Cryotherapy With Dynamic Intermittent Compression Improves Recovery From Revision Total Knee Arthroplasty

Jérôme Murgier, MD [a,*], J. Cailliez, MD [a], M. Wargny, MD [b], P. Chiron [a], E. Cavaignac, MD [a], J.M. Laffosse [a]

[a] *Département de chirurgie Orthopédique et Traumatologique, CHU Toulouse, Toulouse, France*
[b] *Epidemiology Department, CHU Toulouse, Toulouse, France*

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A B S T R A C T

Background: The goal of this study was to assess the efficacy of cryotherapy with dynamic intermittent compression (CDIC) in relieving postoperative pain, decreasing blood loss, and improving functional scores after revision total knee arthroplasty (rTKA).
Methods: We conducted a prospective case control study (level of evidence: I) to evaluate the efficacy of CDIC on postoperative bleeding, pain, and functional outcomes after rTKA. Forty three cases were included at a single institution and divided in 2 groups: a control group without CDIC (n = 19) and an experimental group with CDIC (n = 24). Bleeding was evaluated by calculating total blood loss, pain at rest was evaluated with a visual analog scale on postoperative day 3, and function was assessed using the Oxford score at 6 months postoperatively. The comparative analysis was performed using the Fisher exact test.
Results: The CDIC group had significantly lower total blood loss (260 vs 465 mL; $P < .05$), significantly less pain on day 3 (1 vs 3; $P < .05$), and a significantly higher functional score (42 vs 40; $P < .05$) than the control group.
Conclusion: This is the first report dealing with the use of CDIC after rTKA. According to our results, it improves the recovery of patients who underwent rTKA; thus, it should be integrated into our daily practice.

Revision total knee arthroplasty (rTKA) procedures cause blood loss. Postoperative anemia is associated with a higher risk of infection [1], patient dissatisfaction [2], and postoperative blood transfusion with its inherent risks [3].

rTKA is a major orthopedic procedure that causes soft tissue damages that contribute to localized pain, which in turn reduces range of motion and causes persistent quadriceps atrophy [4]. Sig nificant blood loss after this procedure (up to 1.5 L) can lead to sys temic complications [3]. Despite progress in multimodal analgesia and anesthetic methods, total knee arthroplasty (TKA) is a painful surgery [4]. Nonpharmacologic treatments can also play a role, most notably cryotherapy which decreases the local metabolism, thereby reducing blood loss and pain [5]. This technique has minimal dis advantages relative to its potential benefits [6].

New devices that combine cryotherapy with dynamic inter mittent compression (CDIC) have recently been introduced. These devices provide a dry cold temperature and maintain a consistent temperature for an extended period of time [4,7]. Although the benefits of these systems were demonstrated in primary TKA [7] and anterior cruciate ligament reconstruction [8], we did not find any published studies evaluating the effect of CDIC in patients undergoing rTKA.

Our hypothesis was that use of CDIC would reduce total blood loss after rTKA. The main objective of this study was to assess its efficacy in terms of postoperative blood loss. Patients who under went rTKA were split into 2 matched groups for comparisons: one group with CDIC and the other one without. The other objectives were to compare blood transfusion rates, pain, functional scores, and complication rates in both groups.

Patients and Methods

This was a single institution, prospective, case control study (level of evidence: 3). It was approved by our hospital's research ethics committee (Number 01 0115).

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* Reprint requests: Jérôme Murgier, MD, Département d'Orthopédie Traumato-logie, CHU Toulouse Hôpital Pierre-Paul Riquet, Place du Docteur Baylac, TSA 40031, 31059 Toulouse Cedex 9, France.

Table 1
Baseline Characteristics and Surgery Related Data for the Cohort.

Characteristics	Control Group (n 19)	CDIC Group (n 24)	*P* Value
Baseline characteristics			
Age, mean (SD), y	66.5 (9.7)	70 (13.9)	.86
Gender, F/M	8/11	8/16	.78
BMI, mean (SD), kg/m^2	29.7 (4.6)	29.7 (4.7)	.89
Preoperative anticoagulants, n (%)	6 (32)	3 (13)	.15
ASA score, n (%)			
1	1 (5)	4 (17)	.17
2	8 (42)	14 (58)	
3	10 (53)	6 (25)	
Surgery-related data			
Surgery time, mean (SD), min	120 (40.2)	118 (43.3)	.84
Tourniquet time, mean (SD), min	98 (27.4)	100 (29.3)	.98
TT osteotomy, n (%)	5 (26)	4 (17)	.48
Patella resurfacing, n (%)	8 (42)	6 (25)	.39

ASA, American Society of Anesthesiologists; BMI, body mass index; CDIC, cryotherapy with dynamic intermittent compression; F, female; M, male; SD, standard deviation; TT, tibial tubercle.

Patients

All patients who underwent single stage rTKA from January 2013 to January 2015 were included.

Patients were excluded when a 2 stage revision or a partial revision was performed. They were also excluded if they had a contraindication to CDIC, such as history of deep vein thrombosis, coagulation disorder, or skin damage at the device application site.

Forty three patients were included (27 males and 16 females). The revisions procedures were carried out with rotating hinge knee prosthesis (RH Knee NexGen; Zimmer, Warsaw, IN) in all cases. A tibial tubercle osteotomy was needed in 9 cases, and the patella was resurfaced in 14 cases during the revision procedure.

The anesthesia and postoperative analgesia protocols used were standardized and similar in the 2 groups. Anticoagulant therapy was initiated 6 hours after the end of surgery in all patients.

The procedure was performed with a tourniquet in all cases. It was released before closing the wound to realize complete hemostasis. The mean procedure duration was 120 minutes (90 140 minutes).

Methods

The population was divided into 2 groups: a control group without CDIC and an experimental one with CDIC. The demographics data in these 2 groups were comparable (Table 1). The patients in the control group were included between January 2013 and April 2014. The patients in the CDIC group were included between May 2014 and January 2015.

The CDIC device used was the Game Ready system (CoolSystems Inc, Concord, CA). It comes with an anatomic wrap that is applied to the knee. This wrap circulates precooled compressed air and water. The temperature controlled unit generates a dry cold temperature; this is more comfortable for the patient than a wet cold temperature, thereby limiting the risk of maceration, bandage deterioration, and skin lesions. The wrap is covered with a removable, washable cover for the patient's health and comfort. The wrap is connected to a portable control unit. The compression is applied intermittently depending on the protocol selected. The surgery support staff was given specific training on how to use the CDIC.

The following protocol was used:

Application: after bandaging, in the operating room and before transfer to recovery room

Intensity: programme 3 (30 minute on/off cycles)

Temperature: 8°C

Application duration: two 8 hour cycles over a 24 hour period and

Treatment duration: 72 hours postoperative.

The control group was treated with regular cold application (4 hours per day) using a cold pack.

The following parameters were measured in both groups: total blood loss, hemoglobin and hematocrit levels on D 1, D+1, and D+5, transfusion volume and rate (red cell concentrate [RCC] units), pain on postoperative day 3, functional outcomes based on the Oxford score at 6 months postoperative, and the number of complications recorded at 6 months postoperative.

Total blood loss was calculated using the preoperative (D 1) and postoperative (D+5) laboratory test results according to the Merculiari formula [9]:

$$\textit{Total blood loss} \quad VST \times (Hct_{pre} \quad Hct_{post\ D5}) + \textit{volume of retransfused RCC*}$$

where the patient's total blood volume $k_1 \times \text{height (m)}^3 + k_2 \times \text{mass (kg)} + k_3$ for men: k_1 0.3669, k_2 0.03219, and k_3 0.6041; and for women: k_1 0.3561, k_2 0.03308, and k_3 0.1833, Hct_{pre} initial preoperative Hct, $Hct_{post\text{-}D5}$ Hct on the morning of the fifth postoperative day.

When transfusion was performed (allogenic or autologous), the total blood loss was equal to the blood loss calculated from the change in hematocrit plus the volume transfused [10].

The indication for RCC transfusion in our surgical unit is standardized to Hb <8 g/dL and/or patient with symptomatic anemia.

Postoperative pain at rest was measured by the surgery unit's nurse using a visual analog scale on the third day postoperative and by looking at the cumulative morphine use on the fifth postoperative day, expressed in morphine equivalent dose (in mg).

The Oxford score [11] was collected preoperatively and postoperatively using the validated French version of the questionnaire [12]. The questionnaire was filled out during a follow up visit 6 months after the procedure.

Statistical Analysis

Cohort characteristics are presented as numbers, means, standard deviations, and ranges. The normal distribution of the data was assessed using the Kolmogorov Smirnov test. For variables that were not normally distributed, data were analyzed using the Mann Whitney test for independent samples and the Wilcoxon signed rank test for dependent samples. Comparison of observed proportions was performed using the Fisher exact test. Statistical analysis was carried out using SPSS 18 statistical software (SPSS Inc, Chicago, IL), and significance was set at $P < .05$.

Results

Blood Loss

The total blood loss was lower in the CDIC group than in the control group (260 vs 465 mL; $P < .05$; Table 2). The hemoglobin and hematocrit levels were similar between groups. The transfusion rate was lower in the CDIC group (8% vs 42%; $P < .05$), and the mean lowest hemoglobin level was lower in the control group with 8.5 g/dL (±1.2) vs 9.6 (±1.6); $P < .005$. In the CDIC group, the number of RCC units given per patient was lower as well. No differences were found in any of the other measured blood related parameters.

Table 2
Summary of Variables Measured in Both Groups.

Variables	Control Group (n 19)	CDIC Group (n 24)	*P* Value
Blood loss			
Hb at D−1, mean (SD), g/dL	12.5 (2.1)	13 (1.8)	.76
Hb at D+5, mean (SD), g/dL	10.4 (1.2)	10.7 (1.3)	.31
Hct at D−1, mean (SD)	37 (5.9)	39.6 (4.9)	.9
Hct at D+5, mean (SD)	31 (3.6)	32.7 (3.6)	.19
Total blood loss, mean (SD), mL	465 (275)	260 (106)	**.024**
Mean lowest Hb level, g/dL	8.5	9.6	**.03**
Transfusion rate, %	42	8	**.013**
Transfusion			
Number of RCC units, % (n)			
0	58 (11)	92 (22)	**.023**
1	5 (1)	0 (0)	
2	26 (5)	4 (1)	
3	11 (2)	4 (1)	
Pain			
VAS D+3, mean (SD)	3 (1)	1 (1)	**.01**
Narcotic consumption at D+5, mean (SD), mg	100 (37)	80 (37)	1
Functional score			
Oxford score, mean (SD)	40 (2.8)	42 (2.4)	**NS**

Bolded values indicate statistical significant differences (<.05).
CDIC, cryotherapy with dynamic intermittent compression; RCC, red cell concentrate; Hb, hemoglobin; Hct, hematocrit; SD, standard deviation; VAS, visual analog scale; NS, non significant.

Pain

Pain at rest on day 3 was lower in the CDIC group than in the control group (1 vs 3; $P < .05$). The cumulative morphine intake at day 5 was not significantly different between groups.

Functional Scores at 6 Months

The Oxford score at 6 months postoperative was higher in the CDIC group than in the control group (42 vs 40).

Complications

There were 4 complications in the CDIC group and 3 in the control group. There were 2 cases of infection recurrence and 1 case of deep vein thrombosis in each group, and 1 case of extensor mechanism disruption in the CDIC group.

Discussion

Our hypothesis was confirmed. The patients in the CDIC group had lower total blood loss than patients in the control group. Moreover, the transfusion rate and the pain were lower in the CDIC group. The functional outcome was similar between the 2 groups at 6 months postoperative.

This is the first study to evaluate the use of CDIC after rTKA. The blood loss was evaluated using a method previously validated for rTKA patients [13]. This method provides a complete view of the total blood loss, as it also takes into account hidden blood loss after TKA [3]. We did not use the blood volume present in the suction drains, as in other studies [14]. This blood loss calculation method is not reliable; it overestimates blood losses and can lead to more blood transfusions [15]. The volume of blood in surgical drains has never been validated as being an objective measure of blood loss [13]. There is no correlation between the volume of blood in the drains and the need for transfusion [16].

CDIC has been used in the sports medicine setting to improve recovery and to treat ligament and bone injuries [8,16]. It has been shown that CDIC improves postoperative recovery by stimulating the tissue repair process [17]. Generally, these systems are provided to healthy athletes undergoing a minor procedure compared with rTKA. We believe that any help is beneficial to a fragile population such as the one undergoing rTKA.

The contribution of CDIC to postoperative recovery from TKA has already been demonstrated. Su et al [7] evaluated CDIC in pa tients undergoing primary TKA and compared it with a control group. In that study, the patients in the CDIC group used the system for 5 days after the procedure. They found a lower narcotic intake and a slight improvement in the functional outcome in patients using CDIC. We also found a tendency of reduced narcotic use (20 mg morphine equivalents in the CDIC group). This reduced narcotic intake reduces the side effects inherent to these agents. Patients feel less medicated and have a better postoperative course. Advanced cryotherapy was compared with icing only in the post operative course of TKA in a randomized controlled trial [4]. The authors concluded that there were no advantages in using advanced cryotherapy in daily practice, particularly because of the additional cost associated with these systems. However, more than one kind of cryotherapy system was used in that study, leading to variability in the results. Moreover, the blood loss was measured only through hemoglobin variations, which does not take into ac count hidden blood loss [3]. In addition, no blood transfusions were performed, as the patients were undergoing primary TKA. The need for transfusion is higher during rTKA [18].

Other therapeutic means have been proposed to reduce bleeding during primary and rTKA procedures. Tranexamic acid has been shown to be effective in hip and knee arthroplasty [19]. Use of thrombin based topical hemostatic agents does not have clear cut benefits. One group has described its benefits in rTKA [13]; how ever, anemia, atrial fibrillation, and infection have been associated with this type of product [14,20–22]. These side effects do not come into play when using CDIC. Thienpont et al [4] bring up the risk of frostbite in the area where CDIC is applied. This is an extremely serious complication that would require an additional major soft tissue procedure [23]. We have not encountered this complication and have not found any documented cases of frostbite with CDIC.

The present study has certain limitations. First, this was a multisurgeon study which increases the variability of the results. However, this also means that the study can be more easily generalized to current practice. Second, this study was performed within a highly specialized TKA surgery unit. Because of the use of advanced anesthesia procedures, analgesic infiltration, and pre ventative multimodal pain management [6], it is possible that a type II error occurred in our interpretation of the results. However, the anesthesia and analgesia techniques did not differ between the control and CDIC groups. Moreover, the transfusion rate—likely the most relevant criteria from a clinical point of view—is subjected to confounding factors because of the patients' comorbidities. Although we use a standardized approach, this bias is still present.

Conclusion

The number of rTKA procedures performed each year will continue to increase [13,24,25]. Since CDIC improves the recovery of patients undergoing rTKA, it should be integrated into our daily practice. Prospective randomized trial is necessary to validate the results of our study.

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