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Effectiveness of non-pharmacological interventions for thirst in ICU patients: a systematic review and network meta-analysis

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Abstract

Aim This study systematically compared the efficacy of non-pharmacological interventions that may improve thirst in intensive care unit (ICU) patients.

Background Thirst is among the most intense and distressing symptoms experienced by ICU patients. Recently, various non-pharmacological interventions have been applied to alleviate thirst symptoms and have shown positive effects. However, there is no consensus on which non-pharmacological intervention is the most effective, making it difficult to choose interventions to alleviate thirst in ICU patients.

Design Systematic review and network meta-analysis based on PRISMA.

Methods Computer searches were conducted in eight Chinese and English databases to identify randomized controlled trials published before October 12, 2024, on non-pharmacological interventions to improve thirst symptoms in ICU patients. Two researchers performed literature screening and data extraction, and RevMan 5.3 and Stata 15.0 software were used for literature quality assessment and data analysis.

Results 24 articles involving 2480 ICU patients and 14 types of non-drug interventions were included. The network meta-analysis results revealed that compared with those in routine care, the degree of thirst in ICU patients was significantly different significant for menthol lozenges, ice water injection, menthol water spray, ice saline water spray, ice menthol water spray, and ice water spray (all $P < 0.05$). According to the ranking results of the cumulative ranking probability curve area (SUCRA), ice menthol water spray is the optimal solution for improving the degree of thirst in ICU patients.

Conclusion Ice menthol water spray is the best non-pharmacological intervention for reducing thirst in ICU patients. When patients experience thirst, such as in the ICU ward, medical staff can use ice peppermint water spray to relieve

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the patient's thirst symptoms. Future research should focus on directly comparing the effects of different non-pharmacological interventions and evaluating their cost-effectiveness.

PROSPERO (International Prospective Register of Systematic Reviews)registration number CRD42024614636.

Relevance to clinical practice The results of this study can provide a basis for medical staff to alleviate the thirst of ICU patients, with the results particularly supporting the use of ice mint water spray to reduce the level of thirst in ICU patients.

Keywords Thirst, Critically ill patients, Non-pharmacological interventions, Network meta-analysis

Introduction

Thirst is a subjective sensation caused by physiological or behavioral factors and is characterized by a lack of sufficient water and a desire to drink. It is an important component of the body's volume and fluid balance regulation mechanism [1]. Patients in the intensive care unit (ICU) are at high risk for discomfort due to factors such as illness, treatment, and medication [2]. Research shows that the incidence of thirst among ICU patients is 76.1%, making it one of the most intense and distressing symptoms experienced by ICU patients [3]. A previous study evaluated symptoms in 171 high-risk ICU patients 405 times, and the results revealed that thirst symptoms were the most severe, with the incidence of moderate to severe thirst reaching as high as 70% [4]. Some critically ill patients still have painful memories of discomfort, such as thirst, even after leaving the ICU [5].

However, most ICU patients are unable to communicate normally with medical staff, and the staff may overlook patients' symptoms of thirst [6]. Persistent thirst not only increases the body's oxygen consumption and metabolic burden on organs but also leads to bacterial colonization in the oropharynx, secondary oral mucosal infections, and retrograde pulmonary infections [7]. Additionally, severe thirst lasting more than 24 h can increase the risk of delirium in ICU patients by 4.95 times [8], increasing the risk of accidental extubation, and is considered a stressor second only to death [2]. Therefore, medical staff must identify the thirst symptoms of ICU patients early and take appropriate measures to alleviate these symptoms early.

Currently, methods to alleviate thirst mainly include spray methods (such as ice water spray, normal temperature water spray, ice menthol water spray, lemon water spray, etc.), direct ingestion methods (such as ice water injection, normal temperature water injection, etc.), and physical stimulation methods (menthol lozenges, oral ice cotton balls, etc.) [9]. Recently, multiple randomized controlled trials (RCTs) have evaluated the effectiveness of non-pharmacological interventions in alleviating thirst in ICU patients. However, most RCTs choose routine care (such as using cotton swabs dipped in water to moisten the lips) as a control, and only a few studies have directly compared the differences between different non-pharmacological interventions. Moreover, several systematic reviews have only assessed the impact of a single non-pharmacological intervention on improving thirst levels [10–11], but there is no high-level evidence comparing the effectiveness of two or more different non-pharmacological interventions in alleviating thirst in ICU patients. Therefore, medical staff are unclear about which non-pharmacological interventions to choose to alleviate patients' thirst symptoms. Currently, ICU medical staff primarily rely on clinical experience to manage thirst, and the interventions and processes lack systematic and standardized approaches [12].

Network meta-analysis (NMA) is a method that allows the comparison of more than two interventions. It enables indirect comparisons of the effects between different interventions on the basis of a common control, merges the results of both direct and indirect comparison evidence, and quantitatively ranks the interventions [13] to help obtain the optimal solution. Therefore, this study compares and ranks the effects of non-pharmacological interventions in preventing thirst in ICU patients through network meta-analysis, aiming to provide a reference for ICU nurses to make reasonable choices regarding oral moisturizing methods.

Methods

Research registration

This study was conducted in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Supplementary File 1). This research protocol has been registered on the PROSPERO platform with the registration number CRD42024614636.

Inclusion and exclusion criteria

Develop the inclusion criteria for the literature based on the PICOS principle. ①Population: ICU patients; ②Intervention: Non-pharmacological interventions; ③Comparison: Routine care (using a cotton swab to moisten the lips with water) or a different non-pharmacological intervention from the intervention group; ④Outcome: Degree of thirst, assessed using the numeric rating scale (NRS) or the visual analog scale (VAS); ⑤Study: Randomized Controlled Trial (RCT).

The exclusion criteria were as follows: duplicate publications; inability to contact the authors to obtain the full text or incomplete data; and studies that involved the combined use of two or more different non-pharmacological interventions.

Search strategy

Computer searches were conducted on PubMed, Web of Science, Embase, the Cochrane Library, Wanfang, CNKI (Chinese National Knowledge Infrastructure), VIP (Chinese Science and Technology Periodical), and the Chinese Biomedical Literature Database, with the search period extending from the establishment of the databases to October 12, 2024 (Supplementary File 2, Table 1). The search terms included "Intensive Care Units/intensive care unit*/ICU/CCU/intensive care/critical* care*/critical* ill*/critical illness critical care nursing" and "thirst/thirsts/xerostomia/xerostomias/hyposalivation*/asialia*/mouth dryness/dryness, mouth". Both used a combination of subject terms and free terms for retrieval, while tracing the references included in the research. Taking the Web of Science as an example, the search strategy is as follows:

#1 TS=(Intensive Care Units OR intensive care unit* OR ICU OR CCU OR intensive care OR critical* care* OR critical* ill* OR critical illness critical care nursing).

#2 TS=(thirst OR thirsts OR xerostomia OR xerostomias OR hyposalivation* OR asialia* OR mouth dryness OR dryness, mouth).

#3 #1 AND #2.

Literature screening and data extraction

Two researchers independently conducted literature searches, imported all the retrieved literature into Endnote X9 software to remove duplicate entries, and then each researcher read the titles and abstracts for initial screening. They subsequently read the full texts of the initially screened literature, excluding irrelevant articles and those for which full texts or complete data could not be obtained. Controversial articles, were resolved issues through discussion or by a third researcher's adjudication. The following information was extracted from the included literature: authors, publication date, country, sample size, age, intervention measures, intervention frequency, assessment tools, etc.

Quality assessment

Two researchers independently conducted a quality assessment of the literature using the standards for RCTs outlined in the Cochrane 5.1.0 systematic review manual. The evaluation content included: random sequence generation, allocation concealment, blinding of participants/researchers, blinding of outcome assessors, completeness of outcome data, selective reporting, and other sources of bias. Determine whether each of the above indicators is classified as low risk, high risk, or unclear. If the literature fully meets the evaluation criteria, the literature quality grade is A; if it partially meets the evaluation criteria, the literature quality grade is B; if it does not meet the evaluation criteria at all, the literature quality grade is C. This study ultimately included A and B level literature. In the process of evaluating the quality of the literature, any disagreements were resolved by consulting a third party.

Statistical analysis

RevMan 5.3 was used for literature quality evaluation, heterogeneity testing, and traditional meta-analysis. An $I^2 \leq 50\%$ or $P > 0.05$ indicated low heterogeneity in the study, and a fixed-effects model was used for the meta-analysis. An $I^2 > 50\%$ or $P \leq 0.05$, it indicated high heterogeneity, and a random-effects model was used for the meta-analysis. Pain scores are quantitative data, so the mean difference (MD) and 95% confidence interval (95%CI) are used as effect sizes.

Stata 15.0 software was used to conduct a frequentist network meta-analysis, and the inconsistency test model was employed to assess the overall consistency among the included studies. When $P > 0.05$, it indicates good consistency between direct and indirect evidence. By ranking the efficacy of 14 different non-drug interventions via surface under the cumulative ranking (SUCRA), a larger SUCRA value indicates that a particular intervention may be more effective. Acomparison-adjusted funnel plot was draw to reflect whether the included studies had literature has publication bias and small sample effects.

Results

Study search results

A total of 2,431 relevant studies were retrieved from 8 databases. All studies were imported into Endnote X9 to remove duplicate studies, resulting in the elimination of 697 duplicates. After the titles and abstracts were read according to the inclusion and exclusion criteria, 1,611 studies were excluded. The remaining studies were read in full, and 99 studies that did not meet the requirements were filtered out, leaving 24 studies for final inclusion. Among them, 19 studies were published in Chinese [14–32]; and 5 studies were published in English (33–37). The specific process and results of the literature screening are shown in Fig. 1.

Basic characteristics of the included studies

A total of 24 RCTs were included, with a total of 2480 cases, and the studies were published between 2017 and 2024. Among them, 4 studies [24, 26, 27, 36] were three-arm studies, 1 study [29] was a four-arm study, and the rest were two-arm studies. The interventions included: ice water spray, normal temperature water spray, ice

Table 1 Basic characteristics of the included studies

			Sample size, *n*		Age, y		Group *			
Author	**Year**	**Country**	**Interv**	**Cont**	**Interv**	**Cont**	**Interv**	**Cont**	**Intervention frequency**	**Assessment tool**
Bao, LY [14]	2022	China	35	35	67.69 ± 13.54	68.11 ± 10.16	E	A	Intervene every 4 h, for 5 days.	NRS
Tu, WY [15]	2020	China	51	50	50.24 ± 13.43	46.96 ± 13.29	E	A	Continuous nebulization for 6 h	VAS
Su, LH [16]	2022	China	30	30	53.67 ± 11.21	53.94 ± 11.16	E	A	Continuous nebulization for 6 h	VAS
Yin, HX [17]	2021	China	46	46	62.02 ± 5.20	61.51 ± 5.22	E	F	Continuous nebulization for 6 h	NRS
Zhang, XX [15]	2021	China	30	30	55.83 ± 14.78	59.17 ± 11.04	B	A	Seven times a day, with an interval of one hour between each session. After seven interventions each day, if the patient indicates thirst, continue the intervention using the same method.	NRS
Zhang, XX [19]	2020	China	31	31	56.13 ± 13.79	60.07 ± 13.24	B	A	7 times a day, with a 1-hour interval between each session, for 2 days.	NRS
Zhang, KL [20]	2022	China	41	41	68.11 ± 6.73	67.43 ± 6.82	B	A	7 times a day, with additional interventions possible based on the patient's condition, for 3 days.	NRS
Mei, BG [21]	2024	China	30	30	71.8 ± 7.7	71.3 ± 9.5	B	A	Once per hour, 6 interventions.	NRS
Lin, R [22]	2017	China	10	10	≥ 18	≥ 18	B	A	Intervene every 30 min, for 6 h.	NRS
Luo, Q [23]	2023	China	60	60	54.92 ± 18.94	53.68 ± 20.01	B	K	9 times a day, with a 2-hour interval between each session, for 2 days.	NRS
Li, YH [24]	2022	China	60	60/60	59.67 ± 10.45	57.65 ± 10.93/ 60.67 ± 10.65	B	H/M	7 times a day, with a 1-hour interval between each session, for 2 days.	NRS
Wang, XY [25]	2024	China	70	70	51.06 ± 11.28	51.41 ± 12.27	H	C	Intervene every 4 h, for 2 days.	VAS
Zhang, Q [26]	2021	China	60/60	60	59.55 ± 15.98/54.40 ± 14.52	57.95 ± 16.22	H/I	C	Intervene based on the patient's thirst until the end of the shift.	NRS
Wang, L [27]	2023	China	41/41	41	18–78/18–78	18–78	C/I	A	Intervention after the patient self-reports thirst	VAS
Ma, JC [28]	2024	China	31	31	58.58 ± 14.73	61.65 ± 12.95	I	B	The intervention time is from 9 AM to 4 PM, with a 1-hour interval between each intervention, for 2 days.	NRS
Li, YL [29]	2023	China	30/30/29	30	67.6 ± 12.29/ 70.14 ± 12.85/ 69.97 ± 11.34	64.7 ± 13.18	B/I/D	C	When the thirst score is greater than a certain value, intervene until the score is less than 3.	NRS
Yan, LJ [30]	2021	China	30	30	59.70 ± 13.26	59.97 ± 14.19	J	A	Four times a day, for 3 days.	NRS
Zhao, Z [31]	2023	China	122	122	55.89 ± 16.81	54.91 ± 16.38	G	A	When the patient's thirst score is greater than 3, intervene once every hour for 12 h.	NRS

Table 1 (continued)

			Sample size, *n*		Age, y		Group *			
Author	**Year**	**Country**	**Interv**	**Cont**	**Interv**	**Cont**	**Interv**	**Cont**	**Intervention frequency**	**Assessment tool**
Zhang, XX [32]	2021	China	38	38	57.82 ± 13.89	60.24 ± 10.40	L	A	Once per hour, intervene 7 times.	NRS
Lian, R. [33]	2024	China	28	28	52.82 ± 17.43	55.89 ± 14.49	B	A	After extubation, interventions were performed once at 0.5 h, 2 h, 4 h, and 6 h.	NRS
Can, S. [15]	2023	Turkey	59	60	58.0 ± 5.3	56.9 ± 7.5	N	A	After extubation, interventions were performed once at 30 min, 60 min, and 90 min.	VAS
Ma, F. Y. [35]	2023	China	69	70	11.2 ± 3.2	11.21 ± 2.9	D	B	Interventions are performed at 0 min, 15 min, and 30 min after the patient is awake, with a 5-minute mouth closure after each intervention.	NRS
Lin, R. [36]	2022	China	47/49	49	54.43 ± 16.21	56.57 ± 13.32	B/C	A	Twice an hour, for 6 h.	NRS
Gungor S [37]	2024	Turkey	55	55	53.20 ± 10.29	50.90 ± 14.52	B	A	Three times per hour, for 16 h.	NRS

Cont, control; Interv, intervention

*A, Routine care; B, Ice water spray; C, Normal temperature water spray; D, Ice menthol water spray; E, Ice saline water spray; F, Saline water spray; G, Glycerin ice water spray; H, Lemon water spray; I, Menthol water spray; J, Oral ice cotton ball; K, Normal temperature water injection; L, Ice water injection; M, Glycerin saline water spray; N, Menthol lozenges

saline water spray, saline water spray, ice menthol water spray, menthol water spray, glycerin ice water spray, glycerin saline water spray, lemon water spray, oral ice cotton ball, menthol lozenges, ice water injection, normal temperature water injection and routine care. The basic characteristics of the included studies are shown in Table 1.

Quality assessment of the included studies

In 24 RCTs, 3 articles [23, 26, 31]were rated as Grade A, whereas the rest were Grade B.

22 studies [14–20, 23–37] described specific randomization methods, whereas the remaining 2 studies [21, 22] only reported randomization without detailing the specific methods.

10 Studies [18, 19, 23, 26–28, 31, 32, 36, 37] reported using allocation concealment.

3 studies [23, 26, 31] implemented blinding for the study subjects.

17 studies [14, 18, 19, 21, 23–34, 36] implemented blinding for outcome assessors, as detailed in Fig. 2.

Results of traditional meta-analysis

The results of the direct comparative analysis showed that ice water spray [MD -2.11, 95% CI (-2.70, -1.52)], oral ice cotton ball [MD -1.80, 95% CI (-2.18, -1.42)], glycerin ice water spray [MD -1.58, 95% CI (-1.83, -1.33)], ice water injection [MD -3.47, 95% CI (-3.96, -2.98)], and menthol lozenge [MD -4.60, 95% CI (-5.18, -4.02)] are superior to routine care in alleviating thirst in ICU patients. Ice menthol water spray is significantly better than normal temperature water spray [MD -3.43, 95% CI (-3.94, -2.92)], ice water spray [MD -2.24, 95% CI (-2.63, -1.85)], and menthol water spray [MD -2.32, 95% CI (-2.83, -1.81)] (Table 2). Ice water spray is considerably better than normal temperature water injection [MD -2.99, 95% CI (-3.53, -2.45)], lemon water spray [MD -3.65, 95% CI (-4.09, -3.21)], and glycerin saline water spray [MD -2.78, 95% CI (-3.20, -2.36)]. Ice saline water spray is significantly better than saline water spray [MD -2.84, 95% CI (-3.08, -2.60)]. Glycerin saline water spray is considerably better than lemon water spray [MD -0.87, 95% CI (-1.21, -0.53)].

Results of network meta-analysis

The dots in the figure represent the sample size of the same intervention, with larger dots indicating a larger sample size (Fig. 3). The lines indicate the number of comparisons between the two interventions, with thicker lines representing more comparisons. The connected dots represent direct comparisons of interventions, whereas the unconnected dots indicate indirect comparisons via network meta-analysis. In the included studies, the sample sizes for ice water spray and routine care were the largest, followed by those for normal-temperature

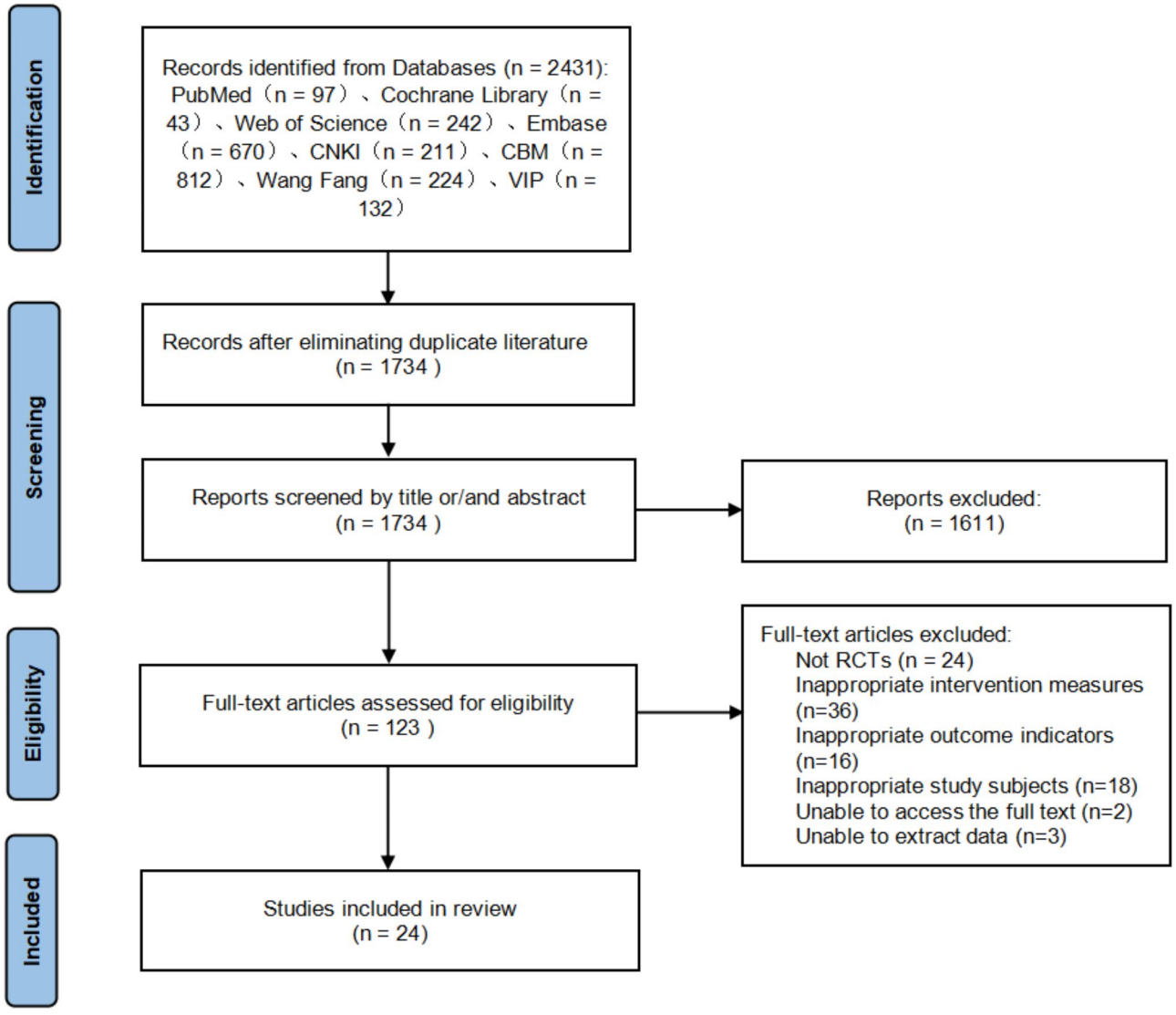

Fig. 1 Schematic of the selection process for included studies

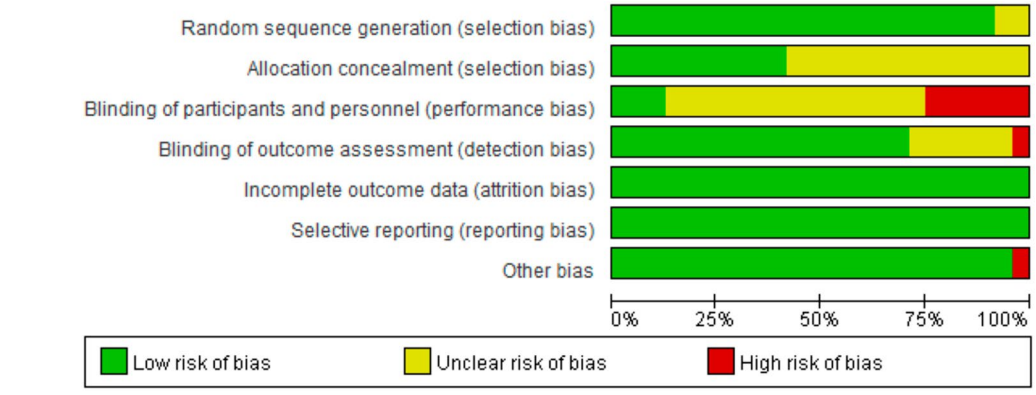

Fig. 2 Bias risk of the included studies

Table 2 Direct comparisons of meta-analysis results

	K	I^2	*P*	Model	MD(95%CI)	*P*
Ice water spray cf. routine care	7	85	< 0.01	Random effect	-2.11(-2.70, -1.52)	< 0.01
Ice saline water spray cf. routine care	3	100	< 0.01	Random effect	-3.36(-7.94, 1.02)	0.13
Normal temperature water spray cf. routine care	2	97	< 0.01	Random effect	-1.53(-3.54, 0.48)	0.14
Menthol water spray cf. routine care	1	-	-	-	-0.50(-1.03, 0.03)	0.06
Oral ice cotton ball cf. routine care	1	-	-	-	-1.80(-2.18, -1.42)	< 0.01
Glycerin ice water spray cf. routine care	1	-	-	-	-1.58(-1.83, -1.33)	< 0.01
Ice water injection cf. routine care	1	-	-	-	-3.47(-3.96, -2.98)	< 0.01
Menthol lozenges cf. routine care	1	-	-	-	-4.60(-5.18, -4.02)	< 0.01
Ice water spray cf. normal temperature water spray	2	89	< 0.01	Random effect	-0.72(-1.69, 0.25)	0.14
Lemon water spray cf. normal temperature water spray	2	95	< 0.01	Random effect	-0.79(-2.36, 0.78)	0.32
Ice menthol water spray cf. normal temperature water spray	1	-	-	-	-3.43(-3.94, -2.92)	< 0.01
Menthol water spray cf. normal temperature water spray	3	87	< 0.01	Random effect	-0.55(-1.33, 0.22)	0.16
Ice water spray cf. normal temperature water injection	1	-	-	-	-2.99(-3.53, -2.45)	< 0.01
Ice water spray cf. lemon water spray	1	-	-	-	-3.65(-4.09, -3.21)	< 0.01
Ice water spray cf. glycerin saline water spray	1	-	-	-	-2.78(-3.20, -2.36)	< 0.01
Ice menthol water spray cf. ice water spray	2	0	0.77	Fixed effect	-2.24(-2.63, -1.85)	< 0.01
Ice saline water spray cf. saline water spray	1	-	-	-	-2.84(-3.08, -2.60)	< 0.01
Glycerin saline water spray cf. lemon water spray	1	-	-	-	-0.87(-1.21, -0.53)	< 0.01
Lemon water spray cf. menthol water spray	1	-	-	-	-0.15(-0.54, 0.24)	0.45
Menthol water spray cf. ice water spray	2	98	< 0.01	Random effect	-1.15(-3.63, 1.34)	0.37
Ice menthol water spray cf. menthol water spray	1	-	-	-	-2.32(-2.83, -1.81)	< 0.01

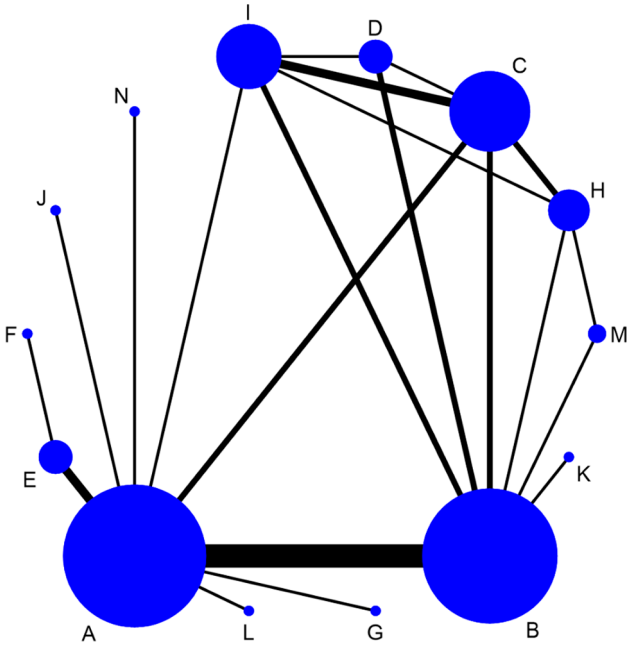

Fig. 3 Evidence network diagram. (**A**) Routine care. (**B**) Ice water spray. (**C**) Normal temperature water spray. (**D**) Ice menthol water spray. (**E**) Ice saline water spray. (**F**) Saline water spray. (**G**) Glycerin ice water spray. (**H**) Lemon water spray. (**I**) Menthol water spray. (**J**) Oral ice cotton ball. (**K**) Normal temperature water injection. (**L**) Ice water injection. (**M**) Glycerin saline water spray. (**N**) Menthol lozenges

water spray. The studies with direct comparisons between ice water spray, ice saline water spray, and routine care were the most numerous.

The inconsistency test model was used to test the inconsistency of the 24 studies, and the results showed that $\chi^2 = 6.01$, $P = 0.739$, with a P-value greater than 0.05, indicating good consistency between direct and indirect evidence (Fig. 4). Therefore, this study used the consistency model to conduct a network meta-analysis.

The network meta-analysis results showed that ice menthol water spray [MD -4.51, 95% CI (-6.84, -2.18)], menthol lozenges [MD -4.60, 95% CI (-7.86, -1.34)], ice water injection [MD -3.47, 95% CI (-6.72, -0.22)], menthol water spray [MD -2.18, 95% CI (-3.98, -0.39)], ice saline water spray [MD -3.46, 95% CI (-5.35 -1.58)], and ice water spray [MD -2.20, 95% CI (-3.30, -1.10)] were more effective than routine care in alleviating thirst in ICU patients (Table 3). Menthol lozenges were more effective than normal temperature water injection [MD -5.39, 95% CI (-10.13, -0.65)]. In addition, ice menthol water spray is more effective than normal temperature water spray [MD -3.33, 95% CI (-5.69, -0.97)] and ice water spray [MD -2.31, 95% CI (-4.45, -0.17)] in improving thirst in ICU patients.

According to the results of the cumulative ranking probability curve area (SUCRA), the ranking of non-pharmacological interventions to alleviate thirst in ICU patients is as follows (Fig. 5 and Table 4): ice menthol water spray > menthol lozenge > ice saline water spray > ice water injection > ice water spray > menthol water

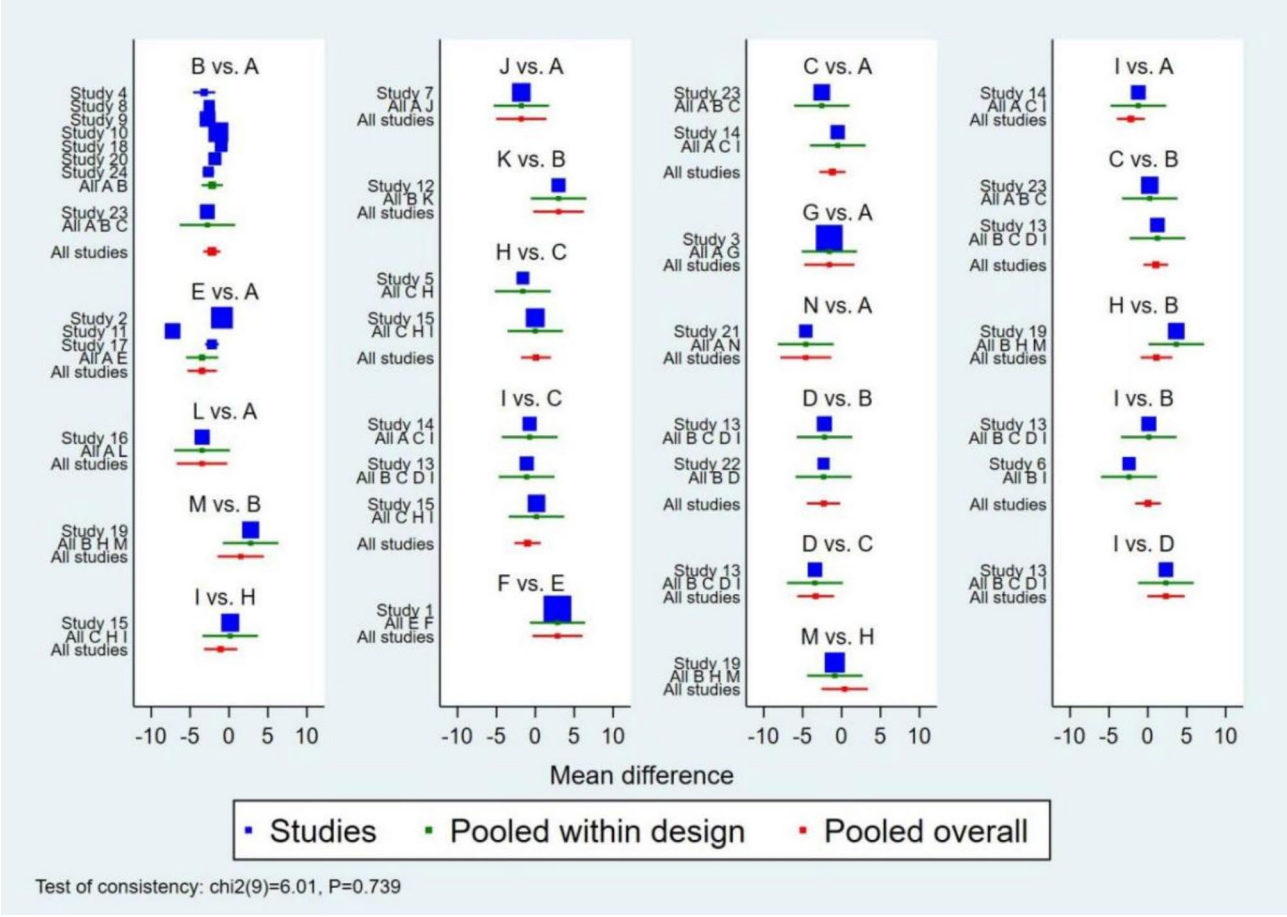

Fig. 4 Inconsistency Test Model Diagram. (**A**) Routine care. (**B**) Ice water spray. (**C**) Normal temperature water spray. (**D**) Ice menthol water spray. (**E**) Ice saline water spray. (**F**) Saline water spray. (**G**) Glycerin ice water spray. (**H**) Lemon water spray. (**I**) Menthol water spray. (**J**) Oral ice cotton ball. (**K**) Normal temperature water injection. (**L**) Ice water injection. (**M**) Glycerin saline water spray. (**N**) Menthol lozenges

spray > oral ice cotton ball > glycerin ice water spray > normal temperature water spray > lemon water spray > glycerin saline water spray > saline water spray > routine care > normal temperature water injection.

Assessment of publication bias

In the studies included in the network meta-analysis, in addition to some with direct comparison subjects, there are also many with indirect comparisons and those that have not yet been compared with each other. Therefore, it is necessary to make relevant adjustments for control groups with different publication biases. By observing the comparison-adjusted funnel plot to assess the related risk, the comparison-adjusted funnel plot was drawn via Stata 15.0 software. The results showed that all included studies were symmetrically arranged around the central line, with a roughly symmetrical distribution, indicating a low possibility of publication bias in the included studies, as shown in Fig. 6.

Discussion

We systematically reviewed the relevant literature and included 24 RCTs, involving 14 non-pharmacological interventions. We conducted a detailed comparison of the effectiveness of these 14 non-pharmacological interventions in alleviating thirst in ICU patients. We found that ice water spray, ice menthol water spray, ice saline water spray, ice water injection, menthol water spray, and menthol lozenge had positive effects on alleviating thirst in ICU patients, particularly ice menthol water spray, menthol lozenge, and ice saline water spray.

The results of traditional meta-analyses have shown that ice menthol water spray is significantly superior to ice water spray, normal temperature water spray, and menthol water spray in alleviating thirst in ICU patients. The results of the network meta-analysis indicate that ice menthol water spray is more effective than normal temperature water spray, ice water spray, and routine care in improving thirst. Additionally, the SUCRA values show that ice peppermint water spray had the highest likelihood of being the best intervention (SUCRA = 89.9),

Table 3 Relative effects of different interventions *

N													
-3.90 (-8.42,0.62)	M												
-1.13 (-5.74,3.48)	2.77 (-1.74,7.28)	L											
-5.39 (-10.13,-0.65)	-1.49 (-5.91,2.93)	-4.26 (-8.99,0.47)	K										
-2.80 (-7.40,1.80)	1.10 (-3.40,5.60)	-1.67 (-6.26,2.92)	2.59 (-2.13,7.31)	J									
-2.42 (-6.14,1.31)	1.48 (-1.75,4.72)	-1.29 (-5.00,2.43)	2.97 (-0.68,6.63)	0.38 (-3.32,4.08)	I								
-3.50 (-7.43,0.42)	0.40 (-2.58,3.37)	-2.37 (-6.29,1.54)	1.89 (-1.95,5.73)	-0.70 (-4.60,3.20)	-1.09 (-3.22,1.05)	H							
-3.02 (-7.61,1.57)	0.88 (-3.61,5.37)	-1.89 (-6.47,2.69)	2.37 (-2.34,7.08)	-0.22 (-4.79,4.35)	-0.60 (-4.29,3.09)	0.48 (-3.41,4.37)	G						
-3.99 (-8.94,0.97)	-0.09 (-4.95,4.78)	-2.86 (-7.80,2.09)	1.40 (-3.67,6.47)	-1.19 (-6.12,3.75)	-1.57 (-5.71,2.57)	-0.48 (-4.80,3.83)	-0.97 (-5.89,3.96)	F					
-1.14 (-4.91,2.63)	2.76 (-0.89,6.41)	-0.01 (-3.76,3.75)	4.25 (0.33,8.17)	1.66 (-2.08,5.41)	1.28 (-1.32,3.88)	2.36 (-0.52,5.25)	1.88 (-1.85,5.62)	2.85 (-0.37,6.07)	E				
-0.09 (-4.10,3.92)	3.81 (0.21,7.40)	1.04 (-2.96,5.04)	5.30 (1.40,9.20)	2.71 (-1.28,6.70)	2.33 (-0.07,4.72)	3.41 (0.65,6.18)	2.93 (-1.05,6.91)	3.90 (-0.50,8.29)	1.05 (-1.95,4.05)	D			
-3.42 (-7.09,0.25)	0.48 (-2.67,3.62)	-2.29 (-5.95,1.37)	1.97 (-1.65,5.59)	-0.62 (-4.27,3.03)	-1.00 (-2.69,0.68)	0.08 (-1.83,1.99)	-0.40 (-4.03,3.23)	0.57 (-3.52,4.65)	-2.28 (-4.81,0.24)	**-3.33 (-5.69,-0.97)**	C		
-2.40 (-5.84,1.04)	1.50 (-1.48,4.48)	-1.27 (-4.70,2.16)	2.99 (-0.27,6.25)	0.40 (-3.02,3.82)	0.02 (-1.64,1.67)	1.10 (-0.93,3.14)	0.62 (-2.78,4.02)	1.59 (-2.30,5.47)	-1.26 (-3.44,0.92)	**-2.31 (-4.45,-0.17)**	1.02 (-0.56,2.60)	B	
-4.60 (-7.86,-1.34)	-0.70 (-3.83,2.43)	**-3.47 (-6.72,-0.22)**	0.79 (-2.65,4.23)	-1.80 (-5.04,1.44)	**-2.18 (-3.98,-0.39)**	-1.10 (-3.28,1.08)	-1.58 (-4.80,1.64)	-0.61 (-4.34,3.11)	**-3.46 (-5.35,-1.58)**	**-4.51 (-6.84,-2.18)**	-1.18 (-2.86,0.50)	**-2.20 (-3.30,-1.10)**	A

Note: Significant results are shown in bold

A, Routine care; B, Ice water spray; C, Normal temperature water spray; D, Ice menthol water spray; E, Ice saline water spray; F, Saline water spray; G, Glycerin ice water spray; H, Lemon water spray; I, Menthol water spray; J, Oral ice cotton ball; K, Normal temperature water injection; L, Ice water injection; M, Glycerin saline water spray; N, Menthol lozenge

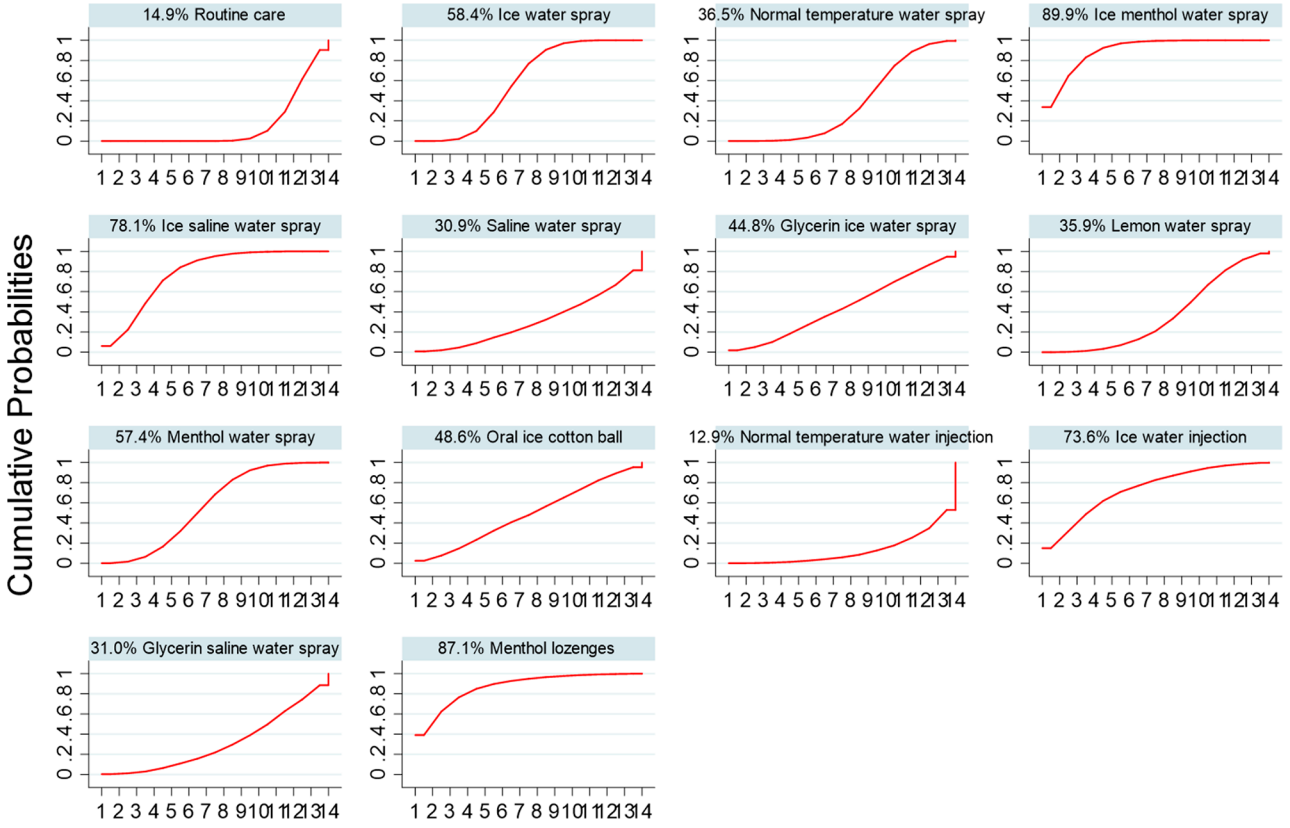

Fig. 5 SUCRA plot of the thirst of ICU patients for different non-drug interventions

Table 4 SUCRA scores of thirst for different non-drug interventions

Treatment	SUCRA	Probability of best, %	Mean rank
Routine care	14.9	0	12.1
Ice water spray	58.4	0	6.4
Normal temperature water spray	36.5	0	9.3
Ice menthol water spray	89.9	33.7	2.3
Ice saline water spray	78.1	6.2	3.8
Saline water spray	30.9	0.7	10.0
Glycerin ice water spray	44.8	1.9	8.2
Lemon water spray	35.9	0	9.3
Menthol water spray	57.4	0.2	6.5
Oral ice cotton ball	48.6	2.6	7.7
Normal temperature water injection	12.9	0.1	12.3
Ice water injection	73.6	15.1	4.4
Glycerin saline water spray	31.0	0.3	10.0
Menthol lozenges	87.1	39.1	2.7

indicating that ice menthol water spray is the most effective intervention for alleviating thirst in ICU patients.

Previous studies have also confirmed that ice menthol water spray can improve the thirst symptoms of ICU patients better than ice water spray, normal-temperature water spray, and menthol water spray can [29].

Research has shown that, compared with normal temperature stimulation, ice stimulation of the oropharynx significantly alleviates patients' thirst symptoms [38]. Ice stimulation can activate cold-sensitive TRPM8 receptor potentials and other transient receptor potentials (TRP) distributed in the oral cavity. These receptors inhibit antidiuretic hormones to regulate or suppress thirst, allowing patients to relieve thirst and increase comfort without consuming large amounts of water [39]. Menthol is a natural agent with antibacterial and cooling effects. It acts on the oral mucosa, increasing neural discharge from cold receptors, enhancing saliva production, and hydrating the oral mucosa [40]. Ice menthol water spray utilizes dual stimulation of low temperature and menthol to produce a lasting cold sensation on the trigeminal nerve and glossopharyngeal region. This can activate transient receptor potential channels in the oropharynx, transmitting signals to the cerebral cortex that indicate satisfaction with drinking, thereby alleviating thirst [41]. Additionally, ice menthol water spray is easy to obtain, convenient to use, and highly feasible for widespread application.

The results of the network meta-analysis and the SUCRA indicate that in addition to ice menthol water spray, menthol lozenge, and ice saline water spray can also effectively alleviate thirst symptoms in ICU patients.

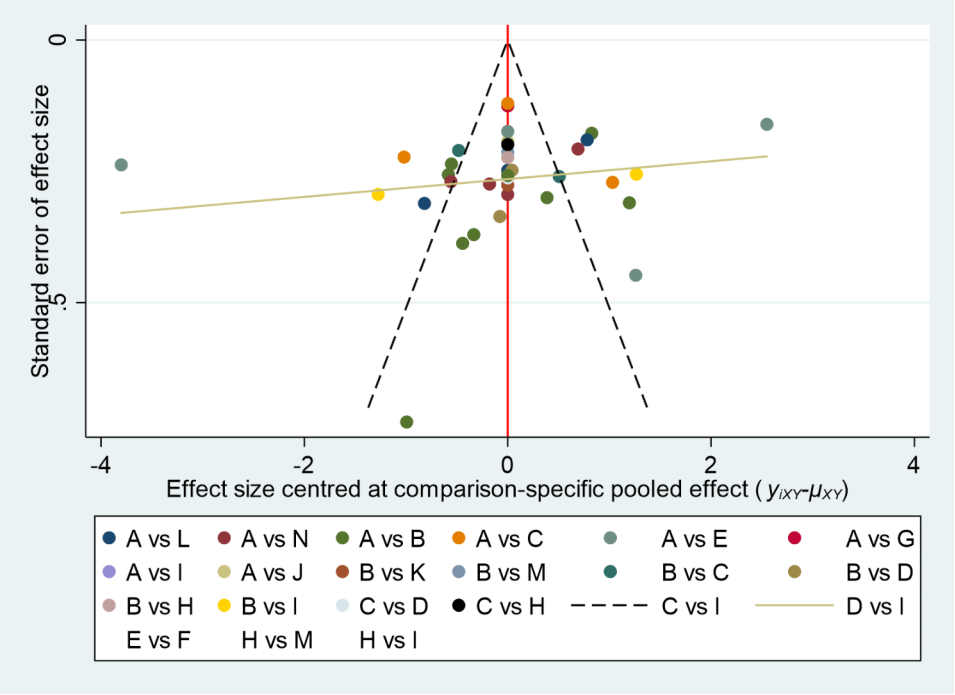

Fig. 6 Comparison-corrected funnel plot of the incidence of MDRPU. (**A**) Routine care. (**B**) Ice water spray. (**C**) Normal temperature water spray. (**D**) Ice menthol water spray. (**E**) Ice saline water spray. (**F**) Saline water spray. (**G**) Glycerin ice water spray. (**H**) Lemon water spray. (**I**) Menthol water spray. (**J**) Oral ice cotton ball. (**K**) Normal temperature water injection. (**L**) Ice water injection. (**M**) Glycerin saline water spray. (**N**) Menthol lozenges

This finding is consistent with previous systematic review results [11]. However, considering that this study identified only one RCT comparing menthol lozenges, with a small sample size and low statistical power, the application effect may be exaggerated. Moreover, McIntyre et al. [42] reported that 41% of ICU patients, especially those with tracheal intubation, experience acquired swallowing disorders. Therefore, healthcare professionals should not only assess patients' thirst symptoms but also accurately evaluate their consciousness and swallowing abilities, as well as their cough reflex and coughing conditions, to avoid increasing the risk of aspiration when direct introduction methods are used.

The ice saline spray is mostly a 0.45% sodium chloride solution diluted with distilled water. It is atomized and sprayed using oxygen propulsion. Continuously stimulating oropharyngeal receptors with cold, it can effectively relieve bronchial spasms and alleviate symptoms such as dryness in the oropharynx. In addition, 0.45% sodium chloride solution is a hypotonic solution, and the osmotic pressure of the moisture remaining in the oral cavity after spraying most closely matches the physiological state, which can better maintain moisture in the oral cavity [43]. Moreover, it saves medical staff time in caring for patients' thirst, thereby improving work efficiency.

Limitations

This study has several limitations: ①Among the included studies, only 10 used allocation concealment, 3 implemented blinding for the study subjects, and 17 implemented blinding for the outcome assessors, which may introduce bias in implementation and measurement, thereby increasing the heterogeneity of the results. Additionally, this study only included A and B grade literature, excluding low-quality studies, and some studies with poor intervention effects may not have been published, thus also introducing a certain degree of publication bias.; ②The results of the direct comparison meta-analysis showed high heterogeneity, which may have interfered with the results; ③Few studies included in the literature involved certain intervention measures, which may increase the randomness of the results and reduce their reliability; ④Some studies did not provide detailed descriptions of the intervention time and frequency, and the number of studies was insufficient to support subgroup analyses of intervention time and frequency; ⑤Considering that combination therapies may interfere with the specific efficacy of defined interventions, it was not possible to evaluate and analyze the various types of combination therapies.

Conclusions

This study included 24 articles and evaluated the effectiveness of 14 non-drug interventions in alleviating thirst in ICU patients. Current evidence shows that ice menthol water spray is the most effective at reducing thirst levels in ICU patients. Clinical nurses can choose appropriate and personalized non-drug interventions to improve patients' thirst symptoms on the basis of their thirst levels, consciousness, and condition. However, this result still requires validation with a large sample size. Future research should conduct direct comparisons between different intervention methods to address the shortcomings of indirect comparisons and provide more evidence-based support for this research field.

Relevance to clinical practice

This study supports the use of non-pharmacological interventions by healthcare professionals to alleviate thirst symptoms in ICU patients, particularly the use of ice peppermint water spray, and highlights the efficacy of different non-pharmacological interventions. This study can help ICU nurses choose appropriate non-pharmacological interventions to improve patients' thirst symptoms in clinical practice. However, before applying non-pharmacological interventions, especially the direct drinking method, healthcare professionals need to conduct a comprehensive assessment of patients' consciousness, swallowing ability, and cough reflex.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Author contributions

All listed authors have contributed substantially to the manuscript in the following ways: Xiao Meng; Zhu Fangfang and Zhang Yanting (Conception, Design, Data Collection, Writer, Literature Review; Analysis and Interpretation); Zheng Anlong and Ma Jing (Interpretation, Literature Review); Wei Shiwen(Literature Review, Writer, Critical Review); Zhang Pu (Literature Review, Writer, Critical Review); Ding Xinbo (Literature Review, Writer, Critical Review).

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Data availability

All data generated or analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author （Xinbo Ding.

Declarations

Ethical approval

An ethics statement is not applicable because this study is based exclusively on published literature..

Consent for publication

Not applicable.

Patient consent

Not applicable.

Permission to reproduce material from other sources

Not applicable.

Competing interests

The authors declare no competing interests.

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