced by the patients.

Also, these findings were in the same line with *Ebrahimi-Rigi et al. (2016),* in a study, "Effect of cold therapy on pain of deep-breathing and coughing in patients after coronary artery bypass grafting," who stated a statistically significant difference regarding pain quality (sensory descriptors) that experienced by the patients. Although, it was reported that cold therapy did not affect affective pain descriptors.

Meanwhile, these findings were incongruent with *Mazloum et al. (2018),* who found non-statistically significant differences regarding sensory and affective items of SF-MPQ between the cold therapy group, placebo, and control group except for hot-burning descriptor (p=0.009). In addition, these findings were incongruent with *Sauls (2002),* who reported a non-statistical significant difference regarding sensory and affective descriptors between the two groups.

7. Conclusion

- Based on the current study's findings, the study hypotheses were supported that patients exposed to cryotherapy after CTR would experience improvement of physiological and behavioral pain parameters compared to controls and will experience reduced pain intensity and quality compared to controls. The present study has proved that cryotherapy was effective in pain reduction associated with chest tube removal after thoracotomy.

8. Recommendations

Based on the findings of the current study, the following recommendations were suggested:

- Motivate critical care nurses to attend conferences and workshops to update their knowledge and practice regarding the application of cryotherapy for relieving pain associated with CTR after thoracotomy.
- Provide periodic in-service educational and training programs for critical care nurses regarding benefits, methods, contraindications, and side effects of cryotherapy for relieving pain associated with CTR after thoracotomy.
- Develop a simplified and comprehensive booklet for critical care nurses, including basic knowledge and practices regarding the application of cryotherapy for relieving pain associated with CTR after thoracotomy.
- Cryotherapy should be included in standard treatment protocol and practice guidelines for reducing pain-associated CTR after thoracotomy.
- Conducting a comparative study to examine the effectiveness of different modes of cryotherapy (e.g., cold spray, ice towel, ice pack, ice chip, and ice massage) to alleviate CTR pain.
- Conducting a comparative study to examine the effectiveness of different non-pharmacological therapeutic methods for managing pain after CTR.
- Conducting future studies to evaluate the suitable therapeutic interval and duration for applying cryotherapy to achieve its clinical benefits for managing pain associated with CTR.

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