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Research Article

Computer-assisted cryocompression therapy reduces pain and enhances rapid recovery of range of motion after unicompartmental knee arthroplasty

Stefano Petrillo[1], Matteo Marullo[1], Guido Bandettini[1], Edoardo Bertello[2], Biagio Zampogna[3,4,5], Laura Mangiavini[6,7], Giuseppe M. Peretti[6,7], Paolo Perazzo[8], Sergio Romagnoli[1], Riccardo Giorgino[6*]

Abstract

Background/Objectives: Knee prosthetic surgery is highly effective for advanced osteoarthritis, improving quality of life. Postoperative pain management and rapid knee range of motion recovery are crucial for avoiding readmissions. Cryocompression therapy reduces pain, swelling, and opioid use. Computer-assisted cryocompression therapy (CA-CCT) shows promise over traditional ice packs in enhancing recovery after unicompartmental knee arthroplasty. This study aims to compare cryocompression therapy and ice pack therapy (IPT) in unicompartmental knee arthroplasty for improved recovery and outcomes. Methods: A single-center retrospective comparative study analyzed the efficacy of CA-CCT versus IPT in 35 patients who underwent medial UKA, matched 1:1 with a control group (35 patients). Both groups were similar in terms of sex, age, body mass index, and preoperative hemoglobin values. All patients underwent spinal anesthesia, used intra-articular drains removed after 6 hours, and followed a standardized analgesic protocol. Statistical analysis was performed to evaluate differences in ROM, visual analogue scale for pain, blood loss, and decrease in Hb. Significance was set at $P < 0.05$. Results: No complications, readmissions, or prolonged hospital stays were reported, with a mean stay of 2 days for both groups. Statistically significant improvements in ROM ($P < 0.00001$) and VAS scores ($P < 0.00001$) were observed in the CA-CCT group at 6, 24 and 48 hours post-surgery compared to the IPT group. Blood loss and Hb decrease were similar between groups ($P = 0.6$ for blood loss and $P = 0.8$ for Hb decrease). Conclusions: CA-CCT significantly improves postoperative pain control and knee function compared to IPT after UKA. Future prospective studies are needed to validate these results and assess the cost-effectiveness of CA-CCT.

Keywords: Unicompartmental Knee Arthroplasty; UKA; Osteoarthritis; Cryocompression Therapy; Ice Pack Therapy

Introduction

Knee prosthetic surgery has firmly established itself as one of the most effective therapeutic interventions for patients suffering from advanced-stage osteoarthritis (OA), a degenerative joint disease that significantly impairs mobility and quality of life. Osteoarthritis is characterized by the breakdown of cartilage within the knee joint, leading to pain, stiffness, and loss of function. As the disease progresses, patients often experience a substantial decline in their ability to perform daily activities, which negatively impacts their overall well-being [1-3]. When conservative treatments such

Affiliation:

[1]Department of Joint Replacement, IRCCS Ospedale Galeazzi San'Ambrogio, Milan, Italy

[2]Residency Program in Orthopaedics and Traumatology, University of Milan, Milan, Italy

[3]Department of Orthopedic and Trauma Surgery, Università Campus Bio-Medico di Roma, Roma, Italy.

[4]Research Unit of Orthopedic and Trauma Surgery, Fondazione Policlinico Universitario Campus Bio-Medico, Rome, Italy.

[5]BIOMORF Department, Biomedical, Dental, Morphological and Functional Images, University of Messina, A.O.U. Policlinico "G.Martino", Messina, Italy

[6]IRCCS Ospedale Galeazzi Sant'Ambrogio, 20157 Milan, Italy

[7]Department of Biomedical Sciences for Health, University of Milan, 20122 Milan, Italy

[8]Intensive care Unit, IRCCS Ospedale Galeazzi Sant'Ambrogio, Milan, Italy

***Corresponding author:**

Riccardo Giorgino, IRCCS Ospedale Galeazzi Sant'Ambrogio, 20157 Milan, Italy

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as medications, physical therapy, or intra-articular injections fail to provide relief, knee arthroplasty, commonly known as knee replacement surgery, becomes a viable option for restoring joint function and alleviating pain. In the context of knee arthroplasty, effective management of postoperative pain and inflammation is critical for promoting recovery, ensuring patient comfort, and facilitating rehabilitation [4,5]. Pain control not only improves patient satisfaction but also supports faster mobilization and recovery of knee range of motion (ROM), which are key components of fast-track surgical protocols aimed at reducing hospital stays and healthcare costs [4,6]. Postoperative ROM recovery is essential, as limited knee mobility can lead to complications such as joint stiffness and functional impairment, potentially delaying discharge and increasing the likelihood of readmission [4,6]. Therefore, optimizing strategies to manage pain, swelling, and inflammation following knee arthroplasty has become a priority in clinical practice.

Cryocompression therapy (CCT), a combination of cryotherapy (cold therapy) and mechanical compression, has emerged as a valuable modality in the postoperative management of knee arthroplasty patients. Cryotherapy works by inducing vasoconstriction, reducing blood flow to the affected area, and subsequently decreasing inflammation and swelling. This reduction in swelling leads to pain relief and diminished reliance on opioid medications, which are commonly prescribed but come with the risk of side effects such as nausea, dizziness, and addiction [7]. Cryotherapy also affects neuronal conduction, specifically by cooling peripheral nerves, which reduces muscle spasms and metabolic activity in neurons. This leads to an overall decrease in pain sensation [7]. Compression therapy complements these effects by applying external pressure to the lower limb, which mitigates venous stasis, lowers the risk of deep venous thrombosis (DVT), and minimizes tissue edema, thereby facilitating the recovery of knee ROM [7]. Despite its effectiveness, the most frequently used cryocompression modalities after knee arthroplasty are still relatively basic, involving ice packs (IPs) and elastic wraps. These traditional methods, while beneficial, offer limited control over temperature regulation and compression intensity, which can result in inconsistent therapeutic outcomes. Recently, advancements in technology have introduced computer-assisted cryocompression therapy (CA-CCT), which provides more precise control over the cooling and compression parameters. This allows for a more tailored treatment experience, potentially leading to better clinical outcomes compared to conventional methods [8]. CA-CCT has already demonstrated efficacy in reducing pain, swelling, and opioid consumption in patients undergoing total knee arthroplasty (TKA) [8]. TKA is a well-established procedure for managing patients with severe, tricompartmental OA, where the entire knee joint is replaced. Several studies have shown that CA-CCT leads to improvements in pain control, early ROM recovery, psychological satisfaction, and a reduction in opioid use following TKA, making it a promising adjunct in postoperative care [8]. However, while the benefits of CA-CCT in TKA are well-documented, there is a lack of research investigating its use in other types of knee replacement surgeries, such as unicompartmental knee arthroplasty (UKA).

UKA, also known as partial knee replacement, is considered the gold standard for treating patients with isolated anteromedial or anterolateral OA, or isolated femoral or tibial condyle osteonecrosis [2,9,10]. Unlike TKA, where the entire knee joint is replaced, UKA involves the replacement of only the affected compartment of the knee, preserving the healthy bone and cartilage. This results in a less invasive procedure with quicker recovery times, reduced postoperative pain, and higher patient satisfaction rates compared to TKA [2,9,10]. Recently, we demonstrated that UKA is associated with rapid recovery and no readmissions, even in patients discharged 24 hours after surgery [9]. Given the faster recovery trajectory of UKA compared to TKA, there is significant interest in identifying postoperative therapies that can further accelerate rehabilitation and optimize outcomes in UKA patients. While cryotherapy and compression have been widely studied in TKA, their application in UKA remains underexplored. To date, no studies have specifically compared the use of CA-CCT and ice pack therapy (IPT) in the context of UKA. Considering the potential benefits of CA-CCT in terms of precise temperature control, enhanced compression, and improved patient comfort, it is plausible that this modality could offer superior outcomes compared to traditional IPT after UKA.

The aim of this study was to compare the efficacy of CA-CCT and IPT in patients undergoing medial UKA for isolated anteromedial OA. Specifically, the study sought to evaluate the effects of these two modalities on postoperative pain levels, blood loss, and the recovery of knee ROM. We hypothesized that the use of CA-CCT would result in faster recovery of knee function, lower pain levels, and improved short-term clinical and functional outcomes compared to IPT. This research represents the first direct comparison of CA-CCT and IPT in the context of UKA, with the potential to inform postoperative care protocols and improve patient outcomes following this increasingly common surgical procedure.

Materials and Methods

The present study was approved by the Ethic Committee board of San Raffaele Univeristy of Milan (ALLCCP Em. 05/2024). A single-center retrospective comparative study was conducted to analyze the efficacy of CA-CCT and IPT after medial UKA. From March 2023 to May 2024, a total of 424 UKAs were performed in 410 patients at our Institution.

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Of these, 35 patients who received CA-CCT were included in the study group. The inclusion and exclusion criteria are listed in table 1.

Table 1: Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
• Isolated anteromedial OA	• Previous ipsilateral knee fracture
• Isolated medial femoral condyle and/ or medial tibial plateau osteonecrosis	• Previous knee surgery
• Isolated lateral femoral condyle and/ or lateral tibial plateau osteonecrosis	• Severe anaemia
• BMI $\leq$ 30 Kg/m^2	• Drugs addiction
• ASA score I-III	• Antidepressant therapy
	• Bleeding disorders or NOAC
	• Cardiovascular diseases
	• Inflammatory diseases

The control group included patients who received IPT and was formed through a 1:1 case-control matching process based on sex, age, body mass index (BMI), OA grade according to Kellgren Lawrence (KL), preoperative Haemoglobin (Hb) values and duration of surgery (Table 2).

Table 2: Groups characteristics. CA-CCT: computer-assisted cryocompression therapy; IP: Ice Pack; P value: result of X2 or Mann-Whitney test; BMI: Body Mass Index; ASA: American Society of Anaesthesiology score.

	CA-CCT	IP	*P value*
Age (years)	64.9 ± 7	66.2 ± 8.4	0.2
Sex	22 males	16 males	0.1
	13 females	19 females	0.2
BMI (Kg/m²)	26.8 ± 2.2	26.3 ± 3.3	0.1
Kellgren-Lawrence			
1	0	0	
2	0	0	
3	24	22	
4	11	13	
ASA score			
1	17	12	
2	18	10	
3	0	3	
Haemoglobin (mg/dl)	14.2 ± 1	14.1 + 0.9	0.7
Pain (visual analogue scale)	7.2 ± 1.3	6 + 2	0.3
Surgery duration (minutes)	41.8 ± 7.3	37.1 ± 12.1	0.1

The operative protocol as well as perioperative pain management was the same in both groups. All surgical procedures were performed by the two senior authors (S.P. and M.M.), who were not involved in data collection. The operative technique used was consistent with that described in our previous studies [9,10], utilizing a standardized reduced instrumentation surgical technique (RIST) and a fast-track recovery protocol. A medial fixed-bearing fully cemented unicompartmental knee arthroplasty (UKA) (Persona Partial Knee; Zimmer Biomet; Warsaw, USA) was implanted via a mini-midvastus surgical approach. At the end of the bone cuts and prior to UKA cementation, local infiltration analgesia (LIA) was administered using 0.2% Ropivacaine, 0.5 mg of Adrenaline, and 90 mg of Ketorolac. Intra-articular (1 g) and systemic tranexamic acid (TXA) were used at a dosage of 10-15 mg/kg, both preoperatively and postoperatively. No tourniquet was used in any of the procedures. An intra-articular drain was positioned at the end of the surgery and was removed after 6 hours. Four hours after surgery, patients started walking with two crutches, bearing full weight. Perioperative pain management therapy was oral and consisted of Celecoxib 200 mg every 12 hours and Paracetamol 1 g every 8 hours. No opioids were administered, but in cases of severe uncontrolled pain (VAS > 7), Ketorolac 15 mg was provided (maximum every 12 hours).

Cryocompression Therapy

In the study group, patients received CA-CCT: the Z-ONE (Zamar Z-One MG455A, Europe) is a medical device based on computer-assisted cold flow, associated with periodic compression cycles that allow selective, constant, and uniform distribution of cold. The CA-CCT machine was programmed with two different cycles according to intermittent compression with compression time of 3 seconds and temperature values: 1) 40 mmHg (intermittency interval 1: lower level) and 7°C for the first 3 hours, and 2) 60 mmHg (intermittency interval 2: moderate level) and 5°C for the subsequent 3 hours. The control group received ice pack therapy (IPT) along with static lower limb compression of 17 mmHg using a Tubigrip. The cryotherapy started immediately after surgery, and continued for 6 hours, associated with static continuous lower limb compression. In both the study and control groups, cryocompression therapy was initiated by a physiotherapist and supervised by medical doctors not involved in the surgical procedure, concluding after 6 hours.

Outcomes

The following data were extracted from patient medical reports: age, sex, BMI, preoperative Hb values, and extension and flexion ROM. Postoperatively, the following variables were measured at 6 and 24 hours after surgery: Hb, ROM, and VAS scores. Mean blood loss (measured as the amount of blood in the drain) was assessed at the time of drain removal,

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6 hours after surgery. Only VAS score and ROM were obtained 48 hrs after surgery.

Statistical analysis

The SPSS for Mac software (G*Power, version 3.1.2, Heinrich Heine University, Dusseldoerf, Germany) was used for all statistical evaluations. A post-hoc power analysis was performed: our study had a power of 0.70 to detect a significant difference with and an alfa error (the probability of yielding a type I error) equal to 0.05.

The independent analyzed variables were the following: age; sex; BMI; KL grade; ASA score, Hb, VAS, surgery duration. Comparison between the 2 groups for each independent variable was carried out with the Mann-Whitney U test for continuous variables and the x2 test for categorical variables. The outcome variables considered (ROM, VAS, blood loss, Hb) were compared using the Mann-Whitney U test. Significance was set at $P< 0.05$.

Results

No patients reported complications, nor were there any readmissions or prolonged hospital stays, with a mean length of hospital stay of 2 days (1-3 days) in both groups. Statistically significant differences were observed in ROM and VAS values between the two groups, as well as in blood loss at 6, 24 and 48 hours after surgery. The comparison between pre- and postoperative VAS was statistically significant in in CA-CCT group ($p<0.05$) at both 6, 24 and 48 hours after surgery. No statistically significant differences were found between the two groups regarding the amount of blood loss and the decrease in hemoglobin values (Tables 3, 4 and 5). No patients required transfusions in either group.

Discussion

The main finding of this study is that CA-CCT is superior to IPT in controlling pain and enhancing recovery of ROM after UKA. We observed significant improvements in knee function and a decrease in pain at both 6, 24 and 48 hours after surgery for patients who received CA-CCT. Conversely, although patients receiving CA-CCT experienced lower blood loss and a smaller decrease in hemoglobin values, no significant differences were found compared to those managed with IP.

The results of this study clearly indicate that CA-CCT provides benefits in pain management and knee function recovery following UKA. This is a crucial aspect in a fast-track context, where managing postoperative pain and achieving rapid ROM recovery is essential for ensuring safe and timely patient discharge, thus reducing the risk of hospital readmissions. The significantly better ROM in the CA-CCT group may translate into increased patient satisfaction and more effective rehabilitation. The superiority of CA-CCT over standard cold therapy (IPT) is likely attributable to the system's ability to maintain a constant temperature and optimal intermittent compression, which enhance the effects of cryotherapy and improve venous drainage, thereby reducing swelling and pain. However, although CA-CCT shows trends towards less blood loss and a smaller reduction in hemoglobin levels compared to IPT, these differences were not statistically significant. This suggests that while CA-CCT may have a positive impact on these parameters, the effect might not be large enough to be clearly apparent with the current sample size or could be influenced by additional uncontrolled variables.

Table 3: Comparison 6 hours after surgery.

Six hours postop	CA-CCT	IPT	*P*
ROM	94.9 ± 14. 8	41.9 ± 15.1	< 0.00001
Pain (VAS)	0.6 ± 1.1	5.7 ± 2.1	<0.00001
Blood loss (ml)	49.7 ± 42.7	54 ± 40	0.6

Table 4: Comparison 24 hours after surgery.

Twenty-four hours postop.	CA-CCT	IPT	*P*
ROM	95.4 ± 8.9	71.1 ± 19.6	< 0.00001
Pain (VAS)	1.4 ± 1.5	5.4 + 2.2	< 0.00001
Hb decrease (mg/dl)	1.1 ± 0.8	1.8 ± 0.7	0.8

Table 5: Comparison 48 hours after surgery.

Forty-eight hours postop.	CA-CCT	IPT	*P*
ROM	91.4 ± 6.9	70.1 ± 7.6	< .00001
Pain (VAS)	2.1 ± 1.3	4.9 + 2.1	< .00001

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It was difficult to compare our results with those obtained in the literature because no studies have been found regarding the use of CA-CCT in UKA. Nevertheless, our study's results are partly consistent with the existing literature in TKA. In the recent study by Marinova et al., which compared the efficacy of cryocompression (Game Ready™) versus standard cold therapy (ice and static compression) in the early postoperative recovery phase following total knee arthroplasty, the superiority of this therapy was less clear. Although the Game Ready™ group showed improved knee extension in the first two weeks, no significant differences in pain, flexion, or overall recovery between the groups were observed [8]. However, when compared to our CA-CCT machine, the Game Ready is not able to apply combined cryo- and compression therapy. Cryotherapy with computer assistance (cTreatment®) was compared by Sadoghi et al. to standard cryotherapy, showing a significant improvement in ROM on the sixth postoperative day in the cTreatment® group, with an average gain of 7 degrees. Pain during movement was significantly lower in the cTreatment® group on the second postoperative day [11]. Similarly, Brouwers et al. analyzed the role of computer-assisted cryotherapy with overlapping results. During the first postoperative week, the cryotherapy group reported less pain and lower opioid use compared to standard postoperative care. However, no significant differences between groups were found in knee function, swelling, or overall satisfaction [12]. The effectiveness of this treatment appears to be particularly evident in the immediate postoperative period. The role of cryotherapy after TKA seems to be mainly in reducing opioid consumption during the first postoperative week [13,14].

In this study, we evaluated the efficacy of two different cryocompression therapy methods (CA-CCT and IPT) in reducing the inflammatory response, alleviating pain, and improving ROM within a fast-track protocol following UKA. The superior outcomes observed in patients managed with CA-CCT confirm our hypothesis. A notable strength of this study is that all surgical procedures were performed by two highly experienced surgeons, each performing over 200 knee arthroplasties annually, using a standardized surgical technique. Additionally, all clinical and functional evaluations were conducted by two orthopedic surgeons who were not involved in the surgical procedures, ensuring objectivity in the outcome assessments.

On the other hand, the study has some limitations that should be considered when interpreting the results. One of the main limitations is the retrospective nature of the study, which could introduce selection bias or uncontrolled confounding factors. An important limitation is that we did not perform an a priori power analysis and sample size calculation, and instead, we enrolled all eligible patients managed at our institution during the index period. However, the post hoc power analysis indicated that the enrolled sample provided sufficient statistical power to support our results. Another limitation is the short 24-hour follow-up period, which does not allow us to assess the long-term efficacy of CA-CCT compared to IP, nor to monitor potential late complications that might emerge. Future studies should include an extended follow-up to determine whether the short-term benefits observed with CA-CCT are sustained over the long term, potentially contributing to more complete rehabilitation and faster return to daily activities. However, as we have already shown in our recent study [9], the emerging trend in fast-track protocol and more specifically in UKA is to safely discharge patients not more than 24 hours after surgery. Additionally, although our cohort included a reasonable number of patients, the sample size remains limited, particularly given the single-center nature of the study. Conducting multicenter studies with a larger and more diverse sample could provide further evidence on the effectiveness of CA-CCT and help establish stronger clinical guidelines. Finally, another consideration is the absence of a comparative economic analysis between CA-CCT and IP. Although CA-CCT seems to offer clinical advantages, it is important to evaluate its cost-benefit ratio, as it may involve higher costs compared to traditional cryotherapy methods. Incorporating an economic analysis could help determine whether the observed clinical benefits justify the potential increase in costs, making CA-CCT a sustainable and preferable choice in the postoperative management of patients undergoing UKA.

In conclusion, our study suggests that CA-CCT is an effective method for improving pain management and early functional recovery after UKA. However, the limitations of our study highlight the need for further prospective research with a more robust methodological design to confirm these results and more clearly define the role of CA-CCT in clinical practice.

Conclusions

This study demonstrated that CA-CCT offers significant advantages over traditional IPT in managing pain and enhancing the recovery of ROM following UKA. Patients treated with CA-CCT experienced not only reduced pain but also notable improvements in knee function within the first 24 hours after surgery, contributing to a faster recovery. Despite these promising results, further prospective studies with larger sample sizes are necessary to validate these findings and assess the cost-effectiveness of CA-CCT in a wider range of clinical settings, including its long-term benefits.

Author contributions

Conceptualization, S.P. and R.G.; methodology, S.P., M.M., G.B., E.B. and P.P.; validation, R.G. and S.P.;

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investigation, S.P., M.M., G.B., E.B., P.P. and S.R.; data curation, S.P.; writing—original draft preparation, S.P. and R.G.; writing—review and editing, S.P. and R.G.; supervision, G.M.P., L.M., B.Z. and S.R. All authors have read and agreed to the published version of the manuscript.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee Board of San Raffaele University of Milan (IR: ALLCCP, Em. 05/2024).

Informed consent statement

Patient consent was waived due to sensitive and personal data being treated anonymously.

Data availability statement

Data supporting the reported results can be found in database generated during the study.

Conflicts of interest

The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CA-CCT Computer-assisted cryocompression therapy

CCT Cryocompression therapy

DVT Deep venous thrombosis

IPT Ice pack therapy

LIA Local infiltration analgesia

KL Kellgren Lawrence

OA Osteoarthritis

RIST Reduced instrumentation surgical technique

ROM Range of motion

TKA Total knee arthtroplasty

TXA Tranexamic acid

UKA Unicompartmental knee arthroplasty

VAS Visual Analogue Scale

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