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Review

Cryotherapy Treatment After Unicompartmental and Total Knee Arthroplasty: A Review

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ABSTRACT

Background: Cryotherapy is widely utilized to enhance recovery after knee surgeries. However, the outcome parameters often vary between studies. Therefore, the purpose of this review is to compare (1) no cryotherapy vs cryotherapy; (2) cold pack cryotherapy vs continuous flow device cryotherapy; (3) various protocols of application of these cryotherapy methods; and (4) cost-benefit analysis in patients who had unicompartmental knee arthroplasty (UKA) or total knee arthroplasty (TKA).
Methods: A search for "knee" and "cryotherapy" using PubMed, EBSCO Host, and SCOPUS was performed, yielding 187 initial reports. After selecting for RCTs relevant to our study, 16 studies were included.
Results: Of the 8 studies that compared the immediate postoperative outcomes between patients who did and did not receive cryotherapy, 5 studies favored cryotherapy (2 cold packs and 3 continuous cold flow devices). Of the 6 studies comparing the use of cold packs and continuous cold flow devices in patients who underwent UKA or TKA, 3 favor the use of continuous flow devices. There was no difference in pain, postoperative opioid consumption, or drain output between 2 different temperature settings of continuous cold flow device.
Conclusion: The optimal device to use may be one that offers continuous circulating cold flow, as there were more studies demonstrating better outcomes. In addition, the pain relieving effects of cryotherapy may help minimize pain medication use, such as with opioids, which are associated with numerous potential side effects as well as dependence and addiction. Meta-analysis on the most recent RCTs should be performed next.

Although total knee arthroplasty (TKA) has been shown to have excellent long-term benefits and outcomes, patients may experience substantial pain, swelling, and inflammation [1–3] during the immediate postoperative and rehabilitative periods [3–6]. Moreover, the pain, swelling, and inflammation can make the recovery period challenging in terms of weight bearing, ambulation, and range-of-motion (ROM) [2,3,7,8]. Additionally, suboptimal management during recovery can lead to worse long-term functional outcomes [7].

There are several modalities that have been shown to be beneficial in terms of reducing pain and swelling symptoms following knee surgery [3,7,9]. One of these modalities that have been widely utilized to enhance recovery is cryotherapy. Cryotherapy involves the application of cold/low temperature to the skin around the incision or injury [10]. There are a number of devices that deliver this modality including ice bags, cold water, cold packs, and continuous cold flow devices, all of which can be utilized with or without compression. Although multiple reports have assessed the efficacy of cryotherapy for treating patients after knee surgery, the outcomes often vary between the studies. These varied outcomes can result in difficulties in determining optimal modality, device, and duration of use.

Therefore, the purpose of this review is to evaluate the different applications of cryotherapy that are used after knee surgery. Specifically, we reviewed randomized controlled trials (RCTs) comparing (1) no cryotherapy vs cryotherapy; (2) cold pack cryotherapy vs continuous flow device cryotherapy; (3) various protocols of application of these cryotherapy methods; and (4) cost-benefit analysis in patients who had unicompartmental knee arthroplasty (UKA) or TKA.

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Table 1
Studies Comparing Cryotherapy With No Cryotherapy Cohort.

Study (Author, Year PMID)	Type of Study	No. of Patients	Modality			Parameters Assessed (Pain, Swelling, Ambulation, Etc.)	Timing of Evaluation	Protocol of Administration	Concomitant Analgesia	Salient Finding for Each Parameter Assessed	Cohort Favored in the Study
			Control (n)	Study (n)							
Wittig-Wells et al (2015) [11]	RCT	29	First pain episode: analgesia only Second pain episode: analgesia and cryotherapy (15)	First pain episode: analgesia and cryotherapy Second pain episode: analgesia only (14)		Pain changes Satisfaction with pain management	30 and 60 min after analgesic	Cryotherapy given for 30 min	Same in both groups: acetaminophen with hydrocodone or acetaminophen with oxycodone	Pain: analgesic alone vs analgesic plus cryotherapy (6.7 ± 1.5 vs 6.9 ± 1.3, $P > .05$). Pain scores decreased at 30 and 60 min after administration of analgesic medication from baseline levels, with scores at 60 min after administration of analgesic medications lower than at 30 min. There was no difference in the change in pain scores after administration of analgesic medications between the 2 treatments or for the order of treatments $P > .05$. Satisfaction: analgesic alone vs analgesic plus cryotherapy (7.5 ± 2.3 vs 8.1 ± 1.8, $P > .05$) Treatment order was found to be significant ($P = .02$) with subjects who received cryotherapy for their second pain episode having higher satisfaction scores	Crushed ice pack
Kang et al (2014) [12]	RCT	46	U/S (15)	Cryotherapy (crushed ice) (15)	Both (16)	Korean WOMAC, ROM, CRP	N/A	5 times a week for 3 wk	N/A	Korean WOMAC: U/S vs cryotherapy vs both at 1 wk (66.9 ± 3.0 vs 66.5 ± 2.3 vs 66.5 ± 2.3) At 2 wk (50.3 ± 2.2 vs 47.5 ± 1.9 vs 46.7 ± 2.3) At 3 wk (29.0 ± 2.4 vs 29.8 ± 1.7 vs 28.7 ± 2.3) ROM: U/S vs cryotherapy vs both at 1 wk (102.6 ± 5.6 vs 105.8 ± 8.0 vs 108.6 ± 6.1) At 2 wk (124.1 ± 4.5 vs 124.8 ± 3.9 vs 126.4 ± 5.7) At 3 wk (134.4 ± 4.6 vs 138.1 ± 3.5 vs 140.2 ± 4.4) CRP: U/S vs cryotherapy vs both at 1 wk (3.3 ± 1.1 vs 2.3 ± 0.6 vs 2.0 ± 0.6) At 2 wk (1.8 ± 0.8 vs 1.6 ± 0.7 vs 1.3 ± 0.3) At 3 wk (0.4 ± 0.1 vs 0.5 ± 0.2 vs 0.3 ± 0.1)	Crushed ice cold pack
Holm et al (2012) [13]	R crossover study	20	Elbow icing, then knee on the second day (10)	Knee icing, then elbow on the second day (10)		Maximum knee extension Pain at rest and	2-5 min before and after both treatments	Treated on POD 7 and 10; 30 min of icing	Same in both cohorts: gabapentin 900 mg daily, paracetamol 4 g daily, celecoxib 400 mg	Extension: change associated with knee icing −0.01 ± 0.07 Nm/kg, change associated with elbow icing −0.02 ± 0.07 Nm/kg	None

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Table 1 (*continued*)

Study (Author, Year PMID)	Type of Study	No. of Patients	Modality		Parameters Assessed (Pain, Swelling, Ambulation, Etc.)	Timing of Evaluation	Protocol of Administration	Concomitant Analgesia	Salient Finding for Each Parameter Assessed	Cohort Favored in the Study
			Control (*n*)	Study (*n*)						
					during extension		for each treatment	daily Breakthrough pain: oxycodone 5 mg	($P = .493$) Pain: no effect of knee icing on pain at rest ($P = .475$) or pain during the knee extension strength test ($P = .422$). No effects of treatment order ($P = .934$) or time period (0.886) were observed for knee pain at rest. For knee pain during the knee extension strength measurement, however, an effect of time period ($P = .024$) was observed, indicating that knee pain during the knee extension measurement increased more, but was clinically irrelevant, during the experimental protocol at day 7 (VAS pain increase 1.2 ± 1.6 mm) compared to day 10 (VAS pain increase 0.4 ± 1.5 mm)	
Kuyucu et al (2015) [14]	RCT	60	No circulating cold water (33)	Circulating cold water (27)	Pain Knee Society Scores Blood loss	POD 1, 3, and 5	The cryo/cuff application was started 2 h before the surgery; it was repeated in postoperative sixth hour, and it was applied to the patients for 2 h every day, during the postoperative 4 d	N/A	Pain: no cryo/cuff vs cryo/cuff VPS at POD 1 (4.5 vs 2.1, $P < .05$) At POD 3 (3.3 vs 2.5, $P < .05$) At POD 5 (3.3 vs 3, $P < .05$) Blood loss: no cryo/cuff vs cryo/cuff Hb (mmol/dL) at POD 1 (10.8 ± 8.3-12.5 vs 10.3 ± 8.9-12.1, $P > .05$) At POD 3 (9.3 ± 7-12.8 vs 9.6 ± 7.4-11.4, $P > .05$) At POD 5 (9 ± 8.4-10.5 vs 9.1 ± 8.5-10.1, $P > .05$) Drainage: no cryo/cuff vs cryo/cuff postoperative bleeding (cc): (400.4 ± 140-650 vs 365 ± 150-900, $P > .05$) Knee Society Function Score: no cryo/cuff vs cryo/cuff postoperative (80.3 ± 77-86 vs 90.5 ± 88-92, $P < .05$)	Continuous cold flow device
Smith et al (2002) [15]	RCT	84	Compression bandage (40)	Continuous cold flow device (44)	Wound drainage Transfusion Pain Flexion Swelling Analgesia use Length of stay Other events	Preop, 24 and 48 h postop	24 h, then the same protocol as controls	No difference in opioid use	No statistically significant differences for total length of stay, knee swelling (preoperative, 24 and 48 h postop), flexion (preop, 24 and 48 h postop), wound drainage, transfusions, or hemoglobin Mean drainage in compression bandage vs cold therapy at 48 h (824.7 ± 366 vs 900 ± 484, $P = .267$)	None

									Transfusion in compression bandage vs cold therapy (951 ± 516 vs 1076 ± 502, $P = .991$) Pain in compression bandage vs cold therapy at day 1 (4.2 ± 2 vs 4.3 ± 1.8, $P = .320$) At day 2 (4.8 ± 1.9 vs 4.3 ± 2, $P = .720$) At day 3 (3.5 ± 1.9 vs 4.2 ± 1.8, $P = .665$) Swelling in compression bandage vs cold therapy at day 1 (439 ± 36 vs 438 ± 33, $P = .837$) At day 2 (445 ± 38 vs 439 ± 26, $P = .512$) Flexion in compression bandage vs cold therapy at day 1 (83.6 ± 12.9 vs 81.3 ± 11.8, $P = .384$) At day 2 (86.6 ± 12.3 vs 84.9 ± 13.4, $P = .950$)	
Desteli et al 2015 [16]	RCT	87	No cryotherapy treatment (45)	Continuous cold flow device (42)	Blood loss Drainage	Preoperative day, POD 2	C-pads were applied to the operated knees preoperatively for 90 min until they were taken to the operation hall and postoperatively for 6 h on the day of surgery starting just after the operation and for 2 h for subsequent 2 d Control group received standard cold therapy with ice packages 8 times for 15 min with 45-min intervals for the operation day and postoperative second day	Same in both cohorts: diclofenac sodium 3 mL IV BID, 100 mg tramadol hydrochloride once and at 5 h postoperatively	Hemoglobin (g/dL) postoperative 48th hour no cryotherapy therapy vs cryotherapy therapy (11.22 ± 1.14 vs 9.91 ± 1.25, $P < .001$) VAS pain: 6.1 points in the study group vs. 6.6 points in the control group ($P > .05$)	Continuous cold flow device
Kullenberg et al (2006) [17]	RCT	83	Epidural analgesia (40)	Continuous cold flow device (43)	Pain Analgesia use ROM Weight bearing Length of stay	Pain: POD 1, 3, and during exercise ROM: POD 1, at discharge, and 3 wk postop	After surgery to POD 3	Same in both cohorts: tramadol 150 mg BID, paracetamol 1 g QID Breakthrough pain: ketobemidon 2.5-5 mg IV	Pain: VAS in cryotherapy vs epidural analgesia at POD 1 (2.1 ± 1.0 vs 2.2 ± 0.8) At POD 3 (0.8 ± 0.9 vs 1.2 ± 0.7) During exercise (3.4 ± 1.5 vs 2.3 ± 1.7)	Continuous cold flow device

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Table 1 (*continued*)

Study (Author, Year PMID)	Type of Study	No. of Patients	Modality			Parameters Assessed (Pain, Swelling, Ambulation, Etc.)	Timing of Evaluation	Protocol of Administration	Concomitant Analgesia	Salient Finding for Each Parameter Assessed	Cohort Favored in the Study
			Control (n)	Study (n)							
										ROM: in cryotherapy vs epidural analgesia at POD 1 (50.4 ± 8 vs 51.4 ± 11.1) At discharge (75.1 ± 10.5 vs 62.9 ± 12.8, $P = .0019$) At 3 wk postop (98.9 ± 9.4 vs 87.6 ± 7.8, $P = .0045$) Weight bearing (% of body weight) in cryotherapy vs epidural analgesia (64.6 ± 13 vs 65.4 ± 12.6)	
Holmström et al (2005) [18]	RCT	61	Control (17)	Epidural analgesia (21)	Continuous cold flow device (23)	Pain Bleeding Swelling ROM Function	N/A	Cryo: 48 h postop Epidural: 48 h postop	Same in both cohorts: paracetamol 500 mg, dextropropoxyfene 50 and 100 mg Breakthrough pain: morphine oral 5 mg and IV 5 mg/mL	Pain: there was no significant difference between the groups in the assessment of pain, neither at rest nor on motion at any observation time Blood loss and swelling: no statistically significant differences existed in blood loss and swelling ROM: there was no significant difference in neither active nor passive ROM on any occasion	None

PMID, PubMed ID; U/S, ultrasound; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; N/A, not-applicable; VPS, Visual Pain Score; IV, intravenous; BID, twice per day; QID, four times per day.

Methods

A literature search was performed using PubMed, EBSCO Host, and SCOPUS to identify studies that were published between January 2002 and February 2017. We applied broad search terminology using the terms "knee" and "cryotherapy." This initial search yielded 187 reports. Two of the authors independently reviewed the titles and abstracts of this search to screen for studies that encompassed cryotherapy for any type of knee surgery, and reports that were written in the English language, which yielded 44 that were relevant. To offer a review of the highest level of evidence available, the authors included only RCTs. Studies were excluded if they were (1) nonrandomized prospective trials; (2) single-arm prospective studies; (3) retrospective or case-control studies; (4) case series or reports; (5) expert opinions; or (6) meta-analysis. After review of the full reports by the authors, there were another 28 studies excluded due to not meeting the aforementioned criteria. A total of 16 studies were eventually included. There were 2 studies that assessed cryotherapy after UKA, and 14 studies that assessed cryotherapy following TKA.

Results

No Cryotherapy vs Cryotherapy

Eight studies compared the immediate postoperative outcomes between patients who did and did not receive cryotherapy (Table 1). Of the 3 studies that utilized crushed ice packs as a cryotherapy modality, 2 studies favored cryotherapy (patient satisfaction $P = .02$; Korean Western Ontario and McMaster Universities Arthritis Index, ROM $P < .05$) and 1 study found no significant difference between the 2 cohorts (strength $P = .493$; pain $P = .475$). Of the 5 studies evaluating the effectiveness of continuous cold flow devices, 3 reports favored the intervention (pain $P < .05$ at postoperative day [POD] 1, POD 3, and POD 5; Knee Society Scores $P < .05$; hemoglobin levels $P < .001$; and ROM $P = .0045$), while the other 2 found no significant differences between the cohorts.

Wittig-Wells et al [11] performed an RCT with a crossover design that included 29 patients who received either analgesia only on the first pain episode and then analgesia along with cryotherapy on the second pain episode ($n = 15$) or analgesia along with cryotherapy on the first pain episode and then analgesia only on the second episode ($n = 14$). They found that there were no significant differences in pain or satisfaction between the 2 groups. However, the treatment order resulted in significantly higher satisfaction scores in the subjects who received cryotherapy for their second pain episode ($P = .02$). Similarly, Kang et al [12] evaluated the effect of pulsed ultrasound and cryotherapy on recovery after TKA in 46 patients. The authors concluded that cryotherapy alone and in combination with pulsed ultrasound are effective modalities for recovery of joint function after TKA. In a study of 20 patients who underwent unilateral TKA, Holm et al [13] compared knee extension strength and knee pain between those who received knee icing and those who received elbow icing (control). They found no significant differences in strength and pain between the 2 cohorts.

Kuyucu et al [14] evaluated 60 patients who received either circulating cold water ($n = 27$) or no-circulating cold water ($n = 33$) cryotherapy. They reported that pain was significantly reduced in the circulating cold water cohort compared to no-circulating cold water group on POD 1 (2.1 vs 4.5 points; $P < .05$), POD 3 (2.5 vs 3.3 points; $P < .05$), and POD 5 (3 vs 3.3 points; $P < .05$). Also, the postoperative Knee Society Function Score was higher in the circulating cold water group compared to the no-circulating cold water group (90.5 vs 80.3 points; $P < .05$). However, there were no differences in postoperative drainage or blood loss. In addition, Desteli et al [16] assessed 87 patients who received either cryotherapy treatment ($n = 42$) or no cryotherapy ($n = 45$). They reported that the control group had a significantly lower mean postoperative hemoglobin level as compared to the cryotherapy group 48 hours postoperative (9.9 vs 11.2 g/dL; $P < .001$). Kullenberg et al [17] reported on 83 patients who received either epidural analgesia ($n = 40$) or cryotherapy ($n = 43$), and they found that ROM was significantly better in the cryotherapy group compared to the epidural analgesia group on the day of discharge (75.1° vs 62.9°; $P = .0019$) and at 3 weeks after surgery (98.9° vs 87.6°; $P = .0045$). However, there were no differences in terms of pain or weight bearing.

Smith et al [15] assessed 84 patients who received a compression bandage ($n = 40$) or cold therapy ($n = 44$), and they found no significant differences between the modalities in terms of pain, lengths-of-stay, knee swelling, knee flexion, wound drainage, transfusions, or hemoglobin levels. In addition, Holmström et al [18] reported on 61 patients who received epidural analgesia ($n = 21$), cryotherapy (n = 23), or were controls (n = 17), and found that there were no significant differences between the groups in terms of pain, blood loss, swelling, or ROM.

In summary, of the 8 studies that compared the immediate postoperative outcomes between patients who did and did not receive cryotherapy, 5 studies favored cryotherapy (2 ice packs and 3 continuous cold flow devices).

Cold Pack Cryotherapy vs Continuous Flow Device Cryotherapy

There were 6 studies comparing immediate postoperative outcomes and recovery after TKA between patients who received cold packs and those who received continuous cold flow device (Table 2). Of these, 3 studies demonstrated superiority of continuous cold flow device (pain $P = .01$; patient satisfaction $P = .004$; pain $P < .05$), 1 study favored cold packs (ROM $P = .0235$), and 2 studies demonstrated no differences between these cryotherapy modalities ($P > .05$).

Schinsky et al [19] reported on 97 patients who received either an ice/gel pack ($n = 49$) or circulating cold water ($n = 48$) treatment. Although there were no significant differences between the groups in terms of visual analog scale (VAS) pain level on the day of discharge or at 3-week follow-up, they found that the average VAS pain level was significantly reduced in the ice/gel pack group at 6-week follow-up when compared to the circulating cold water group (2.3 vs 2.4 points; $P = .01$). However, there were no differences in terms of knee swelling or ROM. Similarly, Bech et al [20] reported on 78 patients who received either ice bags ($n = 34$) or consistent cooling using an icing device ($n = 37$). They found a significant increase in patient satisfaction in the continuous device group as compared to the ice bag group (96.9% vs 63%; $P = .004$). However, there were no differences in terms of pain, ROM, nausea or vomiting, opioid use, blood loss, or lengths-of-stay. Demoulin et al [21] evaluated 66 patients who received a cold pack ($n = 22$), cryocuff ($n = 22$), or gaseous cryotherapy ($n = 22$) after TKA. They found that pain increased following surgery in the cold pack ($P < .05$) and gaseous cryotherapy ($P < .01$) groups, whereas it remained stable in the cryocuff group; however, pain was not significantly different between the groups on POD 7. Furthermore, there were no differences in terms of mobility or knee girth.

Thienpont [22] evaluated 100 patients who received either cold packs ($n = 50$) or advanced cryotherapy ($n = 50$), and reported that there were no significant differences in pain, swelling, lengths-of-stay, blood loss, or inflammatory tests. However, active knee flexion at 6 weeks postoperative was better in the cold packs group compared to the cryotherapy group (120° vs 114°; $P = .024$).

Su et al [23] reported on 187 patients who received either ice and static compression ($n = 84$) or cryopneumatic treatment ($n = 103$). They found that there was a significant improvement in the 6-minute walk test in the cryopneumatic treatment group as compared to the static compression group at 6-week follow-up (29.4 vs 7.9 m; $P = .13$), but not at the 2-week follow-up. Additionally, there were no differences in pain, knee girth, ROM, or the timed up and go test. Similarly, Ruffilli et al [24] assessed 50 patients who received either crushed ice packs ($n = 26$) or a continuous cold flow device ($n = 24$). They found that there were no significant differences in pain or knee circumference on PODs 1, 3, or 7. Also, there were no significant differences in terms of blood loss or wound drainage on POD 1.

In summary, of the 6 studies comparing the use of cold packs and continuous cold flow devices in patients who underwent TKA, majority of the studies (3) favor the use of continuous flow devices.

Various Applications

One study evaluated a different mode of cold pack application, and found pressurized salt ice packs to be more effective than nonpressurized ice packs in pain modulation (Table 3). Another study compared continuous flow devices set at 75°F and 45°F and found no significant difference in immediate postoperative outcomes.

Pan et al [25] assessed 69 patients who received either water ice packs ($n = 35$) or pressurized salt ice packs ($n = 34$), and they found significantly lower pain scores in the pressurized salt ice packs group compared to the water ice packs group at 12 ($P < .05$), 24, 48, and 72 ($P < .01$) hours postoperative. They also found that the knee girth was significantly smaller in the pressurized salt ice packs group compared to the water ice packs group, but only at 48 hours postoperative ($P < .05$). Additionally, compared to the water ice pack cohort, the pressurized salt ice packs cohort were better in terms of the number of times the ice pack slipped off the patient's knee (0 vs 85 times; $P < .001$) and the number of times that the wound dressings became moist (2 vs 67 times; $P < .001$).

Radkowski et al [26] assessed 64 patients who received either cryotherapy at a temperature of 75°F ($n = 36$) or 45°F ($n = 28$) with a continuous cold flow device, and reported that there were no differences in terms of pain, postoperative opioid consumption, or drain output.

In summary, pressurized cold packs appear to be more effective in reducing pain and edema, as well as less likely to slip. However, there was no difference in pain, postoperative opioid consumption, or drain output between 2 different temperature settings of continuous cold flow device.

Cost-Benefit Analysis

In a study by Schinsky et al [19], ice/gel pack wrap was $97.34 cheaper than circulating cold water device. Similarly, in a study Kullenberg et al [16], the authors found the cold compression to be cost effective. However, when considering the costs of opioid analgesics and their potential side effects, this may be a cost-effective option for some patients if it is found to be more efficacious than ice packs.

Table 2
Studies Comparing Cold Packs and Continuous Cold Flow.

Study (Author, Year PMID)	Type of Study	No. of Patients	Modality		Parameters Assessed (Pain, Swelling, Ambulation, Etc.)	Timing of Evaluation	Protocol of Administration	Concomitant Analgesia	Salient Finding for Each Parameter Assessed	Cohort Favored in the Study
			Control (*n*)	Study (*n*)						
Schinsky et al (2016) [19]	RCT	97	Ice/gel pack (49)	Circulating cold water (48)	Pain Swelling Blood loss ROM Compliance Hospital staff satisfaction Adverse events	Until 6 wk after surgery	Ice/gel packs to patients were instructed to replace with fresh frozen packs every 3-4 h Circulation cold water was continuous during days 1-3. On days 4-10, instructions were: 1 h on and 1 h off during awake time and continuous during sleep. Day 11 after surgery and beyond instructions were as needed for pain control: continuous for 1 h intervals, not to exceed 12 h a day and it may be continuously used during sleep as needed for pain control	Same in both cohorts: long- and short-acting oral narcotics, celecoxib Breakthrough pain: intravenous narcotics	Pain: ice/gel pack vs circulation cold water at discharge (4.85 ± 2.14 vs 4.82 ± 2.10, $P = .97$) At 3 wk (2.96 ± 2.20 vs 2.68 ± 1.68, $P = .82$) At 6 wk (2.26 ± 2.44 vs 2.36 ± 2.03, $P = .01$) Swelling: at first dressing change ice/gel pack vs circulating cold water (2.83 ± 5.28 vs 2.56 ± 5.37, $P = .41$) At 3-wk follow-up (2.69 ± 5.25 vs 1.83 ± 4.70, $P = .22$) At 6-wk follow-up (1.56 ± 4.32 vs 0.94 ± 4.56, $P = .28$) ROM on discharge-flexion: ice/gel pack vs circulating cold water (79.48 ± 11.69 vs 75.92 ± 15.71, $P = .89$) ROM on discharge-extension: ice/gel pack vs circulation cold water (6.00 ± 7.94 vs 8.32 ± 6.95, $P = .86$)	Continuous cold flow device
Bech et al (2015) [20]	RCT	71	Ice bag (34)	Consistent cooling using an icing device (37)	Pain intensity Passive ROM Nausea or vomiting Opioid use Blood loss Lower limb function Length of stay Patient-reported compliance and satisfaction	24-48 h postop	Control group received ice bags at a frequency requested by the patient for 48 h For the intervention group, the device was applied immediately after surgery and remained in place for 48 h, except for brief episodes: after 1 h, and every 4 h thereafter, for nursing assessment for skin or nerve damage; during exercise; and during ambulation	Same in both groups: acetaminophen 650 mg Q6H, long-acting opioid BID, long-acting COX-2 selective NSAID Breakthrough pain: opioid as needed	Pain: NPRS in ice bag vs consistent cooling device (3.6 ± 0.27 vs 3.8 ± 0.25, $P = .67$) PROM: ice bag vs continuous device (59.8 ± 3.1 vs 54.0 ± 2.4, $P = .14$) Nausea or vomiting: ice bag vs continuous device (15.6 vs 34.3, $P = .08$) Opioid use: ice bag vs continuous device (42.3 ± 4.9 vs 49.9 ± 5.8, $P = .33$) Blood loss: change in Hg (g/dL) in ice bag vs continuous device (−8.8 ± 1.7 vs −7.7 ± 1.8, $P = .68$) Length of stay: ice bag vs continuous device (4.8 ± 0.39 vs 5.8 ± 0.64, $P = .2$) Patient satisfaction: patient who recommended “yes,” % in ice bag vs continuous device (63% vs 96.9%, $P = .004$)	Continuous cold flow device

Demoulin et al (2012) [21]	RCT	66	Cold pack (22)	Continuous cold flow device (22)	Gaseous cryotherapy (22)	Pain Mobility Knee girth	N/A	Cold pack group: gel pack was applied for 20 min 5 times a day. Cryocuff group: was applied for 20 min 5 times a day Gaseous cryotherapy: hyperbaric CO_2 cryotherapy was applied to patients for 90 s 3 times a day	N/A	Pain: following surgery pain increased significantly in the cold pack group ($P < .05$) and gaseous cryotherapy group ($P < .01$), whereas it remained stable in the cryocuff group. At POD 7, pain intensity was slightly higher in the cold pack group than in the other groups but the difference between groups remained nonsignificant ($P = .452$) Mobility: following surgery, there was no significant difference between groups in terms of ROM. Girth: there was no significant difference between groups	Continuous cold flow device
Thienpont (2014) [22]	RCT	100	Cold packs (50)	Advanced cryotherapy (50)		Pain-VAS and analgesic use ROM Swelling Blood loss	Pain and analgesic use on POD 2 ROM: POD 1, 4, and 6 wk after surgery Swelling at 6 wk Blood loss POD 2 and 4	In the advanced cryotherapy group, patients received 4 h of continuous cooling at 11°C immediately after surgery. The day after surgery the protocol consisted of 2 h of treatment followed by their standard physiotherapy followed by 2 h of advanced cryotherapy treatment In the cold packs group, patients received 15 min of cold pack treatment on arrival to the recovery room and again on arrival to the ward. This would be repeated 2 h and 4 h after surgery. The following days patients received the same cold pack cryotherapy 15 min after their physiotherapy session and during the evening and night whenever they considered it useful	Same in both cohorts: preoperative 1000 mg acetaminophen, 100 mg celecoxib Postoperative: 4 doses 1000 mg acetaminophen, 2 doses 100 mg celecoxib Breakthrough pain: morphine for the first 48 h, tramadol after 48 h	Pain: no difference was observed between the treatment and control groups in terms of VAS pain scores at rest, movement, and walking Mean VAS in cold pack vs advanced cryotherapy on day 2 at rest (3.5 ± 2.5 vs 4 ± 3, $P = .1842$), movement (5.5 ± 2.5 vs 5.5 ± 2.5, $P = .6781$), and walking (4.5 ± 2 vs 5.5 ± 2.5, $P = .0854$) No differences in functional results up to 6 wk including ROM, straight leg raising, walking without aid, swelling, and hematoma were found between the 2 groups, except for active flexion at 6 wk after surgery, for which the control group (cold packs) outperformed the treatment group (120° vs 114°, $P = .0235$) No differences in length of stay were observed No differences in blood loss and inflammatory tests were found	Cold pack

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Table 2 (*continued*)

Study (Author, Year PMID)	Type of Study	No. of Patients	Modality		Parameters Assessed (Pain, Swelling, Ambulation, Etc.)	Timing of Evaluation	Protocol of Administration	Concomitant Analgesia	Salient Finding for Each Parameter Assessed	Cohort Favored in the Study
			Control (*n*)	Study (*n*)						
Su et al (2012) [23]	RCT	187	Ice and static compression (84)	Cryopneumatic treatment (103)	ROM Knee girth 6 MWT TUG test Pain Narcotic consumption	At least 4 times per day for 2 wk	Within 3 h postoperation	Same in both groups: cryopneumatic group mean 509 mg of morphine equivalents, compared with ice and static compression, mean 680 mg in the first 2 wk	At 2 wk, there was no significant difference between the study and control groups with respect to knee girth and ROM Mean 6 MWT: static compression vs cryopneumatic treatment at 2 wk (−107.7 vs −118.2, P = not significant) At 6 wk (7.9 vs 29.4, $P = .13$) Mean TUG test: static compression vs cryopneumatic treatment at 2 wk (5 vs 4.5, P = not significant) At 6 wk (−2.4 vs −1.5, P = not significant) Pain: mean VAS static compression vs cryopneumatic treatment at 2 wk (−13.5 vs −9, P = not significant) At 6 wk (−22.1 vs −23.4, P = not significant)	None
Ruffilli et al (2016) [24]	RCT	50	Crushed ice packs (26)	Continuous cold flow device (24)	Pain Analgesic consumption ROM Drain output Blood loss	POD 1, 3, and 7	Continuous cold flow device was placed in the operating room and turned on in the ward (no intervals were noted) Ice cold packs were applied and changed every 30 min Analgesics: acetaminophen was given 3 times a day Two doses of morphine were administered subcutaneously for first 48 h and switched over to tramadol after 48 h All patients were discharged after 7 d from surgery	Same in both cohorts: fixed interval of acetaminophen 1000 mg IV TID Breakthrough pain: 2 doses of morphine 20 mg/mL SubQ for the first 28 h Tramadol 100 mg/mL after 48 h	Pain: postoperative day 1: crushed ice vs device (2.6 ± 1.8 vs 3.5 ± 2.3, $P = .2$) Day 3 (2.1 ± 1.4 vs 2.0 ± 1.6, $P = .7$) Day 7 (2.0 ± 1.6 vs 1.6 ± 1.5, $P = .3$) Blood loss (mL): only measured at day 1. Crushed ice vs device (1103 ± 464 vs 1005 ± 604, $P = .6$) Drainage (mL) only measured at day 1. Crushed ice vs device (242.9 ± 225.1 vs 230.3 ± 216.5, $P = .8$) There was no significant difference in knee circumference at days 1, 3, and 7	None

PMID, PubMed ID; N/A, not-applicable; IV, intravenous; BID, twice per day; Q6H, every 6 hours; COX-2, cyclooxygenase 2; NSAID, non-steroidal anti-inflammatory drug; NPRS, Numerical Pain Rating Scale; PROM, passive range of motion; MWT, minute walking test; TUG test, timed up and go test; SubQ, subcutaneous.

Table 3
Studies Comparing the Application of Cold Packs.

Study (Author, Year PMID)	Type of Study	No. of Patients	Modality		Parameters Assessed (Pain, Swelling, Ambulation, Etc.)	Timing of Evaluation	Protocol of Administration	Concomitant Analgesia	Salient Finding for Each Parameter Assessed	Cohort Favored in the Study
			Control (*n*)	Study (*n*)						
Pan et al (2015) [25]	RCT	69	Water ice packs (35)	Pressurized salt ice packs (34)	Pain B/L knee girth Slipping times of the ice packs Times of wound dressing or bed moist	12, 24, 48, and 72 h after TKA	Cold therapy was used for patients in both groups with 6 h after operation, which lasts for 3 days (every day performed 2 split an hour long treatment)	N/A	Pain: lower scores in pressurized ice packs vs water ice packs in 12 ($P < .05$), 24, 48, 72 h ($P < .01$) Ice pack slippage in pressurized salt ice packs vs water ice packs (0 ± 0 vs 85 ± 40, $P = .000$) Wound dressing or bed unit moist situation in pressurized salt ice packs vs water ice packs (2 ± 0.98 vs 67 ± 31.9, $P = .000$)	Pressurized salt ice packs
Radkowski et al (2007) [26]	RCT	64	Continuous flow device at 75° (36)	Continuous flow device at 45° (28)	Pain Analgesic use Postop drainage Knee function ROM	POD 1, 3, and 30	The cryotherapy device was used continuously during the patients' hospital stay, but discontinued upon discharge home	Same in both cohorts	Pain: average verbal analog pain scale in 45° vs 75° for POD 1 (6.0 vs 5.5), POD 3 (7.1 vs 6.3), and POD 30 (6.2 vs 6.5), $P = .4$ Postop opioid consumption: in 45° vs 75° at POD 1 (7.1% vs 5.6%, $P = .961$) At POD 3 (46.4% vs 25.0%, $P = .111$) Drain output in 45° vs 75° at POD 1 (448 ± 350-542 vs 519 ± 415-623, $P = .398$)	None

PMID, PubMed ID; N/A, not-applicable; B/L, bilateral.

This study has several limitations. Although several studies have demonstrated statistically significant reduction in postoperative pain scores with the use of cryotherapy, many of these studies may not have demonstrated a clinically significant reduction in pain. However, an MCID on a VAS scale in acute postsurgical pain is a subjective value and many different thresholds are reported in the literature, ranging from approximately 1 point [2,3,7–11,14–40] to 2 points [36]. In addition, patients with higher levels of pain may require greater changes in VAS score to achieve MCID [37]. Larger studies are needed in order to elucidate whether cryotherapy can reduce pain scores with an MCID threshold of 1-2 points on VAS scale. Of the 16 reports included in this study, 12 reported the multimodal regiment utilized, which was the same for both cohorts (Tables 1-3). The other 4 studies did not specify what analgesic protocol was used. Because all the reports that described analgesic protocols had the same treatment for both study and control cohorts, these should not necessarily confound the outcomes. Furthermore, we did not evaluate the effect of different types of cold packs used in different studies (crushed ice vs gel pack). However, these techniques have the same potential shortcomings as highlighted above—no control of temperature and possible underlying tissue damage/cold burns.

Conclusion

In this study, we reviewed the use of cryotherapy after UKA and TKA. The low temperature from the use of cryotherapy likely affects the internal environment of the knee and has anti-inflammatory effects, demonstrated by a positive correlation with the low temperature and inflammatory markers [38]. Additionally, the use of cryotherapy might help with early postoperative function. Although the majority of studies favor cryotherapy, we want to highlight that there are still several studies that show no difference. Although we were not able to discern which cryotherapy method is the most efficacious, we recommend the use of cryotherapy for management of patients who undergo UKA and TKA. The optimal device to use may be one that offers continuous circulating cold flow with compression, as it was associated with better outcomes, and allows for better temperature control. Additionally, these devices do not suffer from the same diminishing cold effectiveness over time as traditional ice packs do. Furthermore, continuous circulating cold flow devices may help prevent devastating complications such as underlying tissue damage/cold burns that can occur [39,40]. In addition, the pain relieving effects of cryotherapy may help minimize pain medication use, such as that with opioids, which are associated with numerous potential side effects as well as dependence and addiction. Future studies should meta-analyze the most recent RCTs that specifically evaluate the effectiveness of these newer continuous cold flow devices in UKA and TKA.

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