Cold application for pain and anxiety reduction following chest tube removal : A systematic review and meta-analysis

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Research

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Abstract

Background and Objective: Data on the effects of cold application on reducing pain and anxiety after chest tube removal (CTR) are inconsistent. This study aimed to conduct a systematic review and meta-analysis to evaluate the effects of cold application on pain and anxiety reduction after CTR.

Methods: We searched six databases, including Embase, Ovid Medline, Cochrane Library, Scopus, the Index to Taiwan Periodical Literature System, and Airiti Library, to identify relevant articles up to the end of February 2021. We limited the language to English and Chinese and the design to randomized controlled trials (RCTs). All studies were reviewed by two independent investigators. The Cochrane Collaboration's tool was used to assess the risk of bias, and Review Manager 5.4 was used to conduct the meta-analysis.

Results: Ten RCTs with 623 participants were included in the meta-analysis. The use of cold application could effectively reduce immediate pain and had persistent effects on pain after CTR. There were significant effects of cold application on reducing anxiety. The meta-regression showed that a drop in skin temperature to the 13°C target of cold application was significantly more effective for the immediate reduction in pain intensity compared with receiving up to 20 minutes target of cold application.

Conclusion: Cold application is a safe and easy-to-administer nonpharmacological method with immediate and persistent effects on pain and anxiety relief after CTR. In particular, skin temperature drops to the 13°C target of cold application were effective for immediate reduction of pain intensity following CTR.

Introduction

A primary goal of chest tube removal (CTR) is the removal of tubes without the introduction of air or contaminants into the pleural space [1, 2]. The removal of a chest drain is a painful and frightening experience; however, most guidelines regarding CTR do not mention this. The act of removing the chest tube often causes pulling of the endothelial tissue adhered to the chest tube and stimulates intercostal nerves and inflamed pleura, all of which can cause pain [3-5]. A study conducted by Al-Otaibi et al.[6] found that the procedure of removing a chest tube not only causes moderate to severe pain but also increases anxiety. The source of anxiety may be related to fear and worry about the pain caused by the upcoming chest tube removal procedure.[6]

Currently, analgesics, including opioid and nonopioid drugs, are routinely prescribed to patients who are about to undergo CTR to alleviate pain during the procedure [6]. However, the use of analgesics may cause side effects such as hypoventilation, nausea, allergic reactions, and gastrointestinal bleeding [7]. Nonpharmacological interventions for pain related to chest tube removal, including music therapy, aromatherapy, and cold application, have been investigated [4, 7, 8]. Few studies have focused on the effects of music therapy and aromatherapy for reducing pain after CTR.

Cold application is a common nonpharmacological intervention used to relieve the pain caused by CTR [9]. Some studies have shown that cold application can also decrease anxiety levels [4, 8]. The mechanism of cold application mainly involves a slowing of the metabolism in skin tissue, an acceleration of nerve conduction and an increase the pain threshold, thereby reducing pain [10, 11]. Lee et al. [12] proposed that there was a residual effect of cold application on nerve velocity that could last 30 minutes after the removal of ice. However, the effectiveness of cold application for pain and anxiety level reductions are inconclusive. In addition, the chest tube management guideline does not mention pharmacological or nonpharmacological pain control for chest tube removals [13, 14]. The aim of the present systematic review and meta-analysis was to evaluate recent RCTs that analyze the effects of cold application on pain and anxiety after CTR. Furthermore, we also explored the effective period of time and target temperature of cold application related to pain relief after CTR.

Methods

Search strategy

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [15] (Supplementary Table 1 shows the PRISMA checklist) to explore the efficacy of cold application on pain intensity and anxiety levels in adults after CTR. Six databases, including Embase, Ovid Medline, Cochrane Library, Scopus, the Index to Taiwan Periodical Literature System, and Airiti Library, were systematically searched to identify relevant articles published from 1975 to February 2021. Reference lists of relevant articles were reviewed to identify additional studies. Four main concepts, chest tube removal, cold application, pain, and anxiety search strategy used combination with controlled vocabulary (11 MeSH terms and 5 Emtree terms) and free-text terms (19 synonyms plus truncation symbols) (Supplementary Table 2 shows the search strategy). The study protocol was registered in the PROSPERO international prospective register of systematic review (CRD42021245482).

Eligibility criteria

The inclusion criteria included (1) publications in either the Chinese or English language, (2) randomized controlled trials (3) adults (aged 18 years and over) who had at least one chest tube removed from the pleural or mediastinal spaces in which (4) the experimental group received cold application and usual care and (5) the control group received usual care (or no treatment), and (6) the study outcome must have included a measurement of pain or anxiety. The exclusion criteria were as follows: (1) the experimental and control groups received different analgesic dosages before CTR; or (2) the experimental group received two or more nonpharmacological interventions.

Data extraction and quality assessment

Two reviewers (C. T. Chen and S. H. Tsai) independently extracted and assessed the quality of eligible articles using the Cochrane Collaboration's tool. The seven domains were rated as either low risk, unclear, or high risk [16]. Any disagreements were resolved by consensus or consultation with a third author (J. L.

Wang).

Data synthesis and analysis

We used Review Manager 5.4 to analyze the effect of cold application on pain intensity and anxiety levels in adults after CTR. The mean difference (MD) and 95% confidence intervals (CIs) were used to analyze continuous outcomes of pain intensity and anxiety level. Heterogeneity was assessed using Cochrane's Q statistic and I-squared [17]. If the I^2 value>50% or P value < 0.10 was defined as statistical heterogeneity, sensitivity analysis with meta-regression was conducted by the software Open MetaAnalyst with a random-effects model [18]. A funnel plot was applied to evaluate publication bias.

Result

Literature search

A total of 110 articles were retrieved from six electronic databases and websites, and 35 articles were removed due to duplications. After the title, abstract and keywords were reviewed, 52 articles were discarded as not being sufficiently relevant, and 5 articles were abstracts for conferences. A total of 16 full-text articles were left for consideration. Eight articles were excluded for the following reasons: non-RCTs (n=3), irrelevant outcomes (n=2), same study reported twice (n=1), study without any report of standard deviation and 95% confidence intervals (n=3), and high risk of bias (n=2). Finally, 10 articles met the inclusion criteria and were included in the qualitative synthesis (Fig 1).

Methodological quality assessment

Among the 10 studies, 5 studies (50%) were rated as having a low risk of bias for random sequence generation because they were randomly employed using random number generators, random number tables, block randomization, eight-member block randomization, or computer programs [7, 8, 19-21], and 5 studies were rated as having an unclear risk of random sequence generation [3, 4, 22-24]. One study was rated as having an unclear risk of concealment because the author did not provide a detailed explanation [8], and 9 studies (90%) were rated as having high risks of allocation concealment [3, 4, 7, 19-24]. Two studies were rated as having unclear risks of blinding of participants or researchers [8, 23], and 8 studies (80%) were rated as having high risks of blinding of participants or researchers [3, 4, 7, 19-22, 24]. Because cold application is a nonpharmacologic therapy, it is difficult to blind both participants and researchers. Two studies were rated as low-risk for the blinding of the outcome assessments [8, 19], and 8 studies (80%) were rated as high-risk for the blinding of the outcome assessments [3, 4, 7, 20-24]. All studies (100%) were rated as low-risk for incomplete outcome data, selective reporting, and other biases. The results are depicted in Supplemental Figure 1.

Study characteristics

The characteristics of the ten included RCTs are summarized in Table 1. Five intervention studies used cold application [8, 20-22, 24], and 5 intervention studies used cold application plus a standard drug treatment [3, 4, 7, 19, 23]. The intervention durations varied from 10 minutes to 20 minutes [3, 4, 8, 11, 20-23], and 2 studies showed that cold application applied to the skin dropped the skin temperature to 13.6°C before CTR [7, 24]. The cold application was applied to the area surrounding the chest tube with 9-inch[8], 7-cm[24], 5-cm [23], and 6-inch [22] diameters. The major outcomes included the pain intensity and anxiety level. Pain intensities were measured by using the vertical visual analog scale (VAS), Numeric Rating Scale (NRS), and McGill Melzack Pain Questionnaire (MPQ). Anxiety levels were measured by the State Trait Anxiety Invent (STAI) and Hamilton Anxiety Scale (HAS). No adverse events were reported from any study.

Cold application and immediate pain intensity

Ten studies using the VAS or NRS measurement were included in the meta-analysis to assess pain intensity. Due to high heterogeneity ($P < 0.00001$, $I^2 = 83\%$), the random effects model was selected. The results showed that cold application significantly reduced immediate pain intensity after CTR (MD: 1.32, 95% CI = -1.77 to -0.87, $P < 0.00001$) (Fig 2a).

Meta-regression of time and temperature target of cold application

Due to the high heterogeneity and variety of cold applications, covariates for meta-regression were divided into time up to 20 minutes and skin temperature drops to the 13°C target of cold application. The results showed that skin temperature drops to the 13°C target of cold application were more effective for the immediate reduction of pain intensity, compared to receiving cold application over a duration up to 20 minutes after CTR (coefficient: -0.979, Std. error 0.376, *P= 0.009*) (Fig 2b).

Cold application and persistent effects (15 minutes) on pain intensity

Six studies were included in the meta-analysis, and the results revealed that cold applications had significantly persistent effects (15 minutes) on pain intensity (MD: -0.50, 95% CI = -0.95 to -0.05, $P = 0.03$) after CTR (Fig 3).

Cold application and anxiety level

Three studies were included in the meta-analysis to assess anxiety levels. The random effects model was selected due to high heterogeneity ($P = 0.02$, $I^2 = 76\%$). The results revealed that cold application significantly reduced anxiety levels after CTR (SMD: -0.74, 95% CI = -1.40 to -0.07, $P = 0.03$) (Fig 4). Two studies showed that cold application did not significantly reduce immediate anxiety levels after CTR (SMD: -0.50, 95% CI = -1.41 to -0.41, $P = 0.28$). Only one

study showed a significant difference between the anxiety scores of the cold application and control groups 20 minutes after CTR (SMD: -1.19, 95% CI = -1.74 to -0.64, $P < 0.0001$) (Fig 4).

Publication bias

Funnel plots were investigated through visual inspection to assess the publication bias of the included studies. The shape of the funnel plot showed evidence of obvious symmetry (Supplemental Figure 2).

Discussion

Several randomized studies have discussed the effect of cold application on pain caused by CTR. However, owing to the small sample sizes of the various studies, different strategies of cold application, and different time pain evaluation points considered after CTR, no certain effect of cold application alleviation after CTR can be confirmed. This study is the first to use a meta-analysis to investigate the effect of cold application on pain caused by CTR. The results of the meta-analysis show that cold application can effectively reduce immediate pain intensity after CTR. This result is similar to those from the two studies conducted by Sajad et al. [20] and Ertug and Ulker [24], respectively. In addition to pain relief after CTR, cold application was also reported to reduce pain before arterial puncture and intramuscular injection, but few studies have been reported [25, 26]. Cold application can lower the skin tissue temperature, impede the sensory nerve response and nerve conduction speed, and produce anesthetic effects, resulting in analgesia [27].

Currently, there is no consensus on the strategy of cold application regarding pain relief after CTR. Our meta-regression showed that a skin temperature drop to a target of 13°C effectively and immediately reduced the pain intensity following CTR. A study by Lowitzsch et al.[28] found that applying cold application to the skin and causing its temperature to drop to 27°C led to a change in the nerve conduction velocity. When the skin temperature drops to 10°C–15°C, cell metabolism slows, and the anti-inflammatory effect is augmented [27, 29-31]. If the skin temperature drops to 13.6°C or the cold application lasts 20 minutes, an analgesic effect can then be achieved [12, 27, 32]. Based on the abovementioned research results and arguments, it is recommended to check whether the regional skin temperature has reached 13.6°C when cold application is applied as a method to reduce pain in patients undergoing CTR. If the equipment is not available for checking skin temperature, 20 minute of cold application is recommended before performing CTR [3, 20].

In terms of the effect of persistent cold application (15 minutes) on pain after CTR, the meta-analysis shows that there is a significant difference in the pain intensity between the experimental group and control group. This result is consistent with the findings of Mokadem et al. [4] Lee et al.[12] pointed out that even after the cold application is removed, a residual effect reducing the nerve conduction velocity remains, such that analgesia is maintained.

Regarding the effect of cold application on anxiety reduction among patients receiving CTR, the result shows a significant difference but high heterogeneity. We supposed that this may be related to different tools, varying time points of anxiety evaluation, and the limited number of 160 participants. The results should be explained with caution. Further studies are required to confirm the effects of cold application on reducing anxiety levels after CTR.

Among the papers included in this systematic literature study, nine out of the ten included studies did not mention whether there were any complications of wound infection or frostbite in the experimental groups in which patients received cold application. Only one study indicated that no side effects were noted [24]. According to a systematic literature review by Greenstein [27], if a cold application causes the skin temperature to drop to −5°C or cold is applied for > 30 minutes, temporary or permanent frostbite or nerve damage may occur. Therefore, before and during cold application, it is necessary to closely monitor patients' skin temperature and the application duration. In addition, for patients with a medical history of Raynaud's disease, rheumatoid arthritis, cryoglobulinemia, cold urticaria, arteriosclerosis, or vascular injury, cold application is not recommended owing to contraindication concerns [27, 33].

Limitations

This study has some limitations. First, the search strategies were limited to two languages, Chinese and English, and we only included ten studies with small sample sizes, which may affect the precision of our outcomes. Second, various studies have used different cold application strategies combined with different types of medications; therefore, we could not evaluate the effectiveness of different types of cold application on pain intensity in detail, and we do not know if combinations with other relaxation methods help. Third, the initial subjective pain intensity of the participants in all studies was not equal, which may contribute to heterogeneity. Fourth, most of the studies lacked a good concealment and blinding method; therefore, the results should be interpreted with caution. Finally, most eligibility criteria included participants over the age of 18 who underwent cardiothoracic surgery and had at least one chest tube; therefore, the generalization of the results may not be suitable to pediatric or medical patients with CTR.

Conclusion

The results from this meta-analysis revealed that cold application can efficiently reduce pain intensity after CTR. When the skin temperature dropped to the target of 13°C with cold application, the effect was a more immediate reduction in pain intensity following CTR. Cold application is an effective and safe, nonpharmacological strategy that is easy to administer by a healthcare worker. Cold application could be included in the standard nonpharmacological management for reducing pain during CTR.

Declarations

Ethical Approval and Consent to participate

Not applicable.

Consent for publication

All authors have read and agreed to the submission of the manuscript.

Availability of supporting data

All data used and analyzed during this study are included in this published article and additional files.

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Author Contributions:

CT Chen and SH Tsai were responsible for this study's design. CT Chen completed the analysis of the data and manuscript preparation. YC Chen and HH Tung were responsible for revising the manuscript. CT Chen, HH Tung, YC Chen, JL Wang, SH Tsai, YT Huang, and TF Hsu approved the final manuscript.

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Conflict of interest:

The authors declare no potential conflicts of interest in this study.

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Table

Table 1. characteristics of included studies

Author, year	Sample (I/C)	Age (mean±SD)	Intervention Description (before CTR)	Control Descriptio (before CTR)
Sauls, 2002	50 (25/25)	T:59.7±13.06,	Ice pack 10 mins	Water pac from 87° I to 89° F
Demir and Khorshid, 2010	90 (30/30/30)	T:53.4±14.04	Cold application 4C° 20 mins plus SDT	C^1: warm applicatio 18-24C° plus SDT, C^2: SDT
Ertug and Ulker, 2012	140 (70/70)	I:48.74±16.59, C:49.17±16.20	Ice bag until skin temperature reached 13°C	No interventi
Payami et al., 2014	66 (32/34)	I:57.31±7.8, C:60.18±6.2	Cold pack 4C°20 mins plus SDT	Room temperatu get pack plus SDT
Gorji et al., 2014	90 (30/30/30)	I:57.75±9.38, C:58.48±9.78	I^1:Cool gel packs until skin temperature reached 13° plus SDT I^2: Relaxation skill 5mins plus SDT	SDT
Hasanzadeh et al., 2016	80 (I^1:20,I^2:20,I^3:20/C:20)	T:54.3±10.9	I^1: Cooling gel pack until skin temperature reached 13°C plus SDT I^2:inhaled lavender oil 20 mins plus SDT I^3:Cold with cooling gel pack plus inhaled lavender oil 20mins plus SDT	SDT
Mokadem et al., 2017	120 (I^1:30,I^2:30,I^3:30/C:30)	I^1:40.25±10.98I^2:37.55±14.12,I^3:39.15±10.99 C:41.25±10.7	I^1:Cool gel pack 15 mins plus SDT I^2:Breathing exercises plus SDT I^3:Cool get pack and breathing exercises plus SDT	SDT
Yarahmadi et al., 2018	174 (I^1:43,I^2:44,I^3:43/C:44)	I^1:58.9±8.3,I^2:60±5.7,I^3:59.4±6.3,C:56.8± 9.2	I^1:Ice pack -5°C 20 mins I^2:Listening to music 30 mins I^3:Ie pack plus music	No interventi
Aktas and Karabulut,2019	120 (I^1:30,I^2:30,I^3:30/C:30)	I^1:62.6±12.11,I^2:64.13±9.59,I^3:64.8±7.07,C:65.8±7.23	I^1:Cold gel packet 20 mins I^2:Music therapy 20 mins I^3:lidocaine spray	No interventi
Zahra et al.,2021	120 (I^1:30,I^2:30,I^3:30/C:30)	I^1:57.70±10.16,I^2:59.43±11.78,I^3:51.26±15.77,C:53.83±12.25	I^1:Ice bag 20 mins I^2:Respiratory exercise 20 mins I^3:Ice bag and respiratory exercise	No interventi

I/C: intervention/control, T:toal, SD: standard deviation, VAS: Visual Analogue Scale, NRS: Numeric Rating Scale, CTR: chest tube removed, SF-MPQ: Short-form McGill Pain Questionnaire, STAI: State Trait Anxiety Invent, HAM-A: Hamilton Anxiety Scale, SDT: standard drug treatment,

Figures

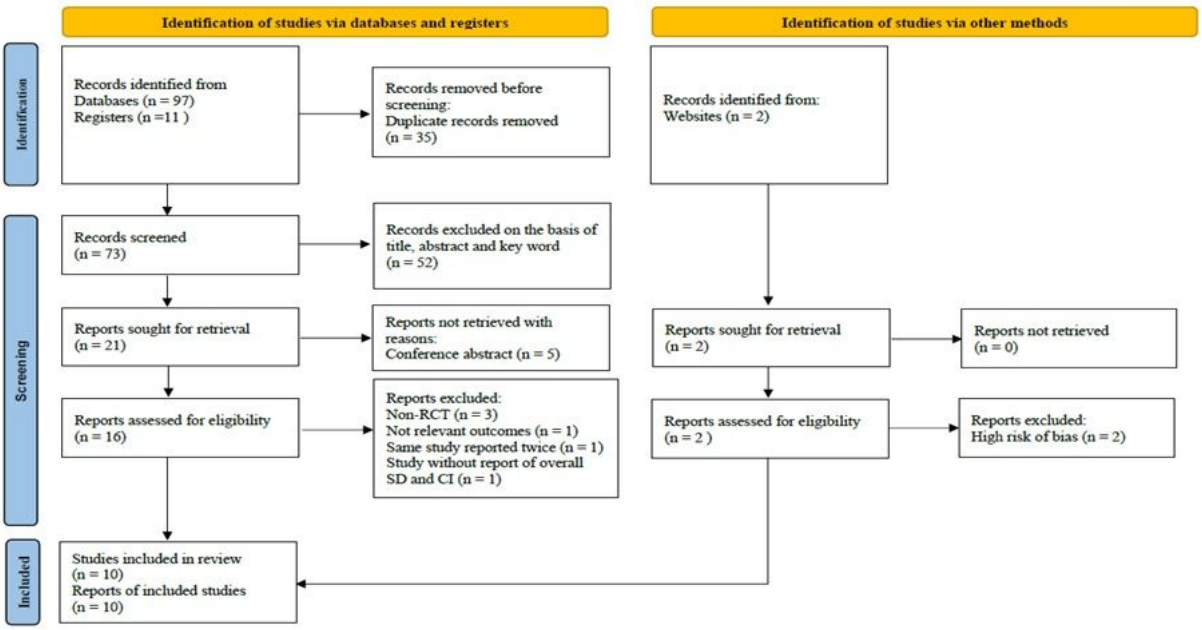

Figure 1

PRISMA diagram for the literature search and selection process.

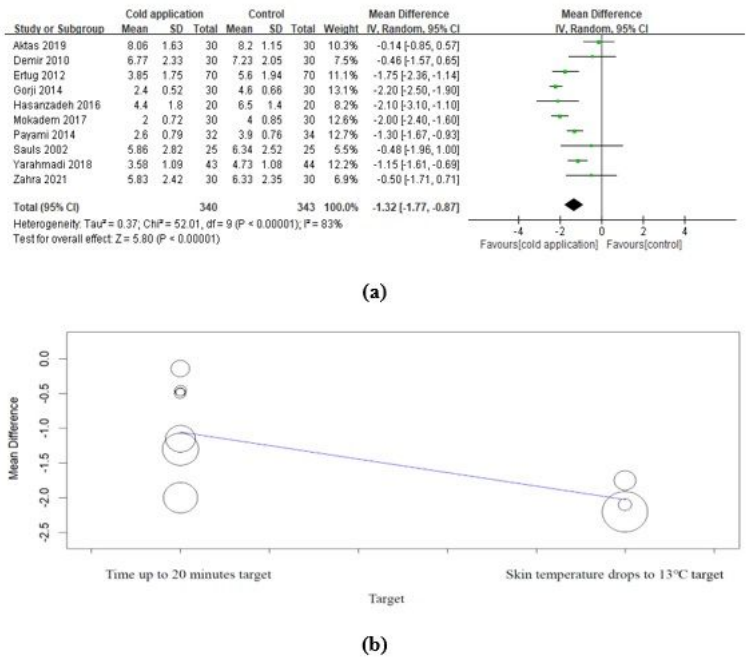

Figure 2

(a) Mean difference in the effects of cold application on reducing pain intensity (Visual Analog Scale, VAS; Numerical Rating Scale, NRS) immediately after CTR compared with the control. (b) Bubble plots of covariate meta-regression between time up to 20 minutes and skin temperature drops to the 13°C target of cold application.

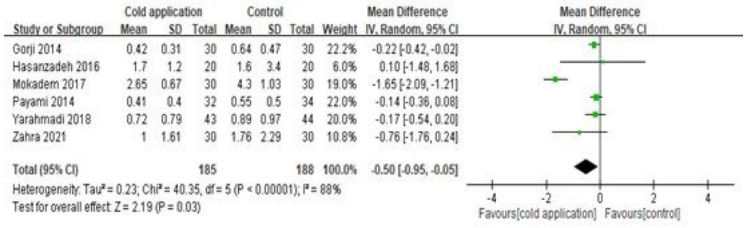

Figure 3

Mean difference in the effects of cold application persistent effect (15 minutes) on pain intensity after CTR compared with the control.

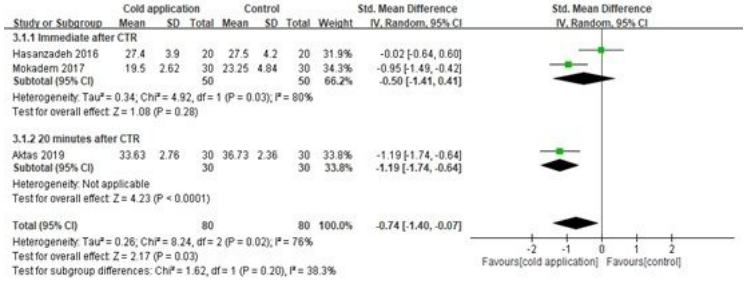

Figure 4

Standard mean difference in the effects of cold application on anxiety level after CTR compared with the control.

Supplementary Files

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