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Effects of Temperature and Volume of Intraoperative Normal Saline Irrigation on Postoperative Pain, Swelling, and Serum Markers of Inflammation in Patients After Elective, Arthroscopic, Single-Bundle Surgical Reconstruction of the Anterior Cruciate Ligament: A Retrospective, Single-Center Study

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Background: Arthroscopic single-bundle surgical reconstruction of the anterior cruciate ligament (ACL) is often performed electively after 3 weeks of mobilization therapy. The present single-center retrospective study aimed to investigate the effects of temperature and volume of intraoperative normal saline irrigation on postoperative pain and swelling and on serum markers of inflammation following elective, arthroscopic, single-bundle surgical reconstruction of the ACL.





Material/Methods: Clinical data from 716 patients with non-acute ACL injuries who met the criteria between March 2015 and May 2020 were retrospectively analyzed. The patients were broken into 5 groups, depending on the volume or temperature of intraoperative irrigation with normal saline. At specific times after surgery, pain, knee swelling, and skin temperature were assessed. Postoperative levels of serum C-reactive protein (CRP), interleukin (IL)-1, IL-6, and IL-10 also were measured.

Results: Visual analog scale (VAS) scores for pain, rates of swelling, and skin temperature differed significantly among the 5 groups at all postoperative time points ($P < 0.001$). The VAS scores ($P = 0.322$) and ratings for swelling ($P = 0.245$), and skin temperature ($P = 0.093$) were not significantly different among the volume groups. There were no significant differences in the VAS scores ($P = 0.055$), swelling ratings ($P = 0.570$), or skin temperatures ($P = 0.321$) among the groups that received irrigation with normal saline at different temperatures. There were no significant differences in postoperative serum levels of CRP, IL-1, IL-6, or IL-10 among the groups ($P > 0.05$).

Conclusions: Irrigation with different volumes and temperatures of normal saline did not have a significant effect on postoperative pain, swelling, or serum markers of inflammation.

Keywords: Arthroscopy • Knee • Pain, Postoperative • Therapeutic Irrigation

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Background

Injuries to the anterior cruciate ligament (ACL) are common and arthroscopic reconstruction is a routine procedure in Sports Medicine [1,2]. The ACL plays a major role in maintaining knee stability and function [2-4]; therefore, most patients require treatment after an ACL injury. Eighty-one percent of patients are able to return to exercise after ACL reconstruction [4]. After surgery, patients need to undertake rigorous postoperative rehabilitation exercise, but postoperative swelling and pain in the knee can affect movement of the joint and cause difficulties [4-8]. Intraoperative intervention and postoperative management are routinely used to reduce postoperative pain and swelling [9-12].

After ACL reconstruction surgery, it is necessary to continue irrigation with saline under arthroscopy for a period of time to clean the dissociative tissue in the joint cavity [13,14]. One study [15] reported that the temperature of the saline solution used for irrigation during arthroscopic meniscus resection did not affect postoperative pain in and swelling of the knee. Another study [16] indicated out that a difference in volume of saline solution did not affect postoperative pain and swelling in the knee. Because of fear about serious infection and joint fibrosis, surgeons are cautious in attempting surgery soon after an ACL injury [17,18]. ACL reconstruction at 3 weeks results in good functional outcomes without increasing risk of complications such as arthrofibrosis and limitation in range of motion [19].

Studies of postoperative pain and swelling in patients with ACL injuries that happened >3 weeks previously (non-acute) who have undergone arthroscopic ACL reconstruction with irrigation using different temperatures and volumes of saline are rare. Arthroscopic single-bundle surgical reconstruction of the ACL is commonly performed electively using general anesthesia, after 3 weeks of mobilization therapy. Therefore, the present single-center, retrospective study aimed to investigate the effects of irrigation with normal saline at different temperatures and volumes on pain, swelling, and serum markers of inflammation after elective, arthroscopic, single-bundle surgical reconstruction of the ACL.

Material and Methods

The Ethics Committee of the Affiliated Hospital of Qingdao University approved the protocol for the present study, which was conducted in conformity with ethical principles of research. Inclusion criteria were as follows: non-acute ACL injury diagnosed in our department between March 2015 and May 2020; unilateral, arthroscopic, single-bundle ACL reconstruction; and follow-up with complete clinical data. Exclusion

criteria were as follows: ACL injury combined with meniscus injury or injury to other ligaments; transplantation of the peroneus longus tendon in addition to ACL reconstruction; ACL injury combined with joint dislocation and fracture; ACL injury combined with compound injury, which led to a procedure time that was long and exceeded expectations; and patient refusal of follow-up. All patients underwent a preoperative magnetic resonance imaging to exclude combined or complicated ligament injuries to their knees.

A total of 716 patients who met the criteria were included. The flowchart of patients and their division into 5 groups, according to type of intraoperative irrigation, is shown in **Figure 1**. No more than three 3-L bags of saline were used in any of the 5 groups during the main step of arthroscopic ACL reconstruction. The non-irrigation group (n=139) did not receive irrigation with room-temperature saline (0 L, 23°C) after ACL reconstruction. In the 1-L group (n=143), irrigation after ACL reconstruction was with room-temperature saline (1 L, 23°C). In the 3-L group (n=147), irrigation after ACL reconstruction was with room-temperature saline (3 L, 23°C). The constant-temperature group (n=142) received irrigation with constant-temperature (0 L, 36°C) rather than room-temperature saline throughout the operation and no irrigation with room-temperature saline after ACL reconstruction. The cold-temperature group (n=145) received irrigation with cold (0 L, 4°C) instead of room-temperature saline throughout the operation and no irrigation with room-temperature saline after ACL reconstruction. The volume groups were non-irrigation and 1- and 3-L irrigation. The temperature groups were non-irrigation and constant and cold temperatures.

Surgical Technique

Patients underwent arthroscopic, single-bundle ACL reconstruction under general anesthesia. Arthroscopic channel incisions were made and routine exploration was performed to confirm injury to the ACL. The ipsilateral hamstring tendons (the half and gracilis tendons) were stripped as spare tendons. The surgeons drilled femoral and tibial tunnels and then pulled the spare tendons into the tunnels. An Endo-Button (Smith & Nephew) was used to fix the femoral end and then tibial end was fixed with an absorbable squeeze screw (Smith & Nephew). Saline bags were hung on a bedside infusion stand and the pressure was set at approximately 80 mmHg. An arthroscope connected to the saline bags was used as the water inlet and a planer connected to the suction device was used as the water outlet. No more than 3 bags containing 3 L of saline were used during arthroscopic ACL reconstruction. After that step was complete, normal saline irrigation was performed in the irrigation groups but withheld from the non-irrigation group. Finally, sodium hyaluronate was injected into the joint cavity and the leg was bandaged with an elastic bandage.

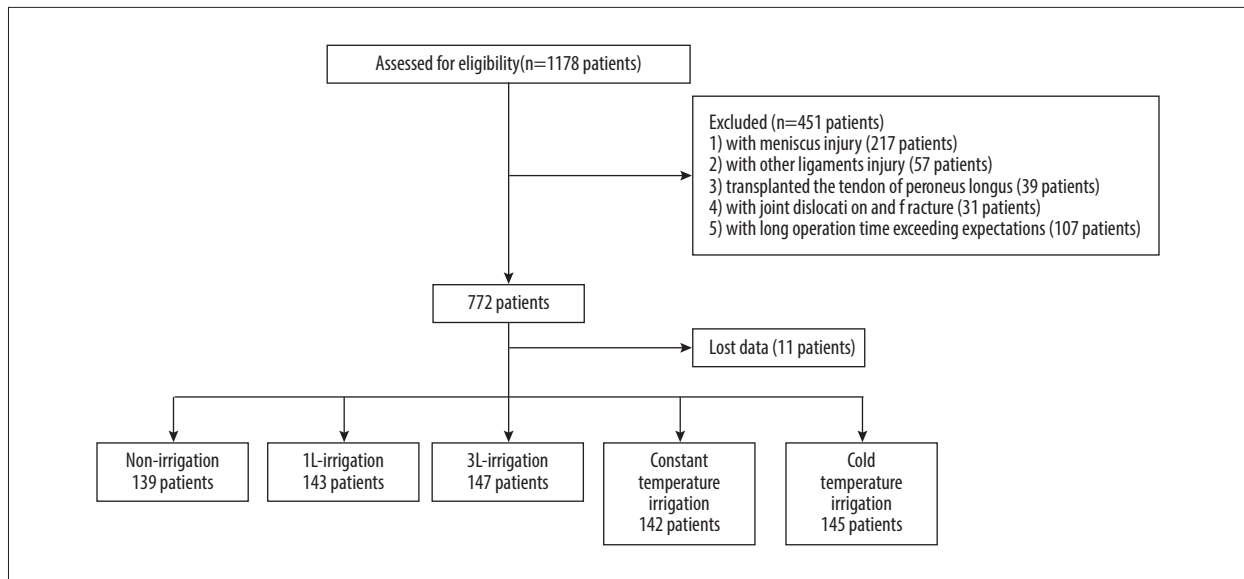


Figure 1. Flowchart of study design.

Non-steroidal anti-inflammatory analgesics were routinely given and cold compresses applied after the procedure. To foster restoration of muscle function and joint activity, gradual rehabilitation exercises were performed beginning on day 2 after surgery, in keeping with the plan for rehabilitation after ACL reconstruction. All of the surgeries were completed by the same doctor, who had 20 years of clinical experience. He was blinded to the different patient groups.

Clinical Evaluation

A visual analog scale (VAS) was used to determine pain at 6, 12, 24, 48, and 72 h after surgery. To assess swelling, knee circumference was measured at 2 cm above the superior border of the patella at 6, 12, 24, 48, and 72 h after surgery. The postoperative knee swelling rating on the injured side was defined as the knee circumference on the injured side minus the knee circumference on the uninjured side, both measured in centimeters [15]. Skin temperature of the knee was measured at the center of the anterior patella on postoperative days 1, 3, and 5. Limbs were exposed to room temperature for 5 minutes bilaterally and then the skin temperature was measured with a skin temperature gun. The skin temperature on the injured side was defined as the skin temperature on the injured side minus the skin temperature on the uninjured side, both measured in degrees centigrade (°C) [20]. Serum levels of C-reactive protein (CRP) were measured on postoperative days 1 and 3. Serum levels of interleukin (IL)-1, IL-6, and IL-10 were measured 6, 12, and 24 h after surgery. All VAS scores and data measurements were completed by the same doctor, who had 7 years of clinical experience.

Statistical Analysis

All data analyses were performed using SPSS software, version 26.0. A chi-square test was used for categorical variables. Measurements of data such as VAS scores, knee swelling ratings, skin temperatures, and serum levels of CRP, IL-1, IL-6, and IL-10 were expressed as means±standard deviations. Comparisons at different time points were performed using analysis of variance. $P<0.05$ was considered statistically significant.

Results

There were no statistically significant differences in sex, age, body mass index (BMI), or MRI classification among the 5 groups ($P>0.05$). Baseline information for the 5 groups is shown in **Table 1**. All surgical incisions healed during the first stage and there were no postoperative complications. The non-irrigation and 1- and 3-L irrigation groups were considered the volume groups. The non-irrigation and constant- and cold-temperature groups were considered the temperature groups. Among the 5 groups, there were statistically significant differences in VAS scores at all postoperative time points evaluated ($P<0.001$). There was no statistically significant difference in VAS scores among the volume groups ($P=0.322$ or among the temperature groups ($P=0.055$). Detailed VAS data are shown in **Table 2**. All groups showed a decreasing trend in the amount of swelling ($P<0.001$). There were no significant differences in swelling among the volume or temperature groups ($P=0.245$ and $P=0.570$, respectively). Detailed data on swelling are shown in **Table 3**. In all 5 groups, temperature ratings were significantly different at the various postoperative times ($P<0.001$). There

Table 1. Clinical and demographic characteristics of 716 patients after arthroscopic single-bundle surgical reconstruction of the ACL performed under general anesthesia.

	Sex		Age (x±s)	BMI (x±s, kg/m ²)	Operative side		ACL injury classification	
	Male	Female			Left	Right	Grade II	Grade III
Non-irrigation	65	74	39.8±5.0	23.0±1.3	66	73	99	40
1-L irrigation	70	73	40.5±4.9	23.2±1.2	72	71	112	31
3-L irrigation	67	80	39.6±5.4	23.2±1.6	69	78	108	39
Constant temperature	65	77	40.5±5.1	23.2±1.2	60	82	97	45
Cold temperature	71	74	40.2±5.5	23.3±1.2	75	70	110	35
P value	0.959		0.473	0.437	0.572		0.348	

ACL – anterior cruciate ligament; BMI – body mass index.

Table 2. Comparison of VAS results in 716 patients after arthroscopic single-bundle surgical reconstruction of the ACL performed under general anesthesia.

	N	Postoperative timepoint				
		6 h	12 h	24 h	48 h	72 h
Non-irrigation	139	4.51±1.02	5.27±1.09	6.13±0.56	4.24±0.82	3.10±0.83
1-L irrigation	143	4.40±1.01	5.31±1.15	6.11±0.62	4.08±1.01	3.13±0.94
3-L irrigation	147	4.56±1.10	5.50±1.18	6.16±0.64	4.16±0.93	3.05±0.89
P value		0.390	0.198	0.766	0.344	0.711
Non-irrigation	139	4.51±1.02	5.27±1.09	6.13±0.56	4.24±0.82	3.10±0.83
Constant temperature	142	4.46±0.99	5.30±1.11	6.13±0.56	4.22±0.83	3.05±0.80
Cold temperature	145	4.36±1.02	5.34±1.16	6.21±0.59	4.07±1.01	3.08±0.95
P value		0.433	0.865	0.401	0.199	0.883

ACL – anterior cruciate ligament; VAS – visual analog scale.

Table 3. Comparison of swelling ratings in 716 patients after arthroscopic single-bundle surgical reconstruction of the ACL performed under general anesthesia.

	N	Postoperative timepoint				
		6 h	12 h	24 h	48 h	72 h
Non-irrigation	139	4.55±0.39	3.98±0.35	3.01±0.32	2.09±0.45	1.04±0.39
1-L irrigation	143	4.51±0.49	4.06±0.33	3.03±0.34	2.16±0.37	1.05±0.40
3-L irrigation	147	4.49±0.49	4.02±0.34	3.01±0.35	2.16±0.37	1.06±0.40
P value		0.541	0.176	0.838	0.248	0.990
Non-irrigation	139	4.55±0.39	3.98±0.35	3.01±0.32	2.09±0.45	1.05±0.39
Constant temperature	142	4.51±0.44	4.02±0.33	3.03±0.33	2.13±0.41	1.05±0.40
Cold temperature	145	4.50±0.49	4.01±0.34	3.02±0.35	2.16±0.37	1.08±0.43
P value		0.606	0.615	0.857	0.344	0.830

ACL – anterior cruciate ligament.

Table 4. Comparison of skin temperature ratings and CRP in 716 patients after arthroscopic single-bundle surgical reconstruction of the ACL performed under general anesthesia.

	N	Postoperative skin temperature			Postoperative CRP (mg/L)	
		1 d	3 d	5 d	1 d	3 d
Non-irrigation	139	2.78±0.25	2.43±0.33	2.00±0.48	1.18±0.65	1.21±0.68
1-L irrigation	143	2.77±0.28	2.39±0.27	2.01±0.46	1.23±0.65	1.21±0.56
3-L irrigation	147	2.75±0.30	2.43±0.33	1.91±0.45	1.22±0.65	1.22±0.60
<i>P</i> value		0.691	0.431	0.155	0.832	0.988
Non-irrigation	139	2.78±0.25	2.43±0.33	2.00±0.48	1.18±0.65	1.21±0.68
Constant temperature	142	2.76±0.28	2.37±0.44	1.87±0.50	1.21±0.66	1.20±0.60
Cold temperature	145	2.79±0.23	2.41±0.41	1.95±0.51	1.22±0.65	1.20±0.58
<i>P</i> value		0.735	0.435	0.123	0.904	0.985

ACL – anterior cruciate ligament; CRP – C-reactive protein.

Table 5. Comparison of results with IL-1, IL-6, and IL-10 in 716 patients following arthroscopic single-bundle surgical reconstruction of the ACL performed under general anesthesia.

	Postoperative IL-1 level			Postoperative IL-6 level			Postoperative IL-10 level		
	6 h	12 h	24 h	6 h	12 h	24 h	6 h	12 h	24 h
No irrigation	6.2±1.7	6.2±1.7	5.7±1.9	109.8±16.8	93.5±11.7	79.5±11.9	5.1±1.4	4.7±1.4	4.5±1.6
1-L irrigation	6.2±1.7	5.8±1.9	5.8±1.8	109.1±17.2	91.9±11.9	78.4±12.0	5.0±1.3	4.7±1.5	4.7±1.6
3-L irrigation	6.0±1.8	6.1±1.8	5.8±1.8	111.5±15.7	94.0±12.0	79.0±11.5	5.3±1.3	4.8±1.7	4.5±1.6
<i>P</i> value	0.631	0.315	0.927	0.449	0.295	0.751	0.346	0.648	0.628
No irrigation	6.2±1.7	6.2±1.7	5.7±1.9	109.8±16.8	93.5±11.7	79.5±11.9	5.1±1.4	4.7±1.4	4.5±1.6
Constant temperature	6.1±1.7	6.2±1.9	5.7±2.0	109.6±14.6	92.3±12.9	79.0±14.9	5.1±1.4	4.9±1.5	4.6±1.6
Cold temperature	6.1±1.6	6.0±1.8	5.8±1.9	112.7±15.4	92.8±11.7	80.2±12.9	5.0±1.4	4.8±1.6	4.5±1.7
<i>P</i> value	0.796	0.547	0.908	0.172	0.705	0.754	0.632	0.646	0.853

ACL – anterior cruciate ligament; CRP – C-reactive protein; IL – interleukin.

was no significant difference in temperature ratings among the volume or temperature groups ($P=0.321$ and $P=0.093$, respectively). Detailed data on temperature ratings are shown in **Table 4**. Furthermore, there were no significant differences in CRP levels among the volume or temperature groups (both, $P>0.05$) (**Table 4**). There were no statistically significant differences in IL-1, IL-6, or IL-10 levels in the volume or temperature groups (both, $P>0.05$) (**Table 5**).

Discussion

In the present study, we compared outcomes of intraoperative irrigation with different volumes of normal saline during follow-up of patients who had undergone ACL surgery. Our results

showed no statistically significant differences among the volume or temperature groups in VAS scores, swelling, or skin temperature. Moreover, postoperative serum levels of CRP, IL-1, IL-6, and IL-10 were similar in the volume and temperature groups. In general, arthroscopic techniques are believed to be quicker, safer, simpler, and more effective than open surgery because they result in a smaller wound [21-23]. During arthroscopic knee surgery, flushing the site with saline irrigation often is necessary to clear the surgical field and improve visualization. Fluids such as normal saline, lactated Ringer's solution, and carbohydrate solutions typically are used for irrigation to expand the joint and provide visibility sufficient that the procedure can continue [23,24].

Similar studies have reported that the temperature [15] and volume [16] of saline solution used in irrigation during arthroscopic

meniscus resection does not affect postoperative pain and swelling in the knee. The inference is that cold saline irrigation of the joint does not change the temperature of superficial knee tissues such as the skin and muscles. In our study, we focused on ACL reconstruction. As is well known, arthroscopic ACL reconstruction requires drilling femoral and tibial tunnels, which results in bone debris that must be carefully cleared to ensure a successful procedure. Compared with a partial meniscus resection, the operative time for ACL repairs is longer while the procedure is more complicated and generates more impurities. An extended irrigation time would be more practical following ACL reconstruction than meniscus resection. In the present study, emphasis was placed on whether use of differing volumes of continuous saline for intraoperative irrigation would affect postoperative pain and swelling. We also focused on the effect on postoperative pain, swelling, and serum inflammation values of the temperature of the irrigation solution used during ACL surgery. The temperature of saline used in the operating room is generally 23°C, whereas normal body temperature is 36°C [25,26]. Here, we summarize results of previous studies similar to ours, which focused on a comprehensive assessment of the effects of different volumes and temperatures of intraoperative irrigation on postoperative pain, swelling, and serum inflammation values in patients undergoing ACL surgery.

One research paper demonstrated that normal saline supplemented with epinephrine (concentration 1 mg/L) reduced bleeding volume during arthroscopic procedures, improving visibility and reducing operative time [27]. Postoperative pain and swelling in the knee also were observed; postoperative symptoms improved substantially, which led to a quicker postoperative recovery in patients. In that study, an appropriate amount of epinephrine was added to the normal saline before the intraoperative conditions were noted and postoperative symptoms observed. In some countries, this has now become the criterion standard for practice in arthroscopic surgeries; however, it has not been adopted universally. Most hospitals use conventional saline for arthroscopic surgery. Therefore, the present study is of great significance because the aim was to identify ways to improve a practice that is widely utilized.

Recent research has indicated that use of a mechanical irrigation system is superior to gravity irrigation [28,29]. The advantages are constant flow, greater joint expansion, an improved field of vision, a reduced tourniquet requirement, and less operative bleeding. Although a mechanical irrigation system has many advantages, it comes with high usage and maintenance costs, as well as a requirement that the surgical team learn a complicated technique. For these reasons, such a system is rarely used in arthroscopic surgery; the preferred method is gravity-mediated irrigation. The present study focused on a gravity irrigation system, but the differential volumes of saline

were applied in the same way as with a mechanical irrigation system. In the future, gravity-mediated irrigation may be replaced by mechanical irrigation, but our research is still of importance because it focused on improving the practice that is utilized most commonly.

The results of the present study indicate that the different saline volumes and temperatures did not aggravate or worsen postoperative pain and swelling. This was in contrast to the initial assumptions about the study. We hypothesized that enlarging the joint capacity and irrigating for a longer period of time would lead to more fluid penetration into the interstitial space and result in increased postoperative pain and swelling. That, however, was not the case; there were no significant differences in postoperative VAS scores, swelling, or temperature ratings for different volumes of irrigation. Therefore, although we used 3 different volumes of saline, the extra fluid appeared to be absorbed without issue. Arthroscopic irrigation was performed throughout the whole surgical procedure, so the total volume of saline was similar among the 3 groups. This could infer that the different volumes of saline used in this study were not large enough to have a detrimental effect on postoperative symptoms. In future research, a larger volume of saline could be used to test the effect on postoperative outcomes following arthroscopic surgery. We believed that such a volume would not be beneficial; therefore, it was not incorporated into the present study.

We used skin temperature to as a marker of the inflammatory reaction in local superficial tissues. In clinical practice, a temperature difference of 1°C to 2°C can be distinguished by touching the patient's skin. In the present study, early postoperative rehabilitation was tailored according a patient's postoperative arthritic reaction. Saline at different temperatures is known to affect the temperature of the skin over the knee joint to some extent. Some research indicates that room-temperature irrigation is a physical stimulus for the body that can cause a decrease in a patient's core temperature [30-32]. The mechanism for the decrease in core body temperature at the beginning of irrigation is complicated and difficult to understand. Opinions about it in recent studies have differed; most research infers that the changes in body temperature are related to the continuous cold stimulation of the irrigation [31,32]. However, the present study showed that there was no significant difference among the 3 groups in which fluid at varying temperatures was used for irrigation. This suggests that, although the core temperature of the knee may have changed after surgery, the temperature differences in the irrigation fluid were not large enough to influence postoperative symptoms.

Another study suggested that cold stimulation may affect the immune system and upregulate the levels of inflammatory cytokines, including pro-inflammatory and anti-inflammatory

cytokines [33]. IL-1, IL-6, IL-10, and CRP levels were considered indicators of inflammation. Brenner studied the response of the human immune system to cold and found that a cold stimulus led to elevated IL-6 levels [34]. The present study indicated that serum levels of IL-1, IL-6, IL-10, and CRP did not differ significantly after surgery, which suggests that the inflammatory response was the same even when the temperature and volume of the irrigation fluid varied. While our study is of great value to the field of arthroscopic surgery, because ACL reconstruction is limited as a surgical procedure, further research is needed regarding the volume and temperature of saline used during irrigation.

The present study had several limitations. Given the characteristics of ACL surgery, we could not do larger-volume irrigation because of the potential negative impact on patients. Using even more fluid or solutions at other temperatures could affect postoperative outcomes. Because ours was a retrospective study with all its associated biases, prospective, randomized, controlled studies are needed to validate the results.

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Conclusions

The findings from the present retrospective, single-center study showed that irrigation with different volumes and temperatures of normal saline did not have a significant effect on postoperative pain, swelling, or serum markers of inflammation in patients who underwent elective, arthroscopic, single-bundle surgical reconstruction of the ACL.

Ethics Approval

The study was approved by the Ethics Committee of The Affiliated Hospital of Qingdao University.

Conflict of interest

None.

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